MODULE 3

IoT Platforms Design Methodology: Introduction, IoT Design Methodology, Case Study on IoT System for Weather Monitoring, loT Systems - Logical Design using Python: Introduction, Installing Python, Python Data Types and Data structures, Control flow, Functions, Modules, Packages, File Handling, Operations, Classes, Python Packages of Interest for IoT.

IoT Platforms Design Methodology

3.1 Introduction

IoT systems are made up of many components and levels, which makes designing them complex. Designers often choose specific products or services, which can lead to vendor lock-in. This makes it difficult to update or change parts of the system later.To solve this problem, the chapter introduces a general design method that does not depend on any specific product, service, or programming language. This method helps reduce design time, maintenance, and improves system flexibility and compatibility. It is based on the IoT-A reference model but can be used for various industry needs.

3.2 IoT Design Methodology

Figure 5.1 shows the steps involved in the IoT system design methodology. Each of these steps is explained in the sections that follow. To explain these steps, we use the example of a smart IoT-based home automation system.

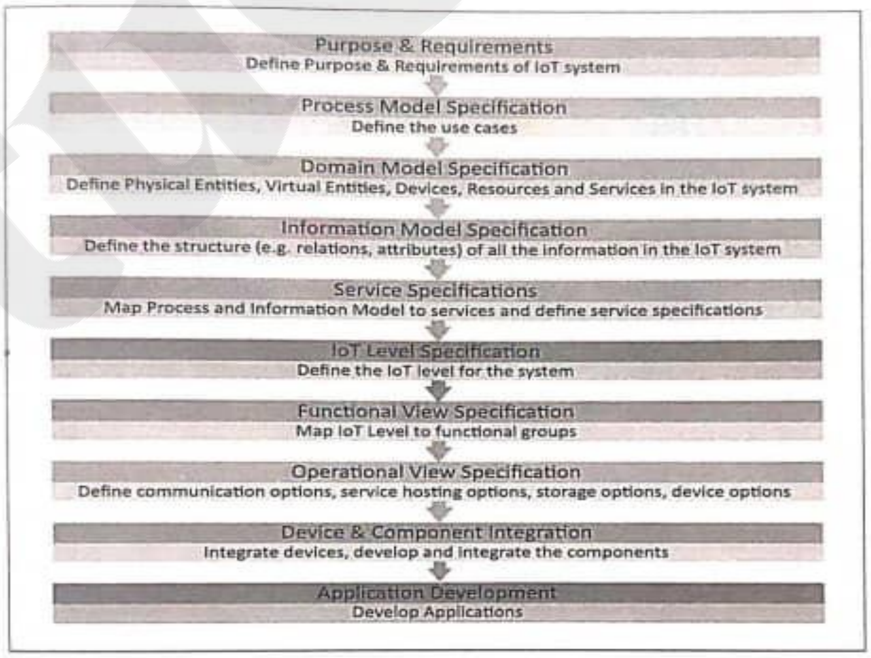

Purpose & Requirements
Define Purpose & Requirements of IoT system
Process Model Specification
Define the use cases
Domain Model Specification
Define Physical Entities, Virtual Entities, Devices, Resources and Services in the IoT system
Information Model Specification
Define the structure (e.g. relations, attributes) of all the information in the IoT system
Service Specifications
Map Process and Information Model to services and define service specifications
IoT Level Specification
Define the IoT level for the system
Functional View Specification
Map IoT Level to functional groups
Operational View Specification
Define communication options, service hosting options, storage options, device options
Device & Component Integration
Integrate devices, develop and integrate the components
Application Development
Develop Applications

Figure 5.1: Steps involved in IoT system design methodology

3.2.1 Step 1: Purpose & Requirements Specification

The first step in IoT system design methodology is to define the purpose and requirements of the system. In this step, the system purpose, behavior and requirements (such as data collection requirements, data analysis requirements, system management requirements, data privacy and security requirements, user interface requirements, ...) are captured. Applying this to our example of a smart home automation system, the purpose and requirements for the system may be described as follows:

Purpose: A home automation system that allows controlling of the lights in a home remotely using a web application.
Behaviour: The home automation system should have auto and manual modes. In auto mode, the system measures the light level in the room and switches on the light when it gets dark. In manual mode, the system provides the option of manually and remotely switching on/off the light.
System Management Requirement: The system should provide remote monitoring and control functions.
Data Analysis Requirement: The system should perform local analysis of the data.
Application Deployment Requirement: The application should be deployed locally on the device, but should be accessible remotely.
Security Requirement: The system should have basic user authentication capability.

3.2.2 Step 2: Process Specification

The second step in the IoT design methodology is to define the process specification. In this step, the use cases of the IoT system are formally described based on and derived from the purpose and requirement specifications. **Figure 5.2** shows the process diagram for the home automation system. The process diagram shows the two modes of the system – auto and manual. In a process diagram, the circle denotes the start of a process, diamond denotes a decision box and rectangle denotes a state or attribute. When the auto mode is chosen, the system monitors the light level. If the light level is low, the system changes the state of the light to “on”. Whereas, if the light level is high, the system changes the state of the light to “off’. When the manual mode is chosen, the system checks the light state set by the user. If the light state set by the user is “on”, the system changes the state of light to “on”. Whereas, if the light state set by the user is “off’, the system changes the state of light to “off’.

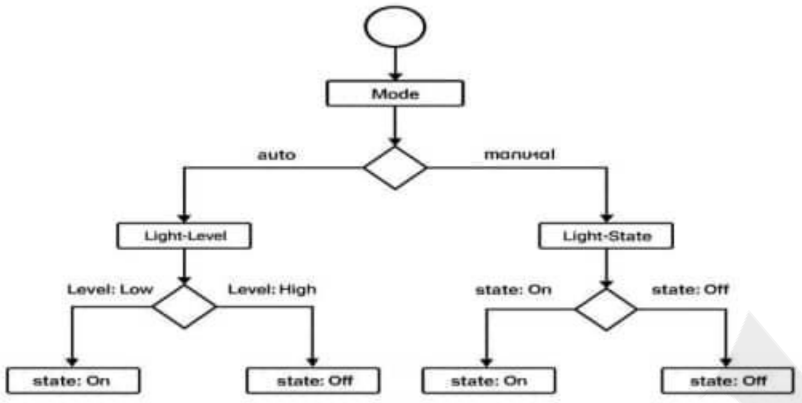


Figure 5.2: Process specification for home automation IoT system

3.2.3 Step 3: Domain Model Specification

The third step in the IoT design methodology is to define the Domain Model. The domain model describes the main concepts, entities and objects in the domain of IoT system to be designed. Domain model defines the attributes of the objects and relationships between objects. Domain model provides an abstract representation of the concepts, objects and entities in the IoT domain, independent of any specific technology or platform. With the domain model, the IoT system designers can get an understanding of the IoT domain for which the system is to be designed. Figure 5.3 shows the domain model for the home automation system example. The entities, objects and concepts defined in the domain model include:

- **Physical Entity:**
  Physical Entity is a discrete and identifiable entity in the physical environment (e.g., a room, a light, an appliance, a car, etc.). The IoT system provides information about the Physical Entity (using sensors) or performs actuation upon the Physical Entity (e.g., switching on a light). In the home automation example, there are two Physical Entities involved – one is the room in the home (of which the lighting conditions are to be monitored) and the other is the light appliance to be controlled.
- **Virtual Entity:**
  Virtual Entity is a representation of the Physical Entity in the digital world. For each Physical Entity, there is a Virtual Entity in the domain model. In the home automation example, there is one Virtual Entity for the room to be monitored, another for the appliance to be controlled.
- **Device:**
  Device provides a medium for interactions between Physical Entities and Virtual Entities. Devices are either attached to Physical Entities or placed near Physical Entities. Devices are used to gather information about Physical Entities (e.g., from sensors), perform actuation upon Physical Entities (e.g., using actuators) or used to process information (e.g., using tags). In the home automation example, the device is a single-board mini computer which has light sensor and actuator (relay switch) attached to it.
- **Resource:**
  Resources are software components which can be either "on-device" or "network-resources". On-device resources are hosted on the device and include software components that either provide information or enable actuation upon the Physical Entity to which the device is attached. Network resources include software components that are available in network (such as a database). In the home automation example, the on-device resource is the operating system

that runs on the single-board minicomputer.

- **Service:**
  Services provide an interface for interacting with the Physical Entity. Services access the resources hosted on the device or the network resources to obtain information about the Physical Entity or perform actuation upon the Physical Entity.

  In the home automation example, there are three services:
  (1) a service that sets mode to auto or manual, or retrieves the current mode;(2) a service that sets the light appliance state to on/off, or retrieves the current light state; (3) a controller service that runs as a native service on the device.

- When in auto mode, the controller service monitors the light level and switches the light on/off and updates the status in the status database.
  When in manual mode, the controller service retrieves the current state from the database and switches the light on/off.
- The process of deriving the services from the process specification and information model is described in the later sections.

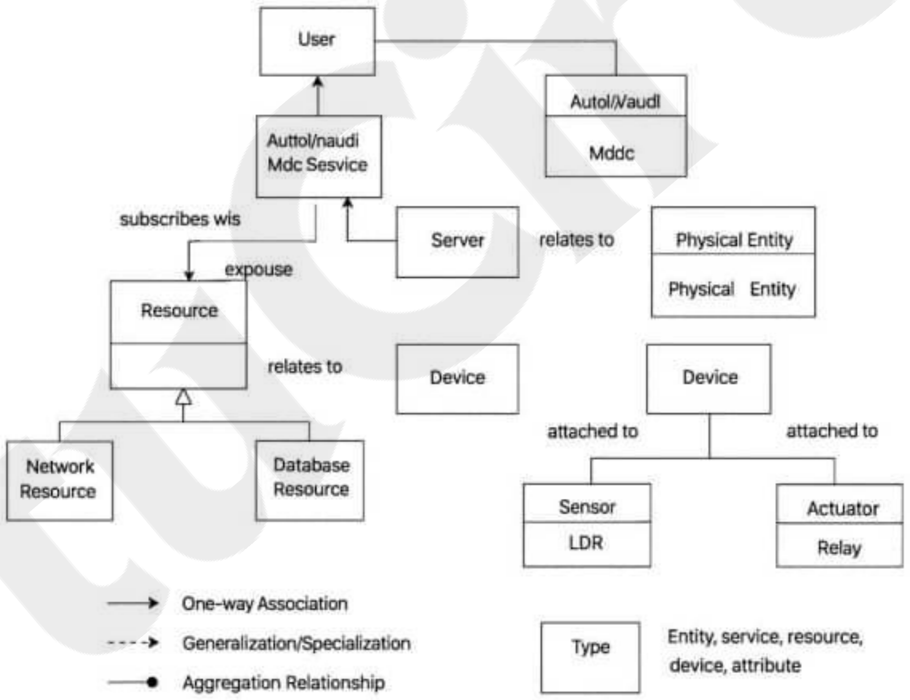


Figure 5.3: Domain model of the home automation IoT system

3.2.4 Step 4: Information Model Specification

The fourth step in the IoT design methodology is to define the Information Model. Information Model defines the structure of all the information in the IoT system, for example, attributes of Virtual Entities, relations, etc. Information model does not describe the specifics of how the information is represented or stored. To define the information model, we first list the Virtual Entities defined in the Domain Model. Information model adds more details to the Virtual

Entities by defining their attributes and relations. In the home automation example, there are two Virtual Entities – a Virtual Entity for the light appliance (with attribute – light state) and a Virtual Entity for the room (with attribute – light level). Figure 5.4 shows the Information Model for the home automation system example.

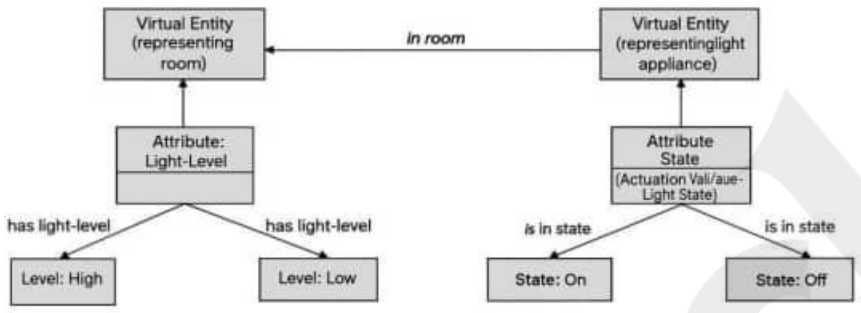

Virtual Entity (representing room)
in room
Virtual Entity (representinglight appliance)
Attribute: Light-Level
Attribute State (Actuation Vali/aue- Light State)
has light-level
has light-level
is in state
is in state
Level: High
Level: Low
State: On
State: Off

Figure 5.4: Informat ion model of the home automation IoT system

3.2.5 Step 5: Service Specifications

The fifth step in the IoT design methodology is to define the service specifications. Service specifications define the services in the IoT system, service types, service inputs/output, service endpoints, service schedules, service preconditions and service effects.
You learned about the Process Specification and Information Model in the previous sections. **Figure 5.5** shows an example of deriving the services from the process specification and information model for the home automation IoT system. From the process specification and information model, we identify the states and attributes. For each state and attribute, we define a service. These services either change the state or attribute values or retrieve the current values. For example, the Mode service sets mode to auto or manual or retrieves the current mode. The State service sets the light appliance state to on/off or retrieves the current light state. The Controller service monitors the light level in auto mode and switches the light on/off and updates the status in the status database. In manual mode, the controller service, retrieves the current state from the database and switches the light on/off.

Figures 5.6, 5.7 and 5.8 show specifications of the controller, mode and state services of the home automation system. The Mode service is a RESTful web service that sets mode to auto or manual (PUT request), or retrieves the current mode (GET request). The mode is updated to/retrieved from the database. The State service is a RESTful web service that sets the light appliance state to on/off (PUT request), or retrieves the current light state (GET request). The state is updated to/retrieved from the status database. The Controller service runs as a native service on the device. When in auto mode, the controller service monitors the light level and switches the light on/off and updates the status in the status database. When in manual mode, the controller service retrieves the current state from the database and switches the light on/off.

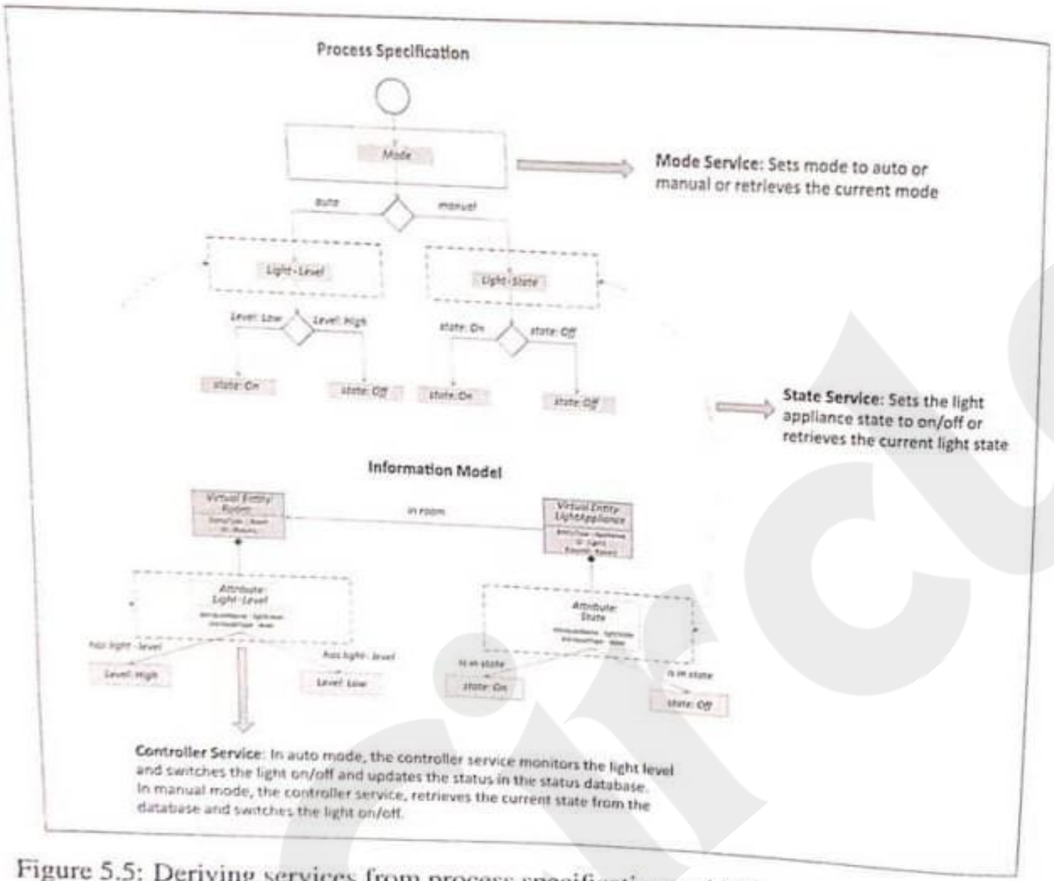

Process Specification
Mode
auto
manual
Mode Service: Sets mode to auto or manual or retrieves the current mode
Light-Level
Light-State
Level: Low
Level: High
state: On
state: Off
state: On
state: Off
state: On
state: Off
State Service: Sets the light appliance state to on/off or retrieves the current light state
Information Model
in room
has light-level
has light-level
Level: High
Level: Low
is in state
is in state
state: On
state: Off
Controller Service: In auto mode, the controller service monitors the light level and switches the light on/off and updates the status in the status database.
In manual mode, the controller service, retrieves the current state from the database and switches the light on/off.

Figure 5.5: Deriving services from process specification and information model for home automation IoT system

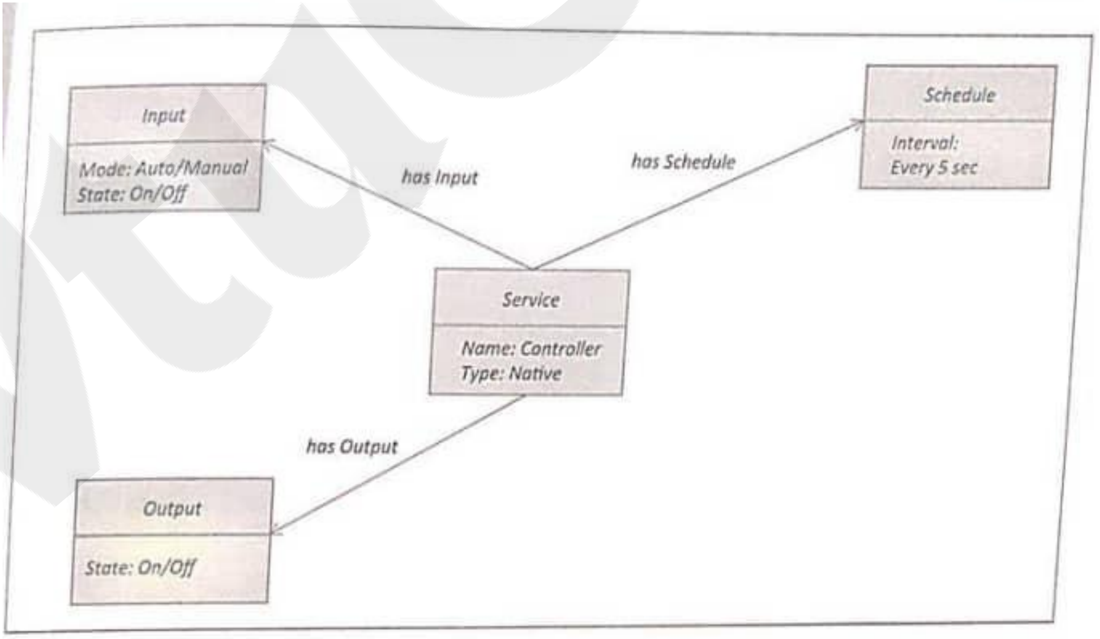


Figure 5.6: Controller service of the home automation IoT system

3.2.6 Step 6: IoT Level Specification

The sixth step in the IoT design methodology is to define the IoT level for the system. In Chapter-1, we defined five IoT deployment levels. **Figure 5.9** shows the deployment level of the home automation IoT system, which is level-1.

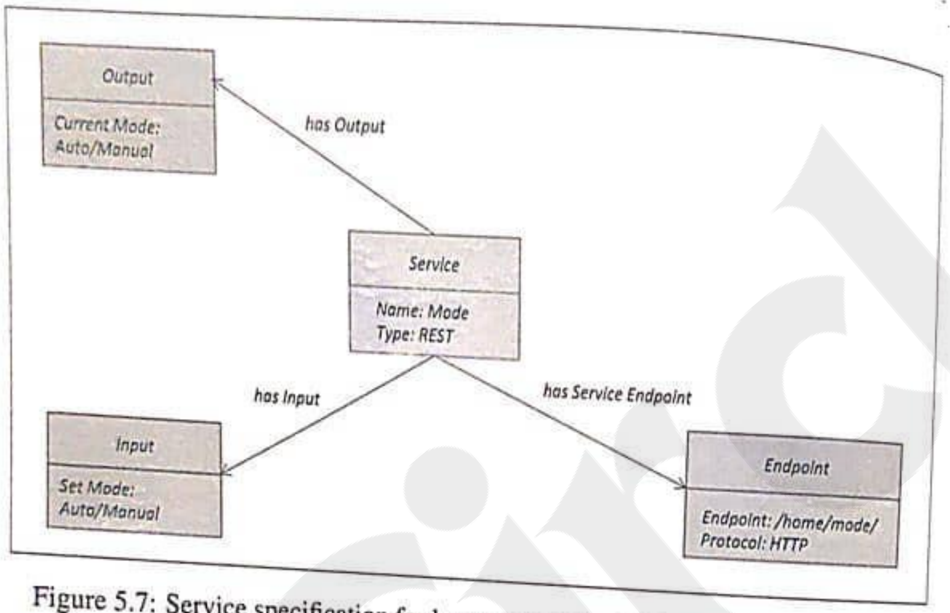


Figure 5.7: Service specification for home automation IoT system - mode service

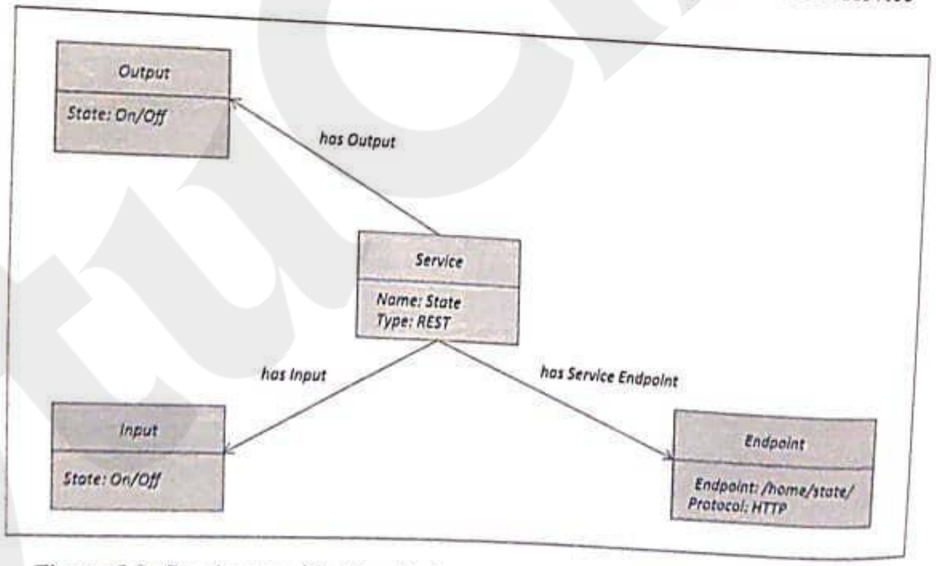


Figure 5.8: Service specification for home automation IoT system - state service

3.2.7 Step 7: Functional View Specification

The seventh step in the IoT design methodology is to define the Functional View. The Functional View (FV) defines the functions of the IoT systems grouped into various Functional Groups (FGs). Each Functional Group either provides functionalities for interacting with instances of

concepts defined in the Domain Model or provides information related to these concepts.
The Functional Groups (FG) included in a Functional View include:

- **Device**: The device FG contains devices for monitoring and control. In the home automation example, the device FG includes a single board mini-computer, a light.

