Python 2.6 Text Processing
Beginner's Guide

The easiest way to learn how to manipulate text with Python

Jeff McNeil

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About the Author

Jeff McNeil has been working in the Internet Services industry for over 10 years. He cut his teeth during the late 90's Internet boom and has been developing software for Unix and Unix-flavored systems ever since. Jeff has been a full-time Python developer for the better half of that time and has professional experience with a collection of other languages, including C, Java, and Perl. He takes an interest in systems administration and server automation problems. Jeff recently joined Google and has had the pleasure of working with some very talented individuals.

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About the Reviewer

Maurice HT Ling completed his Ph.D. in Bioinformatics and B.Sc(Hons) in Molecular and Cell Biology from the University of Melbourne where he worked on microarray analysis and text mining for protein-protein interactions. He is currently an honorary fellow in the University of Melbourne, Australia. Maurice holds several Chief Editorships, including the Python papers, Computational, and Mathematical Biology, and Methods and Cases in Computational, Mathematical and Statistical Biology. In Singapore, he co-founded the Python User Group (Singapore) and is the co-chair of PyCon Asia-Pacific 2010. In his free time, Maurice likes to train in the gym, read, and enjoy a good cup of coffee. He is also a senior fellow of the International Fitness Association, USA.

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Preface

The *Python Text Processing Beginner's Guide* is intended to provide a gentle, hands-on introduction to processing, understanding, and generating textual data using the Python programming language. Care is taken to ensure the content is example-driven, while still providing enough background information to allow for a solid understanding of the topics covered.

Throughout the book, we use real world examples such as logfile processing and PDF creation to help you further understand different aspects of text handling. By the time you've finished, you'll have a solid working knowledge of both structured and unstructured text data management. We'll also look at practical indexing and character encodings.

A good deal of supporting information is included. We'll touch on packaging, Python IO, third-party utilities, and some details on working with the Python 3 series releases. We'll even spend a bit of time porting a small example application to the latest version.

Finally, we do our best to provide a number of high quality external references. While this book will cover a broad range of topics, we also want to help you dig deeper when necessary.

What this book covers

Chapter 1, *Getting Started*: This chapter provides an introduction into character and string data types and how strings are represented using underlying integers. We'll implement a simple encoding script to illustrate how text can be manipulated at the character level. We also set up our systems to allow safe third-party library installation.

Chapter 2, *Working with the IO System*: Here, you'll learn how to access your data. We cover Python's IO capabilities in this chapter. We'll learn how to access files locally and remotely. Finally, we cover how Python's IO layers change in Python 3.

Chapter 3, *Python String Services*: Covers Python's core string functionality. We look at the methods of string objects, the core template classes, and Python's various string formatting methods. We introduce the differences between Unicode and string objects here.

Chapter 4, *Test Processing Using the Standard Library*: The standard Python distribution includes a powerful set of built-in libraries designed to manage textual content. We look at configuration file reading and manipulation, CSV files, and JSON data. We take a bit of a detour at the end of this chapter to learn how to create your own redistributable Python egg files.

Chapter 5, *Regular Expressions*: Looks at Python's regular expression implementation and teaches you how to implement them. We look at standardized concepts as well as Python's extensions. We'll break down a few graphically so that the component parts are easy to piece together. You'll also learn how to safely use regular expressions with international alphabets.

Chapter 6, *Structured Markup*: Introduces you to XML and HTML processing. We create an adventure game using both SAX and DOM approaches. We also look briefly at `lxml` and `ElementTree`. HTML parsing is also covered.

Chapter 7, *Creating Templates*: Using the Mako template language, we'll generate e-mail and HTML text templates much like the ones that you'll encounter within common web frameworks. We visit template creation, inheritance, filters, and custom tag creation.

Chapter 8, *Understanding Encodings and i18n*: We provide a look into character encoding schemes and how they work. For reference, we'll examine ASCII as well as KOI8-R. We also look into Unicode and its various encoding mechanisms. Finally, we finish up with a quick look at application internationalization.

Chapter 9, *Advanced Output Formats*: Provides information on how to generate PDF, Excel, and OpenDocument data. We'll build these document types from scratch using direct Python API calls relying on third-party libraries.

Chapter 10, *Advanced Parsing and Grammars*: A look at more advanced text manipulation techniques such as those used by programming language designers. We'll use the PyParsing library to handle some configuration file management and look into the Python Natural Language Toolkit.

Chapter 11, *Searching and Indexing*: A practical look at full text searching and the benefit an index can provide. We'll use the Nucular system to index a collection of small text files and make them quickly searchable.

Appendix A, *Looking for Additional Resources*: It introduces you to places of interest on the Internet and some community resources. In this appendix, you will learn to create your own documentation and to use Java Lucene based engines. You will also learn about differences between Python 2 & Python 3 and to port code to Python 3.

What you need for this book

This book assumes you've an elementary knowledge of the Python programming language, so we don't provide a tutorial introduction. From a software angle, you'll simply need a version of Python (2.6 or later) installed. Each time we require a third-party library, we'll detail the installation in text.

Who this book is for

If you are a novice Python developer who is interested in processing text then this book is for you. You need no experience with text processing, though basic knowledge of Python would help you to better understand some of the topics covered by this book. As the content of this book develops gradually, you will be able to pick up Python while reading.

Conventions

In this book, you will find several headings appearing frequently.

To give clear instructions of how to complete a procedure or task, we use:

Time for action – heading

1. Action 1
2. Action 2
3. Action 3

Instructions often need some extra explanation so that they make sense, so they are followed with:

What just happened?

This heading explains the working of tasks or instructions that you have just completed.

You will also find some other learning aids in the book, including:

Pop Quiz – heading

These are short multiple choice questions intended to help you test your own understanding.

Have a go hero – heading

These set practical challenges and give you ideas for experimenting with what you have learned.

You will also find a number of styles of text that distinguish between different kinds of information. Here are some examples of these styles, and explanations of their meanings.

Code words in text are shown as follows: "First of all, we imported the `re` module"

A block of code is set as follows:

```
parser = OptionParser()
    parser.add_option('-f', '--file', help="CSV Data File")
    opts, args = parser.parse_args()
    if not opts.file:
```

When we wish to draw your attention to a particular part of a code block, the relevant lines or items are set in bold:

```
def init_game(self):
        """
        Process World XML.
        """
        self.location = parse(open(self.world)).documentElement
```

Any command-line input or output is written as follows:

```
(text_processing)$ python render_mail.py thank_you-e.txt
```

New terms and **important words** are shown in bold. Words that you see on the screen, in menus or dialog boxes for example, appear in the text like this: "Any **X** found in the source data would simply become an **A** in the output data.".

Warnings or important notes appear in a box like this.

Tips and tricks appear like this.

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1
Getting Started

As computer professionals, we deal with text data every day. Developers and programmers interact with XML and source code. System administrators have to process and understand logfiles. Managers need to understand and format financial data and reports. Web designers put in time, hand tuning and polishing up HTML content. Managing this broad range of formats can seem like a daunting task, but it's really not that difficult.

This book aims to introduce you, the programmer, to a variety of methods used to process these data formats. We'll look at approaches ranging from standard language functions through more complex third-party modules. Somewhere in there, we'll cover a utility that's just the right tool for your specific job. In the process, we hope to also cover some Python development best practices.

Where appropriate, we'll look into implementation details enough to help you understand the techniques used. Most of the time, though, we'll work as hard as we can to get you up on your feet and crunching those text files.

You'll find that Python makes tasks like this quite painless through its clean and easy-to-understand syntax, vast community, and the available collection of additional utilities and modules.

In this chapter, we shall:

- Briefly introduce the data formats handled in this book
- Implement a simple ROT13 translator
- Introduce you to basic processing via filter programs
- Learn state machine basics

- Learn how to install supporting libraries and components safely and without administrative access
- Look at where to find more information on introductory topics

Categorizing types of text data

Textual data comes in a variety of formats. For our purposes, we'll categorize text into three very broad groups. Isolating down into segments helps us to understand the problem a bit better, and subsequently choose a parsing approach. Each one of these sweeping groups can be further broken down into more detailed chunks.

One thing to remember when working your way through the book is that text content isn't limited to the Latin alphabet. This is especially true when dealing with data acquired via the Internet. We'll cover some of the techniques and tricks to handling internationalized data in *Chapter 8*, *Understanding Encoding and i18n*.

Providing information through markup

Structured text includes formats such as XML and HTML. These formats generally consist of text content surrounded by special symbols or markers that give extra meaning to a file's contents. These additional tags are usually meant to convey information to the processing application and to arrange information in a tree-like structure. Markup allows a developer to define his or her own data structure, yet rely on standardized parsers to extract elements.

For example, consider the following contrived HTML document.

```
<html>
    <head>
        <title>Hello, World!</title>
    </head>
    <body>
        <p>
            Hi there, all of you earthlings.
        </p>
        <p>
        Take us to your leader.
       </p>
    </body>
</html>
```

In this example, our document's title is clearly identified because it is surrounded by opening and closing `<title>` and `</title>` elements.

Note that although the document's tags give each element a meaning, it's still up to the application developer to understand what to do with a `title` object or a `p` element.

Notice that while it still has meaning to us humans, it is also laid out in such a way as to make it computer friendly. We'll take a deeper look into these formats in *Chapter 6*, *Structured Markup*. Python provides some rich libraries for dealing with these popular formats.

One interesting aspect to these formats is that it's possible to embed references to validation rules as well as the actual document structure. This is a nice benefit in that we're able to rely on the parser to perform markup validation for us. This makes our job much easier as it's possible to trust that the input structure is valid.

Meaning through structured formats

Text data that falls into this category includes things such as configuration files, marker delimited data, e-mail message text, and JavaScript Object Notation web data. Content within this second category does not contain explicit markup much like `XML` and `HTML` does, but the structure and formatting is required as it conveys meaning and information about the text to the parsing application. For example, consider the format of a Windows `INI` file or a Linux system's `/etc/hosts` file. There are no tags, but the column on the left clearly means something other than the column on the right.

Python provides a collection of modules and libraries intended to help us handle popular formats from this category. We'll look at Python's built-in text services in detail when we get to *Chapter 4*, *The Standard Library to the Rescue*.

Understanding freeform content

This category contains data that does not fall into the previous two groupings. This describes e-mail message content, letters, book copy, and other unstructured character-based content. However, this is where we'll largely have to look at building our own processing components. There are external packages available to us if we wish to perform common functions. Some examples include full text searching and more advanced natural language processing.

Ensuring you have Python installed

Our first order of business is to ensure that you have Python installed. You'll need it in order to complete most of the examples in this book. We'll be working with Python 2.6 and we assume that you're using that same version. If there are any drastic differences in earlier releases, we'll make a note of them as we go along. All of the examples should still function properly with Python 2.4 and later versions.

If you don't have Python installed, you can download the latest 2.X version from `http://www.python.org`. Most Linux distributions, as well as Mac OS, usually have a version of Python preinstalled.

At the time of this writing, Python 2.6 was the latest version available, while 2.7 was in an alpha state.

Providing support for Python 3

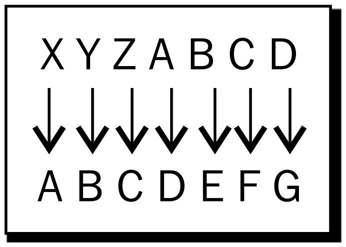
The examples in this book are written for Python 2. However, wherever possible, we will provide code that has already been ported to Python 3. You can find the Python 3 code in the Python3 directories in the code bundle available on the Packt Publishing FTP site.

Unfortunately, we can't promise that all of the third-party libraries that we'll use will support Python 3. The Python community is working hard to port popular modules to version 3.0. However, as the versions are incompatible, there is a lot of work remaining. In situations where we cannot provide example code, we'll note this.

Implementing a simple cipher

Let's get going early here and implement our first script to get a feel for what's in store.

A Caesar Cipher is a simple form of cryptography in which each letter of the alphabet is shifted down by a number of letters. They're generally of no cryptographic use when applied alone, but they do have some valid applications when paired with more advanced techniques.



This preceding diagram depicts a cipher with an offset of three. Any **X** found in the source data would simply become an **A** in the output data. Likewise, any **A** found in the input data would become a **D**.

Time for action – implementing a ROT13 encoder

The most popular implementation of this system is **ROT13**. As its name suggests, ROT13 shifts – or rotates – each letter by 13 spaces to produce an encrypted result. As the English alphabet has 26 letters, we simply run it a second time on the encrypted text in order to get back to our original result.

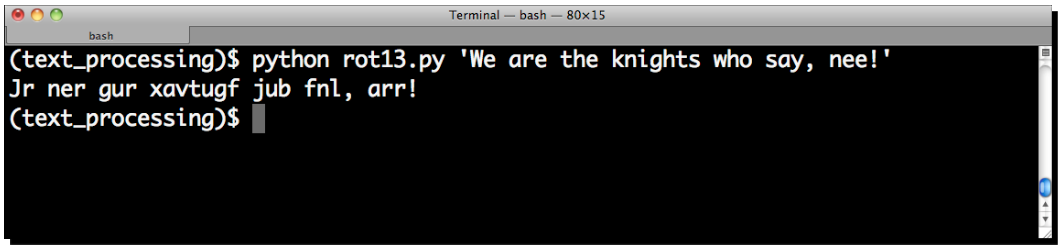
Let's implement a simple version of that algorithm.

1. Start your favorite text editor and create a new Python source file. Save it as `rot13.py`.
2. Enter the following code exactly as you see it below and save the file.

```
import sys
import string

CHAR_MAP = dict(zip(
    string.ascii_lowercase,
    string.ascii_lowercase[13:26] + string.ascii_lowercase[0:13]
    )
)

def rotate13_letter(letter):
    """
    Return the 13-char rotation of a letter.
    """
    do_upper = False
    if letter.isupper():
        do_upper = True

    letter = letter.lower()
    if letter not in CHAR_MAP:
        return letter

    else:
        letter = CHAR_MAP[letter]

        if do_upper:
            letter = letter.upper()

    return letter

if __name__ == '__main__':
        for char in sys.argv[1]:
            sys.stdout.write(rotate13_letter(char))
        sys.stdout.write('\n')
```

3. Now, from a command line, execute the script as follows. If you've entered all of the code correctly, you should see the same output.

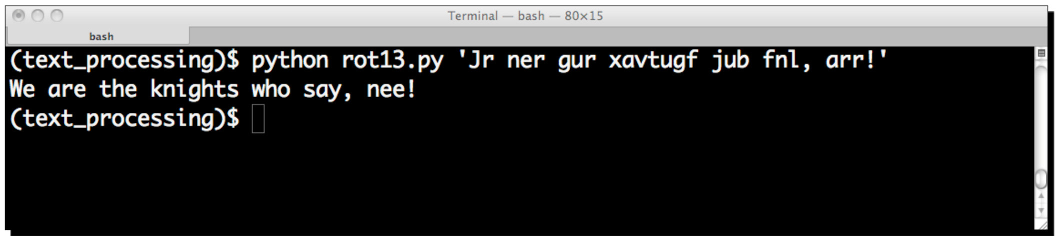
   ```
   $ python rot13.py 'We are the knights who say, nee!'
   ```



```
(text_processing)$ python rot13.py 'We are the knights who say, nee!'
Jr ner gur xavtugf jub fnl, arr!
(text_processing)$
```

4. Run the script a second time, using the output of the first run as the new input string. If everything was entered correctly, the original text should be printed to the console.

   ```
   $ python rot13.py 'Dv ziv gsv pmrtsgh dsl hzb, mvv!'
   ```



```
(text_processing)$ python rot13.py 'Jr ner gur xavtugf jub fnl, arr!'
We are the knights who say, nee!
(text_processing)$
```

What just happened?

We implemented a simple text-oriented cipher using a collection of Python's string handling features. We were able to see it put to use for both encoding and decoding source text. We saw a lot of stuff in this little example, so you should have a good feel for what can be accomplished using the standard Python string object.

Following our initial module imports, we defined a dictionary named `CHAR_MAP`, which gives us a nice and simple way to shift our letters by the required 13 places. The value of a dictionary key is the target letter! We also took advantage of string slicing here. We'll look at slicing a bit more in later chapters, but it's a convenient way for us to extract a substring from an existing string object.

In our translation function `rotate13_letter`, we checked whether our input character was uppercase or lowercase and then saved that as a Boolean attribute. We then forced our input to lowercase for the translation work. As ROT13 operates on letters alone, we only performed a rotation if our input character was a letter of the Latin alphabet. We allowed other values to simply pass through. We could have just as easily forced our string to a pure uppercased value.

The last thing we do in our function is restore the letter to its proper case, if necessary. This should familiarize you with upper- and lowercasing of Python ASCII strings.

We're able to change the case of an entire string using this same method; it's not limited to single characters.

```
>>> name = 'Ryan Miller'
>>> name.upper()
'RYAN MILLER'
>>> "PLEASE DO NOT SHOUT".lower()
'please do not shout'
>>>
```

It's worth pointing out here that a single character string is still a string. There is not a `char` type, which you may be familiar with if you're coming from a different language such as C or C++. However, it is possible to translate between character ASCII codes and back using the `ord` and `chr` built-in methods and a string with a length of one.

Notice how we were able to loop through a string directly using the Python `for` syntax. A string object is a standard Python iterable, and we can walk through them detailed as follows. In practice, however, this isn't something you'll normally do. In most cases, it makes sense to rely on existing libraries.

```
$ python
Python 2.6.1 (r261:67515, Jul  7 2009, 23:51:51)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>> for char in "Foo":
...     print char
...
F
o
o
>>>
```

Finally, you should note that we ended our script with an `if` statement such as the following:

```
>>> if__name__ == '__main__'
```

Python modules all contain an internal `__name__` variable that corresponds to the name of the module. If a module is executed directly from the command line, as is this script, whose name value is set to `__main__`, this code only runs if we've executed this script directly. It will not run if we import this code from a different script. You can import the code directly from the command line and see for yourself.

```
$ python
Python 2.6.1 (r261:67515, Jul  7 2009, 23:51:51)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>> import rot13
>>>  dir(rot13)
['CHAR_MAP', '__builtins__', '__doc__', '__file__', '__name__', '__
package__', 'rotate13_letter', 'string', 'sys']
>>>
```

Notice how we were able to import our module and see all of the methods and attributes inside of it, but the driver code did not execute. This is a convention we'll use throughout the book in order to help achieve maximum reusability.

Have a go hero – more translation work

Each Python string instance contains a collection of methods that operate on one or more characters. You can easily display all of the available methods and attributes by using the `dir` method. For example, enter the following command into a Python window. Python responds by printing a list of all methods on a string object.

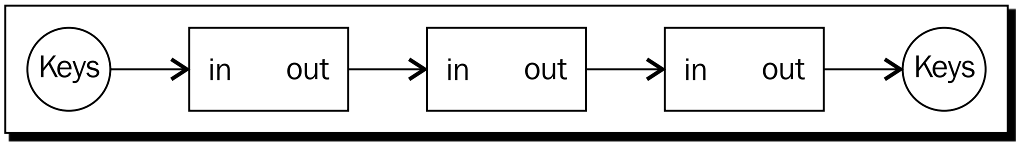
```
>>> dir("content")
['__add__', '__class__', '__contains__', '__delattr__', '__doc__',
'__eq__', '__format__', '__ge__', '__getattribute__', '__getitem__',
'__getnewargs__', '__getslice__', '__gt__', '__hash__', '__init__', '__
le__', '__len__', '__lt__', '__mod__', '__mul__', '__ne__', '__new__',
'__reduce__', '__reduce_ex__', '__repr__', '__rmod__', '__rmul__', '__
setattr__', '__sizeof__', '__str__', '__subclasshook__', '_formatter_
field_name_split', '_formatter_parser', 'capitalize', 'center', 'count',
'decode', 'encode', 'endswith', 'expandtabs', 'find', 'format', 'index',
'isalnum', 'isalpha', 'isdigit', 'islower', 'isspace', 'istitle',
'isupper', 'join', 'ljust', 'lower', 'lstrip', 'partition', 'replace',
'rfind', 'rindex', 'rjust', 'rpartition', 'rsplit', 'rstrip', 'split',
'splitlines', 'startswith', 'strip', 'swapcase', 'title', 'translate',
'upper', 'zfill']
>>>
```

Much like the `isupper` and `islower` methods discussed previously, we also have an `isspace` method. Using this method, in combination with your newfound knowledge of Python strings, update the method we defined previously to translate spaces to underscores and underscores to spaces.

Processing structured markup with a filter

Our ROT13 application works great for simple one-line strings that we can fit on the command line. However, it wouldn't work very well if we wanted to encode an entire file, such as the HTML document we took a look at earlier. In order to support larger text documents, we'll need to change the way we accept input. We'll redesign our application to work as a filter.

A **filter** is an application that reads data from its standard input file descriptor and writes to its standard output file descriptor. This allows users to create command **pipelines** that allow multiple utilities to be strung together. If you've ever typed a command such as `cat /etc/hosts | grep mydomain.com`, you've set up a pipeline



In many circumstances, data is fed into the pipeline via the keyboard and completes its journey when a processed result is displayed on the screen.

Time for action – processing as a filter

Let's make the changes required to allow our simple ROT13 processor to work as a command-line filter. This will allow us to process larger files.

1. Create a new source file and enter the following code. When complete, save the file as `rot13-b.py`.

```
import sys
import string

CHAR_MAP = dict(zip(
    string.ascii_lowercase,
    string.ascii_lowercase[13:26] + string.ascii_lowercase[0:13]
    )
)

def rotate13_letter(letter):
    """
```

```
        Return the 13-char rotation of a letter.
        """
        do_upper = False
        if letter.isupper():
            do_upper = True

        letter = letter.lower()
        if letter not in CHAR_MAP:
            return letter

        else:
            letter = CHAR_MAP[letter]

            if do_upper:
                letter = letter.upper()

        return letter

    if __name__ == '__main__':
        for line in sys.stdin:
            for char in line:
                sys.stdout.write(rotate13_letter(char))
```

2. Enter the following HTML data into a new text file and save it as `sample_page.html`. We'll use this as example input to our updated `rot13.py`.

```
<html>
    <head>
        <title>Hello, World!</title>
    </head>
    <body>
        <p>
            Hi there, all of you earthlings.
        </p>
        <p>
           Take us to your leader.
       </p>
    </body>
</html>
```

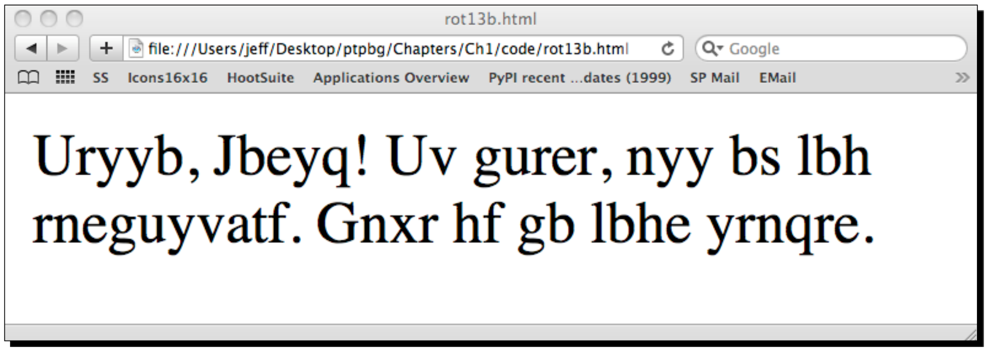
3. Now, run our `rot13.py` example and provide our HTML document as standard input data. The exact method used will vary with your operating system. If you've entered the code successfully, you should simply see a new prompt.

```
$ cat sample_page.html | python rot13-b.py > rot13.html
$
```

4. The contents of `rot13.html` should be as follows. If that's not the case, double back and make sure everything is correct.

```
<ugzy>
    <urnq>
        <gvgyr>Uryyb, Jbeyq!</gvgyr>
    </urnq>
    <obql>
        <c>
            Uv gurer, nyy bs lbh rneguyvatf.
        </c>
        <c>
            Gnxr hf gb lbhe yrnqre.
       </c>
    </obql>
</ugzy>
```

5. Open the translated HTML file using your web browser.


rot13b.html
file:///Users/jeff/Desktop/ptpbg/Chapters/Ch1/code/rot13b.html
Google
SS
Icons16x16
HootSuite
Applications Overview
PyPI recent ...dates (1999)
SP Mail
EMail

Uryyb, Jbeyq! Uv gurer, nyy bs lbh rneguyvatf. Gnxr hf gb lbhe yrnqre.

What just happened?

We updated our `rot13.py` script to read standard input data rather than rely on a command-line option. Doing this provides optimal configurability going forward and lets us feed input of varying length from a collection of different sources. We did this by looping on each line available on the `sys.stdin` file stream and calling our translation function. We wrote each character returned by that function to the `sys.stdout` stream.

Next, we ran our updated script via the command line, using `sample_page.html` as input. As expected, the encoded version was printed on our terminal.

As you can see, there is a major problem with our output. We should have a proper page title and our content should be broken down into different paragraphs.

Remember, structured markup text is sprinkled with
tag elements that define its structure and organization.

In this example, we not only translated the text content, we also translated the markup tags, rendering them meaningless. A web browser would not be able to display this data properly. We'll need to update our processor code to ignore the tags. We'll do just that in the next section.

Time for action – skipping over markup tags

In order to preserve the proper, structured HTML that tags provide, we need to ensure we don't include them in our rotation. To do this, we'll keep track of whether or not our input stream is currently within a tag. If it is, we won't translate our letters.

1. Once again, create a new Python source file and enter the following code. When you're finished, save the file as `rot13-c.py`.

```
import sys
from optparse import OptionParser
import string

CHAR_MAP = dict(zip(
    string.ascii_lowercase,
    string.ascii_lowercase[13:26] + string.ascii_lowercase[0:13]
    )
)

class RotateStream(object):
    """
    General purpose ROT13 Translator

    A ROT13 translator smart enough to skip
    Markup tags if that's what we want.
    """
    MARKUP_START = '<'
    MARKUP_END = '>'

    def __init__(self, skip_tags):
        self.skip_tags = skip_tags

    def rotate13_letter(self, letter):
        """
        Return the 13-char rotation of a letter.
        """
        do_upper = False
        if letter.isupper():
            do_upper = True

        letter = letter.lower()
        if letter not in CHAR_MAP:
            return letter

        else:
            letter = CHAR_MAP[letter]

            if do_upper:
                letter = letter.upper()

        return letter

def rotate_from_file(self, handle):
        """
        Rotate from a file handle.

        Takes a file-like object and translates
        text from it into ROT13 text.
        """
        state_markup = False
        for line in handle:
            for char in line:

                if self.skip_tags:
                    if state_markup:
                        # here we're looking for a closing
                        # '>'
                        if char == self.MARKUP_END:
                            state_markup = False

                    else:
                        # Not in a markup state, rotate
                        # unless we're starting a new
                        # tag
                        if char == self.MARKUP_START:
                            state_markup = True
                        else:
                            char = self.rotate13_letter(char)
                else:
                    char = self.rotate13_letter(char)

                # Make this a generator
                yield char

if __name__ == '__main__':
    parser = OptionParser()

    parser.add_option('-t', '--tags', dest="tags",
        help="Ignore Markup Tags", default=False,
        action="store_true")

    options, args = parser.parse_args()
    rotator = RotateStream(options.tags)

    for letter in rotator.rotate_from_file(sys.stdin):
        sys.stdout.write(letter)
```

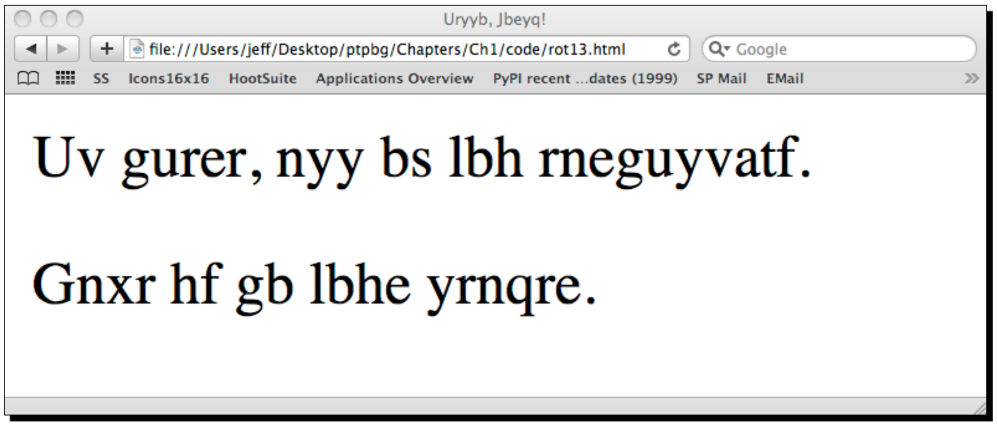
2. Run the same `example.html` file that we created for the last example through the new processor. This time, be sure to pass a `-t` command-line option.

```
$ cat sample_page.html | python rot13-c.py -t > rot13.html
$
```

3. If everything was entered correctly, the contents of `rot13.html` should be exactly as follows.

```
<html>
    <head>
        <title>Uryyb, Jbeyq!</title>
    </head>
    <body>
        <p>
            Uv gurer, nyy bs lbh rneguyvatf.
        </p>
        <p>
            Gnxr hf gb lbhe yrnqre.
       </p>
    </body>
</html>
```

4. Open the translated file in your web browser.


Uryyb, Jbeyq!
file:///Users/jeff/Desktop/ptpbg/Chapters/Ch1/code/rot13.html
Google
SS
Icons16x16
HootSuite
Applications Overview
PyPI recent ...dates (1999)
SP Mail
EMail

Uv gurer, nyy bs lbh rneguyvatf.

Gnxr hf gb lbhe yrnqre.

What just happened?

That was a pretty complex example, so let's step through it. We did quite a bit. First, we moved away from a simple `rotate13_letter` function and wrapped almost all of our functionality in a Python class named `RotateStream`. Doing this helps us ensure that our code will be reusable down the road.

We define a `__init__` method within the class that accepts a single parameter named `skip_tags`. The value of this parameter is assigned to the `self` parameter so we can access it later from within other methods. If this is a `True` value, then our parser class will know that it's not supposed to translate markup tags.

Next, you'll see our familiar `rotate13_letter` method (it's a method now as it's defined within a class). The only real difference here is that in addition to the `letter` parameter, we're also requiring the standard `self` parameter.

Finally, we have our `rotate_from_file` method. This is where the bulk of our new functionality was added. Like before, we're iterating through all of the characters available on a file stream. This time, however, the file stream is passed in as a `handle` parameter. This means that we could have just as easily passed in an open file handle rather than the standard in file handle.

Inside the method, we implement a simple state machine, with two possible states. Our current state is saved in the `state_markup` Boolean attribute. We only rely on it if the value of `self.skip_tags` set in the `__init__` method is `True`.

1. If `state_markup` is `True`, then we're currently within the context of a markup tag and we're looking for the `>` character. When it's found, we'll change `state_markup` to `False`. As we're inside a tag, we'll never ask our class to perform a ROT13 operation.
2. If `state_markup` is `False`, then we're parsing standard text. If we come across the `<` character, then we're entering a new markup tag. We set the value of `state_markup` to `True`. Finally, if we're not in tag, we'll call `rotate13_letter` to perform our ROT13 operation.

You should also notice some unfamiliar code at the end of the source listing. We've taken advantage of the `OptionParser` class, which is part of the standard library. We've added a single option that will allow us to selectively enable our markup bypass functionality. The value of this option is passed into `RotateStream`'s `__init__` method.

The final two lines of the listing show how we pass the `sys.stdin` file handle to `rotate_from_file` and iterate over the results. The `rotate_from_file` method has been defined as a **generator** function. A generator function returns values as it processes rather than waiting until completion. This method avoids storing all of the result in memory and lowers overall application memory consumption.

State machines

A **state machine** is an algorithm that keeps track of an application's internal state. Each state has a set of available transitions and functionality associated with it. In this example, we were either inside or outside of a tag. Application behavior changed depending on our current state. For example, if we were inside then we could transition to outside. The opposite also holds true.

The state machine concept is advanced and won't be covered in detail. However, it is a major method used when implementing text-processing machinery. For example, regular expression engines are generally built on variations of this model. For more information on state machine implementation, see the Wikipedia article available at `http://en.wikipedia.org/wiki/Finite-state_machine`.

Pop Quiz – ROT 13 processing

1. We define `MARKUP_START` and `MARKUP_END` class constants within our `RotateStream` class. How might our state machine be affected if these values were swapped?
2. Is it possible to use ROT13 on a string containing characters found outside of the English alphabet?
3. What would happen if we embedded > or < signs within our text content or tag values?
4. In our example, we read our input a line at a time. Can you think of a way to make this more efficient?

Have a go hero – support multiple input channels

We've briefly covered reading data via standard in as well as processing simple command-line options. Your job is to integrate the two so that your application will simply translate a command-line value if one is present before defaulting to standard input.

If you're able to implement this, try extending the option handling code so that your input string can be passed in to the rotation application using a command-line option.

```
$python rot13-c.py –s 'myinputstring'
zlvachgfgevat
$
```

Supporting third-party modules

Now that we've got our first example out of the way, we're going to take a little bit of a detour and learn how to obtain and install third-party modules. This is important, as we'll install a few throughout the remainder of the book.

The Python community maintains a centralized package repository, termed the **Python Package Index** (or **PyPI**). It is available on the web at `http://pypi.python.org`. From there, it is possible to download packages as compressed source distributions, or in some cases, pre-packaged Python components. PyPI is also a rich source of information. It's a great place to learn about available third-party applications. Links are provided to individual package documentation if it's not included directly into the package's PyPI page.

Packaging in a nutshell

There are at least two different popular methods of packaging and deploying Python packages. The `distutils` package is part of the standard distribution and provides a mechanism for building and installing Python software. Packages that take advantage of the `distutils` system are downloaded as a source distribution and built and installed by a local user. They are installed by simply creating an additional directory structure within the system Python directory that matches the package name.

In an effort to make packages more accessible and self-contained, the concept of the Python Egg was introduced. An egg file is simply a `ZIP` archive of a package. When an egg is installed, the `ZIP` file itself is placed on the Python path, rather than a subdirectory.

Time for action – installing SetupTools

Egg files have largely become the de facto standard in Python packaging. In order to install, develop, and build egg files, it is necessary to install a third-party tool kit. The most popular is **SetupTools**, and this is what we'll be working with throughout this book. The installation process is fairly easy to complete and is rather self-contained. Installing SetupTools gives us access to the `easy_install` command, which automates the download and installation of packages that have been registered with PyPI.

1. Download the installation script, which is available at `http://peak.telecommunity.com/dist/ez_setup.py`. This same script will be used for all versions of Python.

2. As an administrative user, run the `ez_setup.py` script from the command line. The SetupTools installation process will complete. If you've executed the script with the proper rights, you should see output similar as follows:

```
# python ez_setup.py
Downloading http://pypi.python.org/packages/2.6/s/setuptools/
setuptools-0.6c11-py2.6.egg
Processing setuptools-0.6c11-py2.6.egg
creating /usr/lib/python2.6/site-packages/setuptools-0.6c11-
py2.6.egg
Extracting setuptools-0.6c11-py2.6.egg to /usr/lib/python2.6/site-
packages
Adding setuptools 0.6c11 to easy-install.pth file
Installing easy_install script to /usr/bin
Installing easy_install-2.6 script to /usr/bin

Installed /usr/lib/python2.6/site-packages/setuptools-0.6c11-
py2.6.egg
Processing dependencies for setuptools==0.6c11
Finished processing dependencies for setuptools==0.6c11
#
```

What just happened?

We downloaded the `SetupTools` installation script and executed it as an administrative user. By doing so, our system Python environment was configured so that we can install egg files in the future via the SetupTools `easy_install` system.

SetupTools does not currently work with Python 3.0. There is, however, an alternative available via the Distribute project. Distribute is intended to be a drop-in replacement for SetupTools and will work with either major Python version. For more information, or to download the installer, visit `http://pypi.python.org/pypi/distribute`.

Running a virtual environment

Now that we have `SetupTools` installed, we can install third-party packages by simply running the `easy_install` command. This is nice because package dependencies will automatically be downloaded and installed so we no longer have to do this manually. However, there's still one piece missing. Even though we can install these packages easily, we still need to retain administrative privileges to do so. Additionally, all of the packages that we chose to install will be placed in the system's Python library directory, which has the potential to cause inconsistencies and problems down the road.. As you've probably guessed, there's a utility to address that.

> Python 2.6 introduces the concept of a local user package directory. This is simply an additional location found within your user home directory that Python searches for installed packages. It is possible to install eggs into this location via `easy_install` with a `–user` command-line switch. For more information, see `http://www.python.org/dev/peps/pep-0370/`.

Configuring virtualenv

The `virtualenv` package, distributed as a Python egg, allows us to create an isolated Python environment anywhere we wish. The environment comes complete with a `bin` directory containing a Python binary, its own installation of `SetupTools`, and an instance-specific library directory. In short, it creates a location for us to install and configure Python without interfering with the system installation.

Time for action – configuring a virtual environment

Here, we'll enable the `virtualenv` package, which will illustrate how to install packages from the PyPI site. We'll also configure our first environment, which we'll use throughout the book for the rest of our examples and code illustrations.

1. As a user with administrative privileges, install `virtualenv` from the system command line by running `easy_install virtualenv`. If you have the correct permissions, your output should be similar to the following.

```
Searching for virtualenv
Reading http://pypi.python.org/simple/virtualenv/
Reading http://virtualenv.openplans.org
Best match: virtualenv 1.4.5
Downloading http://pypi.python.org/packages/source/v/virtualenv/
virtualenv-1.4.5.tar.gz#md5=d3c621dd9797789fef78442e336df63e
Processing virtualenv-1.4.5.tar.gz
```

```
Running virtualenv-1.4.5/setup.py -q bdist_egg --dist-dir /tmp/
easy_install-rJXhVC/virtualenv-1.4.5/egg-dist-tmp-AvWcd1
warning: no previously-included files matching '*.*' found under
directory 'docs/_templates'
Adding virtualenv 1.4.5 to easy-install.pth file
Installing virtualenv script to /usr/bin

Installed /usr/lib/python2.6/site-packages/virtualenv-1.4.5-
py2.6.egg
Processing dependencies for virtualenv
Finished processing dependencies for virtualenv
```

2. Drop administrative privileges as we won't need them any longer. Ensure that you're within your home directory and create a new virtual instance by running:

```
 $ virtualenv --no-site-packages text_processing
```

3. Step into the newly created `text_processing` directory and activate the virtual environment. Windows users will do this by simply running the `Scripts\activate` application, while Linux users must instead source the script using the shell's dot operator.

```
$ . bin/activate
```

4. If you've done this correctly, you should now see your command-line prompt change to include the string (`text_processing`). This serves as a visual cue to remind you that you're operating within a specific virtual environment.

```
(text_processing)$ pwd
/home/jmcneil/text_processing
(text_processing)$ which python
/home/jmcneil/text_processing/bin/python
(text_processing)$
```

5. Finally, deactivate the environment by running the deactivate command. This will return your shell environment to default. Note that once you've done this, you're once again working with the system's Python install.

```
(text_processing)$ deactivate
$ which python
/usr/bin/python
$
```

If you're running Windows, by default `python.exe` and `easy_install.exe` are not placed on your system `%PATH%`. You'll need to manually configure your `%PATH%` variable to include `C:\Python2.6\ and C:\Python2.6\Scripts`. Additional scripts added by `easy_install` will also be placed in this directory, so it's worth setting up your `%PATH%` variable.

What just happened?

We installed the `virtualenv` package using the `easy_install` command directly off of the Python Package index. This is the method we'll use for installing any third-party packages going forward. You should now be familiar with the `easy_install` process. Also, note that for the remainder of the book, we'll operate from within this `text_processing` virtual environment. Additional packages are installed using this same technique from within the confines of our environment.

After the install process was completed, we configured and activated our first virtual environment. You saw how to create a new instance via the `virtualenv` command and you also learned how to subsequently activate it using the `bin/activate` script. Finally, we showed you how to deactivate your environment and return to your system's default state.

Have a go hero – install your own environment

Now that you know how to set up your own isolated Python environment, you're encouraged to create a second one and install a collection of third-party utilities in order to get the hang of the installation process.

1. Create a new environment and name it as of your own choice.
2. Point your browser to `http://pypi.python.org` and select one or more packages that you find interesting. Install them via the `easy_install` command within your new virtual environment.

Note that you should not require administrative privileges to do this. If you receive an error about permissions, make certain you've remembered to activate your new environment. Deactivate when complete. Some of the packages available for install may require a correctly configured C-language compiler.

Where to get help?

The Python community is a friendly bunch of people. There is a wide range of online resources you can take advantage of if you find yourself stuck. Let's take a quick look at what's out there.

- Home site: The Python website, available at `http://www.python.org`. Specifically, the documentation section. The standard library reference is a wonderful asset and should be something you keep at your fingertips. This site also contains a wonderful tutorial as well as a complete language specification.
- Member groups: The `comp.lang.python` newsgroup. Available via Google groups as well as an e-mail gateway, this provides a general-purpose location to ask Python-related questions. A very smart bunch of developers patrol this group; you're certain to get a quality answer.
- Forums: Stack Overflow, available at `http://www.stackoverflow.com`. Stack overflow is a website dedicated to developers. You're welcome to ask your questions, as well as answer others' inquires, if you're up to it!
- Mailing list: If you have a beginner-level question, there is a Python tutor mailing list available off of the `Python.org` site. This is a great place to ask your beginner questions no matter how basic they might be!
- Centralized package repository: The Python Package Index at `http://pypi.python.org`. Chances are someone has already had to do exactly what it is you're doing.

If all else fails, you're more than welcome to contact the author via e-mail to `questions@packtpub.com`. Every effort will be made to answer your question, or point you to a freely available resource where you can find your resolution.

Summary

This chapter introduced you to the different categories of text that we'll cover in greater detail throughout the book and provided you with a little bit of information as to how we'll manage our packaging going forward.

We performed a few low-level text translations by implementing a ROT13 encoder and highlighted the differences between freeform and structured markup. We'll examine these categories in much greater detail as we move on. The goal of that exercise was to learn some byte-level transformation techniques.

Finally, we touched on a couple of different ways to read data into our applications. In our next chapter, we'll spend a great deal of time getting to know the IO system and learning how you can extract text from a collection of sources.

2
Working with the IO System

Now that we've covered some basic text-processing methods and introduced you to some core Python best practices, it's time we take a look at how to actually get to your data. Reading some example text from the command line is an easy process, but getting to real world data can be more difficult. However, it's important to understand how to do so.

Python provides all of the standard file IO mechanisms you would expect from any full-featured programming language. Additionally, there is a wide range of standard library modules included that enable you to access data via various network services such as HTTP, HTTPS, and FTP.

In this chapter, we'll focus on those methods and systems. We'll look at standard file functionality, the extended abilities within the standard library, and how these components can be used interchangeably in many situations.

As part of our introduction to file input and output, we'll also cover some common exception-handling techniques that are especially helpful when dealing with external data.

In this chapter, we shall:

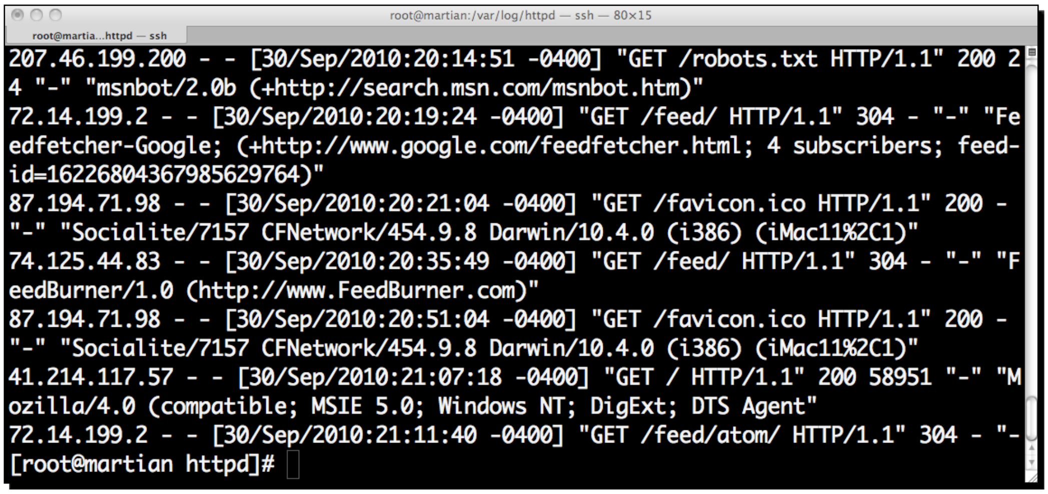
- Look at Python's file IO and examine the objects created by the `open` factory function
- Understand text-based and raw IO, and how they differ
- Examine the `urllib` and `urllib2` modules and detail file access via HTTP and FTP streams
- Handle file IO using Context Managers
- Learn about file-like objects and methods to use objects interchangeably for maximum reuse

- Introduce exceptions with a specific focus on idioms specific to file IO and how to deal with certain error conditions
- Introduce a web server logfile processor, which we'll expand upon throughout future chapters
- Examine ways to deal with multiple files
- We'll also spend some time looking at changes to the IO subsystem in future versions of Python

Parsing web server logs

We're going to introduce a web server log parser in this section that we'll build upon throughout the remainder of the book. We're going to start by assuming the logfile is in the standard Apache combined format.

For example, the following line represents an HTTP request for the root directory of a website. The request is successful, as indicated by the 200 series response code.


root@martian:/var/log/httpd — ssh — 80×15
root@martia...httpd — ssh

```
207.46.199.200 - - [30/Sep/2010:20:14:51 -0400] "GET /robots.txt HTTP/1.1" 200 2
4 "-" "msnbot/2.0b (+http://search.msn.com/msnbot.htm)"
72.14.199.2 - - [30/Sep/2010:20:19:24 -0400] "GET /feed/ HTTP/1.1" 304 - "-" "Fe
edfetcher-Google; (+http://www.google.com/feedfetcher.html; 4 subscribers; feed-
id=16226804367985629764)"
87.194.71.98 - - [30/Sep/2010:20:21:04 -0400] "GET /favicon.ico HTTP/1.1" 200 -
"-" "Socialite/7157 CFNetwork/454.9.8 Darwin/10.4.0 (i386) (iMac11%2C1)"
74.125.44.83 - - [30/Sep/2010:20:35:49 -0400] "GET /feed/ HTTP/1.1" 304 - "-" "F
eedBurner/1.0 (http://www.FeedBurner.com)"
87.194.71.98 - - [30/Sep/2010:20:51:04 -0400] "GET /favicon.ico HTTP/1.1" 200 -
"-" "Socialite/7157 CFNetwork/454.9.8 Darwin/10.4.0 (i386) (iMac11%2C1)"
41.214.117.57 - - [30/Sep/2010:21:07:18 -0400] "GET / HTTP/1.1" 200 58951 "-" "M
ozilla/4.0 (compatible; MSIE 5.0; Windows NT; DigExt; DTS Agent"
72.14.199.2 - - [30/Sep/2010:21:11:40 -0400] "GET /feed/atom/ HTTP/1.1" 304 - "-
[root@martian httpd]#
```

In order, the above line contains the remote IP address of the client, the remote **identd** name, the authenticated username, the server's timestamp, the first line of the request, the HTTP response code, the size of the file as returned by the server, the referring page, and finally the User Agent, or the browser software running on the end user's computer.

The dashes in the previous screenshot indicate a missing value. This doesn't necessarily correspond to an error condition. For example, if the page is not password-protected then there will be no remote user. The dash is a common condition we'll need to handle.

[For more information on web server log formats and available data points, please see your web server documentation. Apache logs were used to write this book; documentation for the Apache web server is available at `http://httpd.apache.org/docs/2.2/mod/mod_log_config.html`]

Time for action – generating transfer statistics

Now, let's start our processor. Initially, we'll build enough functionality to scan our logfile as read via standard input and report files served over a given size. System administrators may find utilities such as this useful when attempting to track down abusive users. It's also generally a good idea to iteratively add functionality to an application in development.

1. First, step into the virtual environment created in *Chapter 1*, *Getting Started* and activate it so that all of our work is isolated locally. Only the UNIX method is shown here.

```
$ cd text_processing/
$ . bin/activate
```

2. Create an empty Python file and name it `logscan.py`. Enter the following code:

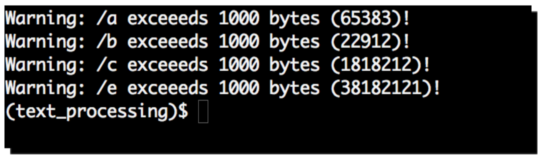
```
#!/usr/bin/python
import sys
from optparse import OptionParser

class LogProcessor(object):
    """
    Process a combined log format.

    This processor handles logfiles in a combined format,
    objects that act on the results are passed in to
    the init method as a series of methods.
    """
    def __init__(self, call_chain=None):
        """
        Setup parser.

        Save the call chain. Each time we process a log,
        we'll run the list of callbacks with the processed
        log results.
        """
        if call_chain is None:
            call_chain = []
        self._call_chain = call_chain
    def split(self, line):
        """
        Split a logfile.

        Initially, we just want size and requested file name, so
        we'll split on spaces and pull the data out.
        """
        parts = line.split()
        return {
            'size': 0 if parts[9] == '-' else int(parts[9]),
            'file_requested': parts[6]
        }

    def parse(self, handle):
        """
        Parses the logfile.

        Returns a dictionary composed of log entry values
        for easy data summation.
        """
        for line in stream:
            fields = self.split(line)
            for func in self._call_chain:
                func(fields)

class MaxSizeHandler(object):
    """
    Check a file's size.
    """
    def __init__(self, size):
        self.size = size

    def process(self, fields):
        """
        Looks at each line individually.

        Looks at each parsed log line individually and
        performs a size calculation. If it's bigger than
        our self.size, we just print a warning.
        """
if fields['size'] > self.size:
            print >>sys.stderr, \
                'Warning: %s exceeeds %d bytes (%d)!' % \
                    (fields['file_requested'], self.size,
                     fields['size'])

if __name__ == '__main__':
    parser = OptionParser()

    parser.add_option('-s', '--size', dest="size",
        help="Maximum File Size Allowed",
            default=0, type="int")

    opts,args = parser.parse_args()
    call_chain = []

    size_check = MaxSizeHandler(opts.size)
    call_chain.append(size_check.process)
    processor = LogProcessor(call_chain)
    processor.parse(sys.stdin)
```

3. Now, create a new file and name it `example.log`. Enter the following mock logdata. Note that each line begins with `127.0.0.1` and should be entered as such.

```
127.0.0.1 - - [29/Mar/2010:00:48:05 +0000] "GET /a HTTP/1.1" 200
65383 "-" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1; SV1;
.NET CLR 1.1.4322)"
127.0.0.1 - - [29/Mar/2010:00:48:05 +0000] "GET /b HTTP/1.1" 200
22912 "-" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1; SV1;
.NET CLR 1.1.4322)"
127.0.0.1 - - [29/Mar/2010:00:48:05 +0000] "GET /c HTTP/1.1" 200
1818212 "-" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1;
SV1; .NET CLR 1.1.4322)"
127.0.0.1 - - [29/Mar/2010:00:48:05 +0000] "GET /d HTTP/1.1" 200
888 "-" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1; SV1;
.NET CLR 1.1.4322)"
127.0.0.1 - - [29/Mar/2010:00:48:05 +0000] "GET /e HTTP/1.1" 200
38182121 "-" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1;
SV1; .NET CLR 1.1.4322)"
```

4. Now run the `logscan.py` script by entering the following command. If all code and data has been entered correctly, you should see the following output.

```
(text_processing)$ cat example.log | python logscan.py  -s 1000
```



```
Warning: /a exceeeds 1000 bytes (65383)!
Warning: /b exceeeds 1000 bytes (22912)!
Warning: /c exceeeds 1000 bytes (1818212)!
Warning: /e exceeeds 1000 bytes (38182121)!
(text_processing)$
```

What just happened?

Let's go through the code and look at what's going on. We expanded on concepts from the first chapter and introduced quite a few new elements here. It's important that you understand this example as we'll use it as the foundation for many of our future exercises.

First, recognize what should be familiar to you. We've parsed our arguments, ensured that our main code is only executed when our script is started directly, and we created a couple of classes that make up our application. We also passed the open file stream to our `parse` method, much like we did with our ROT13 example. Simple!

This application is largely composed of two main classes: `LogProcessor` and `MaxSizeHandler`. We split it off like this to ensure we can expand in the future. Perhaps we'll want to add more checks or handle logfiles in a different format. This approach ensures that is possible.

The `__init__` method of `LogProcessor` takes a `call_chain` argument, which defaults to `None`. This will contain a list of functions that we'll call for each line in the logfile, passing in the values parsed out of each line as a dictionary.

If you look further into the `__init__` method, you'll see the following code:

```
if call_chain is None:
            call_chain = []
        self._call_chain = call_chain
```

This may look peculiar to you. Why wouldn't we simply default `call_chain` to an empty list object? The answer is actually rather complex. For now, simply understand that if we do that, we may accidentally share a copy of `call_chain` among all instances of our class!

[If you're curious as to why using an empty list is a bad idea, have a look at `http://www.ferg.org/projects/python_gotchas.html#contents_item_6.2`. Most of the time, what you actually get is not what you would expect and subtle bugs slip into your code.]

In our `split` method, we break our logfile line up at the space boundary. Obviously, this doesn't work if we needed some of the fields that contain spaces, but we're not that far yet. For now, this is an acceptable approach. Note the check for the dash here. It's possible that the web server may not report a size on each request. Consider the effect of a browser cache where new data is not transferred over the network if it hasn't changed on the server.

[The `split` method utilizes Python's conditional expressions, which first appeared in version 2.5. If you're using an earlier version of Python, you'll need to expand into a traditional `if - else` block.]

Finally, we have our `parse` method. This method is responsible for translating each line of the logfile into a useable dictionary and passing it into each method in our stored `call_chain`.

Next, we have our MaxSizeHandler class. This class ought to be rather straightforward. At initialization time, we store a maximum file size. When our process method is called as part of the call_chain run, we simply print a warning if the current file exceeds the threshold.

The script proper should look largely familiar to you. We parse our command-line options via the OptionParser class, but this time we introduce type translation. We create an instance of MaxSizeHandler and add its process method to our call_chain list. Finally, that list is used to create a new LogProcessor instance and we call its parse method.

Python methods and functions are considered to be **first class objects**. What does this mean? Simply put, you can pass them around to methods, assign them to collections, and bind them as other attributes just as if they were simple data types such as integers, strings, and class instances. No wrapper classes required!

Using objects interchangeably

The big take-away from this example is that objects can be designed such that they're interchangeable. The technical term for this is **Polymorphism**. This comes into play throughout the chapter as we look at different methods of accessing datafiles.

Time for action – introducing a new log format

Let's take a closer look at this concept. Let's assume for a second that a colleague heard about your nifty log-processing program and wanted to use it to parse his data. The trouble is that he's already tried his hand at solving the problem with standard shell utilities and his import format is slightly different. It's simply a list of file names followed by the file size in bytes.

1. Using logscan.py as a template, create a new file named logscan-b.py. The two files should be exactly the same.
2. Add an additional class directly below LogProcessor as follows.

```
class ColumnLogProcessor(LogProcessor):
    def split(self, line):
        parts = line.split()
        return {
            'size': int(parts[1]),
            'file_requested': parts[0]
        }
```

3. Now, change the line that creates a `LogProcessor` object. Instead, we want it to create a `ColumnLogProcess` object.

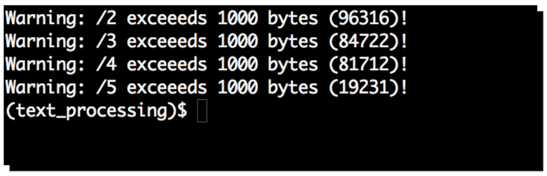
```
call_chain.append(size_check.process)
processor = ColumnLogProcessor(call_chain)
processor.parse(sys.stdin)
processor = ColumnLogProcessor(call_chain)
```

4. Create a new input file and name it `example-b.log`. Enter test data exactly as follows.

```
/1 1000
/2 96316
/3 84722
/4 81712
/5 19231
```

5. Finally, run the updated source code. If you entered everything correctly, your output should be as follows.

```
(text_processing)$  cat example-b.log | python logscan-b.py -s
1000
```



```
Warning: /2 exceeeds 1000 bytes (96316)!
Warning: /3 exceeeds 1000 bytes (84722)!
Warning: /4 exceeeds 1000 bytes (81712)!
Warning: /5 exceeeds 1000 bytes (19231)!
(text_processing)$
```

What just happened?

We added support for a new log input format simply by replacing the `parse` method of our log processor. We did this by inheriting from `LogProcessor` and creating a new class, overriding `parse`.

There are no additional changes required to support an entirely new format. As long as your new `LogProcessor` class implements the required methods and returns the proper values, it's a piece of cake. Your `LogProcessor` subclass could have done something much more elaborate, such as process each line via regular expressions or handle missing elements gracefully.

Conversely, adding new `call_chain` methods is just as easy. As long as the function in the list takes a dictionary as input, you can add new processing methods as well.

Have a go hero – creating a new processing class

In these examples, we've printed a warning if a file exceeds a threshold. Instead, what if we wanted to warn if a file was below a given threshold? This might be useful if we thought our web server was truncating results or returning invalid data. Your job is to add a new handler class to the `call_chain` that warns if a file is below a specific size. It should be able to run side-by-side along with the existing `MaxSizeHandler` handler.

Accessing files directly

Up until now, we've read all of our data via a standard input pipe. This is a perfectly acceptable and extensible way of handling input. However, Python provides a very simple mechanism for accessing files directly. There are situations where direct file access is preferable. For example, perhaps you're accessing data from within a web application and using standard IO just isn't possible.

Time for action – accessing files directly

Let's update our `LogProcessor` so that we can pass a file on the command line rather than read all of our data via `sys.stdin`.

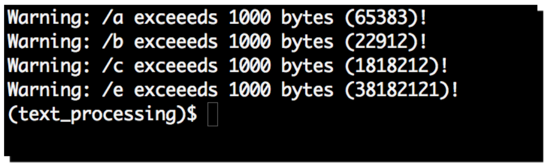
1. Create a new file named `logscan-c.py`, using `logscan.py` as your template. We'll be adding file access support to this original "combined format" processor.

2. Update the code in the `__name__ == '__main__'` section as follows.

```
if __name__ == '__main__':
    parser = OptionParser()

    parser.add_option('-s', '--size', dest="size",
        help="Maximum File Size Allowed",
            default=0, type="int")

    parser.add_option('-f', '--file', dest="file",
        help="Path to Web Log File", default="-")

    opts,args = parser.parse_args()
    call_chain = []

    if opts.file == '-':
        file_stream = sys.stdin
    else:
        try:
            file_stream = open(opts.file, 'r')
        except IOError, e:
            print >>sys.stderr, str(e)
            sys.exit(-1)

    size_check = MaxSizeHandler(opts.size)
    call_chain.append(size_check.process)
    processor = LogProcessor(call_chain)
    processor.parse(file_stream)
```

3. Run the updated application from the command line as follows:

```
(text_processing)$  python logscan-c.py -s 1000 -f example.log
```



```
Warning: /a exceeeds 1000 bytes (65383)!
Warning: /b exceeeds 1000 bytes (22912)!
Warning: /c exceeeds 1000 bytes (1818212)!
Warning: /e exceeeds 1000 bytes (38182121)!
(text_processing)$
```

What just happened?

There are a couple of things here that are new. First, we added a second option to our command-line parser. Using a `–f` or a `–file` switch, you can now pass in the name of a logfile you wish to parse. We set the default value to a single dash, which signifies we should use `sys.stdin` as we did in our earlier examples. Using a dash in this manner is common with command-line-based utilities such as `tar` and `cat`.

Next, if an actual file name was passed via our new switch, we're going to open it here via Python's built-in `open` function. `open` returns a file object and binds it to the `file_stream` attribute. The first argument to open is the file name; the second is the mode we wish to use.

```
>>> open('/etc/hosts', 'r')
<open file '/etc/hosts', mode 'r' at 0x10047d250>
>>>
```

Notice that if a file name wasn't passed in, we simply assign `sys.stdin` to `file_stream`. Both of these objects are considered to be file-like objects. They implement the same set of core functionality, though the input sources are different. This is another example of polymorphism.

Finally, we've wrapped our `open` method in a `try/except` block in order to catch any exceptions that may bubble up from the `open` function. In this example, we are catching `IOErrors` only. Any other programming error triggered inside the `try` block will simply trigger a stack trace.

[The Python exception hierarchy is described in detail at `http://docs.python.org/library/exceptions.html#exception-hierarchy`. Errors generated during Input/Output operations generally raise `IOError` exceptions. You should take some time to familiarize yourself with the layout of Python's exception classes.]

The `open` function is a built-in factory for python `file` objects. It is possible to call the `file` object directly, but that is discouraged. In later versions of Python, a call to open actually returns a layered IO object and not just a simple file class.

It's possible to open a file in either text or binary mode. By default, a file is opened using text mode. To tell Python that you're working with binary data, you simply need to pass a `b` in as an additional mode flag. So, if you wanted to open a file for appending binary data, you would use a flag of `ab`. Binary mode is only significant on DOS/Windows systems. When text data is written on a Windows machine, trailing newlines are converted to a newline-carriage return combination. The file object needs to take that into account.

Astute readers should have noticed that we never actually closed the file. We simply left it open and allowed the operating system to reclaim resources when we were finished. While this is alright for small applications like this, we need to be careful to close all files in real applications.

Context managers

The `with` statement has been a Python fixture since 2.5. The statement allows the developer to create a new code block while holding a resource. When the code block exits, the resource is automatically closed. This is true even if the code block exits in error.

[It's also possible to use context managers for other resources as the context manager protocol is quite extensible.]

The following example illustrates the use of a context manager.

```
Python 2.6.1 (r261:67515, Jul  7 2009, 23:51:51)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more
information.
>>> with open('/etc/passwd') as f:
...     for line in f:
...         if line.startswith('root:'):
...             print line
...
root:*:0:0:System Administrator:/var/root:/bin/sh
>>> f.read()
```

```
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: I/O operation on closed file
>>>
```

In this example, we opened our system password database and assigned the value returned by the `open` function to `f`. While we were in the subsequent block, we were able to perform file IO as we normally would.

When we exited the block by decreasing the indent, the context manager associated with the file object ensured the file was automatically closed for us. This is evident by the exception raised when we tried to simply read the object outside of the `with` statement. Note that while the attribute `f` is still a valid object, the underlying file descriptor has already been closed.

To achieve the same closed-file guarantee without the `with` statement, we would need to do something such as the following.

```
Python 2.6.1 (r261:67515, Jul  7 2009, 23:51:51)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more
information.
>>> try:
...     f = open('/etc/hosts')
...     print len(f.read())
... finally:
...     try:
...         f.close()
...     except AttributeError:
...         pass
...
345
>>>
```

Here, the code within the `finally` block is executed whether or not the proceeding `try` block completes successfully. Within our `finally` block, we've nested yet another `try`. This is because if the original `open` had failed, then `f` was never bound. Attempting to close it would result in an `AttributeError` exception originating from `f.close`!

You're encouraged to take advantage of the `with` statement as it's a wonderful way to avoid file descriptor leaks within long-running applications.

Handling other file types

As we've seen, the Python file-like object is a powerful thing. But, there's more. Let's imagine for a second that your server logfiles are compressed in order to save on storage space. We can make one more simple change to our script so that we have native support for common compression formats.

Time for action – handling compressed files

In this example, we'll add support for common compression formats using Python's standard library.

1. Using the code in `logscan-c.py` as your starting point, create `logscan-d.py`. Add a new function just below the `MaxSizeHandler` class.

```
def get_stream(path):
    """
    Detect compression.

    If the file name ends in a compression
    suffix, we'll open it using the correct
    algorith. If not, we just return a standard
    file object.
    """
    _open = open
    if path.endswith('.gz'):
        _open = gzip.open
    elif path.endswith('.bz2'):
        _open = bz2.open

    return _open(path)
```

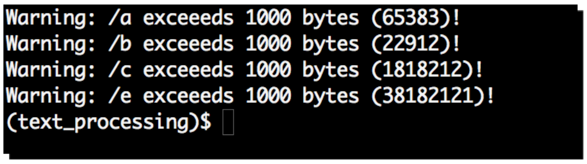
2. Within our main section, update the line that reads `open(opts.file)` to read `get_stream(opts.file)..`

3. At the top of the listing, ensure that you're importing the two new compression modules referenced in `get_stream`.

```
import gzip
import bz2
```

4. Finally, we can compress our example log using `GZIP` and run our log scanner as we have in earlier examples.

```
(text_processing)$ gzip example.log
(text_processing)$ python logscan-d.py -f example.log.gz -s 1000
```



```
Warning: /a exceeeds 1000 bytes (65383)!
Warning: /b exceeeds 1000 bytes (22912)!
Warning: /c exceeeds 1000 bytes (1818212)!
Warning: /e exceeeds 1000 bytes (38182121)!
(text_processing)$
```

What just happened?

In this example, we added support for both `GZIP` and `BZ2` compressed files as supported by Python's standard library.

The bulk of the new functionality resides in the `get_stream` function we've added. We look at the file extension provided by the user and make a determination as to which open function we want to use. If the file appears to be compressed, we'll use a compression-specific approach. If the file appears to be plain text, we'll default to the built-in `open` function we used in our earlier examples.

In order to add our new functionality into the mix, we've replaced our call to `open` within the main code to reference our new `get_stream` function.

Implementing file-like objects

As mentioned earlier, objects can be used interchangeably as long as they provide the same set of externally facing methods. This is referred to as implementing a protocol, or more commonly, an interface. Languages such as Java, C#, and Objective-C utilize strict interfaces that require a developer to implement a minimum set of functionality within a class

Python, on the other hand, does not enforce such restrictions. Python's type system is referred to as **Duck Typing**. If it looks like a duck and quacks like a duck, then it must be a duck.

While Python itself does not support strict interfaces, there are third-party libraries available designed to fill that perceived gap. The Zope project is heavily based on a library-based interface system. For more information, see `http://www.zope.org/Products/ZopeInterface`.

Probably the most common protocol you'll see within Python code is the **file-like object**. Not surprisingly, a file-like object is a Python object designed to "stand in" for a real file object. The compression streams, as well as the `sys.stdin` pipe that we looked at earlier, are all examples of a file-like object.

These objects do not necessarily need to implement all of the methods associated with a real file object. For example, a read-only object needs to only implement the proper `read` methods, and a `socket` stream doesn't need to implement a `seek` method.

File object methods

Let's take a closer look at some of the methods found on a standard file object. It's important to understand file objects as proper IO and data access can dramatically affect the speed and performance of a data-bound application. This is not an all-inclusive list. To see a detailed breakdown, visit the `http://docs.python.org/library/stdtypes.html#file-objects`.

Objects are free to implement as many of these as they wish, so be prepared to deal with exceptions if you're not certain where your file object is coming from.

close

The `close` method is responsible for flushing data and closing the underlying file descriptor. Any attempt to access a file after it has been closed will result in a `ValueError` exception. This also sets the `.closed` attribute to `True`. Note that it is possible to call the `close` method more than once without triggering an error.

fileno

The `fileno` method returns the underlying integer file descriptor. Many lower-level IO functions (especially those found in the `os` module) require a standard system-level file descriptor.

flush

The `flush` method causes Python to clear the internal I/O buffer and force data to disk. This doesn't perform a disk sync, however, as data may still simply reside in OS memory.

read

The `read` method will read data from the file object and return it as a string. If a `size` argument is passed in then this method will read that much data from the file object, in bytes. If the size argument is not passed in then `read` will go until `EOF` is reached.

readline

The `readline` method will read a single line from a file, retaining the trailing newline character. A `size` argument may be passed in, which limits the amount of data that will be read. If the maximum size is smaller than line length, an incomplete line may be returned. Each call returns a successive line in a file.

```
(text_processing)$ python
Python 2.6.1 (r261:67515, Jul  7 2009, 23:51:51)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
```

```
Type "help", "copyright", "credits", or "license" for more information.
>>> f = open('/etc/passwd')
>>> f.readline()
'##\n'
>>> f.readline()
'# User Database\n'
>>> f.readline()
'# \n'
>>> f.readline()
'# Note that this file is consulted directly only when the system is
running\n'
>>>
```

This is a convenient method to extract the first line of a file; however, there are better methods if you wish to simply loop through the context of a text file.

readlines

This method reads each line of a file into a list, until it reaches `EOF`. Each element of the list is one line within a file. As with the `readline` method, each line retains its trailing new line. This method is acceptable for smaller files, but can trigger heavy memory use if used on larger files.

The idiomatic way to loop through a text file is to loop on the file object directly, as we've done in previous examples.

seek

As IO is performed, an offset within the instance is changed accordingly. Subsequent reads (or writes) will take place at that current location. The `seek` method allows us to manually set that offset value. To expand upon the read line example from above, let's introduce a seek.

```
(text_processing)$ python
Python 2.6.1 (r261:67515, Jul  7 2009, 23:51:51)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> f = open('/etc/passwd')
>>> f.readline()
'##\n'
>>> f.readline()
'# User Database\n'
>>> f.seek(0)
>>> f.readline()
'##\n'
>>> f.readline()
'# User Database\n'
>>>
```

Notice how the call to seek moves us back to the beginning of the file and we begin reading the same data a second time. This method is frequently left out of non file-based file-like objects, or is coded as a `null` operation.

tell

This is the counterpart to `seek`. Calling `tell` returns the current location of the file pointer as an integer offset.

write

The `write` method simply takes a `source` argument and writes it to the open file. It is not possible to pass in a desired size; the entire string is pushed to disk. If you wish to only write a portion then you should limit the size via string slicing. A `flush` or a `close` may be required before the data written appears on disk. String slicing is covered in our chapter on Python String Services.

writelines

The `writelines` method is the counterpart to the `readlines` method. Given a list or a sequence of strings, they will be written to the file. Newlines are not automatically added (just as they are not automatically stripped from `readlines`). This is generally equivalent to calling write for each element in a list.

Remember that not all of these methods need to be implemented on all file-like objects. It's up to you to implement what is needed and convey that via proper documentation.

Enabling universal newlines

Python utilizes a universal newlines system. Remember that the end-of-line marker varies by operating system. On Unix and Unix derivatives, a line is marked with a `\n` terminator. On Windows systems, a line ends with a `\r\n` combination.

Universal newlines support abstracts that out and presents each end-of-line marker as a `\n` to the programmer. To enable this support, append a `U` to the mode string when calling the built-in `open` function.

Accessing multiple files

Let's take a little break from our `LogProcessing` application and look at Python's `fileinput` module. In situations where you need to open more than one file and iterate through the continents of each sequentially, this module can be a great help.

Note that as of the time of writing, the PyEnchant modules were not compatible with Python 3. Therefore, these examples will only work with Python 2.

Time for action – spell-checking HTML content

In this example, we'll build a small application that can be used to check spelling in a collection of HTML documents. We'll utilize the PyEnchant library here, which is based upon the Enchant spell-check system.

1. Step into the virtual environment that we've created for our examples and run the activate script for your platform.
2. Next, we'll install the pyenchant libraries using the easy_install utility. The spell-check system is available on PyPI. Note that you must already have the Enchant system installed on your workstation. Ubuntu users can install the libenchant1c2a library. Windows users should follow the instructions at http://www.abisource.com/projects/enchant/. There are binary packages available. You may also need to install the en_US dictionary, which is also covered at the previous URL.
3. Using easy_install, we'll add the PyEnchant libraries to our virtual environment.

```
(text_processing)$ easy_install pyenchant
Searching for pyenchant
Reading http://pypi.python.org/simple/pyenchant/
Reading http://pyenchant.sourceforge.net/
Best match: pyenchant 1.6.1
Downloading http://pypi.python.org/packages/2.6/p/pyenchant/
pyenchant-1.6.1-py2.6.egg#md5=21d991be432cc92781575b42225a6d3e
Processing pyenchant-1.6.1-py2.6.egg
creating /home/jmcneil/text_processing/lib/python2.6/site-
packages/pyenchant-1.6.1-py2.6.egg
Extracting pyenchant-1.6.1-py2.6.egg to /home/jmcneil/text_
processing/lib/python2.6/site-packages
Adding pyenchant 1.6.1 to easy-install.pth file

Installed /home/jmcneil/text_processing/lib/python2.6/site-
packages/pyenchant-1.6.1-py2.6.egg
Processing dependencies for pyenchant
Finished processing dependencies for pyenchant
(text_processing)$
```

4. Create this first HTML file and name it `index.html`. This will be the main page of our very basic website.

```
<html>
<head>
    <title>Welcome to our home page</title>
</head>
<body>
    <h1>Unladen Swallow Spped<h1>
    There is an ongoing debate in the Python community regarding
    the speed of an unladen swallw. This site aims to settle
    that debate.
    <ul>
        <li><a href="air_speed.html">Air Speed</a>
    </ul>
<body>
</html>
Now create this second HTML file and name it air_speed.html, as
referenced in the anchor tag above.
<html>
<head>
    <title>Air speed</title>
<head>
<body>
    In order to maintain speed, a swallow must flap its wings 32
times per second?
</body>
</html>
</html>
```

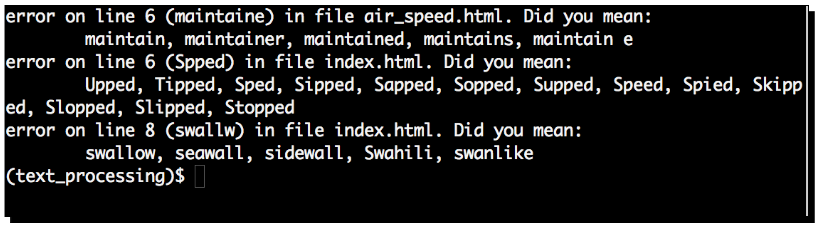
5. Finally, we'll create our code. Create the following file and name it `html_spelling.py`. Save it and exit your editor.

```
import fileinput
import enchant
from enchant.tokenize import get_tokenizer,
from enchant.tokenize import HTMLChunker
__metaclass__ = type
class HTMLSpellChecker:
    def __init__(self, lang='en_US'):
        """
        Setup tokenizer.
        Create a new tokenizer based on lang.
        This lets us skip the HTML and only
```

```
            care about our contents.
            """
            self.lang = lang
            self._dict = enchant.Dict(self.lang)
            self._tk = get_tokenizer(self.lang,
                  chunkers=(HTMLChunker,))

        def __call__(self, line):
            for word,off in self._tk(line):
                if not self._dict.check(word):
                    yield word, self._dict.suggest(word)

    if __name__ == '__main__':

        check = HTMLSpellChecker()
        for line in fileinput.input():
            for word,suggestions in check(line):
                print "error on line %d (%s) in file %s. \
    Did you mean one of %s?" % \
                    (fileinput.filelineno(), word, \
    fileinput.filename(),
                        ', '.join(suggestions))
```

6. Run the last script using the HTML files we created as input on the command line. If you've entered everything correctly, you should see the following output. Note we've reformatted here to avoid potentially confusing line-wrapping.