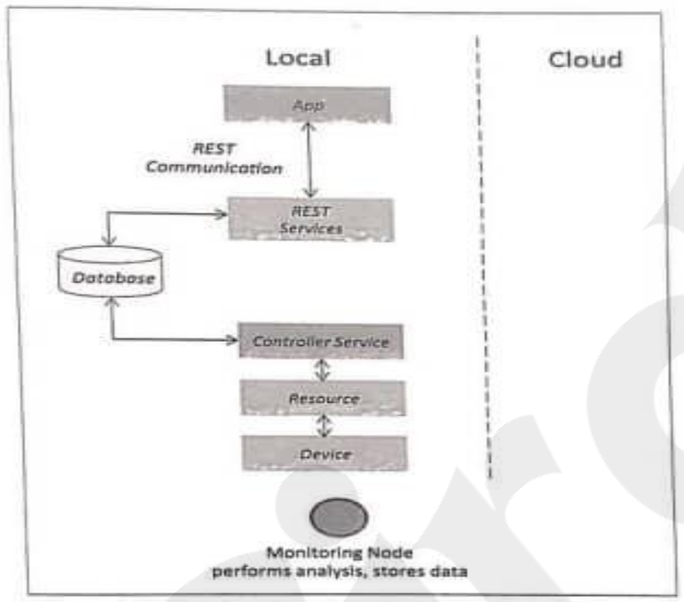


Figure 5.9: Deployment design of the home automation IoT system

Communication: The communication FG handles the communication for the IoT system. The communication FG includes the communication protocols that form the backbone of IoT systems and enable network connectivity. You learned about various link, network, transport and application layer protocols in Chapter-1. The communication FG also includes the communication APIs (such as REST and WebSocket) that are used by the services and applications to exchange data over the network. In the home automation example the communication protocols include – 802.11 (link layer), IPv4/IPv6 (network layer), TCP (transport layer), and HTTP (application layer). The communication API used in the home automation examples is a REST-based API.
Services: The service FG includes various services involved in the IoT system such as services for device monitoring, device control services, data publishing services and services for device discovery.in home automation example, there are two REST service (mode and state service) and one native service (controller service).
Management: The management FG includes all functionalities that are needed to configure and manage the IoT system.
Security: The security FG includes security mechanisms for the IoT system such as authentication, authorization, data security, etc.
Application: The application FG includes applications that provide an interface to the users to control and monitor various aspects of the IoT system. Applications also allow users to view the system status and the processed data.

Figure 5.10 shows an example of mapping deployment level to functional groups for home automation IoT system device maps to the Device FG (sensors, actuators devices, computing devices) and the Management FG (device management). Resources map to the Device FG (on-device resource) and Communication FG (communication APIs and protocols). Controller service maps to the Services FG (native service). Web Services map to Services FG. Database maps to the Management FG (database management) and Security FG (database security). Application maps to the Application FG (web application, application and database servers), Management FG (app management) and Security FG (app security).

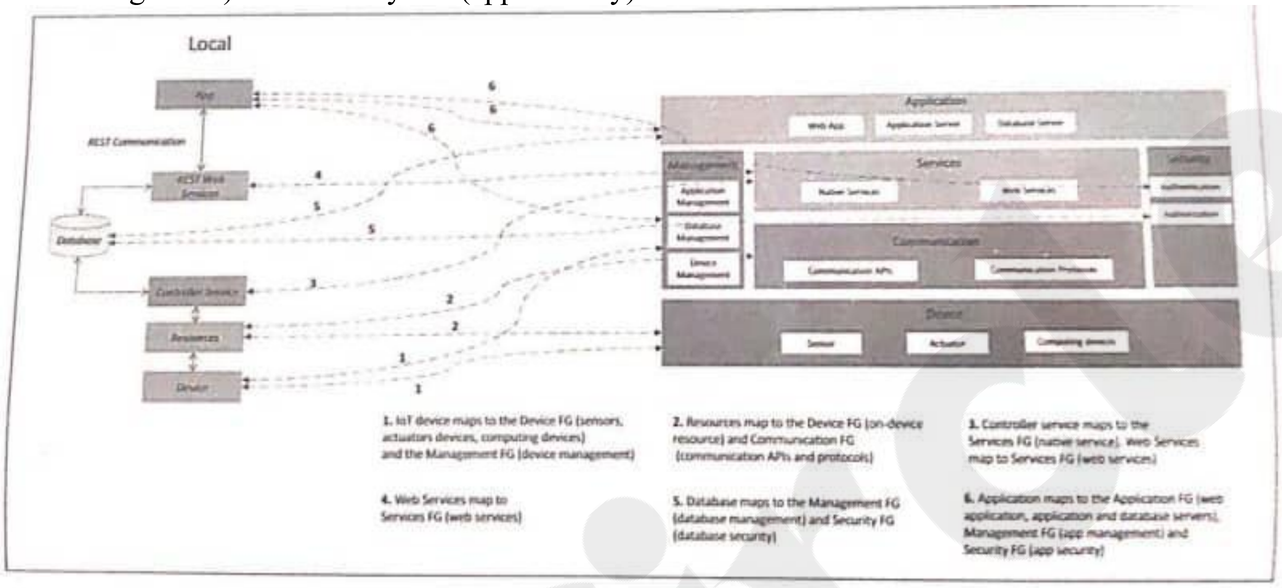

Local
App
REST Communication
REST Web Services
Database
Controller Service
Resources
Device
Application
Web App
Application Server
Database Server
Management
Application Management
Database Management
Device Management
Services
Native Services
Web Services
Security
Authentication
Authorization
Communication
Communication APIs
Communication Protocols
Device
Sensor
Actuator
Computing devices
1. IoT device maps to the Device FG (sensors, actuators devices, computing devices) and the Management FG (device management)
2. Resources map to the Device FG (on-device resource) and Communication FG (communication APIs and protocols)
3. Controller service maps to the Services FG (native service). Web Services map to Services FG (web services)
4. Web Services map to Services FG (web services)
5. Database maps to the Management FG (database management) and Security FG (database security)
6. Application maps to the Application FG (web application, application and database servers), Management FG (app management) and Security FG (app security)

Figure 5.10: Mapping deployment level to functional groups for home automation IoT system

3.2.8 Step 8: Operational View Specification

The eighth step in the IoT design methodology is to define the Operational View Specifications.
In this step, various options pertaining to the IoT system deployment and operation are defined, such as service hosting options, storage options, device options, application hosting options, etc.
Figure 5.11 shows an example of mapping functional groups to operational view specifications for home automation IoT system.

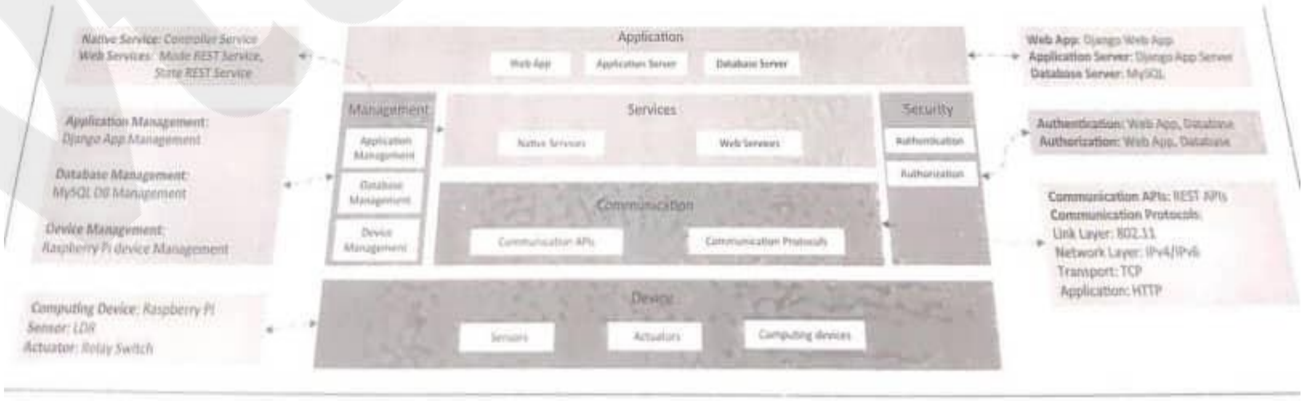


Figure 5.11: Mapping functional groups to operational view for home automation IoT system

Operational View specifications for the home automation example are as follows:

Devices: Computing device (Raspberry Pi), light dependent resistor (sensor), relay switch (actuator).

Communication APIs: REST APIs

Communication Protocols:

- Link Layer – 802.11
- Network Layer – IPv4/IPv6
- Transport – TCP
- Application – HTTP

Services:

1. **Controller Service** – Hosted on device, implemented in Python and run as a native service.
2. **Mode service** – REST-ful web service, hosted on device, implemented in Python.
3. **State service** – REST-ful web service, hosted on device, implemented with Django-REST Framework.

Application:

- Web Application – Django Web Application,
- Application Server – Django App Server,
- Database Server – MySQL

Security:

- Authentication: Web App, Database
- Authorization: Web App, Database

Management:

- Application Management – Django App Management
- Database Management – MySQL DB Management
- Device Management – Raspberry Pi device Management

3.2.9 Step 9: Device & Component Integration

The ninth step in the IoT design methodology is the integration of the devices and components. **Figure 5.12** shows a schematic diagram of the home automation IoT system. The devices and components used in this example are Raspberry Pi minicomputer, LDR sensor and relay switch actuator. A detailed description of Raspberry Pi board and how to interface sensors and actuators with the board is provided in later chapters.

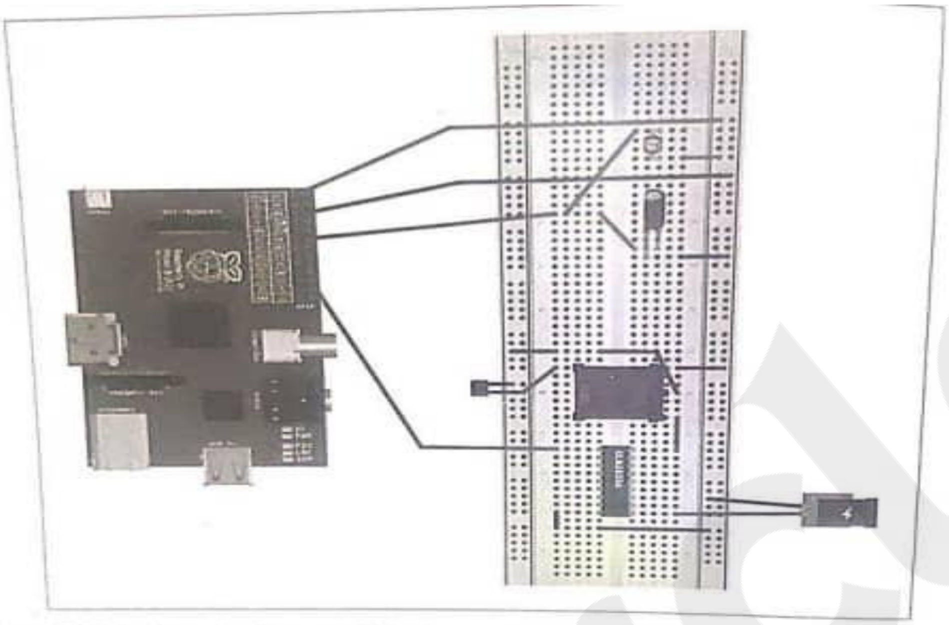


Figure 5.12: Schematic diagram of the home automation IoT system showing the device, sensor and actuator integrated

3.2.10 Step 10: Application Development

The final step in the IoT design methodology is to develop the IoT application. **Figure 5.13** shows a screenshot of the home automation web application. The application has controls for the mode (auto on or auto off) and the light (on or off). In the auto mode, the IoT system controls the light appliance automatically based on the lighting conditions in the room. When auto mode is enabled the light control in the application is disabled and it reflects the current state of the light. When the auto mode is disabled, the light control is enabled and it is used for manually controlling the light.

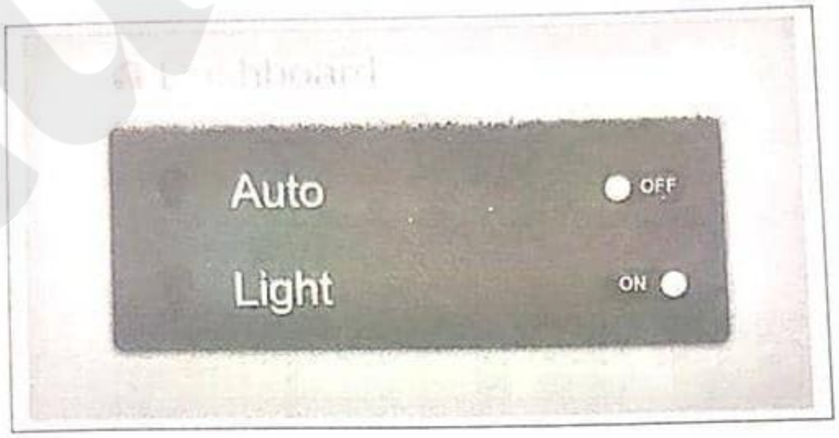


Figure 5.13: Home automation web application screenshot

3.3 Case Study on IoT System for Weather Monitoring

In this section we present a case study on design of an IoT system for weather monitoring using the IoT design methodology. The purpose of the weather monitoring system is to collect data on environmental conditions such as temperature, pressure, humidity and light.in an area using multiple end nodes. The end nodes send the data to the cloud where the data is aggregated and analysed.

Figure 5.14 shows the process specification for the weather monitoring system. The process specification shows that the sensors are read after fixed intervals and the sensor measurements are stored.

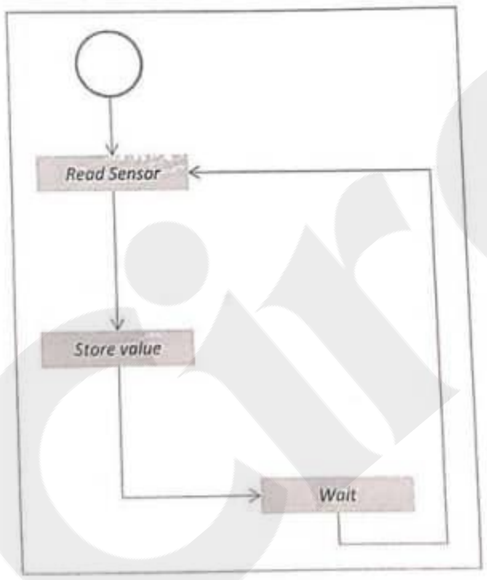


Figure 5.14: Process specification for weather monitoring IoT system

Figure 5.15 shows the domain model for the weather monitoring system. In this domain model the physical entity is the environment which is being monitored. There is a virtual entity for the environment. Devices include temperature sensor, pressure sensor, humidity sensor, light sensor and single-board minicomputer. Resources are software components which can be either on-device or network-resources. Services include the controller service that monitors the temperature, pressure, humidity and light and sends the readings to the cloud.

Figure 5.16 shows the information model for the weather monitoring system. In this example, there is one virtual entity for the environment being sensed. The virtual entity has attributes – temperature, pressure, humidity and light.

Figure 5.17 shows an example of deriving the services from the process specification and information model for the weather monitoring system.

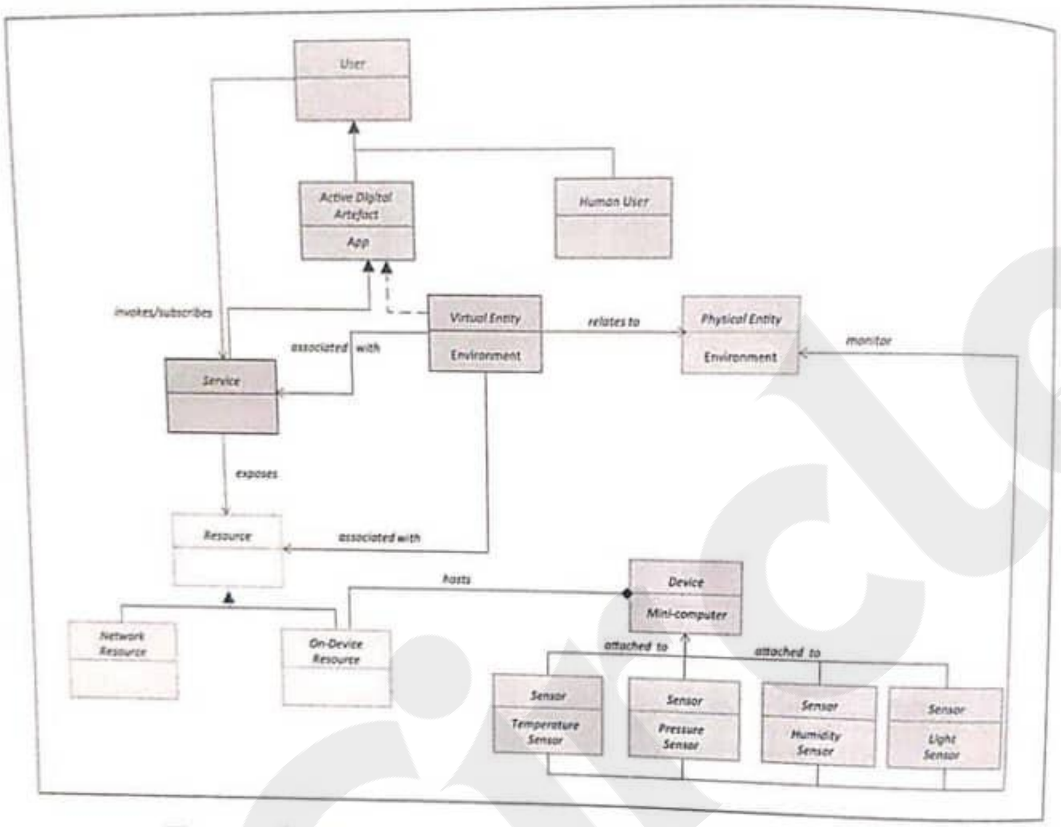


Figure 5.15: Domain model for weather monitoring IoT system

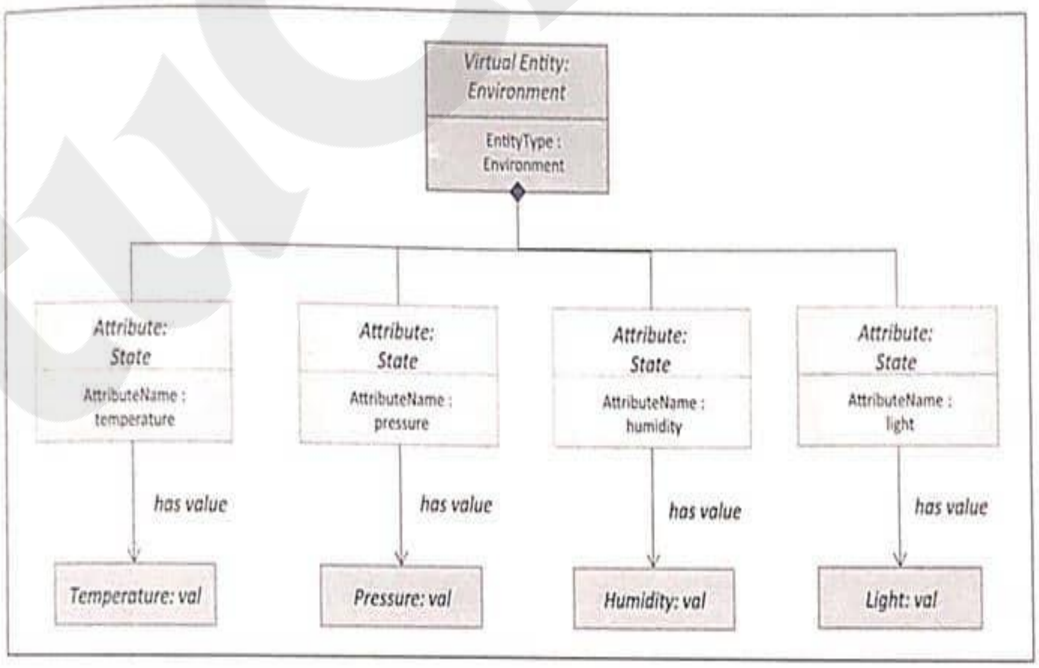


Figure 5.16: Information model for weather monitoring IoT system

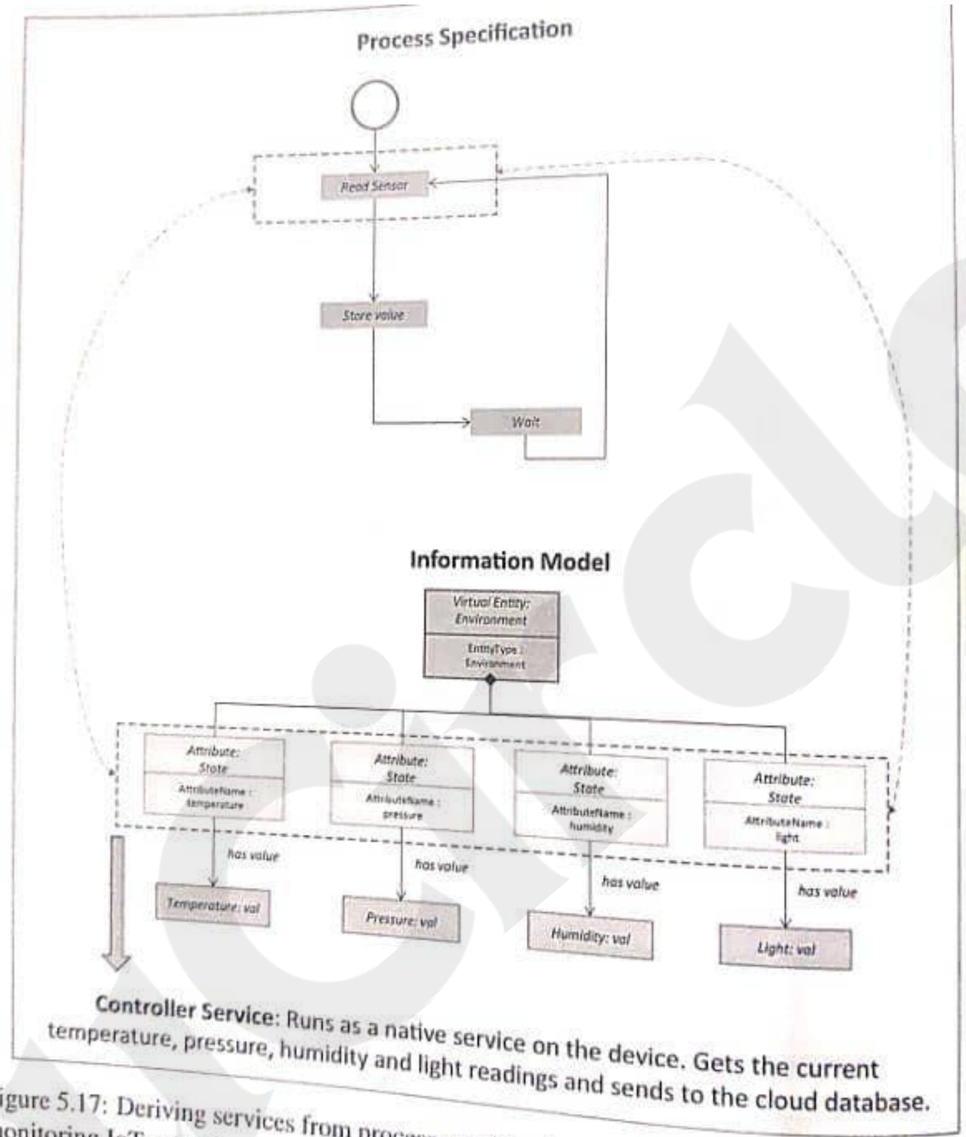


Figure 5.17: Deriving services from process specification and information model for weather monitoring IoT system

Figure 5.18 shows the specification of the controller service for the weather monitoring system. The controller service runs as a native service on the device and monitors temperature, pressure, humidity and light once every 15 seconds. The controller service calls the REST service to store these measurements in the cloud. In Chapter-8 we describe a Platform-as-a-Service called **Xively** that can be used for creating solutions for Internet of Things.