   `(text_processing)$ python html_spelling.py *.html`



```
error on line 6 (maintaine) in file air_speed.html. Did you mean:
        maintain, maintainer, maintained, maintains, maintain e
error on line 6 (Spped) in file index.html. Did you mean:
        Upped, Tipped, Sped, Sipped, Sapped, Sopped, Supped, Speed, Spied, Skipp
ed, Slopped, Slipped, Stopped
error on line 8 (swallw) in file index.html. Did you mean:
        swallow, seawall, sidewall, Swahili, swanlike
(text_processing)$
```

What just happened?

We took a look at a few new things in this example, in addition to Python's `fileinput` module. Let's step though this example slowly as there's quite a bit going on.

First of all, we imported all of our necessary modules. Following the standards, we first imported the modules that are part of the Python standard library, and then we required third-party packages. In this case, we're using the third-party **PyEnchant** toolkit.

Next, we bump into something that's probably unfamiliar to you: `__metaclass__ = type`. The core Python developers changed the class implementation (for the better) before the release of Python 2.1. We have both new style and old style classes. New style classes must inherit from the object in some manner, or be explicitly assigned a `metaclass` of type. This is a neat little trick that tells Python to create only new style classes in this module.

Our `HTMLSpellChecker` class is responsible for performing the spell-check. In the `__init__` method, we create both a dictionary (which has no relation to the built in `dict` type) and a `tokenizer`. We'll use the dictionary for both spell-check and to ask for suggestions if we've found a misspelled word. The `tokenizer` object will be used to split each line into its component parts. The `chunkers=(HTMLChunker,)` argument tells Enchant that we're working with HTML, and that it should automatically strip markup. The provided `HTMLChunker` class saves us some extra work, though we'll cover how to do that via regular expressions later in the book.

Next, we define a `__call__` method. This method is special as it is executed each time a Python object is called directly, as if it were a function.

```
(text_processing)$ python
Python 2.6.1 (r261:67515, Jul  7 2009, 23:51:51)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> class A(object):
...     def __call__(self):
...         print "A is for Apple"
...
>>> a = A()
>>> a()
A is for Apple
>>> a.__call__()
A is for Apple
>>>
```

This example illustrates the usage of a `__call__` method in detail. Notice how we can simply treat our object as if it were a function. Of course, it's also possible to call the `__call__` method directly.

Within the body of the `__call__` method, we tokenize each line, using the `tokenizer` we created within `__init__`. PyEnchant strips out the HTML for us. Each word is then validated via the dictionary. If it is not found, the application will provide a list of suggestions. The `yield` keyword marks this method as a generator, so we `yield` each spelling error and its suggestions back to our caller.

Now, we get to our main content. The first line is familiar. We're simply creating an instance of our `HTMLSpellChecker` class. The next section is where we put `fileinput` to use.

The call to `fileinput.input` creates an iterator that transparently chains together all of the files we passed in on the command line. Helper functions `fileinput.filelineno`, and `fileinput.filename` give us the current file's line number and the current file's name, respectively.

In Python, an **iterator** is a type of object that implements an interface that allows the developer to easily iterate through its contents. For more information on iteration, see `http://docs.python.org/library/stdtypes.html#iterator-types`.

You may have noticed that we don't actually pass any file names to the `fileinput.input` method. The module actually defaults to the values on the command line, and assumes they are valid paths. If nothing is passed on the command line then the module will fall back to standard input. It is possible to bypass this behavior and pass in our own list of files.

Simplifying multiple file access

The `fileinput` module takes a lot of complexity in opening and managing multiple files. In addition to current file and line number, it's possible to look at things such as absolute line number among all files and access file object-specific items such as a file's specific integer descriptor.

Using a classic approach, one would need to open each file manually and iterate through, retaining overall position information.

As we said previously, it's possible to use `fileinput` without relying on the value of the command-line arguments on `sys.argv`. The `fileinput.input` function takes an optional list of files to use read rather than working with the default.

A drawback in using the module-level methods is that we'll be creating a single instance of `fileinput.FileInput` under the covers, which holds global state. Doing this ensures that we cannot have more than one iterator active at one point of time and that it's not a thread-safe operation.

Thankfully, we can easily overcome these limitations by building our own instance of `fileinput.FileInput` rather than relying on the module-convenient functions.

```
>>> import fileinput
>>> input = fileinput.FileInput(['/etc/hosts'])
>>> for line in input:
...     if line.startswith('127'):
...             print line
...
127.0.0.1 localhost
>>>
```

Each `fileinput.FileInput` instance contains the same methods available to us at the module-level, though they all operate on their own separate context and do not interfere with each other.

Inplace filtering

Finally, the `fileinput` module contains an `inplace` filter feature that isn't very widely utilized. If the `fileinput.input` function is called with an `inplace=1` keyword argument, or if `inplace=1` is passed to the `fileinput.FileInput` constructor, the opened files are renamed to backup files and standard output is redirected to the original file. Inplace filtering is disabled when reading from standard input.

For example, take a look at the following snippet of code.

```
import sys
import fileinput

# Iterate through all lines and replace
# convert everything to uppercase.
for line in fileinput.input(inplace=1, backup='.bak'):
    sys.stdout.write(line.upper())
```

Running this script with a text file on the command line will first generate a backup of the text file, ending in a `.bak` extension. Next, the original file will be overwritten with whatever is printed as the standard output. Specifically, we're simply translating all of the text to uppercase here.

If you accidentally divide by zero and don't handle the exception, your destination file can be left in a corrupted state as your application may exit unexpectedly before you write any data to your file.

When using this approach, ensure you're properly handling exceptions as your file will be opened in `write` mode and truncated accordingly.

Pop Quiz – file-like objects

1. As we've seen, file-like objects do not necessarily need to implement the entire standard file object's methods. If an attempt is made to run a method and that method does not exist, what happens?
2. In what situation might you be better off using the `readlines` method of a file versus iterating over the file object itself?
3. What happens if you attempt to open a text file and you specify binary mode?
4. What is the difference between a file object and a file-like object?

Accessing remote files

We've now had a somewhat complete crash-course in Python I/O. We've covered files, file-like objects, handling multiple files, writing filter programs, and even modifying files "inplace" using some slightly esoteric features of the `fileinput` module.

Python's standard library contains a whole series of modules, which allow you to access data on remote systems almost as easily as you would access local file. Through the file-like object protocol, most I/O is transparent once the protocol-level session has been configured and established.

Time for action – spell-checking live HTML pages

In this example, we'll update our HTML spell-checker so that we can check pages that are already being served, without requiring local access to the file system. To do this, we'll make use of the Python `urllib2` module.

1. We'll be using `html_spelling.py` file as our base here, so create a copy of it and name the file `html_spelling-b.py`.
2. At the top of the file, update your import statements to include `urllib2`, and remove the `fileinput` module as we'll not take advantage of it in this example.

```
import urllib2
import enchant
import optparse
```

3. Now, we'll update our module-level main code and add an option to accept a URL on the command-line.

```
if __name__ == '__main__':
    parser = optparse.OptionParser()
    parser.add_option('-u', '--url', help="URL to Check")
    opts, args = parser.parse_args()

    if not opts.url:
        parser.error("URL is required")
```

4. Finally, change the `fileinput.input` call to reference `urllib2.urlopen`, add a line number counter, and polish up the output content.

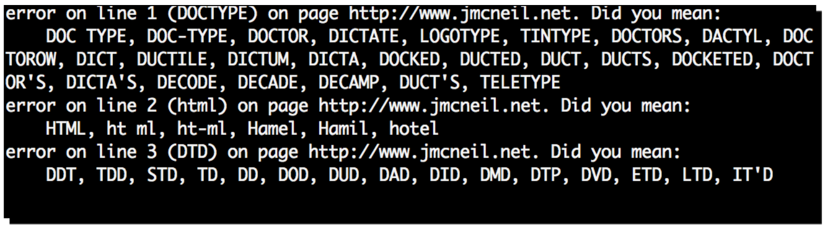
```
for line in urllib2.urlopen(opts.url):
        lineno = 0
        for word,suggestions in check(line):
            lineno += 1
            print "error on line %d (%s) on page %s. Did you 
mean:\n\t%s" % \
                (lineno, word, opts.url, ', '.join(suggestions))
```

5. That should be it. The final listing should look like the following code. Notice how little we had to change.

```
import urllib2
import enchant
import optparse

from enchant.tokenize import get_tokenizer
from enchant.tokenize import HTMLChunker

__metaclass__ = type

class HTMLSpellChecker:
    def __init__(self, lang='en_US'):
        """
        Setup tokenizer.

        Create a new tokenizer based on lang.
        This lets us skip the HTML and only
        care about our contents.
        """
        self.lang = lang
        self._dict = enchant.Dict(self.lang)
        self._tk = get_tokenizer(self.lang,
              chunkers=(HTMLChunker,))

    def __call__(self, line):
        for word,off in self._tk(line):
            if not self._dict.check(word):
                yield word, self._dict.suggest(word)

if __name__ == '__main__':
    parser = optparse.OptionParser()
    parser.add_option('-u', '--url', help="URL to Check")
    opts, args = parser.parse_args()

    if not opts.url:
        parser.error("URL is required")

    check = HTMLSpellChecker()
    for line in urllib2.urlopen(opts.url):
        lineno = 0
        for word,suggestions in check(line):
            lineno += 1
            print "error on line %d (%s) on page %s. Did you 
mean:\n\t%s" % \
                (lineno, word, opts.url, ', '.join(suggestions))
```

6. Now, run the application with a URL passed in on the command line. If it was coded correctly, your output should resemble the following.

```
(text_processing)$ python html_spelling-b.py --url=http://www.
jmcneil.net
```



```
error on line 1 (DOCTYPE) on page http://www.jmcneil.net. Did you mean:
    DOC TYPE, DOC-TYPE, DOCTOR, DICTATE, LOGOTYPE, TINTYPE, DOCTORS, DACTYL, DOC
TOROW, DICT, DUCTILE, DICTUM, DICTA, DOCKED, DUCTED, DUCT, DUCTS, DOCKETED, DOCT
OR'S, DICTA'S, DECODE, DECADE, DECAMP, DUCT'S, TELETYPE
error on line 2 (html) on page http://www.jmcneil.net. Did you mean:
    HTML, ht ml, ht-ml, Hamel, Hamil, hotel
error on line 3 (DTD) on page http://www.jmcneil.net. Did you mean:
    DDT, TDD, STD, TD, DD, DOD, DUD, DAD, DID, DMD, DTP, DVD, ETD, LTD, IT'D
```

What just happened?

By simply changing a few lines of code, we were able to access a web page and scan for spelling errors almost exactly as we did when we checked our local files. Of course, you're seeing a limitation of our dictionary here. Our spell-checker sees words such as `DOCTYPE`, `DTD`, and `HTML` as misspelled as they do not fall under the `en_US` category.

We could fix this by adding a custom dictionary to the spell-checker that includes technical lingo, but the goal in this example is to introduce I/O with the `urllib2` module.

One important thing to note is that the `urllib2.urlopen` method supports more than just the `HTTP` protocol. You can also access files using the secure-sockets layer by simply passing in an `HTTPS` URL. It's even possible to access local files by passing a path into the `urllib2.urlopen` method.

Yes, there is a `urllib` module. It is simply named `urllib`. This newer version is far more extensible and is recommended. However, it can be a bit tricky to understand in detail. There is a great reference available out there that describes some of the intricacies in a simple manner. The document is titled "urllib2: The Missing Manual" and is available at `http://www.voidspace.org.uk/python/articles/urllib2.shtml`.

The `urllib2.urlopen` can also directly access files via the `FTP` protocol. It's quite simple; the URL you pass into `urlopen` simply needs to begin with `ftp://`.

Have a go hero – access web logs remotely

As we've covered both web LogProcessing and the `urllib2` module superficially, you should be able to update our earlier LogProcessing application to access files remotely. You don't need an external account to try this. Remember, URLs beginning with `file://` are valid `urllib2.urlopen` URLs. You can make this change and test it locally.

Error handling

By now, you may have noticed that while we're able to access a range of protocols using this same mechanism, they all potentially return different errors and raise varying exceptions. There are two obvious solutions to this problem: we could catch each individual exception explicitly, or simply catch an exception located at the top of the exception hierarchy.

Fortunately, we don't need to take either of those sub-optimal approaches. When an internal error occurs within the `urllib2.urlopen` function, a `urllib2.URLError` exception is raised. This gives us a convenient way to catch relevant exceptions while letting unrelated problems bubble up. Let's take a quick look at an example to solidify the point.

Python's exception hierarchy is worth getting to know. You can read up on exceptions in detail at `http://docs.python.org/library/exceptions.html`.

Time for action – handling urllib 2 errors

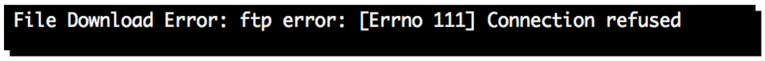
In this example, we'll update our HTML spell-checker in order to handle network errors slightly more gracefully. Whenever you provide utilities and interfaces to your users, you should present errors in a clean manner (while logging any valid stack traces).

1. We're going to build off `html_spelling-b.py`, so copy it over and rename it to `html_spelling-c.py`.
2. At the top of the file, add `import sys`. We'll need access to the methods within the `sys` module.
3. Update the `__name__ == '__main__'` section to include some additional exception-handling logic.

```
if __name__ == '__main__':
    parser = optparse.OptionParser()
    parser.add_option('-u', '--url', help="URL to Check")
    opts, args = parser.parse_args()

    if not opts.url:
        parser.error("URL is required")

    check = HTMLSpellChecker()
    try:
        source = urllib2.urlopen(opts.url)
    except urllib2.URLError, e:
        reason = str(e)
        try:
            reason = str(e.reason)
        except AttributeError:
            pass

        print >>sys.stderr, "File Download Error: %s" % reason
        sys.exit(-1)

    for line in urllib2.urlopen(opts.url):
        lineno = 0
        for word,suggestions in check(line):
            lineno += 1
            print "error on line %d (%s) on page %s. Did you
mean:\n\t%s" % \
                  (lineno, word, opts.url, ', '.join(suggestions))
```

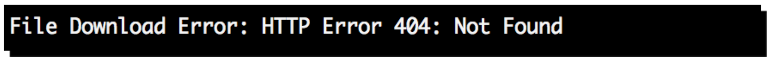
4. You should now be able to execute this code and pass in a pair of invalid URL values, using different protocols. Your output should be similar to the following.

```
(text_processing)$ python html_spelling-c.html --url=ftp://
localhost
```



```
File Download Error: ftp error: [Errno 111] Connection refused
```

```
(text_processing)$ python html_spelling-c.html --url=http://www.
jmcneil.net/notfound.html
```



```
File Download Error: HTTP Error 404: Not Found
```

What just happened?

We made a small update to our main code so that we can better handle exceptions bubbling up from the `urllib2` module.

In our exception handler's `except` statement, we do something that might seem slightly peculiar. First, we bind the value of `str(e)` to an attribute named `reason`. Next, we set up another `try/except` block and attempt to bind the value of `str(e.reason)` to that same reason attribute. Why would we do that?

The explanation is simple. Some of the exceptions bubbling up have a `reason` attribute, which provides more information. Specifically, the `FTP` errors contain it. We always try to pull the more specific error. If it doesn't exist, that will raise an `AttributeError` exception. We just ignore it and go with the first value of `reason`.

Our method of accessing the `reason` attribute highlights Python's Duck Typing design again. It would have been possible for us to check whether a `reason` attribute existed on our `URLError` object before attempting to access it. In other words, we could have ensured our object adhered to a strict interface. This approach is usually dubbed **Look Before You Leap**.

Instead, we took the other (and more Python standard) way. We just did it and handled the fallout in the event of an error. This is sometimes referred to as **Easier to Ask Forgiveness than Permission**.

Finally, we simply printed out a meaningful error and exited our application. If you had observed the examples of this chapter, you'd notice that it does not matter which protocol type we use.

Handling string IO instances

There's one more IO library that we'll take a look at in this chapter – Python's `StringIO` module. In many of your applications, you're likely to run into a situation where it would be convenient to write to a location in memory rather than using string operations or direct IO to a temporary file.

`StringIO` handles just this. A `StringIO` instance is a file-like object that simply appends written data to a location in memory.

```
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import StringIO
>>> handle = StringIO.StringIO()
>>> handle.write('A')
>>> handle.write('B')
>>> handle.getvalue()
'AB'
>>> handle.seek(0)
>>> handle.write("a")
>>> handle.getvalue()
'aB'
>>>
```

Looking at the example, you can see that the `StringIO` instance supports file methods such as `seek` and `write`. By calling `getvalue`, we're able to retrieve the entire in-memory string representation.

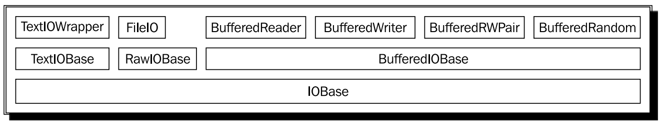
There's also a `cStringIO` module, which implements nearly the same interface and is quite a bit faster, though there are limitations on Unicode values and subclassing that should be understood before using it. For more information, see the `StringIO` library documentation available at `http://docs.python.org/library/stringio.html`.

The `StringIO` modules changed a bit between Python 2 and Python 3. Both the `StringIO` and the `cStringIO` modules are gone. Instead, developers should use `io.StringIO` for textual data and `IO.BytesIO` for binary data. There is no longer a differentiation between a pure Python implementation and the `C-level` implementation.

Understanding IO in Python 3

The last thing we'll look at in this chapter is the IO system in Python 3.0. In order to ease transition, the new IO code has been back-ported to Python 2.6 and is available via the `IO` module.

The new IO system introduces a layered approach, almost comparable to Java's IO system. At the bottom lies the `IOBase` class, which provides commonalities among the `IO stream` classes. From there, objects are stacked according to `IO` type, buffering capability, and `read/write` support.



While the details look complex, the actual interface to system IO really doesn't change too much. For example, the `io.open` call can generally be used the same way. However, there are some differences.

Most importantly, binary mode matters. The text will be decoded automatically into Unicode using the system's locale, or a codec passed. If a file isn't truly text, it shouldn't be opened as text. Files opened in binary mode now return a different object type than files opened in text mode.

```
Python 2.6.1 (r261:67515, Jul  7 2009, 23:51:51)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import io
>>> io.open('/etc/hosts')
<io.TextIOWrapper object at 0x10049d250>
>>> io.open('/bin/ls', 'rb')
<io.BufferedReader object at 0x10049d210>
>>>
```

Notice that opening a file in text mode, which is the default mode, returns a `TextIOWrapper` object whereas opening a file in binary mode returns a `BufferdReader` object. Although it doesn't appear as a subclass of `BufferedIOBase`, `TextIOWrapper` does actually implement buffered IO.

The new `io.open` method is intended to replace the built-in `open` method as of 3.0. As with the existing function, it can also be used in a context manager.

For more details on the new Python IO system, see the documentation available at `http://docs.python.org/release/3.0.1/library/io.html`. This covers the new IO system in detail and underscores some of the changes between major Python releases.

Summary

This chapter served as a crash course on Python IO. The goal here is to ensure that you know how to actually access your data in order to process it.

We covered quite a bit here and really focused on understanding Python's IO system. Most textual data you'll process will likely come from local disk files, so understanding this material is important.

You also learned how to build your own file-like-objects and take advantage of polymorphism, a powerful object-oriented development attribute. We covered HTTP and compressed data, but as you've seen, the underlying access methods do not matter when the exposed interface follows the file-like object protocol.

In the next chapter, we'll examine text handling using Python's built in string functions.

3
Python String Services

Python's built-in string services provide all of the text-processing functionality you would expect from any full-featured programming language. This includes methods to search, test, and create new string objects from existing ones.

String objects also provide a C-like format mechanism that allows us to build new string objects and interpolate them with standard Python values and user-defined objects. Later versions of Python are built on this concept.

Additionally, the actual string objects provide a rich set of methods and functions that may be used to further manipulate textual string data.

In this chapter, we will:

- Cover the basics of Python string and Unicode objects so that you'll understand the similarities and differences.
- Take a detailed look at Python string formatting so that you'll understand how to easily build new strings. We'll look at the older and more common syntax as well as the newer formats as defined in PEP-3101.
- Familiarize yourself with the methods found on the standard Python string objects as well as the Unicode components.
- Dive into built-in string templating. We'll see more examples on templating in more detail in *Chapter 7*, *Creating Templates*.

Understanding the basics of string object

Python supports both Unicode and ASCII-encoded text data. However, in versions of Python earlier than 3.0, there are two built-in objects to manage text data. The `str` type holds standard byte-width characters, while the `unicode` type exists to deal with wider unicode data.

All Python string objects are immutable, regardless of encoding type. This generally means that methods that operate on strings all return new objects and not modified text. The big exception to this rule is the `StringIO` module as covered in *Chapter 2*, *Working with the IO System*. Editing `StringIO` data via its file-like interface results in manipulation of the underlying string content.

Python's built-in string services do not operate on any type of structured data. They deal with text data at the character-level.

In Python 2.7, a new **memoryview** module has been introduced. These objects allow certain C-based data types to expose their contents via a byte-oriented interface. Strings support this functionality. Generally speaking, however, a `memoryview` object shouldn't be used for standard text operations.

Defining strings

Strings can be defined in a variety of ways, using a variety of different quoting methods. The Python interpreter treats string values differently based on the choice of quotes used. Let's look at an example that includes a variety of different definition approaches.

Time for action – employee management

In this short and rather contrived example, we'll handle some simple employee records and just print them to the screen. Along the way, however, we'll cover the various different ways a developer can quote and define string literals. A **literal** is a value that is explicitly entered, and not computed.

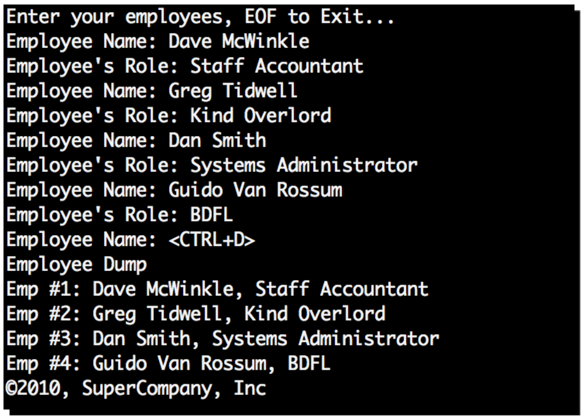
1. From within our text processing virtual environment, create a new file and name it `string_definitions.py`.

2. Enter the following code:

```
import sys
import re

class BadEmployeeFormat(Exception):
    """Badly formatted employee name"""

def get_employee():
    """
    Retrieve user information.

    This method simply prompts the user for
    an employee's name and his current job
    title.
    """
    employee = raw_input('Employee Name: ')
    role = raw_input("Employee's Role: ")
    if not re.match(r'^.+\s.+', employee):
        raise BadEmployeeFormat('Full Name Required '
            'for records database.' )
    return {'name': employee, 'role': role }

if __name__ == '__main__':
    employees = []
    print 'Enter your employees, EOF to Exit...'
    while True:
        try:
            employees.append(get_employee())
        except EOFError:
            print
            print "Employee Dump"
            for number, employee in enumerate(employees):
                print 'Emp #%d: %s, %s' % (number+1,
                    employee['name'], employee['role'])
            print u'\N{Copyright Sign}2010, SuperCompany, Inc.'
            sys.exit(0)
        except BadEmployeeFormat, e:
                print >>sys.stderr, 'Error: ' + str(e)
```

3. Assuming that you've entered the content correctly, run it on the command line. Your output should be similar to the following:

(text_processing)$ python string_definitions.py



```
Enter your employees, EOF to Exit...
Employee Name: Dave McWinkle
Employee's Role: Staff Accountant
Employee Name: Greg Tidwell
Employee's Role: Kind Overlord
Employee Name: Dan Smith
Employee's Role: Systems Administrator
Employee Name: Guido Van Rossum
Employee's Role: BDFL
Employee Name: <CTRL+D>
Employee Dump
Emp #1: Dave McWinkle, Staff Accountant
Emp #2: Greg Tidwell, Kind Overlord
Emp #3: Dan Smith, Systems Administrator
Emp #4: Guido Van Rossum, BDFL
©2010, SuperCompany, Inc
```

What just happened?

Let us go through this example. There are quite a few things to point out.

The very first thing we do, other than import our required modules, is define a custom exception class named BadEmployeeFormat. We simply have a subclass Exception and define a new docstring. Note that no pass keyword is required; the docstring is essentially the body of our class. We do this because later on in this example, we'll raise this error if an employee name doesn't match our simple validation.

Now, note that our docstring is enclosed by triple quotes. As you've probably guessed, that holds a special meaning. Python strings enclosed in triple quotes preserve line endings so that multiline strings are represented correctly. Consider the following example.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> s = """This is a multiline string.
...
... There are many like it, but this one
... is mine.
... """
>>>
>>> print s
This is a multiline string.

There are many like it, but this one
is mine.

>>>
```

As you can see, the new line values are included. Note that all other values still require additional escaping. For example, including a \t will still translate to a tab character.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> t = """This still creates a \tab"""
>>> print t
This still creates a 	ab
>>>
```

After our exception class, we create a module-level function named get_employee that is responsible for collecting, testing, and returning employee data. The first thing you should notice is another triple quoted docstring. You should note that docstrings do not have to be triple-quoted, but they do need to be string literals.

The very first line of code within `get_employee` calls `raw_input`, which simply receives a single line of text via standard input, trimming the trailing newline. The single-quoted string passed to it serves as the text prompt that the caller will see on the command line.

The very next line includes another call to `raw_input`, asking for the employee's role. Notice that this invocation includes the prompt text in double quotes. Why is that? The answer is simple. We used an apostrophe in the word "employee's" in order to indicate ownership. Both double and single quotes serve the same functional purpose. There is nothing different about them, as in other languages. They're both allowed in order to let you include one set of quotes within the other without resorting to long sequences of escapes. As you can see, the following string variables are all the same.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> single = '"Yes, I\'m a programmer", she said.'
>>> double = "\"Yes, I'm a programmer\", she said."
>>> triple = """Yes, I'm a programmer", she said."""
>>> print single
"Yes, I'm a programmer", she said.
>>> print double
"Yes, I'm a programmer", she said.
>>> print triple
Yes, I'm a programmer", she said.
>>>
```

The Python convention is to use single quotes for strings unless there is an override needed to use a different format, so you should also adhere to this whenever possible.

On the next line, we call `re.match`. This is a very simple **regular expression** that is used to validate the employee's name. We're checking to ensure that the input value contained a space because we want the end-user to supply both the first and last name. We'd do a much better job in a real application (where we would probably ask for both values independently).

The call to `re.match` includes a single-quoted string, but it's prefixed with a single `r`. That leading `r` indicates that we're defining a **raw string**. A raw string is interpreted as-is, and escape sequences hold no special meaning. The most common use of raw strings is probably within regular expressions like this. The following brief example details the difference between manual escapes and raw strings.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> standard = '\n\nOur Data\n\n'
>>> raw = r'\n\nOur Data\n\n'
>>> print standard

Our Data

>>> print raw
\n\nOur Data\n\n
>>>
```

Using the standard string syntax, we would have had to include backslashes if we wished to mute the escape interpretation, and our string value would have been `'\\n\\nOur Data\\n\\n'`. Of course, this is a much more difficult string to read.

Users of the popular Django framework may recognize this syntax. Django uses regular expressions to express HTTP request-routing rules. By default, these regular expressions are all contained within raw string definitions.

If the regular expression test fails, we'll `raise` our `BadEmployeeFormat` exception that we defined at the top of this example. Look carefully at the `raise` statement. Notice that the string passed into `BadEmployeeFormat's __init__` method is actually composed of two strings. When the Python interpreter encounters string literals separated by white space, it automatically concatenates them together. This provides a nice way for the developer to wrap his or her strings neatly without creating long and hard to manage lines. As these strings were defined within the parenthesis following `BadEmployeeFormat`, we were able to include a newline.

Now, within our main section, we create an infinite loop and begin calling `get_employee`. We append the result of each successful call onto our employees list. If an exception is raised from within `get_employee`, we might have to take some additional action.

If `EOFError` bubbles up then a user has clicked *Ctrl + d* (*Ctrl + z* on Windows), indicating that they have no more data to supply. The `raw_input` function actually raises the exception; we just let it percolate up the call stack. The first thing we do within this handler is print out some status text we notify the user that we're dumping our employee list.

Next, we have a `for` loop that iterates on the results of `enumerate(employee)`. **Enumerate** is a convenient function that, when given a sequence as an argument, returns the zero-based loop number as well as the actual value in a `tuple`, like in this example snippet:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> for c,i in enumerate(xrange(2)):
...     print "Loop %d, xrange value %d" % (c,i)
...
```

```
Loop 0, xrange value 0
Loop 1, xrange value 1
>>>
```

Each employee's name and role is printed out this way. This continues until we reach the end of the list, at which point we're going to print a simple copyright statement.

When our employee application becomes wildly popular, we want to be certain that we're protected after all! The copyright line introduces yet another string variant – a **Unicode** literal. Unicode strings contain all of the functionality of standard string objects, plus some encoding specifics.

A Unicode literal can be created by prepending any standard string with a single `u`, much like we did with the `r` for raw strings. Additionally, Unicode strings introduce the `\N` escape sequence, which allows us to insert a Unicode character by standardized name rather than literally or by character code.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> russian_pm = u'\N{CYRILLIC CAPITAL LETTER PE}\N{CYRILLIC SMALL
LETTER U}\N{CYRILLIC SMALL LETTER TE}\N{CYRILLIC SMALL LETTER SHORT
I}\N{CYRILLIC SMALL LETTER EN}'
>>> print russian_pm
Путйн
>>> russian_pm = u'\u041f\u0443\u0442\u0439\u043d'
>>> print russian_pm
Путйн
>>>
```

As of now, you should understand that Unicode allows us to represent characters outside of the ASCII range. This includes symbols such as the one we added above as well as alphabets such as **Cyrillic**, which at one point would have required its own encoding standard (in fact, **KOI8** is just that). We'll cover Unicode and additional text encodings in much more detail when we get to *Chapter 8*, *Understanding Encodings and i18n*

Finally, we'll catch our `BadEmployeeFormat` exception. This indicates that our test regular expression didn't match. Here, you'll see that we're concatenating a string literal with a calculated value, so we can't simply place them adjacent within our source listing. We use plus-syntax to create a new string, which is a concatenation of the two.

One important thing to remember is that, although there are three different variants of quotes and raw string modifiers, there are only two string types: `unicode` and `str`.

Building non-literal strings

The majority of the strings you'll create in a manual fashion will be done using literals. In most other scenarios, text data is generated as the result of a function or a method call. Consider the value returned by `sys.stdin.readline`. We'll cover some of the common methods for building strings programmatically as we progress through this chapter.

> Python 3.0 eliminates the concept of a separate byte string and Unicode string. All strings in Python 3.0 are Unicode. Defining a string using the `u'content'` approach while running under Py3k will simply result in a `SyntaxError` exception. As there is only one string type, the previously mentioned `basestring` is no longer valid within Python 3.0, either. A `bytes` type replaces the standard string object and is used to represent raw byte data, such as binary information.

Pop Quiz – string literals

1. We've seen where we would use raw strings and we've seen where we would use Unicode strings. Where might you wish to combine the two? Is it even possible?
2. What do you suppose would happen if you tried to concatenate a Unicode object and a standard Python string? Here's a hint: what happens when you divide a whole integer by a float?
3. Suppose a `ZeroDivisionError` or an `AttributeError` is triggered from within `get_employee`. What do you suppose would happen?

String formatting

In addition to simply creating plain old strings as we've just covered, Python also lets you format them using a C `sprintf` style syntax. Strings in later versions of Python also support a more advanced `format` method.

Time for action – customizing log processor output

Let's revisit and extend our web server log processor now. Our first versions simply printed text to `sys.stdout` when information was encountered. Let's expand upon that a bit. Using Python's built-in string formatters, we'll do a better job at reporting what we find. In fact, we'll delegate that responsibility to the classes responsible for evaluating the parsed log data.

We'll also add some additional processing meta-output as well, such as how many lines we've processed and how long it takes to execute the entire report. This is helpful information as we further extend our log processor.

1. We're going to use `logscan-c.py` from *Chapter 2*, *Working with the IO System* as our base here, so copy it over and rename it as `logscan-e.py`.
2. Update the code in `logscan-e.py` to resemble the following.

```
import time
import sys
from optparse import OptionParser

class LogProcessor(object):
    """
    Process a combined log format.

    This processor handles logfiles in a combined format;
    objects that act on the results are passed in to
    the init method as a series of methods.
    """
    def __init__(self, call_chain=None):
        """
        Setup parser.

        Save the call chain. Each time we process a log,
        we'll run the list of callbacks with the processed
        log results.
        """
        if call_chain is None:
            call_chain = []
        self._call_chain = call_chain

    def split(self, line):
        """
        Split a logfile.

        Initially we just want size and requested filename, so
        we'll split on spaces and pull the data out.
        """
        parts = line.split()
        return {
            'size': 0 if parts[9] == '-' else int(parts[9]),
            'file_requested': parts[6]
        }

    def report(self):
        """
        Run report chain.
        """
        for c in self._call_chain:
            print c.title
            print '=' * len(c.title)
```

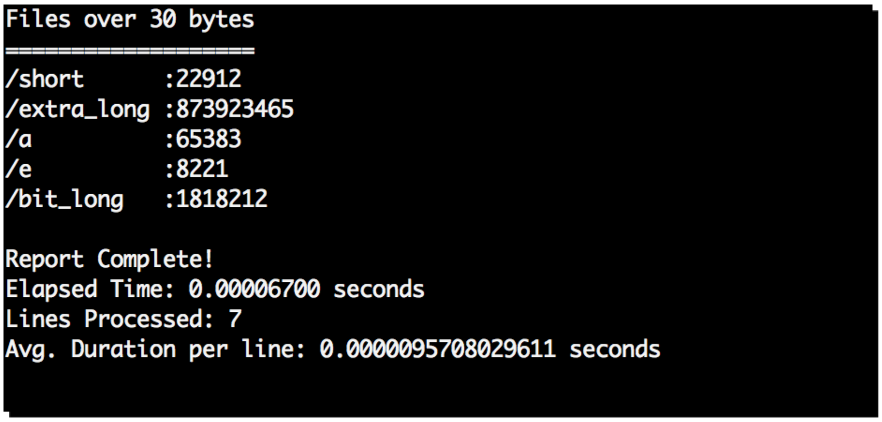
```
                c.report()
                print

        def parse(self, handle):
            """
            Parses the logfile.

            Returns a dictionary composed of log entry values,
            for easy data summation.
            """
            line_count = 0
            for line in handle:
                line_count += 1
                fields = self.split(line)
                for handler in self._call_chain:
                    getattr(handler, 'process')(fields)

            return line_count

    class MaxSizeHandler(object):
        """
        Check a file's size.
        """
        def __init__(self, size):
            self.size = size
            self.name_size = 0
            self.warning_files = set()

        @property
        def title(self):
            return 'Files over %d bytes' % self.size

        def process(self, fields):
            """
            Looks at each line individually.

            Looks at each parsed log line individually and
            performs a size calculation. If it's bigger than
            our self.size, we just print a warning.
            """
            if fields['size'] > self.size:
                self.warning_files.add(
                    (fields['file_requested'], fields['size']))

                # We want to keep track of the longest file
                # name, for formatting later.
                fs = len(fields['file_requested'])
                if fs > self.name_size:
                    self.name_size = fs
        def report(self):
            """
            Format the Max Size Report.

            This method formats the report and prints
            it to the console.
            """
            for f,s in self.warning_files:
                print '%-*s :%d' % (self.name_size, f, s)

    if __name__ == '__main__':
        parser = OptionParser()

        parser.add_option('-s', '--size', dest="size",
            help="Maximum File Size Allowed",
                default=0, type="int")

        parser.add_option('-f', '--file', dest="file",
            help="Path to Web Log File", default="-")

        opts,args = parser.parse_args()
        call_chain = []

        if opts.file == '-':
            file_stream = sys.stdin
        else:
            try:
                file_stream = open(opts.file)
            except IOError, e:
                print >>sys.stderr, str(e)
                sys.exit(-1)

        size_check = MaxSizeHandler(opts.size)
        call_chain.append(size_check)
        processor = LogProcessor(call_chain)

        initial = time.time()
        line_count = processor.parse(file_stream)
        duration = time.time() - initial

        # Ask the processor to display the
        # individual reports.
        processor.report()

        # Print our internal statistics
        print "Report Complete!"
        print "Elapsed Time: %#.8f seconds" % duration
        print "Lines Processed: %d" % line_count
        print "Avg. Duration per line: %#.16f seconds" %  \
            (duration / line_count) if line_count else 0
```

3. Now, in order to illustrate what's going on here, create a new file named `example2.log`, and enter the following data. Note that each line begins with 127.0.0.1.

```
127.0.0.1 - - [29/Mar/2010:00:48:05 +0000] "GET /a HTTP/1.1" 200
65383 "-" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1; SV1;
.NET CLR 1.1.4322)"
127.0.0.1 - - [29/Mar/2010:00:48:05 +0000] "GET /short HTTP/1.1"
200 22912 "-" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1;
SV1; .NET CLR 1.1.4322)"
127.0.0.1 - - [29/Mar/2010:00:48:05 +0000] "GET /bit_long
HTTP/1.1" 200 1818212 "-" "Mozilla/4.0 (compatible; MSIE 6.0;
Windows NT 5.1; SV1; .NET CLR 1.1.4322)"
127.0.0.1 - - [29/Mar/2010:00:48:05 +0000] "GET /extra_long
HTTP/1.1" 200 873923465 "-" "Mozilla/4.0 (compatible; MSIE 6.0;
Windows NT 5.1; SV1; .NET CLR 1.1.4322)"
127.0.0.1 - - [29/Mar/2010:00:48:05 +0000] "GET /e HTTP/1.1" 200
8221 "-" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1; SV1;
.NET CLR 1.1.4322)"
127.0.0.1 - - [29/Mar/2010:00:48:05 +0000] "GET /e HTTP/1.1" 200 4
"-" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1; SV1; .NET
CLR 1.1.4322)"
127.0.0.1 - - [29/Mar/2010:00:48:05 +0000] "GET /d HTTP/1.1" 200
22 "-" "Mozilla/4.0 (compatible; MSIE 6.0; Windows NT 5.1; SV1;
.NET CLR 1.1.4322)"
```

4. Now, from within our virtual environment, run this code on the command line. Your output should be similar as follows:

```
(text_processing)$ cat example2.log | python logscan-e.py -s 30
```



```
Files over 30 bytes
===================
/short      :22912
/extra_long :873923465
/a          :65383
/e          :8221
/bit_long   :1818212

Report Complete!
Elapsed Time: 0.00006700 seconds
Lines Processed: 7
Avg. Duration per line: 0.0000095708029611 seconds
```

What just happened?

We introduced some extended string formatting mechanisms and extended our code to be a little bit more extensible, which is generally a good practice.

First of all, we're importing the `time` module. We use this to calculate runtime and other things as we move forward. As we introduce new methods of extracting and parsing these files, it's nice to have a means to measure the performance hit or gain associated with the change.

We updated the `LogProcessor` class in a few places. First, we've added a `report` method. This method will pull the `title` off of each log handler defined and display it, followed by a separator bar. Next, the `report` method will call each handler class directly and ask it to print its own report segment.

The `parse` function has been updated to return the number of lines processed for statistics purposes. We've also replaced our direct call to `handle` with a dynamic lookup of a `process` function. This is a great example of Python's dynamic nature and duck-typing at work. We did this so that we can get at more of the class fields directly in other areas. Simply passing the parsing function around limits what we have access to.

The `MaxSizeHandler` got an even bigger facelift this time through. We've added instance level variables `name_size` and `warning_files`. The `name_size` variable keeps track of the longest filename we've found while `warning_files` is a `set` object.

The following three lines define a Python `property`:

```
@property
def title(self):
    return 'Files over %d bytes' % self.size
```

A `property` is a special object that appears to be an attribute when accessed directly, but is actually handled by a method under the scenes. When we access `c.title` from within `LogProcessor`, we're actually triggering an instance of `MaxSizeHandler`'s `title` method.

We've made changes to our `process` method, too. It now appends a `tuple` for each file name/size pair that exceeds our maximum allowed size. Why did we use a set? Simple. If the same file is accessed multiple times, we only want to display it once for each size. Python lets us use `tuples` as unique values within a `set` object as they're immutable. As is the nature of `set`s, adding the same value multiple times is a null operation. A value only exists once within a `set`.

Note that sets were available only as an external module up until 2.6. Prior to that, it was necessary to '`from sets import set`' at the top of your module. If you're running an earlier version, you'll have to take this precaution.

We finish up this revision of the `MaxSizeHandler` class by updating the longest filename, if applicable, and defining our `report` function.

If you take a closer look at `report`, you'll see a line containing a string format that reads `'%-*s :%d' % (self.name_size, f, s)`. There is a bit of formatter magic included here. We'll take a closer look at this syntax below, but understand that this line prints a file's name and corresponding size. It also ensures that each size value lines up in a columnar format, to the right of the longest filename we've found. We're allotting for variations in filename size and spacing our sizes accordingly to void a jagged –edge look.

Finally, we hit our main section. Not a whole lot has changed here. We've added code to track how long we run and how many lines we've processed as returned by `processor.parse`. We've also switched to passing instances of our handler classes to `LogProcessor`'s `__init__` method rather than specific functions.

At the bottom of the main section, we've introduced another variation of the formatting expression. Here, we're shoring up some of our decimal formatting and using some alternate formatting methods available to us. The '`#`' in this line alters the way the string is rendered.

Percent (modulo) formatting

This is the oldest method of string format available within Python, and as such, it's the most popular one. We've been using it throughout the book so far, though this example introduced some of the more esoteric features.

A percent formatter expression consists of two main parts a format string and a tuple or a dictionary of formatting values. Format strings consist of plain text with format specifications mixed in it. Format specifications begin with a percent sign and instruct Python on how to translate a data value into printed text.

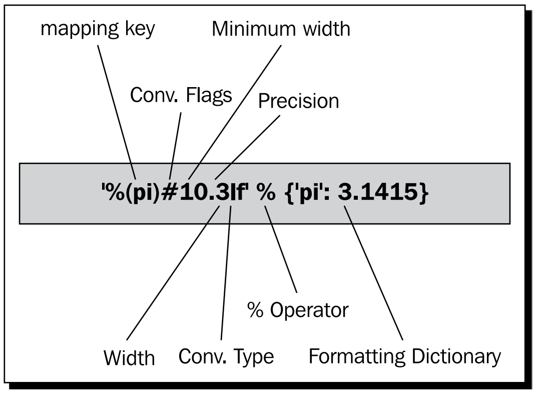
These two main components are then separated via a percent sign, or modulus operator. If you're formatting a string with a single `%` specifier then the use of a tuple is not necessary. For example, simple string formatting expressions usually look like the following:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> "%d + %d = %d" % (1,2,3)
'1 + 2 = 3'
>>> '%d %% %d = %d' % (5,2,1)
'5 % 2 = 1'
>>> 'I am a %s programmer' % 'python'
'I am a python programmer'
>>>
```

It is also possible to use a dictionary instead of a tuple, if the corresponding key is specified in parenthesis after the `%` operator, like in this example.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> user = {'uid': 0, 'gid': 0, 'login': 'root'}
>>> 'Logged in as %(login)s with uid %(uid)d and gid %(gid)d' % user
'Logged in as root with uid 0 and gid 0'
>>>
```

Each formatting specification consists of a variety of different elements, most of which are usually left out. Here is a diagram detailing all of the available modifiers.



This example uses a dictionary to provide the mapped values. Let's review each possible component. Remember that some of the possible values change depending on whether we've used a dictionary or a tuple.

Mapping key

If the mapping key is present then the format conversion expects a dictionary after the dividing percent sign. The mapping key is quite simply a key into the dictionary you'll provide.

Conversion flags

These are optional values that change the way the provided value is displayed. There are a series of different flags available.

Flag	Usage
#	Dictates that an alternate format should be used. Alternate formats vary by formatting time. For example, using this flag with a floating point ensures that the decimal point is present, even if not required.
0	If the minimal display width is greater than the value, pad with zero for numeric values.
-	The printed value is left-justified in relation to the padding. The default is to right-justify.
<space>	Signifies that a space should be left after a positive number.
+	Add a sign character. Has a higher precedence than `<space>`.

In the above example, we specified an alternate format in order to ensure that the decimal is always present.

Minimum width

If the value to be translated does not meet this minimum length, it will be padded accordingly. If a `*` (asterisk) is passed in as opposed to a number, the value will be taken from the tuple of values.

This is the approach taken in our last example. We programmatically determined the padding we wanted to use and inserted it into our values tuple while forcing left-justification.

Precision

This is valid for floating-point numbers. The precision indicates how many places after the decimal to display. In the preceding diagram, we specified four places in the value, but only requested three in the formatting. The following small example details the use of the precision option. Note that the value printed versions the value provided.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> '%.3f' % 3.1415
'3.142'
>>>
```

As you can see, the value we've supplied is rounded up correctly and printed.

Width

These have no use in Python and do not change the formatting at all. They are largely carried over from C's `sprintf` functionality. Accepted values are `l`, `L`, or `h`. If they are supplied, they are simply ignored.

Conversion type

The data type we're converting from. These are generally the same as found in C. However, the `r` and the `s` types are slightly special and we'll cover them below. Here is a list of the valid conversion formats.

Conversion	**Description**
d, i	Signed Decimal
o	Signed Octal
x	Signed hexadecimal in lowercase
X	Signed hexadecimal in uppercase
u	Obsolete – identical to d
e	Floating point exponential in lowercase
E	Floating point exponential in uppercase
F,f	Floating point decimal
g	Lowercase exponential if exponent is less than -4, otherwise use decimal format.
G	Uppercase exponential if exponent is less than -4, otherwise use decimal format.
c	Single character. Can be an integer value or a string of one.
r	Object `repr` value, see below.
s	Object `str` value, see below.
%	Literal percent sign.

Using string special methods

If an object has a `__str__` method then it is implicitly called whenever an instance of that object is passed to the `str` built-in function. Accepted practice is to return human-friendly string representation of that object.

Likewise, if an object contains a `__repr__` method, passing that object to the `repr` built-in should return a Python-friendly representation of that object. Historically, that means enough text to recreate the object via `eval`, but that's not a strict requirement.

Using `%s` or `%r` results in the values of `__str__` or `__repr__` replacing the formatting specification. For example, consider the following code.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
```

```
Type "help", "copyright", "credits", or "license" for more information.
>>> class MicroController(object):
...     def __init__(self, brand, bits):
...             self.brand = brand
...             self.bits = bits
...     def __str__(self):
...             return '%s %s-bit CPU' % (self.brand, self.bits)
...
>>> m = MicroController('WhizBang', 8)
>>> 'my box runs a %s' % m
'my box runs a WhizBang 8-bit CPU'
>>>
```

This is very convenient while formatting strings containing representations of objects. Though, in some cases, it can be somewhat misleading.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> 'I have %s bits' % 8
'I have 8 bits'
>>>
```

In many languages, an approach like that would simply result in either a syntax error or a memory-related crash. Python treats it differently, however, as the result of `str(8)` is the string representation of the number eight.

Have a go hero – make log processing more readable

So, now you should have a pretty good grasp of percent string formatting. All of the file sizes outputted in our example above are in pure bytes. That's great for accuracy's sake, but it can be quite difficult on the eyes.

Update all of the preceding output to display as kilobytes in a decimal form. We don't want to display decimals beyond two places as that could get just as difficult to read.

Using the format method approach

As of Python 2.6 (and all values of 3.0), the `format` method has been available to all string and Unicode objects. This method was introduced to combat flexibility restrictions in the percent approach. While this is a much more powerful and flexible method of string formatting, it's only available in newer versions of Python. If your code must run on older distributions, you're stuck with the classic percent-formatting approach.

Instead of marking our format specifications with percent signs, the `format` method expects formatting information to be enclosed in curly braces.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> platforms = {'linux': 121, 'windows': 120, 'solaris': 12}
>>> 'We have {0} platforms, Linux: {linux}, Windows: {windows}, and
Solaris: {solaris}'.format(
… 3, **platforms)
'We have 3 platforms, Linux: 121, Windows: 120, and Solaris: 12'
>>>
```

In the simplest cases, numeric values in curly braces represent positional arguments while text names represent keyword arguments.

In addition to the new `format` method found on string objects, Python 2.6 and above also have a new built-in method – `format`. This essentially provides a means to access the features of the string object's `format`, without requiring a temporary string. Under the hood, it triggers a call to a formatted object's `__format__` method. For more information on the `__format__` method, see `http://python.org/dev/peps/pep-3101/`.

Time for action – adding status code data

First of all, note that this example won't work if you're using a version of Python less than 2.6. If you fall into that category, you'll have to either upgrade your version, or simply pass over this section.

We're going to update our `LogProcessor` script to report on the collection of HTTP response codes found within the logfile. We'll simply add an additional handler to process the parsed data.

1. Using `logscan-e.py` as a base, create `logscan-f.py` and add the following additional import statement:

   ```
   from collections import defaultdict
   ```

2. Now, we're going to change the `split` method of `LogProcessor` to also include HTTP status code information.

   ```
   def split(self, line):
           """
           Split a logfile.
           Initially, we just want size and requested filename, so
   ```

```
        we'll split on spaces and pull the data out.
        """
        parts = line.split()
        return {
            'size': 0 if parts[9] == '-' else int(parts[9]),
            'file_requested': parts[6],
            'status': parts[8]
        }
```

3. Now, directly below the `LogProcessor` class, add the following new handler class.

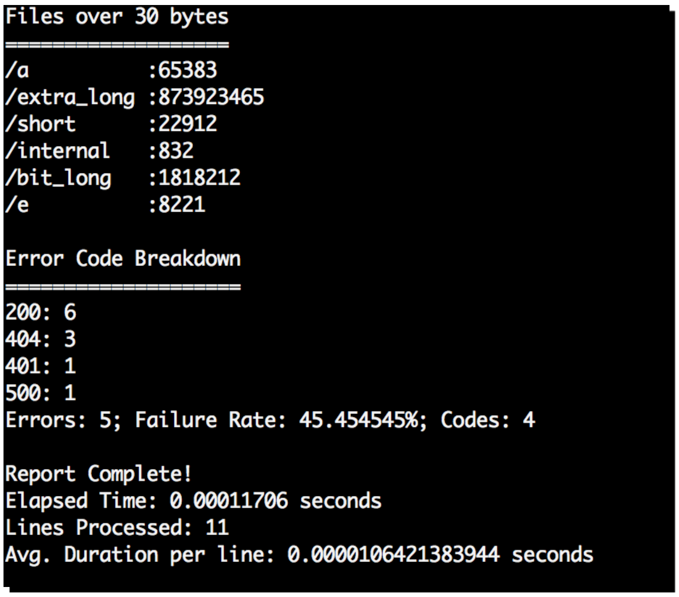
```
class ErrorCodeHandler(object):
    """
    Collect Error Code Information.
    """
    title = 'Error Code Breakdown'

    def __init__(self):
        self.error_codes = defaultdict(int)
        self.errors = 0
        self.lines = 0

    def process(self, fields):
        """
        Scan each line's data.

        Reading each line in, we'll save out the
        number of response codes we run into so we
        can get a picture of our success rate.
        """
        code = fields['status']
        self.error_codes[code] += 1

        # Assume anything > 400 is
        # an HTTP error
        self.lines += 1
        if int(code) >= 400:
            self.errors += 1

    def report(self):
        """
        Print out Status Summary.

        Create the status segment of the
        report.
        """
        longest_num = sorted(self.error_codes.values())[-1]
        longest = len(str(longest_num))

        for k,v in self.error_codes.items():
            print '{0}: {1:>{2}}'.format(k, v, longest)

        # Print summary information
        print
 'Errors: {0}; Failure Rate: {1:%}; Codes: {2}'.format(
            self.errors, float(self.errors)/self.lines,
                len(self.error_codes.keys()))
```

4. Finally, add the following line to the main section, right below:

```
call_chain.append(size_check).
call_chain.append(ErrorCodeHandler())
```

5. Now, run the updated application. Your output should resemble the following:

```
(text_processing)$ cat example2.log | python logscan-f.py -s 30
```



```
Files over 30 bytes
===================
/a          :65383
/extra_long :873923465
/short      :22912
/internal   :832
/bit_long   :1818212
/e          :8221

Error Code Breakdown
====================
200: 6
404: 3
401: 1
500: 1
Errors: 5; Failure Rate: 45.454545%; Codes: 4

Report Complete!
Elapsed Time: 0.00011706 seconds
Lines Processed: 11
Avg. Duration per line: 0.0000106421383944 seconds
```

What just happened?

Let's take a quick survey of the changes we made to this application. First of all, we imported `defaultdict`. This is a rather useful object. It also acts as a dictionary. However, if a referenced key doesn't exist, it calls the function supplied and uses its value to seed the dictionary before returning. A standard dictionary would simply raise a `KeyError`, as in the following example:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
```

```
Type "help", "copyright", "credits", or "license" for more information.
>>> d = {}
>>> d['200'] += 1
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
KeyError: '200'
>>> from collections import defaultdict
>>> d_dict = defaultdict(int)
>>> d_dict['200'] += 1
>>> d_dict
defaultdict(<type 'int'>, {'200': 1})
>>>
```

Next, we're just updating the `parse` method to return the eighth field in each line, which happens to be the HTTP status code as returned to the client.

In the new handler class, `ErrorCodeHandler`, we set up three instance-level variables. The `defaultdict` object detailed previously, and two counters that represent the number of errors we've run into as well as the number of lines we've processed.

The `process` method adds to the `defaultdict` each time an error is encountered. If a specific value hasn't been added yet, the dictionary defaults (hence its name) to the value of `int()`, which will be zero.

The `defaultdict` type is a useful helper when tallying or extracting information from logfiles or other unknown sources of data when you're not certain whether a specific key will exist and want to add it dynamically.

Next, we increase our line number counter. If the error number is greater than 400 then we also increment our error counter. You should note that we're actually passing the value of code to the `int` function before doing the comparison. Why is this?

Python is a dynamically-typed language; however, it is still strictly-typed. For example, a HTTP code value of '200' is a textual representation of a number; it is still a string type. The value was assigned its type when we extracted it as a substring from a line in a logfile, which itself was read in as a collection of strings. So, without the explicit conversion, we're comparing an integer (400) against a string representation of a number. The result probably isn't what you would expect.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> snum = '1000'
>>> snum == 1000
False
>>> int(snum) == 1000
True
```

This is a common gotcha and has actually been rectified in Python 3.0. Attempting to perform the preceding comparison will result in a `TypeError` when using Python 3.

```
>>> '1000' > 1000
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unorderable types: str() > int()
>>>
```

Within the `report` method, we next sort the `self.error_code` dictionary values via the built-in `sorted` function. We take the highest number in that list, via a subscript of `-1`, and convert it into a string. We then take the length of that string. We'll use this value for a formatting modifier later in this method.

The next section loops through all of the response codes we've run into thus far and prints them out to the screen, though it does that via the string `format` method.

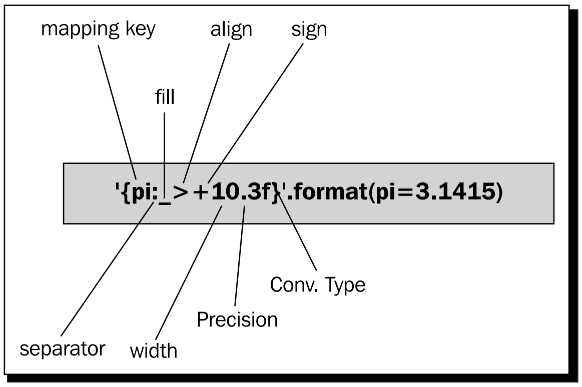
The last thing we do within the `report` method is display a summary of the error code data we've collected while processing a logfile. Here, we're also using the `format` method rather than traditional percent-sign formatting.

Finally, within our main section, we added an instance of `ErrorCodeHandler` to the `call_chain` list that is passed into `LogProcessor`'s `__init__` method. This ensures that it will be included during logfile processing.

Making use of conversion specifiers

As we mentioned earlier, conversion markup is enclosed in curly braces as opposed to the percent prefix as used in standard string formatting. In addition to the replacement value, though, the curly braces also contain all of the same formatting information (with some new options) that the standard methods support.

Let's take another look at that graphical breakdown of a format string, but this time we'll use the newer format syntax.



Notice how the replacement value name or position is separated from the formatting arguments by a colon. The colon itself holds no other special meaning. This example does not include all possible combinations. When using the format method, the `#` option is only valid for integers. Likewise, the precision argument is only valid for floating point values.

Fill

The `fill` argument allows us to specify which character we should use to pad our string if the minimum width is less than the actual width of the replacement value. Any character can be used other than a closing brace, which would signify the end of the format specification.

Align

This signifies how text should be aligned in relation to the fill characters if actual width is less than minimum width.

Flag	Usage
<	The field is left-aligned, this is the default alignment.
>	The field is right-aligned.
=	This forces the padding to be placed between a sign character and the value. This is only valid for numeric types.
^	Forces the value to be centered within the available spacing.

Sign

This field is valid only for numeric types and is used to determine how the sign information is displayed, if at all.

Flag	Usage
+	Sign data is always displayed.
-	Python should only display the sign for negative numbers. This is the default behavior.
<space>	Leading space should be used on positive, while a sign should be used when the value is negative.

Width

This specifies the minimum width of the field. If the actual value is shorter, the result will be padded according to the alignment rules using the fill character.

Precision

This specifies the floating-point precision. As mentioned previously, this is only valid for floating-point values. Floating-point numbers are rounded and not simply truncated.

Type

The type field is the last argument in the format specification and details how the value should be displayed. Unlike standard percent-formatting, this is no longer a required field. If not specified, a default is used based on the value's type.

There are quite a few new type flags introduced with the format method and some of the implementation details are rather complex. For a complete introduction to type fields for use with the format function, see `http://docs.python.org/library/string.html#format-string-syntax`.

The following table contains a survey of the available values.

Flag	Usage
s	String output. This is the default for strings and class instances
b	Binary output
d	Decimal output
o	Octal format
x	Hexadecimal format using lowercase letters
X	Hexadecimal format using uppercase letters
n	Same as the d flag, though it uses local information to display correctly based on your preferences. This is the default for integers
e	Exponent (Scientific) Notation using lowercase letters
E	Exponent (Scientific) Notation using uppercase letters
f	Fixed point
F	Same as the 'f' type
g	General format. There is a collection of rules regarding display for this type. See the Python documentation for details. This is the default for floating-point values
G	Uppercase version of 'g'
%	Percentage. Multiplies a number by 100 and displays in 'f' format, followed by a percent sign

Have a go hero – updating the file size check to use the format method

Now that you've got a crash course in Python string-formatting methods, you should be able to work with both approaches. Take a few minutes and back up to update the `MaxSizeHandler` class to use `format` methods rather than percent syntax. However, you'll probably want to create a temporary copy.

You may find the Python documentation helpful in addition to the tables included in this chapter. Formatting markup seems to be one area that many developers never really seem to fully grasp. Take a moment and stand out from the crowd!

Creating templates

It's often said within the Python community that every programmer, at some point, implements his or her own Python-based template language. The good news, then, is that we don't have to as so many of them already exist!

There's a large collection of very powerful third-party templating libraries available for Python. We'll cover them in more detail (and even write our own) in *Chapter 7*, *Creating Templates*.

Python includes an elementary templating class within the `string` module. The `Template` class doesn't provide any advanced features such as code execution or inherited blocks. In general, it's a simple way to replace tokens within a text file with Python values.

Time for action – displaying warnings on malformed lines

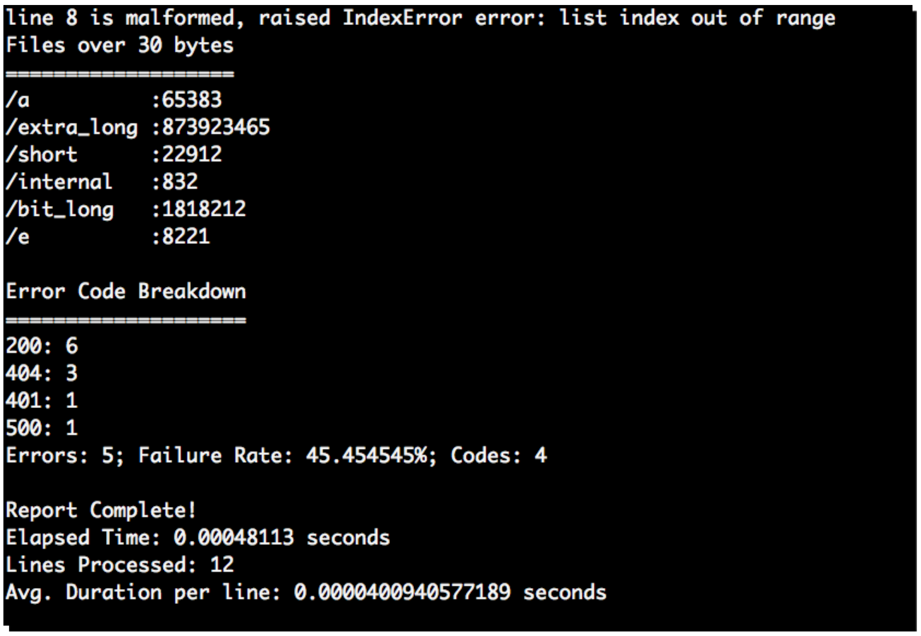
Up until now, we've assumed that all of our lines processed are very well-formed and will never generate exceptions. In order to illustrate the use of the Template class, we'll fix that here. Under normal circumstances, it would probably be preferred to simply print an error just quietly pass by incorrectly formatted lines.

1. Using `logscan-f.py` as a starting place, create `logscan-g.py`. We'll use this as our starting point.
2. At the top of the file, add `import string` to the list of modules imported.
3. Immediately after the `docstring` for `LogProcessor`, add the following code:
```
tmpl = string.Template(
        'line $line is malformed, raised $exc error: $error')
```
4. Replace the parse method in `LogProcessor` with the following new method:
```
def parse(self, handle):
        """
        Parses the logfile.

        Returns a dictionary composed of log entry values,
        for easy data summation.
        """
        line_count = 0
        for line in handle:
            line_count += 1
            try:
                fields = self.split(line)
            except Exception, e:
                print >>sys.stderr, self.tmpl.substitute(
                        line=line_count,
                        exc=e.__class__.__name__,
                        error=e)
                continue
            for handler in self._call_chain:
                getattr(handler, 'process')(fields)

        return line_count
```

5. Finally, copy `example2.log` over and create `example3.log`. Insert a `:q!` on line eight, followed by a newline. This should be the only text on that line.

6. Running the example should produce the following output:

   `(text_processing)$ cat example3.log | python logscan-g.py -s 30`



```
line 8 is malformed, raised IndexError error: list index out of range
Files over 30 bytes
===================
/a          :65383
/extra_long :873923465
/short      :22912
/internal   :832
/bit_long   :1818212
/e          :8221

Error Code Breakdown
====================
200: 6
404: 3
401: 1
500: 1
Errors: 5; Failure Rate: 45.454545%; Codes: 4

Report Complete!
Elapsed Time: 0.00048113 seconds
Lines Processed: 12
Avg. Duration per line: 0.0000400940577189 seconds
```

What just happened?

After importing the required `string` module, we created a `Template` object within the `LogProcessor` class definition. By adding it where we did, we ensured that it's only created once. If we had placed it within a method, it would be created each time that specific method was called.

Next, we updated our `parse` method to catch any exceptions that rise up from within `split`. If we happen to catch an error, we populate our template with values describing the exception and print the rendered result to the screen via standard error.

Template syntax

When we create an instance of `Template`, we pass in the template string we'll use. The syntax is fairly straightforward. If we want a value to be replaced, we simply precede it with a dollar sign. Two `$` characters adjacent to each other act as an escape; they are replaced with a single character in the rendered text.

If the identifier we intend to replace is embedded in a longer string, we can surround it with braces. A small example may clarify this concept.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> from string import Template
>>> template = Template('${name} has $$${amount} in his ${loc}et')
>>>
```

Rendering a template

Once we've created a template object, we use it to render a new string by calling either its `substitute` or `safe_substitute` methods.

```
>>> template.substitute(name='Bill Gates', amount=35000000000,
loc='wall')
'Bill Gates has $35000000000 in his wallet'
>>> template.substitute(name='Joe', amount=10, loc='blank')
'Joe has $10 in his blanket'
>>>
```

If a template variable is left off, or if a standalone dollar sign is encountered, the `substitute` method raises an error. If the `safe_substitute` alternative is used, errors are simply ignored and the conversion will not take place. Notice the difference in both approaches below:

```
>>> template.substitute(name='Joe', amount=10)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "/System/Library/Frameworks/Python.framework/Versions/2.6/lib/
python2.6/string.py", line 170, in substitute
    return self.pattern.sub(convert, self.template)
  File "/System/Library/Frameworks/Python.framework/Versions/2.6/lib/
python2.6/string.py", line 160, in convert
    val = mapping[named]
KeyError: 'loc'
>>> template.safe_substitute(name='Joe', amount=10)
'Joe has $10 in his ${loc}et'
>>>
```

Pop Quiz – string formatting

1. In what situation might you elect to use the `string.Template` class versus traditional string formatting?
2. What method might you use to pass a dictionary of values into the format method?
3. We know that expressions such as `"1" + 2` are invalid. What do you think would be the result of `"1" + "2"`?

Calling string object methods

In addition to providing powerful creation and formatting mechanisms, Python string objects also provide a collection of useful methods. We've already seen a few of them in our earlier examples. For example, we called `line.split()` within our `LogProcessor` class in order to separate a text line into pieces, delimited by space characters.

All of these methods are present on both standard byte strings and Unicode objects. As a general rule, Unicode objects return Unicode while byte string methods return byte strings.

Time for action – simple manipulation with string methods

In this example, we'll extend our little employee data-gathering script present earlier in the chapter. The goal is to illustrate the use of some of the string object methods.

1. Create a new file and name it `string_definitions-b.py`.

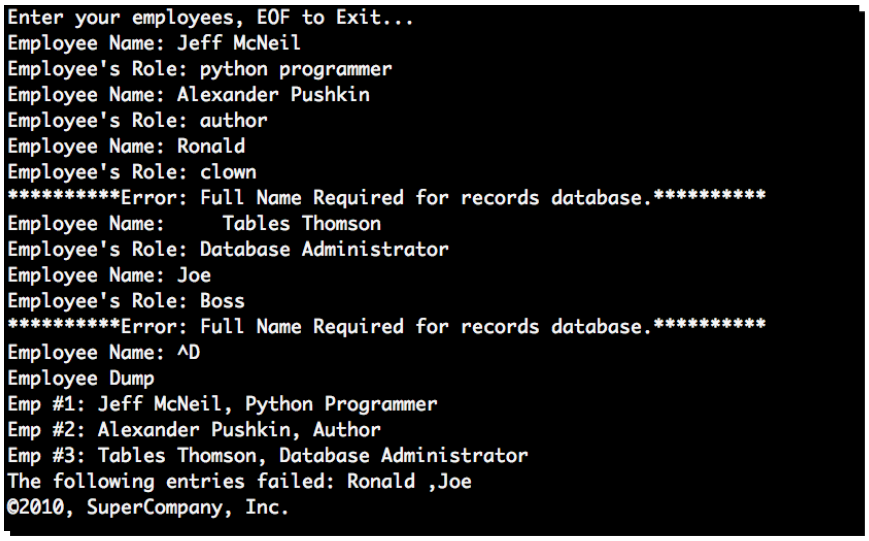
2. Enter the following code:

```
import sys

class BadEmployeeFormat(Exception):
    """Badly formatted employee name"""
    def __init__(self, reason, name):
        Exception.__init__(self, reason)
        self.name = name

def get_employee():
    """
    Retrieve user information.

    This method simply prompts the user for
    an employee's name and his current job
    title.
```

```
        """
        employee = raw_input('Employee Name: ')
        role = raw_input("Employee's Role: ")
        employee, role = employee.strip(), role.strip()

        # Make sure we have a full name
        if not employee.count(' '):
            raise BadEmployeeFormat('Full Name Required '
                'for records database.', employee )
        return {'name': employee, 'role': role }

    if __name__ == '__main__':
        employees = []
        failed_entries = []
        print 'Enter your employees, EOF to Exit...'
        while True:
            try:
                employees.append(get_employee())
            except EOFError:
                print
                print "Employee Dump"
                for number, employee in enumerate(employees):
                    print 'Emp #%d: %s, %s' % (number+1,
                        employee['name'], employee['role'].title())

                print 'The following entries failed: ' +
    ', '.join(failed_entries)
                print u'\N{Copyright Sign}2010, SuperCompany, Inc.'
                sys.exit(0)
            except BadEmployeeFormat, e:
                failed_entries.append(e.name)
                err_msg = 'Error: ' + str(e)
                print >>sys.stderr, err_msg.center(len(err_msg)+20,
    '*')
```

3. Run this example from the command line. If you entered it correctly then you should see output similar to the following:

```
(text_processing)$ python string_definitions-b.py
```



```
Enter your employees, EOF to Exit...
Employee Name: Jeff McNeil
Employee's Role: python programmer
Employee Name: Alexander Pushkin
Employee's Role: author
Employee Name: Ronald
Employee's Role: clown
**********Error: Full Name Required for records database.**********
Employee Name:     Tables Thomson
Employee's Role: Database Administrator
Employee Name: Joe
Employee's Role: Boss
**********Error: Full Name Required for records database.**********
Employee Name: ^D
Employee Dump
Emp #1: Jeff McNeil, Python Programmer
Emp #2: Alexander Pushkin, Author
Emp #3: Tables Thomson, Database Administrator
The following entries failed: Ronald ,Joe
©2010, SuperCompany, Inc.
```

What just happened?

There's not a whole lot extra going on in this new example. We've simply cleaned up our data a little bit more and took the liberty of notifying the user which employees were not successfully entered.

The first thing you'll notice is that we updated our `BadEmployeeFormat` exception to take an additional argument, the employee name. We do this so we can append the failed employee's information to a list within our main section.

The next update you'll run into is the `employee, role = employee.strip(), role.strip()` line. Each string (`employee`, `role`) might have white space on either end. Calling the `strip` method trims the string down and removes that spacing. If we wanted to, we could have passed additional characters into the strip and it would have removed those as well:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> 'ABC123DEF'.strip('ABCDEF')
'123'
>>>
```

The `strip` method removes any of the characters that appear in the argument string if they appear in the source string.

We've updated our check for a space to simply scan for a single space character rather than using our regular expression. The downside here, though, is that this check will pass even if data was entered incorrectly. Consider 'AlexanderPushkin', for example.

In the main section, we've added a `failed_entries` list. Whenever we catch a `BadEmployeeFormat` exception, we append the name of the employee to this list. When we receive our `EOFError`, we join this list via `', '.join(failed_entries)`. Note that in Python, `join` is a method of a string object and not a method of a list or an array data structure.

Now that we've seen some of them put to use, let's take a closer look at some of the methods available on string and Unicode objects. However, this isn't a complete survey. For a detailed description of all methods available on Python string objects, see the Python documentation.

Aligning text

There are four methods available on string objects that allow you to manage alignment and justification. Those methods are `center`, `ljust`, `rjust`, and `zfill`. We've seen the `center` method used previously. The `ljust` and `rjust` methods simply change the orientation of a supplied padding character.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> 'abc'.rjust(5, '*')
'**abc'
>>> 'abc'.ljust(5, '*')
'abc**'
>>> 'abc'.center(5, '*')
'*abc*'
>>>
```

The `zfill` method adds zeros to the left of the string object, up to the passed-in minimum width argument.

Detecting character classes

These methods correspond to a set of standard C character identification methods. However, unlike their C equivalents, it is possible to test all values of a specific string and not just a single character.

These methods include `isalnum`, `isalpha`, `isdigit`, `isspace`, `istitle`, `isupper`, and `islower`. These methods all test the entire string value; if any one character doesn't fit the bill, these methods simply return `False`.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
```

```
>>> '1'.isdigit()
True
>>> '1f'.isdigit()
False
>>> 'Back to the Future'.istitle()
False
>>> 'Back To The Future'.istitle()
True
>>> 'abc123'.isalnum()
True
>>>
```

The one method here that might not be clear up front is the `istitle` method. This returns `True` if all words within a string have their first letter capitalized.

Casing

Strings objects contain four methods for updating capitalization: `title`, `capitalize`, `upper`, and `lower`. Both the `upper` and `lower` methods change casing for an entire string. The `capitalize` and `title` methods are slightly different. Have a look at them in action:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> position = 'VP of marketing mumbo jumbo'
>>> position.title()
'Vp Of Marketing Mumbo Jumbo'
>>> city = 'buffalo'
>>> city.capitalize()
'Buffalo'
>>>
```

Notice how the `title` method returns the string in title case while the `capitalize` method simply capitalizes the first character of the string.

Searching strings

There are a number of methods associated with string objects that help with searching and comparison. To check for general quality, simply use the double equal sign comparison operator.

The `count`, `find`, `index`, `replace`, `rfind`, `rindex`, `startswith`, and `endswith` methods all scan a string for the occurrence of a substring. Additionally, it's possible to use the `in` keyword to test for a substring's occurrence within a larger string.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> 'one' in 'Bone Dry'
True
>>> 'one' == 'one'
True
>>>
```

We've already introduced you to the `count` method, so we'll skip over that here. `find` and `index` are both similar. When called, both return the offset into a string in which the substring is found. The difference, however, is how they'll respond in the event that the test string isn't present. The `find` method will simply return a `-1`. The `index` method will raise a `ValueError`.

Both `startswith` and `endswith` test to see whether their respective end is made up of the test string passed in.

The `replace` method allows you to replace a given substring within a larger string with an optional upper bound on the number of times the operation takes place. In the following example, notice how only one of the 'string-a' values is replaced:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> 'trout salmon turkey perch flounder'.replace('turkey', 'shark')
'trout salmon shark perch flounder'
>>> 'string-a string-b string-a'.replace('string-a', 'string', 1)
'string string-b string-a'
>>>
```

Finally, `rfind` and `rindex` are identical to `find` and `index`, except that they'll work from the end of the string rather than the beginning.

Dealing with lists of strings

There are four methods for dealing with string parts – `join`, `split`, `partition`, and `rpartition`. We've already seen them to some extent, but let's take a closer look as they're commonly-used string methods.

The `split` method takes a delimiter and an optional number of max splits. It will return a list of strings as broken up by the delimiter. If the separator is not found then a single element list is returned that contains the original string text. The optional maximum separator limits on how many times the split takes place. An example might help solidify its usage:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> string  = 'cheese,mouse,cat,dog'
>>> string.split(',')
['cheese', 'mouse', 'cat', 'dog']
>>> string.split('banana')
['cheese,mouse,cat,dog']
>>> string.split(',', 2)
['cheese', 'mouse', 'cat,dog']
>>>
```

We've already covered the `join` method; it places a string together given a list of elements. It is common to join around an empty string in order to simply concatenate a larger list of values.

Finally, we have `partition` and `rpartition`. These methods act much like the `split` method, except that they'll return three values - the part before a separator, the separator itself, and finally the part after the separator.

Treating strings as sequences

Remember that Python strings can be interpreted as **sequences** of characters as well. This means that all common sequence operations will also work on a string. It's possible to iterate through a string or break it into pieces using standard **slicing** syntax.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> 'abcdefg'[2-5]
'e'
>>> 'abcdefg'[2:5]
'cde'
>>> 'abcdefg'[2:5]
'cde'
>>> for i in 'abcdefg'[2:5]:
...     print 'Letter %c' % i
...
Letter c
Letter d
Letter e
>>>
```

This works for both byte strings as well as Unicode strings as Python deals with the underlying method calls at a character-level, and not a byte-level.

Have a go hero – dive into the string object

We've covered the majority of the string methods here as well as the most common usage scenarios, but we've not touched on all of them. Additionally, there are options we've not touched on.

Open a Python prompt and have a look at all of the methods and attributes available on a standard string object.

```
>>> dir('')
['__add__', '__class__', '__contains__', '__delattr__', '__doc__',
'__eq__', '__format__', '__ge__', '__getattribute__', '__getitem__',
'__getnewargs__', '__getslice__', '__gt__', '__hash__', '__init__',
'__le__', '__len__', '__lt__', '__mod__', '__mul__', '__ne__', '__
new__', '__reduce__', '__reduce_ex__', '__repr__', '__rmod__', '__
rmul__', '__setattr__', '__sizeof__', '__str__', '__subclasshook__',
'_formatter_field_name_split', '_formatter_parser', 'capitalize',
'center', 'count', 'decode', 'encode', 'endswith', 'expandtabs',
'find', 'format', 'index', 'isalnum', 'isalpha', 'isdigit', 'islower',
'isspace', 'istitle', 'isupper', 'join', 'ljust', 'lower', 'lstrip',
'partition', 'replace', 'rfind', 'rindex', 'rjust', 'rpartition',
'rsplit', 'rstrip', 'split', 'splitlines', 'startswith', 'strip',
'swapcase', 'title', 'translate', 'upper', 'zfill']
```

Using the output of `dir`, as well as the Python documentation (either online or via `pydoc`), spend some time and familiarize yourself with the available functions. You'll be glad you did!

Summary

We covered a lot of detail in this chapter. Python's string services provide a clean mechanism for dealing with text data at the character-level. You should now be familiar with built-in templating, formatting, and core string manipulation. These techniques are valid and should be considered before many more advanced approaches are evaluated.

Next, we'll leave the string basics behind and step into the standard library for a look at how to handle some of the more commonly encountered text formats. Python makes processing standard formats easy!

4
Text Processing Using the Standard Library

In addition to its powerful built-in string manipulation abilities, Python also ships with an array of standard library modules designed to parse and manipulate common standardized text formats.

Using the standard library, it's possible to parse INI files, read CSV and related files, and access common data formats used on the web, such as JSON. In this chapter, we'll take a look at some of these modules and look at how they can help us process text data a layer above the string management foundation.

We'll take a closer look at the following:

- **CSV**, or **Comma Separated Values**. Python provides a rich mechanism for accessing and extracting data from this common format commonly used as a spreadsheet stand-in.
- Parse and rely on INI files. We'll look at the standard Configuration File parsing classes for our own purposes and as a means to read Microsoft Windows configurations.
- We'll parse JSON data as it's often used as a data delivery mechanism on the Internet.
- Learn how to better organize our log processing application via modules and packages in order to make it more extensible going forward.

Reading CSV data

Comma separated values, or **CSV**, is a generic term that refers to columnar data, which is simply separated by commas. In fact, in spite of its name, the delimiter may actually be a different character. Other common delimiters include a tab, a space, or a semi-colon.

The major drawback to CSV data is that there is no standardization. In some circumstances, data elements will be quoted. In other circumstances, the writing application may include column or row headers along with the CSV data. Furthermore, consider the effects of the various line-endings used by different operating systems.

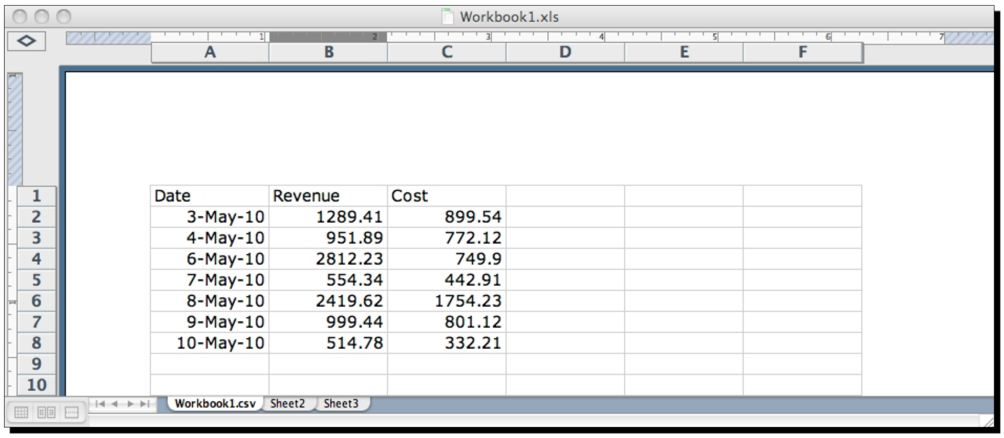
Clearly, it's not just a matter of splitting a comma-delimited line. Python's CSV support aims to work around the formatting variations and provide a standardized interface.

Time for action – processing Excel formats

The `csv` module provides support for formatting differences by allowing the use of different dialects. Dialects provide details such as which delimiter to use and how to address data element quoting.

In this example, we'll create an Excel spreadsheet and save it as a CSV document. We can then open that via Python and access all of the fields directly.

1. First, we'll need to create an Excel spreadsheet and build an initial dataset. We'll use some mock financial data. Build up a spreadsheet that includes the following data:



Date	Revenue	Cost
3-May-10	1289.41	899.54
4-May-10	951.89	772.12
6-May-10	2812.23	749.9
7-May-10	554.34	442.91
8-May-10	2419.62	1754.23
9-May-10	999.44	801.12
10-May-10	514.78	332.21

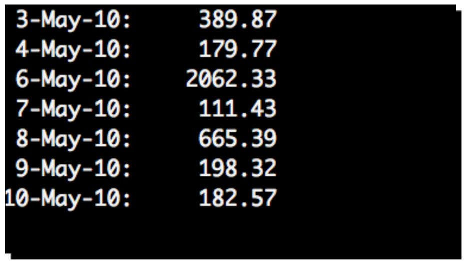
2. Now, from the File menu, select **Save As**. The Save As dialog contains a Format drop-down. From this dropdown, select **CSV (Comma Delimited)**. Name the file `Workbook1.csv`. Note that if you do not have Excel, these sample files are downloadable from the Packt Publishing FTP Site.

3. Create a new Python file and name it `csv_reader.py`. Enter the following code:

```
import csv
import sys
from optparse import OptionParser

def calculate_profit(day):
    return float(day['Revenue']) - float(day['Cost'])

if __name__ == '__main__':
    parser = OptionParser()
    parser.add_option('-f', '--file', help="CSV Data File")
    opts, args = parser.parse_args()

    if not opts.file:
        parser.error('File name is required')

    # Create a dict reader from an open file
    # handle and iterate through rows.
    reader = csv.DictReader(open(opts.file, 'rU'))
    for day in reader:
        print '%10s: %10.2f' % \
            (day['Date'], calculate_profit(day))
```

4. Running the preceding code should produce the following output, if you've copied it correctly.

```
(text_processing)$ python csv_reader.py --file=./Workbook1.csv
```



```
 3-May-10:     389.87
 4-May-10:     179.77
 6-May-10:    2062.33
 7-May-10:     111.43
 8-May-10:     665.39
 9-May-10:     198.32
10-May-10:     182.57
```

What just happened?

Let's walk through the code here. By now, you should be familiar with both the `__name__ == '__main__'` section as well as the option parser. We won't cover that boilerplate stuff any longer.

The first interesting line is `redirect = csv.DictReader(open(opts.file, 'rU'))`. There are two things worth pointing out on this line alone. First, we're opening the file using Universal Newline support. This is because Excel will save the CSV file according to our platform's convention. We want Python just to hide all of that for us here.

Secondly, we're creating an instance of `csv.DictReader`. The basic approach to accessing CSV data is via the `csv.reader` method. However, this requires us to access each row via an array index. The `csv.DictReader` class uses the first row in the CSV file (by default) as the dictionary keys. This makes it much easier to access data by name.

If we had used the standard reader, we would have had to parse our data as in the following small example snippet:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import csv
>>> reader = csv.reader(open('Workbook1.csv', 'rU'))
>>> for row in reader:
...     print 'Revenue on ' + row[0] + ': ' + row[1]
...
Revenue on Date: Revenue
Revenue on 3-May-10: 1289.41
Revenue on 4-May-10: 951.89
Revenue on 6-May-10: 2812.23
Revenue on 7-May-10: 554.341
Revenue on 8-May-10: 2419.62
Revenue on 9-May-10: 999.44
Revenue on 10-May-10: 514.78
>>>
```

As you can see, the dictionary approach makes it much easier to handle the processed data.

Next, we iterate through each row in the dataset and print out a profit summary. If you take a look at the `calculate_profit` function, you'll see how we do this. As mentioned before, Python is not only dynamically-typed, but also strongly-typed once a value has been created. We have to explicitly create new floating-point types based on the text value in order to perform our subtraction operation.

Finally, our `print` statement uses classic percent-formatting and adds a little bit of padding in order to keep everything easy to read.

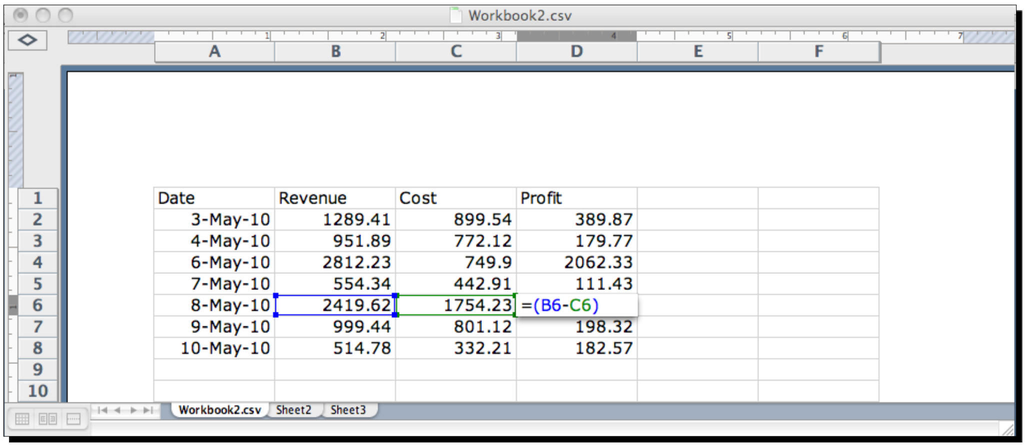
If you were paying attention, you'll remember we mentioned that we need a dialect in order to process a `CSV` file. What gives? We didn't specify one, did we? Well, no. Python defaults to the Excel dialect, which is exactly what we're using in our example.

If you're familiar with Excel, you're probably wondering why we used Python to calculate our profit rather than letting Excel do it for us. After all, that's what a spreadsheet application is for!

Time for action – CSV and formulas

Let's run though an example and illustrate why we chose to calculate the values ourselves rather than letting Excel do it.

1. First, open Excel again and add a new column. We're going to name it **Profit**. The value of this column should be a simple formula, `=(BX-CX)`, where 'X' is the row number you're at. Repeat until your spreadsheet looks like this:



	A	B	C	D	E	F
1	Date	Revenue	Cost	Profit		
2	3-May-10	1289.41	899.54	389.87		
3	4-May-10	951.89	772.12	179.77		
4	6-May-10	2812.23	749.9	2062.33		
5	7-May-10	554.34	442.91	111.43		
6	8-May-10	2419.62	1754.23	=(B6-C6)		
7	9-May-10	999.44	801.12	198.32		
8	10-May-10	514.78	332.21	182.57		
9						
10						

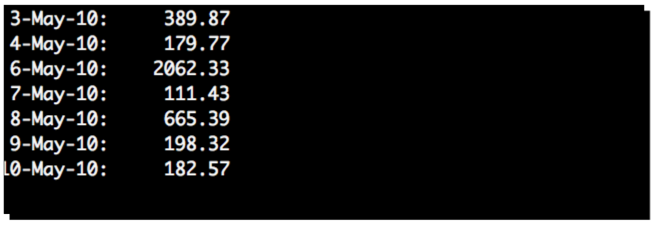
2. Now, like we did with our first example, save this as `Workbook2.csv`. You'll need to accept any warnings that Excel gives you. This document is also available on the Packt Publishing FTP site.

3. Using `csv_reader.py` as a starting point, create `csv_reader-b.py` and modify the `calculate_profit` function to read as follows.

```
def calculate_profit(day):
    return float(day['Profit'])
```

4. Running the example using the new CSV input should produce the following results, if you've entered the code correctly.

```
(text_processing)$ python csv_reader-b.py --file=Workbook2.csv
```



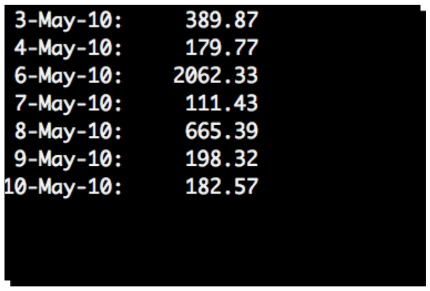
```
3-May-10:     389.87
4-May-10:     179.77
6-May-10:    2062.33
7-May-10:     111.43
8-May-10:     665.39
9-May-10:     198.32
L0-May-10:    182.57
```

5. Now, open the `Workbook2.csv` file in a text editor and add a `1` to every revenue column to increase net revenue by a visible amount. Save it as `Workbook2a.csv`. The updated text file should look like this:

```
Date,Revenue,Cost,Profit,,
3-May-10,11289.41,899.54,389.87,,
4-May-10,1951.89,772.12,179.77,,
6-May-10,12812.23,749.9,2062.33,,
7-May-10,1554.34,442.91,111.43,,
8-May-10,12419.62,1754.23,665.39,,
9-May-10,1999.44,801.12,198.32,,
10-May-10,1514.78,332.21,182.57,,
```

6. Finally, let's run the application again, using this new source of input.

```
(text_processing)$ python csv_reader-b.py --file=Workbook2a.csv
```



```
 3-May-10:     389.87
 4-May-10:     179.77
 6-May-10:    2062.33
 7-May-10:     111.43
 8-May-10:     665.39
 9-May-10:     198.32
10-May-10:     182.57
```

What just happened?

There's not much new code here. We simply updated our `calculate_profit` function to return the Profit dictionary key rather than perform the calculation. Pretty simple.

But, what happened? Why was the output the same for both runs? CSV data generated with Excel (and probably all spreadsheet tools) does not contain formula information. Formula results are calculated before the data is saved and the target cells receive that value.

The important thing to remember here is that if you're dealing with spreadsheet data, you cannot rely on formula contents. If an input value to a formula changes outside of the application, you'll need to perform that calculation yourself, within Python.

[If you have a desire to read and manipulate native Excel files, the `xlrd` module provides that functionality. It is available on the Python Package Index at `http://pypi.python.org/pypi/xlrd/0.7.1`.]

Reading non-Excel data

Not all CSV data is generated and written by Microsoft Excel. In fact, it's a fairly open and flexible format and is used in a lot of other arenas as well. For example, many shopping-cart applications and online-banking utilities allow end users to export data using this format as most all spreadsheet applications can read it.

In order to read a non-Excel format, we'll need to define our own CSV dialect, which tells the parser what to expect as a delimiter, whether values are quoted, and a few other details as well.

Time for action – processing custom CSV formats

In this example, we'll build a `Dialect` class that is responsible for interpreting our own format. We'll use some alternate delimiters and some different processing settings. This is the general approach you'll use when parsing your own format files.

We're going to process a UNIX style `/etc/passwd` file in this example. If you're not familiar with the format, here's a small sample:

```
root:x:0:0:root:/root:/bin/bash
daemon:x:1:1:daemon:/usr/sbin:/bin/sh
bin:x:2:2:bin:/bin:/bin/sh
sys:x:3:3:sys:/dev:/bin/sh
sync:x:4:65534:sync:/bin:/bin/sync
games:x:5:60:games:/usr/games:/bin/sh
man:x:6:12:man:/var/cache/man:/bin/sh
lp:x:7:7:lp:/var/spool/lpd:/bin/sh
mail:x:8:8:mail:/var/mail:/bin/sh
news:x:9:9:news:/var/spool/news:/bin/sh
uucp:x:10:10:uucp:/var/spool/uucp:/bin/sh
proxy:x:13:13:proxy:/bin:/bin/sh
www-data:x:33:33:www-data:/var/www:/bin/sh
backup:x:34:34:backup:/var/backups:/bin/sh
```

Each line is a colon-separated list of values. We're only going to concern ourselves with the first and the last values - the user's login name and the shell application that is executed when a login occurs.

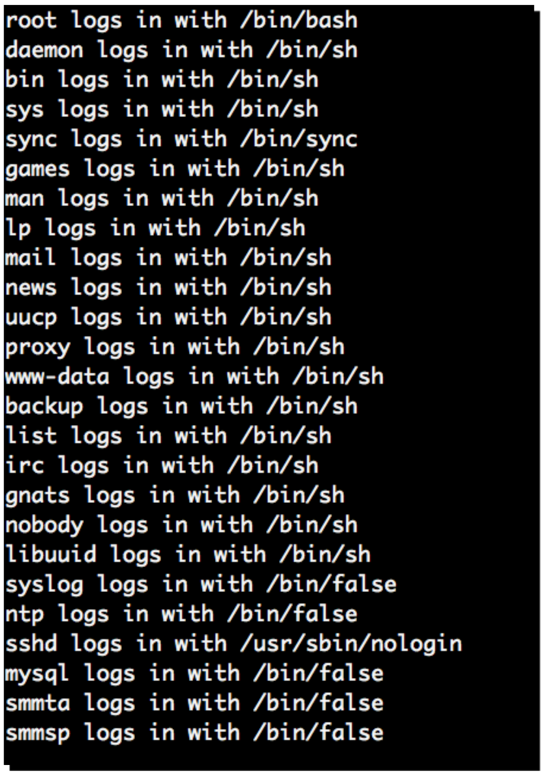
[If you're following along using a Windows machine, you obviously do not have an `/etc/passwd` file. An example file is available on the Packt Publishing FTP site. These examples will use that file so they match up for all users.]

1. Create a new file named `csv_reader-c.py` and enter the following code. Note that this file is based on the `csv_reader.py` source we created earlier in the chapter.

```
import csv
import sys
from optparse import OptionParser

if __name__ == '__main__':
    parser = OptionParser()
    parser.add_option('-f', '--file', help="CSV Data File")
    opts, args = parser.parse_args()

    if not opts.file:
        parser.error('File name is required')

    csv.register_dialect('passwd', delimiter=':',
        quoting=csv.QUOTE_NONE)

    dict_keys = ('login', 'pwd', 'uid', 'gid',
        'comment', 'home', 'shell')

    # Create a dict reader from an open file
    # handle and iterate through rows.
    reader = csv.DictReader(
        open(opts.file, 'rU'), fieldnames=dict_keys,
          dialect='passwd')
    for user in reader:
        print '%s logs in with %s' % \
            (user['login'], user['shell'])
```

2. Run the preceding example using an `/etc/passwd` file as input. We'll use the example provided, but feel free to use your own if you wish.

```
(text_processing)$ python csv_translate.py --file=passwd > pwd.csv
```



```
root logs in with /bin/bash
daemon logs in with /bin/sh
bin logs in with /bin/sh
sys logs in with /bin/sh
sync logs in with /bin/sync
games logs in with /bin/sh
man logs in with /bin/sh
lp logs in with /bin/sh
mail logs in with /bin/sh
news logs in with /bin/sh
uucp logs in with /bin/sh
proxy logs in with /bin/sh
www-data logs in with /bin/sh
backup logs in with /bin/sh
list logs in with /bin/sh
irc logs in with /bin/sh
gnats logs in with /bin/sh
nobody logs in with /bin/sh
libuuid logs in with /bin/sh
syslog logs in with /bin/false
ntp logs in with /bin/false
sshd logs in with /usr/sbin/nologin
mysql logs in with /bin/false
smmta logs in with /bin/false
smmsp logs in with /bin/false
```

What just happened?

We made a few changes to our `csv_reader.py` code in order to manage UNIX `/etc/passwd` files to illustrate how you would go about processing non-Excel compatible formats.

The first line we'll look at is the call to `csv.register_dialect`. In this call, we're adding an entirely new CSV dialect, named `passwd`. We're setting the delimiter to a single colon and configuring the system not to expect quotes. This is a convenient way to introduce a new dialect, but it's not the only way.

If we had a reason to, we could have extended the `Dialect` class and passed that in instead of a series of keyword arguments to `csv.register_dialect`. In most cases, though, you will do it this way as a `Dialect` is simply a collection of processing options.

Next, we create a `tuple` of dictionary keys. The `DictReader` uses the first line of a `CSV` file as it's a set of dictionary keys by default. As a password file does not contain a header as our Excel sheets did, we need to explicitly pass in the list of dictionary keys to use. They should be in the order in which they'll be split.

Finally, we call `csv.DictReader` again, but this time, we specify the dialect name to use as well as the dictionary keys in the tuple we just created. The remainder of this example simply prints out a user and her corresponding login shell.

Writing CSV data

We've looked at methods for parsing two different dialects of CSV: Excel formats and our own custom format. Let's wrap up our discussion on CSV by looking at how we would write out a new file.

Time for action – creating a spreadsheet of UNIX users

We're going to read our UNIX password database using the code we've already developed, and transform it into an Excel-friendly CSV dialect. We should then be able to open our list of users in spreadsheet format if we choose.

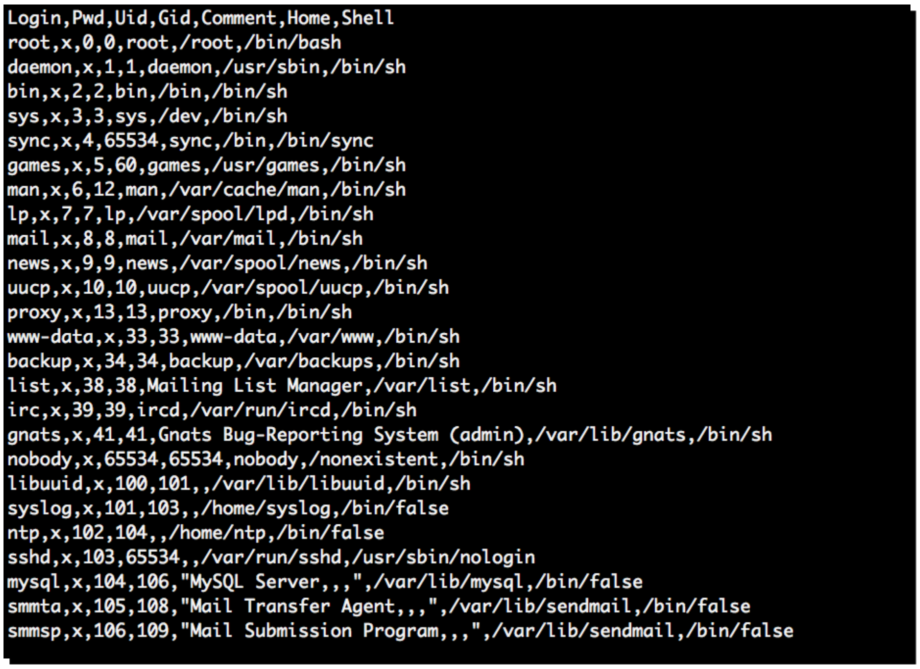
1. Create a new file and name it `csv_translate.py`.
2. Enter the following code:

```
import csv
import sys
from optparse import OptionParser

parser = OptionParser()
parser.add_option('-f', '--file', help="CSV Data File")
opts, args = parser.parse_args()

if not opts.file:
    parser.error('File name is required')

csv.register_dialect('passwd', delimiter=':',
    quoting=csv.QUOTE_NONE)

dict_keys = ('login', 'pwd', 'uid', 'gid',
    'comment', 'home', 'shell')

print ','.join([i.title() for i in dict_keys])
writer = csv.DictWriter(sys.stdout, dict_keys)

# Create a dict reader from an open file
# handle and iterate through rows.
reader = csv.DictReader(
    open(opts.file, 'rU'), fieldnames=dict_keys, dialect='passwd')

writer.writerows(reader)
```

3. Now, run the example using the supplied `passwd` file as your input. Redirect the output to a file named `passwd.csv`.

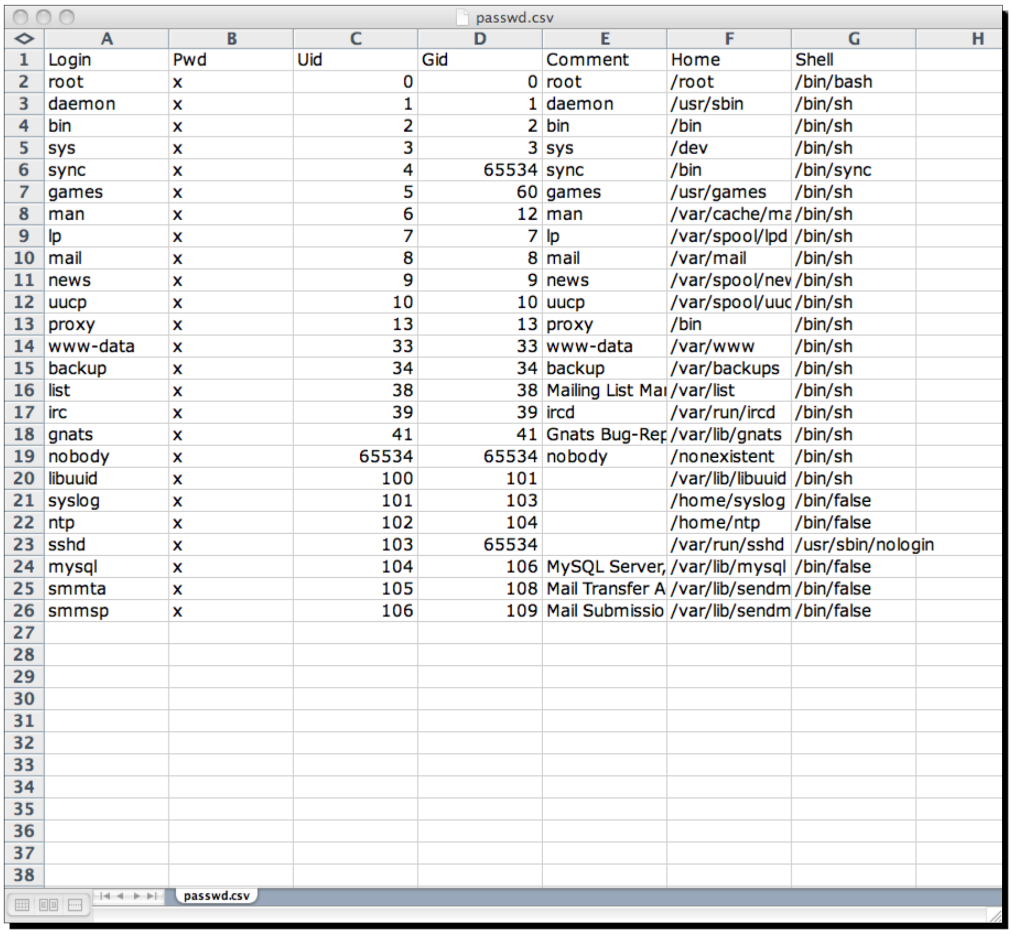
   ```
   (text_processing)$ python csv_translate.py --file=passwd > passwd.
   csv
   ```

4. The contents of the newly created CSV file should be exactly as follows.



```
Login,Pwd,Uid,Gid,Comment,Home,Shell
root,x,0,0,root,/root,/bin/bash
daemon,x,1,1,daemon,/usr/sbin,/bin/sh
bin,x,2,2,bin,/bin,/bin/sh
sys,x,3,3,sys,/dev,/bin/sh
sync,x,4,65534,sync,/bin,/bin/sync
games,x,5,60,games,/usr/games,/bin/sh
man,x,6,12,man,/var/cache/man,/bin/sh
lp,x,7,7,lp,/var/spool/lpd,/bin/sh
mail,x,8,8,mail,/var/mail,/bin/sh
news,x,9,9,news,/var/spool/news,/bin/sh
uucp,x,10,10,uucp,/var/spool/uucp,/bin/sh
proxy,x,13,13,proxy,/bin,/bin/sh
www-data,x,33,33,www-data,/var/www,/bin/sh
backup,x,34,34,backup,/var/backups,/bin/sh
list,x,38,38,Mailing List Manager,/var/list,/bin/sh
irc,x,39,39,ircd,/var/run/ircd,/bin/sh
gnats,x,41,41,Gnats Bug-Reporting System (admin),/var/lib/gnats,/bin/sh
nobody,x,65534,65534,nobody,/nonexistent,/bin/sh
libuuid,x,100,101,,/var/lib/libuuid,/bin/sh
syslog,x,101,103,,/home/syslog,/bin/false
ntp,x,102,104,,/home/ntp,/bin/false
sshd,x,103,65534,,/var/run/sshd,/usr/sbin/nologin
mysql,x,104,106,"MySQL Server,,,",/var/lib/mysql,/bin/false
smmta,x,105,108,"Mail Transfer Agent,,,",/var/lib/sendmail,/bin/false
smmsp,x,106,109,"Mail Submission Program,,,",/var/lib/sendmail,/bin/false
```

5. Finally, open the new CSV file in Microsoft Excel or OpenOffice. The rendered spreadsheet should resemble the following screenshot:



passwd.csv

	A	B	C	D	E	F	G	H
1	Login	Pwd	Uid	Gid	Comment	Home	Shell	
2	root	x	0	0	root	/root	/bin/bash	
3	daemon	x	1	1	daemon	/usr/sbin	/bin/sh	
4	bin	x	2	2	bin	/bin	/bin/sh	
5	sys	x	3	3	sys	/dev	/bin/sh	
6	sync	x	4	65534	sync	/bin	/bin/sync	
7	games	x	5	60	games	/usr/games	/bin/sh	
8	man	x	6	12	man	/var/cache/ma	/bin/sh	
9	lp	x	7	7	lp	/var/spool/lpd	/bin/sh	
10	mail	x	8	8	mail	/var/mail	/bin/sh	
11	news	x	9	9	news	/var/spool/nev	/bin/sh	
12	uucp	x	10	10	uucp	/var/spool/uuc	/bin/sh	
13	proxy	x	13	13	proxy	/bin	/bin/sh	
14	www-data	x	33	33	www-data	/var/www	/bin/sh	
15	backup	x	34	34	backup	/var/backups	/bin/sh	
16	list	x	38	38	Mailing List Mai	/var/list	/bin/sh	
17	irc	x	39	39	ircd	/var/run/ircd	/bin/sh	
18	gnats	x	41	41	Gnats Bug-Rep	/var/lib/gnats	/bin/sh	
19	nobody	x	65534	65534	nobody	/nonexistent	/bin/sh	
20	libuuid	x	100	101		/var/lib/libuuid	/bin/sh	
21	syslog	x	101	103		/home/syslog	/bin/false	
22	ntp	x	102	104		/home/ntp	/bin/false	
23	sshd	x	103	65534		/var/run/sshd	/usr/sbin/nologin	
24	mysql	x	104	106	MySQL Server,	/var/lib/mysql	/bin/false	
25	smmta	x	105	108	Mail Transfer A	/var/lib/sendm	/bin/false	
26	smmsp	x	106	109	Mail Submissio	/var/lib/sendm	/bin/false	
27								
28								
29								
30								
31								
32								
33								
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38								

What just happened?

Using two different dialects, we read from our password file and wrote Excel-friendly CSV to our standard output channel.

Lets skip over the boilerplate code again and look at what makes this example actually work. First, the two lines that appear directly under the `dict_key` assignment line. We're doing two important things here. First, we translate the keys we've been using into title case via **a list comprehension** and join them with a comma. Both of these steps use string object methods covered in the previous chapter. In the same line, we then print this newly generated value. This serves as the top line of the new CSV.

The next line creates a `writer` object, which simply takes a file-like object and a list of dictionary keys. Note that the list of keys is required here as Python's dictionaries are unordered. This tells the writer in which order to print the dictionary values. The actual write logic executes much like the following small example:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> dicts = [{'key1': 'value1', 'key2': 'value2'}, {'key1': 'value1',
'key2': 'value2'}]
>>> key_order = ('key2', 'key1')
>>> for d in dicts:
...     print ','.join([d[key] for key in key_order])
...
value2,value1
value2,value1
>>>
```

Finally, we call `writer.writerows(reader)` to read all of the data from the source CSV and print it to the new destination. The `writerows` method of a `DictWriter` object expects a sequence of dictionaries with the appropriate keys.

Pop Quiz – CSV handling

1. We've described two methods of creating new CSV dialects. What are they? In what situations might you choose one over the other?
2. What's the drawback to simply using the `split` method of the `string` object for parsing CSV data? Why isn't this approach reliable?
3. How are formulas executed once a spreadsheet document has been saved in a text-only CSV format?

Have a go hero – detecting CSV dialects

One aspect of the CSV module we didn't cover here is the `csv.Sniffer` class. This class attempts to build a new dialect based on a sample segment of a CSV file. You can read more about the `Sniffer` class at `http://docs.python.org/library/csv.html`.

Given your knowledge of CSV files and how to process them, update the previous code to automatically detect the CSV dialect in use given our example `passwd` file. If you're using a UNIX system, try it on your own `passwd` file. Does it work? In which situations do you run into issues?

Modifying application configuration files

As you develop applications, you're going to want to allow your end users to make runtime changes without updating and editing source code. This is where the need for a configuration file comes in.

You've surely dealt with them before as you've set up and managed different computer systems and applications. Perhaps you've had to edit one while defining a web server virtual host, or while configuring drivers or boot preferences.

For the most part, applications choose their own configuration formats and implement their own parsers, to some degree. Some files contain simple name-value pairs while others build programming-language-like structures. Still others implement sections and segment values even further.

Luckily, Python provides a full-featured configuration file management module for us, so we don't have to worry about writing our own error-prone processing logic. As an added benefit, Python's `ConfigParser` module also supports the generation of new configuration files using Python data structures. This means we can easily write new files as well.

Time for action – adding basic configuration read support

In this example, we'll add some basic configuration file support into our ever-growing log-processing application. There are a few values that we've been passing on the command line that have become somewhat repetitive. Let's fix that.

1. First, create `logscan-h.py`, using `logscan-g.py` as your starting place.
2. Update the `import` statements at the top of the file to look like this:
   ```
   import time
   import string
   import sys
   from optparse import OptionParser
   from collections import defaultdict
   from ConfigParser import SafeConfigParser
   from ConfigParser import ParsingError
   ```
3. Now, directly below the `MaxSizeHandler` class, add the following `configuration parser` function. Note that this is not a part of the `MaxSizeHandler` class and should not have a base indent.
   ```
   def load_config():
       """
       Load configuration.
   ```

```
    Reads the name of the configuration
    of sys.argv and loads our config.
    from disk.
    """
    parser = OptionParser()
    parser.add_option('-c', '--config', dest='config',
        help="Configuration File Path")

    opts, args = parser.parse_args()
    if not opts.config:
        parser.error('Configuration File Required')

    config_parser = SafeConfigParser()
    if not config_parser.read(opts.config):
        parser.error('Could not parse configuration')

    return config_parser
```

4. We need to update our `__main__` section to take advantage of our new configuration file support. Update your main section to read as follows:

```
if __name__ == '__main__':

    config = load_config()

    input_source = config.get('main', 'input_source')
    if input_source == '-':
        file_stream = sys.stdin
    else:
        try:
            file_stream = open(input_source)
        except IOError, e:
            print >>sys.stderr, str(e)
            sys.exit(-1)

    size_check = MaxSizeHandler(
        int(config.get(
            'maxsize', 'threshold')
        )
    )
    call_chain = []
    call_chain.append(size_check)
    call_chain.append(ErrorCodeHandler())
    processor = LogProcessor(call_chain)

    initial = time.time()
    line_count = processor.parse(file_stream)
    duration = time.time() - initial

    # Ask the processor to display the
```

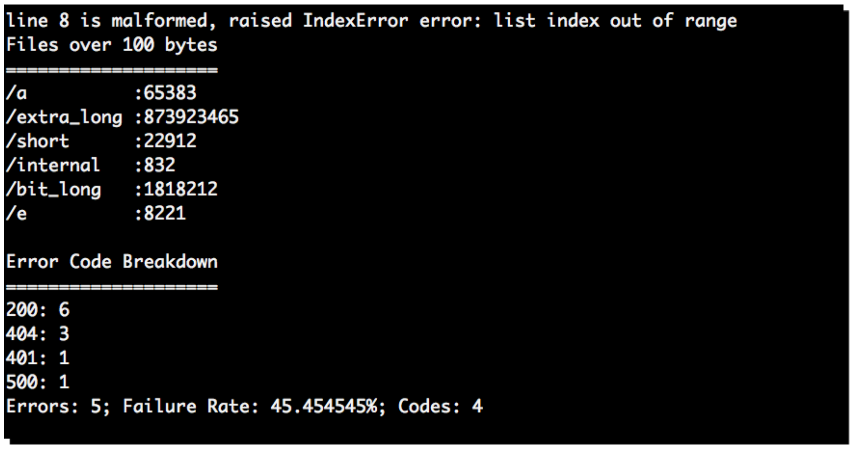
```
        # individual reports.
        processor.report()

        if config.getboolean('display', 'show_footer'):
            # Print our internal statistics
            print "Report Complete!"
            print "Elapsed Time: %#.8f seconds" % duration
            print "Lines Processed: %d" % line_count
            print "Avg. Duration per line: %#.16f seconds" % \
                (duration / line_count) if line_count else 0
```

5. The next thing to do is create a basic configuration file. Enter the following text into a file named `logscan.cfg`:

```
[main]
# Input filename. This must be either a pathname or a simple
# dash (-), which signifies we'll use standard in.
input_source = example3.log

[maxsize]
# When we hit this threshold, we'll alert for maximum
# file size.
threshold = 100

[display]
# Whether we want to see the final footer calculations or
# not. Sometimes things like this just get in the way.
show_footer = no
```

6. Now, let's run the example using this configuration. If you entered everything correctly, then your output should resemble the following:

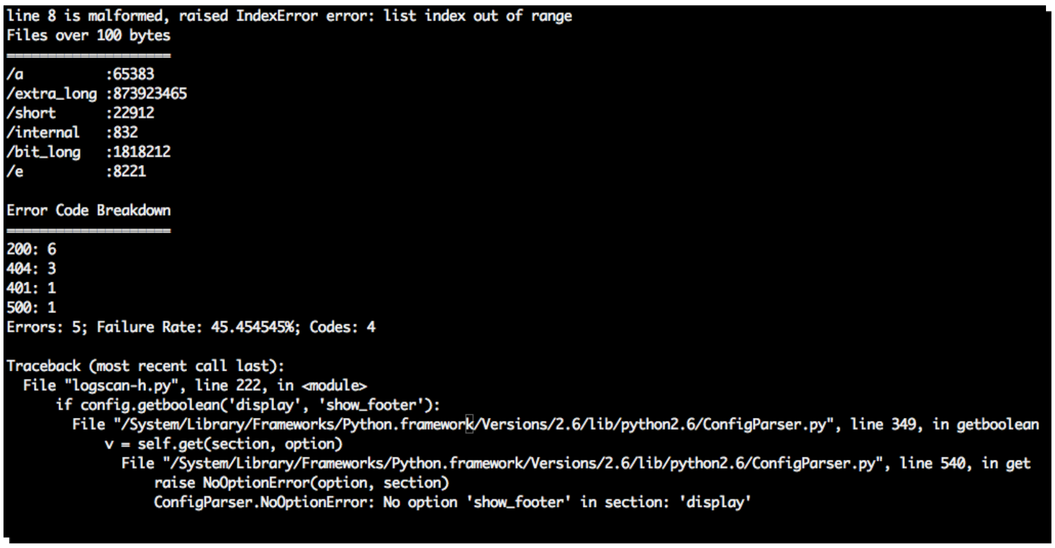
```
(text_processing)$ python logscan-h.py --config=logscan.cfg
```



```
line 8 is malformed, raised IndexError error: list index out of range
Files over 100 bytes
====================
/a          :65383
/extra_long :873923465
/short      :22912
/internal   :832
/bit_long   :1818212
/e          :8221

Error Code Breakdown
====================
200: 6
404: 3
401: 1
500: 1
Errors: 5; Failure Rate: 45.454545%; Codes: 4
```

7. Finally, open up the configuration file and comment out the very last line. It should begin with `show_footer`. Run the application again. You should see the following output:

```
(text_processing)$ python logscan-h.py --config=logscan.cfg
```



```
line 8 is malformed, raised IndexError error: list index out of range
Files over 100 bytes
====================
/a          :65383
/extra_long :873923465
/short      :22912
/internal   :832
/bit_long   :1818212
/e          :8221

Error Code Breakdown
====================
200: 6
404: 3
401: 1
500: 1
Errors: 5; Failure Rate: 45.454545%; Codes: 4

Traceback (most recent call last):
  File "logscan-h.py", line 222, in <module>
      if config.getboolean('display', 'show_footer'):
        File "/System/Library/Frameworks/Python.framework/Versions/2.6/lib/python2.6/ConfigParser.py", line 349, in getboolean
            v = self.get(section, option)
              File "/System/Library/Frameworks/Python.framework/Versions/2.6/lib/python2.6/ConfigParser.py", line 540, in get
                  raise NoOptionError(option, section)
                  ConfigParser.NoOptionError: No option 'show_footer' in section: 'display'
```

What just happened?

We opened, scanned, processed, converted, and used elements of an ini-style configuration file without having to deal with a single split or white space trim! Let's have a closer look at how we set everything up.

First off, we updated our import statements to include the needed classes within the `ConfigParser` module. In many cases, it's simpler to just import the `ConfigParser` module itself rather than individual classes. We did it this way in order to save a bit of space in the example text.

Next, we added a `load_config` function that is responsible for handling most of the actual work. The first thing we do here is parse our command line for a single `–c` (or `–config`) option, which is the location of our file. This option is required and we'll exit if it's not found (more on that later).

Next, we instantiate a `SafeConfigParser` class and attempt to make it read the name of the file we pass in via the command-line option. If the read doesn't succeed then we exit with a rather generic error. We return the `config_parser` object after we have read our file.

Skip now to our `__main__` section. The very first thing we do here is process our configuration file via the new function. The very next line shows the canonical way for accessing data, via the `get` method. The `get` method takes a configuration file section as well as a value name. This first access retrieves the `input_source` value, which is the name of our logfile.

Next, we access the configuration object again when we create our `MaxSizeHandler` class. We pull the threshold size out and pass it to the constructor.

> Notice that we have to explicitly convert our data to an integer type. Values read via configuration files are typed as strings.

The final time we access our configuration object is near the bottom when we check the display section for the `show_footer` value. If it's not `True`, we won't print our familiar footer text. Here, we use a convenience method available to us, called `getboolean`. There are a series of these methods available that automatically handle the data transformation for us.

The last thing we did was to comment out a configuration line and run our application. In doing so, you'll notice that it results in a fatal error! This probably isn't what we want most of the time. It's possible to avoid this situation and set reasonable default values.

> One nice thing about the `SafeConfigParser` classes is that they're also able to read Microsoft Windows configuration files directly. However, none of the `ConfigParser` classes support value-type prefixes found in extended version INI syntax.

Using value interpolation

One really interesting feature of the `ConfigParser` module is that it supports configuration value interpolation, or substitution, directly within the configuration file itself. This is a very useful feature.

Time for action – relying on configuration value interpolation

For this example, we'll simply update our configuration file to take advantage of this feature. There are no Python code changes necessary.

1. First, add a new configuration value to the `[main]` section of `logscan.cfg`. The name of the value should be `dir` and the value should be the full path to the directory that you're executing examples from.

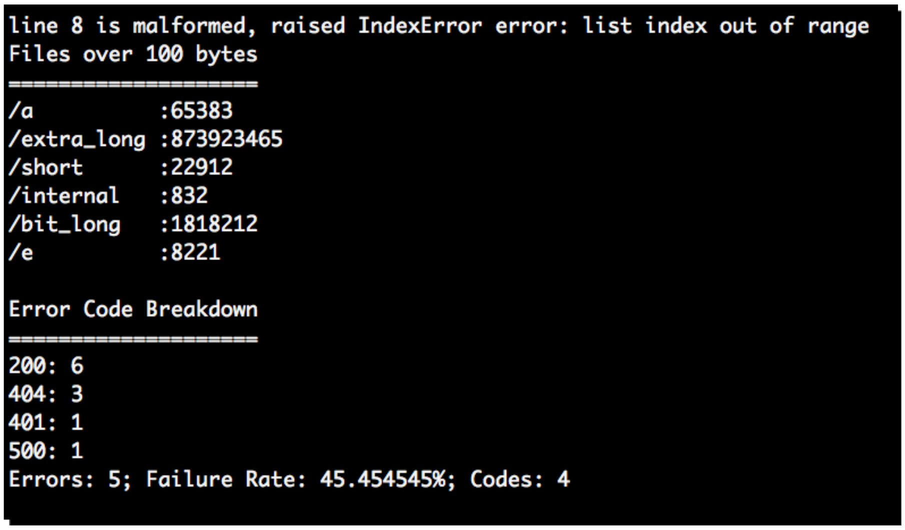
```
[main]
# The main directory Where we're running from (or, rather, where
# we store logfiles and write output to)
dir = /Users/jeff/Desktop/ptpbg/Chapters/Ch4
```

2. Next, you're going to update the `input_source` configuration option to reference this full path.

```
# Input filename. This must be either a pathname or a simple
# dash (-), which signifies we'll use standard in.
input_source = %(dir)s/www.log
```

3. Finally, running this updated example should produce the same output as the previous execution did.

```
(text_processing)$ python logscan-h.py --config=logscan.cfg
```



```
line 8 is malformed, raised IndexError error: list index out of range
Files over 100 bytes
====================
/a          :65383
/extra_long :873923465
/short      :22912
/internal   :832
/bit_long   :1818212
/e          :8221

Error Code Breakdown
====================
200: 6
404: 3
401: 1
500: 1
Errors: 5; Failure Rate: 45.454545%; Codes: 4
```

What just happened?

We included the value of a `configuration` option within a second one by using the familiar percent syntax. This allows us to build complex configuration values by relying on interpolation and not repeating data.

Order is not significant. We could have placed the `dir` value below `input_source` and the example would have worked perfectly fine. Values are not retrieved until they are accessed. It is possible to access any values within the current section, or within the special defaults collections detailed as follows.

It's also possible to pass additional values to be used or interpolation in to the method. This is a convenient way to generate configurations that depend on the current state of an application, such as a web-aware script.

Consider the following configuration file:

```
[redirects]
client_history = http://yourdomain.com/%(ip)s/history
```

Given this snippet, it's easy to imagine a web application, which redirects users to a URL based on their client IP. As we don't have this information at startup time, we can't resolve the full URL until a request is actually made. To include the source IP address, we could modify the way we use the `get` function:

```
return config.get('redirects', 'client_history',
vars={'ip': client_ip})
```

Finally, assuming a client IP of 127.0.0.1, our `client_history` URL would render to `http://yourdomain.com/127.0.0.1/history`.

Handling default options

In addition to passing a `vars` keyword argument to the `get` method, there are two other ways you can supply default values for interpolation: a `DEFAULT` section within a configuration file, or by passing a dictionary of default values into `SafeConfigParser` when you create an instance.

Both of these options are different than the keyword argument approach in one big area. In addition to serving as interpolated values, these elements will be returned verbatim if a configuration option referenced with the `get` function doesn't exist within the specified section. In effect, it's possible to use these defaults as global configuration option defaults and not simply interpolation defaults.

Time for action – configuration defaults

In this example, we'll add some defaults to our configuration. This makes things easy on our users as they don't have to configure every possible item.

1. As usual, create a new copy of our logscan script. You should base it on `logscan-h.py` and name it `logscan-i.py`.
2. At the top of the file, add `import os` above the first `import` statement.
3. Next, update the `load_config` method. Replace the line that reads `config_parser = SafeConfigParser()` with the following:

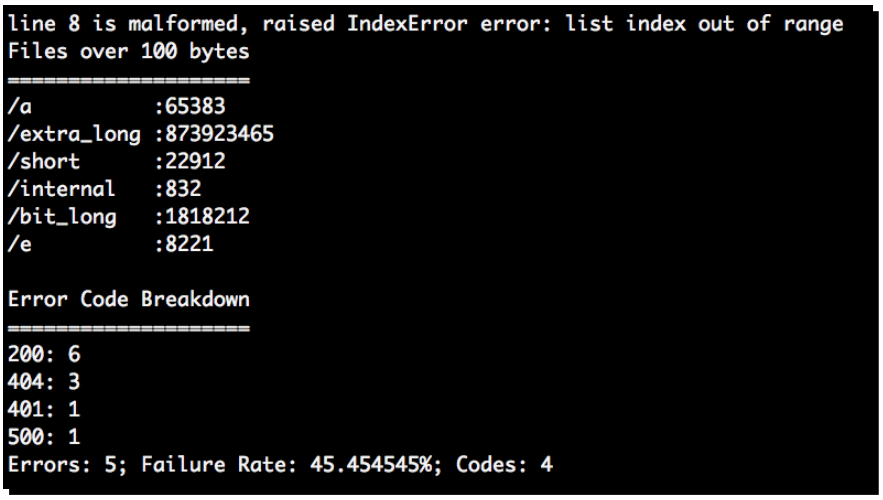
```
# Build config parser and set some
    # reasonable defaults.
    config_parser = SafeConfigParser(
        defaults={
            'input_source': '-',
            'dir': os.getcwd(),
            'threshold': '0',
            'show_footer': 'True'
        }
    )
```

4. Remove (or comment) the line that defines the current directory within the `logscan.cfg` file.

5. Remove or comment out the line that reads `show_footer = no` within the configuration file.

6. Finally, run the updated logscan script. It should run through to completion without error.

```
(text_processing)$ python logscan-i.py --config=logscan.cfg
```



```
line 8 is malformed, raised IndexError error: list index out of range
Files over 100 bytes
====================
/a          :65383
/extra_long :873923465
/short      :22912
/internal   :832
/bit_long   :1818212
/e          :8221

Error Code Breakdown
====================
200: 6
404: 3
401: 1
500: 1
Errors: 5; Failure Rate: 45.454545%; Codes: 4
```

What just happened?

First, we simply imported the `os` module as we reference it later in the script when we determine the current working directory.

Next, jump down to the `parse_config` function and have a look at the changes we've made to `SafeConfigParser`. We're passing in a dictionary of default options here. We're also making things easier on our users by defaulting the `dir` value to be the current working directory, which is available via `os.getcwd`.

Finally, we comment out or remove a required configuration option and take the default value.

You may have noticed that all of the options we've passed in as default values are string options and not native types where applicable. The reason for this is simple. The shortcut methods (such as `getboolean`) expect a text value, which they'll parse in order to handle the type translation. If a non-text value is passed in, they'll raise an exception.

> If you wish to use Unicode characters within your configuration files, you'll need to use the `readfp` method of the `SafeConfigParser` object rather than the `read` method. Pass in a file-like object opened with the `codecs.open` method rather than the standard built-in `open` method. More on this when we get to *Chapter 8*, *Understanding Encoding and i18n*. Of course, this is no longer relevent with Python 3.

Have a go hero – overriding configuration options

The `read` method of a `SafeConfigParser` class actually allows you to pass in a sequence of configuration files. This is done so that you can provide a system-wide configuration such as `/etc/myapp.conf`, and then a local per-user configuration file such as `~/.myapp.conf`. Generally, the per-user configuration is more specific.

When the `read` function is called, it returns a list of successfully processed configuration files. Earlier versions of Python simply returned the number of successfully processed configuration files.

Now that you know this, update `logscan-i.py` so that it pulls its defaults out of a separate configuration file and then reads a second per-user file, which overrides those defaults.

Writing configuration data

In addition to simply reading and retrieving data from configurations files, it's possible to generate or modify existing files. This provides you with an easy method to save an application's state for later use in a nice, user-editable format.

> Be careful when you edit existing configuration files. Comments will not be preserved. Overwriting user-generated comments is not a very user-friendly thing to do!

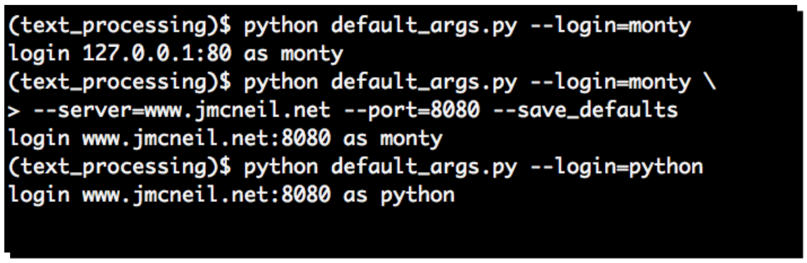
Time for action – generating a configuration file

We're going to take a break from our log processing scripts again with this example. Instead, we're going to put together a skeleton application that stores its command-line options as configuration defaults. This is a useful tactic that can be used to trim down on the number of required command-line options your utilities require.

1. First, create a new file and name it `default_args.py`.
2. Enter the following source code as it appears as follows:

```
from ConfigParser import SafeConfigParser
from optparse import OptionParser

class OptionState(object):
    section = 'cmd_args'
    def __init__(self, defaults='defaults.ini'):
        self.defaults = defaults
        self.parser = SafeConfigParser(
            defaults={
                'server': '127.0.0.1',
                'port': '80',
                'login': ''
            }
        )
        self.parser.read(self.defaults)
        if not self.parser.has_section(self.section):
            self.parser.add_section(self.section)

    def get_option(self, option):
        """
        Return a default argument.
        """
        return self.parser.get(
            self.section, option)

    def set_option(self, option, value):
        """
        Set an option on the parser.

        These can be any element, but we coerce
        them to string to get full interpolation
        support.
        """
        self.parser.set(
            self.section, option, str(value))

    def store(self, options):
        """
        Serialize out our configuration.
        """
        for op in options.option_list:
            if op.dest:
                self.set_option(
                    op.dest, getattr(opts, op.dest))

        # Write new configuration out.
        with open(self.defaults, 'w') as f:
            self.parser.write(f)

if __name__ == '__main__':
    defs = OptionState()

    options = OptionParser()
    options.add_option('-s', '--server', help="Server Host",
    default=defs.get_option('server'))
    options.add_option('-p', '--port', help="Server Port",
default=defs.get_option('port'))
    options.add_option('-l', '--login', help="Server Login",
default=defs.get_option('login'))

    # If this is passed, we'll save our defaults out.
    # Notice this always defaults to False!
    options.add_option('-d', '--save_defaults',
help="Save Defaults", action='store_true', default=False)

    opts, args = options.parse_args()


    # Save options
    if opts.save_defaults:
        defs.store(options)

    print 'login %s:%d as %s' % (opts.server, int(opts.port),
opts.login)
```

3. Run the script as shown in the following screenshot:



```
(text_processing)$ python default_args.py --login=monty
login 127.0.0.1:80 as monty
(text_processing)$ python default_args.py --login=monty \
> --server=www.jmcneil.net --port=8080 --save_defaults
login www.jmcneil.net:8080 as monty
(text_processing)$ python default_args.py --login=python
login www.jmcneil.net:8080 as python
```

4. If you entered the code correctly, you should now have a file named `defaults.ini` located within the current working directory. The contents should be similar to the following:

```
[DEFAULT]
login =
port = 80
server = 127.0.0.1

[cmd_args]
login = monty
port = 8080
save_defaults = True
server = www.jmcneil.net
```

What just happened?

The majority of the work here belongs in the `OptionState` class. The first thing we do in the `__init__` method is set up a `SafeConfigParser`. We set some reasonable defaults, which will wind up also being used as command-line option defaults. We then read our configuration files as we always have.

The next line is new to you, though. We check to see if a `cmd_args` section exists within the processed text file. If one doesn't exist, we add one programmatically. We don't add any options at this point, though. We just rely on the defaults as set just before.

The next method should look familiar to you. We're simply reading a configuration entry out of a `SafeConfigParser` object. There's nothing new here.

The `set_option` method sets the value of an option passed in to the string representation of value. This overrides any defaults that have been set.

Finally, we have the `store` method. The `store` method accepts an array of command-line options and calls `self.set_option` for each one. The `dest` attribute used defaults to the string value of the long option name, minus the leading dashes. A destination can also be arbitrarily set via the `dest` keyword argument on an `OptionParser`.

Everything is wired up within the `__main__` section. We create an instance of our `OptionState` class, which is responsible for generating our command-line defaults. Next, we use `OptionState`'s `get_option` method when setting up our command-line options instead of passing in static values. Finally, if a user requested the defaults be stored, we do that by calling `defs.store`.

When we look at the newly generated configuration file, note that it has a `DEFAULT` section, which holds a configuration file-formatted representation of the initial dictionary. We also include the section that we build manually.

Have a go hero – clearing configuration defaults

We've shown you how to read and write to textual configuration files using Python's built-in `ConfigParser` module. To solidify your knowledge, take a minute and add a `–clear_defaults` option to the `default_args.py` application. Aside from simply removing the file, a good place to start might be the `remove_section` method of the configuration parser objects.

Reconfiguring our source

Until now, we've been working with flat Python source listings. This is a perfectly acceptable way of organizing code when dealing with smaller scripts, but it gets difficult to manage as projects get bigger.

Let's take a bit of a detour and look at a better method of source organization. We'll use this approach throughout the rest of the book, where appropriate.

A note on Python 3

The packages outlined in this section are not fully compatible with Python 3. However, both `distribute` and `virtualenv3` are available. The `distribute` package provides an API-compatible alternative to SetupTools that works with both current, major Python versions. The latter package, `virtualenv3`, is functionally equivalent to `virtualenv`. If you intend to follow along using Python 3, you may want to install these packages. More information is available at `http://pypi.python.org/pypi/virtualenv3/1.3.4.2` and `http://pypi.python.org/pypi/distribute`.

The distribute package provides a mechanism for automatically running the `2to3` utility in an effort to help developers provide code for both major versions. We'll cover that tool in the appendix.

Time for action – creating an egg-based package

We're going to create a Python egg-based package. From here, we'll do all of our development work. We detailed the installation of SetupTools and Python Eggs in the first chapter. Here, we'll learn how to roll our own packages.

1. First, create a new directory and name it `text_beginner`, and step into it.
2. Now, we're going to create a `setup.py` file, which will be used to package our source bundle and handle dependencies. Create a `setup.py` file with the following contents:

```
from setuptools import setup, find_packages

setup(
    name='text_beginner',
    version='0.1',
    description='Text Beginner Package',
    author='Your Name',
    author_email='Your Email',
    install_requires=[],
    packages=find_packages(),
    include_package_data=True,
    zip_safe=False,
    entry_points = {
        'console_scripts': [
            'logscan = logscan.cmd:main'
        ]
    },
)
```

3. Create a subdirectory, and name it `logscan`. Create an empty `logscan/__init__.py` file. This marks `text_beginner/logscan` as a Python package.
4. Now, create a new Python file within the `logscan` directory and name it `core.py`. We'll use `logscan-i.py` as a template.
5. First, let's update our `import` statements. There are few elements we can strip out of the module.

```
"""
This module contains all of our core log processing classes.
"""

import os
import string
import sys
from collections import defaultdict
from ConfigParser import SafeConfigParser
from ConfigParser import ParsingError
```

6. Next, update the `report method` of the `LogProcessor` class that we've been working with to resemble the following.

```
    def report(self):
        """
        Run report chain.
        """
        for c in self._call_chain:
            c.report()
```

7. Introduce the following class to `core.py`. It will serve as the root object of the inheritance hierarchy for all of the handlers that we'll define from here on out.

```
class BaseHandler(object):
    """
    A Base class for all handlers.

    Not meant to be instanced directly.
    Contains common methods and functions used
    within each handler.
    """
    def __init__(self, output, format):
        self.output = output
        self.format = format
    def do_text(self, results):
        """Render Text Data"""
        print >>self.output, results

    def render(self, results):
        """Dispatch the appropriate render routine"""
        getattr(self, 'do_%s' % self.format)(results)
        self.output.write('\n')

    def print_title(self):
        """
        Uniform title print method.
        """
        print >>self.output, "%s\n" % self.title, \
            "=" * len(self.title)
```

8. Update our `ErrorCodeHandler` class to look like the following code example:

```
class ErrorCodeHandler(BaseHandler):
    """
    Collect Error Code Information.
    """
    title = 'Error Code Breakdown'

    def __init__(self, output=sys.stdout, format='text'):
        super(ErrorCodeHandler, self).__init__(output, format)
        self.error_codes = defaultdict(int)
        self.errors = 0
        self.lines = 0

    def process(self, fields):
        """
        Scan each line's data.

        Reading each line in, we'll save out the
        number of response codes we run into so we
        can get a picture of our success rate.
        """
        code = fields['status']
        self.error_codes[code] += 1

        # Assume anything > 400 is
        # an HTTP error
        self.lines += 1
        if int(code) >= 400:
            self.errors += 1

    def do_text(self, results):
        """
        Print out Status Summary.

        Create the status segment of the
        report.
        """
        self.print_title()
        longest_num = sorted(results.values())[-1]
        longest = len(str(longest_num))

        for k,v in results.items():
            print >>self.output,
'{0}: {1:>{2}}'.format(k, v, longest)

        # Print summary information
        print >>self.output,
'Errors: {0}; Failure Rate: {1:%}; Codes: {2}'.format(
            self.errors, float(self.errors)/self.lines,
                len(results.keys()))

    def report(self):
        return self.render(self.error_codes)
```

9. Along with the `ErrorCodeHandler` class, `MaxSizeHandler` now needs to be updated in order to reflect base class usage.

```
class MaxSizeHandler(BaseHandler):
    """
    Check a file's size.
    """
    def __init__(self, size, output=sys.stdout, format='text'):
        super(MaxSizeHandler, self).__init__(output, format)
        self.size = size
        self.name_size = 0
        self.warning_files = set()

    @property
```

```
        def title(self):
            return 'Files over %d bytes' % self.size

        def process(self, fields):
            """
            Looks at each line individually.

            Looks at each parsed log line individually and
            performs a size calculation. If it's bigger than
            our self.size, we just print a warning.
            """
            if fields['size'] > self.size:
                self.warning_files.add(
                    (fields['file_requested'], fields['size']))

                # We want to keep track of the longest filename for
                formatting later.
                fs = len(fields['file_requested'])
                if fs > self.name_size:
                    self.name_size = fs

        def do_text(self, result):
            """
            Format the Max Size Report.

            This method formats the report and prints
            it to the console.
            """
            self.print_title()
            for f,s in result.items():
                print >>self.output, '%-*s :%d' %
    (self.name_size, f, s)

        def report(self):
            return self.render(
                dict(self.warning_files))
```

10. Finally, make sure the new module ends with the following two utility functions:

```
    def load_config(config_file):
        """
        Load configuration.

        Reads the name of the configuration
        of sys.argv and loads our config.
        from disk.
        """
        config_parser = SafeConfigParser(
            defaults={
                'input_source': '-',
            'dir': os.getcwd(),
            'threshold': '0',
            'show_footer': 'True',
            'output_format': 'text',
            'output_file': '-'
        }
    )

    if not config_parser.read(config_file):
        parser.error('Could not parse configuration')

    return config_parser

def get_stream(filename, default, mode):
    """
    Return a file stream.

    If a '-' was passed in then we just
    return the default. In any other case,
    we return an open file with the specified
    mode.
    """
    if filename == '-':
        return default
    else:
        return(open(filename, mode))
```

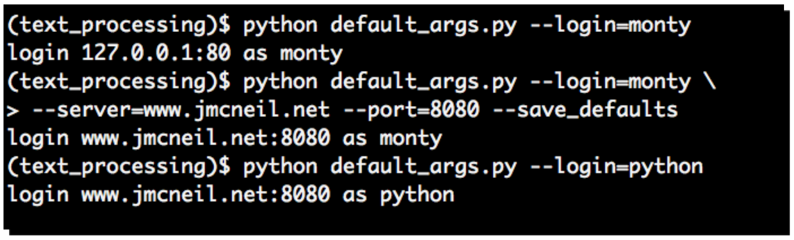
11. Now, create a file named `cmd.py` within the `logscan` directory, and ensure the contents are as follows:

```
"""
Command line entry points.
"""

import sys
import time
import optparse

# Our imports
from logscan.core import get_stream
from logscan.core import load_config
from logscan.core import ErrorCodeHandler, MaxSizeHandler
from logscan.core import LogProcessor

def main(arg_list=None):
    """
    Log Scanner Main.