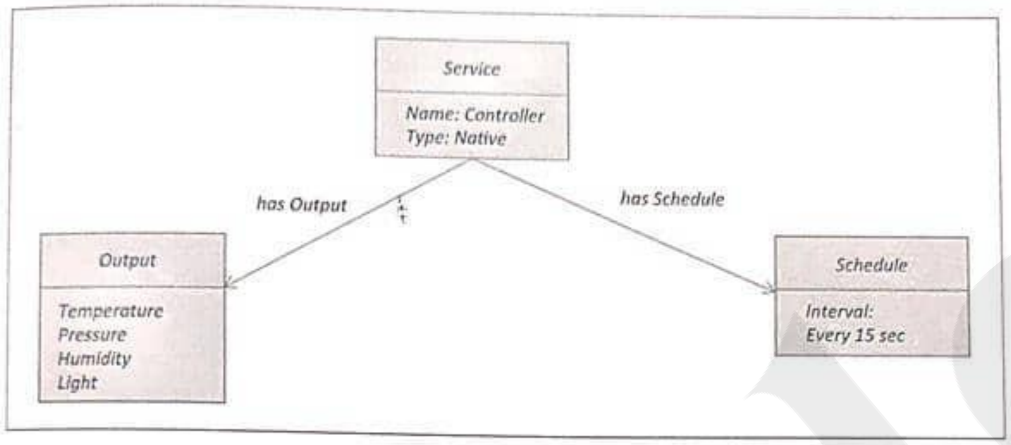


Figure 5.18: Controller service of the weather monitoring IoT system

Figure 5.19 shows the deployment design for the system. The system consists of multiple nodes placed in different locations for monitoring temperature, humidity and pressure in an area. The end nodes are equipped with various sensors (such as temperature, pressure, humidity and light). The end nodes send the data to the cloud and the data is stored in a cloud database. The analysis of data is done in the cloud to aggregate the data and make predictions. A cloud-based application is used for visualizing the data. The centralized controller can send control commands to the end nodes, for example, to configure the monitoring interval on the end nodes.

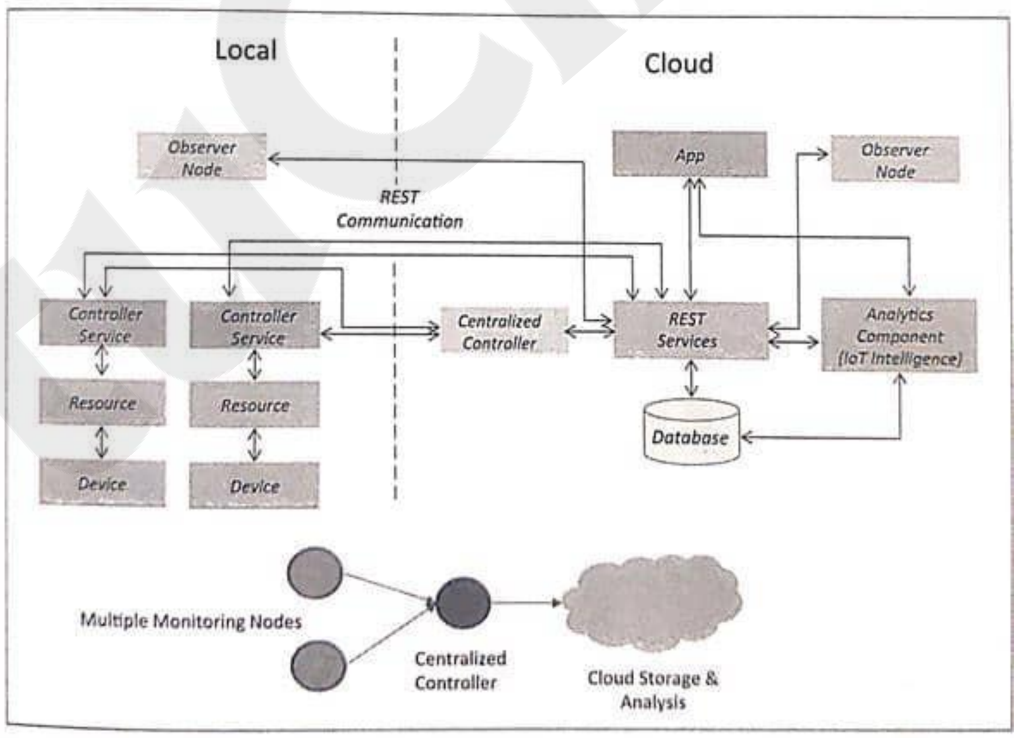


Figure 5.19: Deployment design of the weather monitoring IoT system

Figure 5.20 shows an example of mapping deployment level to functional groups for the weather monitoring system.

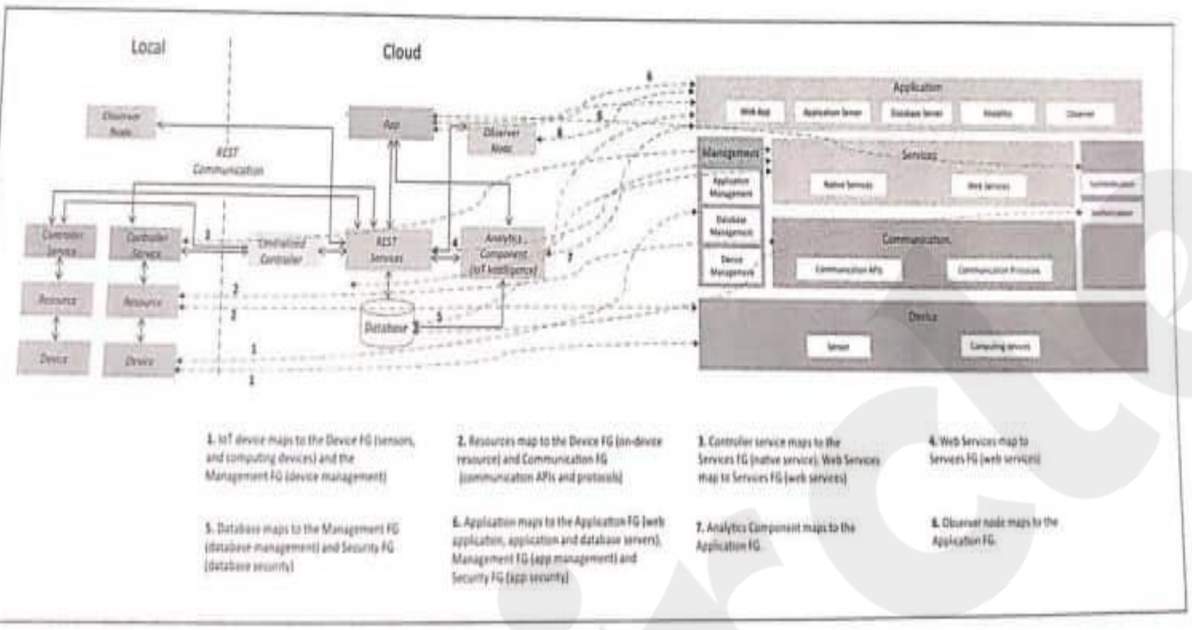

Local
Cloud
Observer Node
REST Communication
App
Observer Node
Controller Service
Controller Service
Centralized Controller
REST Services
Analytics Component (IoT Intelligence)
Resource
Resource
Device
Device
Database
Application
Web App
Application Server
Database Server
Analytics
Observer
Management
Application Management
Database Management
Device Management
Services
Native Services
Web Services
Communication
Communication APIs
Communication Protocols
Device
Sensor
Computing devices
1. IoT device maps to the Device FG (sensors, and computing devices) and the Management FG (device management)
2. Resources map to the Device FG (on-device resource) and Communication FG (communicaton APIs and protocols)
3. Controller service maps to the Services FG (native service). Web Services map to Services FG (web services)
4. Web Services map to Services FG (web services)
5. Database maps to the Management FG (database management) and Security FG (database security)
6. Application maps to the Application FG (web application, application and database servers), Management FG (app management) and Security FG (app security)
7. Analytics Component maps to the Application FG
8. Observer node maps to the Application FG

Figure 5.20: Mapping deployment level to functional groups for the weather monitoring IoT system

Figure 5.21 shows an example of mapping functional groups to operational view specifications for the weather monitoring system.

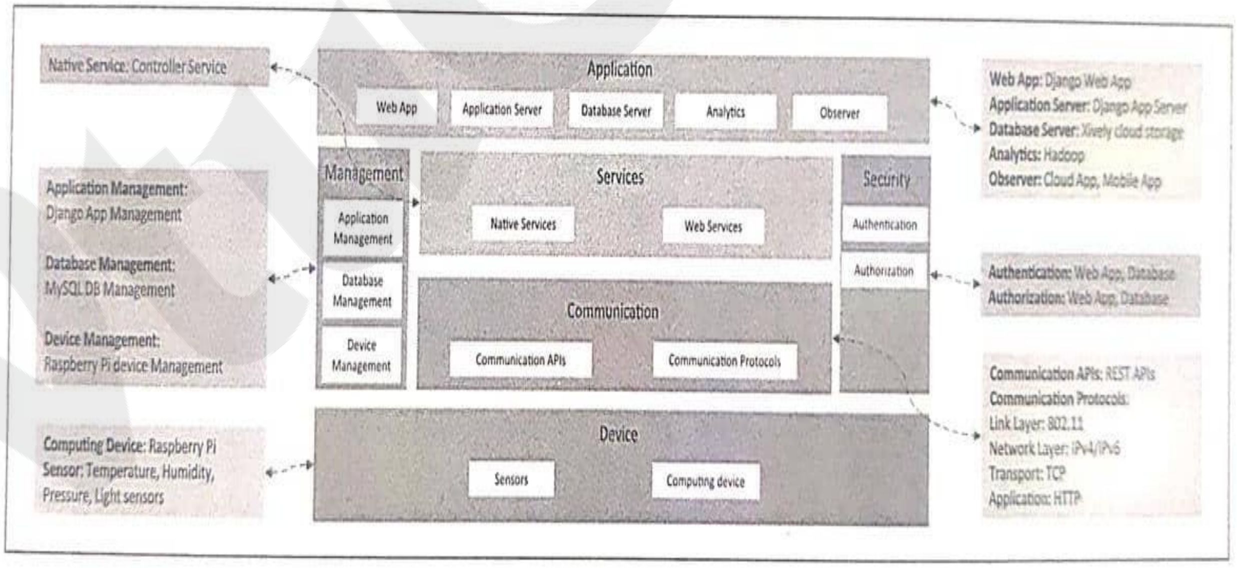

Native Service: Controller Service
Application
Web App
Application Server
Database Server
Analytics
Observer
Web App: Django Web App
Application Server: Django App Server
Database Server: Xively cloud storage
Analytics: Hadoop
Observer: Cloud App, Mobile App
Application Management: Django App Management
Database Management: MySQL DB Management
Device Management: Raspberry Pi device Management
Management
Application Management
Database Management
Device Management
Services
Native Services
Web Services
Security
Authentication
Authorization
Authentication: Web App, Database
Authorization: Web App, Database
Communication
Communication APIs
Communication Protocols
Communication APIs: REST APIs
Communication Protocols:
Link Layer: 802.11
Network Layer: IPv4/IPv6
Transport: TCP
Application: HTTP
Computing Device: Raspberry Pi
Sensor: Temperature, Humidity, Pressure, Light sensors
Device
Sensors
Computing device

Figure 5.21: Mapping functional groups to operational view for the weather monitoring IoT system

Figure 5.22 shows a schematic diagram of the weather monitoring system. The devices and components used in this example are Raspberry Pi minicomputer, temperature sensor, humidity sensor, pressure sensor and LDR sensor.

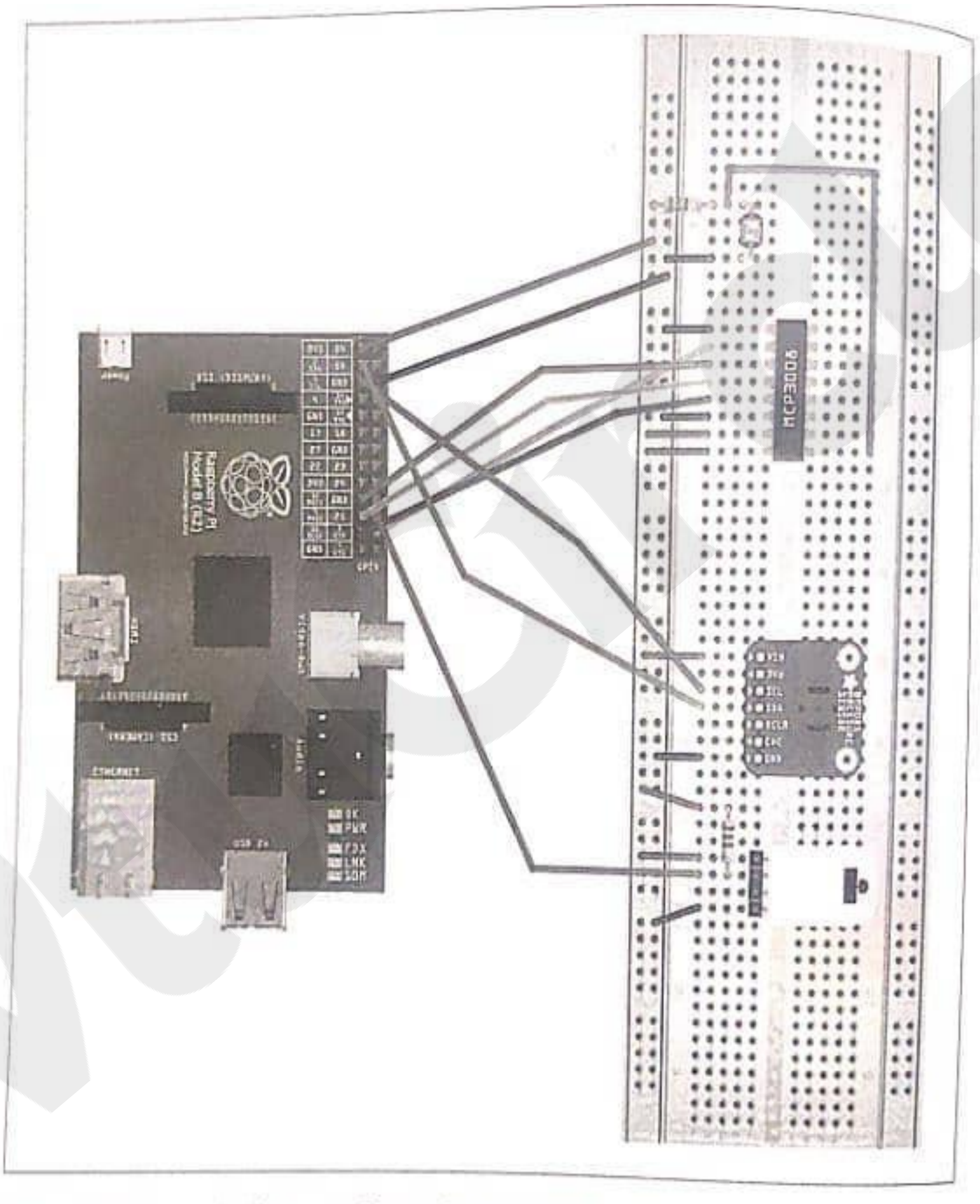


Figure 5.22: Schematic diagram of a weather monitoring end-node showing the device and sensors

IoT Systems - Logical Design using Python

3.4 : Introduction

Python is a general-purpose high-level programming language. Python 2.0 was released in the year 2000 and Python 3.0 was released in the year 2008. The 3.0 version is not backward compatible with earlier releases. The most recent release of Python is version 3.3. Currently, there is limited library support for the 3.x versions with operating systems such as Linux and Mac still using Python 2.x as default language. The exercises and examples in this book have been developed with Python version 2.7.

The main characteristics of Python are:

Multi-paradigm programming language
Python supports more than one programming paradigm including object-oriented programming and structured programming.

Interpreted Language
Python is an interpreted language and does not require an explicit compilation step. The Python interpreter executes the program source code directly, statement by statement, as a processor or scripting engine does.

Interactive Language
Python provides an interactive mode in which the user can submit commands at the Python prompt and interact with the interpreter directly.

The key benefits of Python are:

Easy-to-learn, read and maintain
Python is a minimalistic language with relatively few keywords, uses English keywords and has fewer syntactical constructions as compared to other languages. Reading Python programs is easy with pseudo-code like constructs. Python is easy to learn yet an extremely powerful language for a wide range of applications. Due to its simplicity, programs written in Python are generally easy to maintain.

Object and Procedure Oriented
Python supports both procedure-oriented programming and object-oriented programming. Procedure oriented paradigm allows programs to be written around procedures or functions that allow reuse of code. Procedure oriented paradigm allows programs to be written around objects that include both data and functionality.

Extendable
Python is an extendable language and allows integration of low-level modules written in languages such as C/C++. This is useful when you want to speed up a critical portion of a program.

Scalable

Due to the minimalistic nature of Python, it provides a manageable structure for large programs.

Portable

Since Python is an interpreted language, programmers do not have to worry about compilation, linking and loading of programs. Python programs can be directly executed from source code and copied from one machine to another without worrying about portability. The Python interpreter converts the source code to an intermediate form called byte codes and then translates this into the native language of your specific system and then runs it.

Broad Library Support

Python has a broad library support and works on various platforms such as Windows, Linux, Mac, etc. There are a large number of Python packages available for various applications such as machine learning, image processing, network programming, cryptography, etc.

3.5 Installing Python

Python is a highly portable language that works on various platforms such as Windows, Linux, Mac, etc. This section describes the Python installation steps for Windows and Linux:

Windows

Python binaries for Windows can be downloaded from http://www.python.org/getit. For the examples and exercises in this book, you would require Python 2.7 which can be directly downloaded from:

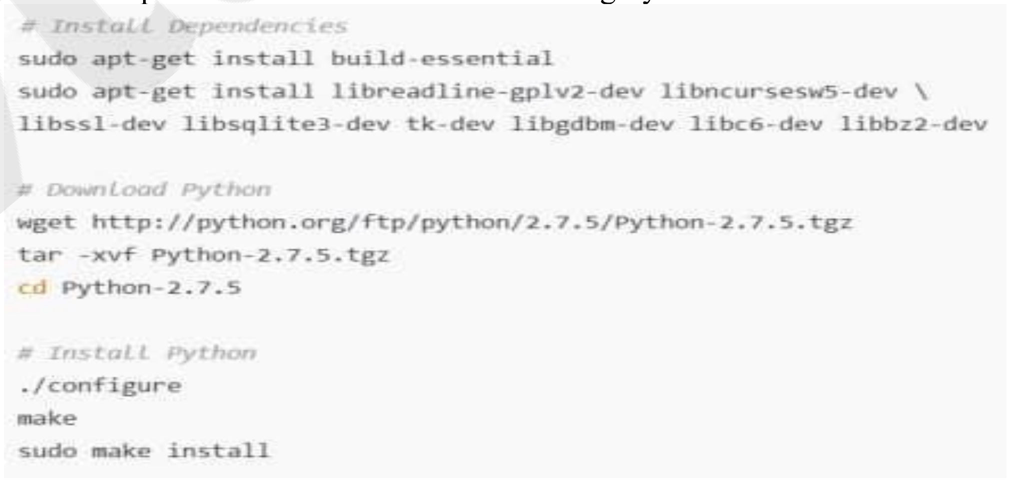
http://www.python.org/ftp/python/2.7.5/python-2.7.5.msi

Once the Python binary is installed you can run the Python shell at the command prompt using:

> python

Linux

Box 6.1 provides the commands for installing Python on Ubuntu.