    We still separate main off. This keeps it possible
    to use it from within yet another module, if we
```

```
        ever want to do that.
        """
        parser = optparse.OptionParser()
        parser.add_option('-c', '--config', dest='config',
            help="Configuration File Path")

        opts, args = parser.parse_args(arg_list)
        if not opts.config:
            parser.error('Configuration File Required')

        # Now we can load the configuration file
        config = load_config(opts.config)

        file_stream = get_stream(
            config.get('main', 'input_source'), sys.stdin, 'r')

        output_stream = get_stream(
            config.get('main', 'output_file'), sys.stdout, 'w')

        output_format = config.get('display', 'output_format')

        call_chain = []

        # Size Check
        call_chain.append(
            MaxSizeHandler(
                int(config.get(
                    'maxsize', 'threshold')
                ), output_stream, output_format)
           )

        # Error Code Checks
        call_chain.append(
            ErrorCodeHandler(
                output_stream, output_format)
            )

        # Build a processor object
        processor = LogProcessor(call_chain)

        initial = time.time()
        line_count = processor.parse(file_stream)
        duration = time.time() - initial
    # Ask the processor to display the
    # individual reports.
        processor.report()

        if config.getboolean('display', 'show_footer'):
            # Print our internal statistics, this always
            # goes to standard out.
            print
            print "Report Complete!"
        print "Elapsed Time: %#.8f seconds" % duration
        print "Lines Processed: %d" % line_count
        print "Avg. Duration per line: %#.16f seconds" % \
            (duration / line_count) if line_count else 0
```

12. Now, from within the `text_beginner` directory, issue a `python setup.py develop` command. Your output should resemble the following:

```
(text_processing)$ python setup.py develop
```



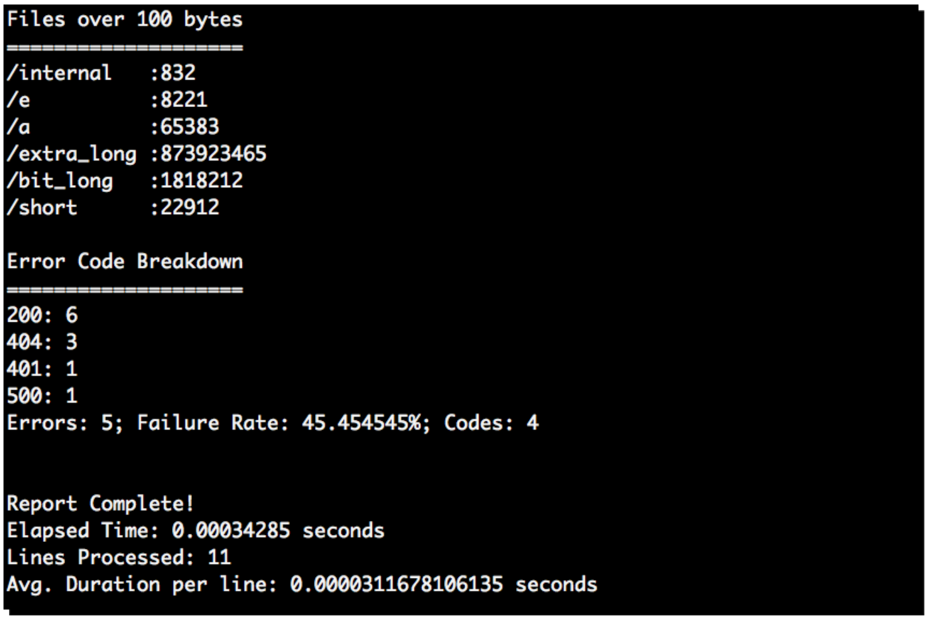
```
(text_processing)$ python default_args.py --login=monty
login 127.0.0.1:80 as monty
(text_processing)$ python default_args.py --login=monty \
> --server=www.jmcneil.net --port=8080 --save_defaults
login www.jmcneil.net:8080 as monty
(text_processing)$ python default_args.py --login=python
login www.jmcneil.net:8080 as python
```

13. Now, copy the `example3.log` as well as your configuration file into the `text_beginner` directory. Update your configuration to read as follows:

```
[main]
# Input filename. This must be either a pathname or a simple
# dash (-), which signifies we'll use standard in.
#input_source =
#output_file =

[maxsize]
# When we hit this threshold, we'll alert for maximum
# file size.
threshold = 100

[display]
# Whether we want to see the final footer calculations or
# not. Sometimes things like this just get in the way.
show_footer = yes

# Output format desired
output_format = text
```

14. Finally, run the updated command with the proper command-line options:

```
(text_processing)$ cat example3.log | logscan --config=logscan.cfg
```



```
Files over 100 bytes
====================
/internal    :832
/e           :8221
/a           :65383
/extra_long  :873923465
/bit_long    :1818212
/short       :22912

Error Code Breakdown
====================
200: 6
404: 3
401: 1
500: 1
Errors: 5; Failure Rate: 45.454545%; Codes: 4


Report Complete!
Elapsed Time: 0.00034285 seconds
Lines Processed: 11
Avg. Duration per line: 0.0000311678106135 seconds
```

What just happened?

We reconfigured our source package to use SetupTools. As it grows larger, this ought to make it much easier to manage and develop against.

First, we set up a new directory structure. At the very top level, we have the `text_beginner` directory. This serves as our development home. All packages we add will go below here, within their own package directories.

Next, we create a new directory for our logscan application, named `logscan`. Within this directory, we've split our source up into two listings: `cmd.py` and `core.py`. The `core.py` contains the entire log processing framework while the `cmd.py` contains the main method entry point. You should note that we've even wrapped our main code in its own function.

In addition to separating the code into two modules, we made some fairly big changes to the classes that now live in `core.py`. Let's go through them.

First, we removed all printing and spacing code from the `LogProcessor` class. We did this so that we can push all formatting into the actual `Handler` classes. This gives us a nice separation of concerns between the processing driver and the individual report handlers.

Next, we introduced a class named `BaseHandler`. `BaseHandler` saves the desired output channel as well as the desired report format; more on that in a bit.

Now, take a look at both `MaxSizeHandler` and `ErrorCodeHandler`. We've updated them to inherit from `BaseHandler`. We've also augmented the `__init__` methods such that they take a desired output format as well as an output file-like object. This provides a wealth of reuse potential.

Additionally, we've renamed each report method to `do_text`, and changed our print functions to ensure they're directing output to the designated output stream. Of course, both new `__init__` parameters have default values, so we don't break compatibility with any existing libraries that may depend on this code.

Our report methods have been updated to simply call `self.render`, with a dictionary of result values. Here's where our base class comes in. When render is called, it dynamically looks up for a formatting function, based on the desired format. That method is called and passed in the `results` object. As both handlers now inherit from `BaseHandler`, we can simply add `do_*` methods to the base handler and immediately have new formats available within all reports!

Our `load_config` method is slightly different now. Instead of reading the command line within the module, we've pushed that off to the main entry-point function. Here, we just read the configuration file as requested. We've also added new options for desired output channel as well as report format.

Finally, we've added a helper method to return a stream. If a dash is passed in then we'll return a default value. If anything other than a dash is passed, we'll open the file and return its open object.

Now, let's take a look at `cmd.py`.

There's not too much different about this code. We've simply encapsulated it all within a main function. Additionally, we're passing in the new configuration parameters to our handlers.

Understanding the setup.py file

The glue that really ties everything together here is the `setup.py` script. `setup.py` simply imports SetupTools methods and calls a method named `setup`, with some keyword arguments that further define our package.

Have a look at the `entry_points` line. This replaces our need for a `__name__ == '__main__'` section. When we ran our `setup.py develop` command earlier, `SetupTools` automatically generated console script named `logscan`, which simply invoked the main function of our `cmd.py` file! What's even better is that its platform-agnostic and automatically placed in a location that's on your system PATH.

In addition to placing our logscan utility on our PATH, it also ensured that our working directory was put on Python's `sys.path`. This allows us to develop our applications without needing to reinstall an egg distribution each time or otherwise manipulate our `sys.path` variable.

> SetupTools is a very in-depth system that we've really only touched the surface of. For more information, see `http://peak.telecommunity.com/DevCenter/setuptools`.

Have a go hero – building some eggs!

By simply defining a `setup` function, you've gained access to a wealth of 'python setup.py' commands. At the command line, run python `setup.py –help-commands`. Take a minute to familiarize yourself with what some of these do. Most importantly, look at the `bdist_egg` command.

Working with JSON

JSON, or **JavaScript Object Notation**, is a popular text-based object representation format used to pass data between systems on the Internet. JSON is popular because of its relative simplicity as compared against traditional markup approaches such as XML. The Python standard library ships with a `json` module, which can be used to serialize and de-serialize standard Python objects to and from JSON format.

As its name suggests, JSON documents follow the same syntax as JavaScript Object code.

Time for action – writing JSON data

Note that this requires Python 2.6. If you're using an earlier version, you'll need to install the `simplejson` library that's available via the Python Package Index. simply run `easy_install simplesjson` from within your virtual environment.

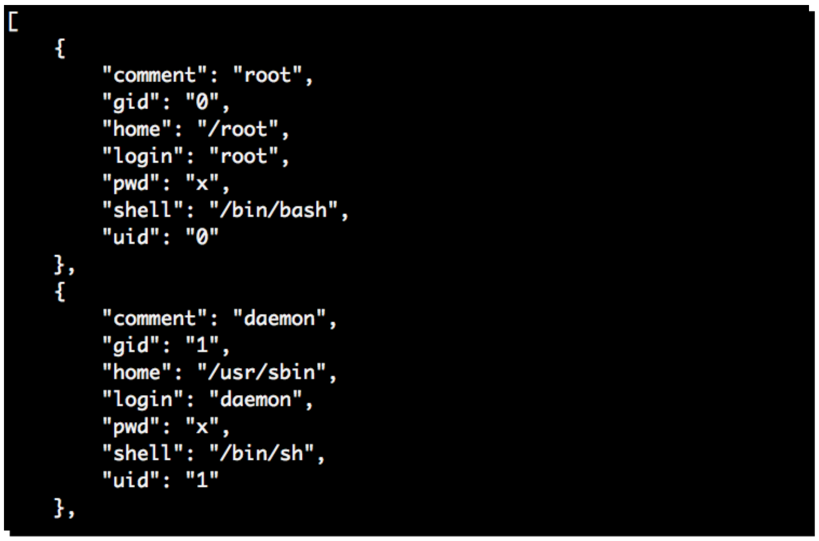
In this example, we'll update our CSV reader to output a list of UNIX users in our password file in JSON format.

1. Create a new file named `csv_reader-d.py`. You can use `csv_reader-c.py` as a base, or create an empty file.
2. Update the code in `csv_reader-d.py` to contain the following:

```
import csv
import sys
import json
```

```
from optparse import OptionParser

if __name__ == '__main__':
    parser = OptionParser()
    parser.add_option('-f', '--file', help="CSV Data File")
    opts, args = parser.parse_args()

    if not opts.file:
        parser.error('File name is required')

    csv.register_dialect('passwd', delimiter=':',
        quoting=csv.QUOTE_NONE)

    dict_keys = ('login', 'pwd', 'uid', 'gid',
        'comment', 'home', 'shell')

    # Create a dict reader from an open file
    # handle and iterate through rows.
    reader = csv.DictReader(
        open(opts.file, 'rU'), fieldnames=dict_keys,
dialect='passwd')

    # Dump the contents
    json.dump(
        list(reader), sys.stdout,
            sort_keys=True, indent=4)
```

3. Now, run the example script. If you've entered the code correctly, you should see the following output. The following screenshot has been truncated to save on space. Your actual output will be much longer.



```
[
    {
        "comment": "root",
        "gid": "0",
        "home": "/root",
        "login": "root",
        "pwd": "x",
        "shell": "/bin/bash",
        "uid": "0"
    },
    {
        "comment": "daemon",
        "gid": "1",
        "home": "/usr/sbin",
        "login": "daemon",
        "pwd": "x",
        "shell": "/bin/sh",
        "uid": "1"
    },
```

What just happened?

We updated our `csv_reader-c.py` script to include JSON support. All of this was done in two lines of Python! Well, four if we count code formatting.

First, we simply imported the `json` module; this does most of the work for us. The only other change in this code was the addition of a call to `json.dump` after we parse the UNIX password file. We pass in two keyword arguments: `sort_keys` and `indent`. This ensures our output is nice and human readable.

Encoding data

The actual encoding step is handled by the `dump` function, found within the `json` module. Given a basic Python type, dump will write JSON-formatted output to the file-like object given as its first argument. The following table details how Python types are translated.

Python type	JSON result
dictionary	object
list or a tuple	array
basestring subclasses	string
Int, floats, and longs	number
Boolean True	true
Boolean False	false
None	null

Attempting to translate complex objects such as class instances into JSON encoding will result in a `TypeError` exception. We can also translate Python objects into string data, as opposed to simply printing it.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import json
>>> json.dumps({'d': {'a': 1}})
'{"d": {"a": 1}}'
>>>
```

In this little example, we used the `dumps` function rather than the dump function. The difference is that while the dump function prints its output to the passed-in file object, `dumps` simply returns the string representation to the caller.

Decoding data

JSON decoding is just as easy as the encoding process. Let's load our JSON data back in and manipulate it programmatically.

```
(text_processing)$ python csv_reader-d.py -f passwd > users.json
(text_processing)$ python
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import json
>>> data = json.load(open('users.json'))
>>> for user in data:
...     if user['uid'] == '0':
...             print user
...
{u'comment': u'root', u'shell': u'/bin/bash', u'uid': u'0', u'pwd':
u'x', u'gid': u'0', u'home': u'/root', u'login': u'root'}
>>>
```

The `json` module also includes a loads function, which is comparable to the `dumps` function. Data is loaded in from a source string rather than from a file-like object.

When reading data in from a JSON source, it is coerced into a collection of Python types. The following table outlines those types. Note the subtle differences from the encoding table (for example, all arrays are coerced into tuples).

JSON type	Python result
object	dict
array	list
string	Unicode
number (int)	Int or long
number (real)	float
true	True
false	False
null	None

Pop Quiz – JSON formatting

1. In the preceding decoding example, we compare against the string "0" rather than the integer value 0. Why is that?
2. Is JSON a good mechanism for object serialization? Why or why not? Where might you expect to use JSON data?
3. In addition to being less wordy, why else might JSON make a good text data format for HTTP transfer?

Have a go hero – translating strings to integers

In the previous example, we left our UID and GID values as strings. While this is one way to handle the data, it's not exactly 100% correct. Update the `csv_reader-d.py` file to handle this conversion. You can either do it directly via iteration, or implement your own custom JSON decoder class as outlined at `http://docs.python.org/library/json.html`.

Summary

We covered a bit in this chapter. Most importantly, we detailed three very common text formats that Python handles for you. We also took a minute to refactor our log processing application a bit in order to make it more extensible as we continue to move forward.

You should now be comfortable dealing with JSON, INI format, and CSV file management. The Python standard library does a great job of abstracting implementation details out in order to make manipulation simple. You should now be able to persist user configuration, simplify reporting, and interact with common REST-ful web services!

Our next chapter covers the Swiss army knife of textual data processing—regular expressions.

5
Regular Expressions

Regular expressions are sometimes considered the "Swiss Army Knife" of text processing. They can be used in place of standard string methods and more advanced state-machine processing. They often make for an efficient one-liner, but they can also be used as a core component of a larger application.

There's a lot to them. Searching, matching, grouping, named groups, look-aheads, splits, compilations, and more.

Those of you familiar with the Django framework will recognize them as they are used in order to route requests to controller methods. It's also common to use them internally within web applications as a means to validate incoming data.

In this chapter, we'll look at the following aspects of regular expression usage.

- Basic syntax and special characters. How do you build a regular expression and what should you expect it to match with?
- More advanced processing. Grouping results and performing conditional matches via look-ahead and look-behind assertions. What makes an expression greedy?
- Python's implementation. Elements such as matches versus searches, and regular expression compilation and its effect on processing.
- What happens when we attempt to use regular expressions to process internationalized (non-ASCII) text or look at multiline data?

Simple string matching

Regular expressions are notoriously hard to read, especially if you're not familiar with the obscure syntax. For that reason, let's start simple and look at some easy regular expressions at the most basic level. Before we begin, remember that Python raw strings allow us to include backslashes without the need for additional escaping.

Whenever you define regular expressions, you should do so using the raw string syntax.

Time for action – testing an HTTP URL

In this example, we'll check values as they're entered via the command line as a means to introduce the technology. We'll dive deeper into regular expressions as we move forward. We'll be scanning URLs to ensure our end users inputted valid data.

1. Create a new file and name it `number_regex.py`.
2. Enter the following code:

```
import sys
import re

# Make sure we have a single URL argument.
if len(sys.argv) != 2:
    print >>sys.stderr, "URL Required"
    sys.exit(-1)

# Easier access.
url = sys.argv[1]

# Ensure we were passed a somewhat valid URL.
# This is a superficial test.
if re.match(r'^https?:/{2}\w.+$', url):
    print "This looks valid"
else:
    print "This looks invalid"
```

3. Now, run the example script on the command line a few times, passing various different values to it on the command line.

```
(text_processing)$ python url_regex.py http://www.jmcneil.net
This looks valid
(text_processing)$ python url_regex.py http://intranet
This looks valid
```

```
(text_processing)$ python url_regex.py http://www.packtpub.com
This looks valid
(text_processing)$ python url_regex.py https://store
This looks valid
(text_processing)$ python url_regex.py httpsstore
This looks invalid
(text_processing)$ python url_regex.py https:??store
This looks invalid
(text_processing)$
```

What just happened?

We took a look at a very simple pattern and introduced you to the plumbing needed to perform a match test. Let's walk through this little example, skipping the boilerplate code.

First of all, we imported the `re` module. The `re` module, as you probably inferred from the name, contains all of Python's regular expression support.

> Any time you need to work with regular expressions, you'll need to import the `re` module.

Next, we read a URL from the command line and bind a temporary attribute, which makes for cleaner code. Directly below that, you should notice a line that reads `re.match(r'^https?:/{2}\w.+$', url)`. This line checks to determine whether the string referenced by the `url` attribute matches the `^https?:/{2}\w.+$` pattern.

If a match is found, we'll print a success message; otherwise, the end user would receive some negative feedback indicating that the input value is incorrect.

> This example leaves out a lot of details regarding HTTP URL formats. If you were performing validation on user input, one place to look would be `http://formencode.org/`. **FormEncode** is a HTML form-processing and data-validation framework written by Ian Bicking.

Understanding the match function

The most basic method of testing for a match is via the `re.match` function, as we did in the previous example. The `match` function takes a regular expression pattern and a string value. For example, consider the following snippet of code:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import re
>>> re.match(r'pattern', 'pattern')
<_sre.SRE_Match object at 0x1004811d0>
>>>
```

Here, we simply passed a regular expression of "pattern" and a string literal of "pattern" to the `re.match` function. As they were identical, the result was a match. The returned `Match` object indicates the match was successful. The `re.match` function returns `None` otherwise.

```
>>> re.match(r'pattern', 'failure')
>>>
```

Learning basic syntax

A regular expression is generally a collection of literal string data and special **metacharacters** that represents a pattern of text. The simplest regular expression is just literal text that only matches itself.

In addition to literal text, there are a series of special characters that can be used to convey additional meaning, such as repetition, sets, wildcards, and anchors. Generally, the punctuation characters field this responsibility.

Detecting repetition

When building up expressions, it's useful to be able to match certain repeating patterns without needing to duplicate values. It's also beneficial to perform conditional matches. This lets us check for content such as "match the letter a, followed by the number one at least three times, but no more than seven times."

For example, the code below does just that:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import re
>>> re.match(r'^a1{3,7}$', 'a1111111')
<_sre.SRE_Match object at 0x100481648>
```

```
>>> re.match(r'^a1{3,7}$', '1111111')
>>>
```

If the repetition operator follows a valid regular expression enclosed in parenthesis, it will perform repetition on that entire expression. For example:

```
>>> re.match(r'^(a1){3,7}$', 'a1a1a1')
<_sre.SRE_Match object at 0x100493918>
>>> re.match(r'^(a1){3,7}$', 'a11111')
>>>
```

The following table details all of the special characters that can be used for marking repeating values within a regular expression.

Special character	Meaning
*	Matches zero or more instances of the previous character or group.
?	Matches zero or one instance of the previous entity.
+	Matches one or more of the previous entity.
{m,n}	Matches at least m, but no more than n of the previous entity.
{,n}	Matches from zero up to n of the previous entity.
{m,}	Matches m or more of the previous entity.
{n}	Match exactly n times.

Specifying character sets and classes

In some circumstances, it's useful to collect groups of characters into a set such that any of the values in the set will trigger a match. It's also useful to match any character at all. The dot operator does just that.

A character set is enclosed within standard square brackets. A **set** defines a series of alternating (or) entities that will match a given text value. If the first character within a set is a caret (^) then a negation is performed. All characters not defined by that set would then match.

There are a couple of additional interesting set properties.

1. For ranged values, it's possible to specify an entire selection using a hyphen. For example, `'[0-6a-d]'` would match all values between `0` and `6`, and `a` and `d`.
2. Special characters listed within brackets lose their special meaning. The exceptions to this rule are the hyphen and the closing bracket.

If you need to include a closing bracket or a hyphen within a regular expression, you can either place them as the first elements in the set or escape them by preceding them with a backslash.

As an example, consider the following snippet, which matches a string containing a hexadecimal number.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import re
>>> re.match(r'^0x[a-f0-9]+$', '0xff')
<_sre.SRE_Match object at 0x100481648>
>>> re.match(r'^0x[a-f0-9]+$', '0x01')
<_sre.SRE_Match object at 0x1004816b0>
>>> re.match(r'^0x[a-f0-9]+$', '0xz')
>>>
```

In addition to the bracket notation, Python ships with some predefined classes. Generally, these are letter values prefixed with a backslash escape. When they appear within a set, the set includes all values for which they'll match. The `\d` escape matches all digit values. It would have been possible to write the above example in a slightly more compact manner.

```
>>> re.match(r'^0x[a-f\d]+$', '0x33')
<_sre.SRE_Match object at 0x100481648>
>>> re.match(r'^0x[a-f\d]+$', '0x3f')
<_sre.SRE_Match object at 0x1004816b0>
>>>
```

The following table outlines all of the character sets and classes available:

Special Character	Meaning
[]	Indicates a set. A character will match against any values listed inside of the brackets. Can include classes (escaped letters). Prefixing the entire set with a ^ negates it.
.	Wildcard. Matches any character except a new line (with exceptions detailed later in the chapter).
\d	Matches a digit. By default, this is `[0-9]`.
\D	Matches a non-digit. This is the inverse of `\d`. By default, this is `[^0-9]`.
\s	Matches a white space character.
\S	Matches a non-white space character.
\w	Matches a word character. By default, this can also be defined as `[0-9a-zA-Z_]`.
\W	The inverse of `\w`, matching a non-word character.

One thing that should become apparent is that lowercase classes are matches whereas their uppercase counterparts are the inverse.

Applying anchors to restrict matches

There are times where it's important that patterns match at a certain position within a string of text. Why is this important? Consider a simple number validation test. If a user enters a digit, but mistakenly includes a trailing letter, an expression checking for the existence of a digit alone will pass.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import re
>>> re.match(r'\d', '1f')
<_sre.SRE_Match object at 0x1004811d0>
>>>
```

Well, that's unexpected. The regular expression engine sees the leading '1' and considers it a match. It disregards the rest of the string as we've not instructed it to do anything else with it. To fix the problem that we have just seen, we need to apply anchors.

```
>>> re.match(r'^\d$', '6')
<_sre.SRE_Match object at 0x100481648>
>>> re.match(r'^\d$', '6f')
>>>
```

Now, attempting to sneak in a non-digit character results in no match. By preceding our expression with a caret (^) and terminating it with a dollar sign ($), we effectively said "between the start and the end of this string, there can only be one digit."

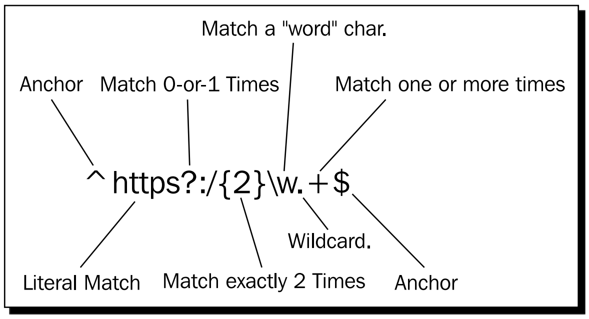
Anchors, among various other metacharacters, are considered **zero-width matches**. Basically, this means that a match doesn't advance the regular expression engine within the test string.

We're not limited to the either end of a string, either. Here's a collection of all of the available anchors provided by Python.

Special character	Meaning
^	Matches at the beginning of a string. If the search is performed in multiline mode, also matches after each new line.
$	Matches at the end of a string. If in multiline mode, also matches just before a new line.
\A	Matches only at the start of a string.
\b	Matches at a word boundary.
\B	Matches when not at a word boundary.
\Z	Matches only at the end of a string.

Wrapping it up

Now that we've covered the basics of regular expression syntax, let's double back and take a look at the expression we used in our first example. It might be a bit easier if we break it down a bit more with a diagram.



Now that we've provided a bit of background, this pattern should make sense. We begin the regular expression with a caret, which matches the beginning of the string. The very next element is the literal `http`. As our caret matches the start of a string and must be immediately followed by `http`, this is equivalent to saying that our string must start with `http`.

Next, we include a question mark after the `s` in `https`. The question mark states that the previous entity should be matched either zero, or one time. By default, the evaluation engine is looking character-by-character, so the previous entity in this case is simply "s." We do this so our test passes for both secure and non-secure addresses.

As we advanced forward in our string, the next special term we run into is `{2}`, and it follows a simple forward slash. This says that the forward slash should appear exactly two times. Now, in the real world, it would probably make more sense to simply type the second slash. Using the repetition check like this not only requires more typing, but it also causes the regular expression engine to work harder.

Immediately after the repetition match, we include a `\w`. The `\w`, if you'll remember from the previous tables, expands to `[0-9a-zA-Z_]`, or any word character. This is to ensure that our URL doesn't begin with a special character.

The dot character after the `\w` matches anything, except a new line. Essentially, we're saying "match anything else, we don't so much care." The plus sign states that the preceding wild card should match at least once.

Finally, we're anchoring the end of the string. However, in this example, this isn't really necessary.

Have a go hero – tidying up our URL test

There are a few intentional inconsistencies and problems with this regular expression as designed. To name a few:

1. Properly formatted URLs should only contain a few special characters. Other values should be URL-encoded using percent escapes. This regular expression doesn't check for that.
2. It's possible to include newline characters towards the end of the URL, which is clearly not supported by any browsers!
3. The `\w` followed by the. `+` implicitly set a minimum limit of two characters after the protocol specification. A single letter is perfectly valid.

You guessed it. Using what we've covered thus far, it should be possible for you to backtrack and update our regular expression in order to fix these flaws. For more information on what characters are allowed, have a look at `http://www.w3schools.com/tags/ref_urlencode.asp`.

Advanced pattern matching

In addition to basic pattern matching, regular expressions let us handle some more advanced situations as well. It's possible to group characters for purposes of precedence and reference, perform conditional checks based on what exists later, or previously, in a string, and limit exactly how much of a match actually constitutes a match. Don't worry; we'll clarify that last phrase as we move on. Let's go!

Grouping

When crafting a regular expression string, there are generally two reasons you would wish to group expression components together: entity precedence or to enable access to matched parts later in your application.

Time for action – regular expression grouping

In this example, we'll return to our LogProcessing application. Here, we'll update our log split routines to divide lines up via a regular expression as opposed to simple string manipulation.

1. In `core.py`, add an `import re` statement to the top of the file. This makes the regular expression engine available to us.

2. Directly above the `__init__` method definition for `LogProcessor`, add the following lines of code. These have been split to avoid wrapping.

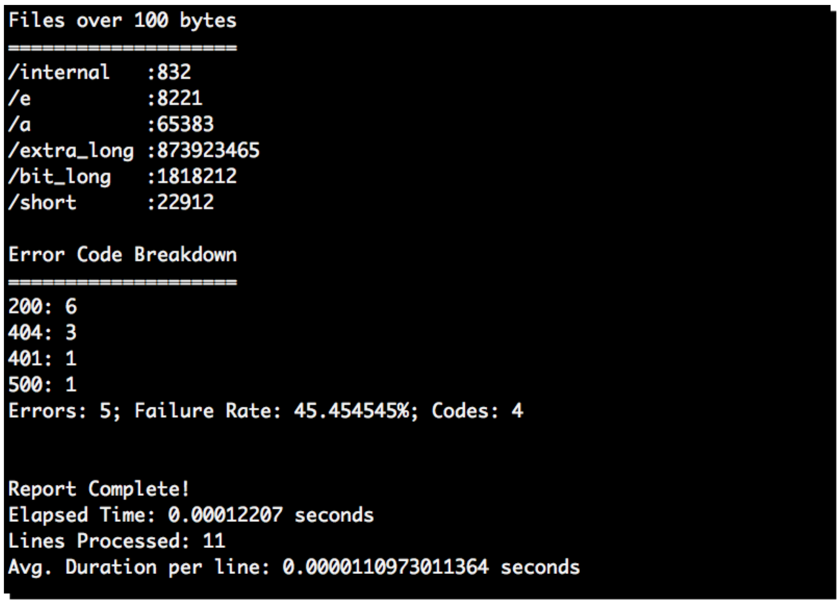
```
_re = re.compile(
            r'^([\d.]+) (\S+) (\S+) \[([\w/:+ ]+)] "(.+?)" ' \
            r'(?P<rcode>\d{3}) (\S+) "(\S+)" "(.+)"')
```

3. Now, we're going to replace the `split` method with one that takes advantage of the new regular expression:

```
def split(self, line):
        """
        Split a logfile.

        Uses a simple regular expression to parse out the Apache
logfile
        entries.
        """
        line = line.strip()
        match = re.match(self._re, line)
        if not match:
            raise ParsingError("Malformed line: " + line)

        return {
            'size': 0 if match.group(6) == '-'
else int(match.group(6)),
            'status': match.group('rcode'),
            'file_requested': match.group(5).split()[1]
        }
```

4. Running the logscan application should now produce the same output as it did when we were using a more basic, `split`-based approach.

```
(text_processing)$ cat example3.log | logscan -c logscan.cfg
```



```
Files over 100 bytes
====================
/internal   :832
/e          :8221
/a          :65383
/extra_long :873923465
/bit_long   :1818212
/short      :22912

Error Code Breakdown
====================
200: 6
404: 3
401: 1
500: 1
Errors: 5; Failure Rate: 45.454545%; Codes: 4


Report Complete!
Elapsed Time: 0.00012207 seconds
Lines Processed: 11
Avg. Duration per line: 0.0000110973011364 seconds
```

What just happened?

First of all, we imported the `re` module so that we have access to Python's regular expression services.

Next, at the `LogProcessor` class level, we defined a regular expression. Though, this time we did so via `re.compile` rather than a simple string. Regular expressions that are used more than a handful of times should be "prepared" by running them through `re.compile` first. This eases the load placed on the system by frequently used patterns. The `re.compile` function returns a `SRE_Pattern` object that can be passed in just about anywhere you can pass in a regular expression.

We then replace our `split` method to take advantage of regular expressions. As you can see, we simply pass `self._re` in as opposed to a string-based regular expression. If we don't have a match, we raise a `ParsingError`, which bubbles up and generates an appropriate error message, much like we would see on an invalid `split` case.

Now, the end of the `split` method probably looks somewhat peculiar to you. Here, we've referenced our matched values via group identification mechanisms rather than by their list index into the split results. Regular expression components surrounded by parenthesis create a group, which can be accessed via the `group` method on the `Match` object later down the road. It's also possible to access a previously matched group from within the same regular expression. Let's look at a somewhat smaller example.

```
>>> match = re.match(r'(0x[0-9a-f]+) (?P<two>\1)', '0xff 0xff')
>>> match.group(1)
'0xff'
>>> match.group(2)
'0xff'
>>> match.group('two')
'0xff'
>>> match.group('failure')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
IndexError: no such group
>>>
```

Here, we surround two distinct regular expressions components with parenthesis, `(0x[0-9a-f]+)`, and `(?P<two>\1)`. The first regular expression matches a hexadecimal number. This becomes group ID 1. The second expression matches whatever was found by the first, via the use of the `\1`. The "backslash-one" syntax references the first match. So, this entire regular expression only matches when we repeat the same hexadecimal number twice, separated with a space. The `?P<two>` syntax is detailed below.

As you can see, the match is referenced after-the-fact using the `match.group` method, which takes a numeric index as its argument. Using standard regular expressions, you'll need to refer to a matched group using its index number. However, if you'll look at the second group, we added a `(?P<name>)` construct. This is a Python extension that lets us refer to groupings by name, rather than by numeric group ID. The result is that we can reference groups of this type by name as opposed to simple numbers.

Finally, if an invalid group ID is passed in, an `IndexError` exception is thrown.

The following table outlines the characters used for building groups within a Python regular expression:

Special character	**Meaning**
`(…)`	Creates a group. The match is then available later in the expression via `\#` syntax and via `match.group(#)` calls.
`(?P<name>…)`	Creates a named-group. Also available later in the match via `\#` syntax and `match.group(#)`, as well as `match.group(name)`.
`(?P=name)`	Matches the previously named group `name`.
`(?:…)`	Matches whatever was within the parenthesis, but is not retrievable via `\#` or `match.group` syntax.

Finally, it's worth pointing out that parenthesis can also be used to alter priority as well. For example, consider this code.

```
>>> re.match(r'abc{2}', 'abcc')
<_sre.SRE_Match object at 0x1004818b8>
>>> re.match(r'a(bc){2}', 'abcc')
>>> re.match(r'a(bc){2}', 'abcbc')
<_sre.SRE_Match object at 0x1004937b0>
>>>
```

Whereas the first example matches `c` exactly two times, the second and third line require us to repeat `bc` twice. This changes the meaning of the regular expression from "repeat the previous character twice" to "repeat the previous match within parenthesis twice." The value within the group could have been its own complex regular expression, such as `a([b-c]){2}`.

Have a go hero – updating our stats processor to use named groups

Spend a couple of minutes and update our statistics processor to use named groups rather than integer-based references. This makes it slightly easier to read the assignment code in the `split` method. You do not need to create names for all of the groups, simply the ones we're actually using will do.

Using greedy versus non-greedy operators

Regular expressions generally like to match as much text as possible before giving up or yielding to the next token in a pattern string. If that behavior is unexpected and not fully understood, it can be difficult to get your regular expression correct. Let's take a look at a small code sample to illustrate the point.

Suppose that with your newfound knowledge of regular expressions, you decided to write a small script to remove the angled brackets surrounding HTML tags. You might be tempted to do it like this:

```
>>> match = re.match(r'(?P<tag><.+>)', '<title>Web Page</title>')
>>> match.group('tag')
'<title>Web Page</title>'
>>>
```

The result is probably not what you expected. The reason we got this result was due to the fact that regular expressions are greedy by nature. That is, they'll attempt to match as much as possible. If you look closely, `<title>` is a match for the supplied regular expression, as is the entire `<title>Web Page</title>` string. Both start with an angled-bracket, contain at least one character, and both end with an angled bracket.

The fix is to insert the question mark character, or the non-greedy operator, directly after the repetition specification. So, the following code snippet fixes the problem.

```
>>> match = re.match(r'(?P<tag><.+?>)', '<title>Web Page</title>')
>>> match.group('tag')
'<title>'
>>>
```

The question mark changes our meaning from "match as much as you possibly can" to "match only the minimum required to actually match."

Assertions

In a lot of cases, it's beneficial to say, "match this only if this next thing matches." In essence, to perform a conditional match based on what might or might not appear later in a string of text.

This is possible via **look-ahead** and **look-behind assertions**. Like anchors, these elements consume no characters during the match process.

The first assertion we'll look at is the **positive look-ahead**. The positive look-ahead will only match at the current location if followed by what's in the assertion. For example:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import re
>>> re.match('(Python) (?=Programming)', 'Python Programming').
groups()
('Python',)
>>> re.match('(Python) (?=Programming)', 'Python Snakes')
>>>
```

Note how there is only one group saved in the first match. This is because the positive look-ahead does not consume any characters. To look at it another way, notice how the following snippet does not match at all:

```
>>> re.match('^(Python) (?=Programming) Language', 'Python Programming
Language')
>>>
```

To make for a match, we need to still check for the "Programming" string, even though we've specified it in the look-ahead.

```
>>> re.match('(Python) (?=Programming)Programming Language',
…          'Python Programming Language')
<_sre.SRE_Match object at 0x1004938a0>
>>>
```

A **negative look-ahead** assertion will only match if the pattern defined in the assertion doesn't match. Assuming we actually didn't want the programming language, we could alter our expression as follows:

```
>>> re.match('(Python) (?!Programming)', 'Python Snake')
>>>
```

Each look-ahead has a corresponding look-behind. That is, it's also possible to check the value of an input string immediately leading up to the match in question. Though unlike look-ahead assertions, these look-behind checks must be of a **fixed width**. This means that while we can check for `abcd`, we could not check for `\w{0,4}`. Here's a quick example of look-behinds at work:

```
<_sre.SRE_Match object at 0x100481648>
>>> re.match('123(?<!abc)456', '123456')
<_sre.SRE_Match object at 0x1004816b0>
>>>
```

The final type of assertion we'll look at is conditional based on whether a group already exists or not. This is a rather powerful construct as it's possible to build a somewhat complex logic directly into a regular expression. Note that doing so, however, is often done at the detriment of readability to other programmers. This functionality is new as of Python 2.4.

```
>>> re.match('^(?P<bracket><)?\w+@\w+\.\w+(?(bracket)>)$',
'<jeff@jmcneil.net')
>>> re.match('^(?P<bracket><)?\w+@\w+\.\w+(?(bracket)>)$',
'<jeff@jmcneil.net>')
<_sre.SRE_Match object at 0x100493918>
>>> re.match('^(?P<bracket><)?\w+@\w+\.\w+(?(bracket)>)$',
'jeff@jmcneil.net')
<_sre.SRE_Match object at 0x1004938a0>
>>>
```

This example shows general usage. Here, if an e-mail address begins with a bracket then it must also end with a bracket.

Here is a summary table of the assertion mechanisms and a description of each:

Special character	Meaning
`(?=…)`	Performs a look-ahead. Checks whether the pattern matches from the current location forward, without consuming any characters.
`(?!...)`	Negative look-ahead. Matches if the pattern doesn't match at the current location. Doesn't consume any characters.
`(?<=…)`	Matches if the pattern (of a fixed width) doesn't match behind given location. Does not move the location pointer backwards.
`(?<!...)`	Matches if the pattern (also of a fixed width) doesn't match behind the given location. As with the positive look-behind, we do not consume any characters.
`(?(name-or-id) match-exp|fail-exp)`	If name or ID exists and has been previously matched, then match the match-exp. If it has not been matched, match the fail-exp. The failure regular expression is optional. Unlike other assertion types, this does consume characters.

Performing an 'or' operation

In some cases, you may run into a situation where a position in your input text may hold more than one possible value. To test for situations like this, you can chain regular expressions together via the '|' operator, which is generally equivalent to an 'or'.

```
>>> re.match('(abc|123|def|cow)', 'abc').groups()
('abc',)
>>> re.match('(abc|123|def|cow)', '123').groups()
('123',)
>>> re.match('(abc|123|def|cow)', '123cow').groups()
('123',)
>>>
```

Here, you'll see that we match the first possible value as evaluated from left to right. We've also included our alternation within a group. The regular expressions may be arbitrarily complex.

Pop Quiz – regular expressions

1. In the HTTP LogProcessing regular expression, we used a `\S` instead of a `\d` for a few numeric fields. Why is that the case? Is there another approach? Hint: a value that is not present is indicated by a single dash (-).
2. Can you think of a use for the `(?:…)` syntax?
3. Why would you compile a regular expression versus using a string representation?

Implementing Python-specific elements

Up until now, most of the regular expression information we've covered has been Python-agnostic (with the exception of the `(?P…)` patterns). Now, let's take a look at some of the more Python-specific elements.

Other search functions

In addition to the `re.match` function we've been using, Python also makes a few other methods available to us. The big limitation on the `match` function is that it will only match at the beginning of a string. Here's a quick survey of the other available methods. We'll outline the following methods:

- `search`
- `findall`
- `finditer`
- `split`
- `sub`

search

The `search` function will match anywhere within a string and is not limited to the beginning. While it is possible to construct `re.match` regular expressions that are equivalent to `re.search` in most cases, it's not always entirely practical.

```
>>> re.match('[0-9]{4}', atl-linux-8423')
>>> re.search('[0-9]{4}', 'atl-linux-8423')
<_sre.SRE_Match object at 0x1005aa988>
>>>
```

This example illustrates the difference given between two machine names. The `match` function does not begin with a matching pattern (and the expression doesn't allow for non-integer buffering), so there is no match. A `search`, on the other hand, scans the entire string for a match, regardless of starting point.

findall and finditer

These are two very useful and very closely related functions. The `findall` function will iterate through a given text buffer and return all non-overlapping matches in a list. The `finditer` method performs the same scan, but returns an `iterator`. The net result is that `finditer` is more memory efficient.

As a general rule, finditer is more efficient than findall as it doesn't require the construction of a new Python list object.

The following snippet of code extracts hash tags from a string and displays their offsets:

```
>>> for i in re.finditer(r'#\w+', 'This post is about #eggs, #ham,
water #buffalo, and #newts'):
...     print '%02d-%02d: %s' % (i.start(), i.end(), i.group(0))
...
19-24: #eggs
26-30: #ham
38-46: #buffalo
52-58: #newts
>>>
```

Also, notice how we've used i.group(0) here. Group zero is another way of referring to the entire match.

split

The split function acts much like the string split function we covered in earlier chapters. Given a regular expression, it separates the given text at each match.

sub

The re.sub function is rather powerful. Given a pattern, it will search a string and replace instances that match the pattern with a replacement value. The replacement value can either be a plain string, or a callable (function). If a function is used, that function is in-turn called with the match object from the corresponding regular expression match. The text that is found is replaced with the return value of the function. The subfunction works as follows.

```
>>> domains  = {'oldsite.com': 'newsite.com'}
>>> def repl(m):
...     return domains.get(m.group(0), m.group(0))
...
>>> re.sub(r'(\w+\.?){2,}', repl, 'newsite.com oldsite.com yoursite.
com')
'newsite.com newsite.com yoursite.com'
>>>
```

When the given pattern matches a domain name, it calls repl. The repl function returns the corresponding value, if one is found in the dictionary. If one isn't found, we simply return what we were passed in.

This isn't an exhaustive list of all of the methods and attributes on the re module. It would be a good idea for you to read up on all of the details at http://docs.python.org/library/re.html.

Compiled expression objects

We've simply been using the re.match module-level function in most situations as it is a quick way to execute our test expressions. This works great for small or infrequently matched patterns. However, compilation provides for a richer feature set and an inherent performance boost.

A regular compiled expression object supports all of the same functionality as the flat module-level functions within the re module. The calling convention differs slightly, though, as re.match(pattern, string) becomes regex.match(string). You should also be aware of the fact that it's possible to pass compiled objects into all of the re module functions.

In addition, these objects support a few additional methods as they contain state not available using module-level calls.

Method	Description
flags	Returns the integer value of the flags passed in when the regular expression object was built.
groups	The number of capturing groups in the pattern.
groupindex	A dictionary mapping (?P<name>…) group identifiers to group numbers. This is an empty dictionary if no symbolic names were used.
pattern	The pattern from which the object was compiled.

The match, search, finditer, and findall methods also accept a start position and an end position so that the range of characters they'll attempt to match can be limited. For example, consider the following snippet of code:

```
>>> import re
>>> re_obj = re.compile(r'[0-9]+')
>>> address = 'Atlanta, GA 30303'
>>> re_obj.search(address)
<_sre.SRE_Match object at 0x100481648>
>>> re_obj.search(address, 0, 10)
>>>
```

The second attempt to match fails because we limit the search to the substring between positions 0 and 10. In this case, Atlanta, G is searched.

Dealing with performance issues

Using Python's `timeit` module, we can run a quick performance benchmark for both a compiled and a standard textual regular expression.

```
(text_processing)$ python -m timeit -s 'import re; m =
re.compile("^[0-9]{2}-[abcd]{3}")' 'm.match("05-abc")'
1000000 loops, best of 3: 0.491 usec per loop
(text_processing)$ python -m timeit -s 'import re' 're.match("^[0-9]
{2}-[abcd]{3}", "05-abc")'
1000000 loops, best of 3: 1.76 usec per loop
(text_processing)$
```

In this simple example, we matched two numbers, followed by a dash, and a series of three letters in a set. As is evident by the preceding output, compilation reduces the amount of time required to process this match by more than a factor of three.

You should familiarize yourself with Python's `timeit` module as you work with the language. It provides a very simple method to test and evaluate segments of code for performance comparison, just as we did above. For more information, see `http://docs.python.org/library/timeit.html`.

Parser flags

The `re` module exports a number of flags that alter the way the engine processes text. It is possible to pass a series of flags into a module-level function, or as part of the call to `re.compile`. Multiple flags should be strung together using the bitwise-or operator (|). Of course, flags passed in during a compilation are retained across matches.

Flag	Description
`re.I` `re.IGNORECASE`	Performs case-insensitive matching. When this flag is used, `[A-Z]` would also match any lowercase letter of the Latin alphabet as well.
`re.L` `re.LOCALE`	Makes `\w`, `\W`, `\b`, `\B`, `\s`, and `\S` dependent on the current locale.
`re.M` `re.MULTILINE`	When this is specified, the ^ character is altered such that it matches at the beginning of the string and immediately following any newline. The `$` character, in turn, changes such that it matches at the end of the string and immediately preceding a newline.
`re.S` `re.DOTALL`	Under normal circumstances, the `dot` operator matches everything except a newline. When this is specified, the dot will also match the newline.

Flag	**Description**
`re.U` `re.UNICODE`	Makes `\w`, `\W`, `\b`, `\B`, `\D`, `\s`, and `\S` dependent on the Unicode character properties database.
`re.X` `re.VERBOSE`	Using this flag lets you write "pretty" regular expressions. White space is ignored, except when it appears in a character class or prefixed with a non-escaped backslash. Also, when the line includes a bare `#`, the remainder of the line is treated as a comment.

Unicode regular expressions

If you find yourself writing applications for systems that have to work outside of the standard ASCII character set, there are certain things you should pay attention to while crafting regular expression patterns.

First and foremost, Unicode regular expressions should always be flagged as Unicode. This means that (in versions of Python prior to 3.0), they should begin with a `u` character. Unicode literals should then match as standard ASCII strings do. It is also possible to use a Unicode escape rather than a symbol. For example:

```
>>> import re
>>> s = u'0000 000 000'
>>> re.match(ur'\u043e000.+', s)
<_sre.SRE_Match object at 0x1004816b0>
>>> re.match(r'0000.+', s)
>>>
```

Our example string matches perfectly when the expression text is a Unicode object. However, as expected, it fails when we attempt to pass an ASCII string pattern.

Character sets work in a similar fashion:

```
>>> import re
>>> s = u'0000 000 000'
>>> re.match(ur'[0-0]+', s)
<_sre.SRE_Match object at 0x1004816b0>
```

Matching words (`\w`) is slightly more complicated. Remember, by default, the `\w` class `matches [0-9a-zA-Z_]`. If we try to apply it to characters that do not fit that range, we won't match. The trick is to include the `re.UNICODE` flag as part of our `match` function. This ensures that Python honors the Unicode database.

```
>>> import re
>>> s = u'0000 000 000'
>>> re.match(ur'^(\w+).+', s)
```

```
>>>
>>> re.match(ur'^(\w+).+', s, re.UNICODE)
<_sre.SRE_Match object at 0x100492be8>
>>> re.match(ur'^(\w+).+', s, re.UNICODE).group(1)
oooo
>>>
```

The most important thing to remember if you're testing or searching non-ASCII data is that common tests such as `[a-zA-Z]` for data elements such as a person's name are not necessarily valid. A good thumb-rule is to stick to the character class escapes (`\w, \s`) while including the `re.UNICODE` flag. This ensures that you'll match where you intend to.

When working through regular expressions that support non-ASCII letters, it's a good idea to test them often. A good resource for wide characters is `http://www.translit.ru`. You can generate UTF-8 Cyrillic data of any length or format required. You can also find complete Unicode escape charts at `http://unicode.org/charts/`.

The match object

Till now, we've skimmed over a very important part of Python regular expressions - the `Match` object. A `Match` object is returned each time a match is found in a string that we've searched. You've seen this in previous examples in lines such as `<_sre.SRE_Match object at 0x100492be8>`.

Truthfully, much of the match object has already been covered. For example, we've seen the `group` and the `groups` functions, which retrieve a matched group or a tuple of all matched groups as a result of a match operation. We've also seen usage of the `start` and `end` methods, which return offsets into a string corresponding to where a match begins and where a match ends.

Let's take a look at one more example, though, to solidify the concepts we've touched on thus far.

Processing bind zone files

One of the most common server packages available on the Internet is **BIND**. Bind relies on a series of DNS zone files, which contain query-to-response mappings. Most commonly, hostname to IP matches.

These zone files are simply flat text files saved in a directory. On most UNIX distributions, they're located under `/var/named`. However, Ubuntu in particular places them under `/etc/`.

In this example, we'll write a script to extract the **MX** (**Mail Exchanger**) records from a DNS zone configuration file and display them. MX records are composed of a few fields. Here's a complete example:

```
domain.com.  900 IN MX 5 mx1.domain.com.
domain.com.  900 IN MX 10 mx1.domain.com.
```

This details two MX records for the `domain.com` domain, each with a time-to-live of 900. The `record` class is `IN`, for Internet, and the corresponding type is `MX`. The number following the record type is a weight, or a preference. MX records with a lower preference are preferred. Higher preference records are only used if the lower preference records are not accessible. Finally, a server name is specified.

This sounds straightforward until we throw in a few caveats.

- The domain may not be present. If it isn't listed, it should default to the same as the previous line.
- The domain may be `@`, in which case it should default to the name of the zone. There's a bit more magic to this; more on that later.
- The TTL may be left off. If the TTL is left off, the zone default should be used. A zone default is specified with a `$TTL X` line.
- If a hostname, either the domain or the MX record value itself, doesn't end with a trailing period, we should append the name of the current zone to it.
- The whole thing can be in uppercase, lowercase, or some random combination of the two.
- The class may be left out, in which case it defaults to `IN`.

Time for action – reading DNS records

Let's implement a regular expression-based solution that addresses all of these points and displays sorted MX record values.

1. First, let's create an example zone file. This is also available as `example.zone` from the Packt.com FTP site.

```
$TTL 86400
@   IN  SOA ns1.linode.com. domains.siteperceptive.com. (
                    2010060806
                    14400
                    14400
                    1209600
                    86400
               )
```

```
@       NS  ns1.linode.com.
@       NS  ns2.linode.com.
@       NS  ns3.linode.com.
@       NS  ns4.linode.com.
@       NS  ns5.linode.com.
jmcneil.net.       IN    MX  5   alt2.aspmx.l.google.com.
jmcneil.net.       IN    MX  1   aspmx.l.google.com.
        IN    MX  10  aspmx2.googlemail.com.
        900   IN  MX  10  aspmx3.googlemail.com.
        900   in  mx  10  aspmx4.googlemail.com.
@       900   IN  MX  10  aspmx5.googlemail.com.
@       900   MX  5   alt1.aspmx.l.google.com.
@           A     127.0.0.1
sandbox     IN    CNAME   jmcneil.net.
www         IN    CNAME   jmcneil.net.
blog        IN    CNAME   jmcneil.net.
```

2. Now, within the `text_beginner` package directory, create a subdirectory named `dnszone` and create an empty `__init__.py` within it.

3. Create a file named `mx_order.py` in that same directory with the following contents.

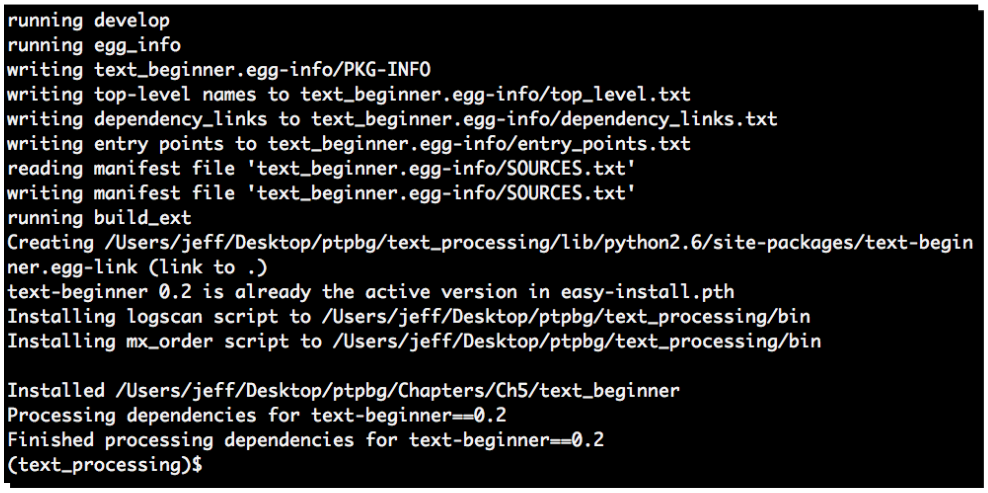
```
import re
import optparse
from collections import namedtuple

# Two differnet lines to make for
# easier fomatting.
ttl_re = r'^(\$TTL\s+(?P<ttl>\d+).*)$'
mx_re = r'^((?P<dom>@|[\w.]+))?\s+(?P<dttl>\d+)?.*MX\s+(?P<wt>\
d+)\s+(?P<tgt>.+).*$'

# This makes it easier to reference our values and
# makes code more readable.
MxRecord = namedtuple('MxRecord', 'wt, dom, dttl, tgt')

# Compile it up. We'll accept either
# one of the previous expressions.
zone_re = re.compile('%s|%s' % (ttl_re, mx_re),
    re.MULTILINE | re.IGNORECASE)

def zoneify(zone, record):
    """
    Format the record correctly.
    """
    if not record or record == '@':
       record =  zone + '.'
    elif not record.endswith('.'):
        record = record + '.%s.' % zone
    return record

def parse_zone(zone, text):
    """
    Parse a zone for MX records.

    Iterates through a zone file and pulls
    out relevant information.
    """
    ttl = None
    records = []
    for match in zone_re.finditer(open(text).read()):
        ngrps = match.groupdict()
        if ngrps['ttl']:
            ttl = ngrps['ttl']
        else:
            dom = zoneify(zone, ngrps['dom'])
            dttl = ngrps['dttl'] or ttl
            tgt = zoneify(zone, ngrps['tgt'])
            wt = int(ngrps['wt'])

            records.append(
                MxRecord(wt, dom, dttl, tgt))

    return sorted(records)

def main(arg_list=None):
    parser = optparse.OptionParser()
    parser.add_option('-z', '--zone', help="Zone Name")
    parser.add_option('-f', '--file', help="Zone File")
    opts, args = parser.parse_args()
    if not opts.zone or not opts.file:
        parser.error("zone and file required")

    results = parse_zone(opts.zone, opts.file)
    print "Mail eXchangers in preference order:"
    print
    for mx in results:
        print "%s %6s %4d %s" % \
            (mx.dom, mx.dttl, mx.wt, mx.tgt)
```

4. Next, we're going to change the `entry_points` dictionary passed into `setup()` within `setup.py` to the following:

```
entry_points = {
        'console_scripts': [
            'logscan = logscan.cmd:main',
            'mx_order = dnszone.mx_order:main'
        ]
    },
```

5. Within the package directory, re-run `setup.py develop` so it picks up the new entry points.

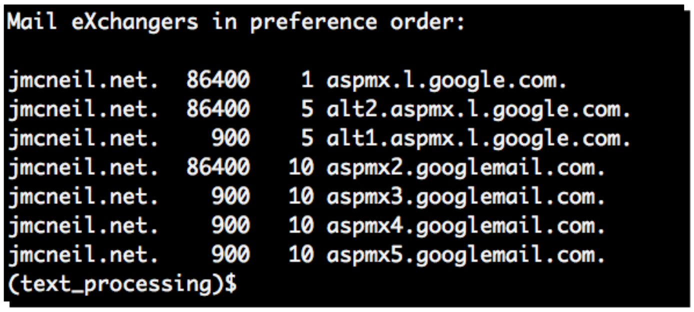
```
(text_processing)$ python setup.py develop
```



```
running develop
running egg_info
writing text_beginner.egg-info/PKG-INFO
writing top-level names to text_beginner.egg-info/top_level.txt
writing dependency_links to text_beginner.egg-info/dependency_links.txt
writing entry points to text_beginner.egg-info/entry_points.txt
reading manifest file 'text_beginner.egg-info/SOURCES.txt'
writing manifest file 'text_beginner.egg-info/SOURCES.txt'
running build_ext
Creating /Users/jeff/Desktop/ptpbg/text_processing/lib/python2.6/site-packages/text-begin
ner.egg-link (link to .)
text-beginner 0.2 is already the active version in easy-install.pth
Installing logscan script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing mx_order script to /Users/jeff/Desktop/ptpbg/text_processing/bin

Installed /Users/jeff/Desktop/ptpbg/Chapters/Ch5/text_beginner
Processing dependencies for text-beginner==0.2
Finished processing dependencies for text-beginner==0.2
(text_processing)$
```

6. Finally, let's run the application and check the output.

```
(text_processing)$ mx_order -z jmcneil.net -f example.zone
```



```
Mail eXchangers in preference order:

jmcneil.net.  86400    1 aspmx.l.google.com.
jmcneil.net.  86400    5 alt2.aspmx.l.google.com.
jmcneil.net.    900    5 alt1.aspmx.l.google.com.
jmcneil.net.  86400   10 aspmx2.googlemail.com.
jmcneil.net.    900   10 aspmx3.googlemail.com.
jmcneil.net.    900   10 aspmx4.googlemail.com.
jmcneil.net.    900   10 aspmx5.googlemail.com.
(text_processing)$
```

What just happened?

We loaded an entire zone file into memory and processed it for mail exchanger records. If we came across a TTL, we used that as our default. If a per-record TTL was specified, we used that as it's more specific. Let's step through the code.

The very first lines, other than our import statements, are the regular expressions we'll use to process this file. In this case, we define two and then join them together around a surrounding | operator. This is to illustrate that it's entirely possible to build regular expressions dynamically.

Next, we compile the union of both singular regular expressions and bind it to an attribute named `zone_re`. Note that we pass two compilation flags here: `re.IGNORECASE` and `re.MULTILINE`. We're going to search case in a case-insensitive manner and we want to process an entire chunk of data at once, rather than a clean line.

The `zoneinfy` function handles a number of our record-naming requirements. Here, we append the zone name wherever applicable.

The `parse_zone` function attempts to match our regular expression against every line in the file read in. Note that because we've specified `re.MULTILINE`, ^ will match following any new line and $ will match immediately before one. By default, these only match at the actual beginning and end of a string, respectively.

We loop through all of the results and assign a named groups dictionary to `ngrps`. Here, you'll see something slightly strange. Whereas a standard Python `dict` will raise a `KeyError` if a key used does not exist, this version of a dictionary will return `None`.

If a TTL exists then we pull the value out and use that as our default TTL. Otherwise, we parse the record as if it's an MX.

Finally, we assign values to a named tuple and sort it. Tuples sort first based on the first element; in this case, the weight. This is exactly the behavior we're after.

Finally, we wrap the whole thing up in our `main` function, which we've referenced from `setup.py`. This is what is called when `mx_order` is executed on the command line.

The regular expression we used to parse the file is somewhat long; however, we've covered every element included. At this point, you should be able to piece through it and make sense of it. However, there are a few things to note:

- As we dynamically join the strings together, it's not readily apparent that MX matches with two empty group matches for the TTL portion of the search. This is one reason `(?P<n>…)` naming is helpful position is a non-issue.
- A semicolon begins a comment, and comments are allowed at the end of a line. We did not account for that here.
- If a TTL is not set via $TTL and does not appear in the record itself, the value from the DNS SOA record is used. We've not touched on SOA processing here.

For more information on BIND and zone file format, check out `http://www.isc.org`. The Internet Software Consortium produces and ships the daemon and a collection of revolver tools.

Have a go hero – adding support for $ORIGIN

So, we lied a little bit when we stated that the name of the zone replaces `@` and is appended to any name without a trailing dot. Strictly speaking, the value of `$ORIGIN` is used in both of those situations. If not set, `$ORIGIN` defaults to the name of the zone.

Syntactically speaking, `$ORIGIN` is defined exactly like a `$TTL` is defined. The string "`$ORIGIN`" appears and is followed immediately by a new DNS name.

Update the preceding code such that if an `$ORIGIN name.com` appears, subsequent insertions of the zone name use that rather than what we've passed on the command line.

For bonus points, update the regular expressions used, and the `zoneify` method to avoid using the `endswith` method of the string objects.

Pop Quiz – understanding the Pythonisms

1. What is the major difference between the `match` method and the `search` method? Where might you prefer one to the other?
2. What's the benefit to using `finditer` over `findall`?
3. Is there a downside to using Python's named-group feature? Why might you avoid that approach?

Summary

In this chapter, we looked at both regular expression syntax and the Python-specific implementation details. You should have a solid grasp of Python regular expressions and understand how to implement them.

In this chapter, we broke apart a regular expression graphically in order to help you understand how the pieces fit together. We built on that knowledge to parse HTML data, BIND zone files, and even internationalized characters in the Cyrillic alphabet.

Finally, we covered some Python specifics. These are non-portable additions on the Python regular expression implementation.

Our next chapter moves into the processing of structured text documents such as XML and HTML. We'll move away from our system-based examples and create a dungeon-crawling game for a bit of variety.

6
Structured Markup

In this chapter, we'll take a look at XML and its cousin, HTML. We'll concentrate on Python's built-in markup processing modules that can be found within the standard library, but we'll also introduce you to a couple of the more common third-party packages available on the Python package index.

We'll start by looking at some technologies for processing XML documents and we'll move on into reading HTML data. Throughout the chapter, we'll develop a simple command-line-based adventure game, which uses an XML document as a world definition. We'll process our world definition using different processing approaches.

More specifically, we'll address the following technologies:

- `SAX`, or event-driven XML processing. Python provides a couple of different methods to perform SAX parsing – standard parse methods and incremental processing.
- DOM handling both Python's `xml.dom.minidom` module and an introduction to `ElementTree`.
- Creating documents programmatically.
- The `lxml` third-party package, which provides an API much like `ElementTree`, but adds additional support for XPath, XSLT, and schema validation.
- A quick look at HTML processing via the `HTMLParser` module and an introduction to the `BeautifulSoup` package.

By the end of this chapter, you should be able to process XML and HTML documents in a variety of ways based on the needs of your application.

XML data

We'll use the same XML document for the majority of the examples in this chapter. Our document is fairly basic and does not include namespace or schema elements. Go ahead and create `world00.xml` and enter the following content. This XML file is also available from the Packt Publishing FTP site and can be downloaded.

```
<?xml version="1.0" encoding="utf-8"?>
<dungeon>
    <description>A cold dungeon with no windows and only faint torch
      light.</description>
    <hallway direction="north">
        <description>A hallway leading deeper into the
          darkness...</description>
        <room direction="east">
            <description>
                This looks to be an abandoned guard post.
            </description>
            <chest>
                <trap hp="10">
                <description>This chest is full of
                  bats!</description>
                </trap>
            </chest>
            <chest>
              <potion hp="10"/>
            </chest>
        </room>

        <room direction="north">
            <description>
              A wooden cot and a skeleton provide the decor.
            </description>
            <chest>
               <trap hp="15">
                 <description>This chest is full of poison
                   fungus!</description>
                </trap>
            </chest>
            <chest>
               <potion hp="25"/>
            </chest>

            <hallway direction="east">
                <description>
                  A long hallway, you hear footsteps to the south.
                </description>
                <room direction="north">
                    <description>This one is empty.</description>
                </room>
                <room direction="south">
                    <description>This room smells like a
                      goblin?</description>
                    <monster kind="goblin" min_dmg="5" max_dmg="25"/>
                </room>
            </hallway>
        </room>

<room direction="west">
            <description>
                Not much here, though you hear a noise to the
                  northwest.
            </description>
            <chest>
                <potion hp="25"/>
            </chest>

            <hallway direction="north">
                <description>
                    There is a faint light at the end of this hall.
                </description>
                <room direction="west">
                    <description>You've entered the lair of the
                      dragon!</description>
                    <monster kind="dragon" min_dmg="2500"
                      max_dmg="5000"/>
                </room>

                <room direction="north">
                    <description>The air is much drier
                      here...</description>
                    <chest>
                      <potion hp="30"/>
                    </chest>

                    <hallway direction="west">
                        <description>The floor seems to slant
                          upwards.</description>
                        <room direction="north">
                          <description>You've
                            Escaped!</description>
                            <exit/>
                        </room>
                    </hallway>
                </room>
            </hallway>
        </room>
    </hallway>
</dungeon>
```

Here, we've defined a simple document without any namespace or schema information. In fact, the only non-markup line is the XML version and encoding specification found at the top of the file. Let's look at some basic methods we can use to parse this file.

SAX processing

SAX is the first of two industry standard approaches available when processing XML documents. `SAX`, or Simple API for XML, is an event-driven approach. Our applications will define handlers, which are triggered whenever the XML processor encounters elements in the document. Python supplies the `xml.sax` module, which provides a framework for SAX-driven processing.

Generally speaking, SAX is a better approach when dealing with large XML documents as it is not necessary to load the entire document into memory when processing.

[SAX, while generally better performing, is more difficult for a programmer to master as it doesn't provide for ready-made XML-driven data structures. That's up to the developer to create.]

Time for action – event-driven processing

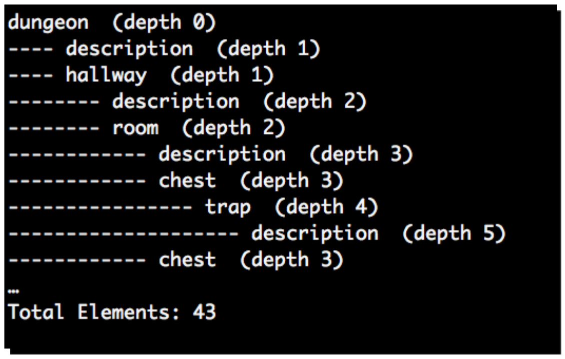
In this first example, we'll use the SAX XML processor in order to format a simple representation of the XML elements that make up a document. Based on the current position, we'll change our indent level. The goal here is to simply understand the event-driven mechanism behind `SAX` processing.

1. Create a file named `xml_indent.py` and enter the following code:

```
from xml.sax import make_parser
from xml.sax.handler import ContentHandler

class IndentHandler(ContentHandler):
    def __init__(self, *args, **kw):
        ContentHandler.__init__(self, *args, **kw)
        self.indent = 0
        self._factor = 4
        self.elements = 0

    def startElement(self, name, attrs):
        """
        Called when an element is encountered.
        """
        if self.indent:
            print '-' * (self.indent * self._factor),

        print name, " (depth %d)" % self.indent
        self.elements += 1
        self.indent += 1

    def endElement(self, name):
        self.indent -= 1

# This enters the XML parsing loop
handler = IndentHandler()
parser = make_parser()
parser.setContentHandler(handler)
parser.parse(open('world00.xml'))
print "Total Elements: %d" % handler.elements
```

2. Running this test script should generate the following results. In this case, they've been limited in order to conserve space.

(text_processing)$ python xml_indent.py



```
dungeon  (depth 0)
---- description  (depth 1)
---- hallway  (depth 1)
-------- description  (depth 2)
-------- room  (depth 2)
------------ description  (depth 3)
------------ chest  (depth 3)
---------------- trap  (depth 4)
-------------------- description  (depth 5)
------------ chest  (depth 3)
…
Total Elements: 43
```

What just happened?

The very first thing we did in this example is import the resources required to support event-driven XML processing. From `xml.sax`, we imported the `make_parser` function, and from `xml.sax.handler`, we imported the `ContentHandler` base class.

Next, we define a subclass of `ContentHandler`, which we called `IndentHandler`. This handler is where all of the work takes place. It's our job to override methods such that we handle the XML data appropriately. There are a series of methods that may be overridden here. The following table provides an outline:

Method	**Description**
`setDocumentLocator`	Must be passed an instance of `xml.sax.xmlreader.Locator`. This provides a mechanism to find the parser's current location in the file.
`startDocument`	Called at the start of document processing. Not, however, when the first (root) element is encountered.
`endDocument`	Called at the end of document processing.
`startPrefixMapping`	Triggered when a prefix mapping is encountered. For example, when a namespace prefix (such as `myns:element`) is mapped to a URL.
`endPrefixMapping`	Exit scope of URL Prefix mapping.
`startElement`	Called on an element open, such as `<dungeon>`. Also, a mapping of attributes is passed in.
`endElement`	Called when an element closes, such as `</dungeon>`.
`startElementNS`	Called when an element is encountered with a distinct namespace. Namespaces processing must be enabled via the `setFeature` method of a parser object.
`endElementNS`	Called when an element with a specific namespace terminates. As with `startElementNS`, namespace processing must be switched on.
`characters`	Called when character data is discovered. This also includes whitespace and newline data when XML documents are formatted for reading.
`ignorableWhiteSpace`	Fired when the parser runs into ignorable whitespace.
`processingInstruction`	Notification when the XML processing runs into a processing instruction.
`skippedEntity`	Alerts your code when an entity is skipped.

In this example, we're going to simply define a `startElement` and an `endElement` method and we won't bother with namespace-handling.

Whenever an opening element is encountered (such as `<room>`), our `startElement` method is executed by the parser with the name of the element encountered, as well as a mapping of the attributes associated with it. Following our room example, the mapping would contain a single key: the `direction` of the room with respect to where the player is currently located.

When called, we increase our `self_indent` attribute, so we know how far over on the screen to print this element. We also keep a counter, `self.elements`, to track how many XML elements we encounter.

Finally, when the corresponding closing tag (`</room>`) is encountered, we decrement the value of `self._indent` by one as to show the relationship between elements.

The remaining code is responsible for wiring up our processor. First, we create an instance of our handler and name it `handler`. Next, we call `make_parser`, which is located within `xml.sax`. The `make_parser` function takes an optional list of modules to search for a valid XML SAX parser. If no list is specified, a default ordering is used. In most cases, this is the correct approach.

Finally, we associate our handler with the parser, and tell the SAX engine to go to work by calling `parser.parser` with a file-like object as its only parameter.

The output of our application shows us where in the XML hierarchy each element lies by varying the degree of indentation.

Incremental processing

The `xml.sax` module also allows us to perform **incremental processing**. This is a useful technique when dealing with a larger XML document, especially one that we may be retrieving via a slow network link.

Incremental processing allows us to spoon-feed XML data to our processor as it becomes available. When all of the data has been downloaded, we simply call a `close` method. Our handler callbacks are called as data is fed in, as soon as it's possible.

Time for action – driving incremental processing

In this example, we're simply going to update our previous XML indent code to read data via an incremental approach.

1. Using `xml_indent.py` as a template, create a new file and name it `xml_increment.py`.
2. Replace all of the code below the `IndentHandler` class definition with the following new code.

```
# This enters the XML parsing loop
handler = IndentHandler()
parser = make_parser()
parser.setContentHandler(handler)

xml_doc = open('world00.xml')
```

```
while True:
    data = xml_doc.read(10)
    if not data:
        break
    parser.feed(data)

parser.close()

print "Total Elements: %d" % handler.elements
```

3. Run the example. You should have the same results as in the initial example.

What just happened?

Instead of processing the XML input via the `parser.parse` method, we added our data as it was available in 10 character chunks. While this is a slightly contrived example, this is a very useful approach when dealing with asynchronous frameworks such as `Eventlet` or `Twisted`.

Each call to the `parser.feed` method made more data available for processing. Data is read in via `xml_doc.read` in 10 byte increments. When we read the last line of the file (signified by the zero-length read), we called `parser.close` to complete processing.

Note that it is possible to reuse a parser instance in this manner by calling `parser.reset`. This resets all states and prepares the same object instances for reuse.

Building an application

When working with event-driven XML processing, any in-memory structure that your programs require must be built manually. Additionally, state and position must be remembered in order to create context needed to build those structures. For example, a `<description>` tag might appear just about anywhere, but it's rather meaningless unless it can be associated with the item it's describing. In order to know this, it's generally required to know what the parent element is.

Time for action – creating a dungeon adventure game

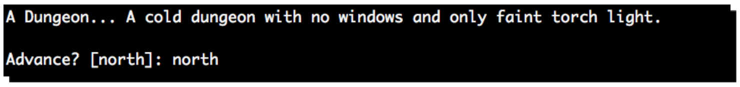
Here, we're going to look at a small adventure game based on the `world00.xml` file we created earlier in the chapter. The goal is to illustrate how we need to handle different tags and a larger, branching XML structure with event-driven processing. You should also notice that we need to create our own structural classes to maintain a representation of our world in memory, rather than allowing the XML system to do that for us.

1. Create a new file and name it `sax_explore.py`.

2. This is a rather long example, so we'll not provide the entire listing here. We're using the `sax_explore.py` file from the Packt Publishing code bundle. Save it to your current directory or enter it into your text editor.

3. Start up the game and play through a few rounds.

```
(text_processing)$ python sax_explore.py
```



```
A Dungeon... A cold dungeon with no windows and only faint torch light.

Advance? [north]: north
```

What just happened?

Quite a lot happened behind the scenes here. Let's take it slowly and walk through the provided source code. Most of this you should be familiar with.

Excluding imports, the first 80 lines or so of this example are spent creating classes that will be used to identify elements of the game. We'll create instances of these classes in a tree-like object graph that we can traverse as our adventure moves us through individual rooms and hallways. We take advantage of some inheritance here to provide some uniform `__str__` values. Consider the following snippet of code:

```
class GameElement:
    """A Game Component"""
    descr = None
    def __str__(self):
      return 'A %s... %s' % \
        (self.__class__.__name__, self.descr if self.descr else '')
```

Any classes that inherit from `GameElement` will automatically gain access to this specific `__str__` implementation.

Class collections like this (or more opaque, general types) are common when dealing with event-driven XML processing.

Of note here are `NAV_MAP` and `HP_MAP`. We directly map the name of an XML element to a class name in order to allow for dynamic creation of instances, which is detailed later.

```
NAV_MAP = { 'room': Room, 'hallway': Hallway, 'dungeon': Dungeon }
HP_MAP = { 'trap': Trap, 'potion': Potion }
```

Next, we define a somewhat large class named `Adventure`. Within this new class, we added an `advance` method, which really serves as the core of our game here. Upon entering a new location, we print a summary of the current location and call `self._manage_monster` and `self._manage_chests` to handle both monsters and chests, respectively. The last thing we do in our `advance` method is define a list of places that our brave knight can visit. If the current location has a `parent` attribute set then we add the "back" possibility.

We then call advance again on the destination location that is selected by the player.

Now, we get to our XML processing class, GameHandler. GameHandler is a subclass of the ContentHandler class. We took this same approach in our earlier examples.

The majority of the work is done in the startElement method. Our big goal here is to build our object tree based on information we find in the XML file. When startElement is called, we try to retrieve our parent element via a method named self._get_parent. This is a utility method we've added that pulls the top value off of an instance-level stack of all currently open elements. We'll use the parent object (if one exists) in various places throughout startElement.

When processing tree-structured data (such as XML), stacks are a great way to keep track of current context. As elements are opened, they are pushed on to a stack structure. Due to the FIFO nature, the top item on the stack is always the deepest element in the XML tree currently open.

Next, we check and see if our element name is in the NAV_MAP dictionary we created earlier. If we find it here, this means that it's either a Room or a Hallway. We add the new existing destination to the parent object via the add_exit method. Elements of this type are eligible to be passed to the advance method of our Adventure class. This is done by creating instances of the classes listed in NAV_MAP.

```
    if name in NAV_MAP:
        new_object = NAV_MAP[name](parent)
```

Next, we handle XML objects that cause an increase or a decrease in available hit points. When we reach zero available hit points, our adventure is over. Both the trap and the potion element can affect our available hit point pool. As these are only found within chests, we add a parent.contents attribute pointing to the newly discovered HP modifier.

Now, we handle our monsters. Each monster has a set of attributes that define its kind, maximum damage, and minimum damage. When a monster hits, a number is randomly generated between these values. Here, we create that Monster object from the XML data and assign a parent.monster attribute so we know to perform the monster logic when we enter a room with a monster present.

We repeat the same type of checks for chest, exit, and description elements. When each type is encountered, we assign the appropriate data to the parent object and instantiate a new internal representation.

The very last thing we do is append the new object to our self._stack stack. This ensures the proper parent object is referenced with the next event.

The next method we define is `characters`. This is called whenever the XML processor runs into any text content. There are two common issues here:

1. This data may not be passed in one chunk. The underlying XML processor may only call this callback multiple times with segments of text.
2. All character data is included. This means new lines at the end of XML elements and spaces included to make documents easier for humans to process.

To combat issue number one, we append `content` to a list each time `characters` is called. This ensures that we handle the situation where we're called more than once. Finally, to address the second concern, we skip this altogether if a string is entirely space. Any strings appended are stripped of leading and trailing whitespace as well.

The last method in our handler is `endElement`. This is called when a closing tag is encountered. We do two things here. First, we pop the top element off of our `self._stack` list. The `del` keyword is fine here as another reference already exists in our internal representation. We're simply removing the reference to the object found in our stack.

Finally, if the closing element is a description tag, we `join` the list together on an empty string and assign it to the parent's description attribute.

And, lastly, we launch our game within our `__name__ == '__main__'` section.

Event-driven XML processing is a very detailed subject. We've only scratched the surface here, though you should know enough to build scripts that take advantage of these techniques. For more information, you should spend some time and study the Python `xml.sax` library documentation available at `http://docs.python.org/library/markup.html`.

Pop Quiz – SAX processing

1. What are the benefits to SAX? Where might you elect to use this form of XML handling?
2. What are the negatives?
3. What are two important things to remember when dealing with text data callbacks and SAX processing?
4. When is `startElementNS` called versus `startElement`?

Have a go hero – adding gold

About the only thing worse than being stuck in a dungeon is having no money when you get out. Take a few minutes to add the concept of gold pieces into our game. To do this, you'll need to define a new XML element that can be found within a chest and you'll need to add the appropriate plumbing within the source.

The Document Object Model

While a SAX parser simply generates events as various elements of an XML document are encountered, a DOM parser takes it further and defines an in-memory structure detailing the document. Python provides support for DOM processing via the `xml.dom.minidom` module. In addition, there are third-party modules that further enhance Python's DOM capabilities, such as `lxml`.

The `ElementTree` packages also provide a DOM-like interface. We'll look at that approach when we get into XPath processing.

xml.dom.minidom

Python's standard library includes a minimal DOM implementation with `xml.dom.minidom`. These libraries provide the basic functionality needed to load an XML structure into memory and provide a set of common methods that can be used to traverse and search the tree. Let's take a look at an example to clarify.

Time for action – updating our game to use DOM processing

In this example, we'll update our game to use a DOM parser as opposed to a SAX parser. You should notice how the in-memory structure is built for us and we no longer have to maintain our own object graph. We'll reuse the same XML document for this example:

1. Copy `sax_explore.py` over to a new file named `dom_explore.py`.
2. At the top of the file, update your import statements so they read as follows:

```
import sys
import random
from xml.dom.minidom import parse
```

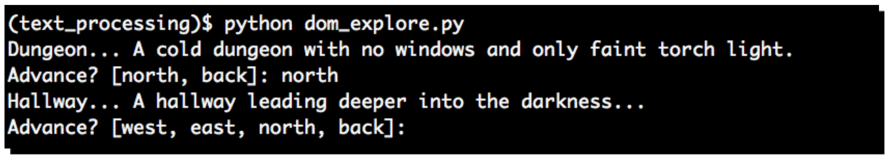
3. Remove all code, with the following exceptions: `YouDiedError`, our `__metaclass__` line, and the `__name__ == '__main__'` section.

4. Update the `Adventure` class to contain the following Python code:

```
import sys
import random
from xml.dom.minidom import parse

__metaclass__ = type

class YouDiedError(Exception):
    """Our Adventure has ended..."""

# World holds dungeons and information
# regarding our adventure.
class Adventure:
    def __init__(self, world, hp=35):
        self.location = None
        self.hp = hp
        self.world = world

    def init_game(self):
        """
        Process World XML.
        """
        self.location = parse(open(self.world)).documentElement

    def start_game(self):
        """
        Starts the game.
        """
        self.advance(self.location)

    def _decr_hp(self, change):
        """
        Lower HP.

        Lower's HP and takes getting killed
        into account.
        """
        self.hp -= change
        print "You have taken %d points of damage!" % change
        if self.hp <= 0:
            raise YouDiedError("You have expired...")

        print "You have %d HP remaining." % self.hp

    def _manage_monster(self):
        """
        Handle monster hits.
        """
        monster = self.get_nodes('monster')
        if monster:
            monster = monster[0]
            print "You've encountered a %s!" % \
                monster.getAttribute('kind')
            max_dmg = int(monster.getAttribute('max_dmg'))
            min_dmg = int(monster.getAttribute('min_dmg'))
            self._decr_hp(random.randint(min_dmg, max_dmg))
    def _open_chest(self, chest):
        """
        Open a treasure chest.
        """
        chest.opened = True
        modifier = self.get_nodes('trap', chest) or \
                self.get_nodes('potion', chest)
        if not modifier:
            print "This chest is empty..."
        else:
            modifier = modifier[0]
            hp_change = int(modifier.getAttribute('hp'))
            if modifier.nodeName == 'trap':
                print self.get_description(modifier)
                self._decr_hp(hp_change)
            else:
                print "You've found a potion!"
                print "Health restored by %d HP!" % hp_change
                self.hp += hp_change
    def _manage_chests(self):
        """
        Handle Treasure Chests.
        """
        chests = self.get_nodes('chest')
        if chests:
            while True:
                closed_chests = [i for i in chests if not
                        hasattr(i, 'opened')]
                if closed_chests:
                    chest_count = len(closed_chests)
                    print "There is %d unopened chest(s) here!" %
\
                        chest_count
                    choice = raw_input("Open which? [%s, none]: "
% \
                        ', '.join([str(i) for i in
                                xrange(chest_count)]))
                    if choice == "none":
                        break
                    try:
                        self._open_chest(
                                closed_chests[int(choice)])
                    except (ValueError, IndexError):
                        pass
                # No chests left.
                else:
                    break
    def get_nodes(self, name, parent=None):
        """
        Search the DOM Tree.
        Searches the DOM tree and returns nodes
        of a specific name with a given parent.
        """
        if not parent:
            parent = self.location
        return [node for node in parent.getElementsByTagName(name)
                    if node.parentNode is parent]
    def get_description(self, node):
        """
        Returns a description for an object.
        """
        desc = self.get_nodes('description', node)
        if not desc:
            return ''
        desc = desc[0]
        return ''.join(
            [n.data.strip() for n in desc.childNodes if
                n.nodeType == node.TEXT_NODE])
    def advance(self, where):
        """
        Move into the next room.
        Moves the player into the next room and handles
        whatever consequences have been defined in the
        dungeon.xml file.
        """
        self.location = where
        print '%s... %s' % (where.nodeName.title(),
                self.get_description(where))
        # Exit if this is the end.
        if self.get_nodes('exit'):
            print "You have won."
            sys.exit(0)

        # Perform monster logic.
        self._manage_monster()

        # Perform Chest Logic
        self._manage_chests()

        # Setup available directions menu.
        exits = {}
        for i in (self.get_nodes('hallway') +
                self.get_nodes('room')):
            exits[i.getAttribute('direction')] = i

        directions = exits.keys()
        if self.location.parentNode:
            directions.append('back')

        while True:
            choice = raw_input("Advance? [%s]: " % \
                ', '.join(directions))
            if choice:
                if choice == 'back' and 'back' in directions:
                    self.advance(self.location.parentNode)
                try:
                    self.advance(exits[choice])
                except KeyError:
                    print "That's a brick wall. Try again."

if __name__ == '__main__':
    a = Adventure('world00.xml')
    a.init_game()
    try:
        a.start_game()
    except YouDiedError, e:
        print str(e)
    except (EOFError, KeyboardInterrupt):
        print "Until next time..."
```

5. Finally, run the game as we did in the earlier example.

```
(text_processing)$ python dom_explore.py
```



```
(text_processing)$ python dom_explore.py
Dungeon... A cold dungeon with no windows and only faint torch light.
Advance? [north, back]: north
Hallway... A hallway leading deeper into the darkness...
Advance? [west, east, north, back]:
```

What just happened?

The obvious change is that this example required much less code. This, overall, reads much cleaner. The reason is that the entire document remains in memory post-processing; we no longer have to build additional structures to hold the information read from XML.

Let's walk through our new `Adventure` class.

The very first change you'll see is in `init_game`. Here, we parse the file and save the location of `documentElement` into `self.location`. The `parse` function returns a `Document` object. In turn, the `documentElement` attribute of that `Document` object is the root element of the XML file.

Next, our `_manage_monster` method has changed. As we no longer rely on a `monster.hit` method, we simply calculate the damage here. The first line of this method calls `get_nodes`, which is a new method we've added.

```
def get_nodes(self, name, parent=None):
        """
        Search the DOM Tree.
        Searches the DOM tree and returns nodes
        of a specific name with a given parent.
        """
        if not parent:
            parent = self.location
        return [node for node in parent.getElementsByTagName(name)
                    if node.parentNode is parent]
```

The `get_nodes` method searches the tree, by default at our current location in the dungeon, for elements with a variable name. We're also restricting our result set to include only those elements that are directly children of the current node.

Now, back in `_manage_monster`, we perform our damage logic only if a monster was encountered in the current room. Here, we use the `getAttribute` method of an `xml.dom.minidom.Node` to extract the minimum and maximum damage that this given monster type may cause.

Our `_open_chest` method has been changed as well. Here, we pull traps or potions out of a chest object. The `or` will ensure that we'll return one or the other. If both are empty lists, we'll return the empty list that the potion lookup generates.

Here, you'll also see a call to self.get_description. As we're not creating our own tree-like structure, we pull a description element out of the current chest contents if one exists.

```
def get_description(self, node):
        """
        Returns a description for an object.
        """
        desc = self.get_nodes('description', node)
        if not desc:
            return ''
        desc = desc[0]
        return ''.join(
            [n.data.strip() for n in desc.childNodes if n.nodeType ==
node.TEXT_NODE])
```

The approach taken is very straightforward. We concatenate the entire child nodes of the description object found by get_nodes if they are type node.TEXT_NODE. In addition to TEXT_NODE, other valid types are ELEMENT_NODE, ATTRIBUTE_NODE, TEXT_NODE, CDATA_SECTION_NODE, ENTITY_NODE, PROCESSING_INSTRUCTION_NODE, COMMENT_NODE, DOCUMENT_NODE, DOCUMENT_TYPE_NODE, and NOTATION_NODE.

Our _manage_chests method is quite similar to our monster management routines. We simply pull our chest list using get_nodes. Note that here we're only setting an opened attribute on the node if we've already opened it. If nodes do not have that attribute then they can still be considered closed.

Finally, we have our advance method. There's really not all that much new here that we haven't already covered in our DOM example. As we can't rely on the __str__ methods of our own objects, we have to format the location description manually using the title case of the current node's nodeName and the description.

Have a go hero – cleaning up the dungeon a bit

In this example, we searched for child nodes by calling getElementsByTagName and filtering based on the element's parent object. In a large document, it's probably a bit easier on the system to query for a document's children and filter by node name.

Using the documentation found at http://docs.python.org/library/xml.dom.minidom.html, update the above application to work in this fashion.

While you're out there, spend a while familiarizing yourself with the other methods and options available in xml.dom.minidom.

You may have also noticed that we have a "back" option available to us when we first start up our game when using the DOM parser. This is obviously an error. Update the code such that we no longer follow a parent link if it's at the top of the document.

The minidom implementation doesn't support every available DOM feature as detailed by the specification. According to the Python documentation itself, it's a DOM 1.0 implementation with some DOM 2.0 parts included. Specifically, XML namespaces. The DOM level 1 specification can be found at http://www.w3.org/TR/REC-DOM-Level-1/.

Creating and modifying documents programmatically

As xml.dom.minidom allows you to work with objects representing XML entities, you're able to manipulate them in memory and serialize them out into a new XML document. After creating a document object, we'll simply build a tree structure by appending various new nodes to it.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> from xml.dom.minidom import Document
>>> d = Document()
>>> e = d.createElement('employee')
>>> n = d.createElement('name')
>>> n.appendChild(d.createTextNode('Phoebe Dee'))
<DOM Text node "'Phoebe Dee'">
>>> e.appendChild(n)
<DOM Element: name at 0x100723290>
>>> d.appendChild(e)
<DOM Element: employee at 0x10071ff80>
>>> d.toxml()
'<?xml version="1.0" ?><employee><name>Phoebe Dee</name></employee>'
>>>
```

Here, we first created a Document instance. Next, using the createElement and createTextNode methods of document, we built some new elements. Specifically, a root employee node and a name associated with that employee.

Finally, we tied it all together by calling the appendChild methods of the appropriate Node instances.

Additionally, we can change the structure of an existing document via `appendChild`, `insertBefore`, `removeChild`, and `replaceChild`. The following snippet illustrates this point:

```
>>> s = d.createElement('salary')
>>> s.appendChild(d.createTextNode('$1,292,310.12'))
<DOM Text node "'$1,292,310'...">
>>> e.insertBefore(s, n)
<DOM Element: salary at 0x1004a45a8>
>>> d.toxml()
'<?xml version="1.0" ?><employee><salary>$1,292,310.12</
salary><name>Phoebe Dee</name></employee>'
>>>
```

We simply created a new element, a `salary`, and inserted it before the name of a very well paid employee. The `insertBefore` method takes the new node and the node in which we're going to insert before.

The following table outlines some of the methods that are available for use in updating and serializing DOM-based XML structures. This is not an exhaustive list.

Method	Object	Description
`createAttribute`	Document	Used to build a new attribute that will be part of an element.
`createCDATASection`	Document	Used to create a new CDATA section, which contains characters that might otherwise cause XML processing exceptions.
`createComment`	Document	Builds a new XML comment and escapes it accordingly.
`createDocumentFragment`	Document	Creates a lightweight document. Does not necessarily need to be well formed.
`createElement`	Document	Adds a new XML element
`createProcessingInstruction`	Document	Allows the insertion of an XML Processing Instruction into a document. These are identified by `<? ?>` tags.
`toprettyxml`	Element	Returns a string of neatly formatted XML, rooted at the given node object.
`toxml`	Element	Returns a string of XML, rooted at the given node, minimizing whitespace usage.

Method	Object	Description
`writexml`	Element	Writes an XML document, rooted at the Node, to a file-like object. Additionally, formatting parameters such as indent and newline can be passed in.
`removeAttribute`	Element	Removes an attribute identified by a name.
`setAttribute`	Element	Sets an attribute value.
`normalize`	Node	Joins adjacent text nodes such that they concatenate into one text element.
`createTextNode`	Document	Adds a new text node as outlined earlier.
`appendChild`	Node	Adds a new child element to the node object.
`replaceChild`	Node	Replaces a given child with a new child node.
`removeChild`	Node	Removes a child element from a node.
`insertBefore`	Node	Adds a new node before a specified child node.

Have a go hero – adding multiple dungeons

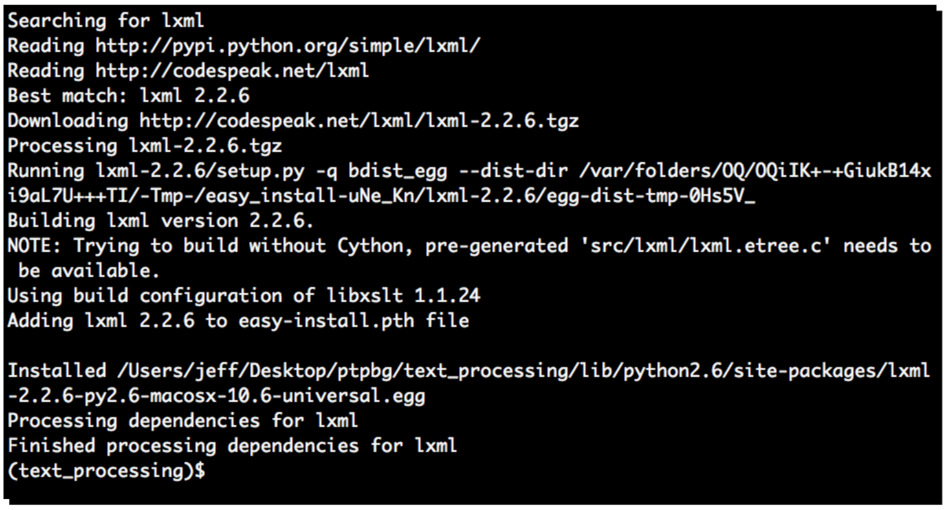
You should have a pretty good feel for the `xml.dom.minidom` implementation now. Update the `dom_explore.py` file and the `world00.xml` datafile in order to support a world with multiple dungeons.

XPath

The final XML topic we'll touch on in this chapter is **XPath**. XPath provides a means for directly addressing an XML element, without the need to iterate or search through child elements. In other words, an XPath expression creates a "path" to a specific XML node.

The `xml.dom.minidom` package does not support XPath. In order to take advantage of these two technologies, we'll need to install the third-party `lxml` package. Use `easy_install` to do so.

```
(text_processing)$ easy_install lxml
```



```
Searching for lxml
Reading http://pypi.python.org/simple/lxml/
Reading http://codespeak.net/lxml
Best match: lxml 2.2.6
Downloading http://codespeak.net/lxml/lxml-2.2.6.tgz
Processing lxml-2.2.6.tgz
Running lxml-2.2.6/setup.py -q bdist_egg --dist-dir /var/folders/OQ/OQiIK+-+GiukB14x
i9aL7U+++TI/-Tmp-/easy_install-uNe_Kn/lxml-2.2.6/egg-dist-tmp-0Hs5V_
Building lxml version 2.2.6.
NOTE: Trying to build without Cython, pre-generated 'src/lxml/lxml.etree.c' needs to
 be available.
Using build configuration of libxslt 1.1.24
Adding lxml 2.2.6 to easy-install.pth file

Installed /Users/jeff/Desktop/ptpbg/text_processing/lib/python2.6/site-packages/lxml
-2.2.6-py2.6-macosx-10.6-universal.egg
Processing dependencies for lxml
Finished processing dependencies for lxml
(text_processing)$
```

Unless you're using a Windows binary egg, you'll need to have `libxml2` and `libxslt` available on your system. If the build process fails for you, see the lxml installation documentation available at `http://codespeak.net/lxml/installation.html`. From here, you can install any needed dependencies.

Accessing XML data using ElementTree

As of Python 2.5, the `ElementTree` API is part of the standard library. If you are using an earlier version, it can also be installed via the Python Package Index. `ElementTree` provides yet another means to access XML data. The `lxml` library was implemented such that it retains API level compatibility with `ElementTree`. You should note that `ElementTree` does provide elementary level XPath support, but not the full scope.

At the core of the `ElementTree` system is the `Element` type. The `Element` instance provides a very Python-friendly means to access XML data. Unlike `xml.dom.minidom`, every XML tag is represented by an element. `Elements` themselves then contain attributes, tag names, text strings, and lists of other elements (children).

Let's take a look at a small snippet of code that helps illustrate the usage of `ElementTree`.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 15:47:53)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
```

```
>>> from StringIO import StringIO
>>> from xml.etree.ElementTree import parse
>>> x = StringIO('''<dinner healthy="no">'''
...     '''<meat>bacon</meat>'''
...     '''<desert>pie</desert>'''
...     '''</dinner>''')
>>> etree = parse(x)
>>> dinner = etree.getroot()
>>> dinner.get('healthy')
'no'
>>> dinner[0]
<Element meat at 1004f7ef0>
>>> dinner[1].text
'pie'
>>>
```

In this snippet, we parse an XML segment and access its various parts. Element objects support a series of dictionary and list-like methods. When accessing using a list context, the subscripted elements represent the children of that specific node. In contrast, when dictionary-like methods are used (`get`, `items`, `keys`), we're able to access the XML attributes of the current node.

Time for action – using XPath in our adventure

In this example, we'll update our adventure game to use XPath as its underlying XML processing technology. This allows us to reduce the code footprint even more while also introducing the `ElementTree` compliant API. In addition, we'll move this version into our working package as we'll revisit it later on in the book.

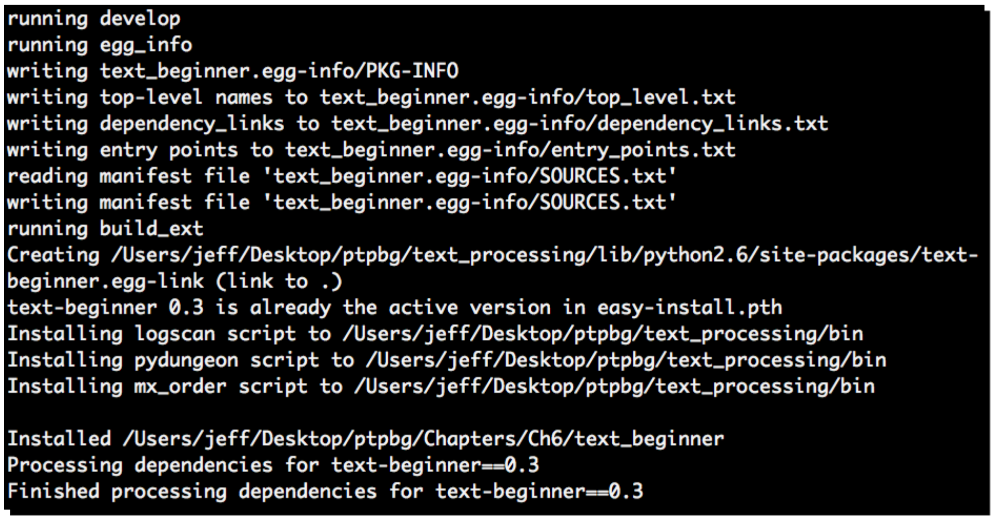
1. First, we're going to create a directory named adventure below our `text_beginner` package and create our `__init__.py` file.

   ```
   (text_processing)$ mkdir text_beginner/adventure
   (text_processing)$ touch text_beginner/adventure/__init__.py
   ```

2. Next, we'll edit our `setup.py` file to add a new entry point. Update the `entry_points` dictionary to look like this:

   ```
   entry_points = {
           'console_scripts': [
               'logscan = logscan.cmd:main',
               'mx_order = dnszone.mx_order:main',
               'pydungeon = adventure.xpath_explore:main'
           ]
       },
   )
   ```

3. Now, run `python setup.py develop` to create the new console script in a directory that resides on your shell's search path.



```
running develop
running egg_info
writing text_beginner.egg-info/PKG-INFO
writing top-level names to text_beginner.egg-info/top_level.txt
writing dependency_links to text_beginner.egg-info/dependency_links.txt
writing entry points to text_beginner.egg-info/entry_points.txt
reading manifest file 'text_beginner.egg-info/SOURCES.txt'
writing manifest file 'text_beginner.egg-info/SOURCES.txt'
running build_ext
Creating /Users/jeff/Desktop/ptpbg/text_processing/lib/python2.6/site-packages/text-
beginner.egg-link (link to .)
text-beginner 0.3 is already the active version in easy-install.pth
Installing logscan script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing pydungeon script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing mx_order script to /Users/jeff/Desktop/ptpbg/text_processing/bin

Installed /Users/jeff/Desktop/ptpbg/Chapters/Ch6/text_beginner
Processing dependencies for text-beginner==0.3
Finished processing dependencies for text-beginner==0.3
```

4. Copy `dom_explore.py` into the adventure directory and save it as `xpath_explore.py`. We'll use this as the base for our updates.

5. At the bottom of the file, add the following main function:

```
def main():
    from optparse import OptionParser
    parser = OptionParser()
    parser.add_option('-w', '--world',
        help='Dungeon Definition XML')
    opts, args = parser.parse_args()

    if not opts.world:
        parser.error("World XML Required")

    a = Adventure(opts.world)
    a.init_game()
    try:
        a.start_game()
    except YouDiedError, e:
        print str(e)
    except (EOFError, KeyboardInterrupt):
        print "Until next time..."
```

6. Remove `xml.dom.minidom` from the import statements at the top and add `from lxml import etree`.

7. Update the `Adventure` class to read as follows:

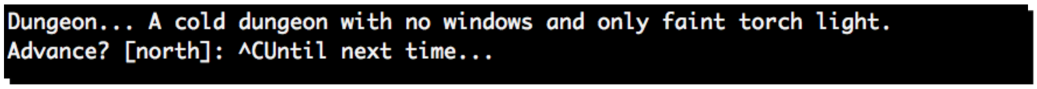
```
class Adventure:
    def __init__(self, world, hp=35):
        self.location = None
        self.hp = hp
        self.world = world
        self.opened = []

    def init_game(self):
        """
        Process World XML.
        """
        self.location = etree.parse(self.world).getroot()

    def start_game(self):
        """
        Starts the game.
        """
        self.advance(self.location)

    def _decr_hp(self, change):
        """
        Lower HP.

        Lower's HP and takes getting killed
        into account.
        """
        self.hp -= change
        print "You have taken %d points of damage!" % change
        if self.hp <= 0:
            raise YouDiedError("You have expired...")

        print "You have %d HP remaining." % self.hp

    def _manage_monster(self):
        """
        Handle monster hits.
        """
        monster = self.get_nodes('monster')
        if monster:
            monster = monster[0]
            print "You've encountered a %s!" % monster.get('kind')
            max_dmg = int(monster.get('max_dmg'))
            min_dmg = int(monster.get('min_dmg'))
            self._decr_hp(random.randint(min_dmg, max_dmg))

    def _open_chest(self, chest):
        """
```

```
            Open a treasure chest.
            """
            self.opened.append(chest)
            modifier = self.get_nodes('trap', chest) or \
                    self.get_nodes('potion', chest)
            if not modifier:
                print "This chest is empty..."
            else:
                modifier = modifier[0]
                hp_change = int(modifier.get('hp'))
                if modifier.tag == 'trap':
                    print self.get_description(modifier)
                    self._decr_hp(hp_change)
                else:
                    print "You've found a potion!"
                    print "Health restored by %d HP!" % hp_change
                    self.hp += hp_change

        def _manage_chests(self):
            """
            Handle Treasure Chests.
            """
            chests = self.get_nodes('chest')
            if chests:

                while True:
                    closed_chests = [i for i in chests if
                            i not in self.opened]
                    if closed_chests:
                        chest_count = len(closed_chests)
                        print "There is %d unopened chest(s) here!" %\
                            chest_count
                        choice = raw_input("Open which? [%s, none]: "
    % \

                            ', '.join([str(i) for i in
                                    xrange(chest_count)]))

                        if choice == "none":
                            break

                        try:
                            self._open_chest(closed_
    chests[int(choice)])
                        except (ValueError, IndexError):
                            pass

                    # No chests left.
                    else:
```

```
                break
    def get_nodes(self, name, parent=None):
        """
        Search the DOM Tree.

        Searches the DOM tree and returns nodes
        of a specific name with a given parent.
        """
        if parent is None:
            parent = self.location

        return parent.xpath(name)

    def get_description(self, node):
        """
        Returns a description for an object.
        """
        return ''.join(node.xpath('description/text()')).strip()

    @property
    def parent(self):
        parent = self.location.xpath('..')
        return parent[0] if parent else None

    def advance(self, where):
        """
        Move into the next room.

        Moves the player into the next room and handles
        whatever consequences have been defined in the
        dungeon.xml file.
        """
        self.location = where
        print '%s... %s' % (where.tag.title(),
            self.get_description(where))

        # Exit if this is the end.
        if self.get_nodes('exit'):
            print "You have won."
            sys.exit(0)

        # Perform monster logic.
        self._manage_monster()

        # Perform Chest Logic
        self._manage_chests()


        # Setup available directions menu.
        exits = {}
        for i in (self.get_nodes('hallway') +
                self.get_nodes('room'):
            exits[i.get('direction')] = i

        directions = exits.keys()
        if self.parent is not None:
            directions.append('back')

        while True:
            choice = raw_input("Advance? [%s]: " % \
                ', '.join(directions))
            if choice:
                if choice == 'back' and 'back' in directions:
                    self.advance(self.parent)
                try:
                    self.advance(exits[choice])
                except KeyError:
                    print "That's a brick wall. Try again."
```

8. Now, run the game via the command line. It should perform exactly as it did in the previous two examples.

```
(text_processing)$ pydungeon -w world00.xml
```



```
Dungeon... A cold dungeon with no windows and only faint torch light.
Advance? [north]: ^CUntil next time...
```

What just happened?

We updated our game to use the `ElementTree` API with the extended XPath support found in the `lxml` package. XPath gives us a very handy method for searching and traversing XML documents. As usual, let's walk through these changes.

First, we updated our import statements to reflect the new XML processing API. We're not using the `ElementTree` API directly here; we're using `lxml`'s implementaion.

Now, if you'll jump to the `Adventure` class, you'll see that we've added a `self.opened` attribute in the `__init__` method. We do this in order to track our open chests as it's not possible to assign arbitrary attributes to `lxml` elements.

Next, in `init_game`, we pull the root element via the `getroot` method. This is the same approach used in our example earlier. It returns an element representing the root XML tag in this document.

In all locations where we are calling `getAttribute`, we've updated our code to call `element.get`.

Now, let's take a look at our `get_nodes` function:

```
def get_nodes(self, name, parent=None):
        """
        Search the DOM Tree.

        Searches the DOM tree and returns nodes
        of a specific name with a given parent.
        """
        if parent is None:
            parent = self.location

        return parent.xpath(name)
```

First, we're explicitly testing whether our `parent` object is `None`, rather than relying on the explicit negative value of `None` as we did earlier via `if parent`. Why? The `ElementTree` API will warn if we do this. Currently, this syntax returns `True` only if an element has children, which can be confusing. Because of this, future releases will be updated to follow standard semantics.

Next, we simply return `parent.xpath(name)`. This is a much cleaner approach than iterating through children or checking parent ownership. In `XPath` syntax, a simple tag name is the equivalent of saying "give me all of the direct child nodes of this object if they're `name` tags." Of course, this could be just about any `XPath` expression.

We also update our `get_description` call. The following line now does the majority of the work, rather than relying on `get_nodes`:

```
return ''.join(node.xpath('description/text()')).strip()
```

Similar to the above expression, this translates to "give me all of the text nodes of child nodes named description where this current node is the parent." As `node.xpath` will return a list, we simply join it and strip off the extra formatting characters.

The last method that uses XPath expressions directly is the parent method, which is declared as a `@property`. We'll return the parent node of the current location, if one exists.

Finally, we've made a few updates to our `advance` method. We're retrieving the tag name via `where.tag.title`, as opposed to the `nodeName` method in our previous example. Additionally, we've updated our navigation code to use `self.parent`.

Much like XML processing, XPath is a very in-depth topic that we've only just brushed upon here. We've covered usage and API implementation. For more details surrounding XPath expression syntax, see `http://www.w3schools.com/XPath/xpath_syntax.asp`. It's recommended that you spend quite a while experimenting with different XPath approaches.

Reading HTML

The Python standard library includes an `HTMLParser` module, which provides an event-driven approach to handling HTML text files. Much like the SAX approach to XML processing, we need to define a series of `callback` methods that the parser will invoke when conditions are met.

Time for action – displaying links in an HTML page

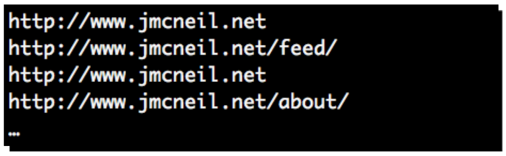
In this example, we'll load an HTML page via the `urllib2` module and extract all of the link information found within.

1. Create a new file and name it `link_scan.py`.
2. Enter the following code:

```
import sys
from HTMLParser import HTMLParser
from urllib2 import urlopen

class LinkDetect(HTMLParser):
    def handle_starttag(self, tag, attrs):
        if tag == 'a':
            try:
                print dict(attrs)['href']
            except KeyError:
                pass

def check_page(url):
    link_finder = LinkDetect()
    file_obj = urlopen(url)
    for line in file_obj:
        link_finder.feed(line)
    link_finder.close()

if __name__ == '__main__':
    check_page(sys.argv[1])
```

3. Run the script against a web URL. Your output should be similar to the following. We've stripped some of the output off in order to conserve space.

```
(text_processing)$ python link_scan.py http://www.jmcneil.net/
```



```
http://www.jmcneil.net
http://www.jmcneil.net/feed/
http://www.jmcneil.net
http://www.jmcneil.net/about/
...
```

What just happened?

Initially, we imported the HTMLParser class from the HTMLParser module. Note that as of Python 3, the HTMLParser module is now known as htmlparser.

Next, we define a subclass of HTMLParser. Here, we only include a handle_starttag method as all of the information we need to know about will be included here. We go on to check the type of tag encountered and print the href value if the tag was an anchor (that indeed had an href attribute).

The last thing we do, outside of boilerplate, is feed our HTML document to the processor. For example purposes, we do this line-by-line by iterating over an open file object. Like our SAX processor, we feed data to the HTMLParser instance in chunks.

In addition to handle_starttag, the following methods are found in the HTMLParser class:

Method	Description
reset	Resets the instance. This causes all unprocessed data to be lost.
feed	Sends data into the instance for processing.
close	Forces the parser to complete and processes any buffered data.
getpos	Returns current line number and offset
handle_startendtag	This is called when an XHTML-style tag in the form of <BR/> is encountered. By default, this just calls handle_starttag followed by handled_endtag.
handle_data	Intended to handle arbitrary data. The base class implementation does nothing.
handle charref	Called to handle character references such as &#ref; the base class does nothing.
handle_entityref	Like handle_charref. Called to process an entity reference such as &amp; the base class does nothing.
handle_comment	Triggered when the parser encounters a comment. Again, the base class does nothing.
handle_decl	Invoked when the parser encounters an SGML declaration. Base class does nothing.
handle_pi	This method is called when a <?... style processing instruction is encountered.
get_starttag_text	Returns the text of the most recently encountered start tag.

BeautifulSoup

In theory, HTML processing should be very much like XML processing. Both are structured documents composed of tags and organized in a tree-like fashion. In practice, HTML is a much more problematic text format to manage.

Consider for a moment the wide range of utilities that are used to build HTML documents; Microsoft FrontPage, DreamWeaver, various online site builder applications, and a good number of desktop applications. Additionally, all web developers aren't made equal.

In short, HTML files are often broken.

The `BeautifulSoup` package does a surprisingly wonderful job of handling quirks and inconsistencies in HTML files. As with `lxml`, we'll need to install `BeautifulSoup` using `easy_install`. For more information regarding BeautifulSoup, see `http://www.crummy.com/software/BeautifulSoup/`.

Have a go hero – updating link extractor to use BeautifulSoup

Take a moment to install `BeatifulSoup` and recode our link scanner. `BeautifulSoup` provides a more "DOM-like" interface to HTML data. If you're going to be retrieving data from live HTML pages, you'll appreciate the simplicity of the API.

Summary

We covered a lot of ground at a high level here. XML is a very detailed topic for which many books have been written. While we went over SAX, DOM, XPath, and the positives and negatives of each, we left out technologies such as XSLT, XML namespaces, and DTD documents.

You've learned how to process XML data using Python's XML library modules. We've also gone over how to manipulate and extract information from HTML pages. As you can imagine, that can be a fairly problematic task. As most web developers know, most HTML isn't very well formed.

In the next chapter, we'll switch our focus more towards generating documents as we take a look at different approaches and technologies that can be used to create templates.

7
Creating Templates

In this chapter, we'll switch gears a little bit and shift from reading and interpreting textual data to generating it. **Templating** *involves the creation of text files, or templates, that contain special markup. When a specialized parser encounters this markup, it replaces it with a computed value.*

In the simplest case, a placeholder is simply swapped for a variable, much like we saw in `string.template` *earlier in this book. However, there is a collection of template libraries available for Python that allow for much more in-depth processing, for example* **Mako***,* **Cheetah***, and* **Zope Page Templates***. Templates provide text rendering as well as more advanced functionality such as program flow control, inheritance, and text output filtering.*

In this chapter, we'll look into the following:

- Syntax and usage of Mako, a popular third-party templating system available for Python.
- Define additional tags and filters so we can handle special cases in which we need our own template-level processing.
- Cover template inheritance and common techniques for laying out a template-based project.
- Provide links and references to other Python-based template packages. There are a lot of them to choose from!

Mako is a very powerful templating system that gives the developer full control over how output text is rendered. It can be considered a relatively low-level language. One of the nice things about Mako is that it follows a very Python-like metaphor. For example, code blocks are referred to as `%defs` and may be overridden along an inheritance chain. Additionally, it's possible to generate any kind of text output with Mako. For example, HTML, text, XML, or ReST markup. It is not restricted to HTML/Web page templating.

One nice thing about Mako is that it doesn't restrict what the developer can do. If the tags provided just don't cut it, write your own! Or, if it makes sense, drop directly into Python.

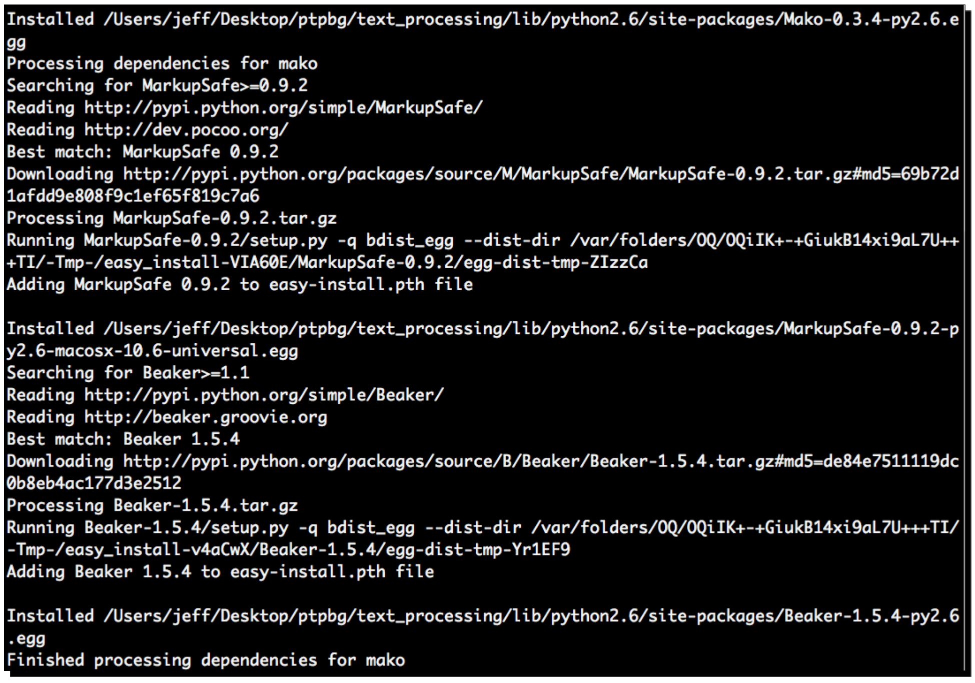
Alright, let's dive in and learn how to write our own Mako templates.

Time for action – installing Mako

The first thing we'll need to do is install the Mako templating system. This can be done via `easy_install`. First, ensure you're within your virtual environment and then enter the following:

```
(text_processing)$ easy_install mako
```

The SetupTools system should download and install Mako and any required dependencies it needs. You should see the output as shown in the next screenshot. We've not included all of the output, in order to save on page space.



```
Installed /Users/jeff/Desktop/ptpbg/text_processing/lib/python2.6/site-packages/Mako-0.3.4-py2.6.e
gg
Processing dependencies for mako
Searching for MarkupSafe>=0.9.2
Reading http://pypi.python.org/simple/MarkupSafe/
Reading http://dev.pocoo.org/
Best match: MarkupSafe 0.9.2
Downloading http://pypi.python.org/packages/source/M/MarkupSafe/MarkupSafe-0.9.2.tar.gz#md5=69b72d
1afdd9e808f9c1ef65f819c7a6
Processing MarkupSafe-0.9.2.tar.gz
Running MarkupSafe-0.9.2/setup.py -q bdist_egg --dist-dir /var/folders/OQ/OQiIK+-+GiukB14xi9aL7U++
+TI/-Tmp-/easy_install-VIA60E/MarkupSafe-0.9.2/egg-dist-tmp-ZIzzCa
Adding MarkupSafe 0.9.2 to easy-install.pth file

Installed /Users/jeff/Desktop/ptpbg/text_processing/lib/python2.6/site-packages/MarkupSafe-0.9.2-p
y2.6-macosx-10.6-universal.egg
Searching for Beaker>=1.1
Reading http://pypi.python.org/simple/Beaker/
Reading http://beaker.groovie.org
Best match: Beaker 1.5.4
Downloading http://pypi.python.org/packages/source/B/Beaker/Beaker-1.5.4.tar.gz#md5=de84e7511119dc
0b8eb4ac177d3e2512
Processing Beaker-1.5.4.tar.gz
Running Beaker-1.5.4/setup.py -q bdist_egg --dist-dir /var/folders/OQ/OQiIK+-+GiukB14xi9aL7U+++TI/
-Tmp-/easy_install-v4aCwX/Beaker-1.5.4/egg-dist-tmp-Yr1EF9
Adding Beaker 1.5.4 to easy-install.pth file

Installed /Users/jeff/Desktop/ptpbg/text_processing/lib/python2.6/site-packages/Beaker-1.5.4-py2.6
.egg
Finished processing dependencies for mako
```

What just happened?

We installed the Mako templating system into your virtual environment. The output will vary based on your operating system and Python version. At the time of this writing, the most current version of Mako is 0.3.4.

Basic Mako usage

In learning to use the Mako templating system, there are really two angles to master. First, the API calls that make the system available to you from within a Python source file, and secondly, the templating syntax and feature set.

Time for action – loading a simple Mako template

In this example, we'll take a look at a very simple implementation. We'll load a basic template and render it accordingly. We'll get into more advanced Mako features as we progress. Just to nail down the fact that Mako can be used to generate any text document, we'll create an e-mail template for an imaginary web store instead of a series of HTML pages.

1. First, create a directory named `templates`. We'll use this to hold our Mako templates that we create.
2. Enter the following text into `templates/thank_you.txt`:

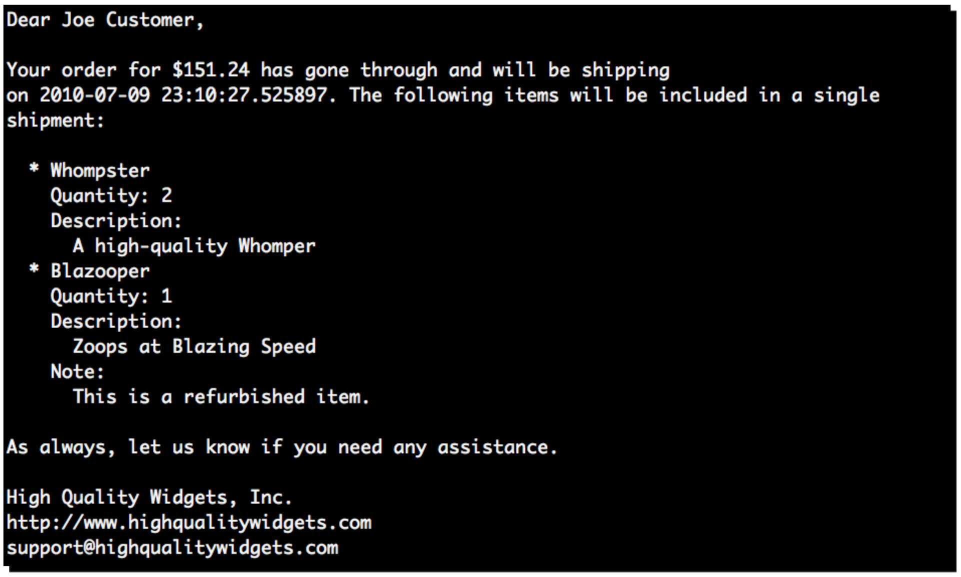
```
Dear ${name},

Your order for $${amount} has gone through and will be shipping
on ${date}. The following items will be included in a single
shipment:

% for item in packing_list:
  * ${item['name']}
    Quantity: ${item['quantity']}
    Description:
      ${item['descr']}
  %if item['used']:
    Note:
      This is a refurbished item.
  %endif
% endfor

As always, let us know if you need any assistance.

High Quality Widgets, Inc.
http://www.highqualitywidgets.com
support@highqualitywidgets.com
```

3. Next, we'll create a Python file named `render_mail.py`. This is responsible for loading the template system and feeding the render process with the required data.

```
#!/usr/bin/env python

import tempfile
import datetime
import sys
import os
from mako.lookup import TemplateLookup

finder = TemplateLookup(
    os.path.join(os.getcwd(), 'templates'),
    os.path.join(tempfile.gettempdir(), 'mako_cache'),
        output_encoding='utf=8', input_encoding='utf-8')

def render_email(name, amount, date, products,
    template='thank_you.txt'):
    """
    Render an e-mail message.

    Given the needed parameters, we'll render an e-mail
    message and return as a string.
    """
    tmpl = finder.get_template(template)
    return tmpl.render(        email=email, name=name,
amount=amount,
date=date, packing_list=products)

if __name__ == '__main__':
    # Some Fake Products
    products = []
    products.append(
        {'name': 'Whompster',
         'quantity': 2,
         'used': False,
         'descr': 'A high-quality Whompster'
         }
     )
    products.append(
        {'name': 'Blazooper',
         'quantity': 1,
         'used': True,
         'descr': 'Zoops at Blazing Speed'
         }
     )

    # Standard Shipping is 3 days.
    ships_on = datetime.datetime.now() +\
 datetime.timedelta(days=3)
    print render_email('joe@customer.com', 'Joe Customer', 151.24,
ships_on, products, sys.argv[1])
```

4. Running the example script should generate a formatted e-mail message that we'll send off to our imaginary user.

```
(text_processing)$ python render_mail.py thank_you.txt
```



```
Dear Joe Customer,

Your order for $151.24 has gone through and will be shipping
on 2010-07-09 23:10:27.525897. The following items will be included in a single
shipment:

  * Whompster
    Quantity: 2
    Description:
      A high-quality Whomper
  * Blazooper
    Quantity: 1
    Description:
      Zoops at Blazing Speed
    Note:
      This is a refurbished item.

As always, let us know if you need any assistance.

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http://www.highqualitywidgets.com
support@highqualitywidgets.com
```

What just happened?

You created your first Mako template. Ignoring for a minute the fact that our date format is rather unsightly and we're only selling to English-speaking customers paying in dollars, we have a functional system here.

Let's step through the Python code first, and then we'll step back and take a look at the template we used to generate the message.

At the top of the file, we import our required Python modules. Here, the only Mako-provided class that we're interested in is `TemplateLookup`, so we bring that in directly.

Next, we create an instance of our `TemplateLookup` object. When we do so, we pass in four arguments.

The first is a directory that we should search when trying to find templates. If we wanted to specify multiple search locations, we could pass in a list of directory strings rather than just a single location. This is done because it is possible for templates to refer to other templates internally, and they'll need a mechanism to locate those resources.

Next, we specify a `cache` directory. When a Mako template is encountered, it is first translated into Python code. By specifying a cache location, those files are saved to disk. This is an optimization that prevents repeated translation. If you encounter problems with templating, it can often be useful to inspect these generated files by hand in order to understand what exactly is going on under-the-hood.

Finally, we specify that we're using `UTF-8` encoding. With regards to the input encoding, it's also possible to prefix our Mako templates with `## -*- coding: utf-8 -*-`. This has the same effect as our programmatic approach.

The first method we've defined here is `render_email`. This method takes a series of arguments and one optional keyword argument, the template name. We default to `thank_you.txt` here for convenience. First, we invoke the template lookup logic via a call to `finder.template`, passing it the name of the template file. If a template is successfully located, a `Template` object is returned. Otherwise, a `mako.exceptions.TopLevelLookupException` is thrown, indicating that the requested template was not found.

We then call the `render` method of the `Template` object. We pass in a series of keyword arguments that correspond to the names we referenced in the template file itself. A bit more on that later. The `render` method returns a string, which is the rendered template content.

The code within the `__name__ == '__main__'` section simply sets up our execution. We generate a list of fake product details and set up a ship date by adding three days to the current date representation. The last line calls `render_email` and prints the generated message to the console.

Now, let's break down the template.

The very first line of our template file contains the string `${name}`. This tells the templating system that it should replace this token with the value of `name`. The contents between the braces can be any valid Python expression; the result will be coerced into a string (or a Unicode object, if that's the output encoding requested). This is referred to as Mako expression syntax.

For example, `${1 + 2 + 3}` would be evaluated to `6`, and then appended to the template's output stream as `str(6)`. This should clarify why our date value was so unsightly; it's technically equivalent to the following Python code:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import datetime
>>> str(datetime.datetime.now())
'2010-07-07 23:20:30.061955'
>>>
```

The next paragraph contains two additional references to template values. Here, we print the amount in question as well as the date. If you recall, the amount is a `float` object and the date is an instance of `datetime.datetime`. The rendered output, as explained previously, contains the string representation of these objects.

Next, we run into a Mako `for` loop.

```
% for item in packing_list:
   ...snip…
% endfor
```

As you can see here, the `for` statement is preceded by a single percent sign. Like standard Python code, the `for` statement ends with a colon. However, indentation is not significant here. In order to terminate the loop, we need to include an `endfor` token.

The first line in the loop contains a dictionary reference enclosed within braces. This assumes that the `item` element, the loop variable, is a valid Python dictionary. The indentation again is not significant; we've simply included it for clarity.

The final interesting line is our `if` statement. Just like in our `for` loop, we prefix it with a single percent sign. The statement itself accepts any valid Python `if` check. In fact, both the `for` loop and the `if` test are translated directly into the temporary Python module.

Generating a template context

When a template is rendered via the `render` method, Mako creates a template context for us using the keyword values we passed in to it. Additionally, there are a few built-in values that will be automatically added. Values that are part of the template context can be accessed freely from within a template; much like global variables that can be accessed within a standard Python script. The context also contains the output stream that Mako will write all of the generated template results to.

In addition to the keyword arguments passed to `render`, the following also appear on the context object:

Attribute	Description
`get`	The `context.get` method can be used to retrieve a value from the context dictionary directly. This also accepts a default value. It is also possible to access a context value using dictionary syntax (`context[key]`).
`keys`	This method returns a list of all of the keys in the context object.
`kwargs`	This attribute contains the keyword arguments originally passed to the `render` function.
`write`	Allows the template author to write data directly to the template output stream, rather than implicitly doing so via text content. It is important to use this method rather than attempt to write to the output stream itself.
`lookup`	Returns the `TemplateLookup` object used to locate the current template.
`UNDEFINED`	When a value is referenced that does not exist in the context, this value is applied. When its `__str__` method is invoked, it raises a `mako.runtime.Undefined` exception that stops template processing.

Remember, any expressions found within a `${}` markup tag are coerced into string format.

In addition to these, Mako also defines a series of namespaces in the context object that are useful when dealing with template inheritance. We'll take a deeper look at these later.

Have a go hero – understanding context internals

The context is essentially the namespace in which a template is executed. Understanding the contents of a context helps you to understand how Mako operates. Update the preceding example to include a call to the context's keys method, and display the results. What you find in there might be somewhat surprising!

Managing execution with control structures

It's possible to include any Python control structure in a Mako template, much like we did earlier with `for` and `if`. Simply prefix the statement with a single percent. It doesn't matter where on the line the percent appears, as long as it is only preceded by white space. Control structures may be nested.

Remember, whenever you include a Python control structure, you need to be sure you terminate it with a colon, much like you would in a standard Python script.

Including Python code

In addition to the control structures and expression evaluation that Mako provides, it's possible to drop into standard Python code at any time. Let's update our e-mail application to reformat our date and make it slightly more attractive.

Time for action – reformatting the date with Python code

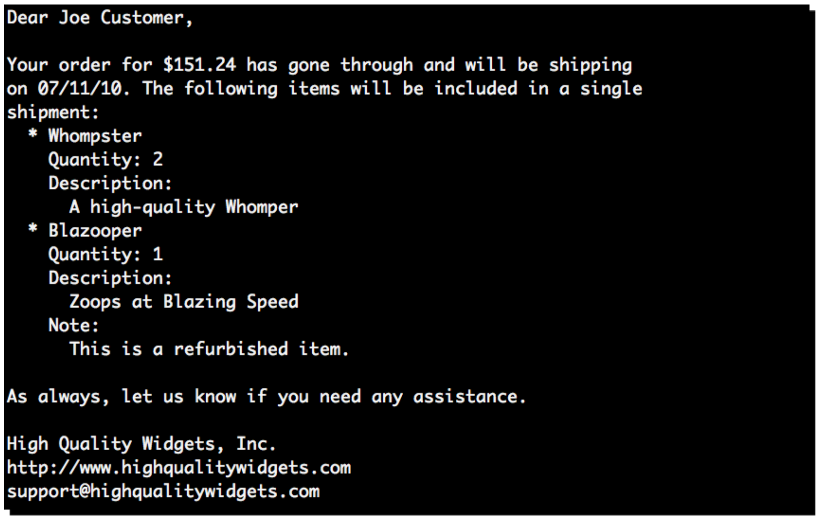
In this example, we'll look at the standard way of dropping in direct Python code. We'll reformat our `date` string via the `strftime` function.

1. Open up the template file we've been working with and add the following code snippet to the top of the file, somewhere before we reference the `date` attribute. Save it as `thank_you-b.txt`.

   ```
   <%
       shipping_on = date.strftime('%x')
   %>
   ```

2. Now, update `${date}` to read `${shipping_on}`.
3. Run the updated script. The revised output should look something like the following:

   ```
   (text_processing)$ python render_mail.py thank_you-b.txt
   ```



```
Dear Joe Customer,

Your order for $151.24 has gone through and will be shipping
on 07/11/10. The following items will be included in a single
shipment:
  * Whompster
    Quantity: 2
    Description:
      A high-quality Whomper
  * Blazooper
    Quantity: 1
    Description:
      Zoops at Blazing Speed
    Note:
      This is a refurbished item.

As always, let us know if you need any assistance.

High Quality Widgets, Inc.
http://www.highqualitywidgets.com
support@highqualitywidgets.com
```

What just happened?

We updated our template to rewrite the date format into something a bit more human-friendly. We also dropped the time from the message as that's not relevant when reporting a ship date to a customer.

As you can see in the previous example, code that is surrounded by `<%` and `%>` tags is executed as standard Python code. Unlike the control structures, indentation within these tags is significant. It is, however, safe to indent your Python blocks in a manner that's consistent with the rest of your template. Mako will automatically adjust the indentation to match the generated Python modules.

In addition to these block tags, you can also include code within `<%!` and `%>`. When these tags are encountered, code is inserted at the module level of the generated Python code and executed only once, when the template is first loaded. This is a good place to stick `import` statements or certain function definitions. If more than one of these blocks occurs within a template, they will be placed at the top of the generated Python file in the order in which they appear.

Finally, at any given point in a template, you can call `return` from within a code block. This immediately terminates the processing of the template.

Adding functionality with tags

Mako provides a great deal of functionality via a series of tags. Tags resemble XML, but the name of the tag is prefixed with a percent sign. Tags may include body data or may simply close. For example, `<%doc>comment text</%doc>` is a valid tag, as is `<%include file="our_header.html"/>`.

Let's go through all of the tags that Mako provides. Here, we'll cover the following tags.

- `include`
- `doc`
- `text`
- `def`

Rendering files with %include

The `include` tag simply renders the template referred to in the tag, using the existing context, and inserts the generated text into the original document. The locations specified by the `TemplateLookup` class are searched. Let's take a look at a brief example.

Here, we'll create a pair of template files. The first one, we'll name `index.html`. This will be our main template that references an external entity.

```
<html>
<%include file="header.html" />
<body>
<h1>Hello, World.</h1>
${id(context.lookup)}
</body>
</html>
```

Our second template is named `header.html`. This contains all of the information found within the HTML `<head></head>` section.

```
<head>
<title>${id(context.lookup)}</title>
</head>
```

Rendering the template generates the following output. Here, we're simply dealing with ASCII text and using the current working directory as our template lookup location.

```
>>> from mako.lookup import TemplateLookup
>>> t = TemplateLookup('.')
>>> t.get_template('index.html').render()
'<html>\n<head>\n<title>4302139536</title>\n</head>\n\n\n<body>\
n<h1>Hello, World.</h1>\n4302139536\n</body>\n</html>\n'
>>> ^D
```

Notice that both `id` values are the same. This is because Mako has used the same `TemplateLookup` object to locate all of the template's references. This same approach is used whenever external template files are referenced.

Generating multiline comments with %doc

This tag allows us to create multiline comments without having to prefix each line with a double hash mark (`##`).

```
<%doc>
     Long description about this code.
     A few more details.
</%doc>
```

Documenting Mako with %text

This tag suspends Mako's processing until it is closed. As stated by the Mako documentation, its purpose is really to help in documenting Mako itself. Any Mako code found within this tag is simply returned as plain text. No substitution or evaluation will take place.

Defining functions with %def

The `def` tag is probably the most widely used tag in a Mako template hierarchy. The `def` tag is used to create a Python function that can be called from within a Mako template. These tags are used to build complex inheritance structures as functions defined in base templates can be overridden.

Time for action – defining Mako def tags

In this example, we'll update our line item generation in our e-mail template to use Mako `def` tags rather than handle it within the `for` loop. We'll introduce you to a few more Mako concepts along the way.

1. Create a new file within the `templates` directory named `thank_you-c.txt` and enter the following Mako template code:

```
<%
    shipping_on = date.strftime('%x')
%>
Dear ${name},

Your order for $${amount} has gone through and will be shipping
on ${shipping_on}. The following items will be included in a
single
shipment:
% for item in packing_list:
${line_item(item['name'], item['quantity'], item['descr'],
item['used'])} \
% endfor

As always, let us know if you need any assistance.

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<%def name="line_item(name, quantity, descr, used)"> \
    ## Render a Single Line Item
    * ${name}
       Quantity: ${quantity}
       Description:
         ${descr}
    %if used:
       Note:
         This is a refurbished item.
    %endif
</%def>
```
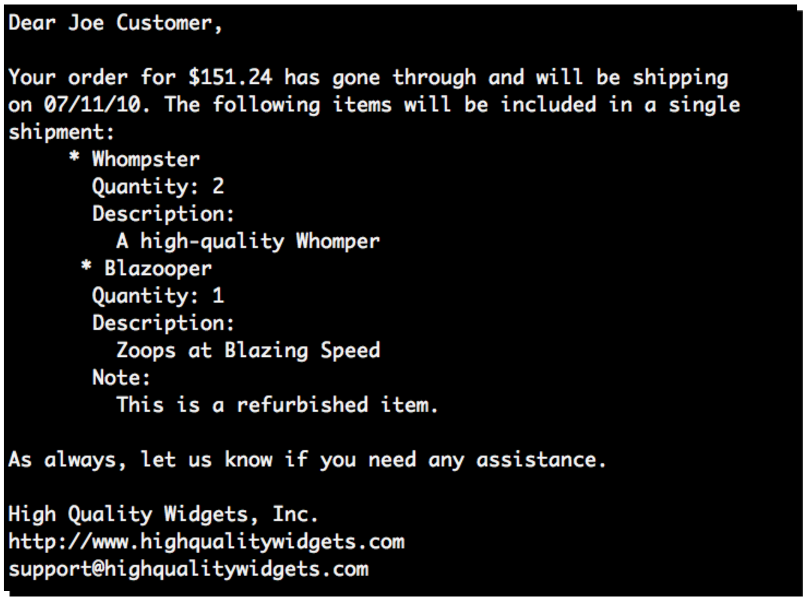

2. Run the example from the command line.

```
(text_processing)$ python render_mail.py thank_you-c.txt
```



```
Dear Joe Customer,

Your order for $151.24 has gone through and will be shipping
on 07/11/10. The following items will be included in a single
shipment:
     * Whompster
       Quantity: 2
       Description:
         A high-quality Whomper
      * Blazooper
       Quantity: 1
       Description:
         Zoops at Blazing Speed
       Note:
         This is a refurbished item.

As always, let us know if you need any assistance.

High Quality Widgets, Inc.
http://www.highqualitywidgets.com
support@highqualitywidgets.com
```

What just happened?

The first interesting line in this example template is found within the `for` loop construct. Here, you'll see the following:

```
${line_item(item['name'], item['quantity'], item['descr'],
item['used'])}\
```

There are no leading spaces and the line is terminated with a backslash. Any leading white space would transfer directly into our output data. While this is fine for formats that disregard adjacent spacing (think HTML), it can cause a problem for e-mail message formatting. Thus, we do not indent.

The trailing backslash ensures the newline found at the end of this call is not transferred to the output buffer. A newline, like leading space, is a valid template character.

Next, we have our `def` itself, which we've included at the bottom of the file.

```
<%def name="line_item(name, quantity, descr, used)"> \
```

We've included the backslash at the end of this `def` for the same reason. We do not want the literal new line transferring to our output buffer. The `def` statement itself is pretty simple. The contents of the `name` attribute contain a very plain Python method signature, much like you would see in a standard `def` statement in a Python source file.

This newly defined function is called for each iteration of our `for` loop, generating the same output as our earlier example, with one exception. As our indentation within our `def` is different, we're actually moving our output over a few extra spaces.

Finally, any code that isn't explicitly placed in a `def` statement is implicitly placed in the `body def`. This comes into play with template inheritance, which we'll touch on in a little bit.

> If you wish to use the output of a def block within an expression statement, you must take some extra precautions. By default, `def` output is sent to the output buffer on the context object and an empty string is returned. For more information, see the Mako template documentation on output buffering available at `http://www.makotemplates.org/docs/filtering.html#filtering_buffering`.

Have a go hero – formatting whitespace

It's essential to remember that everything within a template that doesn't hold special meaning to Mako is transferred to the output buffer. This includes new lines after Mako directives and the white space leading up to them.

Update this latest example and ensure the whitespace formatting is equal to that in `thank_you-b.txt`.

Importing %def sections using %namespace

The `namespace` tag is Mako's equivalent to the Python `import` statement. It allows you, as the template author, to import `def` sections from another template (or Python source file, for that matter).

Time for action – converting mail message to use namespaces

In this example, we'll create another template and move our current `def` into it. Additionally, we'll move some of the reusable logic out of our main template and into our new file. We can then access the `def` blocks within our new template via the `namespace` tag.

1. Create a new template file within the `templates` directory and name it `base.txt`. Ensure that it has the following content:

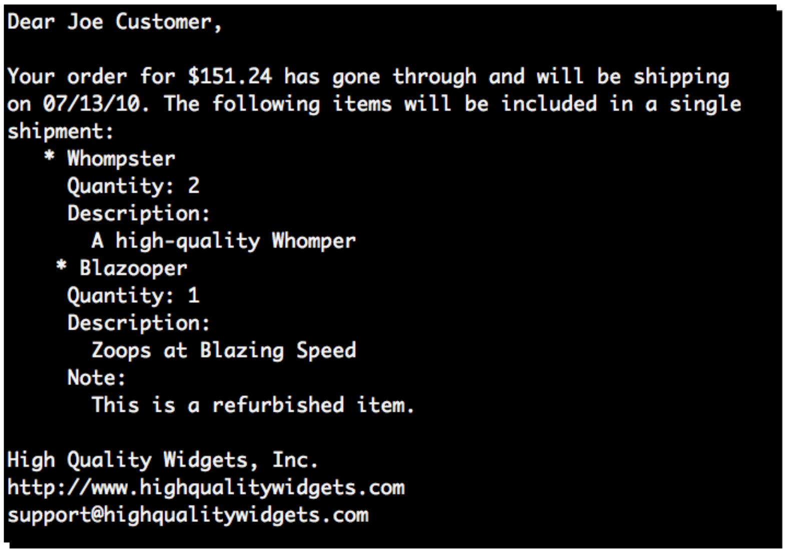
```
<%def name="line_item(name, quantity, descr, used)">\
  ## Render a Single Line Item
  * ${name}
     Quantity: ${quantity}
     Description:
       ${descr}
  %if used:
     Note:
       This is a refurbished item.
  %endif
</%def>

<%def name="footer()">\
High Quality Widgets, Inc.
http://www.highqualitywidgets.com
support@highqualitywidgets.com
</%def>
```

2. Now, create a new Python file and name it `thank_you-d.py`. Enter the following source code:

```
<%namespace name="base" file="base.txt"/>\

Dear ${name},

Your order for $${amount} has gone through and will be shipping
on ${date.strftime('%x')}. The following items will be included in
a single
shipment:
% for item in packing_list:
${base.line_item(item['name'], item['quantity'], item['descr'],
item['used'])} \
% endfor

As always, let us know if you need any assistance.

${base.footer()}
```

3. Run the new example via the command line as we have with our other templates. Your output should be similar to the following:

```
(text_processing)$ python render_mail.py thank_you-d.txt
```



```
Dear Joe Customer,

Your order for $151.24 has gone through and will be shipping
on 07/13/10. The following items will be included in a single
shipment:
   * Whompster
     Quantity: 2
     Description:
       A high-quality Whomper
    * Blazooper
     Quantity: 1
     Description:
       Zoops at Blazing Speed
     Note:
       This is a refurbished item.

High Quality Widgets, Inc.
http://www.highqualitywidgets.com
support@highqualitywidgets.com
```

What just happened?

We separated our templates into two different files. First, we moved our existing `line_item def` into `base.txt`. Next, we moved the code that generates our footer into the same new file and wrapped it in `def` statements. Assuming we generate more than one e-mail message within this project, we might want to share the footer code between templates.

We also moved our `strftime` call into `${date.strftime('%x')}`. There's really no reason to keep that in a Python code block.

At the very type of the main template, we added the following line:

```
<%namespace name="base" file="base.txt"/>\
```

There are two interesting things here. First, the `namespace` tag itself. We imported all functions from within our `base.txt` file and assigned them to the `base` namespace. We also ended the line with a trailing slash in order to ensure the newline doesn't find its way into our output stream again.

Within our `for` loop that iterates through the `packing_list` found in the template context, we've updated our call to `line_item` to use dot-notation. Now, we're calling `base.line_item`. Additionally, we call `base.footer()` at the end to generate our footer text. `Base` is equivalent to the name we gave our namespace. It could really be any valid Python identifier.

As mentioned earlier, the `%namespace` tag is a lot like the Python `import` statement. It's also possible to use it in a few other ways.

Selectively importing def blocks

Instead of using the `name` attribute, we can change the syntax up a bit and selectively import names from a different Mako template into our current context; using the `import` attribute does this.

```
<%namespace file="base.txt" import="line_item, footer"/>
```

Using this syntax, we would not have to qualify our calls to `line_item` and `footer` using the `%namespace` identifier. This is very much similar to using an `import` statement such as the following:

```
 Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> from sys import platform, exit
>>> platform
'darwin'
>>> exit()
(text_processing)$
```

Finally, it is possible to specify `*` as the value for the `import` statement. This brings all defined `def` blocks into the current context.

> As with the standard `import` statement, be careful when using `import="*"`, as you could simply pollute your namespace with values you won't be using. It's often better to either qualify a namespace with a name, or only selectively bring in the functionality you might need.

Filtering output

In a lot of situations, it's preferable to filter or change content before rendering it to the output stream. For example, it's desirable to escape HTML tags that may appear in unexpected places in order to avoid **Cross-site scripting** attacks on sites that we manage.

Enter the Mako filter. **Filters** are translation functions that may be applied to either an expression statement, or the output of a `def` block.

Expression filters

When dealing with an expression statement, filters are applied by appending a list of desired translations after a pipe symbol. For example:

```
${ "   text with <b>html</b> markup..." | h, trim }
```

The preceding line would cause the string literal to be filtered through the HTML escape filter and then through the `trim` function. In function notation, this is close to a call such as:

```
trim(html_escape("   text with <b>html</b> markup..."))
```

Running that specific string literal through a filter chain results in an output with HTML tags escaped and leading white space removed:

```
text with &lt;b&gt;html&lt;/b&gt; markup...
```

Mako provides a series of built-in filters that may be used without any additional configuration. The following table provides an overview:

Filter	**Description**
`u`	Provides URL escaping.
`h`	HTML escaping. Should be applied whenever strings may contain non-safe HTML.
`x`	XML escaping.
`trim`	Removes leading/trailing white space. Internally implemented with `string.strip()`.
`entity`	Replaces applicable strings with HTML entity definitions.
`unicode`	Returns a Python Unicode object (or a `str` in Python 3). This function is applied by default.
`decode.<encoding>`	Decode input into the specified encoding.
`n`	Disable all filters. Only those explicitly listed in the current expression will be applied.

Filtering the output of %def blocks

If you wish to apply a filter to the result of a `%def` block, you can specify the list via the filter attribute.

```
<%def name="filter_example" filter="h, trim">
text with <b>html</b> markup...
</%def>
```

The preceding `def` block would generate the same output as the expression statement when called from a template. The same filters would be applied.

Setting default filters

When we set up a Mako `TemplateLookup` object, one of the parameters we can pass in is a list of default filters that will be applied to each template we render. Simply pass a `default_filters` keyword argument with a list of filters you want to apply by default.

```
lookup = TemplateLookup('.', default_filters=['unicode', 'h'])
```

Inheriting from base templates

So far, we've covered some very useful ways to maximize code reuse when dealing with Mako templates. You've learned how to import other files, define template functions, and how to organize those functions within files and import them using the namespace tag.

This is very useful, but it gets better. Additionally, the `def` tag is really at the center of it all. Mako gives us the ability to inherit from master templates. This lets us maximize reuse and structure larger documents (and web content) in a hierarchical fashion, where each layer is further specialized.

Time for action – updating base template

In this example, we'll update our e-mail templates one more time. This time, we'll update our base template so it contains basic formatting information.

1. First, let's create a new template and name it `top.txt`. This will serve as the top of our inheritance hierarchy. It should contain the following text:

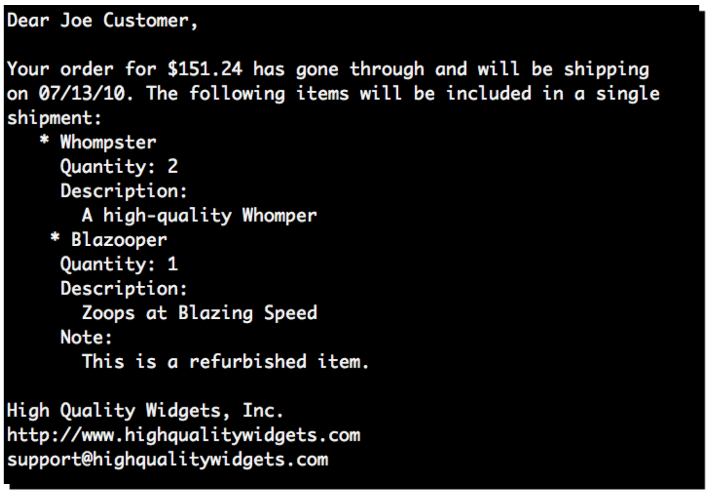
```
## This first section defines the general layout of our
## messages. Greeting, Body, Footer. This top template
## only defines structural and common data.

${self.greeting()}\
${self.body()}\
${self.footer() | trim}

## Code below here defines global def blocks that all
## of our children may use.
<%def name="footer()">\
High Quality Widgets, Inc.
http://www.highqualitywidgets.com
support@highqualitywidgets.com
</%def>
\
<%def name="greeting()">\
Dear ${name},
</%def>
```

2. Next, we'll add a new template file and name it `thank_you-e.txt`. Enter the following text:

```
<%inherit file="top.txt"/>
## This code is rendered as our body() def.
## Any code not in a def is part of body()
Your order for $${amount} has gone through and will be shipping
on ${date.strftime('%x')}. The following items will be included in
a single
shipment:
\
% for item in packing_list:
${line_item(item['name'], item['quantity'], item['descr'],
item['used'])} \
% endfor
\
## Code below here implements our individual def sections
## We don't need line item generation globally.
<%def name="line_item(name, quantity, descr, used)"> \
  ## Render a Single Line Item
  * ${name}
     Quantity: ${quantity}
     Description:
       ${descr}
  %if used:
     Note:
       This is a refurbished item.
  %endif
</%def>
```

3. Finally, running the example code should produce the same, familiar result as previous examples.

```
(text_processing)$ python render_mail.py thank_you-e.txt
```



```
Dear Joe Customer,

Your order for $151.24 has gone through and will be shipping
on 07/13/10. The following items will be included in a single
shipment:
   * Whompster
     Quantity: 2
     Description:
       A high-quality Whomper
    * Blazooper
     Quantity: 1
     Description:
       Zoops at Blazing Speed
     Note:
       This is a refurbished item.

High Quality Widgets, Inc.
http://www.highqualitywidgets.com
support@highqualitywidgets.com
```

What just happened?

We looked at a very simple inheritance hierarchy consisting of a base template and a child template. We also snuck in a few other Mako-isms that we'll look at.

First, we defined our base template, named `top.txt`. Here, we set out the base structure of our finished document. We did this by calling `self.greeting`, `self.body`, and `self.footer` at the top of this template. Note that we included backslashes here in order to leave out the trailing newline following the calls to each method. On the final call to `self.footer`, we introduced the concept of a filter. The results of `self.footer` are fed to the `trim` method, and in turn, the results of that are inserted into the template output stream. In the first two calls, we strip the trailing newline. In the final call, we remove the newline from the results of `self.footer`.

Next, we define two methods - `footer` and `greeting`. These methods are responsible for generating main structures that appear in any message we'll generate.

Remember, any text that's not explicitly part of a `def` tag will become part of the `body` method of a template.

This line tells Mako that this template inherits from `top.txt`. Next, we defined the body of this template. Because none of this text is within a `def`, it is added to the `body` method itself. In this case, it is the introductory paragraph as well as the line items list we created earlier in the chapter. Finally, we close it all up with our `line_item def` as it's unique to this specific message.

Before we look at the application flow here, let's introduce the `self` namespace. The value of `self` is always the most specific (or bottom-most) template in the inheritance hierarchy. This follows right along with the usage of self within a standard Python class library. Referring to `self.<method>` executes the first method encountered in the method resolution order.

So, with that under our belt, let's step through the rendering process.

1. First, we pass the name `thank_you-e.py` to the `get_template` function in our `render_mail.py` file. We call `render` on the returned object with our list of keyword arguments.
2. When the `inherit` is encountered, Mako jumps to the top-most template and beings execution.
3. When we make our call to `self.greeting`, the most specific template is checked first. As we did not define a greeting method within `thank_you-e.py`, the next template in the chain is checked. That just happens to be the top-most template, `top.txt`.
4. Next, we make a call to `self.body`. This is the interesting bit. Even though we did not explicitly define a `def` named body, `self.body` contains the free text of the template, which appears at the lowest level. In this case, `thank_you-e.py`. The net result? We're choosing in the parent template where we want to insert the body text of the child template.
5. Finally, we call `self.footer`, which after not finding a footer method in `thank_you-e.py`, evaluates the `footer` method in `top.txt`.

Growing the inheritance chain

Mako inheritance structures are not limited to one level. In fact, it's possible to have many levels of inheritance. A good example would be a website. It's very common to create a master template, which contains elements such as CSS links, JavaScript information, and analytics links. Section-specific templates inherit directly from that and add their own set of information, perhaps navigation or grid-based layout. Finally, bottom-level templates include the content or the content-generation specifics.

Let's be 100 percent clear. Although Mako lets us build arbitrarily long inheritance chains, it does not support multiple inheritances as we're not actually defining object-oriented classes. There is simply no mechanism to allow for inheritance from two master templates. Mako simply takes the last `%inherit` value and uses that.