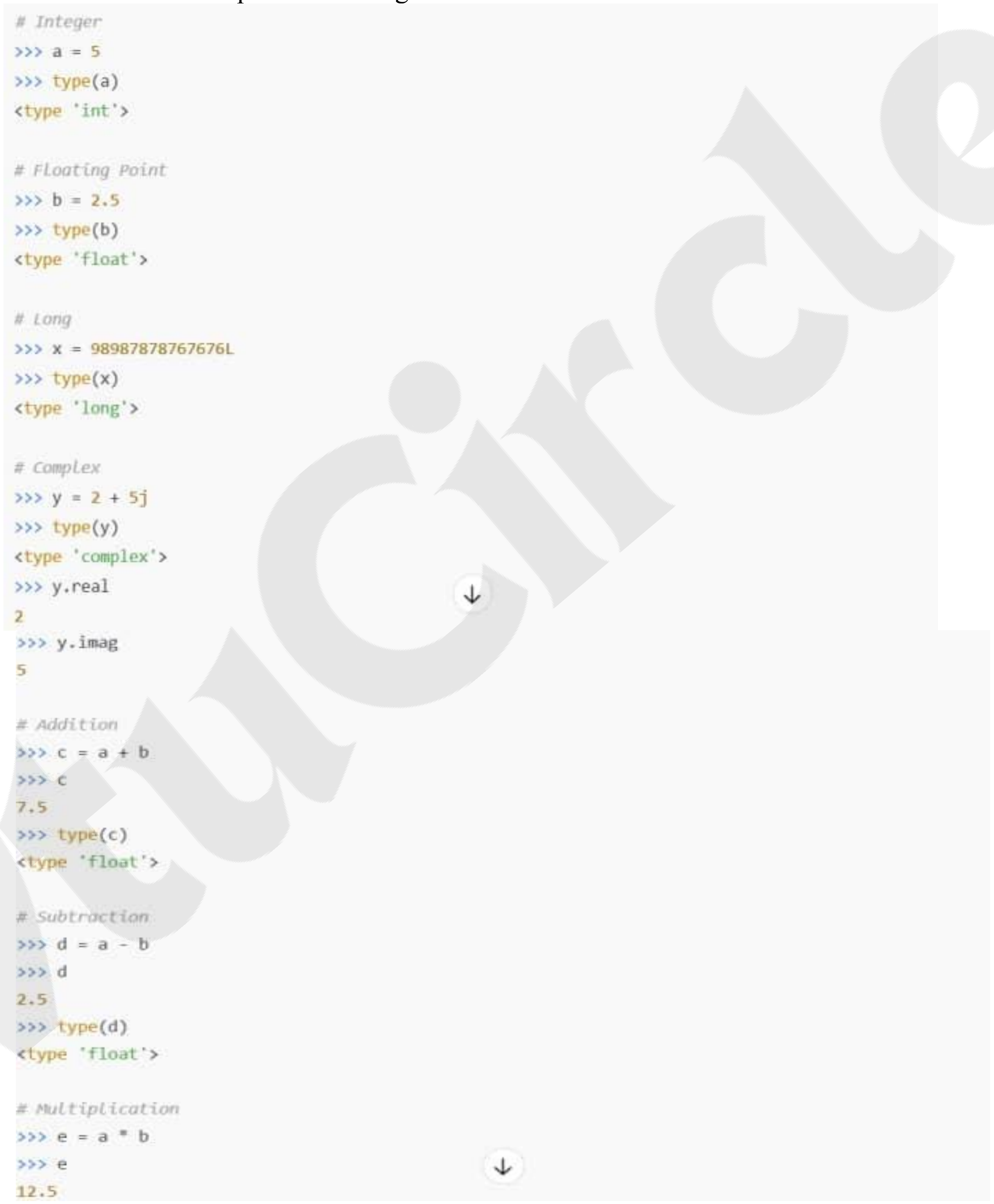


```
# Install Dependencies
sudo apt-get install build-essential
sudo apt-get install libreadline-gplv2-dev libncursesw5-dev \
libssl-dev libsqlite3-dev tk-dev libgdbm-dev libc6-dev libbz2-dev

# Download Python
wget http://python.org/ftp/python/2.7.5/Python-2.7.5.tgz
tar -xvf Python-2.7.5.tgz
cd Python-2.7.5

# Install Python
./configure
make
sudo make install
```

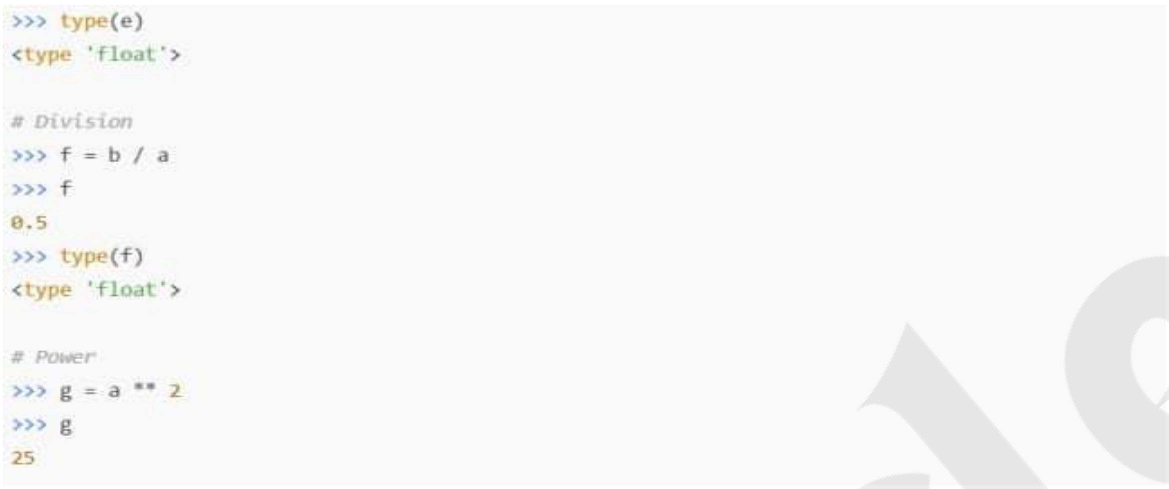
3.6 Python Data Types & Data Structures

3.6.1 Numbers

Number data type is used to store numeric values. Numbers are immutable data types, therefore changing the value of a number data type results in a newly allocated object. Box 6.2 shows some examples of working with numbers.



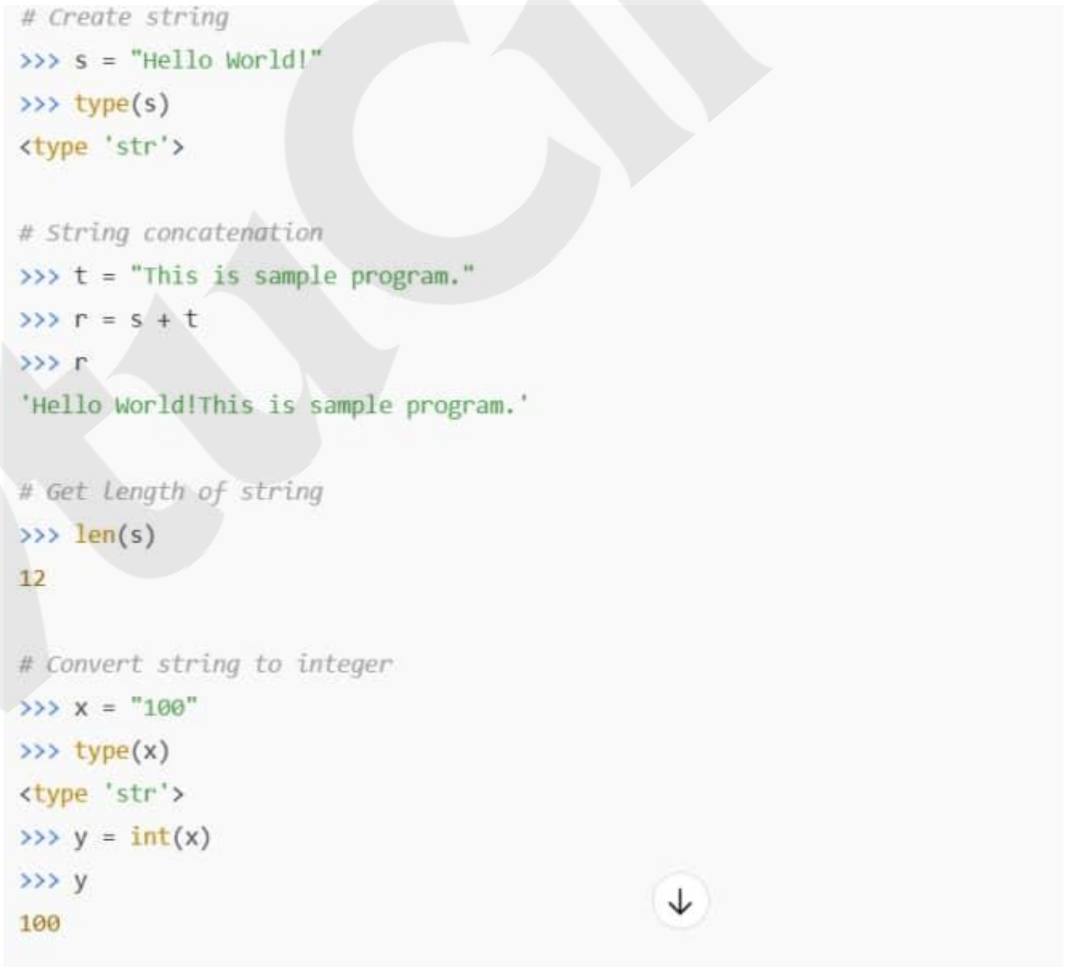
```
# Integer
>>> a = 5
>>> type(a)
<type 'int'>

# Floating Point
>>> b = 2.5
>>> type(b)
<type 'float'>

# Long
>>> x = 98987878767676L
>>> type(x)
<type 'long'>

# Complex
>>> y = 2 + 5j
>>> type(y)
<type 'complex'>
>>> y.real
2
>>> y.imag
5

# Addition
>>> c = a + b
>>> c
7.5
>>> type(c)
<type 'float'>

# Subtraction
>>> d = a - b
>>> d
2.5
>>> type(d)
<type 'float'>

# Multiplication
>>> e = a * b
>>> e
12.5
```



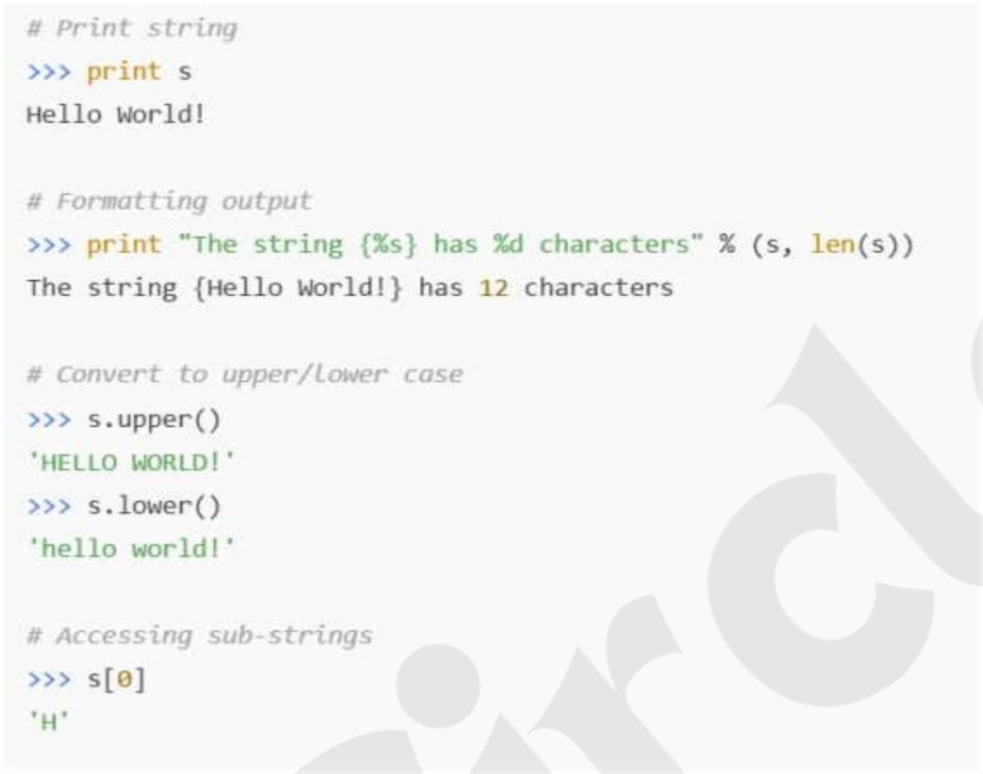
```
>>> type(e)
<type 'float'>

# Division
>>> f = b / a
>>> f
0.5
>>> type(f)
<type 'float'>

# Power
>>> g = a ** 2
>>> g
25
```

3.5.2 Strings

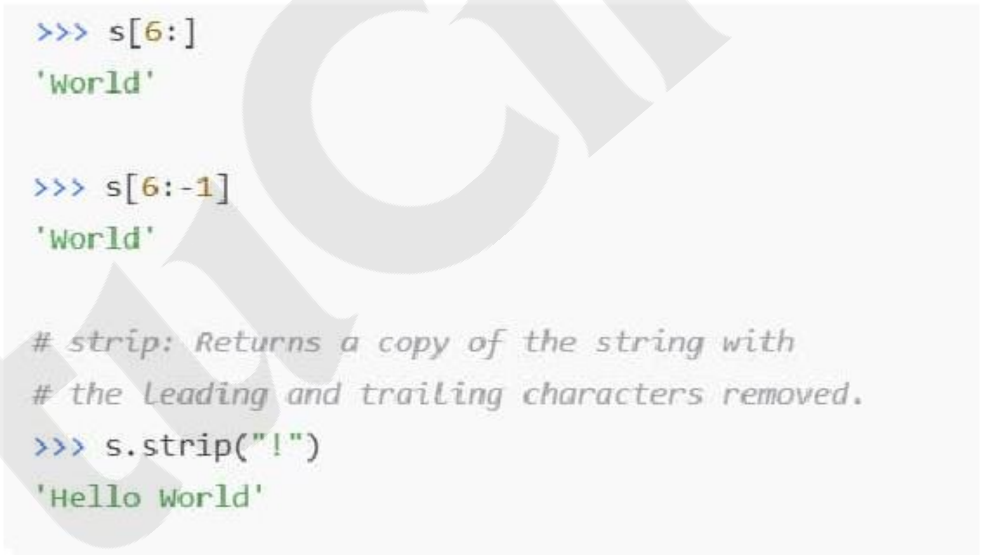
A string is simply a list of characters in order. There are no limits to the number of characters you can have in a string. A string which has zero characters is called an empty string. Box 6.3 shows some examples of working with strings.



```
# Create string
>>> s = "Hello World!"
>>> type(s)
<type 'str'>

# String concatenation
>>> t = "This is sample program."
>>> r = s + t
>>> r
'Hello World!This is sample program.'

# Get length of string
>>> len(s)
12

# Convert string to integer
>>> x = "100"
>>> type(x)
<type 'str'>
>>> y = int(x)
>>> y
100
```



```
# Print string
>>> print s
Hello World!

# Formatting output
>>> print "The string {%s} has %d characters" % (s, len(s))
The string {Hello World!} has 12 characters

# Convert to upper/lower case
>>> s.upper()
'HELLO WORLD!'
>>> s.lower()
'hello world!'

# Accessing sub-strings
>>> s[0]
'H'
```

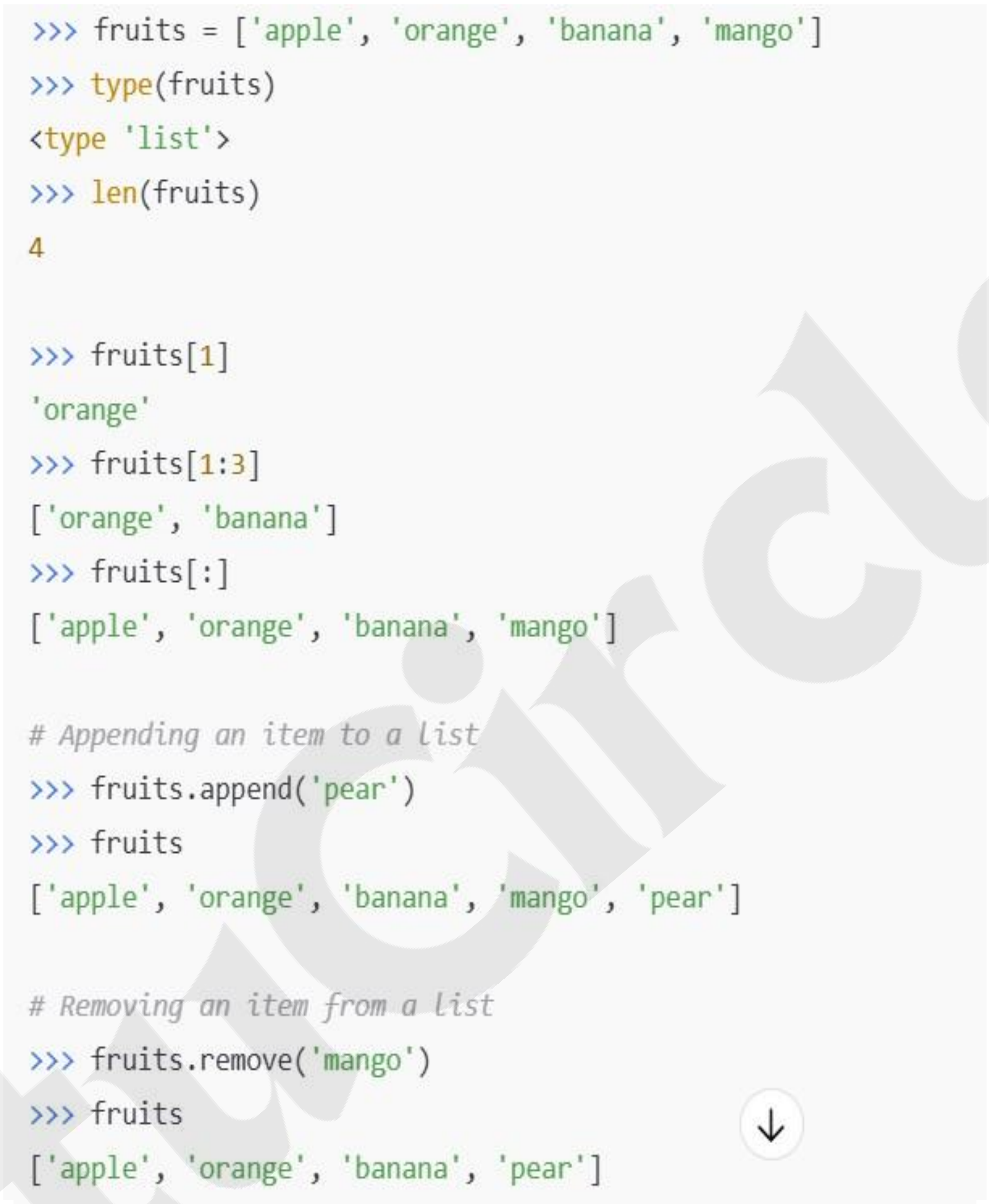


```
>>> s[6:]
'World'

>>> s[6:-1]
'World'

# strip: Returns a copy of the string with
# the leading and trailing characters removed.
>>> s.strip("!")
'Hello World'
```

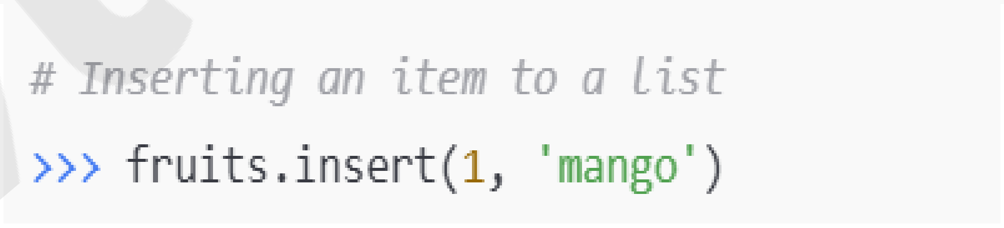
3.5.3 Lists

A **list** is a compound data type used to group together other values.

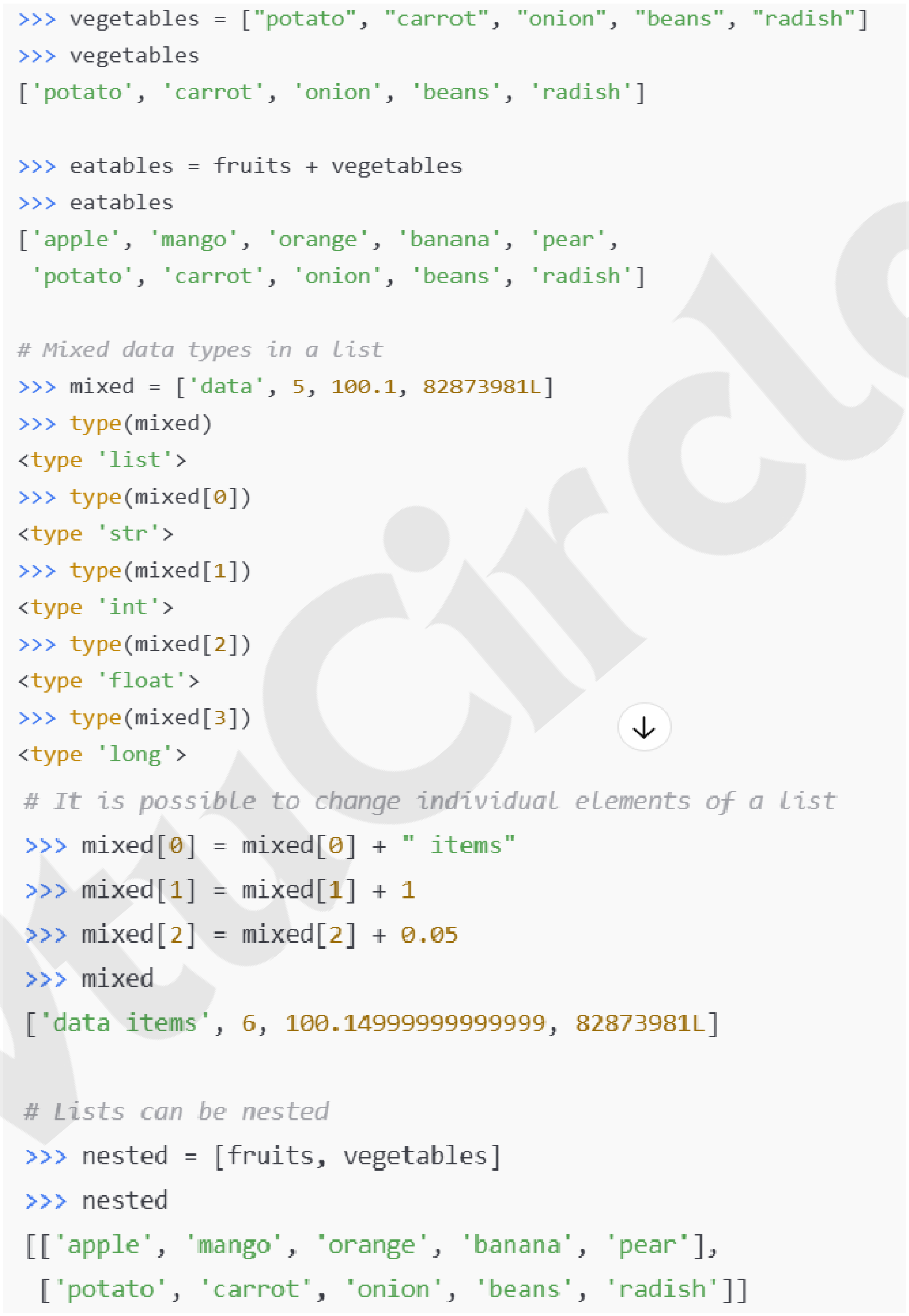
- List items need not all be of the same type.
- A list contains items separated by commas and enclosed within square brackets [].



```
>>> fruits = ['apple', 'orange', 'banana', 'mango']
>>> type(fruits)
<type 'list'>
>>> len(fruits)
4

>>> fruits[1]
'orange'
>>> fruits[1:3]
['orange', 'banana']
>>> fruits[:]
['apple', 'orange', 'banana', 'mango']

# Appending an item to a list
>>> fruits.append('pear')
>>> fruits
['apple', 'orange', 'banana', 'mango', 'pear']

# Removing an item from a list
>>> fruits.remove('mango')
>>> fruits
['apple', 'orange', 'banana', 'pear']
```



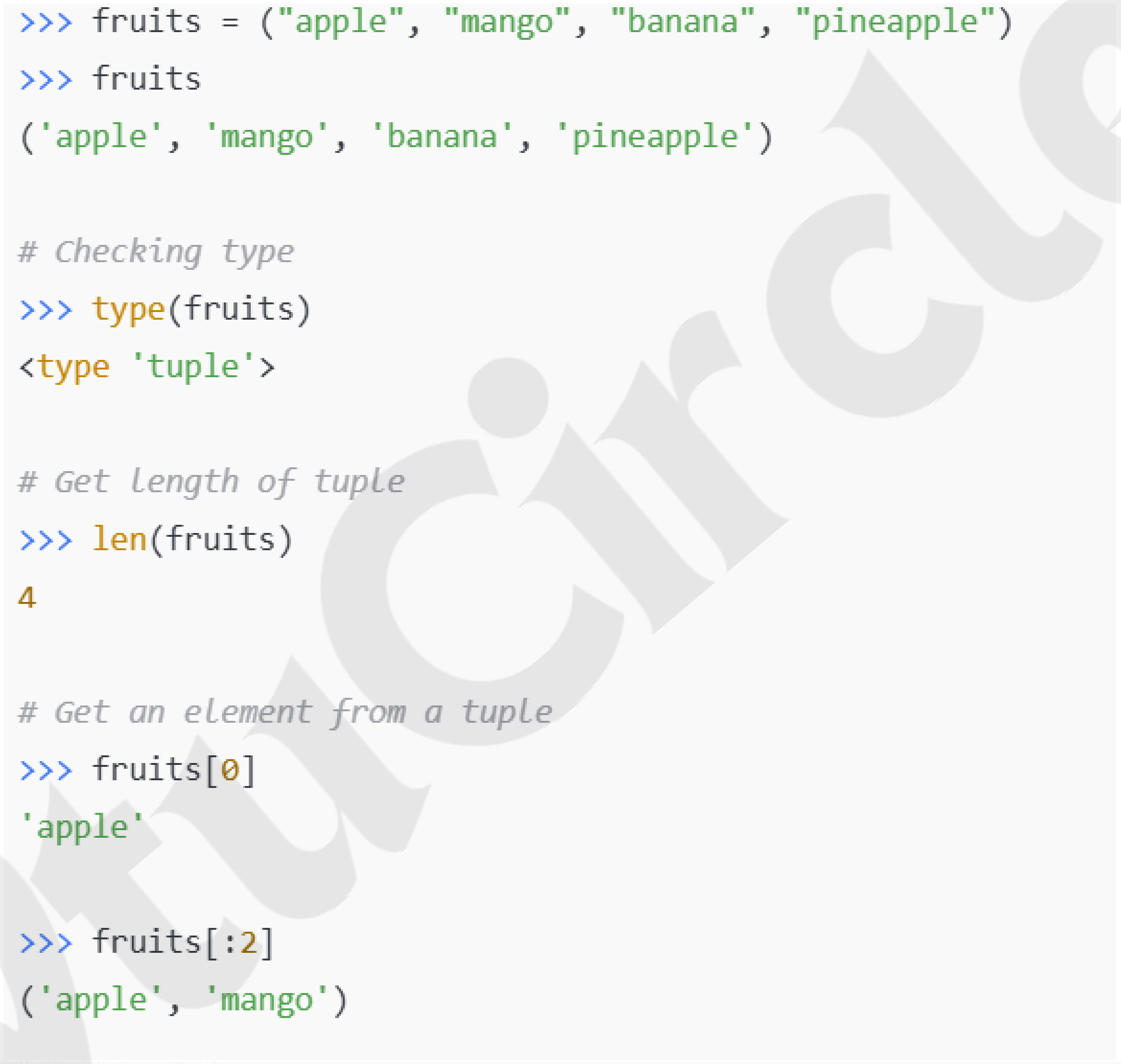
```
# Inserting an item to a list
>>> fruits.insert(1, 'mango')
```



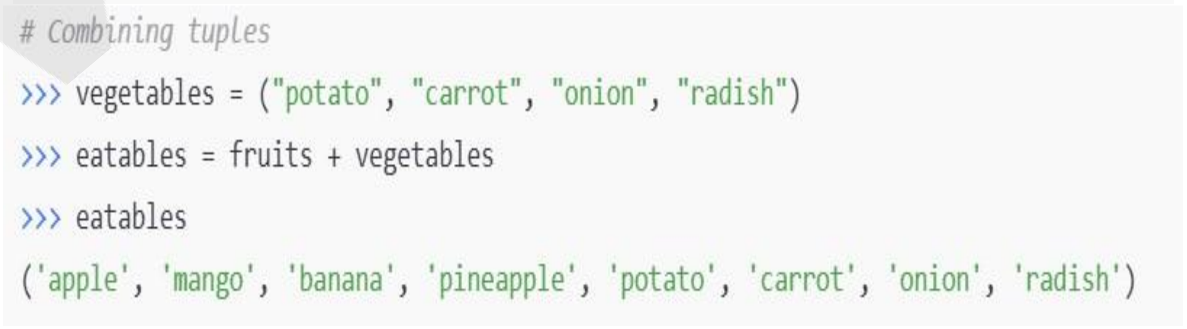
```
>>> vegetables = ["potato", "carrot", "onion", "beans", "radish"]
>>> vegetables
['potato', 'carrot', 'onion', 'beans', 'radish']

>>> eatables = fruits + vegetables
>>> eatables
['apple', 'mango', 'orange', 'banana', 'pear',
 'potato', 'carrot', 'onion', 'beans', 'radish']

# Mixed data types in a list
>>> mixed = ['data', 5, 100.1, 82873981L]
>>> type(mixed)
<type 'list'>
>>> type(mixed[0])
<type 'str'>
>>> type(mixed[1])
<type 'int'>
>>> type(mixed[2])
<type 'float'>
>>> type(mixed[3])
<type 'long'>
# It is possible to change individual elements of a list
>>> mixed[0] = mixed[0] + " items"
>>> mixed[1] = mixed[1] + 1
>>> mixed[2] = mixed[2] + 0.05
>>> mixed
['data items', 6, 100.14999999999999, 82873981L]

# Lists can be nested
>>> nested = [fruits, vegetables]
>>> nested
[['apple', 'mango', 'orange', 'banana', 'pear'],
 ['potato', 'carrot', 'onion', 'beans', 'radish']]
```

3.5.4 Tuples

A tuple is a sequence data type that is similar to the list. A tuple consists of a number of values separated by commas and enclosed within parentheses. Unlike lists, the elements of tuples cannot be changed, so tuples can be thought of as read-only lists. Box 6.5 shows examples of working with tuples.



```
>>> fruits = ("apple", "mango", "banana", "pineapple")
>>> fruits
('apple', 'mango', 'banana', 'pineapple')

# Checking type
>>> type(fruits)
<type 'tuple'>

# Get length of tuple
>>> len(fruits)
4

# Get an element from a tuple
>>> fruits[0]
'apple'

>>> fruits[:2]
('apple', 'mango')
```



```
# Combining tuples
>>> vegetables = ("potato", "carrot", "onion", "radish")
>>> eatables = fruits + vegetables
>>> eatables
('apple', 'mango', 'banana', 'pineapple', 'potato', 'carrot', 'onion', 'radish')
```

3.5.5 Dictionaries

A dictionary is a mapping data type or a kind of hash table that maps keys to values. Keys in a dictionary can be of any data type, though numbers and strings are commonly used for keys. Values in a dictionary can be any data type or object.

Box 6.6 shows examples on working with dictionaries.

```
>>> student = {'name': 'Mary', 'id': '8776', 'major': 'CS'}
>>> student
{'major': 'CS', 'name': 'Mary', 'id': '8776'}

>>> type(student)
<type 'dict'>

# Get length of a dictionary
>>> len(student)
3
```

```
# Get the value of a key in dictionary
>>> student['name']
'Mary'

# Get all items in a dictionary
>>> student.items()
[('major', 'CS'), ('name', 'Mary'), ('id', '8776')]

# Get all keys in a dictionary
>>> student.keys()
['major', 'name', 'id']

# Get all values in a dictionary
>>> student.values()
['CS', 'Mary', '8776']

>>> student
{'major': 'CS', 'name': 'Mary', 'id': '8776'}
```

Nested Dictionaries

```
# A value in a dictionary can be another dictionary
>>> student1 = {'name': 'David', 'id': '9876', 'major': 'ECE'}
>>> students = {1: student, 2: student1}

>>> students
{
  1: {'major': 'CS', 'name': 'Mary', 'id': '8776'},
  2: {'major': 'ECE', 'name': 'David', 'id': '9876'}
}
```

Checking for Key Existence

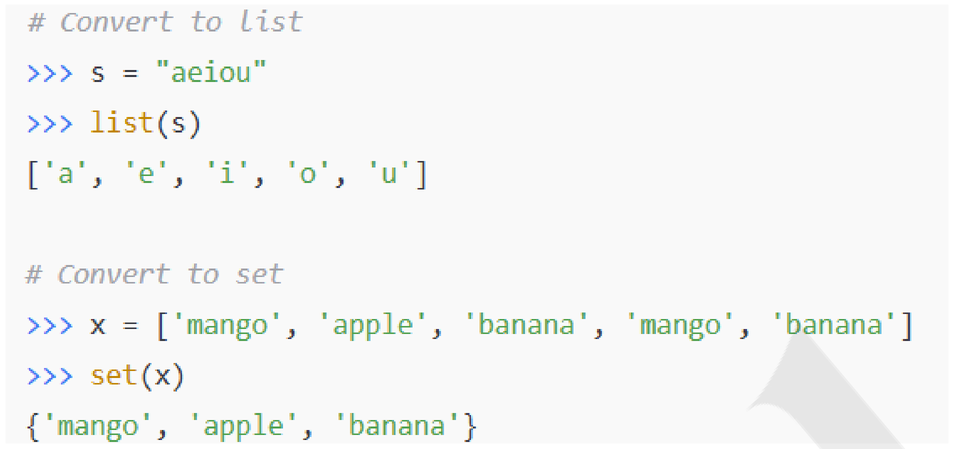
```
# Check if dictionary has a key
>>> student.has_key('name')
True
>>> student.has_key('grade')
False
```

3.5.6 Type Conversions

Box 6.7 shows examples of type conversions.

```
# Convert to string
>>> a = 10000
>>> str(a)
'10000'
```

```
# Convert to int
>>> b = "2013"
>>> int(b)
2013

# Convert to float
>>> float(b)
2013.0

# Convert to long (Python 2 only; in Python 3, int and long are unified)
>>> long(b)
2013L
```

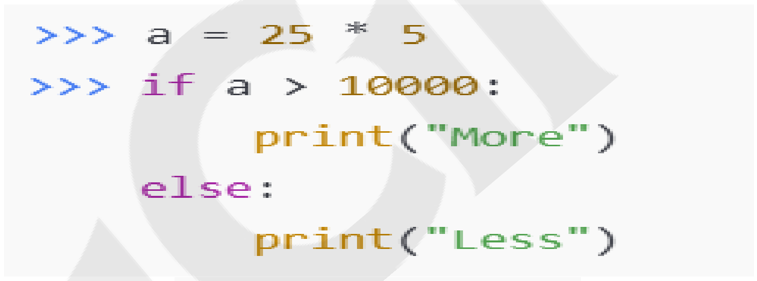


```
# Convert to list
>>> s = "aeiou"
>>> list(s)
['a', 'e', 'i', 'o', 'u']

# Convert to set
>>> x = ['mango', 'apple', 'banana', 'mango', 'banana']
>>> set(x)
{'mango', 'apple', 'banana'}
```

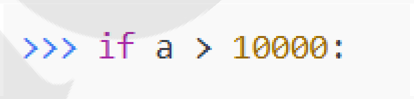
3.6 Control Flow

3.6.1 if Statement

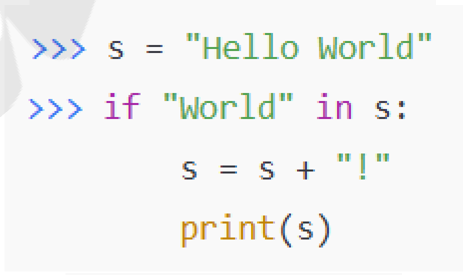
The if statement in Python is similar to the if statement in other languages. Box 6.8 shows examples.



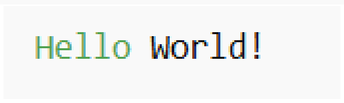
```
>>> a = 25 * 5
>>> if a > 10000:
        print("More")
    else:
        print("Less")
```



```
>>> if a > 10000:
```



```
>>> s = "Hello World"
>>> if "World" in s:
        s = s + "!"
        print(s)
```



```
Hello World!
```

```
>>> student = {'name': 'Mary', 'id': '8776'}
>>> if not student.has_key('major'):
        student['major'] = 'CS'
>>> student
```

```
{'major': 'CS', 'name': 'Mary', 'id': '8776'}
```

3.6.2 for

The for statement in Python iterates over items of any sequence (list, string, etc.) in the order in which they appear in the sequence. This behaviour differs from the for statement in languages such as C, where initialization, incrementing, and stopping criteria are provided.

Box 6.9: for statement examples

```
helloString = "Hello World"
fruits = ['apple', 'orange', 'banana', 'mango']
student = {'name': 'Mary', 'id': '8776', 'major': 'CS'}
```

Looping over characters in a string:

```
for c in helloString:
    print(c)
```

Looping over items in a list:

```
i = 0
for item in fruits:
    print("Fruit-%d: %s" % (i, item))
    i += 1

# Looping over keys in a dictionary
for key in student:
    print("%s: %s" % (key, student[key]))
```

3.6.3 while

The while statement in Python executes the statements within the while loop as long as the condition is true.
Box 6.10 shows a while statement example.

```
# Prints even numbers up to 100
i = 0
while i <= 100:
    if i % 2 == 0:
        print(i)
    i = i + 1
```

3.6.4 range

The range statement in Python generates a list of numbers in arithmetic progression.
Examples are shown in Box 6.11.

```
# Generate a list of numbers from 0 - 9
range(10)
# Output: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]

# Generate a list of numbers from 10 - 100 with increments of 10
range(10, 110, 10)
# Output: [10, 20, 30, 40, 50, 60, 70, 80, 90, 100]
```

3.6.5 break/continue

The break and continue statements in Python are similar to statements in C.

- break exits the for/while loop.
- continue skips the rest of the code inside the loop for the current iteration and jumps to the next iteration.

Box 6.12 shows examples.

```
y = 1
for x in range(4, 256, 4):
    y = y * x
    if y > 512:
        break
    print(y)
```

Output:

```
4
32
384
```

Continue statement example

```
fruits = ['apple', 'orange', 'banana', 'mango']
for item in fruits:
    if item == "banana":
        continue
    else:
        print(item)
```

Output

```
apple
orange
mango
```

3.6.6 pass

The pass statement in Python is a null operation.
It is used when a statement is syntactically required but no command/code should run.
Box 6.13 shows an example.

```python
fruits = ['apple', 'orange', 'banana', 'mango']
for item in fruits:
    if item == "banana":
        pass
    else:
        print(item)
```

Output

```
apple
orange
mango
```

3.7 Functions

A function is a block of code that:

- Takes information in (parameters),
- Performs some computation,
- Returns new information.

A function in Python begins with the def keyword, followed by:

- Function name,
- Parameters (inside parentheses),
- A colon: to start the code block,
- An optional string or docstring.

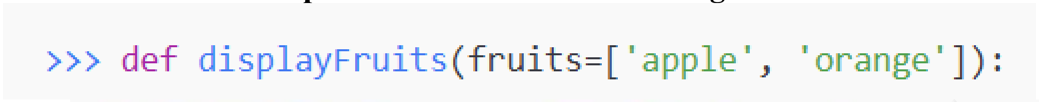
Box 6.14: Example of a function in Python

```python
students = {
    '1': { 'name': 'Bob', 'grade': 2.5 },
    '2': { 'name': 'Mary', 'grade': 3.5 },
    '3': { 'name': 'David', 'grade': 4.2 },
    '4': { 'name': 'John', 'grade': 4.1 },
    '5': { 'name': 'Alex', 'grade': 3.8 }
}

def averageGrade(students):
    "This function computes the average grade"
    sum = 0.0
    for key in students:
        sum = sum + students[key]['grade']
    average = sum / len(students)
    return average

avg = averageGrade(students)
print("The average grade is: %0.2f" % (avg))
```

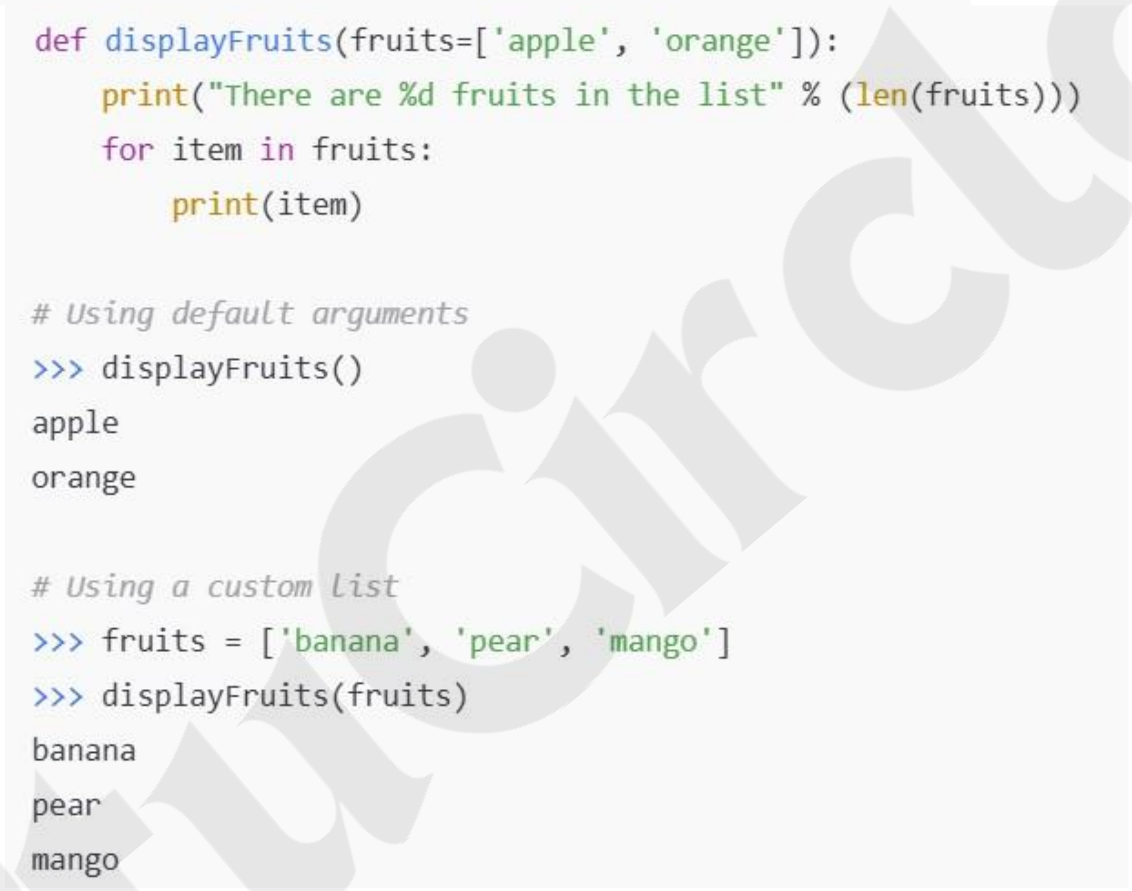
Default Arguments

Functions in Python can have default parameter values. If such a function is called with missing parameters, the default values are used.

Box 6.15: Example of function with default arguments



```
>>> def displayFruits(fruits=['apple', 'orange']):
```



```
def displayFruits(fruits=['apple', 'orange']):
    print("There are %d fruits in the list" % (len(fruits)))
    for item in fruits:
        print(item)

# Using default arguments
>>> displayFruits()
apple
orange

# Using a custom list
>>> fruits = ['banana', 'pear', 'mango']
>>> displayFruits(fruits)
banana
pear
mango
```

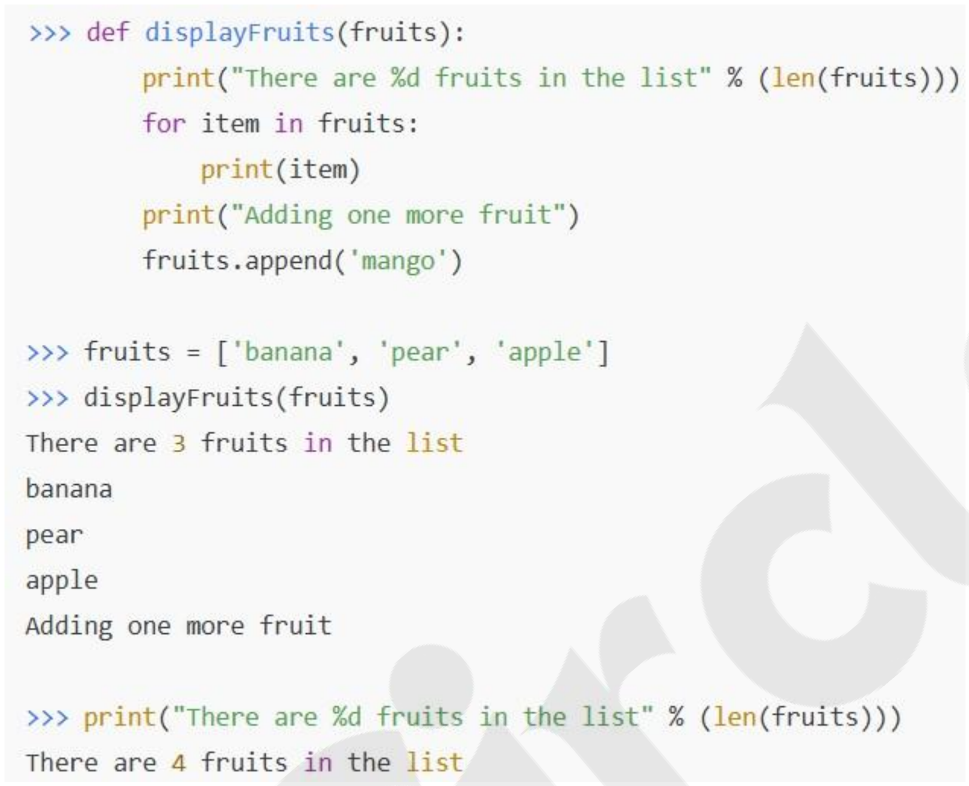
Passing by Reference in Functions

In Python, all parameters are passed by reference. This means:

- If you modify a mutable object (like a list) inside a function,
- The change is reflected in the caller's scope.

Box 6.16: Example of Passing by Reference

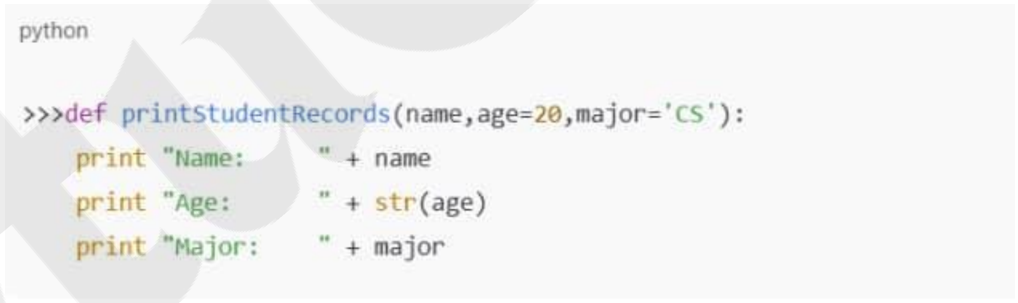
Note: The function displayFruits modifies the original fruits list by adding 'mango', and this change persists after the function call—demonstrating Python’s pass-by-reference behavior for mutable data types like lists.



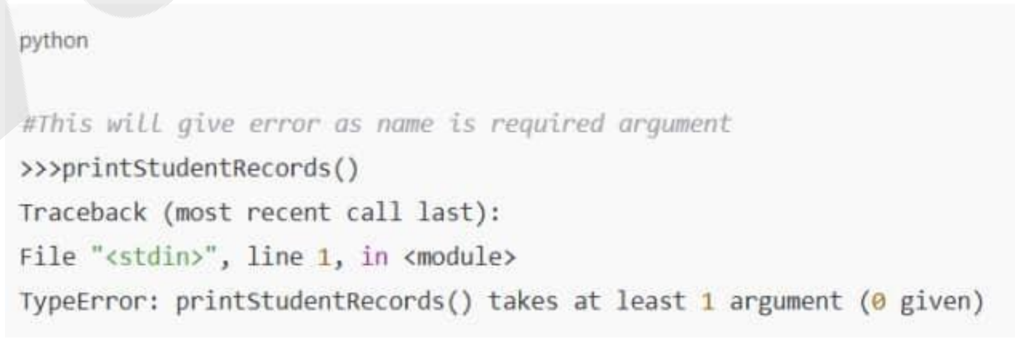
```
>>> def displayFruits(fruits):
        print("There are %d fruits in the list" % (len(fruits)))
        for item in fruits:
            print(item)
        print("Adding one more fruit")
        fruits.append('mango')

>>> fruits = ['banana', 'pear', 'apple']
>>> displayFruits(fruits)
There are 3 fruits in the list
banana
pear
apple
Adding one more fruit

>>> print("There are %d fruits in the list" % (len(fruits)))
There are 4 fruits in the list
```

Functions can also be called using keyword arguments that identify the arguments by the parameter name when the function is called.