Time for action – adding another inheritance layer

So, while we've built the ability to generate an e-mail message, we haven't yet added any header generation or a place to insert things such as copyright and disclaimer links. These are all things we'll want to support if we're going to be sending out professional messages. Let's add another level above our existing `top.txt` file that contains this additional information.

1. Add a new template to the `templates` directory and name it `master.txt`. Enter the following Mako template code:

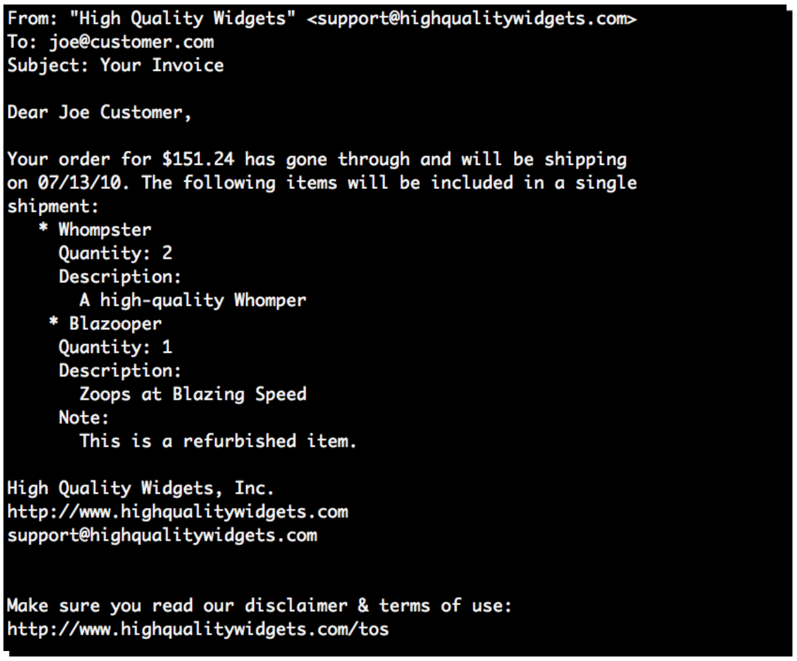
```
<%doc>\
  This file contains all global e-mail data. Things such as
  headers, copyright footers, and "almost protocol level"
  data should go here.
</%doc>
${self.write_headers()}
${next.body()}\
${self.copyright()}\
\
<%def name="write_headers()">\
From: "High Quality Widgets" <support@highqualitywidgets.com>
To: ${email}
Subject: Your Invoice
</%def>
\
<%def name="copyright()">\
Make sure you read our disclaimer & terms of use:
http://www.highqualitywidgets.com/tos
</%def>
```

2. Next, we need to update our `top.txt` file to inherit from the new `master.txt` template. Update `top.txt` to look like the following. Note that we've also standardized on backslashes here instead of calling the `trim` filter.

```
<%inherit file="master.txt"/>\
## This first section defines the general layout of our
## messages. Greeting, Body, Footer. This top template
## only defines structural and common data.
\
${self.greeting()}\
${self.body()}\
${self.footer()}\
\
## Code below here defines global def blocks that all
## of our children may use.
<%def name="footer()">\
High Quality Widgets, Inc.
http://www.highqualitywidgets.com
support@highqualitywidgets.com
</%def>
\
<%def name="greeting()">\
Dear ${name},
</%def>
```

3. Run the example as we have before. Your output should now resemble the following:

```
(text_processing)$ python render_mail.py thank_you-e.txt
```



```
From: "High Quality Widgets" <support@highqualitywidgets.com>
To: joe@customer.com
Subject: Your Invoice

Dear Joe Customer,

Your order for $151.24 has gone through and will be shipping
on 07/13/10. The following items will be included in a single
shipment:
   * Whompster
     Quantity: 2
     Description:
       A high-quality Whomper
    * Blazooper
     Quantity: 1
     Description:
       Zoops at Blazing Speed
     Note:
       This is a refurbished item.

High Quality Widgets, Inc.
http://www.highqualitywidgets.com
support@highqualitywidgets.com


Make sure you read our disclaimer & terms of use:
http://www.highqualitywidgets.com/tos
```

What just happened?

We added an additional layer of inheritance to our e-mail message template chain, letting us sneak in some standard e-mail headers without modifying our existing code too much.

The first thing we did is create our `master.txt` file. We used a `doc` tag to include a multiline comment that outlines what this template is for. Then, in the body section of our template, we called `self.write_headers`, `next.body`, and finally `self.copyright`. Both `write_headers` and `copyright` refer to new `def` blocks that we've defined in this file. There's really nothing new here; they're called and rendered as always.

The call to `body`, however, is slightly different. Instead of using the `self` name, we use `next`. While `self` refers to the lowest level template in the chain, `next` refers to the next template in the chain. So, in this example, we're writing our headers, asking for the immediate child to render its body, and then we're rendering our copyright notice.

In our example, `next.body` is the implicit `body` function in `master.txt`. Calling this function causes the remainder of the template to render as it did originally.

The only other change we've had to make is to `render_email.py`. We've moved things around slightly so that we can pass an e-mail address in as a keyword argument to our existing call to render.

In addition to `next`, you can use `parent`. The `parent` attribute refers to the previous template in the chain. As a rule of thumb, use `next` or `self` when you want the top-most template to determine the layout. Use `parent` if you want the bottom-most template to determine the layout.

> Finally, you have access to the `local` namespace. The `local` namespace attribute references the currently executing template, without performing inheritance-based lookup.

Inheriting attributes

While Mako lets us inherit `def` methods, it is not a fully object-oriented system. It is, however, possible to inherit module-level attributes that are defined in a code block. These are accessible via the `attr` attribute. Here's a brief example:

```
<%!
reply_to = 'sales@site.net'
%>
Please direct replies to ${self.attr.reply_to}
```

And then, in a second template, we'll override the attribute in a new module-level code block.

```
<%!
reply_to = 'support@site.net'
%>
<%inherit file="first_template.txt"/>
```

The output generated by rendering the second template would be as follows:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> from mako.lookup import TemplateLookup
>>> lookup = TemplateLookup('.')
>>> lookup.get_template('second_template.txt').render()
'\n\nPlease direct replies to support@site.net\n\n'
>>>
```

Pop Quiz – inheriting from templates

1. What syntax should you use if you wish to get at the template directly above the current context? Below?
2. How can you prevent Mako from copying newline characters over onto the template output stream?
3. How can you inherit module-level variables introduced via `<%! %>` tags?
4. What namespace should you refer to if you want to access the current template?

Customizing

Mako also allows you to create both custom tags and custom filters. Unlike a lot of other templating languages, it's possible to create a `Mako` tag within a `Mako` template. Of course, it's possible to create a tag within a Python module directly.

Additionally, we can build our own filters. Filters are really nothing more than a function that takes a string as an input parameter and generates a new string as a result. Much like custom tags, it's not necessary (though it is possible) to create them in a standalone Python file.

Custom tags

Technically speaking, we're creating a `def` that supports content and calling it via `<%namespace:defname/>` syntax. Then, within the called `def`, the content within the custom tags is available as the special `caller` namespace.

Time for action – creating custom Mako tags

The concept of custom tags and defs-with-content blocks probably seems slightly confusing. It is a powerful feature, though, so here we'll take a closer look at it. In this example, we'll create a simple template, which produces an HTML layout.

1. Create a new template and name it `page.html`. Enter the following Mako template code:

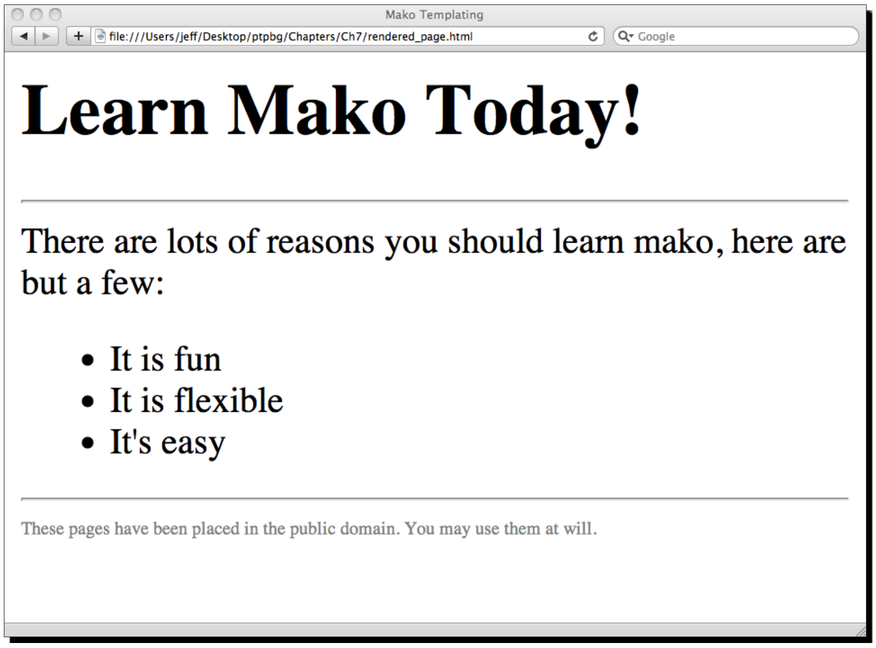
```
<%doc>
    This def creates the layout for our page. Calling
    it generates an entire HTML layout.
</%doc>

<%def name="create_page()">
    <html>
        <head>
            <title>
                ${caller.title()}
            </title>
        </head>
        <body>
            <h1>${caller.header()}</h1>
            <hr/>
            ${caller.body()}
            <hr/>
            ## Inline styles for example purposes.
            <div style="font-size: .5em; color: grey;">
                ${caller.footer()}
            </div>
        </body>
    </html>
</%def>

<%doc>
    Calling our create_page def above, using a different
    syntax. The inner content becomes the caller namespace
    within the above %def tag.
</%doc>
<%self:create_page>
    <%def name="title()">Mako Templating</%def>
    <%def name="header()">Learn Mako Today!</%def>
    <%def name="footer()">
        These pages have been placed in the public domain.
        You may use them at will.
    </%def>
```

```
        There are lots of reasons you should learn mako,
        here are but a few:
        <ul>
            <li>It is fun</li>
            <li>It is flexible</li>
            <li>It's easy</li>
        </ul>
    </%self:create_page>
```

2. Next, let's render our page. Use the `mako-render` command and direct output to your file system.

```
(text_processing)$ cat page.html | mako-render > rendered_page.html
```

3. Now, if you open our newly rendered page in a web browser, you should see something that looks a lot like the following screenshot:


Mako Templating
file:///Users/jeff/Desktop/ptpbg/Chapters/Ch7/rendered_page.html
Google

Learn Mako Today!

There are lots of reasons you should learn mako, here are but a few:

- It is fun
- It is flexible
- It's easy

These pages have been placed in the public domain. You may use them at will.

What just happened?

We defined a new HTML template in Mako that relies on a custom tag for generating the page layout. The tag we defined is `self:create_page`, though we could have put the tag under any namespace. Often, it's easier to separate custom tags like this into standalone namespace definitions.

Our tag is really nothing more than a `def` statement. However, if you look inside the body of our `create_page def`, you'll see that we refer to the `caller` namespace. As touched on above, the `caller` namespace is a namespace that is defined between opening and closing tags that invoke this specific `def`. So, `caller.title`, `caller.header`, and `caller.footer` are additional `def` blocks that are defined within those open and close tags.

Skipping the doc section, the next thing we did is to call our `def`. We invoked the `def` via a new syntax, however. Instead of using the dollar-sign expression syntax, we used a tag that specifically references the namespace and the `def` name. The corresponding `def` is then invoked (including any arguments that may be passed), and the body of `<%self:create_page>` becomes the `caller` namespace in the `create_page def` block. Note that no layout is defined within the custom tag body.

When we rendered the file, we did so via the `mako-render` command-line utility. This is a command-line utility supplied by the Mako package that lets us render pages and dump them to standard out. In this case, we redirected standard out and created a new HTML file.

The contents of the rendered file should look something like this:

```
<html>
        <head>
            <title>
                Mako Templating
            </title>
        </head>
        <body>
            <h1>Learn Mako Today!</h1>
            <hr/>


    There are lots of reasons you should learn mako,
    here are but a few:

    <ul>
        <li>It is fun</li>
        <li>It is flexible</li>
        <li>It's easy</li>
    </ul>

            <hr/>
            <div style="font-size: .5em; color: grey;">

        These pages have been placed in the public domain.
        You may use them at will.

            </div>
        </body>
    </html>
```

Note the extra whitespace present in a few places. A few empty lines leading up to the opening tag were also removed in order to conserve trees. This whitespace is present because we did not use any backslash escapes or `trim` methods. In this case, that's perfectly fine. HTML does not render code differently based on additional whitespace.

Customizing filters

Mako filters are really nothing more than Python functions that take a string as an argument and spit a string back out. They can be defined in Python modules and imported in module-level code blocks, or defined directly within a Mako template.

The following Mako snippet shows a template-based approach to creating a custom filter function:

```
<%
    # A list of sloppy book titles.
    books = ['moby dick', 'python text processing']

    # A filter that forces title case.
    def title_case(in_str):
        return in_str.title()
%>

## Iterate through and print book titles.
%for book in books:
  <li>${book|title_case}</li>
%endfor
```

When this template is rendered, the output would look something like the following:

```
<li>Moby Dick</li>
<li>Python Text Processing</li>
```

Our filter takes a string, converts it to title case, and returns that value. This specific filter is also Unicode safe as we use the methods that are part of the string (or Unicode) object. There's one other interesting thing going on here. Comments within the code blocks do not require double comment characters. This should further solidify the fact that this is simply standard Python code that's moved into the generated module file.

Overviewing alternative approaches

In addition to Mako, there are a number of other Python-templating libraries out there that perform equally as well. Some follow a more XML-based approach (ZPT), whereas others use expression-like syntax, but are slightly more restrictive in what a template designer can do (Django templates). The following table provides a list of other available Python template systems:

Package	URL	Description
`ZPT`	`http://www.zope.org`	Page templates provided with the Zope application server. XML-compliant syntax.
`Jinja2`	`http://jinja.pocoo.org/2/`	An advanced template system based on Django templates. Syntax is similar, though the implementation is slightly more restrictive.
`Cheetah`	`http://www.cheetahtemplate.org/`	A mature and proven template package. Cheetah has been around for a long time.
`Genshi`	`http://genshi.edgewall.org/`	An XML-based template system that's used with the Trac ticketing application.
`Tempita`	`http://pythonpaste.org/tempita/`	A simple template language used in Paste Script.

Finally, remember that the `string` module has its own template capabilities. For situations where minimal logic is required and your core functionality is simply replacing tokens, this is a viable – and very lightweight – approach.

Summary

In this chapter, we covered Mako in detail. However, there are some elements we did not touch on. It's recommended that you further study the Mako API-level documentation, which is available at `http://www.makotemplates.org/docs/`.

You learned how to create basic templates, define functions and create function libraries, and take advantage of template inheritance in order to minimize duplication. Along the way, we took a look at Mako filters and custom tag declaration.

In the next chapter, we'll look into some of the details behind Unicode, encodings in Python, and i18n basics.

8
Understanding Encodings and i18n

In this chapter, we'll look at text-encoding systems, Unicode, and a method for providing translations for your Python applications.

It's important that you understand the differences between characters, encodings, and differing encoding types. Failing to do so can lead to lesser quality software that is hard to make available to an international market. Building a sound foundation here will help you write high-quality, bug-free code.

Specifically, we'll touch on the following topics:

- ASCII and KOI8-R. Two character sets built such that each character representation fits into one byte.
- Unicode and how it alleviates issues created with multiple 8-bit encoding schemes. We'll look at both the Unicode system and the encoding of Unicode characters.
- The Python `codecs` module and the basic `encode` and `decode` methods of string objects. This will help you understand how to move text between Unicode and encoded byte-streams.
- Handling translation marking via the `gettext` module, and the third-party Babel extensions.
- Understand the common exceptions that you'll bump into while dealing with different text encoding types, and how to go about fixing them.

We'll learn quite a bit about Unicode and encodings, including how to translate between them. Finally, we'll wrap up with a short introduction to internationalization and language localizations.

Finally, note that Python 3 uses Unicode string types by default. In short, strings have become byte arrays and Unicode objects have become strings. As such, IO will differ slightly.

Understanding basic character encodings

As we all know, computers deal with numbers, not letters, characters, symbols, or other non-numerical values. Additionally, they deal with these numbers using base-2 systems as it's much easier to manipulate them using simple on/off logic (a bit can only hold a 1 or a 0 value).

That doesn't help us very much when wanting to record and display text content.

Enter character encodings. Character encodings provide a mechanism to map a numeric value (a code point) to a corresponding text value.

Let's take a look at some background and highlight a couple of older character encodings used around the world.

ASCII

ASCII was the first standardized character-encoding system widely used within the United States. The original specification called for each character to consume seven bits. This allowed for 128 individual characters. The decision was made to use only seven bits in order to conserve space. Systems could then use the remaining bit for parity if they so desired.

For example, let's take a look at some elementary Python built-in functions – `ord` and `chr`.

Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)

```
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> s = 'a'
>>> ord(s)
97
>>> chr(97)
'a'
>>>
```

In this example, we pass the string value `'a'` to the `ord` function, which returns its **ordinal**, or integer 97. When we pass the value of 97 to the `chr` function, it returns the string `'a'`.

So, when dealing with textual data, the integer value 97 is interpreted as a lowercase letter `a`. Not surprisingly, the Latin alphabet continues as you might expect:

Latin letter	Numeric (ASCII) value
a	97
b	98
c	99
X	88
Y	89
Z	90

Additionally, text representations of integers are represented the same way. Each number has a corresponding ASCII value associated with it. Due to the placing of control characters within various standards, integer text code values do not coincide with the integer value itself.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> ord('2')
50
>>> ord('3')
51
>>> chr(40 + 50)
'Z'
>>>
```

In practice, this is a non-issue. However, it is something to take note of. Number ranges, just like character ranges, are continuous. In the preceding example, notice how the ASCII character `2` corresponds to `50`, `3` corresponds to `51`, and `Z` corresponds to `90`.

Prior to Python 3, strings were, in general terms, collections of ASCII values. This stems from the `char` value in the C programming language. A single `char` value is limited to an 8-bit signed quantity.

Limitations of ASCII

It is common knowledge that everyone on the planet does not speak the same language. As ASCII only supports a total of 128 different character code points, we obviously run into a limitation. It's simply not possible to represent all of the possible combinations of letters, numbers, and punctuation.

Various encodings extended the ASCII specification to make use of the eighth bit. One of the more common encodings is Latin-1, or ISO-8859-1. This encoding adds a series of new characters above the 128 mark that represents various other glyphs that are present in many Western European languages. It remains backwards-compatible with ASCII, however, as the 7-bit values do not change.

KOI8-R

As C-strings limited us to eight bits per character, other regions developed their own encoding schemes to allow computers to display their native scripts. KOI8-R is an encoding scheme that maps 8-bit values to Russian Cyrillic characters.

KOI8-R, however, does not retain the alphabetic ordering that ASCII values do. It was designed such that if one interprets a KOI8-R code and discards the 8th bit, a valid 7-bit ASCII character is left over. A best-effort attempt was made to keep these weak transliterations pronounceable.

For example, given the Russian Cyrllic string книга (book) in KOI8-R, we can produce the ASCII string `KNIGA`.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>> koi8 = (203, 206, 201, 199, 193)
>>> ''.join(chr(i^128) for i in koi8)
'KNIGA'
>>>
```

Here, we first created a tuple containing the KOI8-R code values associated with our Russian string. Next, we simply cleared the eighth bit. We're left with a close transliteration.

It's important to remember why this was done. KOI8-R exists in a world that is largely 7-bit ASCII. As much of the software written was built to only support this encoding, organizing Cyrllic letters in this fashion provided a little extra insurance that an application would be useable if it didn't handle the full 8-bit KOI8-R character set. While the display wouldn't be pretty, a Russian reader could piece together the intended meaning.

Unicode

We've only looked at two legacy encodings here and it's already apparent we have a problem. Consider all of the additional scripts and variations that exist. We've not touched any of the Japanese Kanji or variations on both the Latin and the Cyrillic alphabets. It's just not possible to fit all of the world's characters into a single byte.

The Unicode specification, as it currently stands, allows for over one million different code points (1,112,064 to be exact). That's more than enough space to hold all of the world's current scripts as well as historic characters. Currently, only about 20 percent of the Unicode space has been assigned.

Let's take a brief overview of Unicode in order to provide a solid understanding of its strengths.

Using Unicode with Python 3

Most of the examples in this chapter are geared towards Python 2. As of Python 3, Unicode support is mostly transparent. As you'll see below, when working with Unicode files in Python 2, it's necessary to take that into account and open the file with the correct methods or decode it after the fact.

Python 3, however, treats strings as Unicode objects without explicit conversion (unless you want to handle that piece yourself). Additionally, text files are read as UTF-8 encoded data unless otherwise specified as binary or of a different text-encoding standard.

The Python 3 examples in the code bundle have been modified to work. However, there's not much additional translation going on. Let's take a quick look at some code snippets. Keep these differences in mind as you work through the chapter if you'll be working with Python 3.

The following snippet shows one way that external data can be treated as Unicode information in Python 2.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> s = open('/etc/hosts').read()
>>> type(s)
<type 'str'>
>>> u = s.decode('utf-8')
>>> type(u)
<type 'unicode'>
>>>
```

However, when dealing with Python 3 examples, string objects are now Unicode and the Unicode object no longer exists.

```
Python 3.1.2 (r312:79360M, Mar 24 2010, 01:33:18)
[GCC 4.0.1 (Apple Inc. build 5493)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> s = open('/etc/hosts').read()
>>> s.decode('utf-8')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
AttributeError: 'str' object has no attribute 'decode'
>>>
```

In this snippet, you can see that there is not a `decode` method on the Python 3 string object. This is because the data is already in Unicode format. The rest of this chapter assumes you're using Python 2, and handles the explicit decoding step.

Understanding Unicode

The Unicode specification defines a character representation and a collection of encoding schemes that aim to unify the various encoding mechanisms used around the world. The initial specification called for a 64k possible values, or code points. However, as the designers quickly determined, more space was needed.

Unicode is not simply an extension of the ASCII standard by an additional 24 bits. This is a common misconception.

The Unicode Consortium actively develops the Unicode specification. The consortium is composed of organizations that have a stake in text-processing standards. More information about the Unicode consortium can be found at their website, which is located at `http://www.unicode.org`. This site is also a great resource for Unicode and character-encoding specifics.

Design goals

There are a few stated design goals of the Unicode consortium. While you do not need to understand these in order to perform operations on Unicode text, knowing them will aid in your overall understanding.

Universality

The standard should provide for all of the characters needed worldwide. It is intended to be used as a universal approach to character representation.

Efficiency

Overall implementation should be simple and efficient. No characters have shift states or escapes, both of which can alter how a value is interpreted and change the meaning of a sequence of bytes. All code points exist on an equal footing and there are no special cases.

Characters, not glyphs

The standard deals with logical character code points and has absolutely nothing to do with onscreen display.

It's important that the difference between a Unicode character and the graphical representation of the character be understood. Unicode simply defines a numeric representation of a specific text element. This representation is the code point. A Unicode code point contains no information regarding the display of the character itself. This is left to the system and the available font libraries.

For example, the ASCII letter P is defined by the code point U+0050. The following, however, are all valid glyphs for the letter P:

A **glyph** is the visual representation that appears on your screen and is independent of the Unicode standard.

Semantics

All characters have well-defined semantics. Nothing is implied by name or position in the Unicode tables.

Plain text

Unicode characters do not encode or retain information such as bold, italics, underling, or strike-through. This is left to rich-text applications, which may use the Unicode character set as a building block.

Logical order

Characters are ordered logically; this roughly equates to phonetic order. Numbers are ordered with the most significant digit first.

Unification

Many writing systems share certain text elements. Examples include common punctuation markers such as the exclamation point and the period. These characters map to the same code point.

Dynamic composition

It is possible to build new characters by combining characters.

Stability

The Unicode standard is stable between revisions. This means that once characters are added, they become immutable. Consider what would happen if the code point for 'A' is suddenly swapped with the code point for 'J'.

Convertibility

Identity is retained such that Unicode values can be translated to and from different, existing standards. Each character in a localized encoding also has a value in the completed Unicode specification.

Organizational structure

The Unicode code space is broken down into 17 planes. Each plane contains a logical grouping of characters. Additionally, two of the planes are reserved for private use. The following table breaks down the set of Unicode planes and details what each is currently used for:

Plane	**Range (hex)**	**Description**
Plane 0: Basic Multilingual Plane	0000-FFFF	Contains all of the currently used scripts. This includes Latin, Cyrillic, Japanese Kanji, Arabic, and so on.
Plane 1: Supplementary Multilingual Plane	10000-1FFFF	Contains things such as math symbols and music notation.
Plane 2: Supplementary Ideographic Plane	20000-2FFFF	Additional Asian characters.
Plane 3 – 13: Unassigned	30000-DFFFF	Currently unassigned.
Plane 14: Supplementary Special Purpose Plane	E0000-EFFFF	Non-graphical characters.
Plane 15-16: Private Use	F0000-10FFFF	Reserved for private organizational use.

Planes are further broken down into blocks and allocation areas, but they are not as reliable as the direct code point value within a plane.

The vast majority of the characters in use today come out of the Basic Multilingual Plane. Some of the more esoteric characters, history elements, and some spill-overs exist within the Supplementary Multilingual Plane.

Finally, as each plane may contain 65,536 code points, the total number of code points available (the **code space**) is 1,114,112.

Unicode characters are commonly written in the form of `U+#`, where the number is the code point value. Characters that fall within the BMP are written with four hexadecimal digits. Characters that extend out of the BMP include the appropriate number.

Backwards compatibility

As mentioned previously, the majority of code points corresponding to modern texts are located within the first plane, the Basic Multilingual Plane. Interestingly, the values for Latin alphabet values within the BMP correspond to the same values within ASCII; whereas the ASCII code point for an upper case 'A' is 65, the Unicode value is `U+0041`, or 65.

Encoding

The encoding specifies the format in which Unicode data is transferred or serialized to disk. It's important to understand that the encoding differs from the code point value, and is simply a method of data serialization. The Unicode specification defines a series of encoding formats, known as Unicode Transmission Formats, or **UTF** standards.

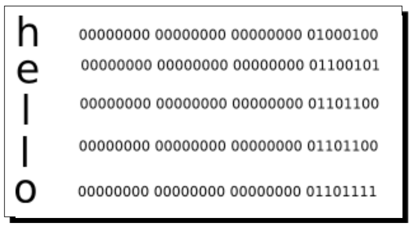
The most basic encoding is `UTF-32` while the most widespread flavor of Unicode data encoding is `UTF-8`. `UTF-8` use is common in Internet applications as it is backwards compatible with the ASCII standard. We'll take a closer look at both encoding types here.

In certain circumstances, the UCS-# notation is used. UCS is similar to UTF; however, it's generally an older standard. Additionally, UCS designations are by byte count, rather than the number of bits. For example, UCS-2 requires 16 bits.

UTF-32

This is the most basic of encoding types. UTF-32 is fixed-width, meaning that all character representations utilize full 32-bits. The result is a very inefficient storage of code point values. This is especially true when dealing with standard ASCII values as they'll require only one byte per character.

Consider the following UTF-32 encoding of a sample string:



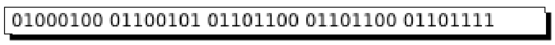
h	00000000 00000000 00000000 01000100
e	00000000 00000000 00000000 01100101
l	00000000 00000000 00000000 01101100
l	00000000 00000000 00000000 01101100
o	00000000 00000000 00000000 01101111

As the preceding example shows, we only require five bytes of relevant information, but we use up a total of 20. 15 of those bytes are zero-value. That's an awful lot of wasted space.

Additionally, multi-byte encoding schemes such as UTF-32 and UTF-16 also need to deal with the intricacies of big-endian vs. little-endian architectures.

UTF-8

The UTF-8 standard is much more compressed. If a character falls within the ASCII range, UTF-8 only requires one byte to encode that value. The previous example string can then be encoded as follows:



```
01000100 01100101 01101100 01101100 01101111
```

So, as the Latin alphabet, within the Basic Multilingual Plane, uses the same code point values as ASCII, and UTF-8 only requires one byte to encode those values, we wind up with an encoded value that is exactly equal to its ASCII counterpart. In short, if you're using ASCII characters, there are no ill effects expected in making a switch to UTF-8 Unicode.

A UTF-8 byte that begins with more than one leading value is the first in a series of that many bytes. As 32 bits is the maximum, there may be up to four leading ones. A single leading one signifies a continuation byte. The code point value is the concatenation of those bytes, minus the control characters.

By default, Python uses UCS-2, or a 16-bit encoding scheme internally. Though, it is possible to build a version of Python that uses UCS-4 by passing in the –`enable-unicode=UCS4` switch to the configure script.

Pop Quiz – character encodings

We spent a lot of time going over some theoretical material in this section as it's important to understand the differences between code points, glyphs, and encoding schemes. The following questions should help you gauge your knowledge.

1. When KOI8-R was developed, why was it designed in such a way to retain a transliteration system between Latin alphabet counterparts?
2. What's the minimum number of bytes used to encode a Unicode code point using UTF-32-based encoding?
3. What is the difference between a glyph and a code point?

The Unicode specification is long and detailed. If you're interested in understanding it from the ground up, it is available online for free, in PDF format. Simply head over to `http://www.unicode.org/standard/standard.html`.

Encodings in Python

Python string objects support both an `encode` and a `decode` method that is used to translate between different text-encoding types. The process of decoding a string translates it from one encoding type into a Python Unicode object. The encoding process translates a string object into a specified encoding type. For our purposes, we'll only look at decoding an external format into Unicode, and encoding Unicode into an external format.

Time for action – manually decoding

In this example, we'll create a simple file that contains some UTF-8 data that exists outside of the ASCII range. This ensures that we'll actually have some multi-byte characters. To generate the test data, point your browser to `http://www.translit.ru`.

1. First, create a text file and name it `russian.txt`. Using the previous site, generate the following text and save the file. The file is also included in a file bundle available on the Packt FTP site.

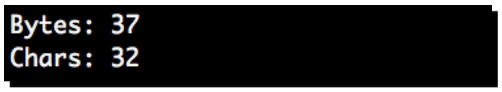
   ```
   Example UTF-8 Multibyte:
   Текст
   ```

2. Next, enter the following code and save it as `utf_coding.py`.

   ```
   #!/usr/bin/python

   with open('russian.txt', 'r') as ru:
       txt = ru.read()

   # Bytes Read
   print "Bytes: %d" % len(txt)

   # First, we'll decode.
   uc = txt.decode('utf-8')

   # Chars after decode
   print "Chars: %d" % len(uc)
   ```

3. Finally, let's run the example code. Your output should be similar to what's seen here.

   ```
   (text_processing)$ python utf_coding.py
   ```



```
Bytes: 37
Chars: 32
```

What just happened?

We handled manual decoding of UTF-8 data. Let's walk through the little example and examine what's happened in greater detail.

The first thing we do here is read in our `russian.txt` file. There's nothing too extraordinary here. After we read in the contents, we print out the number of characters read. According to the previous output, we read 37 characters in.

But, wait a minute. Open your text file again and count the number of individual letters you see. Be sure you account for the new lines and white space. 32? Good.

The reason we have this disconnect is because of the Cyrillic text we've included here. Remember, the code points for these characters are above the ASCII range, and as such, they'll require two bytes each. So, the word "Текст" actually eats up ten bytes, as opposed to five.

Next, we decode the value of our `txt` data by calling the `decode` method with an argument of `utf-8`. This returns a Python `unicode` object. To Python, the initial value of `txt` is simply a byte stream. We need to specify the type of byte stream, or encoding, when calling decode.

Finally, we see now that our application is printing the right value. The length of the newly decoded Unicode string is 32.

Reading Unicode

In versions of Python prior to the 3.0 release, strings are simply a series of bytes. Unicode values are, as covered earlier in the book, independent objects. So, what happens when we read in a UTF-8 encoded file via standard IO routines?

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> t = open('russian.txt').read()
>>> t
'Example UTF-8 Multibyte:\n\xd0\xa2\xd0\xb5\xd0\xba\xd1\x81\xd1\x82\
n\n'
>>>
```

We get exactly what we should expect: a string that contains simply a collection of single-byte character values. As our Latin alphabet text is ASCII-compliant, we see that it is handled correctly. However, our Cyrillic characters require two bytes apiece. In this example, Python simply reads in ten single-byte values. Expanding the string into a larger list ought to help clarify this.

```
>>> pprint.pprint([i for i in t])
['E',
 'x',
 'a',
 'm',
 'p',
 'l',
 'e',
…removed for brevity…
'i',
 'b',
 'y',
 't',
 'e',
 ':',
 '\n',
 '\xd0',
 '\xa2',
 '\xd0',
 '\xb5',
 '\xd0',
 '\xba',
 '\xd1',
 '\x81',
 '\xd1',
 '\x82',
 '\n',
 '\n']
>>>
```

What we have here, then, is simply a string that contains a sequence of valid UTF-8 encoded raw data, and not a decoded string. Explicitly decoding the raw byte sequence gives us a correct `unicode` object. Note that the Cyrillic letters are printed as valid `unicode` escape sequences and are interpreted as multi-byte values (after all, there are five escapes here now, not ten).

```
>>> t.decode('utf-8')
u'Example UTF-8 Multibyte:\n\u0422\u0435\u043a\u0441\u0442\n\n'
>>>
```

This represents a hotbed for bugs. Reading a UTF-8 file in and expecting pure ASCII will not raise an exception. After all, the file simply contains a series of bytes. Errors bubble up later when you attempt to manipulate the data. Play it safe. If you may be working with wide characters, ensure you decode them to Unicode and manipulate the decoded data.

Writing Unicode strings

Now that we've learned how to read and decode data, let's take a look at what happens when we attempt to write down the decoded values.

Time for action – copying Unicode data

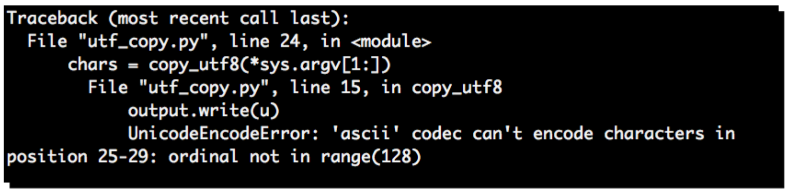
In this example, we'll extend our earlier `utf_reader.py` file and add support for file copy. Note that in a real file copy situation, our application ought to be content agnostic and simply copy byte-for-byte.

1. Create a new Python file and name it `utf_copy.py`. Add the following code:

```
#!/usr/bin/python

import sys

def copy_utf8(src, dst):
    """
    Copy a file.

    Copies a file and returns the number
    of characters that we've copied.
    """
    with open(dst, 'w') as output:
        with open(src, 'r') as input:
            u = input.read().decode('utf-8')
        output.write(u)
    return len(u)

if __name__ == '__main__':
    if len(sys.argv) != 3:
        print >>sys.stderr, "Requires src and dst"
        sys.exit(-1)

    # Run Copy.
    chars = copy_utf8(*sys.argv[1:])
    print "%d chars copied" % chars
```

2. Run the source listing. Your output should resemble the following.

```
(text_processing)$ python utf_copy.py russian.txt russian2.txt
```



```
Traceback (most recent call last):
  File "utf_copy.py", line 24, in <module>
      chars = copy_utf8(*sys.argv[1:])
        File "utf_copy.py", line 15, in copy_utf8
            output.write(u)
            UnicodeEncodeError: 'ascii' codec can't encode characters in
position 25-29: ordinal not in range(128)
```

What just happened?

There are a lot of things to understand here, mostly within the exception thrown. As usual, let's walk through this listing.

The first relevant line is `input.read().decode('utf-8')`. Here, we simply read the contents of our file and `decode` the UTF-8 bytes into a Python `unicode` object. This is much like our earlier example, just compacted a bit more into one line.

Next, we attempt to write via `output.write(u)`. According to our printed exception trace, this is where our error occurs. There is a lot of information packed into that traceback. Let's take a closer look at it.

```
UnicodeEncodeError: 'ascii' codec can't encode characters in position
25-29: ordinal not in range(128)
```

First, we see that it is a `UnicodeEncodeError`. This is the exception type that Python will raise should it run into trouble trying to translate from Unicode encodings. It's also one of the most misunderstood Python exception types.

Next, the error tells us that the ASCII codec couldn't encode characters. Well, the first thing that should stick out here is that we're not dealing with ASCII at all. Why is it that this happens? It turns out that this is a default.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import sys
>>> sys.getdefaultencoding()
'ascii'
>>>
```

Python uses ASCII as its default-encoding scheme. This is why we're running into trouble with an ASCII codec. We could change it, but it's more trouble than it's worth.

Finally, this message tells us that characters in positions 25-29 could not be encoded because the ordinal was not in `range(128)`. So, five characters could not be encoded. Of course! Python is having trouble encoding our UTF-8 multi-byte values, which must begin at position 25.

Why `range(128)`? Well, if you'll remember, ASCII only supports 7 bits worth of values. So, this is Python's way of telling us that the `ord()` value of these specific characters was greater than 7 bits can represent.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> txt = open('russian.txt').read().decode('utf-8')
>>> txt[25]
u'\u0422'
>>> ord(txt[25])
1058
>>> ord(txt[25]) in range(128)
False
>>>
```

Time for action – fixing our copy application

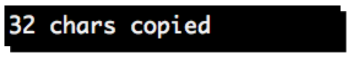
Let's take a quick moment to fix our copy application so it correctly handles the writing of UTF-8 encoded Unicode data.

1. Copy `utf_copy.py` over and name it `utf_copy-a.py`. We'll only be making some small edits.
2. Update the `copy_utf8` function to read as follows.

```
def copy_utf8(src, dst):
    """
    Copy a file.
    Copies a file and returns the number
    of characters that we've copied.
    """
    with open(dst, 'wb') as output:
        with open(src, 'r') as input:
            u = input.read().decode('utf-8')
        output.write(u.encode('utf-8'))
    return len(u)
```

3. Run the example a second time. Your output should be as follows:

```
(text_processing)$ python utf_copy-a.py russian.txt russian2.txt
```



```
32 chars copied
```

What just happened?

We updated our function in two places. First, we modified the file such that it's opened in binary mode. We did this because we're simply trying to put a string of bytes into a destination file.

Next, we called `u.encode('utf-8')` within `output.write`. This extracted a byte stream, in proper UTF-8 format, from the `unicode` object. The net result is that Python was able to simply serialize this byte stream to the destination file.

You guessed it; this is another source of bugs. Remember that an operation on a byte string and a Unicode object results in a Unicode object. If that was unexpected, attempting to write that new text to a file will result in a `UnicodeEncodeError`.

Pop Quiz – Python encodings

1. When encoding Unicode data into a specific text encoding, what type of object is returned?
2. Conversely, when decoding a byte stream, which object type should you expect in return?
3. Why is it important to work with Unicode objects internally and ensure they're only encoded and decoded when leaving and entering a Python application?

Have a go hero – other encodings

So, take into account two key facts. First, KOI8-R allows for the Latin alphabet as well as Cyrillic. Second, the encode function of a `unicode` object allows you to pass in an encoding type. Update our script such that it allows us to save data in KOI8-R encoding if we decided we wanted to.

The codecs module

Python, true to its batteries included approach, provides a module that simplifies dealing with text IO. The `codecs` module provides a series of objects and functions that makes your job as a programmer much easier.

Now that we've looked at the manual `encode` and `decode` methods, let's move on to some of the higher level approaches available to us.

Time for action – changing encodings

In this example, we'll put together a script that reads a UTF-8 file and writes it out to a new file in an encoding specified on the command line. This is actually a handy utility when testing encoding types if you're using something other than UTF-8.

1. Create a new file and name it `utf_translate.py`. Enter the following code:

```
#!/usr/bin/python

import codecs
import sys
```

```
from optparse import OptionParser

def rewrite(src, dst, encoding):
    """
    Read a UTF-8 Stream and rewrite.

    Reads a UTF-8 stream from standard
    in and rewrites it as dst with the
    target encoding.
    """
    with codecs.open(src, 'r', 'utf-8') as input:
        with codecs.open(dst, 'w', encoding) as output:
            for line in input:
                output.write(line)

if __name__ == '__main__':
    parser = OptionParser()
    parser.add_option('-s', '--source',
        help='File to read from')
    parser.add_option('-d', '--destination',
        help='Target file for copy')
    parser.add_option('-e', '--encoding',
        help='Destination Encoding')

    opts, args = parser.parse_args()

    # check count
    if not opts.destination \
            or not opts.encoding or not opts.source:
        parser.error('options missing')

    # check valid encoding
    try:
        codecs.lookup(opts.encoding)
    except LookupError, e:
        parser.error(str(e))

    # Do the work
    rewrite(opts.source,
        opts.destination, opts.encoding)
```

2. Run the above listing. The script should return immediately without printing anything.

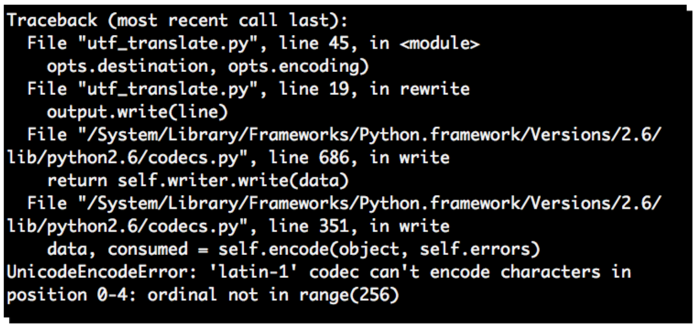
```
(text_processing)$  python utf_translate.py -d outfile -e koi8-r
-s russian.txt
(text_processing)$
```

3. Now, take a look at the `outfile` that was generated by the translation script.

   ```
   Example UTF-8 Multibyte:
   ?????
   ```

4. Finally, run the command one last time with an encoding type that doesn't support either Latin or Cyrllic.

   ```
   (text_processing)$  python utf_translate.py -d outfile -e iso8859-
   1 -s russian.txt
   ```



```
Traceback (most recent call last):
  File "utf_translate.py", line 45, in <module>
    opts.destination, opts.encoding)
  File "utf_translate.py", line 19, in rewrite
    output.write(line)
  File "/System/Library/Frameworks/Python.framework/Versions/2.6/
lib/python2.6/codecs.py", line 686, in write
    return self.writer.write(data)
  File "/System/Library/Frameworks/Python.framework/Versions/2.6/
lib/python2.6/codecs.py", line 351, in write
    data, consumed = self.encode(object, self.errors)
UnicodeEncodeError: 'latin-1' codec can't encode characters in
position 0-4: ordinal not in range(256)
```

What just happened?

The first thing we did in this example is `import` our `codecs` module. This gives us access to Python's internal encodings API.

Let's jump down to the `__main__` section. The first interesting line in this code block is `codecs.lookup(opts.encoding)`. The `lookup` function in the `codecs` module allows us to lookup a codec by name. In this case, we're simply using it as a way to validate that the destination-encoding format is valid. If the codec (encoding) isn't found, this method raises a `LookupError`.

The final line calls our `rewrite` function. Our `rewrite` function relies on `codecs.open` in two places. First, it opens the source file with an encoding type of UTF-8. It next opens the output file, but passes in our user-supplied value as the encoding. We then loop through the source file and write the destination.

The `open` function returns a wrapped file object that transparently handles the encoding steps for us. This means that when we call `input.read`, a Unicode object is returned that has already been decoded. Then, when we call `output.write` and pass a Unicode object, the wrapped file transparently encodes the data.

Also note that `codecs.open` always opens the underlying file in binary mode, even if a text mode is specified. The built-in `open` function of Python 3.0 and above supports an encodings parameter, so there is no longer a need to use the `codecs.open` function.

We ran this script twice. The first run completed successfully, though it may not look that way due to the series of question mark characters that have replaced our Cyrillic listing. The question marks, in this scenario, should be interpreted as your terminal unable to display KOI8-R encoding Cyrillic. The actual byte values are correct.

The second attempt terminated in an exception. Why? Simple. The latin-1 encoding doesn't support Cyrillic letters.

> There are additional documents on the web that further detail Python's Unicode and encoding support. A good place to start is the standard library documentation for the `codecs` module, available at `http://docs.python.org/library/codecs.html`.

Have a go hero – translating it back

We've succeeded in writing some code to translate between UTF-8 and KOI8-R. However, we can't translate back! Update our `utf8_translate.py` file such that we can also supply a source encoding.

Adopting good practices

When dealing with multiple encodings in Python (or in any language, for that matter), there are a few guidelines you should follow. Here's a brief list of some of the most important.

1. Test your code completely. Ensure that any automated tests you might have include characters above the ASCII 7-bit range. Additionally, ensure you add a few multi-byte values. Use some of the text generation sites listed as a good place to generate test data.
2. All internal strings ought to be declared as Unicode. This means that they should be prefixed with a `u` in Python versions prior to 3.0.
3. When you read data in, decode it to Unicode data. This ensures you do not run into any unexpected concatenation or promotion problems.
4. Do not encode into byte data until you write out your textual data.
5. Remember, a code point is not a character. Rather, an abstract concept. Additionally, the code point does not define the glyph on screen.

Overall, Python has very good Unicode support. Understanding it completely will help ensure that you do not run into common errors.

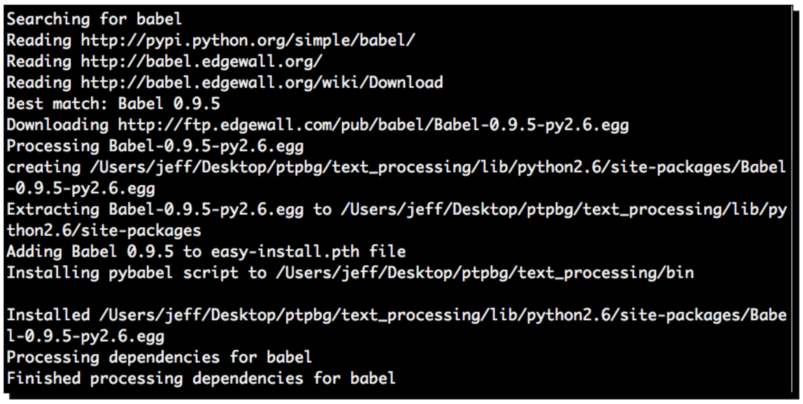
Internationalization and Localization

The final thing we'll touch on in this chapter is the process of making Python applications suitable for different areas of the world. **Internationalization** (**i18n**) can be thought of as making software ready for use with different languages and locales. **Localization** (**L10n**) is the process of configuring it for use within a specific locale.

For example, internationalization would include steps such as marking program text for translation, while localization would encompass actually providing a translation and correctly formatting dates and numbers.

We'll be using the Babel package here, which is available on PyPI and can be installed via `easy_install`. Before we go any further, take a moment to install Babel into your local virtual environment.

```
(text_processing)$ easy_install babel
```



```
Searching for babel
Reading http://pypi.python.org/simple/babel/
Reading http://babel.edgewall.org/
Reading http://babel.edgewall.org/wiki/Download
Best match: Babel 0.9.5
Downloading http://ftp.edgewall.com/pub/babel/Babel-0.9.5-py2.6.egg
Processing Babel-0.9.5-py2.6.egg
creating /Users/jeff/Desktop/ptpbg/text_processing/lib/python2.6/site-packages/Babel
-0.9.5-py2.6.egg
Extracting Babel-0.9.5-py2.6.egg to /Users/jeff/Desktop/ptpbg/text_processing/lib/py
thon2.6/site-packages
Adding Babel 0.9.5 to easy-install.pth file
Installing pybabel script to /Users/jeff/Desktop/ptpbg/text_processing/bin

Installed /Users/jeff/Desktop/ptpbg/text_processing/lib/python2.6/site-packages/Babe
l-0.9.5-py2.6.egg
Processing dependencies for babel
Finished processing dependencies for babel
```

Once installed, you should be able to run the `pybabel` script from the command line.

```
(text_processing)$ pybabel --version
```

If Babel is installed correctly, it should simply print out the installed version and exit. The current version at the time of this writing was 0.9.5.

Babel is an extension to the GNU **gettext** support available with the core Python installation. It doesn't replace it. Rather, it extends. It provides integration with SetupTools and a suite of command-line utilities that can be used to manage translations.

Preparing an application for translation

The gettext module provides core translation services for Python applications. Two APIs are exposed – a general implementation of the GNU services, and a simpler object-oriented class-based API. The Python documentation recommends that the class-based API be used; however, the lower level approach is available if needed.

Generally, the approach used when preparing an application for translation is fairly simple. The following steps are rather standard.

1. Strings within an application are marked for translation using the gettext function, which is usually aliased _ as it's used quite often.
2. Once strings have been marked, an external program is used to extract them into a POT file, which serves as a template for a translator.
3. Translations are generated and saved under directories named for the specific language (en_US, ru_RU). These files are compiled in order to provide faster access.
4. At run time, the gettext function (_) extracts the proper string from the translation database, dependant on the currently configured language.

For more information on gettext, have a look at the manual, which is available at http://www.gnu.org/software/gettext/manual/gettext.html. Additionally, Python provides a fairly full-featured gettext module, which is described within the standard library documentation at http://docs.python.org/library/gettext.html.

Time for action – preparing for multiple languages

In this example, we'll internationalize our utf_copy.py file we created earlier in the chapter. This isn't a very large file, but the steps are still the same. The majority of the work we need to do is outside of the source code realm.

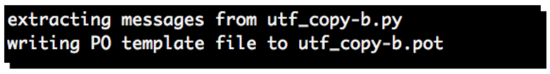
1. Create a new file named utf_copy-b.py. You should use utf_copy-a.py as a template as we'll simply make changes to it.

2. Update the script with the following changes:

```
#!/usr/bin/python

import sys
from gettext import install

# Install the _ function and setup our locale
# directory.
install('utf_copy', 'lang', unicode=True)

def copy_utf8(src, dst):
    """
    Copy a file.

    Copies a file and returns the number
    of characters that we've copied.
    """
    with open(dst, 'wb') as output:
        with open(src, 'r') as input:
            u = input.read().decode('utf-8')
        output.write(u.encode('utf-8'))
    return len(u)

if __name__ == '__main__':
    if len(sys.argv) != 3:
        print >>sys.stderr, _(u"Requires src and dst")
        sys.exit(-1)

    # Run Copy.
    chars = copy_utf8(*sys.argv[1:])

# NOTE: The 'chars' value may be plural
    format_dict = {'chars': chars}
    print _(u"%(chars)d chars copied") % format_dict
```

3. Next, run the following command to prepare a POT file, which is a template for future translation.

```
(text_processing)$ pybabel extract -c 'NOTE:'  --output=utf_copy.
pot .
```



```
extracting messages from utf_copy-b.py
writing PO template file to utf_copy-b.pot
```

What just happened?

We set up our application to handle multiple languages, though we haven't yet localized it to a specific region. Let's take a quick walk-through.

The first thing of interest we did was import the `install` function from the `gettext` module. The `install` function does a couple of things for us. First, it installs the _ alias globally so we do not have to include boilerplate code in each module to make it available. Next, it sets up our internationalization environment.

```
install('utf_copy', 'lang', unicode=True)
```

The first argument to install sets the name (or domain) of our application. In short, translation files will be first named using this argument. Next, we specify where the application should look for its translation database. If this is not specified, the system's default is used. Finally, we tell the translation libraries that we're dealing with Unicode text.

Next, we've surrounded our string constants with the _ function and ensured that they're marked as Unicode. This allows us to extract them at development time and performs the localized lookup at runtime.

Finally, we ran the `pybabel` extract command. This created the POT file, or template, that translators would use to generate translations. The contents of the file are as follows.

```
# Translations template for PROJECT.
# Copyright (C) 2010 ORGANIZATION
# This file is distributed under the same license as the PROJECT
project.
# FIRST AUTHOR <EMAIL@ADDRESS>, 2010.
#
#, fuzzy
msgid ""
msgstr ""
"Project-Id-Version: PROJECT VERSION\n"
"Report-Msgid-Bugs-To: EMAIL@ADDRESS\n"
"POT-Creation-Date: 2010-07-23 22:36-0400\n"
"PO-Revision-Date: YEAR-MO-DA HO:MI+ZONE\n"
"Last-Translator: FULL NAME <EMAIL@ADDRESS>\n"
"Language-Team: LANGUAGE <LL@li.org>\n"
"MIME-Version: 1.0\n"
"Content-Type: text/plain; charset=utf-8\n"
"Content-Transfer-Encoding: 8bit\n"
"Generated-By: Babel 0.9.5\n"

#: utf_copy-b.py:25
msgid "Requires src and dst"
msgstr ""

#. NOTE: The 'chars' value may be plural
#: utf_copy-b.py:36
#, python-format
msgid "%(chars)d chars copied"
msgstr ""
```

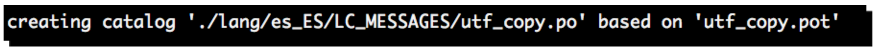
Of special note is the string `NOTE:` above the last translation string. We also passed this on the command line as a `-c` option and prefixed a comment in our source file with it. Any comments beginning with the value passed to `-c` are included as comments to the translator. This is a handy feature.

Time for action – providing translations

Here, we'll add a translation to our application such that users that speak Spanish can easily read the output.

1. Run the following command in order to create the new translation file. This should create the appropriate translation catalogue.

   ```
   (text_processing)$ pybabel init -D utf_copy -l es_ES -i utf_copy.
   pot -d ./lang
   ```

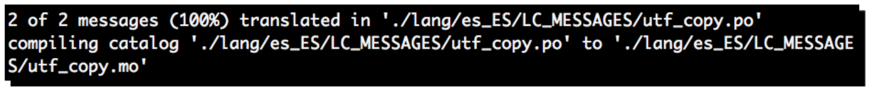
   ```
   creating catalog './lang/es_ES/LC_MESSAGES/utf_copy.po' based on 'utf_copy.pot'
   ```

2. Next, edit `lang/es_ES/LC_MESSAGES/utf_copy.po` and insert the proper translation strings. Only relevant parts of the file are shown.

   ```
   #: utf_copy-b.py:25
   msgid "Requires src and dst"
   msgstr "Fuente y destino requeridos"

   #. NOTE: The 'chars' value may be plural
   #: utf_copy-b.py:36
   #, python-format
   msgid "%(chars)d chars copied"
   msgstr "Letras copiadas: %(chars)d"
   ```

3. Now, we need to compile our message catalogue. Run the following command in order to make the translations useable.

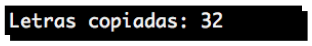
   ```
   (text_processing)$ pybabel compile -f -d ./lang/ -D utf_copy
   --statistics
   ```

   ```
   2 of 2 messages (100%) translated in './lang/es_ES/LC_MESSAGES/utf_copy.po'
   compiling catalog './lang/es_ES/LC_MESSAGES/utf_copy.po' to './lang/es_ES/LC_MESSAGE
   S/utf_copy.mo'
   ```

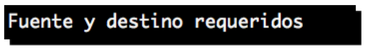
4. Now, run the copy application again with your preferred language set to `es_ES`. This can be done using the following command on a Unix-like system.

   ```
   (text_processing)$ export LANGUAGE=es_ES
   (text_processing)$ python utf_copy-b.py russian.txt russian.txt2
   ```

   ```
   Letras copiadas: 32
   ```

   ```
   (text_processing)$ python utf_copy-b.py
   ```

   ```
   Fuente y destino requeridos
   ```

What just happened?

We finalized localization of our application for users set to `es_ES` (Spanish in Spain).

Notice how we set our `LANGUAGE` environmental variable accordingly. When our application runs, Python will read a few environmental variables in order to determine which language database it should use when rendering the text. `LANGUAGE` is the first in that list, followed by `LC_ALL`, `LC_MESSAGES`, and finally, `LANG`.

Also of interest is the handling of a missing language definition. If we set our language to one that is not supported by our application, notice how the output is handled.

```
(text_processing)$ export LANGUAGE=fr_FR
(text_processing)$ python utf_copy-b.py russian.txt russian.txt2
32 chars copied
```

Our application defaults to the string supplied within the `gettext` _ function.

Looking for more information on internationalization

We've only scratched the surface of internationalization and multiple language support. There's a world of information available that will help you solidify your understanding. Our example here was meant to be an introduction to the process. You may find the following external resources helpful.

1. The Babel documentation is available at `http://babel.edgewall.org/`. However, before reading this, you are strongly encouraged to read the Python standard library documentation for `gettext`.
2. Python's standard library documentation for the `gettext` module, available at `http://docs.python.org/library/gettext.html`.
3. The Pylons documentation provides an excellent resource for internationalization using Babel and methods for extending it into Mako templates. You can read these pages at `http://pylonshq.com/docs/en/1.0/i18n/`.

Pop Quiz – internationalization

1. The process of preparing software to handling multiple locales is called internationalization, or i18n. What is the process of tailoring a package for a specific locale?
2. In our example, we used Python's dictionary formatting syntax in our string rather than the `printf` style formatting. Why is this the case?
3. What are some common problems programmers may run into while dealing with multiple translations?

Summary

In this chapter, we concentrated heavily on encodings and managing them within Python. This is because misunderstanding these concepts can lead to subtle bugs that only show up when wide characters are introduced. We also very briefly covered multiple-language support and internationalization.

Specifically, we touched legacy text encodings such as ASCII and KOI8-R. We introduced Unicode and the differences between code points, character encoding, and display glyphs. We've covered methods to programmatically convert between different encodings. Finally, we wrapped up with an introduction to i18n where you marked a sample application for translation and provided a Spanish string catalog.

In our next chapter, we'll look at ways to enhance text output via a collection of third-party packages.

9
Advanced Output Formats

In this chapter, we'll look at some advanced techniques for generating richer text formats. Up until now, we've largely concerned ourselves with plain text output. Here, we'll shift a little bit. Instead of outputting plain text, we'll look at a few commonly used rich formats.

Generally speaking, the approach is usually the same for each of these different technologies. We'll define a root document entry and add textual elements to the flow, and they'll render appropriately in our saved document.

Specifically, we'll look at how to do the following.

- Build simple PDF output using the **ReportLab** Toolkit's high level **PLATYPUS** framework.
- Generation of true Microsoft Excel output using the `xlwt` module. We covered CSV in an earlier chapter.
- Programmatically create and save OpenDocument files. This is the file format used by Open Office and quite a few other applications. Microsoft Word 2007 supports this format (though not by default).
- Open and edit existing OpenDocument files so that we can use them as templates sources.

We'll not dive into too much detail with any single approach. Rather, the goal of this chapter is to teach you the basics such that you can get started and further explore details on your own. Also, remember that our goal isn't to be pretty; it's to present a useable subset of functionality. In other words, our PDF layouts are ugly!

> Unfortunately, the third-party packages used in this chapter are not yet compatible with Python 3. Therefore, the examples listed here will only work with Python 2.6 and 2.7.

Dealing with PDF files using PLATYPUS

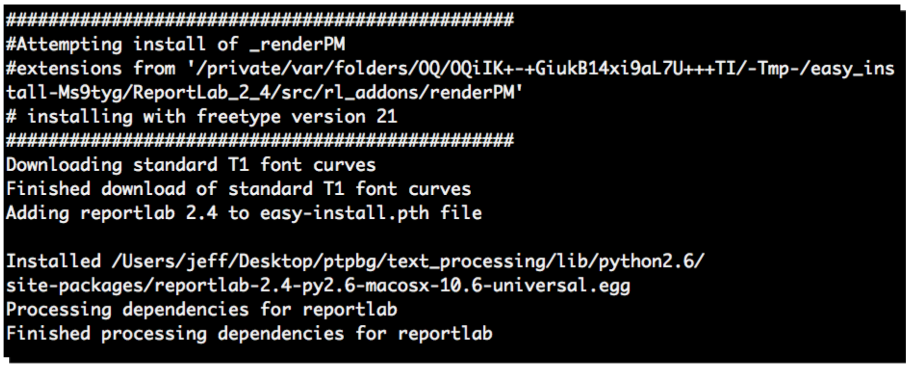
The ReportLab framework provides an easy mechanism for dealing with PDF files. It provides a low-level interface, known as `pdfgen`, as well as a higher-level interface, known as PLATYPUS. **PLATYPUS** is an acronym, which stands for **Page Layout and Typography Using Scripts**. While the pdfgen framework is incredibly powerful, we'll focus on the PLATYPUS system here as it's slightly easier to deal with. We'll still use some of the lower-level primitives as we create and modify our PLATYPUS rendered styles.

> The ReportLab Toolkit is not entirely Open Source. While the pieces we use here are indeed free to use, other portions of the library fall under a commercial license. We'll not be looking at any of those components here. For more information, see the ReportLab website, available at `http://www.reportlab.com`.

Time for action – installing ReportLab

Like all of the other third-party packages we've installed thus far, the ReportLab Toolkit can be installed using SetupTools' `easy_install` command. Go ahead and do that now from your virtual environment. We've truncated the output that we are about to see in order to conserve on space. Only the last lines are shown.

```
(text_processing)$ easy_install reportlab
```



```
################################################
#Attempting install of _renderPM
#extensions from '/private/var/folders/OQ/OQiIK+-+GiukB14xi9aL7U+++TI/-Tmp-/easy_ins
tall-Ms9tyg/ReportLab_2_4/src/rl_addons/renderPM'
# installing with freetype version 21
################################################
Downloading standard T1 font curves
Finished download of standard T1 font curves
Adding reportlab 2.4 to easy-install.pth file

Installed /Users/jeff/Desktop/ptpbg/text_processing/lib/python2.6/
site-packages/reportlab-2.4-py2.6-macosx-10.6-universal.egg
Processing dependencies for reportlab
Finished processing dependencies for reportlab
```

What just happened?

The ReportLab package was downloaded and installed locally. Note that some platforms may require a C compiler in order to complete the installation process. To verify that the packages have been installed correctly, let's simply display the version tag.

```
(text_processing)$ python
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import reportlab
>>> reportlab.Version
'2.4'
>>>
```

Generating PDF documents

In order to build a PDF document using PLATYPUS, we'll arrange elements onto a document template via a flow. The flow is simply a list element that contains our individual document components. When we finally ask the toolkit to generate our output file, it will merge all of our individual components together and produce a PDF.

Time for action – writing PDF with basic layout and style

In this example, we'll generate a PDF that contains a set of basic layout and style mechanisms. First, we'll create a cover page for our document. In a lot of situations, we want our first page to differ from the remainder of our output. We'll then use a different format for the remainder of our document.

1. Create a new Python file and name it `pdf_build.py`. Copy the following code as it appears as follows:

```
import sys
from report lab.PLATYPUS import SimpleDocTemplate, Paragraph
from reportlab.PLATYPUS import Spacer, PageBreak
from reportlab.lib.styles import getSampleStyleSheet
from reportlab.rl_config import defaultPageSize
from reportlab.lib.units import inch
from reportlab.lib import colors
class PDFBuilder(object):
    HEIGHT = defaultPageSize[1]
    WIDTH = defaultPageSize[0]
    def _intro_style(self):
        """Introduction Specific Style"""
        style = getSampleStyleSheet()['Normal']
        style.fontName = 'Helvetica-Oblique'
        style.leftIndent = 64
        style.rightIndent = 64
        style.borderWidth = 1
        style.borderColor = colors.black
        style.borderPadding = 10
        return style

    def __init__(self, filename, title, intro):
        self._filename = filename
        self._title = title
        self._intro = intro
        self._style = getSampleStyleSheet()['Normal']
        self._style.fontName = 'Helvetica'

    def title_page(self, canvas, doc):
        """
        Write our title page.

        Generates the top page of the deck,
        using some special styling.
        """
        canvas.saveState()
        canvas.setFont('Helvetica-Bold', 18)
        canvas.drawCentredString(
            self.WIDTH/2.0, self.HEIGHT-180, self._title)
        canvas.setFont('Helvetica', 12)
        canvas.restoreState()

    def std_page(self, canvas, doc):
        """
        Write our standard pages.
        """
        canvas.saveState()
        canvas.setFont('Helvetica', 9)
        canvas.drawString(inch, 0.75*inch, "%d" % doc.page)
        canvas.restoreState()

    def create(self, content):
        """
        Creates a PDF.

        Saves the PDF named in self._filename.
        The content parameter is an iterable; each
        line is treated as a standard paragraph.
        """
        document = SimpleDocTemplate(self._filename)
        flow = [Spacer(1, 2*inch)]

        # Set our font and print the intro
        # paragraph on the first page.
        flow.append(
            Paragraph(self._intro, self._intro_style()))
        flow.append(PageBreak())

        # Additional content
        for para in content:
            flow.append(
                Paragraph(para, self._style))

            # Space between paragraphs.
            flow.append(Spacer(1, 0.2*inch))

        document.build(
            flow, onFirstPage=self.title_page,
                onLaterPages=self.std_page)

if __name__ == '__main__':

    if len(sys.argv) != 5:
        print "Usage: %s <output> <title> <intro file> <content 
file>" % \
            sys.argv[0]
        sys.exit(-1)

    # Do Stuff
    builder = PDFBuilder(
        sys.argv[1], sys.argv[2], open(sys.argv[3]).read())

    # Generate the rest of the content from a text file
    # containing our paragraphs.
    builder.create(open(sys.argv[4]))
```

2. Next, we'll create a text file that will contain the introductory paragraph. We've placed it in a separate file so it's easier to manipulate. Enter the following into a text file named `intro.txt`.

```
This is an example document that we've created from scratch; it 
has no story to tell. It's purpose? To serve as an example.
```

3. Now, we need to create our PDF content. Let's add one more text file and name `paragraphs.txt`. Feel free to create your own content here. Each new line will start a new paragraph in the resulting PDF. Our test data is as follows.

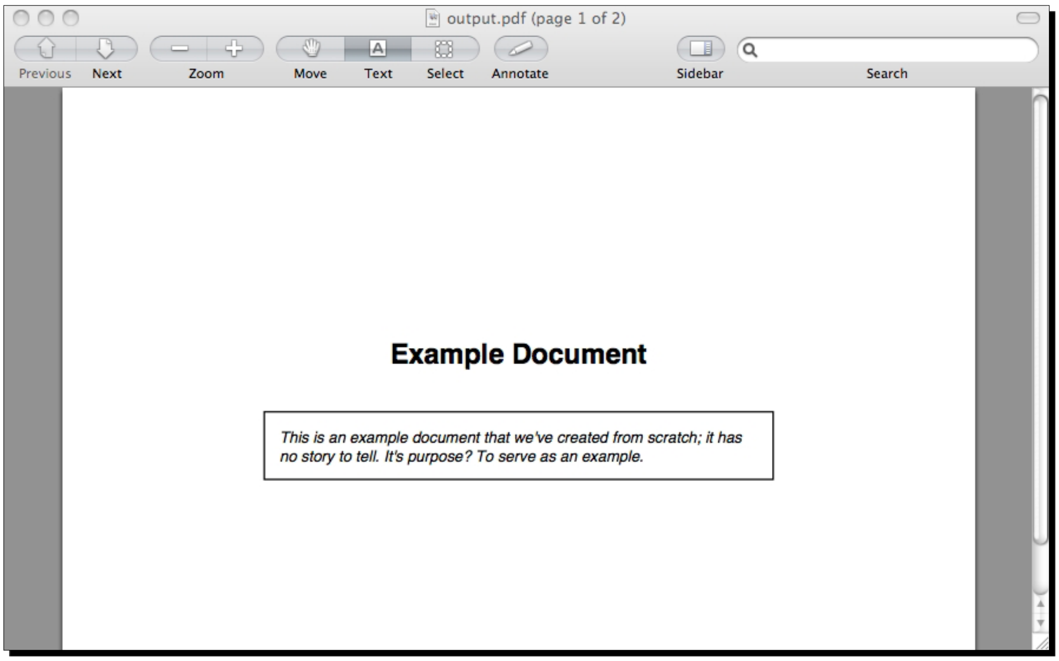
```
This is the first paragraph in our document and it really serves 
no meaning other than example text.
This is the second paragraph in our document and it really serves 
no meaning other than example text.
```

```
This is the third paragraph in our document and it really serves
no meaning other than example text.
This is the fourth paragraph in our document and it really serves
no meaning other than example text.
This is the final paragraph in our document and it really serves
no meaning other than example text.
```

4. Now, let's run the PDF generation script

   ```
   (text_processing)$ python pdf_build.py output.pdf "Example
   Document" intro.txt paragraphs.txt
   ```

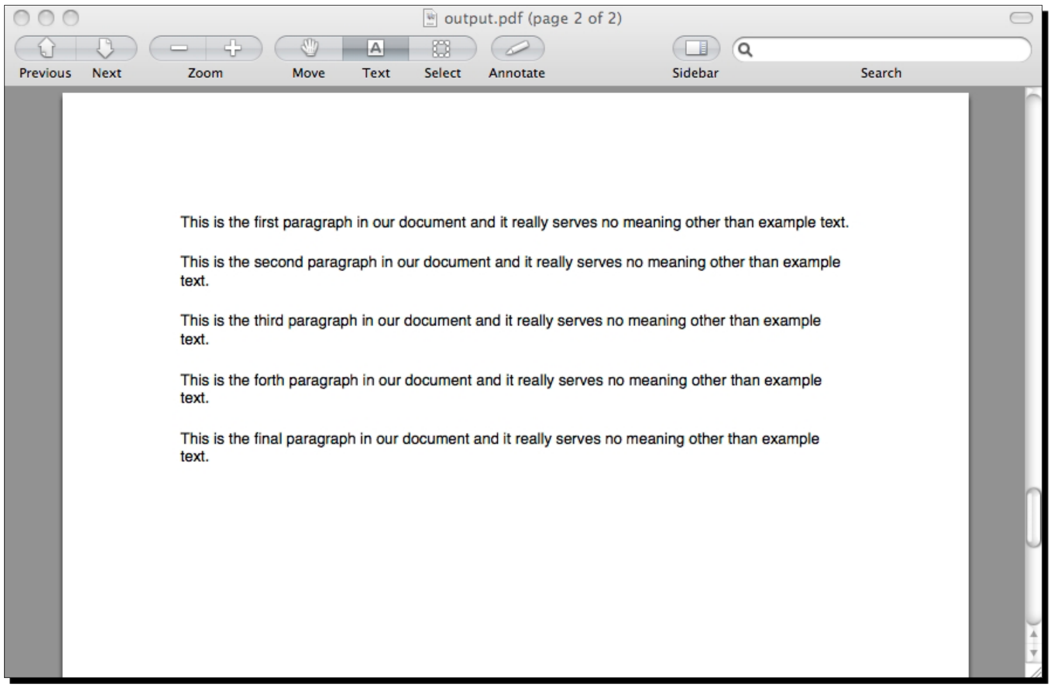
5. If you view the generated document in a reader, the generated pages should resemble the following screenshots:



Example Document

This is an example document that we've created from scratch; it has no story to tell. It's purpose? To serve as an example.

The preceding screenshot displays the clean Title page, which we derive from the command-line arguments and the contents of the introduction file. The next screenshot contains document copy, which we also read from a file.



This is the first paragraph in our document and it really serves no meaning other than example text.

This is the second paragraph in our document and it really serves no meaning other than example text.

This is the third paragraph in our document and it really serves no meaning other than example text.

This is the forth paragraph in our document and it really serves no meaning other than example text.

This is the final paragraph in our document and it really serves no meaning other than example text.

What just happened?

We used the ReportLab Toolkit to generate a basic PDF. In the process, you created two different layouts: one for the initial page and one for subsequent pages. The first page serves as our title page. We printed the document title and a summary paragraph. The second (and third, and so on) pages simply contain text data.

At the top of our code, as always, we import the modules and classes that we'll need to run our script. We import `SimpleDocTemplate`, `Paragraph`, `Spacer`, and `Pagebreak` from the `PLATYPUS` module. These are items that will be added to our document flow.

Next, we bring in `getSampleStyleSheet`. We use this method to generate a sample, or template, stylesheet that we can then change as we need. Stylesheets are used to provide appearance instructions to `Paragraph` objects here, much like they would be used in an HTML document.

The last two lines import the `inch` size as well as some page size defaults. We'll use these to better lay out our content on the page. Note that everything here outside of the first line is part of the more general-purpose portion of the toolkit.

The bulk of our work is handled in the `PDFBuilder` class we've defined. Here, we manage our styles and hide the PDF generation logic. The first thing we do here is assign the default document height and width to class variables named `HEIGHT` and `WIDTH`, respectively. This is done to make our code easier to work with and to make for easier inheritance down the road.

The `_intro_style` method is responsible for generating the paragraph style information that we use for the introductory paragraph that appears in the box. First, we create a new stylesheet by calling `getSampleStyleSheet`. Next, we simply change the attributes that we wish to modify from default.

Style attribute	**Meaning**
`fontName`	Sets the type of font used when drawing text. Here, we use Helvetica-Oblique, which gives us an italic sans-serif.
`leftIndent`	Indent size of the left margin.
`rightIndent`	Indent size of the right margin.
`borderWidth`	Sets a border size. By default, the width is zero, which results in no border being drawn.
`borderColor`	Assigns the color to the border. The `color.black` value is an instance of the ReportLab `Color` class.

The values in the preceding table define the style used for the introductory paragraph, which is different from the standard style. Note that this is not an exhaustive list; this simply details the variables that we've changed.

Next we have our `__init__` method. In addition to setting variables corresponding to the arguments passed, we also create a new stylesheet. This time, we simply change the font used to Helvetica (default is Times New Roman). This will be the style we use for default text.

The next two methods, `title_page` and `std_page`, define layout functions that are called when the PDF engine generates both the first and subsequent pages. Let's walk through the `title_page` method in order to understand what exactly is happening.

First, we save the current state of the `canvas`. This is a lower-level concept that is used throughout the ReportLab Toolkit. We then change the active font to a bold sans serif at 18 point. Next, we draw a string at a specific location in the center of the document. Lastly, we restore our state as it was before the method was executed.

If you take a quick look at `std_page`, you'll see that we're actually deciding how to write the page number. The library isn't taking care of that for us. However, it does help us out by giving us the current page number in the doc object.

Neither the `std_page` nor the `title_page` methods actually lay the text out. They're called when the pages are rendered to perform annotations. This means that they can do things such as write page numbers, draw logos, or insert callout information. The actual text formatting is done via the document flow.

The last method we define is `create`, which is responsible for driving title page creation and feeding the rest of our data into the toolkit. Here, we create a basic document template via `SimpleDocTemplate`. We'll flow all of our components onto this template as we define them.

Next, we create a list named `flow` that contains a `Spacer` instance. The `Spacer` ensures we do not begin writing at the top of the PDF document.

We then build a `Paragraph` containing our introductory text, using the style built in the `self._intro_style` method. We append the `Paragraph` object to our flow and then force a page break by also appending a `PageBreak` object.

Next, we iterate through all of the lines passed into the method as content. Each generates a new `Paragraph` object with our default style.

Finally, we call the `build` method of the document template object. We pass it our flow and two different methods to be called - one when building the first page and one when building subsequent pages.

Our `__main__` section simply sets up calls to our `PDFBuilder` class and reads in our text files for processing.

The ReportLab Toolkit is very heavily documented and is quite easy to work with. For more information, see the documents available at `http://www.reportlab.com/software/opensource/`. There is also a code snippets library that contains some common PDF recipes.

Have a go hero – drawing a logo

The toolkit provides easy mechanisms for including graphics directly into a PDF document. JPEG images can be included without any additional library support. Using the documentation referenced earlier, alter our `title_page` method such that you include a logo image below the introductory paragraph.

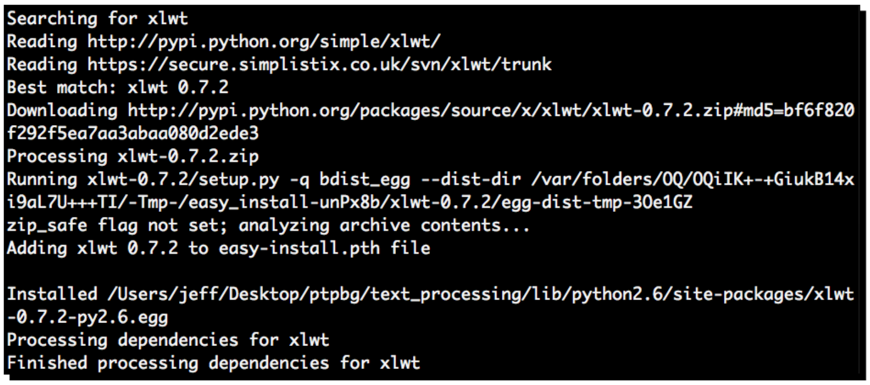
Writing native Excel data

Earlier in this book we looked at writing CSV data, which we were able to open and manipulate using Microsoft Excel. Here, we'll look at a more advanced technique that actually allows us to write actual Excel data (without requiring Microsoft Windows). To do this, we'll be using the `xlwt` package.

Time for action – installing xlwt

Again, like the other third-party modules we've installed thus far, `xlwt` can be downloaded and installed via the `easy_install` system. Activate your virtual environment and install it now. Your output should resemble the following:

```
(text_processing)$ easy_install xlwt
```



```
Searching for xlwt
Reading http://pypi.python.org/simple/xlwt/
Reading https://secure.simplistix.co.uk/svn/xlwt/trunk
Best match: xlwt 0.7.2
Downloading http://pypi.python.org/packages/source/x/xlwt/xlwt-0.7.2.zip#md5=bf6f820
f292f5ea7aa3abaa080d2ede3
Processing xlwt-0.7.2.zip
Running xlwt-0.7.2/setup.py -q bdist_egg --dist-dir /var/folders/OQ/OQiIK+-+GiukB14x
i9aL7U+++TI/-Tmp-/easy_install-unPx8b/xlwt-0.7.2/egg-dist-tmp-3Oe1GZ
zip_safe flag not set; analyzing archive contents...
Adding xlwt 0.7.2 to easy-install.pth file

Installed /Users/jeff/Desktop/ptpbg/text_processing/lib/python2.6/site-packages/xlwt
-0.7.2-py2.6.egg
Processing dependencies for xlwt
Finished processing dependencies for xlwt
```

What just happened?

We installed the `xlwt` packages from the Python Package Index. To ensure your install worked correctly, start up Python and display the current version of the `xlwt` libraries.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import xlwt
>>> xlwt.__VERSION__
'0.7.2'
>>>
```

At the time of this writing, the `xlwt` module supports the generation of Excel `xls` format files, which are compatible with Excel 95 – 2003 (and later). MS Office 2007 and later utilizes **Open Office XML** (**OOXML**).