Box 6.17 shows examples of keyword arguments.



```
python

>>>def printStudentRecords(name,age=20,major='CS'):
    print "Name:      " + name
    print "Age:       " + str(age)
    print "Major:     " + major
```



```
python

#This will give error as name is required argument
>>>printStudentRecords()
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
TypeError: printStudentRecords() takes at least 1 argument (0 given)
```

```python
>>>printStudentRecords(name='Alex')
Name:     Alex
Age:      20
Major:    CS

>>>printStudentRecords(name='Bob',age=22,major='ECE')
Name:     Bob
Age:      22
Major:    ECE

>>>printStudentRecords(name='Alan',major='ECE')
Name:     Alan
Age:      20
Major:    ECE
```

```python
#name is a formal argument.
#**kwargs is a keyword argument that receives all
#arguments except the formal argument as a dictionary.
>>>def student(name, **kwargs):
    print "Student Name:   " + name
    for key in kwargs:
        print key + ": " + kwargs[key]
```

```python
>>>student(name='Bob', age='20', major = 'CS')
Student Name:  Bob
age: 20
major: CS
```

Python functions can have variable length arguments. These variable length arguments are passed as a tuple to the function with an argument prefixed with asterix (*) as shown in

Box 6.18: Example of variable length arguments

```python
def student(name, *varargs):
    print "Student Name: " + name
    for item in varargs:
        print item

>>>student('Nav')
Student Name: Nav

>>>student('Amy', 'Age: 24')
Student Name: Amy
Age: 24

>>>student('Bob', 'Age: 20', 'Major: CS')
Student Name: Bob
Age: 20
Major: CS
```

3.8 Modules

Python allows organizing of the program code into different modules which improves the code readability and management. A module is a Python file that defines some functionality in the form of functions or classes. Modules can be imported using the import keyword. Modules to be imported must be present in the search path. Box 6.19 shows the example of a student module that contains two functions and Box 6.20 shows an example of importing the student module and using it.

Box 6.19: Module student

```
python

def averageGrade(students):
    sum = 0.0
    for key in students:
        sum = sum + students[key]['grade']
    average = sum/len(students)
    return average

def printRecords(students):
    print "There are %d students" % (len(students))
    i=1
    for key in students:
        print "Student-%d: " % (i)
        print "Name: " + students[key]['name']
        print "Grade: " + str(students[key]['grade'])
        i = i+1
```

Box 6.20: Using module student python CopyEdit

```python
>>>import student

>>>students = {'1': {'name' : 'Bob', 'grade': 2.5},
              '2': {'name' : 'Mary', 'grade': 3.5},
              '3': {'name' : 'David', 'grade': 4.2},
              '4': {'name' : 'John', 'grade': 4.1},
              '5': {'name' : 'Alex', 'grade': 3.8}}

>>>student.printRecords(students)
There are 5 students
Student-1:
Name: Bob
Grade: 2.5

Student-2:
Name: David
Grade: 4.2
```

```
Student-3:
Name: Mary
Grade: 3.5

Student-4:
Name: Alex
Grade: 3.8

Student-5:
Name: John
Grade: 4.1

>>>avg = student.averageGrade(students)
>>>print "The average garde is: %0.2f" % (avg)
3.62
```

The import keyword followed by the module name imports all the functions in the module. If you want to use only a specific function it is recommended to import only that function using the keyword from as shown in the example in Box 6.21.

Box 6.21: Importing a specific function from a module

```
>>>from student import averageGrade

>>>students = {'1': {'name' : 'Bob', 'grade': 2.5},
               '2': {'name' : 'Mary', 'grade': 3.5},
               '3': {'name' : 'David', 'grade': 4.2},
               '4': {'name' : 'John', 'grade': 4.1},
               '5': {'name' : 'Alex', 'grade': 3.8}}

>>>avg = averageGrade(students)
>>>print "The average garde is: %0.2f" % (avg)
3.62
```

Python comes with a number of standard modules such as system related modules (sys), OS related module (os), mathematical modules (math, fractions, etc.), Internet related modules (email, json. etc), etc. The complete list of standard modules is available in the Python documentation [87]. Box 6.22 shows an example of listing all names defined in a module using the built-in dir function.

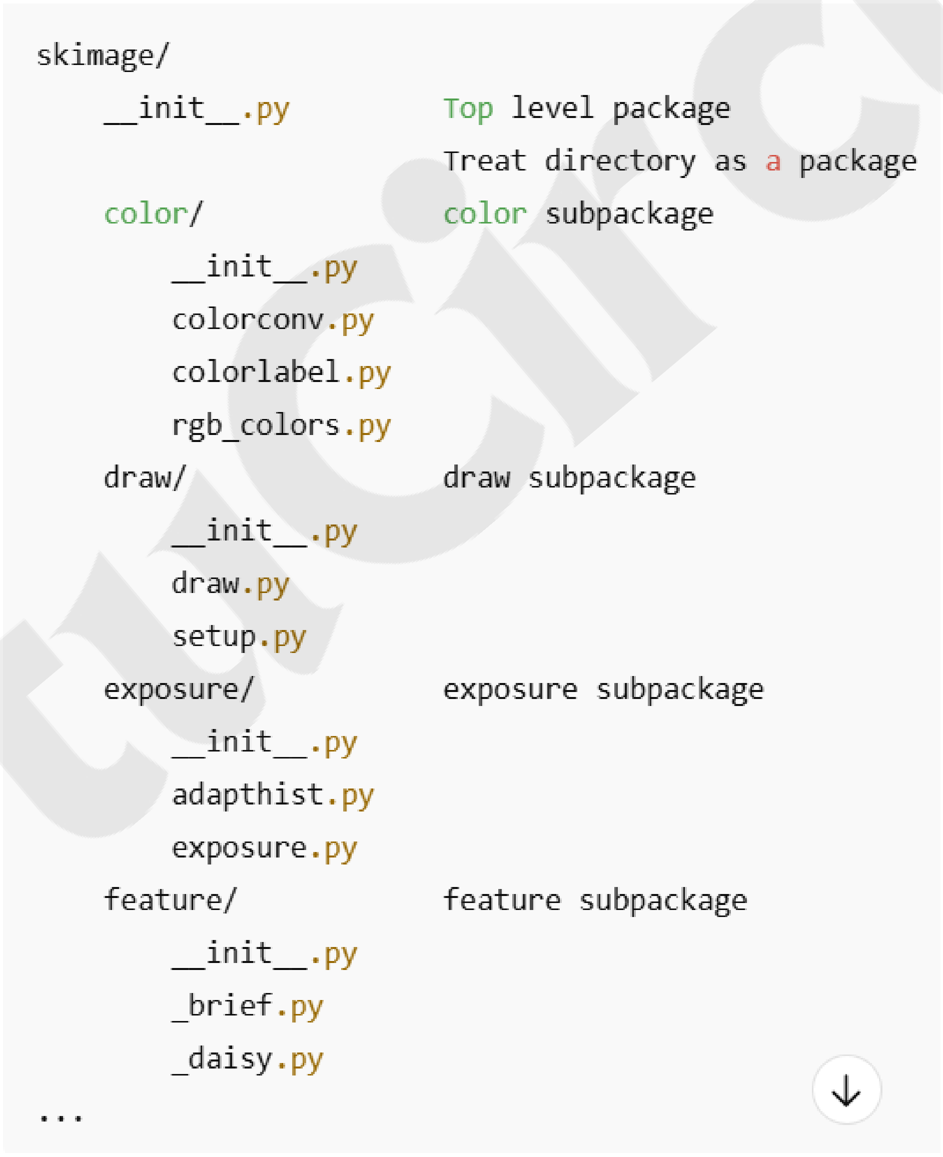
Box 6.22: Listing all names defined in a module

```
>>>import email

>>>dir(email)
['Charset', 'Encoders', 'Errors', 'feedparser', 'Generator', 'Header',
 'Iterators', 'LazyImporter', 'MIMEAudio', 'MIMEBase', 'MIMEImage',
 'MIMEMessages', 'MIMEMultipart', 'MIMENonMultipart', 'MIMEText',
 'Message', '__all__', '__doc__', '__file__', '__name__', '__package__',
 '__version__', 'base64MIME', 'email', 'importer', 'message_from_file',
 'message_from_string', 'mime', 'quopriMIME', 'sys']
```

3.9 Packages

Python package is hierarchical file structure that consists of modules and subpackages. Packages allow better organization of modules related to a single application environment. For example, Box 6.23 shows the listing of the skimage package that provides image processing algorithms. The package is organized into a root directory (skimage) with sub-directories (color, draw, etc) which are sub-packages within the skimage package. Each directory contains a special file named _init_.py which tells Python to treat directories as packages. This file can either be an empty file or contain some initialization code for the package.

Box 6.23: skimage package listing

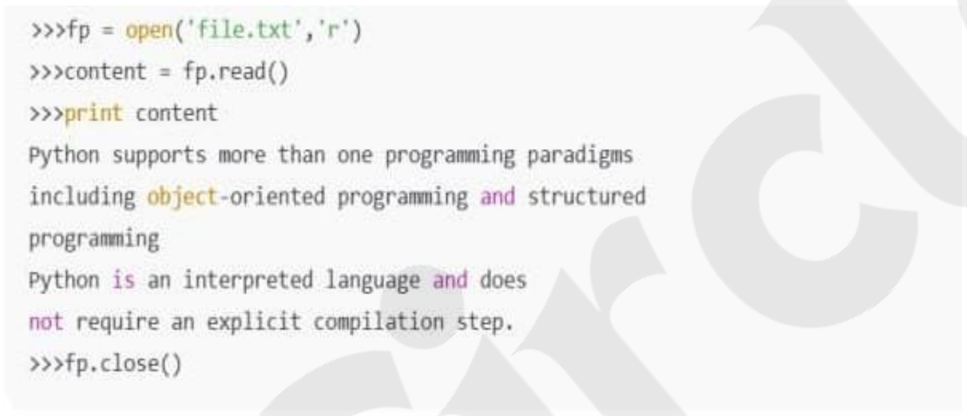


```
skimage/
    __init__.py          Top level package
                         Treat directory as a package
    color/               color subpackage
        __init__.py
        colorconv.py
        colorlabel.py
        rgb_colors.py
    draw/                draw subpackage
        __init__.py
        draw.py
        setup.py
    exposure/            exposure subpackage
        __init__.py
        adapthist.py
        exposure.py
    feature/             feature subpackage
        __init__.py
        _brief.py
        _daisy.py
...
```

3.10 File Handling

Python allows reading and writing to files using the file object. The open(filename, mode) function is used to get a file object. The mode can be read (r), write (w), append (a), read and write (r+ or w+), read-binary (rb), write-binary (wb), etc. Box 6.24 shows an example of reading an entire file with read function. After the file contents have been read the close function is called which closes the file object.

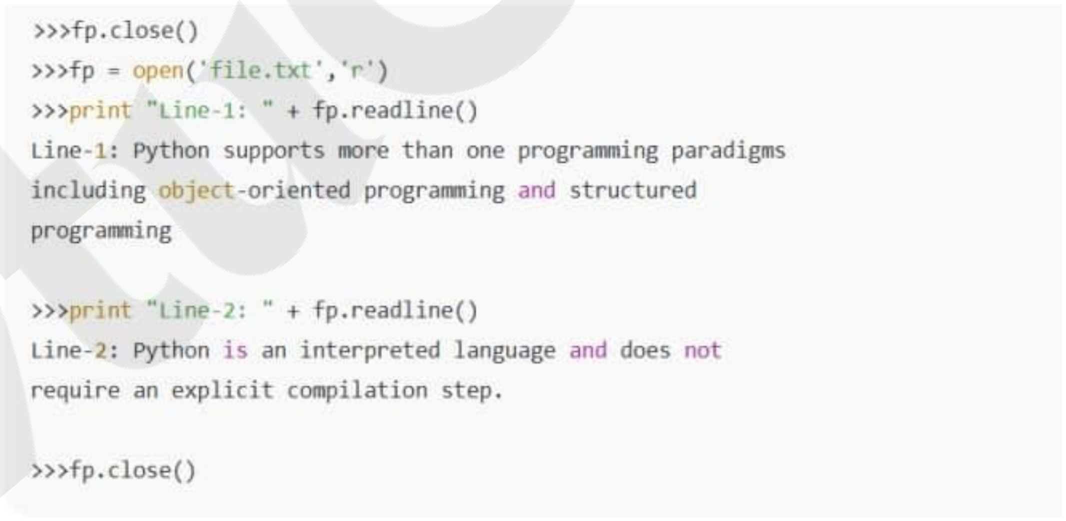
Box 6.24: Example of reading an entire file



```
>>>fp = open('file.txt','r')
>>>content = fp.read()
>>>print content
Python supports more than one programming paradigms
including object-oriented programming and structured
programming
Python is an interpreted language and does
not require an explicit compilation step.
>>>fp.close()
```

Box 6.25 shows an example of reading line by line from a file using the readline function.

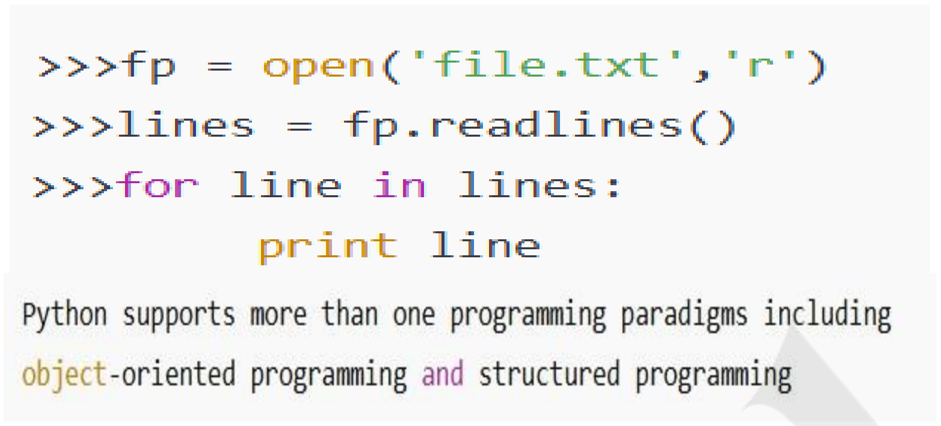
Box 6.25: Example of reading line by line



```
>>>fp.close()
>>>fp = open('file.txt','r')
>>>print "Line-1: " + fp.readline()
Line-1: Python supports more than one programming paradigms
including object-oriented programming and structured
programming

>>>print "Line-2: " + fp.readline()
Line-2: Python is an interpreted language and does not
require an explicit compilation step.

>>>fp.close()
```

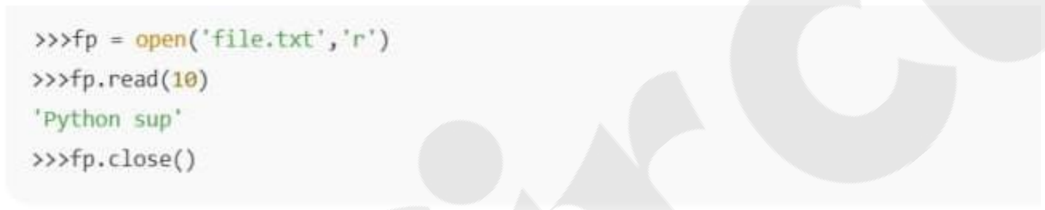
Box 6.26 shows an example of reading lines of a file in a loop using the readlines function.

Box 6.26: Example of reading lines in a loop



```
>>>fp = open('file.txt','r')
>>>lines = fp.readlines()
>>>for line in lines:
        print line
Python supports more than one programming paradigms including
object-oriented programming and structured programming
```

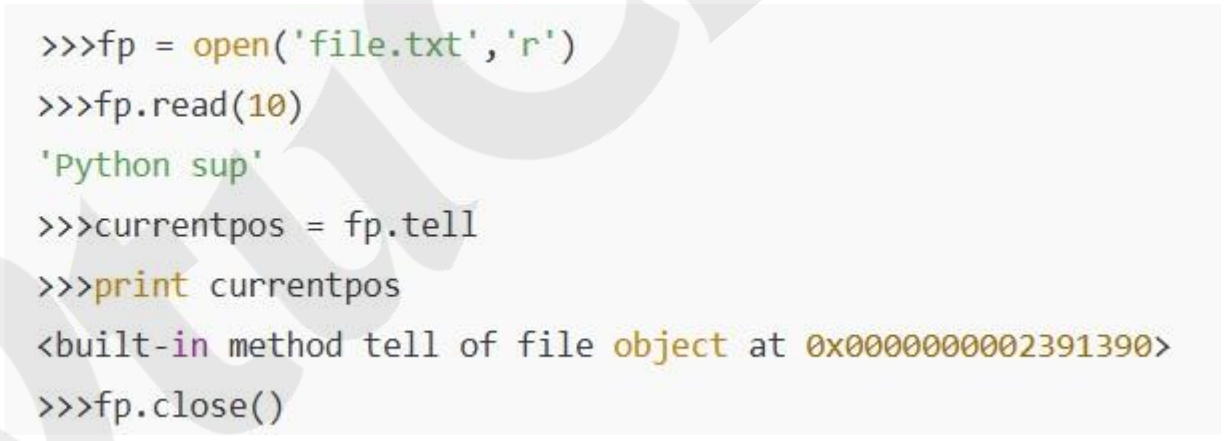
Box 6.27: Example of reading a certain number of bytes



```
>>>fp = open('file.txt','r')
>>>fp.read(10)
'Python sup'
>>>fp.close()
```

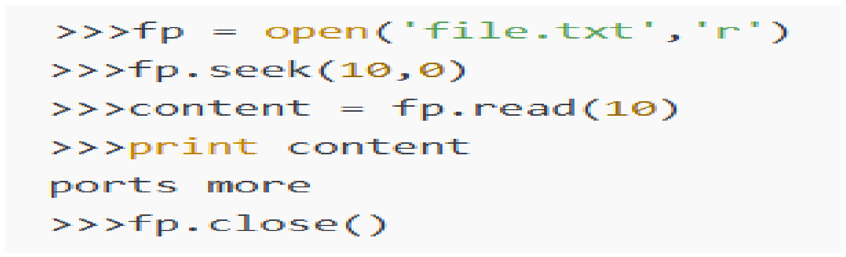
Box 6.28 shows an example of getting the current position of read using the tell function.

Box 6.28: Example of getting the current position of read



```
>>>fp = open('file.txt','r')
>>>fp.read(10)
'Python sup'
>>>currentpos = fp.tell
>>>print currentpos
<built-in method tell of file object at 0x0000000002391390>
>>>fp.close()
```

Box 6.29: Example of seeking to a certain position python CopyEdit



```
>>>fp = open('file.txt','r')
>>>fp.seek(10,0)
>>>content = fp.read(10)
>>>print content
ports more
>>>fp.close()
```

Box 6.30: Example of writing to a file

```
>>>fo = open('file1.txt','w')
>>>content="This is an example of writing to a file in Python."
>>>fo.write(content)
>>>fo.close()
```

3.11 Date/Time Operations

Python provides several functions for date and time access and conversions. The datetime module allows manipulating date and time in several ways. Box 6.31 shows examples of manipulating with date.

Box 6.31: Examples of manipulating with date

```
>>>from datetime import date
>>>now = date.today()
>>>print "Date: " + now.strftime("%m-%d-%y")
Date: 07-24-13
>>>print "Day of Week: " + now.strftime("%A")
Day of Week: Wednesday
>>>print "Month: " + now.strftime("%B")
Month: July

>>>then = date(2013, 6, 7)
>>>timediff = now - then
>>>timediff.days
47
```

The time module in Python provides various time-related functions. Box 6.32 shows examples of manipulating with time.

Box 6.32: Examples of manipulating with time

```
>>>import time
>>>nowtime = time.time()
>>>time.localtime(nowtime)
time.struct_time(tm_year=2013, tm_mon=7, tm_mday=24,
                 tm_sec=11, tm_wday=2, tm_yday=205, tm_isdst=0)
>>>time.asctime(time.localtime(nowtime))

 'Wed Jul 24 16:14:51 2013'


 >>>time.strftime("The date is %d-%m-%y.
 Today is %A.  It is %H hours, %M minutes and %S seconds now.")

 'The date is 24-07-13.  Today is a Wednesday.  It is 16 hours,
 15 minutes and 14 seconds now.'
```

3.12 Classes

Python is an Object-Oriented Programming (OOP) language. Python provides all the standard features of Object-Oriented Programming such as:

1. Classes
2. Class variables
3. Class methods
4. Inheritance
5. Function overloading
6. Operator overloading

Let us briefly look at these OOP concepts:

Class

A class is simply a representation of a type of object and user-defined prototype for an object composed of three things:

- A name
- Attributes
- Operations/methods

Instance/Object

An object is an instance of the data structure defined by a class.

Inheritance

Inheritance is the process of forming a new class from an existing class or base class.

Function Overloading

Function overloading is a form of polymorphism that allows a function to have different meanings, depending on its context.

Operator Overloading

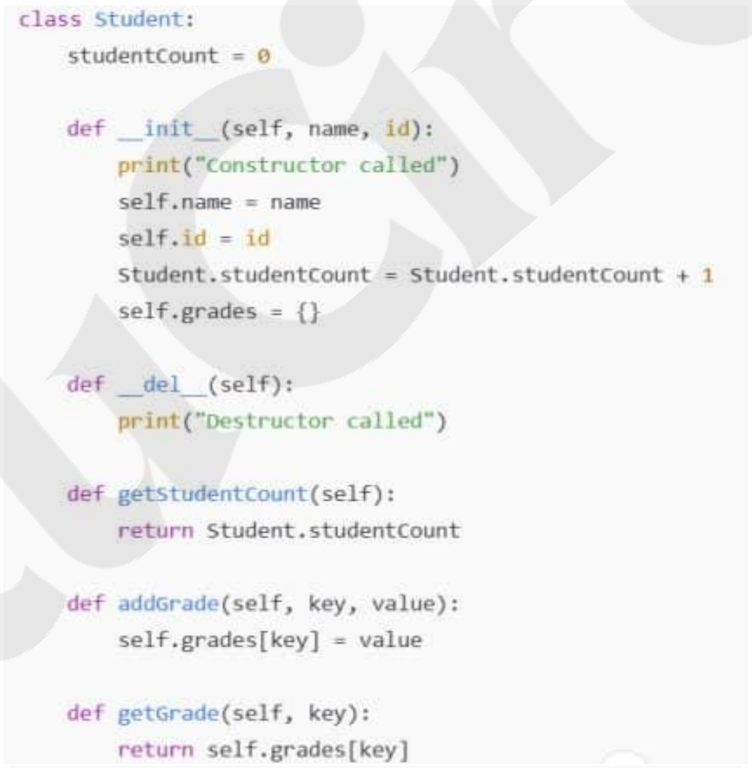
Operator overloading is a form of polymorphism that allows assignment of more than one function to a particular operator.

Function Overriding

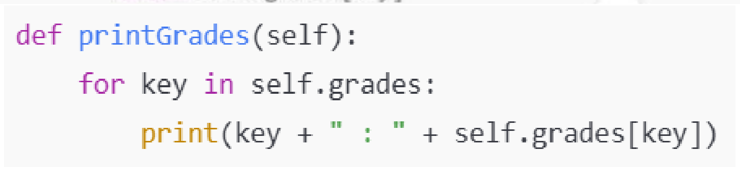
Function overriding allows a child class to provide a specific implementation of a function already provided by the base class.The child class implementation of the overridden function has the same name, parameters, and return type as the function in the base class.

example (Box 6.33) which shows: studentCount as a class variable shared across all instances name, id, and grades as instance variables unique to each object The use of _init_() as the constructor method in Python.

The class constructor initialize a new instance when it is created. The function_del_() is the class destructor.

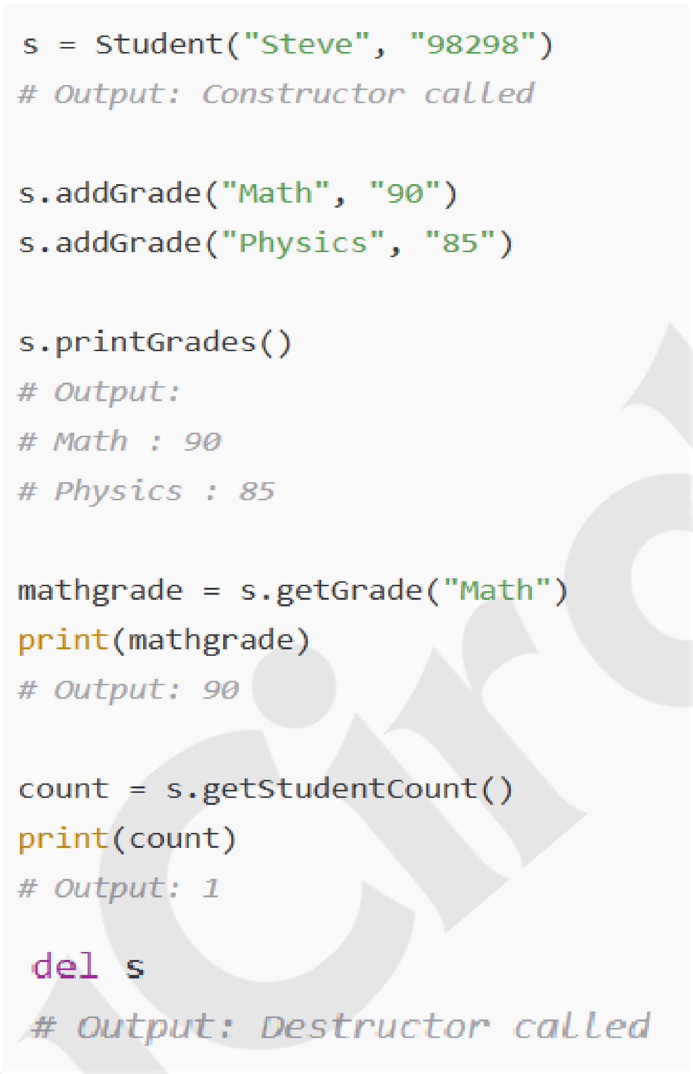


```
class Student:
    studentCount = 0

    def __init__(self, name, id):
        print("Constructor called")
        self.name = name
        self.id = id
        Student.studentCount = Student.studentCount + 1
        self.grades = {}

    def __del__(self):
        print("Destructor called")

    def getStudentCount(self):
        return Student.studentCount

    def addGrade(self, key, value):
        self.grades[key] = value

    def getGrade(self, key):
        return self.grades[key]
```



```
def printGrades(self):
    for key in self.grades:
        print(key + " : " + self.grades[key])
```

Example

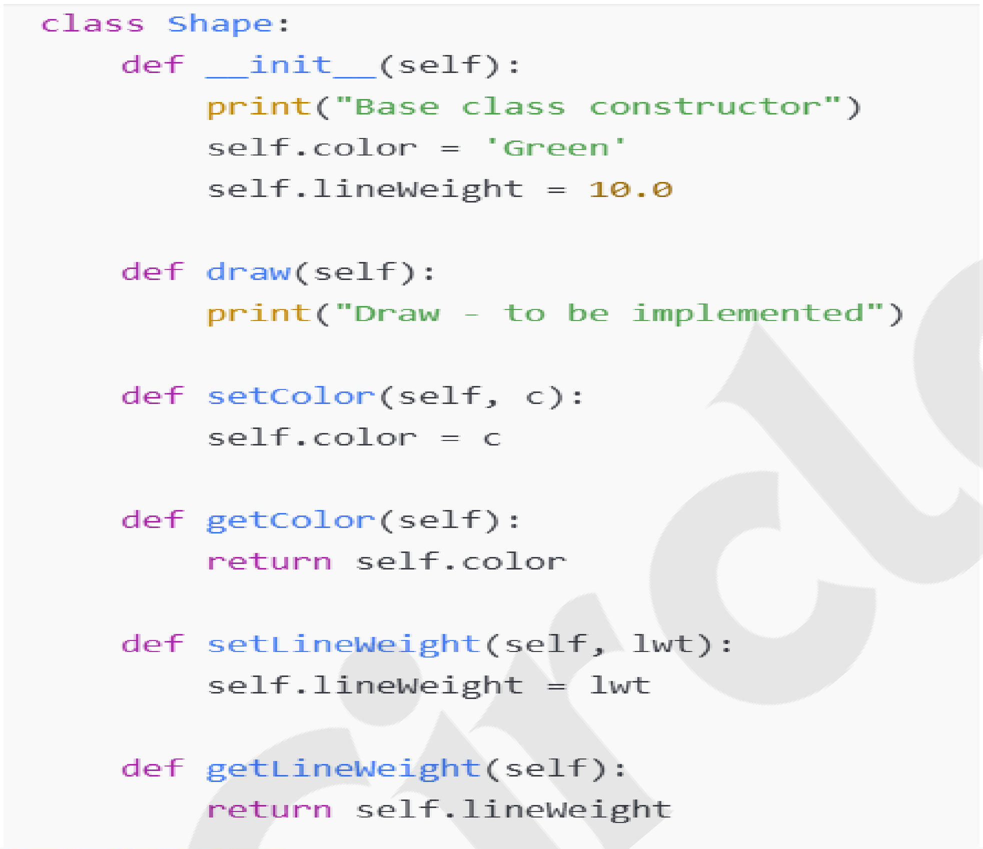


```
s = Student("Steve", "98298")
# Output: Constructor called

s.addGrade("Math", "90")
s.addGrade("Physics", "85")

s.printGrades()
# Output:
# Math : 90
# Physics : 85

mathgrade = s.getGrade("Math")
print(mathgrade)
# Output: 90

count = s.getStudentCount()
print(count)
# Output: 1

 del s
 # Output: Destructor called
```

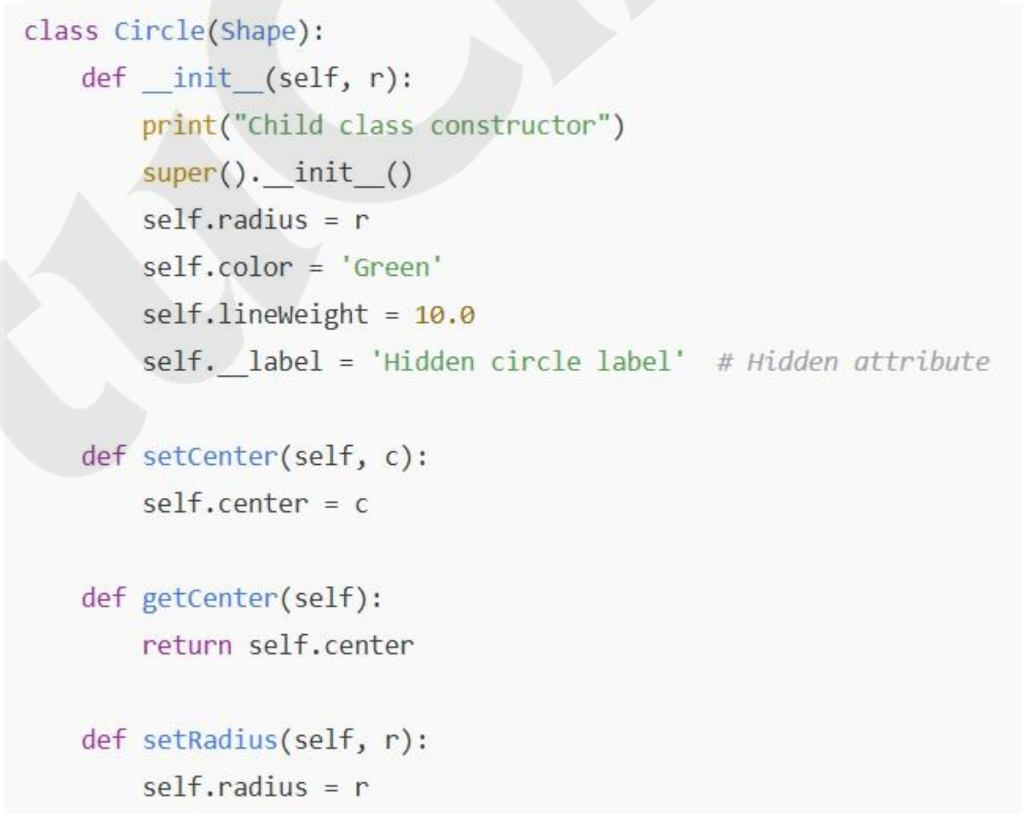
Box 6.34: Examples of class inheritance, in the example

Shape is the **base class**.
Circle is the **derived (child) class**, inheriting from Shape.
super().__init__() is used to call the base class constructor.
_label is a **hidden attribute** due to the double underscore (__), which triggers **name mangling**.

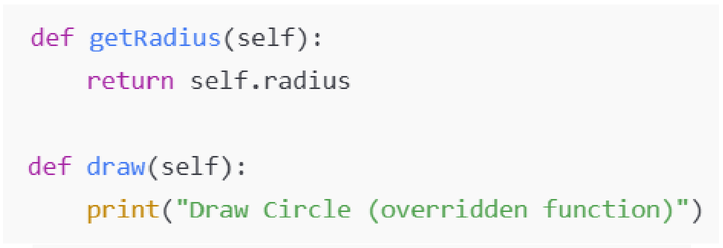
- Internally, __label in Circle becomes _Circle__label.



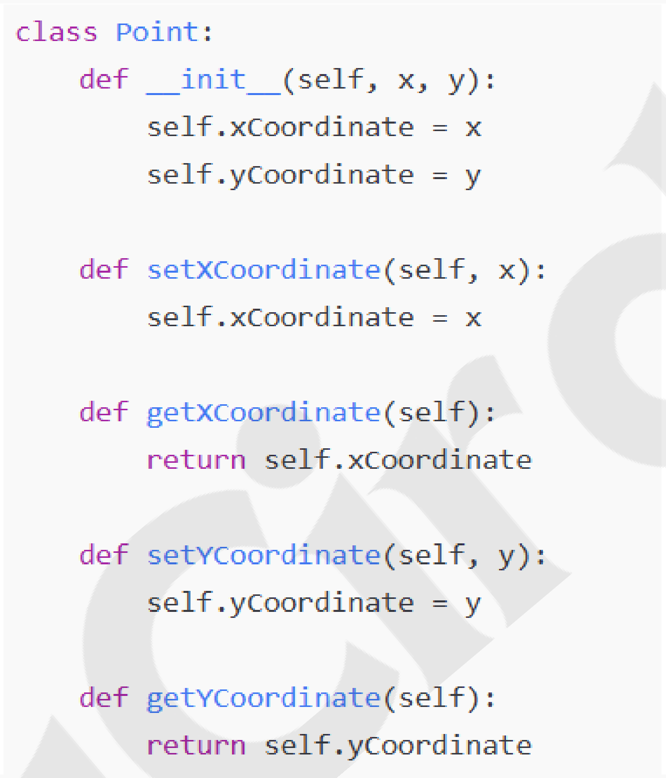
```
class Shape:
    def __init__(self):
        print("Base class constructor")
        self.color = 'Green'
        self.lineWeight = 10.0

    def draw(self):
        print("Draw - to be implemented")

    def setColor(self, c):
        self.color = c

    def getColor(self):
        return self.color

    def setLineWeight(self, lwt):
        self.lineWeight = lwt

    def getLineWeight(self):
        return self.lineWeight
```



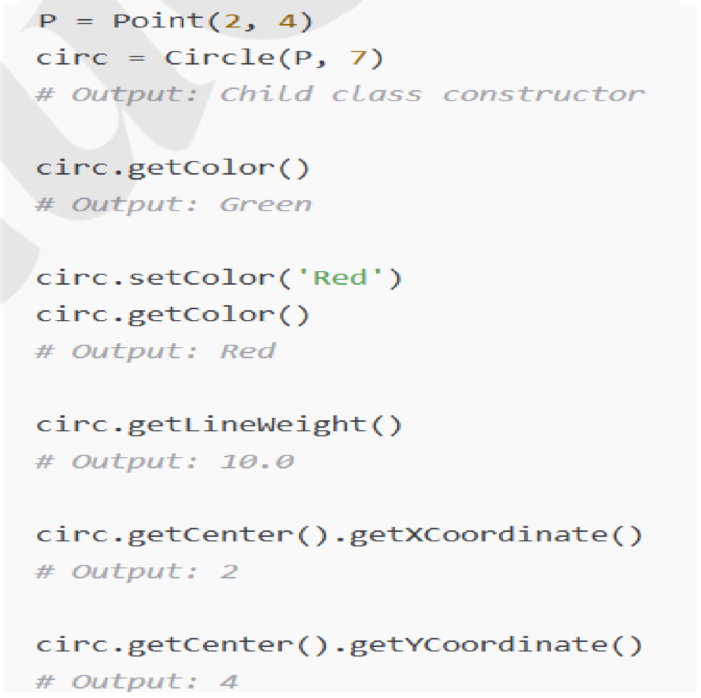
```
class Circle(Shape):
    def __init__(self, r):
        print("Child class constructor")
        super().__init__()
        self.radius = r
        self.color = 'Green'
        self.lineWeight = 10.0
        self.__label = 'Hidden circle label'  # Hidden attribute

    def setCenter(self, c):
        self.center = c

    def getCenter(self):
        return self.center

    def setRadius(self, r):
        self.radius = r
```



```
def getRadius(self):
    return self.radius

def draw(self):
    print("Draw Circle (overridden function)")
```



```
class Point:
    def __init__(self, x, y):
        self.xCoordinate = x
        self.yCoordinate = y

    def setXCoordinate(self, x):
        self.xCoordinate = x

    def getXCoordinate(self):
        return self.xCoordinate

    def setYCoordinate(self, y):
        self.yCoordinate = y

    def getYCoordinate(self):
        return self.yCoordinate
```



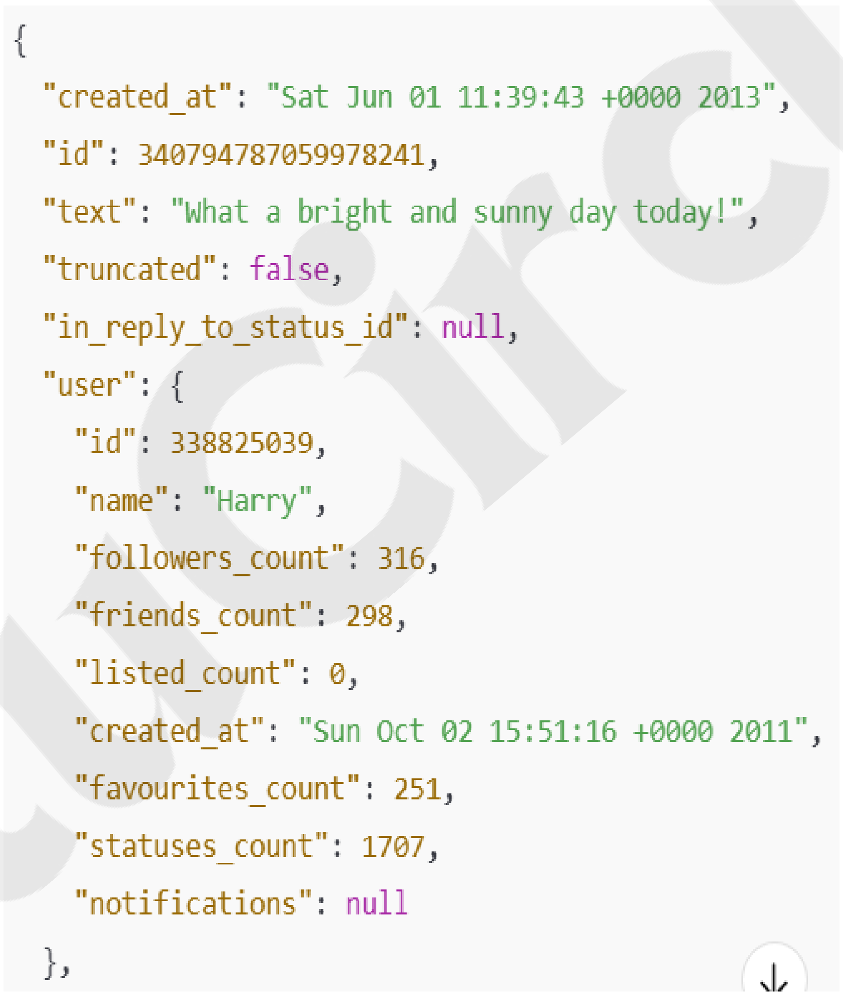
```
P = Point(2, 4)
circ = Circle(P, 7)
# Output: Child class constructor

circ.getColor()
# Output: Green

circ.setColor('Red')
circ.getColor()
# Output: Red

circ.getLineWeight()
# Output: 10.0

circ.getCenter().getXCoordinate()
# Output: 2

circ.getCenter().getYCoordinate()
# Output: 4
```

3.13 Python Packages of Interest for IoT

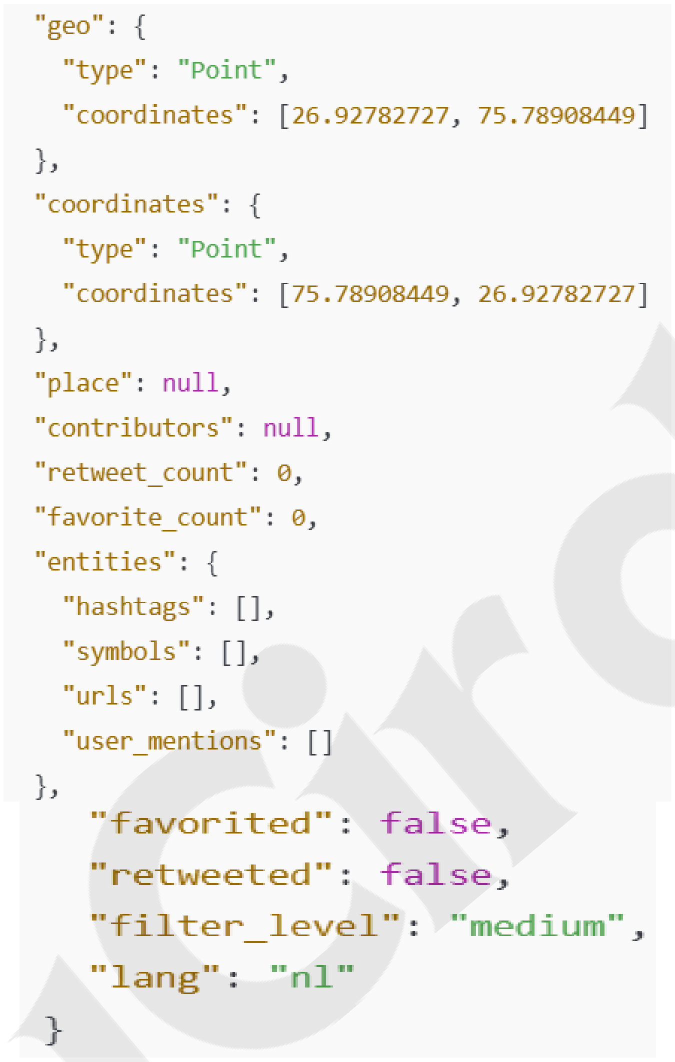
3.13.1 JSON

JavaScript Object Notation (JSON) is an easy to read and write data-interchange format. JSON is used as an alternative to XML and is easy for machines to parse and generate. JSON is built on two structures – a collection of name-value pairs (e.g. a Python dictionary) and ordered lists of values (e.g., a Python list).