Building XLS documents

In this example, we'll build on our CSV examples from *Chapter 4*, *Text Processing Using the Standard Library*. If you'll recall, the first example from that chapter read in a CSV file containing revenue and cost numbers. The script output was simply the profit for each set of inputs. Here, we'll update our approach and generate a spreadsheet using formulas directly.

Time for action – generating XLS data

In this example, we'll reuse the `Worksheet1.csv` file we created in *Chapter 4*, *Text Processing Using the Standard Library*. Copy that file over to your current directory now.

1. Create a new Python file and name it `xls_build.py`. Enter the following code as follows:

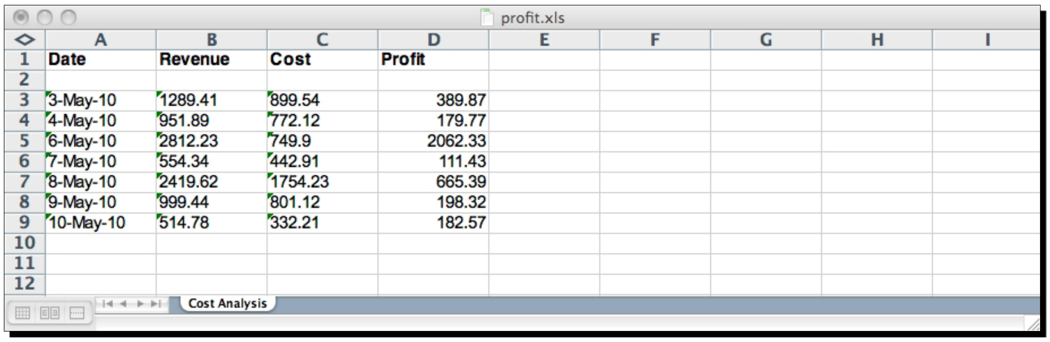
```
import csv
import sys
import xlwt
from xlwt.Utils import rowcol_to_cell

from optparse import OptionParser

def render_header(ws, fields, first_row=0):
    """
    Generate an Excel Header.

    Builds a header line using different
    fonts from the default.
    """
    header_style = xlwt.easyxf(
        'font: name Helvetica, bold on')
    col = 0
    for hdr in fields:
        ws.write(first_row, col, hdr, header_style)
        col += 1
    return first_row + 2

if __name__ == '__main__':
    parser = OptionParser()
    parser.add_option('-f', '--file', help='CSV Data File')
    parser.add_option('-o', '--output', help='Output XLS File')
    opts, args = parser.parse_args()

    if not opts.file or not opts.output:
        parser.error('Input source and output XLS required')

    # Create a dict reader from an open file
    # handle and iterate through rows.
    reader = csv.DictReader(open(opts.file, 'rU'))
```

```
        headers = [field for field in reader.fieldnames if field]
        headers.append('Profit')

        workbook = xlwt.Workbook()
        sheet = workbook.add_sheet('Cost Analysis')

        # Returns the row that we'll start at
        # going forward.
        row = render_header(sheet, headers)

        for day in reader:
            sheet.write(row, 0, day['Date'])
            sheet.write(row, 1, day['Revenue'])
            sheet.write(row, 2, day['Cost'])
            sheet.write(row, 3,
                xlwt.Formula('%s-%s' % (rowcol_to_cell(row, 1),
                    rowcol_to_cell(row, 2))))
            row += 1

        # Save workbook
        workbook.save(opts.output)
```

2. Now, run the command with the following options. It should generate a `profit.xls` in your current working directory.

   ```
   (text_processing)$ python ./xls_build.py -f Workbook1.csv -o profit.xls
   ```

3. Opening the newly created `profit.xls` file. It should resemble the following screenshot. Yes, there is a problem with the rendered data. We'll clean that up in just a little bit.



	A	B	C	D	E	F	G	H	I
1	Date	Revenue	Cost	Profit					
2									
3	3-May-10	1289.41	899.54	389.87					
4	4-May-10	951.89	772.12	179.77					
5	6-May-10	2812.23	749.9	2062.33					
6	7-May-10	554.34	442.91	111.43					
7	8-May-10	2419.62	1754.23	665.39					
8	9-May-10	999.44	801.12	198.32					
9	10-May-10	514.78	332.21	182.57					
10									
11									
12									

4. Now, select a revenue value or a cost value and update. Take note of the profit column and see how it changes as we update our values.

What just happened?

We just updated our example from *Chapter 4*, *Text Processing Using Standard Library* so that it outputs Excel data rather than printing plain text to standard output! Additionally, we incorporated the generation of Excel formulas such that our resulting spreadsheet supports dynamic profit calculation. We were able to do all of this with just a few trivial changes to our existing script.

Lets take a look at exactly how we did it.

First of all, we imported the required modules. In this case, we brought in the `xlwt` package as well as `xlwt.Utils.rowcol_to_cell`. The former provides the majority of the functionality while the latter allows us to translate numeric row and column coordinates into Excel-friendly number + letter locations.

Now, let's skip down to the `__main__` section and follow our application's execution path. We added an additional option, `-o` or `–output`, which contains the destination filename for our new Excel file. We've then updated our parameter checking to ensure both are passed on the command line.

The next relevant changes occur with the following line of code.

```
headers = [field for field in reader.fieldnames if field]
```

Here, we pull all of our headers from the CSV data and strip out anything that doesn't evaluate to `True`. Why did we do this? Simple. If any empty cells made their way into our CSV data, we wouldn't want to include them as empty column headings in our output document.

Note that we also append the string `Profit` to our header list. We'll be the corresponding values in just a bit.

Next, we build our workbook. The `xlwt` package makes this quite easy. It only takes two lines to create a workbook and assign the first worksheet:

```
workbook = xlwt.Workbook()
sheet = workbook.add_sheet('Cost Analysis')
```

Here, we're creating a new workbook and then adding a sheet named `Cost Analysis` to it. If you look at the screenshot earlier in this chapter, you'll see that this is the name given to the tab at the bottom of the spreadsheet.

Now, we call a function we've defined named `render_header` and pass our sheet object to it with the list of headers we want to create. Looking at `render_header`, you'll notice that we first create a specific header style using `xlwt.easyxf`. This factory function takes a string definition of the style to be associated with a cell and returns an appropriate styling object.

Next, we simply iterate through all of our header columns and add them to the document using `ws.write`. Here, `ws` is the worksheet object we passed in to `render_header`.

One thing to note here is that the write method doesn't accept standard Excel cell names. Here, we need to pass in integer coordinates. Additionally, the data type of the inserted cell corresponds to the Python data type written. In this case, each value of `hdr` is a string. The result? These are all string columns in the final document.

We return the position of the first row with two added. This gives us a good logical place to start inserting our real data. We allowed the caller to pass in a starting height in order to provide just a bit more flexibly and reuse.

After our header has been rendered, we iterate through each row in our parsed CSV data and write the values to the sheet in order verbatim. There's no data translation happening at all.

Note the `xlwt.Formula` call. This is where we insert an Excel formula directly into our generated content. As the formula will be embedded, we need to translate from our numeric row and column syntax to the Excel syntax. This is done via our call to `rowcol_to_cell`. The following snippet shows how this is done:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> from xlwt.Utils import rowcol_to_cell
>>> rowcol_to_cell(1,6)
'G2'
>>> rowcol_to_cell(0,6)
'G1'
>>>
```

Finally, we save our new spreadsheet until the name passed on the command line with the embedded formula.

For more information, see the xlwt documentation, available at `https://secure.simplistix.co.uk/svn/xlwt/trunk/xlwt/doc/xlwt.html`. This documentation isn't entirely complete, thus it's probably a good exercise to spend some time reading the source code if you intend to use `xlwt` in a production scenario. Also, note that `xlwt` has a read-focused counterpart, `xlrd`.

Pop Quiz – creating XLS documents

1. In our example, we mentioned that there was a problem with the rendered data. It turns out our integer columns are being interpreted as text data. Why is this?
2. How might you specify a different font or variable font style?
3. What's one benefit to using xlwt versus simply generating Excel-friendly CSV files, like we did in *Chapter 4*, *Text Processing Using the Standard Library*?

Working with OpenDocument files

OpenDocument files are generally just ZIP bundles that contain a collection of XML files, which define the document. At the lowest level, it's possible to parse and edit the XML data directly; however, that requires an intricate knowledge of the relevant schemas and XML elements. A couple of packages exist that abstract out the implementation details. Here, we'll look at the `odfpy` package.

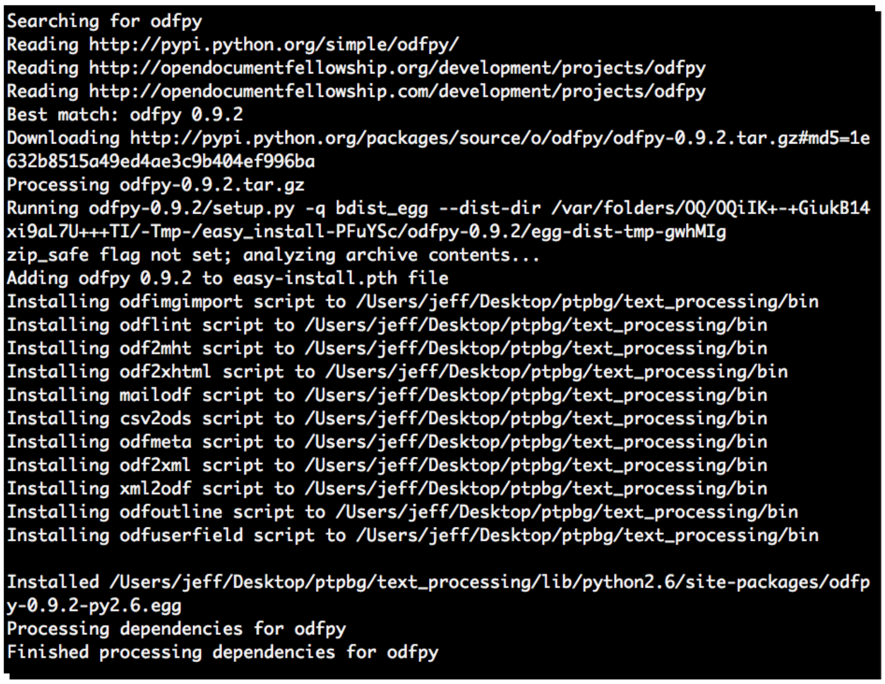
If you need to define and generate a large number of ODF files, I also suggest that you look at the `apply.pod` framework, which is available at `http://appyframework.org/`. It provides an OpenDocument-based templating system that allows you to embed Python code. It's a little advanced for our purposes, though.

OpenDocument files are understood by the OpenOffice package, as well as Microsoft Office 2007 and later. However, it's important to understand that OpenDocument is different than Microsoft's OXML format (`docx`, `xlsx`).

Time for action – installing ODFPy

Again, we'll simply be using `easy_install` to add this third-party package to our virtual environment. Go ahead and do this now.

```
(text_processing)$ easy_install odfpy
```



```
Searching for odfpy
Reading http://pypi.python.org/simple/odfpy/
Reading http://opendocumentfellowship.org/development/projects/odfpy
Reading http://opendocumentfellowship.com/development/projects/odfpy
Best match: odfpy 0.9.2
Downloading http://pypi.python.org/packages/source/o/odfpy/odfpy-0.9.2.tar.gz#md5=1e
632b8515a49ed4ae3c9b404ef996ba
Processing odfpy-0.9.2.tar.gz
Running odfpy-0.9.2/setup.py -q bdist_egg --dist-dir /var/folders/OQ/OQiIK+-+GiukB14
xi9aL7U+++TI/-Tmp-/easy_install-PFuYSc/odfpy-0.9.2/egg-dist-tmp-gwhMIg
zip_safe flag not set; analyzing archive contents...
Adding odfpy 0.9.2 to easy-install.pth file
Installing odfimgimport script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing odflint script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing odf2mht script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing odf2xhtml script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing mailodf script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing csv2ods script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing odfmeta script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing odf2xml script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing xml2odf script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing odfoutline script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing odfuserfield script to /Users/jeff/Desktop/ptpbg/text_processing/bin

Installed /Users/jeff/Desktop/ptpbg/text_processing/lib/python2.6/site-packages/odfp
y-0.9.2-py2.6.egg
Processing dependencies for odfpy
Finished processing dependencies for odfpy
```

What just happened?

Like we did with `xslt` and ReportlLab, we installed a third-party module. Take a minute to ensure the ODF libraries are installed correctly. We'll just start up Python and make sure we can import the top-level package.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import odf
>>> dir(odf)
['__builtins__', '__doc__', '__file__', '__loader__', '__name__', '__
package__', '__path__']
>>>
```

Building an ODT generator

The odfpy package that we're using is a fairly low-level package. It's possible to access the XML data directly if we so choose, though we won't be doing much of that here. The API ought to look familiar to you as we've touched on the ElementTree system in *Chapter 6, Structured Markup*.

Here, we'll look at how you programmatically build and style an OpenDocument Text file, or an **ODT**, for short.

Time for action – generating ODT data

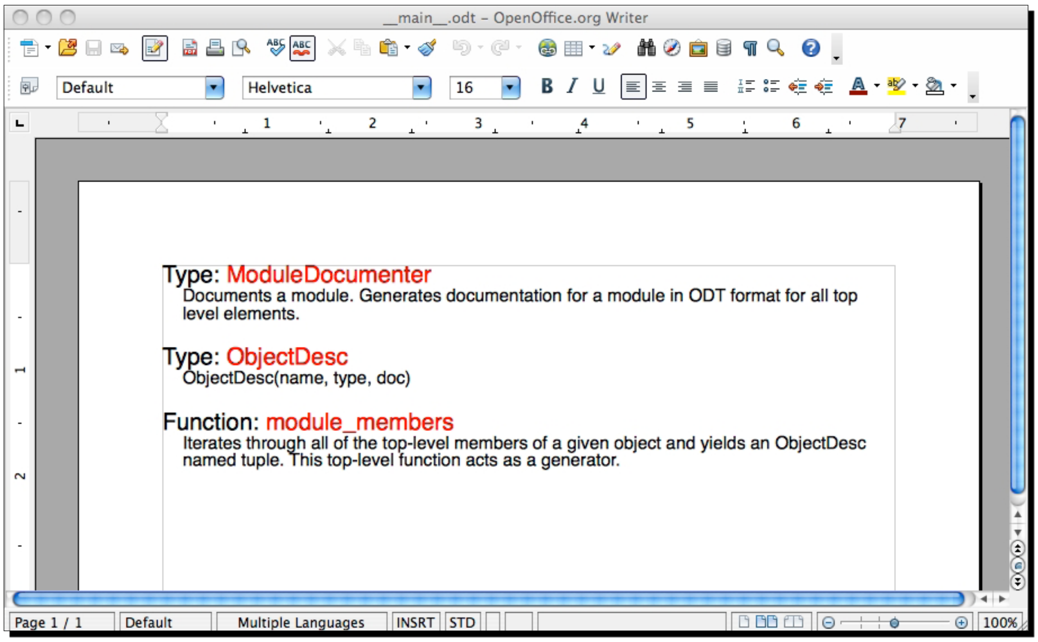
In this example, we'll build a self-documenting Python module. In fact, we'll use Python's powerful introspection functionality and the odfpy package to generate a formatted OpenDocument file that serves as API documentation!

If you haven't done so yet, take a couple of minutes and ensure you have OpenOffice installed. It is freely available at http://www.openoffice.org. OpenOffice also handles common Microsoft Office formats.

1. First, create a new file and name it odf_build.py.
2. Next, either copy over or enter the code as it appears in the ZIP bundle available for download on the Packt Publishing FTP site. We've left it out here in order to save on space.
3. Run the code listing at the command line as follows. A new file named __main__.odt should appear in the current working directory.

```
(text_processing)$ python odt_build.py
```

4. Open the new document file in OpenOffice Writer. The contents should resemble the following screenshot:



Type: ModuleDocumenter
Documents a module. Generates documentation for a module in ODT format for all top level elements.

Type: ObjectDesc
ObjectDesc(name, type, doc)

Function: module_members
Iterates through all of the top-level members of a given object and yields an ObjectDesc named tuple. This top-level function acts as a generator.

What just happened?

We used the `inspect` module to generate a snapshot of the running file. We then used that information to generate an OpenDocument text file documenting the example. Let's step through and look at the relevant parts.

The first thing we did was `import` the required objects. All style information comes from the `odf.style` module. Here, we imported `Style`, `TextProperties`, and `ParagraphProperties`. A little bit more on these in a minute. Next, we imported `OpenDocumentText` from `odf.opendocument`. We're dealing with an OpenDocument text file, so this is all we'll need.

Lastly, we bring in `P` and `Span`. These are much like their HTML counterparts. The `P` function defines a `paragraph` class that acts as a single block of content, whereas the `Span` function defines an inline text snippet that can become part of a larger paragraph.

Next, we define three styles. Each style is then referenced later when we generate our document content. As stated earlier, the `odfpy` module is generally a wrapper around `ElementTree` objects, so this approach should feel somewhat familiar to you.

Let's take a closer look at one of the style definitions.

```
DOC_STYLE = Style(name='DOC_STYLE', family='paragraph')
DOC_STYLE.addElement(
    TextProperties(
        color='#000000', fontsize='12pt', fontfamily='Helvetica'))
DOC_STYLE.addElement(
    ParagraphProperties(
        marginbottom='16pt', marginleft='14pt'))
```

Here, we create a `Style` element and name it `DOC_STYLE`. It has a family of `paragraph`. When we want to apply the style later, we'll need to refer to it by this name. The `family` attribute categorizes which type of element it will apply to. If you attempt to apply a style in a `text` family to an object created with `P`, it simply won't apply.

Next, we call `addElement` twice, each time passing in a new instance of a `properties` class. The `TextProperties` call sets the display information for the text rendered within an element implementing this style. The `ParagraphProperties` call sets properties that are unique to `Paragraph` generated elements.

The following table outlines the style options we used for paragraphs and text elements. This isn't an exhaustive list. For more information, see the `odfpy` documentation that is available at `http://www.osor.eu/projects/odfpy`.

Style attribute	**Family**	**Meaning**
`color`	text	Sets the color of the text using six-digit hexadecimal (HTML) notation.
`fontsize`	text, paragraph	Sets the size of the text rendered within the container.
`fontfamily`	paragraph, text	Sets the font face used within the container.
`margintop`, `marginleft`, `marginbottom`, `marginright`, `margin`	paragraph	Sets the margin.

Just in case you're slightly confused, each of the imported `odfpy` objects is a function. `P`, `Style`, `ParagaphProperties`. All functions. Calling them simply returns an instance of `odf.element.Element`, which is a lower-level XML construct.

Now, let's take a very brief tour of our `module_members` function. There's a little bit of magic going on here. In short, we introspect a Python module and yield information regarding each top-level function and class that it defines. The information yielded is contained in a `namedtuple` we defined previously. Python has some very powerful introspection abilities. For more information, point your browser at `http://docs.python.org/library/inspect.html`.

Our `ModuleDocumentor` class does all of the ODT file generation. In the `__init__` method, we set the output filename, create an empty `document` object, and call `self._add_styles`. If we look at `self._add_styles`, we see the following three lines:

```
self.doc.automaticstyles.addElement(TYPE_STYLE)
self.doc.automaticstyles.addElement(NAME_STYLE)
self.doc.automaticstyles.addElement(DOC_STYLE)
```

In this step, we're adding the global styles we created earlier to our new document object so they can be referenced by content. Technically, we're simply adding the XML data defined in the style objects to the generated ODT XML data.

Now, skip on down to the `__main__` section. We create an instance of `ModuleDocumenter` and pass it `sys.modules['__main__']` and the string `__main__`. What does this mean? We're passing in an instance of the currently running module.

The build method of `ModuleDocumenter` is fairly simple. We iterate through all of the results yielded by the `module_members` generator and build our documentation. As you can see, we call `self.doc.text.AddElement` twice, once with the results of `self._create_header` and once with the results of the `P` function. Again, the `addElement` approach should remind you of some of the XML processing code we examined much earlier.

The `_create_header` method first creates a new paragraph element by calling `P`. Then, it concatenates two `Span` elements using two different style names: `TYPE_STYLE` and `NAME_STYLE`. This gives our paragraph headings the look seen in the text document screenshot. We then return the new paragraph.

The underlying XML generated is as follows (though this is not important, it may help with your overall understanding):

```
<text:p>
  <text:span text:style-name="TYPE_STYLE">Type: </text:span>
  <text:span text:style-name="NAME_STYLE">ModuleDocumenter</text:span>
</text:p>
```

After generating the section header, we build a standalone paragraph, which contains the contents of each `docstring`. We simply use a different style. In all cases, the text content was passed into the `factory` function as the value to the `text` keyword argument.

The XML generated for each `docstring` resembles the following.

```
<text:p text:style-name="DOC_STYLE">ObjectDesc(name, type, doc)</
text:p>
```

Finally, we save our new ODT document by calling `self.doc.save`. Note that we don't include a file extension. The `save` method automatically decides that for us based on the document type if the second argument is `True`.

> The `odfpy` package can be somewhat confusing, and the documentation is slightly lacking. For more information, see the odfpy site at `http://odfpy.forge.osor.eu/`. If you're attempting to write more serious OpenDocument files then reading the OpenDocument standard is very much recommended. It is available online at `http://www.oasis-open.org/committees/download.php/12572/OpenDocument-v1.0-os.pdf`.

Have a go hero – understanding ODF XML files

As we've said, the OpenDocument standard is XML-based. Each ODX file is nothing more than a ZIP-compressed set of XML files (more accurately, a JAR file). Take a break from the Python code for a minute and uncompress the example file we created in this chapter. You'll learn a lot from wading through the contents.

Summary

In this chapter, we took a broad survey of three popular advanced output options. We also pointed out external resources should you need to do any in-depth work with these file types.

Specifically, we touched on the building and styling of simple PDF files using the ReportLab Toolkit, managing native Excel documents as opposed to CSV, and managing and manipulating OpenDocument files like the ones used by OpenOffice.

As a bit of a bonus, you also learned a bit more about Python's powerful introspection abilities as we built a self-documenting application.

In the next chapter we'll look at processing advanced grammars using `PyParsing` and its BNF-like notation.

10
Advanced Parsing and Grammars

In this chapter, we'll look at how to define slightly more advanced grammars using specialized syntax. We'll then learn what it takes to move from a grammar definition into running source code that can be used to process text that fits into that defined grammar. As part of the process, we'll first look at some theory behind it, and then we'll implement with the handy third-party `PyParsing` *library. We'll also examine Python's Natural Language Toolkit, which provides a high quality collection of libraries for managing human languages.*

The contents in this chapter can be used to expand into much more detailed text-processing areas. The foundation laid here, in general terms, is what programming language designers and language researchers might use. In fact, if you download a Python source distribution, you can view Python's grammar files directly!

We'll specifically look at the following points:

- **Backus-Naur Form** (**BNF**) as it's used to define context-free grammars, and what exactly that means.
- The difference between LL and LR parsers.
- Using the PyParsing libraries in a simple case, such as processing e-mail address input.
- A more advanced peek at PyParsing as we extract information from a BIND configuration file. We'll also survey some of the common objects used in conjunction with PyParsing.
- A brief introduction to the **Python Natural Language Toolkit** (**NLTK**), which provides some extended processing capabilities. We'll also look at a couple of interesting examples.

As we go through this chapter, remember that we're brushing over some of these topics without going into much detail. That's okay. The goal of this chapter is to speed up your use on PyParsing and the NLTK such that you can dive deeper into either package when you need to.

Defining a language syntax

Simply put, a **grammar** defines the syntax of a language. In a traditional language, it presents a set of rules that cover sentence structure and word organization. In English, every sentence should have both a subject and a predicate. But, how does this relate to processing textual data?

Just as natural languages have grammar rules that must be followed when authoring or speaking them, text data may also be defined using a defined set of grammatical rules. Just as an English sentence must include the components mentioned previously, we can define a non-spoken grammar that states that a number must be followed by an operator, another number, an equal sign, and then a final number. So, for example, the following string would be grammatically correct given those rules:

```
45+90=145
```

However, attempting to insert a variable into the mix would not be grammatically correct.

```
45+x=135
```

The preceding example is still mathematically valid, though it does not follow the grammar rules laid out. We're interested in grammatical correctness. During parsing, this line should generate an error. Let's take a minute and break the first equation listing previously down a bit more by splitting it into its component parts.

1. First, we have two terms. In this example, they are 45 and 90.
2. Both terms are separated by a plus sign.
3. The second term is followed by an equal sign.
4. The equal sign is followed by the value of the equation.

However, does that capture the entire grammatical definition? Well, not really. If we expand upon the above points, we can come up with a much more complete definition.

1. We have two terms, made up of one or more digits in a series between 0 – 9. There is no upper bound to the width of the number in each term.
2. We have a plus sign, which is not surrounded by any white space whatsoever.
3. Our second term is followed by an equal sign, which again is not buffered by any white space.
4. Finally, our value following the equal sign is grammatically equivalent to the terms preceding it.

Specifying grammar with Backus-Naur Form

The preceding numbered list gives us a nice description about our example equation grammar, but it isn't very computer friendly and can be up for interpretation. Enter **Backus-Naur Form** (in some contexts, you may hear **Backus-Normal Form**, they are equivalent). Backus-Naur, or BNF, gives us a method to formally specify the grammar of a text body, such as a computer programming language.

In a BNF grammar, terms on the left side are defined by terms on the right side. The combination of both terms is considered a **production**. A term is considered **terminal** if it cannot be expanded any more (such as a literal), or **non-terminal** if it is an intermediate value. Finally, BNF-defined grammars are **context free**. A context-free grammar is one in which the left side only defines a single term and does not specify a direct ordering. In contrast, a non-context-free grammar may define literals and position – or context – on the left side of the production. This definition works for our purposes.

BNF form was originally defined by John Backus and subsequently used by Peter Naur with the definition of the Algol 60 language. Wikipedia provides a good landing point for more information about BNF grammars at `http://en.wikipedia.org/wiki/Backus-Naur_Form`.

So, now that we've blurted out a big long string of vocabulary words, let's take a look at what our equation might look like when rewritten as a BNF grammar.

```
<equation> ::= <number> <op> <number> '=' <number>
<number>   ::= <digit> | <digit> <number>
<digit>    ::= '0'|'1'|'2'|'3'|'4'|'5'|'6'|'7'|'8'|'9'
<op>       ::= '+'
```

This probably looks familiar to you. If you've ever read an RFC document or a programming language specification, you've probably seen a section a lot like this. Actual syntax sometimes varies.

Looking at this example, we see that `<equation>`, `<number>`, `<op>`, and `<digit>` are all non-terminal. In other words, they should expand into something else. On the other hand, the plus sign and the list of digits are terminal literals. Once encountered, they cannot be further expanded. The second line is of special interest. This is a recursive rule. It allows us to define a number as a single digit, or a single digit followed by another number. In turn, the second number may simply be a digit, or a digit followed by another number.

Extended BNF, or **EBNF**, is an augmentation to BNF that provides for repetition and recursion via extended syntax. It's simply more concise. Any grammar that is defined in EBNF can be described in BNF as well.

This is the system largely used to define programming language syntax. There exists a collection of utilities known as compiler generators, which generate source code meant for parsing text following a specific grammar. **YACC**, for example, is an acronym for **Yet Another Compiler-Compiler**. The GNU Bison project aims to do just this. More information is available at `http://www.gnu.org/software/bison/manual/index.html`.

Grammar-driven parsing

When parsing an input stream based on a grammar definition, there are generally two common approaches – **LL** and **LR**. Note that while all LL grammars can be parsed as LR, not all LR grammars can be parsed as LL. An LL parser reads text from Left to Right, and applies rules using a left-most association. An LR parser also reads text from Left to Right; however, it applies rules using a right-most association. Both approaches are top-down and designed to handle context-free grammar definitions. Additionally, parsers are categorized by how many characters of look-ahead they require to make a decision. An **LL(1)** parser requires only one character of input at a time, whereas an **LL(k)** grammar requires up to k elements of input.

When creating an LL(1) parser, there are a couple of techniques that can be used, the simplest of which utilizes a state table. In a generic sense, a simple algorithm is as follows:

1. Create tokens for both terminal and non-terminal symbols in our grammar. We'll use this to compare values as we read them in.
2. Generate a state table, which recognizes which rule we've begun to process and updates our state accordingly.
3. Read characters from our input source one at a time and compare them against our current rule. Literals are dropped (match); characters that represent the beginning of a rule then trigger that rule to expand. The next iteration again attempts to match the expanded rule values against the input character.
4. Anything else is a syntax error.

Pretty complex, and this is just a simple case! Fortunately, we can implement grammar-based parsing in Python using the PyParsing library, without the need to worry about intricate parser details.

Parser implementation is a science in itself. It's a fundamental part of programming language design and is worth understanding in greater detail if you intend to develop a domain-specific language of your own. For more information, Wikipedia provides a wealth of information. A good starting point is `http://en.wikipedia.org/wiki/Syntax_analysis`.

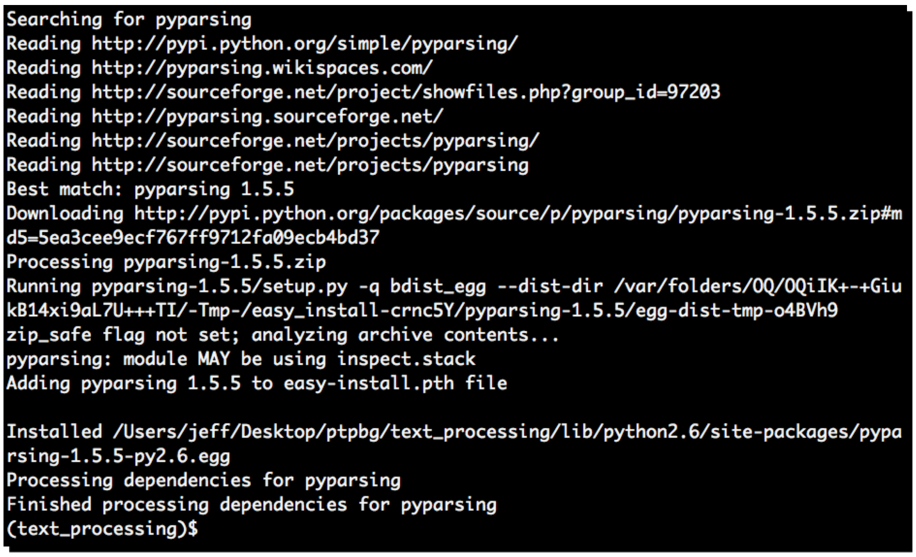
PyParsing

PyParsing is a third-party library that allows the developer to process simple grammars using native Python code. The package is quite flexible in that it provides mechanisms for simple parsing, naming results, and assigning actions to matched values. We'll take a closer look at all of these features here.

Time for action – installing PyParsing

As with other third-party utilities, it can be installed via the `easy_install` command. Go ahead and enter your virtual environment and do that now.

```
(text_processing)$ easy_install pyparsing
```



```
Searching for pyparsing
Reading http://pypi.python.org/simple/pyparsing/
Reading http://pyparsing.wikispaces.com/
Reading http://sourceforge.net/project/showfiles.php?group_id=97203
Reading http://pyparsing.sourceforge.net/
Reading http://sourceforge.net/projects/pyparsing/
Reading http://sourceforge.net/projects/pyparsing
Best match: pyparsing 1.5.5
Downloading http://pypi.python.org/packages/source/p/pyparsing/pyparsing-1.5.5.zip#m
d5=5ea3cee9ecf767ff9712fa09ecb4bd37
Processing pyparsing-1.5.5.zip
Running pyparsing-1.5.5/setup.py -q bdist_egg --dist-dir /var/folders/OQ/OQiIK+-+Giu
kB14xi9aL7U+++TI/-Tmp-/easy_install-crnc5Y/pyparsing-1.5.5/egg-dist-tmp-o4BVh9
zip_safe flag not set; analyzing archive contents...
pyparsing: module MAY be using inspect.stack
Adding pyparsing 1.5.5 to easy-install.pth file

Installed /Users/jeff/Desktop/ptpbg/text_processing/lib/python2.6/site-packages/pypa
rsing-1.5.5-py2.6.egg
Processing dependencies for pyparsing
Finished processing dependencies for pyparsing
(text_processing)$
```

What just happened?

Like we've done a few times before, we installed a third-party module. Let's make sure the install completed successfully by simply starting our interpreter and checking the package version.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import pyparsing
>>> pyparsing.__version__
'1.5.5'
>>>
```

Now, let's look at a smaller snippet to help with your understanding a bit before we get started. In the following example, we define a very basic grammar and parse the input string. Each matched token becomes an element in the returned list.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> from pyparsing import Word
>>> grammar = Word('flower') + ';'
>>> grammar.parseString("low;")
(['low', ';'], {})
>>>
```

That's generally all there is to it. We define a grammar and feed it an input stream. In this example, our grammar is composed of any word composed of the letters in the string `flower`, followed by a semicolon. The library tokenizes the input stream based on our rules and returns a list of matched tokens. We're then free to process however we wish.

Time for action – implementing a calculator

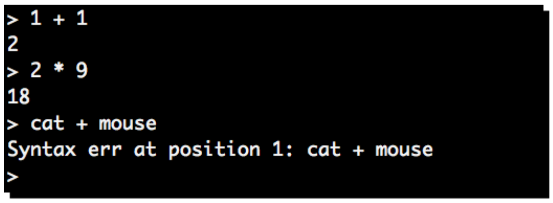
Given that our BNF example earlier in the chapter allows for simple arithmetic, it only makes sense to extend it and implement a text-based calculator as our first PyParsing example. In this example, we'll do just that. We'll only support four basic operations and will limit our example to two terms.

1. Create a new file and name it `calc.py`.
2. Enter the following Python code:

```
import sys
import operator
from pyparsing import nums, oneOf, Word
from pyparsing import ParseException

# Map math operations to callable functions within
# the operator module.
op_map = {
    '*': operator.mul,
    '+': operator.add,
    '/': operator.div,
    '-': operator.sub
}

# define grammar
MATH_GRAMMAR = Word(nums).setResultsName('first_term') + \
    oneOf('+ - / *').setResultsName('op') + \
        Word(nums).setResultsName('second_term')

def handle_line(line):
    """
    Parse a newly read line.
    """
    result = MATH_GRAMMAR.parseString(line)
    return op_map[result.op](int(result.first_term),
        int(result.second_term))

while True:
    try:
        print handle_line(raw_input('> '))
    except ParseException, e:
        print >>sys.stderr, \
            "Syntax err at position %d: %s" % (e.col, e.line)
```

3. Run the example and try a few combinations. Take note of various exception cases and syntax errors.

```
(text_processing)$ python calc.py
```



```
> 1 + 1
2
> 2 * 9
18
> cat + mouse
Syntax err at position 1: cat + mouse
>
```

What just happened?

First, we imported two modules from the standard library. The `sys` module gives us access to the standard error stream. We use the `operator` module to access simple math functions. The `operator` module provides named functions for the standard Python operators.

From the `pyparsing` package, we imported `nums`, `oneOf`, and `Word`. Each of these objects is used to generate our simple Python-based grammar later in the script, so let's look at each one in a bit more detail.

The `nums` object is simply a string containing all of the ASCII representations of digits `0 - 9`. In other words, `nums.isdigit` would return `True`. Next, we have the `oneOf` object. This is a function that generates an instance of `pyparsing.Regex`. Lastly, we have the `Word` object. This is a class that matches words that are composed of characters passed in during instance creation.

Now, with that background, we introduce the following grammar, which has been simplified here for discussion:

```
Word(nums) + oneOf('+ - / *') + Word(nums)
```

In English, this states that we want a word that is made up of only digits, followed by only one of the characters in the operator set, followed by another word that is made up of only digits. The PyParsing library overrides `__add__` such that chaining objects together like this creates a `pyparsing.And` class. The resulting scan operation requires that all elements in its set match.

In this example, we called `setResultsName` for each element in `MATH_GRAMMAR`. This lets us refer to the matched values in a cleaner fashion, rather than relying on messy and error-prone array indexing. Our first example snippet returned a simple list. Referencing a larger return set via indexing would make for some rather ugly Python code!

Now, we can skip to our `handle_line` function. Here, we accept a single parameter, which is the result of a `raw_input` call. We pass that value to `MATH_GRAMMAR.parseString`. If the text entered by the end user matches the grammar we defined then we perform the math operation and return the value.

The `parseString` method is one of a few different approaches towards reading and handling input text. This method is much like the `re.match` function we covered in an earlier chapter. It expects the entire input string to match the specified grammar. In addition, the following driver functions are available on PyParsing objects:

Method	**Description**
`parseFile`	Execute the parse expression on the given file or file name. If this method is passed a file name as opposed to a file-like object, the file is opened, read in is entirety, and then parsed.
`parseWithTabs`	By default, `parse*` methods expand tabs to spaces. This method overrides that functionality. Note that this doesn't actually take an input source; rather, it must be called prior to the parse methods to tell the parser that tabs should not be expanded.
`scanString`	Scans the input string for occurrences of the expressions. This is a generator that yields a tuple of the form (`matched`, `start pos`, `end pos`) for each match in the given input string.
`searchString`	Given an input string, this method returns expression matches found anywhere in the string.

If a parsing error occurs, the `parseString` method will raise a `ParseException`. We catch that in this example and print out some helpful diagnostic information to the console. In addition to the entire input string, the following information is also available on this exception object.

Attribute	Description
`lineno`	The line number of the exception text. This is especially relevant when parsing using `parseFile`.
`col`	The column where the parsing error occurred.
`markInputLine`	This method extracts the exception line from the input string and marks the location of the exception.

Finally, in our example, we print the calculated value of the exception text to the screen (errors are directed to standard error).

Parse actions

In the previous example, we translated our matched terms to integer types by calling the `int` factory method directly. While this is technically correct, PyParsing provides a much cleaner and event-driven way of handling this.

Time for action – handling type translations

Each PyParsing object allows us to set an associated action that is triggered in the event of a match by calling the `setParseAction` method before attempting to scan the input string. In this example, we'll modify our little calculator program to handle type translations that way.

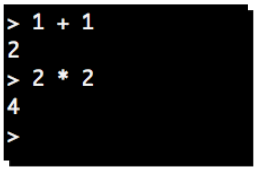
1. Using `calc.py` as a template, create a new file, and name it `calc-b.py`.
2. Update the listing to contain the following code:

```
import sys
import operator
from pyparsing import nums, oneOf, Word
from pyparsing import ParseException

# Map math operations to callable functions within
# the operator module.
op_map = {
    '*': operator.mul,
    '+': operator.add,
    '/': operator.div,
    '-': operator.sub
}

def to_i(s, loc, toks):
    """Translate to int"""
    return int(toks[0])

# define grammar
```

```
MATH_GRAMMAR = Word(nums).setResultsName('first_term').
setParseAction(to_i) + \
    oneOf('+ - / *').setResultsName('op') + \
    Word(nums).setResultsName('second_term').setParseAction(to_i)
def handle_line(line):
    """
    Parse a newly read line.
    """
    result = MATH_GRAMMAR.parseString(line)
    return op_map[result.op](result.first_term,
        result.second_term)
while True:
    try:
        print handle_line(raw_input('> '))
    except ParseException, e:
        print >>sys.stderr, \
            "Syntax err at position %d: %s" % (e.col, e.line)
```

3. Run the example and evaluate a few arithmetic expressions to ensure your changes work as expected.

```
(text_processing)$ python calc-b.py
```



```
> 1 + 1
2
> 2 * 2
4
>
```

What just happened?

We made a couple of small updates to our application so that our type translations happen as our input is parsed, rather than after the fact. Let's look at what we did.

First, we added our `to_i` function. This serves to transform text representations of numbers into integers. When called by the PyParsing engine, it is passed three arguments: the original string, the location of the match, and each individual token in list format. As we're matching an entire word here, it's safe to translate the value at a zero index.

We're confident this translation will occur without exception. In order to trigger the call back in the first place, the string must have matched the equivalent of a `^[0-9]+$` regular expression.

Next, we assign the callbacks via `setParseAction` methods on the PyParsing objects. Each time a match occurs, our method will be called with the previously-described arguments. As our `to_i` function returns a value, it is returned when `parseString` returns rather than what was originally matched.

Finally, we simply update our `handle_line` function to no longer do the integer translation as that's no longer needed.

This is a rather powerful construct as it allows us to translate matched tokens into any value we'd like. Or, we can simply leave them alone and trigger an unrelated action, such as keeping a tally.

Have a go hero – using events to lookup operators

Our operator lookup within `handle_line` is still slightly difficult to read. As it's possible to return any data type we'd like from the callback registered with `parseAction`, update the application to return the `operator` module function corresponding to the requested mathematical operation in a more event-driven fashion. In short, do the map lookup in a registered function.

Suppressing parts of a match

In some situations, you'll want to match based on a somewhat complicated pattern, but only extract a subset for actual use. In many situations, the initial approach would be to perform your PyParsing match, but then extract your useable data via string manipulation. PyParsing provides a useful suppression mechanism and keeps us from having to do this.

Time for action – suppressing portions of a match

In this example, we'll write a simple grammar for parsing a BIND DNS configuration file. In our regular expressions chapter, we learned out to process a zone file. In this example, we'll extract data from a `/etc/named.conf` file using PyParsing.

1. First, we'll create some input data. Create a file named `named.conf` and copy in the following data. This example leaves off the values found in a `named.conf options` section for brevity.

```
zone "example01.com" IN {
    type master;
    file "example01.com.dns";
    allow-update { none; };
};

zone "example02.com" IN {
    file "example02.com.dns";
    type master;
    allow-update { none; };
};
```

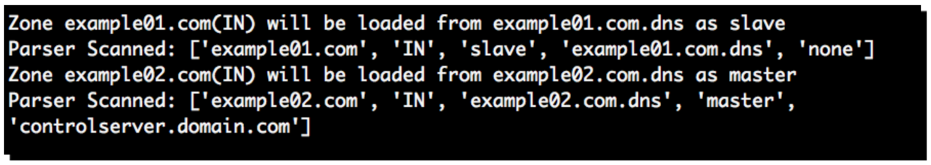
2. Now, create a Python script named `conf_parse.py` and enter the following code listing:

```
import sys

from pyparsing import Word, Suppress
from pyparsing import And, Or
from pyparsing import Literal, QuotedString
from pyparsing import Optional, alphas

# Some Standard tokens that we'll find in
# a BIND configuration.
stmt_term = Suppress(';')
block_start = Suppress('{')
block_term = Suppress('}') + stmt_term

def in_block(expr):
    """
    Sets a config value in a block.

    A block, in this case, is a curly-brace
    delimited chunk of configuration.
    """
    return block_start + expr + block_term

def in_quotes(name):
    """
    Puts a string in between quotes.
    """
    return QuotedString('"').setResultsName(name)

# Zone type, whether it's a master or a slave zone
# that we're loading.
type_ = Suppress('type') + \
    Or((Literal('master'), Literal('slave')
        )).setResultsName('type_') + stmt_term

# Zone file itself.
file_ = Suppress('file') + in_quotes("file") + stmt_term

# Where we can receive dynamic updates from.
allowed_from = Or((Literal('none'), Word(alphas + '.')
        )).setResultsName('update_from') + stmt_term

# Dynamic update line
allow = Suppress('allow-update') + in_block(allowed_from)

# Body can be in any order, we're not picky
```

```
    # so long as they all appear.
    body = type_ & file_ & allow

    # define a zone configuration stanza
    zone = Suppress('zone') + in_quotes("zone") + \
        Optional('IN', default='IN').setResultsName('class_') +\
            in_block(body);

    if __name__ == '__main__':
        for z in zone.searchString(open(sys.argv[1]).read(),):
            print "Zone %s(%s) will be loaded from %s as %s" % \
                (z.zone, z.class_, z.file, z.type_)

            # For debugging and example purposes
            print "Parser Scanned: %s" % z
```

3. Now, let's run the example at the command line:

```
(text_processing)$ python conf_parse.py named.conf
```



```
Zone example01.com(IN) will be loaded from example01.com.dns as slave
Parser Scanned: ['example01.com', 'IN', 'slave', 'example01.com.dns', 'none']
Zone example02.com(IN) will be loaded from example02.com.dns as master
Parser Scanned: ['example02.com', 'IN', 'example02.com.dns', 'master',
'controlserver.domain.com']
```

What just happened?

Let's look at this from two different angles. First, we'll break down the structure of the configuration file into a series of logical rules so we can understand how it should be parsed. Next, we'll look at the code as implemented.

Understanding BIND configuration format

The configuration file format is fairly straightforward, though a bit complex. The language is rich and uses braces and semicolons to delineate statements and configuration stanzas. Given the preceding snippet, we'll define our PyParsing grammar using the following guidelines:

1. Each stanza should begin with the literal keyword `zone`. This marks the beginning of a standalone zone configuration.
2. The zone keyword should be followed by a zone name, enclosed in double quotes. This is the name of the DNS zone that BIND will serve. The name should be followed by an optional IN keyword, which is the DNS class.
3. An open curly brace begins the configuration scope for the zone named in step two. Points four, five, and six can occur in any order, but they must be present here in our example.

4. The keyword `type`, followed by slave or master. This dictates whether or not the zone is a master zone or should be loaded from a master server (yes, we left something off here).
5. The keyword `file`, followed by the name of the zone file containing records for this specific zone. The filename should be in double quotes.
6. The keyword `allow-update`, followed by the beginning of a new block. The block should contain either the keyword `none` or the name of a host that can issue dynamic updates for this zone. The block should then close.
7. A closing brace, followed by a semicolon. This ends the configuration scope for a specific zone.

Now, every logical element (statement) should be ended with a semicolon. This includes single configuration directives as well as end-of-block (`}`) identifiers.

[Whitespace is also insignificant in a BIND configuration file. We should simply ignore it and use the tokens above. It has no meaning.]

Implementing parser

We then put together a script, which does some elementary parsing of our BIND configuration file. We don't support the full grammar, but now that we've built out an example that shouldn't be too difficult to do.

First, we defined some global terms – `stmt_term`, `block_start`, and `block_term`. However, unlike previous examples, we wrapped our string literals in a `Suppress` object. This approach lets us require the tokens for a correct parse, but does not include them in the list that is returned. Basically, we're ignoring tokens that have no meaning other than providing for layout. For example, without `Suppress`, we might expect to see the following:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> from pyparsing import Word, Suppress
>>> grammar = Word('abc') + ';'
>>> grammar.parseString('a;')
(['a', ';'], {})
>>>
```

Notice how the results returned include the semicolon. While it's required for syntactical correctness (as per our own definition), we don't so much care about it in our results. By wrapping the literal in a `Suppress` object, we alter the returned values.

```
>>> grammar = Word('def') + Suppress(';')
>>> grammar.parseString('f;')
```

```
(['f'], {})
>>> grammar.parseString('f')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "/Users/jeff/Desktop/ptpbg/text_processing/lib/python2.6/
site-packages/pyparsing-1.5.5-py2.6.egg/pyparsing.py", line 1100, in
parseString
    raise exc
pyparsing.ParseException: Expected ";" (at char 1), (line:1, col:2)
>>>
```

Here, we see that the semicolon is no longer included in the returned value. However, also note that if we fail to include it, we run into a `ParsingException` because we didn't fall in line with our supplied grammar definition.

Next, we defined a pair of helper functions, `in_block` and `in_quotes`. These functions ought to be fairly straightforward. The first takes an expression and wraps it in our defined `block_start` and `block_term` tokens. The expression can either be a plain text literal or a PyParsing object set. The `in_quotes` generates a `QuotedString` object and gives it a results name, like we covered earlier. The `QuotedString` object matches strings in the form of `"test"` or `"filename.txt"`. The resulting object already has its quotes stripped off for us by default.

Next, we define our configuration file grammar using PyParsing objects. In order, we define our zone type, zone file, allowed update clients, and our allowed update configuration block. Finally, we combine all of those as a body using the logical-AND operator. PyParsing overrides `__and__` such that each value is matched, but in any order.

Finally, we build our zone grammar by matching the zone keyword and zone name followed by the optional `IN`. Finally, we match the body by appending the value of `in_block(body)` to the object we're building up.

Now, jump down to the `__name__ == '__main__'` section. Here, we open our input file and read it in. We iterate over the results of `zone.searchString` and print out information regarding the entire zone definitions found in the file.

PyParsing objects

We introduced quite a few new objects to the mix in the previous example. Let's take a quick survey of some of the other parsing classes available within PyParsing. This isn't all-inclusive. For more information, please see the PyParsing API documentation available at `http://pyparsing.wikispaces.com/Documentation`.

Here, we'll take a quick survey of the following classes.

- `And`
- `CharsNotIn`
- `Combine`
- `FollowedBy`
- `Keyword`
- `Literal`
- `MatchFirst`
- `NotAny`
- `OneOrMore`, `ZeroOrMore`
- `Regex`
- `StringStart`, `StringEnd`
- `White`

And

This class requires that all expressions be matched in the given order. Expressions may be separated by white space. Using the + operator to concatenate expressions results in the creation of an `And` object that includes all of those expressions.

CharsNotIn

This class is responsible for matching words built from characters that are not in a given sequence. This can be thought of as the negation of a Word object. For example, consider the following snippet.

```
>>> g = pyparsing.CharsNotIn('abcd')
>>> g.parseString('def')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "/Users/jeff/Desktop/ptpbg/text_processing/lib/python2.6/
site-packages/pyparsing-1.5.5-py2.6.egg/pyparsing.py", line 1100, in
parseString
    raise exc
pyparsing.ParseException: Expected !W:(abcd) (at char 0), (line:1,
col:1)
>>> g.parseString('xyz')
(['xyz'], {})
>>>
```

As expected, the result is the opposite that we would expect from a Word object. This is a useful approach if you're attempting to weed unwanted characters out of a string value.

Combine

This class combines all matched tokens into a single result string. This one is easier explained with an example rather than a description.

```
>>> g = pyparsing.Combine(pyparsing.Word("flower") + '-' + pyparsing.
Word("power"))
>>> g.parseString('low-rope')
(['low-rope'], {})
>>>
```

Note that the results include only a single string with a value of `low-rope`. Without using the `Combine` class, the results would be returned as `['low', '-', 'rope']`.

FollowedBy

This class performs a look-ahead match. Much like its regular expression cousin of the same name, it does not advance the parse position and it returns a null token. This is helpful for matching conditionally.

Keyword

This class matches a specified string as a keyword. A **keyword** is defined as a string that is immediately followed by a non-keyword character. So, to reuse our configuration parser example, we could have specified our zone type as follows:

```
>>> k = pyparsing.Keyword('type') + pyparsing.Word(pyparsing.alphas) +
';'
>>> k.parseString('type master;')
(['type', 'master', ';'], {})
```

Literal

We've used this class in a few places so far. A `Literal` object defines just that, a string `Literal`. In contrast to `Word`, `Literal` only matches exactly. `Word` will match any word made up of allowed characters. Including a literal string in an expression causes the literal string to be wrapped by `Literal`.

MatchFirst

This class requires that at least one expression matches (multiple may be passed as a sequence into the `__init__` method). If more than one match is found, the first one is returned. This object may be constructed with the logical | operator as the `__or__` special method is overridden on PyParsing objects.

NotAny

This class is also a look-ahead operation. Like `FollowedBy`, it does not advance parse location within the given input string. It simply ensures the input string does not match at the current location. It does not skip over white space. Also, it may be built using the logical-NOT operator, '~'.

OneOrMore, ZeroOrMore

Given an expression, these elements match a collection of expressions. Additionally, if wrapped in a Group, all of the matches are returned in a sub-list of the return value. Let's look at a small example here.

```
>>> g = pyparsing.Group(
…    pyparsing.OneOrMore(pyparsing.Literal('a'))) + 'b' + 'c'
>>> g.parseString('aaaaabc')
([(['a', 'a', 'a', 'a', 'a'], {}), 'b', 'c'], {})
>>>
```

As `a` was wrapped in a `OneOrMore` clause, which was in turn wrapped in a `Group` class, all of the `a` values are returned in a single list. The subsequent matches, however, are not. This of course is not constrained to literals. The expression objects can be of arbitrary complexity.

Regex

This class matches strings that match a given regular expression. It also uses the built-in Python regular expression engine, so any valid Python regular expression is valid here.

StringStart, StringEnd

Much like ^ and the `$` regular expression anchors, `StringStart` and `StringEnd` match if the parser position is either at the start, or at the end, of the input string.

White

This class matches white space. Normally, PyParsing treats white space as insignificant. Use this if you need to ensure proper white space layout. By default, new lines, carriage returns, tabs, and spaces are included. It is possible to override this behavior by passing a `ws` keyword argument containing a sequence of valid white space characters.

Debugging

All of these objects inherit from `ParserElement`. They all may be used as an entry point into the parser by calling the appropriate methods. Additionally, they all support a `setDebug` method, which enables the display of debugging messages generated while running through pattern matching. This is a very useful tool when a defined grammar simply isn't matching as you understand it should. For example, let's set the debugging flag on a small example and look at the output generated by the parser.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> from pyparsing import Word
>>> w = Word("underground") + '-' + Word("party")
>>> w.setDebug()
{{W:(unde...) "-"} W:(part...)}
>>> w.parseString('nerd-art')
Match {W:(unde...) "-" W:(part...)} at loc 0(1,1)
Matched {W:(unde...) "-" W:(part...)} -> ['nerd', '-', 'art']
(['nerd', '-', 'art'], {})
>>>
```

As you can see, the parser tells us what it's doing so we can follow through. Take a minute to enable debugging output on our configuration file parser – it can get quite verbose!

Have a go hero – extending our configuration file parser

The systems administrators out there probably noticed a few problems with our BIND configuration parser. In fact, we've left out quite a bit. Using the BIND 9 configuration reference, which is available at `http://www.bind9.net/manual/bind/9.3.2/Bv9ARM.ch06.html`, ensure that we fully support `allow-update` and the configuration of a master server for zone transfers should the configured zone type be a slave. Of course, you're more than welcome to implement an entire parser if you would like!

Processing data using the Natural Language Toolkit

The **Python Natural Language Toolkit** (**NLTK**) is another third-party application used for processing textual data. The NLTK, however, is geared more towards natural language understanding. In this context, a natural language is one used every day such as English, Russian, or French.

In addition to a collection of parsers, the NLTK includes advanced utilities such as stemming, tokenizing, and classification. Classification in this sense means advanced computer-learning algorithms such as Bayes classifiers and k-means clustering.

You're probably already familiar with the Bayesian filters and don't even realize it! If you've ever trained your mail reader to understand what spam looks like, you've probably been training a Bayesian system.

Time for action – installing NLTK

By now, you should know the drill. To install NLTK, you'll simply use the `easy_install` utility as we have previously. Go ahead and do that now. We'll leave off the `easy_install` output this time in order to conserve a few additional trees. As an aside, if you receive an error about a missing `yaml` module, you'll need to run `easy_install pyyaml` as well.

Once the install is completed, let's go ahead and import the module and check the version. This way, we know we installed NLTK correctly.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import nltk
>>> nltk.__version__
'2.0b9'
>>>
```

What just happened?

We installed the most recent version of NLTK from the Python Package index locally into our virtual environment.

We're running a pre-release of NLTK 2.0 here; your version may be slightly different. However, that shouldn't cause a problem.

NLTK processing examples

We'll look at a couple of small examples here. The Python NLTK has excellent documentation available online. If you're interested in natural language processing, reading it is a must. For more information, point your browser to `http://www.nltk.org/documentation`.

[As of the time of writing, Python 3 is not supported by the NLTK. Examples require Python 2.]

Removing stems

Words are often composed of a stem and a suffix. For example, take the word "`processed`". The stem of this word is `process` and it has a `-ed` suffix. The suffix indicates a past tense action. In this case, the action of processing has completed (we just used another, catch that?). We also see this when we make a singular into a plural. For example, when we go from having one elephant to having 16 elephants.

The problem is further complicated when internationalization makes it into the picture. While the plurality rules for English are fairly straightforward, that's not always the case. Russian, for example, changes the suffix for plurals based on word gender, case, or even whether or not the object is alive (and any associated adjectives change, too!).

Fortunately, this is handled relatively easy with NLTK. The following snippet outlines how this can be handled:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> from nltk import stem
>>> stemmer = stem.PorterStemmer()
>>> for word in 'The dinosaurs once roamed the earth!'.split():
...     stemmer.stem(word)
...
'The'
'dinosaur'
'onc'
'roam'
'the'
'earth!'
```

Here, we created an instance of the `PorterStemmer` class and used it to remove suffixes from the words in our example sentence. However, note what happens with the word `once`. The response isn't quite what we expected when we pass a word without a suffix.

Discovering collocations

A **collocation** is a collection of words that often appear together. A pairing is a termed **bigram** and a triple is referred to as a **trigram**. Given a segment of text, our goal is to parse through and discover common, related phrases. The following example uses the raw text of Mary Shelley's **Frankenstein** as its input data:

```
(text_processing)$ python
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> from nltk.collocations import BigramCollocationFinder
>>> from nltk.collocations import BigramAssocMeasures
>>> bigrams = BigramAssocMeasures()
>>> finder = BigramCollocationFinder.from_words(open('monster.txt').
read().split())
>>> finder.nbest(bigrams.pmi, 10)
```

```
[('"\'Great', "God!'"), ('"\'Heaven', 'forbid!'), ('"Compose',
'yourself,"'), ('"Devil,', 'cease;'), ('"Get', 'well--and'), ('"God',
'knows,"'), ('"Justine', 'Moritz!'), ('"Last', 'Thursday'), ('"No,',
'Justine,"'), ('"Poor', 'William!"')]
>>>
```

In this little example, we read in the contents of our source and split on white space. This became our input stream of words. Next, we created a `finder` based on our word list. Finally, we found the top bigrams by calling the `nbest` method of our finder object. If we wished to look for trigrams, we would use `TrigramCollocationFinder` instead.

If we want to refine our results, we can limit our results to words that appear a minimum number of times as well. This approach may provide for more accurate results depending on the source data and expected usage.

Summary

In this chapter, we covered some parser basics up front in order to help you understand what goes into libraries such as PyParsing and NLTK. It's generally not necessary to implement your own LL or LR parser as there are some very high quality third-party libraries that already contain high quality implementations.

We then moved on to our introduction of PyParsing and NLTK. Specifically, we went over grammar definitions, parsing terminology, and BNF grammars.

Once we covered some background, we looked at using PyParsing to handle a range of jobs from a simple calculator to a more complex configuration file parser. We then moved on to the Python Natural Language Toolkit.

The next chapter will cover how to search and index textual data. We'll also look at indexing and accessing text data that isn't in plain text format.

11
Searching and Indexing

In this chapter, we'll look at two closely related topics: indexing and searching. Why are they related? Simple. Sure, you can search without an appropriate index, but you'll quickly run into performance troubles as your dataset grows beyond a trivial size. If you've ever done any sort of database-driven development, consider the performance problems you might have run into when testing for a value in a non-indexed column.

We'll introduce you to some methods for searching, but more importantly, indexing your data for more efficient search times in this chapter. Our concentration will be on building an index, which you'll then search against. Specifically, we'll dive into the following topics in some form:

- Searching for texts using a straight scan and why this is a poor technique for looking through large files.
- Building full-text indexes using the Nucular third-party package.
- We'll cover what's involved with maintaining a text index created with the Nucular package.
- Extended abilities of Nucular such as word proximity and separating data into fields.
- Extracting searchable content out of proprietary and non-textual formats such as Microsoft Word and Adobe PDF.

Yes, we know Nucular is spelled incorrectly. The fine folks that created and maintain the code base chose that spelling. If you're interested in learning why they chose it, see their project website at `http://nucular.sourceforge.net/`.

Understanding search complexity

Searching and indexing is one area in which plenty of research has been completed. While it may seem simple on the surface, it's actually a rather complex problem. For example, consider the possible runtime of even the simplest approach.

The naïve approach one might take when attempting to find a value in a text collection would be to simply iterate through the source data line by line while attempting to find the string in each line. Let's take a look at that approach.

Time for action – implementing a linear search

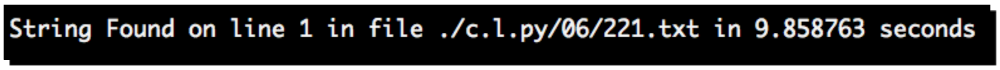
In this example, we'll use a collection of messages from the `comp.lang.python` newsgroup and mailing list. That provides for a nice large dataset spread across multiple files. The message text files are available on the Packt Publishing site in FTP format.

1. Create a new file and name it `text_scan.py`. You should then enter the following code:

```
#!/usr/bin/env python

import os
import sys
import time
from optparse import OptionParser

class StringNotFoundError(Exception):
    """String was not found"""

def search_dir(dirpath, string):
    """Search a file for a string"""
    where = 0
    for base_dir, dirs, files in os.walk(dirpath):
        for f in files:
            open_path = os.path.join(base_dir, f)
            with open(open_path) as fhandle:
                for line in fhandle:
                    if string in line:
                        where += 1
                        return where, open_path

    # if we get here, it wasn't found.
    raise StringNotFoundError(
        "We didn't see %s at all" % string)

if __name__ == '__main__':
    parser = OptionParser()
    parser.add_option('-H', '--haystack',
        help="Base directory to search")
    parser.add_option('-n', '--needle',
        help='What to look for')
    opts, args = parser.parse_args()
    if not opts.needle or not opts.haystack:
        parser.error('Needle and haystack required')
    try:
        start = time.time()
        line, path = search_dir(opts.haystack, opts.needle)
        print "String Found on line %d in file %s in %f seconds" % \
                (line, path, time.time() - start)
    except StringNotFoundError, e:
        print >>sys.stderr, str(e)
```

2. Now, let's run the example once in order to test functionality. Enter the command as follows.

```
(text_processing)$ python text_scan.py -H ./c.l.py/ -n 'b20845b1-7113-4768-9868-85e41d690c35'
```



```
String Found on line 1 in file ./c.l.py/06/221.txt in 9.858763 seconds
```

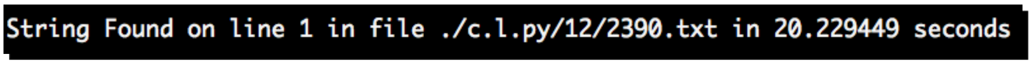
What just happened?

We implemented a simple method for scanning text for a contained value. This code shouldn't require much explanation as we really haven't introduced any new concepts here.

In short, we simply walked through a directory containing all of the messages sent to `comp.lang.python` for a period of one year. For each month, we read all of the available posts. Then, we scanned each post for the given text. In this case, the given text was the message ID of a message in July.

Now, what do you suppose the major drawback to this method is? If you look at the example output, you'll see that our match occurs in just about 9.8 seconds. Now, July isn't going to be the last month searched. Let's update our scan to check for the message ID of a post sent in December.

```
(text_processing)$ python text_scan.py -H ./c.l.py/ -n \
        '4dc0cfea0912241010k5600206bk21ae97a5c284eb05'
```



```
String Found on line 1 in file ./c.l.py/12/2390.txt in 20.229449 seconds
```

Wow! When our match occurs at the midway point, our code completes execution in less than ten seconds. That may be acceptable in some circumstances. But, when we search for a string that occurs near the end of the year, our search takes over 20 seconds. That's more than twice as long as our first search. What do you suppose would happen if we had a text input source 100 times larger than this? Perhaps 1,000 times larger?

This is an example of a linear algorithm. The amount of time it takes to complete is a function of the size of the input data and it's directly proportional. For every byte added, our search time theoretically increases by the same time period (however small). It should be clear that this approach is fine when searching small amounts of data, but becomes unusable when the source text grows (or has to be accessed often).

Algorithm complexity is really beyond our scope; however, it's an interesting topic. Usually, complexity is written in "**big-oh**" notation. Algorithms tend to fall into buckets such as `O(n)`, `O(log n)`, `O(n2)`, and so on. If you're interested in reading up on analysis techniques, O'Reilly's *Practical Algorithms in C* gives quite a nice overview on it.

Have a go hero – understanding why this is bad

Take a minute and run a few sample searches on the data and plot the time on a piece of paper. Along the x-axis, keep track of where your match happened. Along the y-axis, mark the time. When you connect the dots, you'll see what we mean by linear growth!

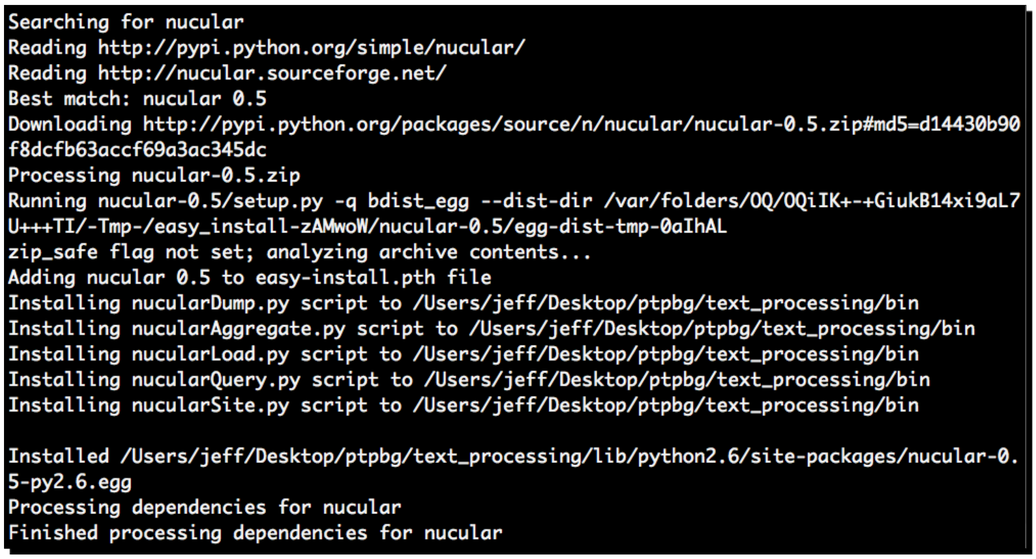
Text indexing

Now that we've explained how searching a datasource in a linear fashion can hurt your application's performance, we'll look at how you can speed it up by adding an index to it. In this example, we'll use the Nucular libraries. Nucular is a third-party package, which is installable via `easy_install`.

Time for action – installing Nucular

Let's go ahead and add the package to your virtual environment now. The following steps should look familiar to you as we've run through this quite a few times so far:

```
(text_processing)$ easy_install nucular
```



```
Searching for nucular
Reading http://pypi.python.org/simple/nucular/
Reading http://nucular.sourceforge.net/
Best match: nucular 0.5
Downloading http://pypi.python.org/packages/source/n/nucular/nucular-0.5.zip#md5=d14430b90
f8dcfb63accf69a3ac345dc
Processing nucular-0.5.zip
Running nucular-0.5/setup.py -q bdist_egg --dist-dir /var/folders/OQ/OQiIK+-+GiukB14xi9aL7
U+++TI/-Tmp-/easy_install-zAMwoW/nucular-0.5/egg-dist-tmp-0aIhAL
zip_safe flag not set; analyzing archive contents...
Adding nucular 0.5 to easy-install.pth file
Installing nucularDump.py script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing nucularAggregate.py script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing nucularLoad.py script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing nucularQuery.py script to /Users/jeff/Desktop/ptpbg/text_processing/bin
Installing nucularSite.py script to /Users/jeff/Desktop/ptpbg/text_processing/bin

Installed /Users/jeff/Desktop/ptpbg/text_processing/lib/python2.6/site-packages/nucular-0.
5-py2.6.egg
Processing dependencies for nucular
Finished processing dependencies for nucular
```

What just happened?

We've installed another third-party module. It should be pretty apparent by now that both SetupTools and Distribute provide a very standard and common method for bundling and distributing packages.

An introduction to Nucular

Now that you've installed the required frameworks, let's take a minute to look at some basic usage.

When using Nucular, you'll need to provide an index directory. This directory then becomes your index database. Index information is stored on disk as plain files rather than in a more complex database structure. The following code creates a simple index directory.

```
(text_processing)$ python
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> from nucular import Nucular
>>> session = Nucular.Nucular('nuke')
>>> session.create()
```

In the preceding example, we passed in a directory named `nuke`, which will become the location of our index database. The object returned is an instance of `Nucular.Nucular` and will be the entry point for all of our work with our newly-created text index.

[Note that the directory specified in the Nucular call does not need to exist; the framework will create it for us. However, if the directory already exists, Nucular will not remove contents unless you tell it to.]

Now that we have a configured data store and a session object, the next step is to stick some information in there. This is done by creating dictionaries that contain the information we wish to make searchable. Let's add some data to our index.

```
>>> session = Nucular.Nucular('nuke')
>>> dog = {'breed': 'Siberian Husky', 'color': 'White and Grey',
'happy': 'Being Cold'}
>>> dog2 = {'breed': 'Basset Hound', 'color': 'Brown', 'happy':
'sleeping'}
>>> session.indexDictionary('siberian', dog)
>>> session.indexDictionary('basset', dog2)
>>> session.store(lazy=False)
```

Well, that was pretty easy! We simply create a series of dictionaries and add an index to them by calling the `indexDictionary` method of our session object. However, the last line is somewhat interesting. We specified a `lazy=False` keyword argument. By default, new entries are not visible until an archive has been aggregated. This may be done directly via Python, or by the `nucularAggregate.py` script that was installed into your path when we ran `easy_install`.

The aggregation updates index structures and makes new entries visible. Applications that write frequently would be better off batching whereas applications that write infrequently can benefit from immediate aggregation.

[Waiting too long between aggregations may cause performance problems. Doing it in real time may also cause performance issues. The trick is to find a proper balance, depending on your workload.]

Now that we have data in our session, we can begin a search on it using a series of different methods. Let's take a look at a very simple search.

```
>>> query = session.Query()
>>> query.anyWord('Grey')
>>> query.resultDictionaries()
[{'color': 'White and Grey', 'i': 'siberian', 'breed': 'Siberian
Husky', 'happy': 'Being Cold'}]
>>>
```

Again, this is a fairly straightforward operation. The `query.anyWord` method searches the index for the appearance of the word in the query, in any field of the dictionaries. If we wanted to specify multiple words, we could do so by calling `query.anyWord` multiple times.

```
>>> query = session.Query()
>>> query.anyWord('Grey')
>>> query.anyWord('sleeping')
>>> query.resultDictionaries()
[]
>>>
```

Notice here that the result returned is an empty list. This is because the operation is a logical-AND. Both words must be present in a given dictionary.

In addition to the `anyWord` query method, there are a series of other approaches available. The following table outlines other methods of querying a Nucular index.

Method	Description
`attributeRange`	Selects values where a specific attribute lies within an alpha range.
`attributeWord`	Matches when a specific word is included within a specific attribute.
`matchAttribute`	Selects entries where the specified attribute exactly matches a value.
`prefixAttribute`	Selects entries where an attribute's value starts with a certain value.
`proximateWords`	Selects entries where a word sequence appears in order near each other in a given attribute.

Time for action – full text indexing

In this example, we'll create a **full text index** using Nucular for our large set of data. We'll use the same `comp.lang.python` messages as used previously, which are available via the Packt Publishing FTP site. We'll only index individual months at a time in order to keep our examples manageable. In aggregate, that gives us over 85,000 files to work with totaling up to 315 MB of raw text data.

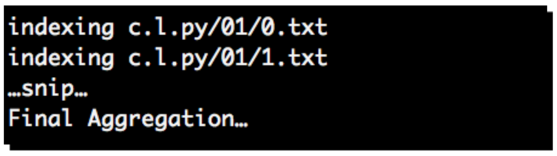
In creating a full text index, we won't separate each message out into its component parts. All of the text for each message will become a single attribute within each Nucular entry.

1. Create a new file and name it as `clp_index.py`. We'll use this to generate our index. Enter the following code:

```
import os
from optparse import OptionParser
from nucular import Nucular

def index_contents(session, where, persist_every=100):
    """Index a directory at a time."""
    for c, i in enumerate(os.listdir(where)):
        full_path = os.path.join(where, i)
        print 'indexing %s' % full_path
        session.indexDictionary(
            full_path, {'full_text': open(full_path).read()})
        # Save it out
        session.store(lazy=True)
        if not c % persist_every:
            print "Aggregating..."
            session.aggregateRecent(verbose=False, fast=True)

    print "Final Aggregation..."
    session.aggregateRecent(verbose=False)
    session.moveTransientToBase()
    session.cleanUp()
if __name__ == '__main__':
    parser = OptionParser()
    parser.add_option('-a', '--archive',
        help="Nucular Index Directory", default="nuke")
    parser.add_option('-p', '--path',
        help='Base Directory. All files indexed')
    parser.add_option('-i', '--init',
        help="Initialize Database", action="store_true",
            default=False)
    opts, args = parser.parse_args()
    if not opts.path:
        parser.error("path is required")
    # create an instance.
    session = Nucular.Nucular(opts.archive)
    if opts.init:
        session.create()

    index_contents(session, opts.path)
```

2. Next, run the script for the first directory provided in order to create the index. To initialize, specify `–init` for the first one. This process will take a few minutes, depending on the speed of your system.

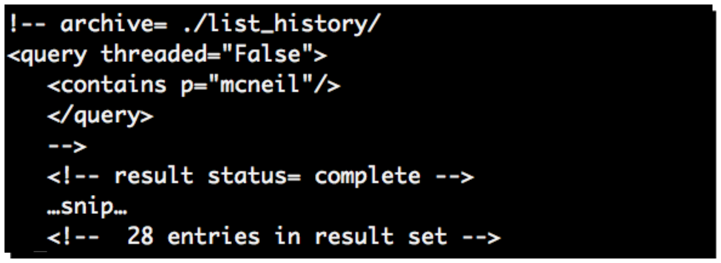
```
(text_processing)$ python clp_index.py --init -a ./list_history -p
c.l.py/01/
```



```
indexing c.l.py/01/0.txt
indexing c.l.py/01/1.txt
…snip…
Final Aggregation…
```

3. Now, we'll run the supplied query script and search the entire index.

   ```
   (text_processing)$ nucularQuery.py --contains mcneil ./list_
   history/
   ```



```
!-- archive= ./list_history/
<query threaded="False">
   <contains p="mcneil"/>
   </query>
   -->
   <!-- result status= complete -->
   …snip…
   <!--  28 entries in result set -->
```

What just happened?

We used the Nucular framework to create a full-text index of the posts sent to `comp.lang.python` during the month of January, 2009. Pretty simple, isn't it? Let's take a look at how we did it.

First, we imported the only Nucular module we need, `Nucular`. Everything else imported ought to look familiar to you by this time.

Next, we defined an `index_contents` function. If you look at this method, you'll see that it's quite generic. It simply takes an open Nucular session, a directory location, and an interval in which we should run a Nucular aggregation. I find that 100 seems to be a good aggregation interval for average e-mail messages or web-page-sized files. This means that we'll recalculate our on-disk indexes after every 100 element insertions.

This method iterates through the contents of the directory passed in and indexes each full document by creating a dictionary with a `full_text` attribute. The full path name to the file is used as the unique key within the Nucular index itself. When we store the new data to the session, we do it in a lazy fashion by passing `lazy=True`. That ensures that we're not rebuilding indexes on every insert. Finally, for every 100 entries, we run our aggregation.

Note that we run one final aggregation process before returning from the method. We want to make sure all of our data is visible to other clients before moving on. We also take this opportunity to clean up and remove some temporary files. Nucular provides `moveTransientToBase` and `cleanUp` session methods that do this for us.

Now, skip to the bottom of the listing. Here, we just create an instance of a Nucular session, initialize it if the correct command-line arguments were passed, and relay processing off to `index_contents`.

As we mentioned earlier, Nucular ships with some canned Python scripts that allow you to perform some basic functions without needing to write any code. Here, we use the `nucularQuery.py` script to query the database. Remember how our search times grew incrementally when we searched further and further into our monster text document earlier in the chapter? Let's take a look at the results now.

Time for action – measuring index benefit

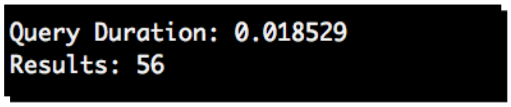
We'll use the following test script to measure the amount of time taken for each query. The provided utilities return XML data and we do not want to count the time needed by the system to structure the document.

1. Create a new Python file and name it `search_for.py`. Enter the following listing as it appears:

```
import sys
import time
from nucular import Nucular

# create an instance.
session = Nucular.Nucular(sys.argv[1])
query = session.Query()
query.anyWord(sys.argv[2])
start = time.time()
d = query.resultDictionaries()
print "Query Duration: %f" % (time.time() - start)
print "Results: %d" % len(d)
```

2. Run the example by passing in the search term `mcneil`, your results should be as follows.

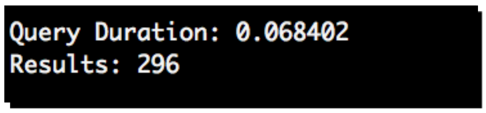
```
(text_processing)$ python search_for.py ./list_history/ mcneil
```



```
Query Duration: 0.018529
Results: 56
```

3. Run it a second time with a different search term. Let's compare the query durations.

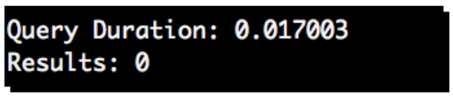
```
(text_processing)$ python search_for.py ./list_history/ Perl
```



```
Query Duration: 0.068402
Results: 296
```

4. Let's go with one more test, just to be sure.

```
(text_processing)$ python search_for.py ./list_history/ Elephant
```



```
Query Duration: 0.017003
Results: 0
```

What just happened?

We put together a simple query script. Nothing here should be new as we've covered the basic programmatic approach to Nucular earlier in the chapter.

When we ran our benchmark script, each call into Nucular responded in less than a tenth of a second. That's a dramatic increase over what we would expect to see given a linear search. Just to underscore the benefit of our indexing approach, let's look at how long a linear search would actually take.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import os
>>> import time
>>> def f():
...     start = time.time()
...     for entry in os.listdir('c.l.py/01'):
...             if 'mcneil' in open(os.path.join('c.l.py/01', entry)):
...                     x = True
...     return time.time() - start
...
>>> f()
0.27669692039489746
>>>
```

The indexed version is almost a full 30 times faster than the linear search, even with this simple example.

Remember, as the data size grows, the linear search time will grow with it. The index method will grow logarithmically with the size of the raw data pool, or at an `O(log n)` rate.

Scripts provided by Nucular

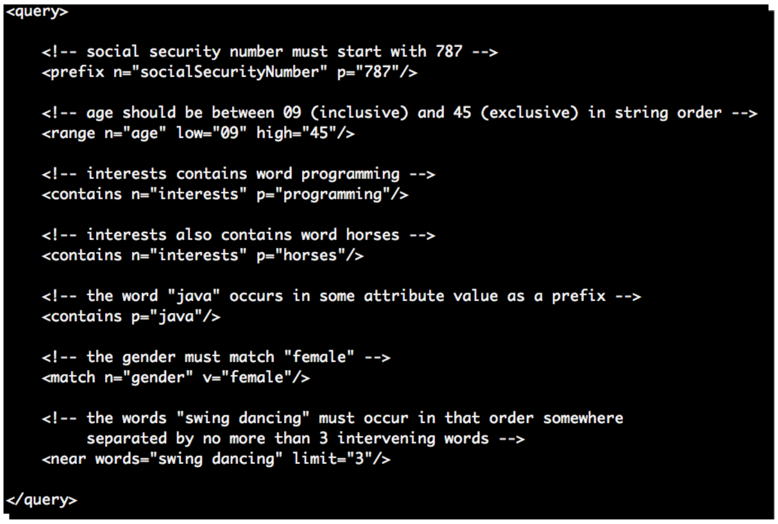
As we've mentioned a couple of times so far, Nucular provides a series of scripts that can be used on the command line. We've used one, but for reference purposes the following table outlines what's provided and provides a summary as to the functionality it supplies.

Utility	Summary
`nucularSite.py`	When given a directory, it creates a new archive. By default, it will give an error if the directory is not empty.
`nucularAggregate.py`	This script performs an aggregation. While the aggregation is running, clients may still search the archive. The utility also provides options that will affect the overall speed and verbosity.
`nucularDump.py`	This will dump the contents of a Nucular archive to XML-format files. These files may then be used to recreate or recover an archive at a later point of time.
`nucularLoad.py`	Loads XML datafiles into a Nucular archive and restores contents.
`nucularQuery.py`	We've used this in passing; however, it provides a full-featured query syntax that allows you to perform the entire query types listed earlier in the chapter.

Using XML files

As you may have guessed by now, Nucular provides some extended XML support. In addition to supplying and dumping data in XML format, it's also possible to define a search action using XML-formatted files. The output of `nucularQuery.py –exampleXML` gives us the expected XML format. It's included below.

```
(text_processing)$ nucularQuery.py  --exampleXML
```



```
<query>

    <!-- social security number must start with 787 -->
    <prefix n="socialSecurityNumber" p="787"/>

    <!-- age should be between 09 (inclusive) and 45 (exclusive) in string order -->
    <range n="age" low="09" high="45"/>

    <!-- interests contains word programming -->
    <contains n="interests" p="programming"/>

    <!-- interests also contains word horses -->
    <contains n="interests" p="horses"/>

    <!-- the word "java" occurs in some attribute value as a prefix -->
    <contains p="java"/>

    <!-- the gender must match "female" -->
    <match n="gender" v="female"/>

    <!-- the words "swing dancing" must occur in that order somewhere
         separated by no more than 3 intervening words -->
    <near words="swing dancing" limit="3"/>

</query>
```

Given that example document, we can construct an XML document that lets us perform the same queries we have performed earlier in the chapter. This provides a nice mechanism for saving queries again for later use.

```
<query>
    <!-- Find my c.l.py posts that month //-->
    <contains  p="mcneil"/>
</query>
```

Then, finally, running `nucularQuery.py` with the`--xml` argument allows us to use this as input rather than a command-line specification.

```
(text_processing)$ nucularQuery.py  --xml mcneil.xml ./list_history/
| head
<!-- archive= ./list_history/
<query threaded="False">
   <contains p="mcneil"/>
</query>
-->
<!-- result status= complete -->
<entries>
…snip..
</entries>
<!--  56 entries in result set -->
```

Advanced Nucular features

In the last section, we indexed all of our messages using a full-text approach. That is a valid option for lots of data formats. However, it doesn't quite give us a level of granularity we might need when making more explicit requests. For example, how might we answer the following question: what messages included the word API in the subject-line, and discussed Python and Unicode?

Given our current configuration, we could ask for all of the messages that contained the strings we wanted to match and then programmatically search the returned dictionary. However, that's not a very efficient approach.

Of course, as we're talking about it, there's bound to be a better way to handle it. As our indexed objects are simply dictionaries, the key is to break each field up into a corresponding dictionary value. Then, we can qualify our searches such that values have to occur within a specific field.

Also, as we've indexed e-mail messages and newsgroup postings, consider the result set we would have if we searched for 'from python.' Quite a few false positives would be returned if we were looking for some information on the `from` keyword! We didn't strip-out any message-control information or header data.

Time for action – field-qualified indexes

In this example, we'll break the Python mailing list messages up into their component parts, which allow us to provide a more granular result. As these are simply mail messages, we'll use Python's `email` module to parse them.

1. Extend the `clp_index.py` file to include some slightly more enhanced functionality. First, add the `import email` statement to the top of the file. Here, we've renamed it `clp_index-a.py`.
2. Next, replace the `index` function in our previous example with the code in the following listing:

```
class IndexDirectory(object):
    def __init__(self, session, where, persist_every=100):
        self.where = where
        self.persist_every = persist_every
        self.session = session

    def index(self):
        for c,i in enumerate(os.listdir(self.where)):
            full_path = os.path.join(self.where, i)
            session.indexDictionary(
                full_path, self.build_dict(full_path))

            session.store(lazy=True)
            if not c % self.persist_every:
                session.aggregateRecent(verbose=False, fast=True)

        # Run a final aggregation.
        session.aggregateRecent(verbose=False)
        session.moveTransientToBase()
        session.cleanUp()

    def build_dict(self, full_path):
        raise NotImplementedError("I'm abstract")

class FullTextIndex(IndexDirectory):
    def build_dict(self, full_path):
        return { 'full_text':  open(full_path).read()}
```

```
class MessageIndex(IndexDirectory):
    def build_dict(self, full_path):
        msg = email.message_from_file(open(full_path))
        indexable = dict(msg)
        indexable['Payload'] = msg.get_payload()
        return indexable

_dispatch_table = {'fulltext': FullTextIndex,
    'message': MessageIndex}
```

3. Now, change everything below the final `parser.add_option` to read as follows:

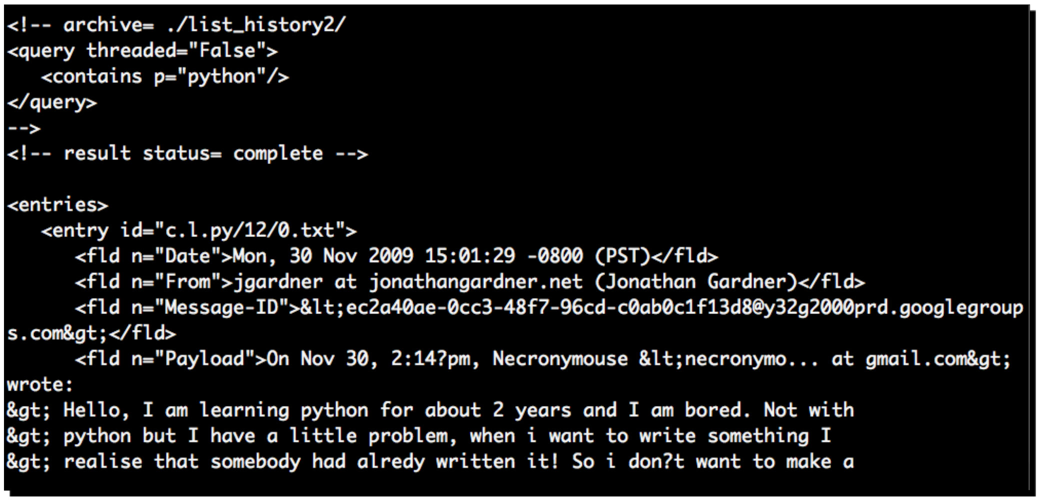
```
parser.add_option('-t', '--type',
        help="Index Type",
             choices=_dispatch_table.keys())

    opts, args = parser.parse_args()
    if not opts.path or not opts.type:
        parser.error("path and type are required")

    # create an instance.
    session = Nucular.Nucular(opts.archive)
    if opts.init:
        session.create()

    # Call correct class.
    _dispatch_table[opts.type](session, opts.path).index()
```

4. Finally, we'll run the updated index code and save our more detailed data to disk. This process is likely to take a few minutes.

```
(text_processing)$ python clp_index-a.py --archive=list_history2
--path=c.l.py/12/ --init --type=message
```

5. Now, if we run a generic search against this new index, you should see the following output.

```
(text_processing)$ nucularQuery.py --contains Python ./list_
history2/
```



```
<!-- archive= ./list_history2/
<query threaded="False">
   <contains p="python"/>
</query>
-->
<!-- result status= complete -->

<entries>
   <entry id="c.l.py/12/0.txt">
      <fld n="Date">Mon, 30 Nov 2009 15:01:29 -0800 (PST)</fld>
      <fld n="From">jgardner at jonathangardner.net (Jonathan Gardner)</fld>
      <fld n="Message-ID">&lt;ec2a40ae-0cc3-48f7-96cd-c0ab0c1f13d8@y32g2000prd.googlegroup
s.com&gt;</fld>
      <fld n="Payload">On Nov 30, 2:14?pm, Necronymouse &lt;necronymo... at gmail.com&gt;
wrote:
&gt; Hello, I am learning python for about 2 years and I am bored. Not with
&gt; python but I have a little problem, when i want to write something I
&gt; realise that somebody had alredy written it! So i don?t want to make a
```

What just happened?

We implemented a Python script to generate two different types of Nucular indexes, depending on the command-line arguments passed in.

The very first thing we did was import the `email` module as we use it to parse the messages files later in the script.

Next, the first interesting thing you'll see is the `IndexDirectory` class. As the only difference between our indexing approaches is the data kept in the dictionary, we created this to serve as a base class. All of our logic remains the same; we've just wrapped it in a class. Though, we did remove some of the status messages.

We did not implement the `build_dict` method here. In fact, we actually raise a `NotImplementedError` if a caller were to attempt to call this method directly. This serves to indicate that this method is part of our class interface, but is left to subclasses to manage.

Next, you'll see the `FullTextIndex` class. This is a subclass of `IndexDirectory`. It simply does what we did in our previous function. It wraps the contents of an entire file within a dictionary. If this class is used then we'll see the same behavior as before.

Next, we have a `MessageIndex` class. `MessageIndex` parses an e-mail message using `email.message_from_file` and creates a dictionary using the results. The `Message` class has a dictionary-like interface, so we can create a new dictionary by simple calling the `dict` singleton with the instance of that class. We then add the entire contents of the message to yet another dictionary value by calling `msg.get_payload`. Finally, we simply return this dictionary.

The last thing you'll see outside of our main section is a line that looks like the following:

```
_dispatch_table = {'fulltext': FullTextIndex', 'message':
MessageIndex}
```

The `fulltext` and `message` keys are passed on the command line. Those values are used as indexes into this table, which provides us with the functionality our user is requesting. Remember the polymorphism talk we had earlier in the book?

Now, we skip to our main section. There's really nothing overly interesting going on here. Note that we pass `_dispatch_table.keys()` as the value of the `choices` keyword argument when building our options map. Lastly, we use the command-line argument supplied by the user as our index into the dictionary and call our corresponding `index` method (though, remember, we don't care which instance we're working with).

Finally, look at the output of `nucularQuery.py`. You should notice it's slightly different from our previous example. Most importantly, you should see that the data is now separated by individual field names rather than one simple blob. For example, we now have additional XML elements such as `<fld n="Date">` and `<fld n="From">`. As you might assume, `fld` is short for "field" and `n` is short for "name".

Performing an enhanced search

The separation into fields is nice, but the real benefit becomes apparent when we perform some additional searches. Let's create a simple application that allows users to query in a slightly more complex manner.

Time for action – performing advanced Nucular queries

In this example, we'll perform a search against the subject, and then qualify it with a full text search of the message itself. This provides an introduction to some of the more advanced portions of Nucular queries.

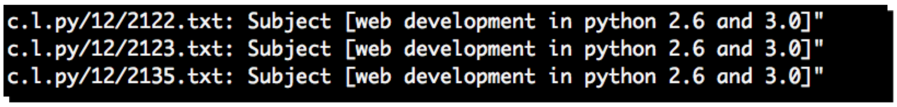
1. Create a script named `field_search.py` and enter the code as it appears in the following listing:

```
from optparse import OptionParser
from nucular import Nucular
```

```
MAX_WORDSPACE = 5

if __name__ == '__main__':
    parser = OptionParser()
    parser.add_option('-a', '--archive',
        help="Nucular Index Directory", default="nuke")

    parser.add_option('-s', '--subject',
        help="Search subjects for this word")

    parser.add_option('-p', '--proximate',
        help="A proximate search. These words"
             "must be within %d words."
"Comma Sep." % MAX_WORDSPACE)

    opts, args = parser.parse_args()
    if not opts.subject or not opts.proximate:
        parser.error('subject and word list required')

    # create an instance.
    session = Nucular.Nucular(opts.archive)
    query = session.Query()

    query.attributeWord('Subject', opts.subject)
    query.proximateWords(
        opts.proximate.split(','), MAX_WORDSPACE)

    for d in query.resultDictionaries():
        print '%(i)s: Subject [%(Subject)s]"' % d
```

2. Run the following query from the command line using the new script:

```
(text_processing)$ python field_search.py --subject='python'
--proximate="mysql,postgres"  --archive=list_history2/
```



```
c.l.py/12/2122.txt: Subject [web development in python 2.6 and 3.0]"
c.l.py/12/2123.txt: Subject [web development in python 2.6 and 3.0]"
c.l.py/12/2135.txt: Subject [web development in python 2.6 and 3.0]"
```

3. Now, let's qualify the search a little bit more and run the query again. Pay attention to the output this time.

```
(text_processing)$ python field_search.py --subject='python' --pro
ximate="mysql,postgres,choices"  --archive=list_history2/
```

What just happened?

We created a script, which lets us perform some more enhanced queries against a Nucular index by taking advantage of the fielded index we created earlier.

Most of this code should be familiar to you, so let's jump down to the bottom of the main section right away. Here, we call two query functions, `attributeWord` and `proximateWords`. The first method allows us to perform the same type of query we saw in the `anyWord` method, but restrict it to a specific dictionary value. The `Subject` string parameter to `attributeWords` is the dictionary key we're interested in for this specific search.

> Why the uppercase `Subject`? We've used the `email` module to parse our message here, and that gives us the uppercase value.

The next method is slightly more interesting. The `proximateWords` method allows us to search for a collection of words (supplied here by separating a comma-separated command-line value). The caveat? These words have to appear within a designated number of words of each other. Here, we're using the constant `5`.

Our results show this in action. We asked for any messages with the word `python` in the subject. On the first query, we asked for `mysql` and `postgres` in the proximate field. This may give us a list of messages in which developers are debating the virtues of both RDBMS engines from a Python perspective. But, at the same time, it also limits the results. For example, if someone had posted release notes into an e-mail message, we might not be as interested. We're of course assuming the terms would be further separated in a release notes document.

Next, we added a third word: `choices`. This results in an empty dictionary results list. Note that the word "choices" does appear in the originally returned results, just not close enough to its friends to still count as a match when added to the search criteria.

Pop Quiz – introduction to Nucular

1. What, besides convenience, is the most important reason to use a text-indexing approach rather than a brute-force linear text scan?
2. Even with an index, what might be a limiting factor with respect to query speed? What might you do to enhance it?
3. What is the simplest method for backing up and restoring a Nucular database?
4. Does Nucular support simultaneous reads and write?

Indexing and searching other data

The last thing we'll look at in this chapter is how to index and search data that is textual in nature, but not stored in a plain text format. We'll look at a simple format in our examples, but the techniques here apply to other formats as well. Excel, PDF, even comments and descriptions found in UML diagrams, MP3 files, or CAD drawings. If you have the ability to programmatically extract content from a file then you can use this approach. Note that we've already done this with plain text messages in our example above!

Time for action – indexing Open Office documents

Earlier in the book we looked at generating enhanced output formats. One of the formats we looked at was Open Office Writer, which is accessible via the **ODFPy** framework. Here, we'll use that same framework to index the contents of an ODF document.

For this example, we've provided an ODF document entitled **About Python**. This is simply the contents of the **ABOUT** page on the `http://python.org/` website. Also, you should already have the packages installed (if you've been following along). If you do not have them installed, you can do so now by using the `easy_install odfpy` command.

1. Using the contents of the file created in the last example as a template, copy it over and name it `clp_index-b.py`.
2. Update the code in the file to resemble the following:

```
import os
import sys
import email
from odf import opendocument

from optparse import OptionParser
from nucular import Nucular

class NotIndexFriendly(Exception):
    """Given Indexer Won't Support Format"""

class IndexDirectory(object):
    def __init__(self, session, where, persist_every=100):
        self.where = where
        self.persist_every = persist_every
        self.session = session

    def index(self):
        for c,i in enumerate(os.listdir(self.where)):
            full_path = os.path.join(self.where, i)
            try:
                index_target = self.build_dict(full_path)
            except NotIndexFriendly, e:
                print >>sys.stderr, "we cannot index %s: %s" % \
                    (full_path, str(e))
                continue

            session.indexDictionary(full_path, index_target)

            session.store(lazy=True)
            if not c % self.persist_every:
                session.aggregateRecent(verbose=False, fast=True)

        # Run a final aggregation.
        session.aggregateRecent(verbose=False)
        session.moveTransientToBase()
        session.cleanUp()

    def build_dict(self, full_path):
        raise NotImplementedError("I'm abstract")

class FullTextIndex(IndexDirectory):
    def load_text(self, path):
        return open(path).read()

    def _walk_odf(self, element, text=None):
        if text is None:
            text = []
        if element.nodeType == element.TEXT_NODE:
            text.append(element.data)

        for child in element.childNodes:
            self._walk_odf(child, text)
        return ''.join(text)

    def load_odt(self, path):
        return self._walk_odf(
            opendocument.load(path).body)

    def build_dict(self, full_path):
        dispatch = {'.txt': self.load_text,
            '.odt': self.load_odt}

        # Pull a reader from our dispatch table,
        # or none.
        reader = dispatch.get(
            os.path.splitext(full_path)[-1], None)

        if not reader:
            raise NotIndexFriendly(
"Not Indexable Type: %s" % full_path)

        # Return a full text mesg.
        return { 'full_text':  reader(full_path)}
```

```
class MessageIndex(IndexDirectory):
    def build_dict(self, full_path):
        if not full_path.endswith('.txt'):
            raise NotIndexFriendly("Only Text Messages Supported")
        msg = email.message_from_file(open(full_path))
        indexable = dict(msg)
        indexable['Payload'] = msg.get_payload()
        return indexable
_dispatch_table = {'fulltext': FullTextIndex,
    'message': MessageIndex}
if __name__ == '__main__':
    parser = OptionParser()
    parser.add_option('-a', '--archive',
        help="Nucular Index Directory", default="nuke")
    parser.add_option('-p', '--path',
        help='Base Directory. All files indexed')
    parser.add_option('-i', '--init',
        help="Initialize Database", action="store_true",
            default=False)
    parser.add_option('-t', '--type',
        help="Index Type",
            choices=_dispatch_table.keys())
    opts, args = parser.parse_args()
    if not opts.path or not opts.type:
        parser.error("path and type are required")
    # create an instance.
    session = Nucular.Nucular(opts.archive)
    if opts.init:
        session.create()
    # Call correct class.
    _dispatch_table[opts.type](session, opts.path).index()
```

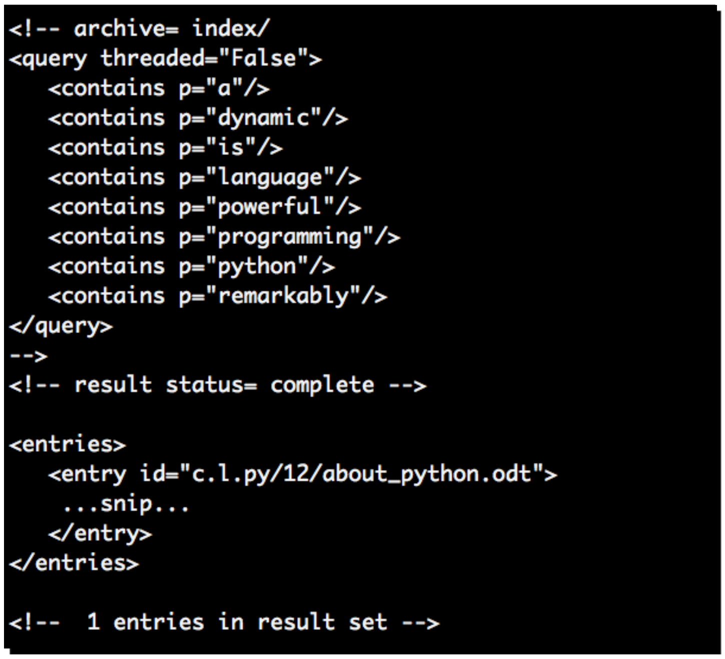
2. Now, copy the Open Office document into `c.l.py/12`. We'll index it as part of a standard full-text index creation.

3. Run the following command, which will include the new ODT support in the text index. This command may take a few minutes to complete. If the command completes successfully, you should see no output.

```
(text_processing)$ python clp_index-b.py -t message --init
--path=c.l.py/12--archive=./index --type=fulltext
```

4. Now that we've indexed the data and included our Open Office document, let's run another search against the index. This time, we'll look for data appearing in the ODT file. Run the following command against our newly updated directory. Note that we've trimmed the output slightly to save on space.

```
$(text processing)$ nucularQuery.py --contains 'Python is a
remarkably powerful dynamic programming language' index/
```



```
<!-- archive= index/
<query threaded="False">
   <contains p="a"/>
   <contains p="dynamic"/>
   <contains p="is"/>
   <contains p="language"/>
   <contains p="powerful"/>
   <contains p="programming"/>
   <contains p="python"/>
   <contains p="remarkably"/>
</query>
-->
<!-- result status= complete -->

<entries>
   <entry id="c.l.py/12/about_python.odt">
    ...snip...
   </entry>
</entries>

<!--  1 entries in result set -->
```

What just happened?

We updated our index script to allow indexing of Open Document files. Along the way, we added some additional file-type checking to ensure we only index the right types. The approach is rather simple; we just extract the text copy from the document file and pass that into the indexer. Let's walk through it.

First, we imported the `opendocument` module from the `odf` package. This is much like we did in *Chapter 9*, *Advanced Output Formats*. Right below our `import` statements, we defined an exception and named it `NotIndexFriendly`. This exception will be triggered from within our `build_dict` methods whenever we run into a file type that we cannot handle.

Now, skip down to the `index` method within `IndexDirectory`. We've updated this method to catch `NotIndexFriendly` and print a warning to `sys.stderr`. This ensures that we give timely feedback to our users and continue processing other files. After all, we wouldn't want a stray file in a directory to terminate a long-running index job.

We'll come back to our `FullTextIndex` class in a second. First, jump down to `MessageIndex`. In the `build_dict` method, we've started to raise `NotIndexFriendly` if anything other than a plain text document is passed in. Our messages shouldn't be anything more.

Now, double back to `FullTextIndex`. We did a few interesting things here. First off, we separated out our file-reading logic into two different methods: `load_text` and `load_odt`. The `load_text` method does exactly what we were doing in a previous revision. It just reads text data from disk and passes the raw contents back.

The `load_odt` method, however, calls `opendocument.load` with the full path name. This triggers the `opendocument` module to parse the file and return an object representation. We then pass the `.body` attribute of that object to `self._walk_odf`.

If you'll remember, the ODF package relies on XML processing libraries under the hood. So, the body of the ODT file is the root element of an XML structure. In the `self._walk_odf` method, we iterate through the tree and append all text node data into a list. At the end, we join those values together and return as a string.

Next, we set up another dispatch table within `build_dict` that calls the appropriate method, using the file extension as a guide. If we're passed a file that we don't support, we simply raise `NotIndexFriendly` and everything continues to work upstream.

Lastly, we ran the Nucular query script with a string found in our test ODF file. Notice how that file is listed as the result output. The ODF format is now included in our index.

If you wish to add additional formats, you'll simply need to add a method that understands how to remove markup or binary data from the raw file and return plain text, which the Nucular indexer can handle.

When dealing with data that isn't plain text (and even data that is, for that matter), it's usually better to store a pointer to the file itself within the index. When a specific entry is a hit, return the file, or display it. This is a requirement for non-text data.

Other index systems

We used Nucular here, but there are other indexing systems that are available for use that may suit your needs slightly better. Nucular was used because it's a pure Python framework that is quite general purpose; it handles most scenarios wonderfully. Let's take a quick survey of the alternatives.

- Apache Lucene
- ZODB and zc.catalog
- SQL text indexing

Apache Lucene

The Lucene project provides a server-based indexing system written in the Java programming language. Lucene is a very high performance system that is used by many large organizations such as **CNet Reviews** and **Monster.com**. While the server implementation is Java-based, there are connectors for a wide variety of programming languages, including Python. For more information on Lucene, see `http://lucene.apache.org/java/docs/index.html`.

ZODB and zc.catalog

The ZODB is an object-oriented database. Unlike traditional RDBMS databases such as MySQL and Postgres, ZODB allows you to simply persist objects. This makes for an intuitive development experience as there's no more column to attribute mapping required when persisting object state. This package provides indexing, but also handles more advanced topics such as stemming, like we tackled in our last chapter. For more information, see `http://pypi.python.org/pypi/zc.catalog/1.4.1`. Also, the Grok framework, which aims to simplify the Zope stack, has done a great job with exporting search functionality for use with the ZODB. This is a great place to start. See `http://grok.zope.org/` to get started.

SQL text indexing

Many databases provide full text support. If the data set you're working with is already persisted to one of these systems then this may be a better approach. Note that this is not the same as an SQL index on a frequently used column! Consult your vendor documentation for more information. If you're using MySQL, you can read up on the feature set at `http://dev.mysql.com/doc/refman/5.1/en/fulltext-search.html`.

Summary

We covered quite a bit of information in this chapter while introducing you to the concepts of indexing and text-searching. You should understand why keeping indexes is vitally important if you plan to sift through large quantities of textual data.

Specifically, we touched on linear searching and how time increases with the amount of data being scanned. We rectified the problem by introducing the Nucular framework, a pure Python text indexing. Finally, we introduced you to some alternative indexing systems that may suite your needs better.

In the last chapter, we'll spend some time showing you where to get help if you need it and where to look for more information. We'll also take a quick look at the standard Python 2 to Python 3 porting procedure.

A
Looking for Additional Resources

Here, we'll shift our focus a bit again. Our goal here is to introduce you to places of interest on the Internet, the Python community, and additional technologies and resources you may find useful. We'll also provide a brief introduction into the differences between Python 2 and Python 3 to aid in the ongoing transition.

We'll touch on the following elements.

- Python mailing lists, groups, documentation, and community resources. Where can you go to get help and help others?
- Introduction to some other related utilities developed for other languages that you might find useful.
- Differences between Python 2 and Python 3 that you'll need to take into account when working with the later version.
- Tips and techniques for porting code to Python 3, including available utilities that make the transition easier.

We've covered a great deal of technical information, with a focus on getting things done. By now, you should be familiar with structured documents, raw text data, processing techniques, searching, regular expressions, and a collection of third-party libraries that make your life easier. In this chapter, we'll show you how to help yourself, dig up more detailed information, and take part in the wider Python community.

We'll focus on both Python-related resources as well as other text management systems. In many cases, it is possible to use different technologies from Python, so there are many options available to you.

We'll finish up by running through Python 3 and showing you how simple the upgrade process can be by porting a small script we developed earlier in the book using the included utilities.

Python resources

First and foremost, the Python standard documentation is a wonderful tool and stands to help you with just about any project. Python is known for its batteries included approach. In other words, there are a lot of common utilities that reside in the Python standard library whereas a third-party extension might be required for a different language. The main Python documentation page can be found at `http://docs.python.org`.

If you're new to Python then the Python.org tutorial is highly recommended. The tutorial provides an up-to-date introduction to the language. It is kept in lockstep with major releases of the language, so you're certain to cover up-to-date material.

Previous versions of both the standard library reference and the official tutorial are also available, so if the version of Python you happen to have on your system is older than the latest available release, you can access the corresponding documentation.

Unofficial documentation

Mark Pilgrim's *Dive into Python* is available online, free of charge, and can be purchased in paperback format. This serves as a comprehensive guide to the language. The text is available online at `http://www.diveintopython.org`. If you're interested in Python 3 specifically, Packt Publishing's *Python 3 Object Oriented Programming* is a great book to add to your collection.

If you're not fully familiar with the standard library yet, another good resource is Doug Hellmann's Python Module of the Week series in which he dives into each standard library in detail. Doug's series can be found at `http://www.doughellmann.com/projects/PyMOTW/`. Familiarizing yourself with the standard library can help you avoid reinventing the wheel in your own projects.

Python enhancement proposals

We've referenced a few PEP documents throughout this book, but we haven't gone into much detail as to what they are. Whenever a core change is made to the language or its supporting cast (libraries and so on), the change usually goes through a proposal process. The advocate for change authors a Python Enhancement Proposal, which is then presented to the appropriate audience for inclusion or dismissal. The PEP index, identified as PEP 0, can be found at `http://www.python.org/dev/peps/`. Some of the more string- and text-related proposals are as follows:

- `http://www.python.org/dev/peps/pep-0292/`. PEP292 introduced the `$`-formatting used in the `string.template` module.
- `http://www.python.org/dev/peps/pep-3101/`. PEP3101 details the advanced string formatting mechanisms that rely upon the braces syntax.
- `http://www.python.org/dev/peps/pep-0261/`. Extension of Python's Unicode support behind the Basic Multilingual Plane.
- `http://www.python.org/dev/peps/pep-0100/`. Introduction of Unicode to the Python programming language.

This, of course, is not an exhaustive list. PEPs, while informative, are also geared towards the language developer. They can be a helpful resource, but they're usually written with language developers in mind.

> Throughout this book, we've tried to adhere to Python's PEP8 for style guidelines. PEP8 provides style rules for Python code specifically in the Python library. However, it's become the community standard. PEP8 can be found at http://www.python.org/dev/peps/pep-8/.

Self-documenting

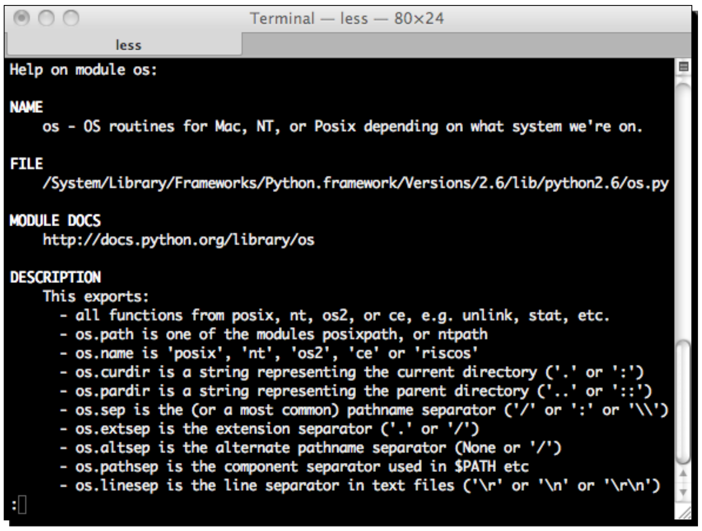
In addition to standard developer documentation, Python is quite self-documenting. Good programming practice dictates that developers specify documentation strings at class, method, module, and function level. By doing this, they ensure that API documentation is always kept up to date.

> For an overview of Python's documentation string standards, see PEP (Python Enhancement Proposal) 257, which is available at `http://www.python.org/dev/peps/pep-0257/`. Note that these are the guidelines Python itself uses. You're free to invent your own organizational guidelines.

Doc strings, of course, translate directly into usable Python documentation. For example, the `help` function provides a mechanism for you to display doc string generated content from within the interactive REPL loop.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> import os
>>> help(os)
```

The preceding example generates a help page that resembles a standard UNIX manual page. It also provides some extended information on the attributes and inheritance hierarchy that is available via introspection routines.



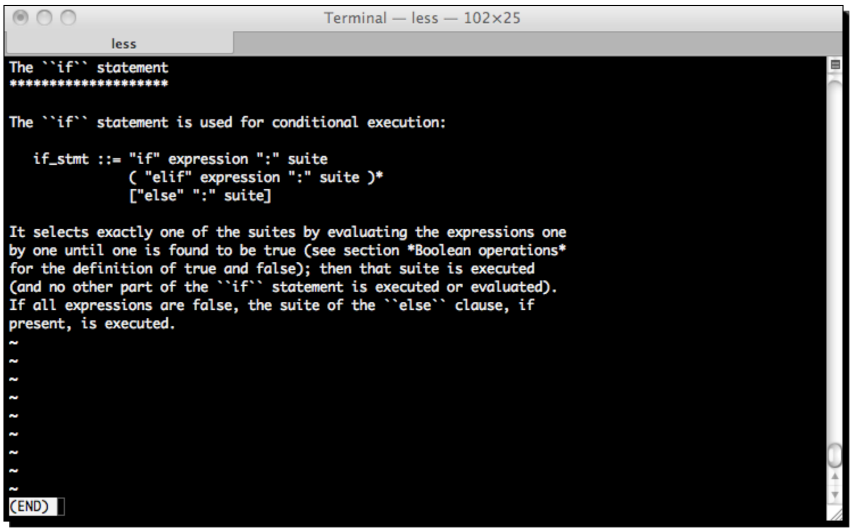
```
Help on module os:

NAME
    os - OS routines for Mac, NT, or Posix depending on what system we're on.

FILE
    /System/Library/Frameworks/Python.framework/Versions/2.6/lib/python2.6/os.py

MODULE DOCS
    http://docs.python.org/library/os

DESCRIPTION
    This exports:
      - all functions from posix, nt, os2, or ce, e.g. unlink, stat, etc.
      - os.path is one of the modules posixpath, or ntpath
      - os.name is 'posix', 'nt', 'os2', 'ce' or 'riscos'
      - os.curdir is a string representing the current directory ('.' or ':')
      - os.pardir is a string representing the parent directory ('..' or '::')
      - os.sep is the (or a most common) pathname separator ('/' or ':' or '\\')
      - os.extsep is the extension separator ('.' or '/')
      - os.altsep is the alternate pathname separator (None or '/')
      - os.pathsep is the component separator used in $PATH etc
      - os.linesep is the line separator in text files ('\r' or '\n' or '\r\n')
:
```

Additionally, most Python installs include the `pydoc` command, which provides a command-line method to access the same help data.

Both online help methods are not limited to library documentation. It is also possible to use either method to display information regarding Python's keywords and topics. For example, let's look at the following command line:

```
(text_processing)$ pydoc if
```

That statement generates output that resembles the following. It may differ depending on the location of your installed Python and the operating system you're using.



```
The ``if`` statement
********************

The ``if`` statement is used for conditional execution:

   if_stmt ::= "if" expression ":" suite
               ( "elif" expression ":" suite )*
               ["else" ":" suite]

It selects exactly one of the suites by evaluating the expressions one
by one until one is found to be true (see section *Boolean operations*
for the definition of true and false); then that suite is executed
(and no other part of the ``if`` statement is executed or evaluated).
If all expressions are false, the suite of the ``else`` clause, if
present, is executed.
~
~
~
~
~
~
~
~
~
(END)
```

You may also notice, when you exit the previous screen, that pydoc prints recommended help topics to the screen. In this case, it will print **Related help topics: TRUTHVALUE.** This provides a nice way to introduce you to other topics that are related to the exact search keyword.

> The pydoc script itself also allows you to run a local web server, search by keyword, generate flat HTML output, or search via a graphical interface. Simply running the command without any arguments will display usage information.

Using other documentation tools

In addition to the built-in help and pydoc systems, there are third-party utilities that can be used to generate more in-depth API documentation:

- The Sphinx documentation system. This is a more advanced system that allows you to provide raw documentation in addition to your documentation strings. Sphinx can then be configured to extract source documentation via settings. More information is available at http://sphinx.pocoo.org/.
- The Doxygen system, available at http://www.stack.nl/~dimitri/doxygen/, works with a variety of languages and supports a variety of output format. It can also be used to extract source-based documentation.
- The epydoc package, which is available at http://epydoc.sourceforge.net/. This package uses a lightweight markup to generate detailed package documentation. This is similar to the Javadoc system.

These are wonderful utilities, though their intent is more to document your own code rather than view standard Python documentation.

Community resources

Python comes with a collection of useful modules and libraries and a world-class community. There are numerous ways you can interact, both in requesting help and providing guidance. Let's take a look at the options.

Following groups and mailing lists

There are mailing lists and groups out there for general Python usage, beginners' questions, and special interest groups. Available lists are detailed at `http://www.python.org/community/lists/`. Let's outline a few of the more popular ones here.

- The `comp.lang.python` group is the main high-traffic Python discussion group. This is a somewhat high volume group where experienced Python developers discuss problems, designs, and answer questions throughout the day. This is a wonderful resource. It is possible to access this group via Google Groups such that you don't have to manage the e-mail volume.
- The Python-tutor mailing list is designed to be a place for beginners to ask questions that may be less-than-welcome on the `comp.lang.python` group. For example, it's also a wonderful place to lend your expertise and help others learn the technology.
- Python-Dev is where development of the Python language takes place. This is not for questions related to development in Python; rather, this is for development of Python.
- Python-Help is a rather interesting list. You may send Python-related questions to this mailbox and it will be monitored by a set of volunteers. They may, depending on the experience level, address your question in private.
- The Python Papers Anthology, available at `http://www.pythonpapers.org`, is a thorough collection of industry and academic documents available on the web. Their goal is to disseminate information regarding Python technologies and their application.

In addition to the standard mailing lists, there is a collection of Special Interest Groups that narrows down into yet more specific territory. SIGs are formed to address and maintain a specific area of Python. Membership is informal. For a list of all of the active SIGs, see the main page at `http://www.python.org/community/sigs/`.

Finding a users' group

Python users' groups are local organizations that are managed by local individuals that share a common interest in the Python programming language. Generally, users' groups hold a meeting on a re-occurring schedule and encourage discussion and information-sharing between members. This is a wonderful way to get involved with the Python community, make friends, and learn about a specific area of the language you may not be familiar with. There are two resources for finding Python users' groups.

First, `http://wiki.python.org/moin/LocalUserGroups`, which provides a list of groups broken down by geographic region. Second, `http://www.meetup.com/` is also a great resource. The `http://python.meetup.com/` site provides a listing of scheduled Python-related meetups in your local area.

These are also great places to try on your speaking and presentation skills with a friendly, tolerant, and eager audience.

Attending a local Python conference

Each year, various large-scale Python conferences are held all over the planet. These are highly technical events. While vendors are present, the focus is on Python technology discussion. For information about the various Python conferences, see `http://www.pycon.org`. These events are packed full of tutorials, sessions, and coding sprints. Volunteers within the Python community put these conferences together.

Honorable mention

In addition to the Python-based systems we examined throughout the book, there are a number of other high quality systems out there. While not pure Python, many of them provide a means to access data or communicate with a server component in a language agnostic manner. We'll take a look at some of the more common systems here.

Lucene and Solr

We touched on the topic briefly in *Chapter 11*, *Searching and Indexing*, but didn't go into very much detail. The Apache Foundation's Lucene project, located at `http://lucene.apache.org`, is the de facto standard in open source indexing and searching.

The core Lucene project is a Java-based collection that provides file indexing and searching capabilities, much like the Nucular system we looked at. There is a set of Java libraries available for use and command-line tools that may be used without much Java knowledge.

The Lucene project also ships an indexing server named Solr. Solr, on the other hand, is a full-featured search server that runs on top of a Tomcat (or other compliant) application container. Solr exports a rich REST-like XML/JSON API and allows you to index and query against it using any programming language that supports such interaction (Python, of course, is included).

Some of the highlights include:

- Rich document handling, such as Microsoft Word or rich text documents.
- Full text search with hit highlighting, dynamic clustering, and support for database integration.
- Scalability through replication to collections of other Solr servers in order to horizontally disperse load.
- Spelling suggestions, support for "more documents like this", field sorting, automatic suggestions, and search results clustering using Carrot2. More information about Carrot2 is available at `http://search.carrot2.org/`.
- A ready-to-use administration interface that includes information such as logging, cache statistics, and replication details.

If you're about to embark upon a project that requires highly scalable search functionality for a variety of different data types, Solr might save you quite a bit of work. The main page is available at `http://lucene.apache.org/solr`.

There is a Python version of the Lucene engine, named PyLucene. This, however, isn't a direct port of the libraries. Rather, it's a wrapper around the existing Java functionality. This may or may not be suitable to all Python deployments, so we chose not to cover it in this book.

One final note here is that if you're using the Python Java implementation, you can access native Lucene libraries directly from within Python. You can read up on the Java implementation at `http://www.jython.org`.

Generating C-based parsers with GNU Bison

Bison is a parser-generator that can be used to generate C-based parse code using an annotated context-free grammar. Bison is compatible with YACC, so if you're familiar, the migration shouldn't be terribly difficult.

Bison allows the developer to define a file, which contains a prologue, an epilogue, and a collection of Bison grammar rules. The general format of a Bison input file is as follows:

```
%{
  Prologue
}%
Bison Parsing Declarations
%%
Grammar Rules
%%
Epilogue
```

As the output of a Bison run is a C source file, the Prologue is generally used for forward declarations and prototypes, and the Epilogue is used for additional functions that may be used in the processing. A Bison-generated parser must then be compiled and linked in to a C application. GNU Bison documentation is available at http://www.gnu.org/software/bison/.

There is also a Python Lex and Yacc implementation available at http://www.dabeaz.com/ply/. Its self-stated goal is to simply mimic the functionality of standard Lex and Yacc utilities.

Apache Tika

Tika is another Apache Java project. The Tika utilities extract structured data from various document types. When processing non-plain-text file types, Lucene relies upon the Tika libraries to extract and normalize data for indexing. Tika is located on the Internet at http://tika.apache.org/.

This is quite a powerful package. In addition to text extraction, Tika supports EXIF data found in images, metadata from MP3, and extraction of information from FLV Flash videos. While not callable directly from CPython, Tika supplies command-line utilities that may be used programmatically via the subprocess module.

Getting started with Python 3

As we've mentioned, Python 3 is the next major release of the Python programming language. As of the time of writing, the most recent version of Python 3 was 3.1.2. Python 3 aims to clean up a lot of the language cruft that remained through years of backwards-compatible development. That's the good news. The bad news is that a number of the changes made to the language are not compatible. In other words, your code will break. This was the first intentionally backwards-incompatible release.

In this section, we'll highlight some core differences between Python 2 and Python 3. We'll also step through the recommended porting process so you can get a feel as to how to move your code forward. For an overview of the Python 3 development and porting process, you should read PEP3000, available at `http://www.python.org/dev/peps/pep-3000/`.

[Python 3 is a rather clean language and the porting process is not terribly difficult. However, many of the common third-party packages have not yet been ported. If your applications rely on libraries, which are not compatible, you may have to hold off on your upgrade. Or, better yet, perhaps you could donate some of your expertise and help with the effort!]

Major language changes

There are some big changes to Python proper that you'll need to understand when moving into Python 3. The Python website has an excellent guide to the changes present in version 3.0. The guide is available at `http://docs.python.org/release/3.0.1/whatsnew/3.0.html`. This doesn't cover the latest version; however, it does cover the larger major version switch. However, we'll survey some of the major syntactical changes here. It may also be beneficial to read PEP3100, which provides a collection of changes made to the language during the upgrade to version 3. It is available at `http://www.python.org/dev/peps/pep-3100/`.

Print is now a function

In previous versions, `print` was a statement. No parentheses were required and you couldn't pass print around as a first class object. That changes with Python 3. The following snippet is valid Python 2 code:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> f = open('outfile', 'w')
>>> print >>f, "The Output"
>>>
```

Running the preceding code in a Python 3 loop, however, results in an exception bubbling up the call stack and your application terminating. The Python 3 way is as follows.

```
Python 3.1.2 (r312:79360M, Mar 24 2010, 01:33:18)
[GCC 4.0.1 (Apple Inc. build 5493)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> f = open('outfile', 'w')
>>> print('The Output', file=f)
>>>
```

It will take some time to get used to treating `print` as a function rather than a statement, but it's worth it. This now allows `print` to be passed around as a first class object, on par with any user-defined wrappers that would have been used previously.

This change is documented in PEP3105, which is available at `http://www.python.org/dev/peps/pep-3105/`.

Catching exceptions

Python's syntax for catching exceptions has been changed as well. Previously, programmers would write code similar to the following.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> try:
...     1/0
... except ZeroDivisionError, e:
...     print e
...
integer division or modulo by zero
```

This is perfectly valid syntax; however, it often leads to bugs that are not always easy to discover during development. Consider the following code:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> try:
...     1/0
... except ZeroDivisionError, OSError:
...     print "Got an Error"
...
Got an Error
>>>
```

What's wrong with this? Exactly. The developer intends to catch either `ZeroDivisionError` or `OSError`. However, that's not how this is treated. Here, we actually assign the value of the caught `ZeroDivisionError` object to `OSError`! To eliminate that problem (and awkward syntax), the `as` keyword is now required in this situation.

```
Python 3.1.2 (r312:79360M, Mar 24 2010, 01:33:18)
[GCC 4.0.1 (Apple Inc. build 5493)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> try:
...     1/0
... except (ZeroDivisionError, OSError) as e:
...     print(e)
...
int division or modulo by zero
>>>
```

Attempting to use the syntax in the Python 2 example results in a `SyntaxError` exception. This ensures there is no ambiguity following the `except` statement.

Exception changes were proposed in PEP3110. These updates actually made it into the Python 2 series as well. More information is available at `http://www.python.org/dev/peps/pep-3110/`.

[It is acceptable to use the `as` keyword for exception purposes in Python 2.6 as well. If your code does not need to run on earlier interpreters, you can go right ahead and use the newer syntax now.]

Using metaclasses

Metaclasses are a bit of an advanced topic; however, their syntax is worthy of mention. A metaclass is essentially a class that is responsible for building a class. Try not to think about that too hard just yet!

Previous versions of Python enforced a series of rules that would be used to determine what a class' metaclass would be. Programmers could specify one explicitly by inserting an attribute named `__metaclass__` into the class definition. It was also possible to do this at the module level, which would cause all defined classes in that module to default to newstyle.

In Python 3, all classes are new style. If you have a need to specify a metaclass, you can now do so via a keyword style argument within the class definition.

```
Python 3.1.2 (r312:79360M, Mar 24 2010, 01:33:18)
[GCC 4.0.1 (Apple Inc. build 5493)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> class UselessMetaclassStatement(metaclass=type):
...     pass
...
>>>
```

The above example, while pointless, illustrates the new syntax.

New reserved words

Subsets of Python tokens are now treated as reserved words and cannot be reassigned. Python 3 adds `True`, `False`, `None`, `as`, and `with`. The latter two were reserved as of 2.6 with a warning on `None` reassignment.

Major library changes

As should be expected, a number of modules in the standard library were updated, added, or removed. Many of them were changed to support proper PEP8-compliant naming conventions. For example, `Queue` becomes `queue` and `ConfigParser` becomes `configparser`. The list of changes is exhaustive. For a detailed look, see `http://www.python.org/dev/peps/pep-3108/`, which describes all of the updates.

Changes to list comprehensions

Python's list comprehensions are a powerful feature. They've been changed in Python 3 and generally cleaned up a bit. There are two major changes that you should remember. First, loop control variables are no longer leaked.

For example, the following is valid in Python 2:

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more information.
>>> [i for i in range(10)]
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
>>> i
9
>>>
```

The above example would result in a `NameError` under Python 3 when attempting to access `i` outside of the list compression proper.

Also, the `[i for i in 1,2,3]` syntax is no longer valid. Literals like this must now be enclosed in parenthesis (making them valid tuples). So, the `[i for i in (1,2,3)]` should now be used.

Migrating to Python 3

Now, we'll look at the migration process from Python 2 up to Python 3. It's really not as difficult as it sounds! The Python 3 distribution ships with a utility named `2to3`, which handles the changes we've outlined below, as well as many others. The recommended update process is as follows:

1. Ensure you have up-to-date unit tests so that you can validate functionality after you've made all of the required updates.
2. Under Python 2.6 (or 2.7), run your code with the -3 switch. This enables Python 3-related warnings. Take the time to go through and fix them manually.
3. Run the `2to3` utility on the updated code once it runs cleanly with a -3.

4. Manually fix all of your code until your unit tests are again passing, as they should be after any major update.

For more detailed information on the `2to3` utility, see `http://docs.python.org/release/3.0.1/library/2to3.html`. In the following section, we'll run through the process with some of our example code.

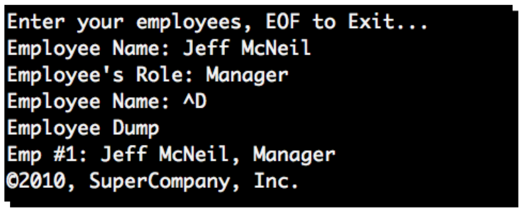
Unit tests are very important in situations like this. Having good unit test coverage ensures that you won't be caught off guard after a major language update like this. We'll skip that step here in our example, but they should always be in place in a production setting.

Time for action – using 2to3 to move to Python 3

In this example, we'll use the `string_definitions.py` file we created in *Chapter 3*, *Python String Services*. This is a very simple little application and includes content that will be updated by the automated utility.

First, we'll run the utility under Python -3 to determine whether there's anything we should manually handle.

```
(text_processing)$ python -3 string_definitions.py
```

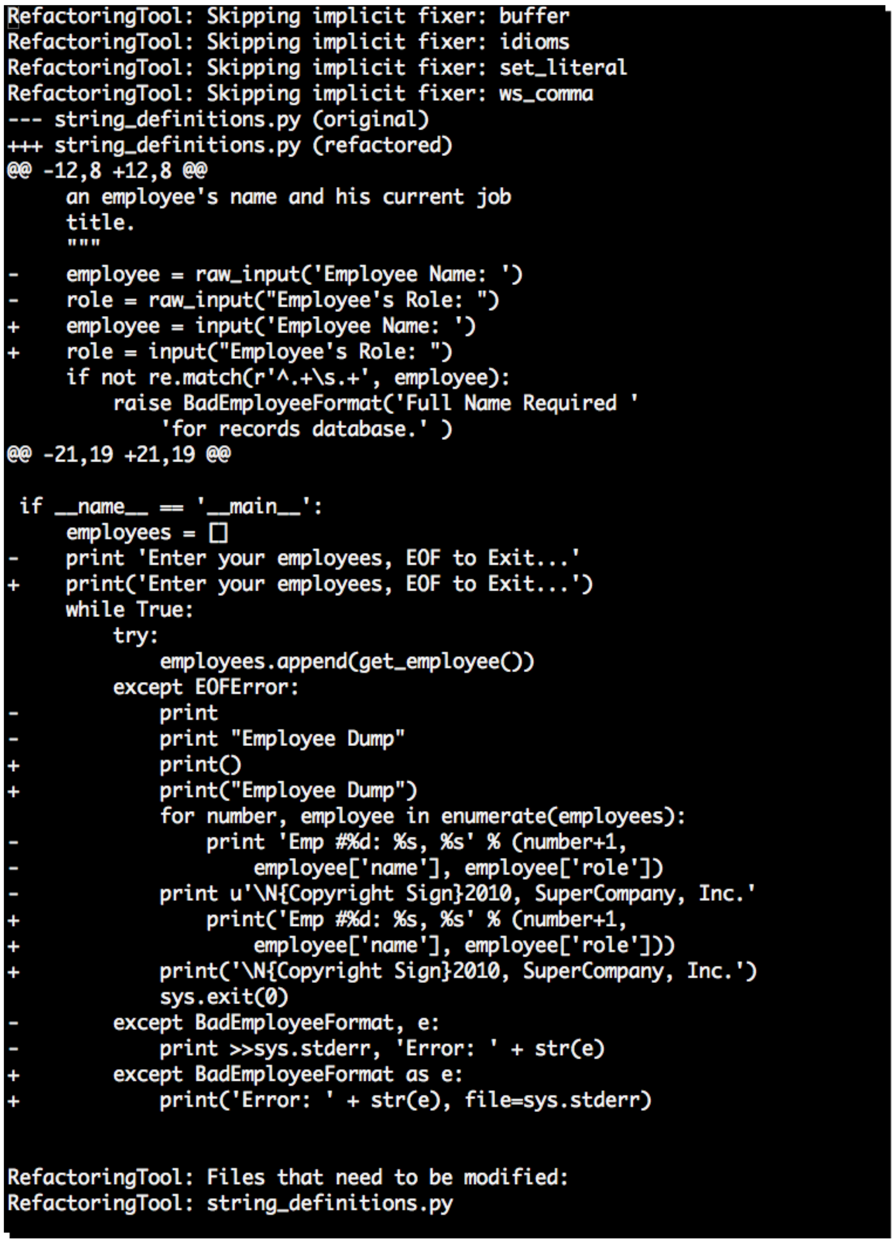


```
Enter your employees, EOF to Exit...
Employee Name: Jeff McNeil
Employee's Role: Manager
Employee Name: ^D
Employee Dump
Emp #1: Jeff McNeil, Manager
©2010, SuperCompany, Inc.
```

The automated process should work nicely. Follow these steps below to complete the update:

1. Run 2to3 on the `string_definitions.py` file. Examine the output for any unexpected code changes.

```
(text_processing)$ 2to3 string_definitions.py
```



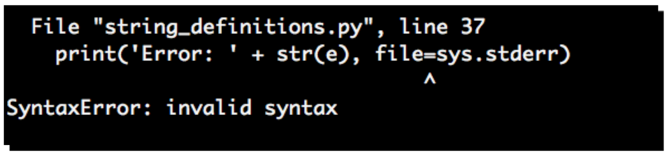
```
RefactoringTool: Skipping implicit fixer: buffer
RefactoringTool: Skipping implicit fixer: idioms
RefactoringTool: Skipping implicit fixer: set_literal
RefactoringTool: Skipping implicit fixer: ws_comma
--- string_definitions.py (original)
+++ string_definitions.py (refactored)
@@ -12,8 +12,8 @@
     an employee's name and his current job
     title.
     """
-    employee = raw_input('Employee Name: ')
-    role = raw_input("Employee's Role: ")
+    employee = input('Employee Name: ')
+    role = input("Employee's Role: ")
     if not re.match(r'^.+\s.+', employee):
         raise BadEmployeeFormat('Full Name Required '
             'for records database.' )
@@ -21,19 +21,19 @@

 if __name__ == '__main__':
     employees = []
-    print 'Enter your employees, EOF to Exit...'
+    print('Enter your employees, EOF to Exit...')
     while True:
         try:
             employees.append(get_employee())
         except EOFError:
-            print
-            print "Employee Dump"
+            print()
+            print("Employee Dump")
             for number, employee in enumerate(employees):
-                print 'Emp #%d: %s, %s' % (number+1,
-                    employee['name'], employee['role'])
-            print u'\N{Copyright Sign}2010, SuperCompany, Inc.'
+                print('Emp #%d: %s, %s' % (number+1,
+                    employee['name'], employee['role']))
+            print('\N{Copyright Sign}2010, SuperCompany, Inc.')
             sys.exit(0)
-        except BadEmployeeFormat, e:
-            print >>sys.stderr, 'Error: ' + str(e)
+        except BadEmployeeFormat as e:
+            print('Error: ' + str(e), file=sys.stderr)


RefactoringTool: Files that need to be modified:
RefactoringTool: string_definitions.py
```

2. Now that we've seen what will happen, run the `2to3` script again using the `-w` option, which triggers a write-back to disk. Output should match the output in the previous step, so we'll not list in here.

```
(text_processing)$ 2to3 -w string_definitions.py
```

3. First, let's attempt to run the updated code using Python 2. Your output should look similar to the following:

   ```
   (text_processing)$ python string_definitions.py
   ```



```
  File "string_definitions.py", line 37
    print('Error: ' + str(e), file=sys.stderr)
                                  ^
SyntaxError: invalid syntax
```

4. Now, run the new source file with the Python 3 interpreter. It should execute as it did under Python 2.

   ```
   (text_processing)$ python3 string_definitions.py
   ```

What just happened?

We ran though upgrading a simple Python 2 source file and updated it to Python 3. The first thing we did was run the utility in a read-only mode. This lets us see the upcoming changes before we committed them to disk. When we were satisfied with our updates, we wrote them out by passing the `-w` switch.

Take a minute to look at the computed `diff` that `2to3` output. In addition to the changes we detailed in the previous section, the script also translated all of the `raw_input` calls to `input`. The resulting file is fully Python 3 compatible (though a backup should appear in the current working directory, just in case).

Summary

In this chapter, we went a little bit off target from pure text data processing. We covered sources of documentation and touched on ways to create your own documentation. Next, we spent some time going over community resources and ways you can get involved; either in person or via groups and mailing lists.

We then spent a little bit of time on some other applications and libraries that you may find useful. Specifically, the Java Lucene-based engines are very high-quality components.

Finally, we spent some more time on Python 3. Hopefully, you feel comfortable now with some of the major changes and the process to move your code forward. The most difficult part of the process is dealing with incompatible third-party utilities.

B
Pop Quiz Answers

Chapter 1: Getting Started

ROT 13 Processing Answers

1	If the values were simply swapped, we would ROT13 encode the tag contents and allow the text data within the tags to pass through unchanged.
2	Technically, yes, as long as the resulting alphabet contains 26 letters. However, this specific implementation relies on the ASCII character set as defined in the string module.
3	Depending on the current state, we could throw our parser off. This is possible, however, using more advanced markup techniques that we'll cover later.
4	We could update our code to read in raw chunks rather than concern ourselves with line boundaries.

Chapter 2: Working with the IO System

File-like objects

1	Python will raise an `AttributeError` exception. The first part of any method execution is standard attribute lookup. If the method cannot be found, it certainly cannot be called.
2	You might be better off calling readlines in two situations. First, for an arbitrarily small data set. Additionally, if you're planning on randomly accessing various lines within a file and need to retain those values in memory.
3	Absolutely nothing. A file will open correctly regardless of the mode passed in. It's writing the file that causes issues.
4	A file object represents an actual on-disk file entity. A file-like object behaves like a file, but the data may come from any arbitrary source.

Chapter 3: Python String Services

String literals

1	Yes, it's possible and the use cases are largely the same. There's one caveat, though: you must define such strings using ur'string' and not ru'string'. Remember, a raw string just affects how it is interpreted, whereas a Unicode string generates an entirely new data type.
2	Strings promote to the "widest" value. For example, Unicode + Unicode is Unicode. At the same time, Unicode + String is Unicode.
3	The exception would have been handled in the default fashion. Our application would terminate and Python would print a back trace.

String formatting

1	Essentially, in places where you're printing the same string repeatedly, but with different values in constant places. It's also useful when creating longer strings such as e-mail message content; you can save your template in an external file and access it via Python's file IO mechanisms.
2	If you have an existing dictionary, you can pass it to a string's format method by prepending it with two asterisks.

```
Python 2.6.1 (r261:67515, Feb 11 2010, 00:51:29)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits", or "license" for more
information.
>>> d = {'a': 1, 'b': 2}
>>> '{a}/{b} = Half'.format(**d)
'1/2 = Half'
>>>
```

3	The answer in this case is a string representation of 12. The + operator, when applied to strings, results in a concatenation.

Chapter 4: Text Processing Using the Standard Library

CSV handling

1	It's possible to create a subclass of `Dialect`, or build a new dialect directly via keyword arguments to the `register_dialect` function of the csv module. It's generally quicker to use the `register_dialect` approach. However, supporting the former simply means defining a few extra attributes. That's useful if you already have data encapsulated in a class.
2	Consider a comma-separated value that contains a comma! The `split` method will return two values here instead of one. This is where the quoting logic within the csv module pays off.
3	They're not. Formulas are spreadsheet concepts that do not carry over into plain text.

JSON formatting

1	This is because we read in a text source to begin with and do not perform any integer casting or type conversion.
2	Generally speaking, no. There are other methods that can be used for Object Serialization, such as the `pickle` module. Complex structures are not saved out. JSON is usually best suited for data transfer rather than object serialization or marshalling.
3	Because of its small size. XML includes a lot of markup and tag structure, whereas JSON does not.

Chapter 5: Regular Expressions

Regular expressions

1	We need to match either a number or a dash. Another approach would be to use a `'|'` and explicitly match either a `\d` or a literal dash.
2	Consider the `(?(name-or-id)yes|no)` approach using a group number versus a group name. This lets us group for precedence without assigning to a numeric group.
3	Frequently used regular expressions will perform much better if pre-compiled. This way, they do not need to go through the process each time.

Understanding the Pythonisms

1	The `match` method only matches at the beginning of a string, whereas search will scan a string for a match. The `match` method would make more sense when testing a small, discrete value such as an HTML form submission whereas search might be preferred when looking for a "needle in a haystack".
2	The `finditer` method returns an interator whereas `findall` is going to return a list. The former uses less memory than the list construction.
3	It's a non-standard Python extension. If you wish to use the expression elsewhere without modification, chances are you'll have to update it.

Chapter 6: Structured Markup

SAX processing

1	SAX can use less memory as the entire XML document is not loaded. It's a good choice when reading larger documents or when you do not need the entire context.
2	Processing is generally more complex, requiring the application developer to keep state and build her own object hierarchy to represent the XML tree structure.
3	That all text isn't necessarily delivered in one call and that all non-element data is included. This means all "pretty formatting" whitespace will be passed into your callback.
4	The *NS versions are called when operating in Name Space mode, which is turned on via the appropriate `parser.setFeature` toggle.

Chapter 7: Creating Templates

Template inheritance

1	To access the next template, reference the next namespace. To access the previous, reference the parent namespace.
2	Add a backslash right before the new line character appears in the input stream.
3	Define them where needed and refer to them via `self.attr`.
4	You should use the local namespace to reference the currently executing template.

Chapter 8: Understanding Encoding and i18n

Character encodings

1	As many systems only supported 7-bit values, it was an attempt to retain usability in the event that software didn't support 8-bit values.
2	32.
3	A glyph is the graphical representation seen on your screen whereas a code point is an abstract value given to a Unicode character.

Python encodings

1	When encoding Unicode data, a string object is returned. Note that if you're using Python 3 then a bytes object is returned.
2	A Unicode object. However, as Python 3 strings are Unicode, you'll receive a string object for later versions of Python.
3	Not doing so can easily introduce bugs. You can wind up with a UTF encoded string type, or raise exceptions when writing data containing code points higher than 128.

Internationalization

1	Localization or L10n. Note the capital "L" used.
2	Because ordering of words may change in different languages. Using this syntax allows the translator to move the variable and not rely on positioning.
3	Plurals, for one. Consider English uses the "s" to signify plural, while Russian utilizes many endings to indicate plural. Gender, numbers, and tense all provide the same challenges.

Chapter 9: Advanced Output Formats

Creating XLS documents

1	When we wrote our integers to our Excel objects, they were written as Python strings. The typing information simply carried over.
2	We could call `xlwt.easyxf` again and pass in different options. Spend a minute and play with various font and decoration options to gain a feel for what's possible.
3	We can embed formulas in native XLS files.

Chapter 11: Searching and Indexing

Introduction to Nucular

1	Searching complexity and completion time. A straight search grows linearly as data is added whereas most indexes will grow logarithmically.
2	Disk IO! Nucular indexes are persisted to disk. Therefore, the faster your disks, the faster your results.
3	The supplied `nucularDump.py` and `nucularLoad.py` files.
4	Yes.

Index