JSON format is often used for serializing and transmitting structured data over a network connection, for example, transmitting data between a server and web application. **Box 6.35 shows an example of a Twitter tweet object encoded as JSON.**

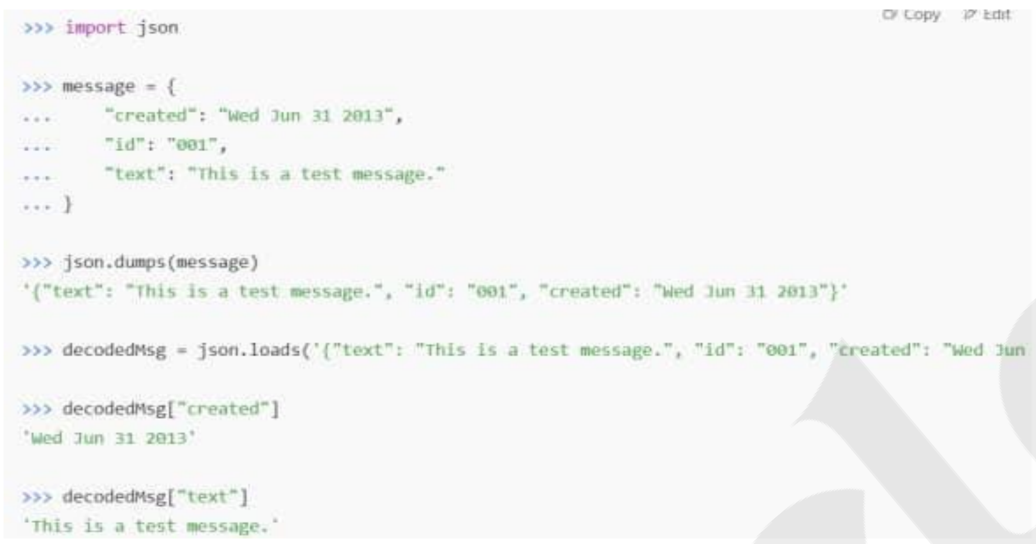


```
{
  "created_at": "Sat Jun 01 11:39:43 +0000 2013",
  "id": 340794787059978241,
  "text": "What a bright and sunny day today!",
  "truncated": false,
  "in_reply_to_status_id": null,
  "user": {
    "id": 338825039,
    "name": "Harry",
    "followers_count": 316,
    "friends_count": 298,
    "listed_count": 0,
    "created_at": "Sun Oct 02 15:51:16 +0000 2011",
    "favourites_count": 251,
    "statuses_count": 1707,
    "notifications": null
  },
```



```
"geo": {
  "type": "Point",
  "coordinates": [26.92782727, 75.78908449]
},
"coordinates": {
  "type": "Point",
  "coordinates": [75.78908449, 26.92782727]
},
"place": null,
"contributors": null,
"retweet_count": 0,
"favorite_count": 0,
"entities": {
  "hashtags": [],
  "symbols": [],
  "urls": [],
  "user_mentions": []
},
    "favorited": false,
    "retweeted": false,
    "filter_level": "medium",
    "lang": "nl"
 }
```

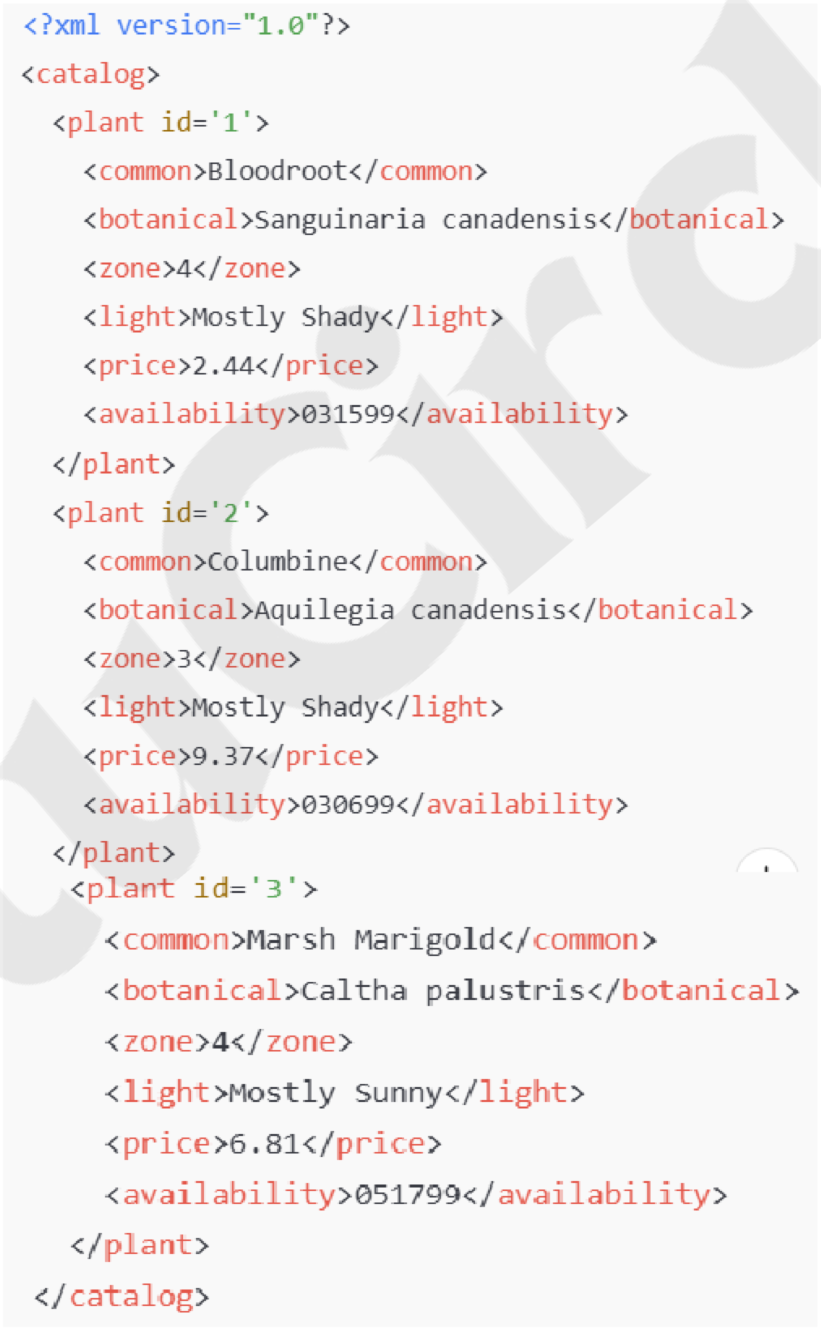
Exchange of information encoded as JSON involves encoding and decoding steps. The Python JSON package provides functions for encoding and decoding JSON. **Box 6.36 shows an example of JSON encoding and decoding.**



```
>>> import json

>>> message = {
...     "created": "Wed Jun 31 2013",
...     "id": "001",
...     "text": "This is a test message."
... }

>>> json.dumps(message)
'{"text": "This is a test message.", "id": "001", "created": "Wed Jun 31 2013"}'

>>> decodedMsg = json.loads('{"text": "This is a test message.", "id": "001", "created": "Wed Jun

>>> decodedMsg["created"]
'Wed Jun 31 2013'

>>> decodedMsg["text"]
'This is a test message.'
```

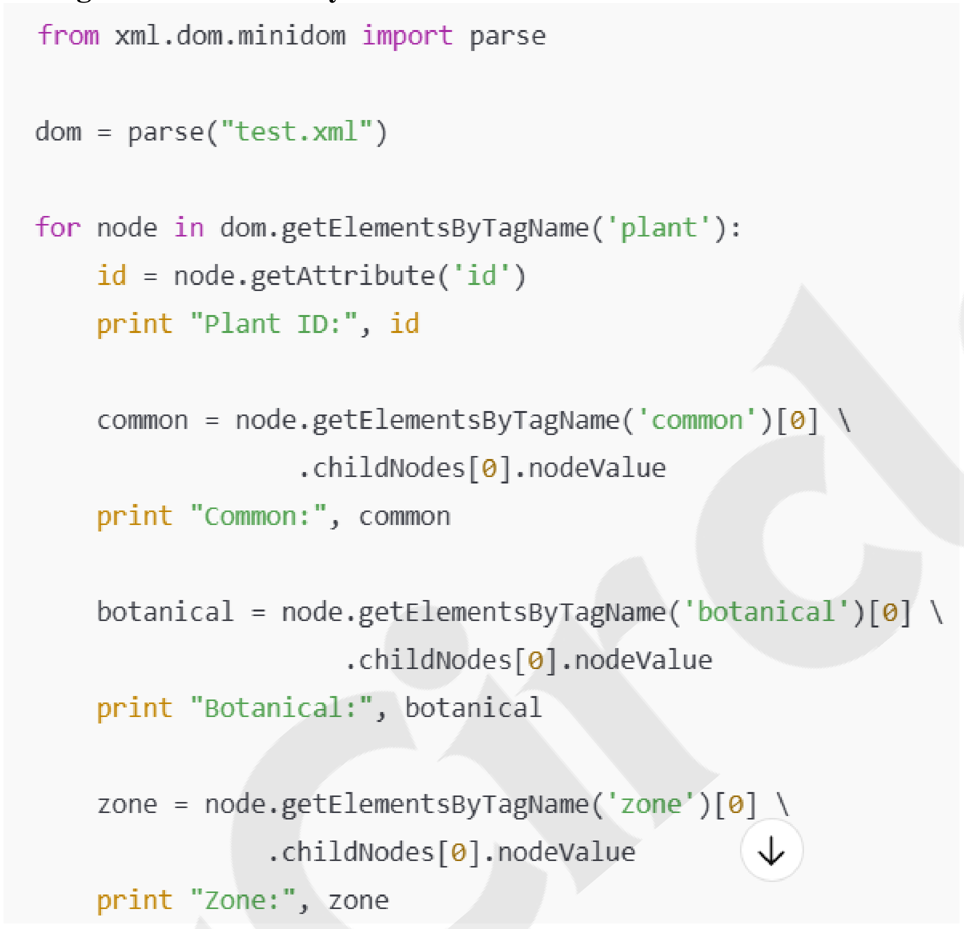
3.13.2 XML

XML (Extensible Markup Language) is a data format for structured document interchange. **Box 6.37 shows an example of an XML file**. In this section you will learn how to parse, read and write XML with Python. The Python *minidom* library provides a minimal implementation of the Document Object Model interface and has an API similar to that in other languages. **Box 6.38 shows a Python program for parsing an XML file. Box 6.39 shows a Python program for creating an XML file.**



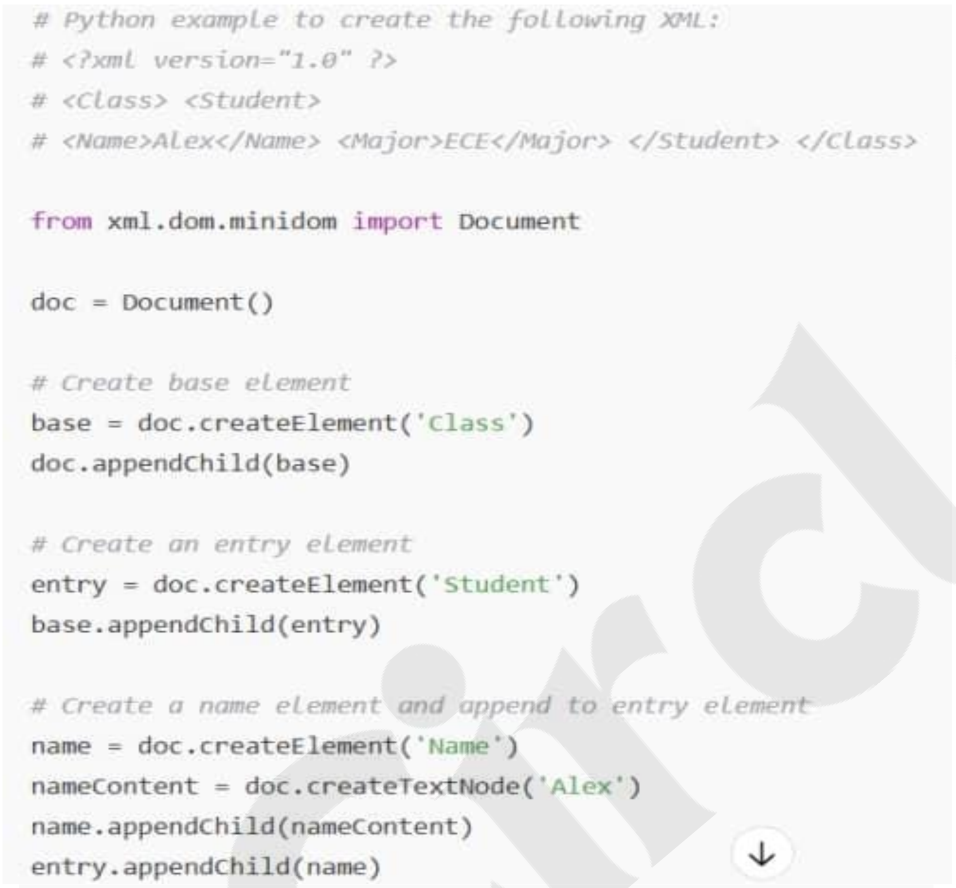
```
<?xml version="1.0"?>
<catalog>
  <plant id='1'>
    <common>Bloodroot</common>
    <botanical>Sanguinaria canadensis</botanical>
    <zone>4</zone>
    <light>Mostly Shady</light>
    <price>2.44</price>
    <availability>031599</availability>
  </plant>
  <plant id='2'>
    <common>Columbine</common>
    <botanical>Aquilegia canadensis</botanical>
    <zone>3</zone>
    <light>Mostly Shady</light>
    <price>9.37</price>
    <availability>030699</availability>
  </plant>
  <plant id='3'>
    <common>Marsh Marigold</common>
    <botanical>Caltha palustris</botanical>
    <zone>4</zone>
    <light>Mostly Sunny</light>
    <price>6.81</price>
    <availability>051799</availability>
  </plant>
</catalog>
```

Box 6.38: Parsing an XML file in Python

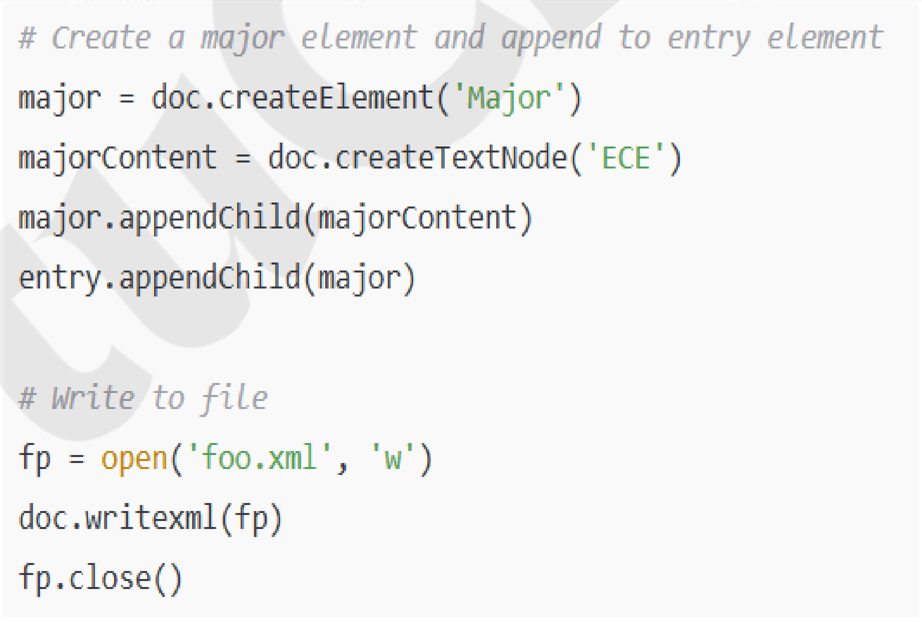


```
from xml.dom.minidom import parse

dom = parse("test.xml")

for node in dom.getElementsByTagName('plant'):
    id = node.getAttribute('id')
    print "Plant ID:", id

    common = node.getElementsByTagName('common')[0] \
                 .childNodes[0].nodeValue
    print "Common:", common

    botanical = node.getElementsByTagName('botanical')[0] \
                    .childNodes[0].nodeValue
    print "Botanical:", botanical

    zone = node.getElementsByTagName('zone')[0] \
               .childNodes[0].nodeValue
    print "Zone:", zone
```

Box 6.39: Creating an XML File with Python



```
# Python example to create the following XML:
# <?xml version="1.0" ?>
# <Class> <Student>
# <Name>Alex</Name> <Major>ECE</Major> </Student> </Class>

from xml.dom.minidom import Document

doc = Document()

# Create base element
base = doc.createElement('Class')
doc.appendChild(base)

# Create an entry element
entry = doc.createElement('Student')
base.appendChild(entry)

# Create a name element and append to entry element
name = doc.createElement('Name')
nameContent = doc.createTextNode('Alex')
name.appendChild(nameContent)
entry.appendChild(name)
```



```
# Create a major element and append to entry element
major = doc.createElement('Major')
majorContent = doc.createTextNode('ECE')
major.appendChild(majorContent)
entry.appendChild(major)


# Write to file
fp = open('foo.xml', 'w')
doc.writexml(fp)
fp.close()
```

3.13.3 HTTPLib & URLLib

HTTPLib2 and URLLib2 are Python libraries used in network/internet programming. HTTPLib2 is an HTTP client library and URLLib2 is a library for fetching URLs.
Box 6.40 shows an example of an HTTP GET request using the HTTPLib. The variable

resp contains the response headers and *content* contains the content retrieved from the URL.

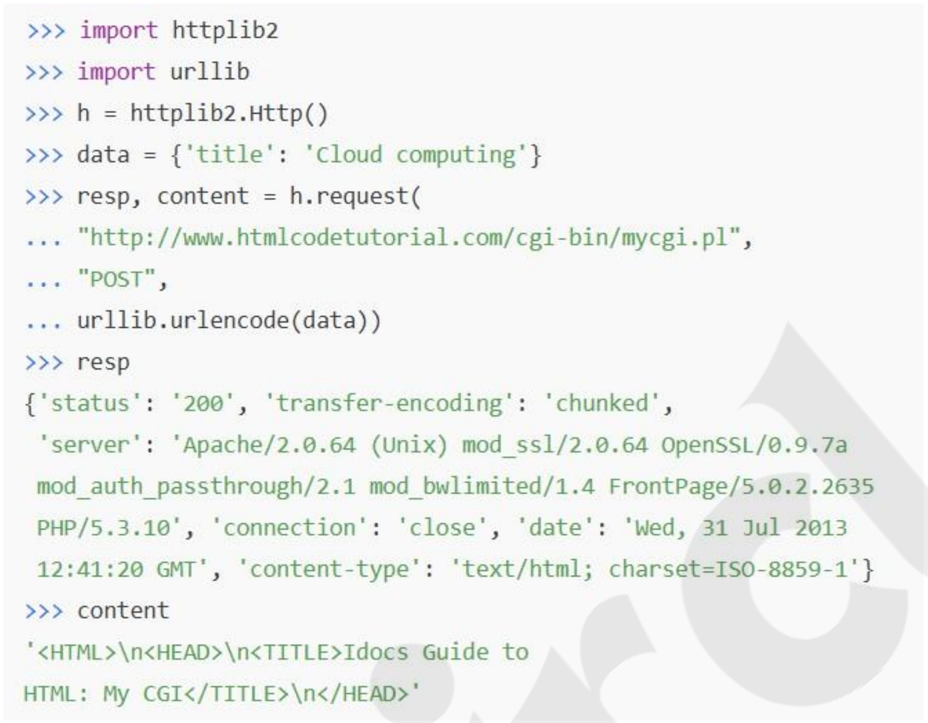
```
>>> import httplib2
>>> h = httplib2.Http()
>>> resp, content = h.request("http://example.com", "GET")
>>> resp
{'status': '200', 'content-length': '1270', 'content-location':
 'http://example.com', 'x-cache': 'HIT', 'accept-ranges':
 'bytes', 'server': 'ECS (qpm/F858)', 'last-modified': 'Thu,
 25 Apr 2013 16:13:23 GMT', 'etag':
 '"780602-4f6-4db31b2978ec0"', 'date': 'Wed, 31 Jul 2013 12:36:05 GMT',
 'content-type': 'text/html; charset=UTF-8'}

>>> content
'<!doctype html>\n<html>\n<head>\n
<title>Example Domain</title>\n\n
<meta charset="utf-8"/>\n'
```

Box 6.41 shows an HTTP request example using URLLib2. A request object is created by calling urllib2.Request with the URL to fetch as input parameter. Then urllib2.urlopen is called with the request object which returns the response object for the requested URL. The

```
>>> import urllib2
>>>
>>> req = urllib2.Request('http://example.com')
>>> response = urllib2.urlopen(req)
>>> response_page = response.read()
>>> response_page
'<!doctype html>\n<html>\n<head>\n
<title>Example Domain</title>\n\n
<meta charset="utf-8" />\n'
```

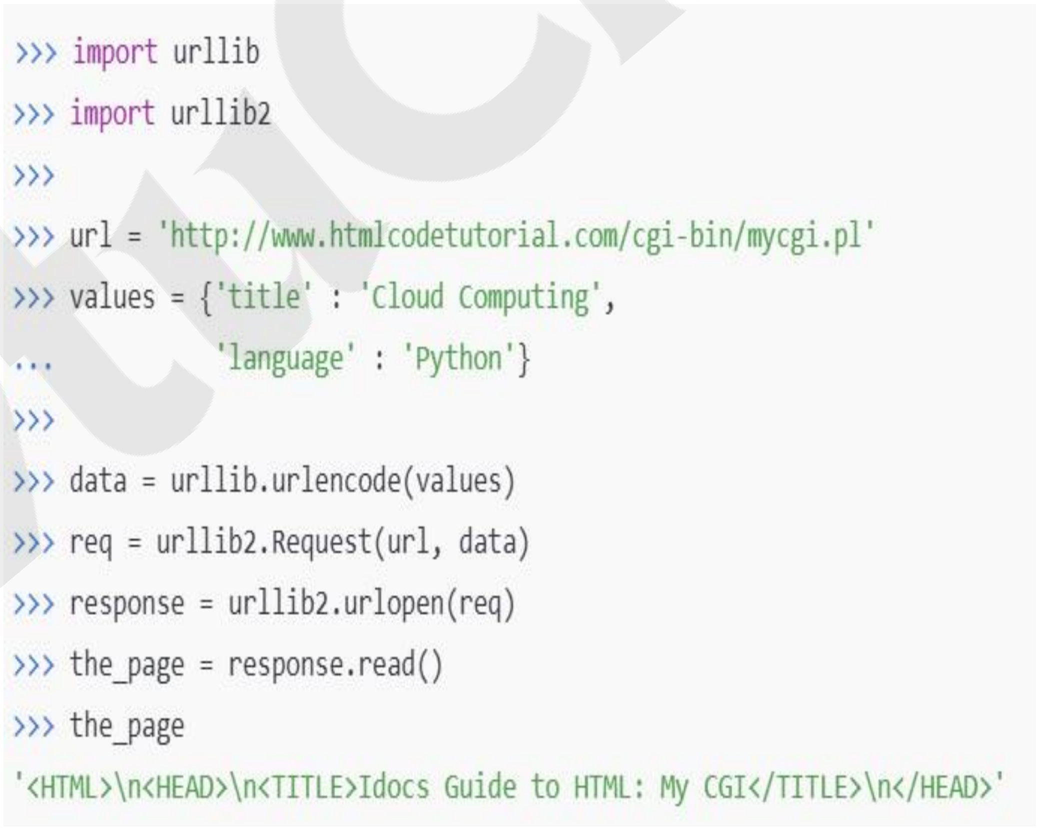
response object is read by calling read function.

Box 6.42 shows an example of an HTTP POST request. The data in the POST body is encoded using the urlencode function from urllib.



```
>>> import httplib2
>>> import urllib
>>> h = httplib2.Http()
>>> data = {'title': 'Cloud computing'}
>>> resp, content = h.request(
... "http://www.htmlcodetutorial.com/cgi-bin/mycgi.pl",
... "POST",
... urllib.urlencode(data))
>>> resp
{'status': '200', 'transfer-encoding': 'chunked',
 'server': 'Apache/2.0.64 (Unix) mod_ssl/2.0.64 OpenSSL/0.9.7a
 mod_auth_passthrough/2.1 mod_bwlimited/1.4 FrontPage/5.0.2.2635
 PHP/5.3.10', 'connection': 'close', 'date': 'Wed, 31 Jul 2013
 12:41:20 GMT', 'content-type': 'text/html; charset=ISO-8859-1'}
>>> content
'<HTML>\n<HEAD>\n<TITLE>Idocs Guide to
HTML: My CGI</TITLE>\n</HEAD>'
```

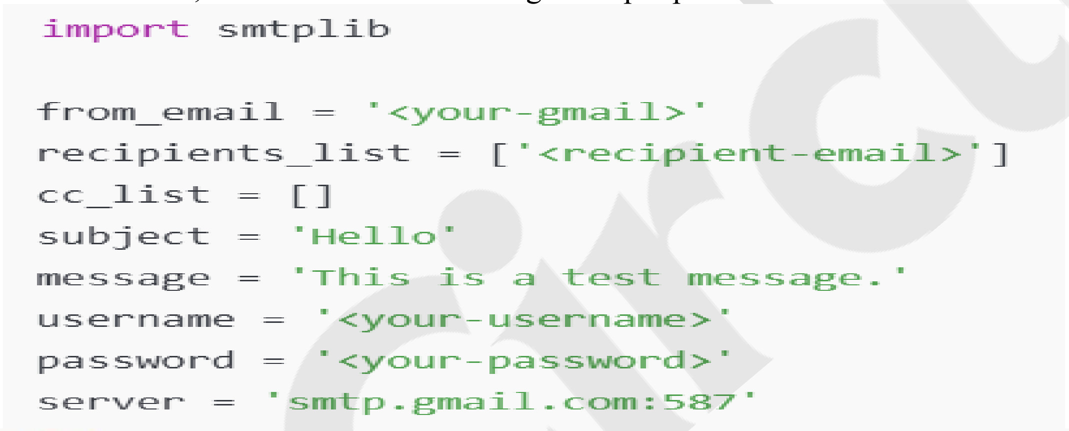
Box 6.43 shows an example of sending data to a URL using URLLib2 (e.g., an HTML form submission). This example is similar to the HTTP POST example in **Box 6.42** and uses the **URLLib2 request object** instead of **HTTPLib2**.



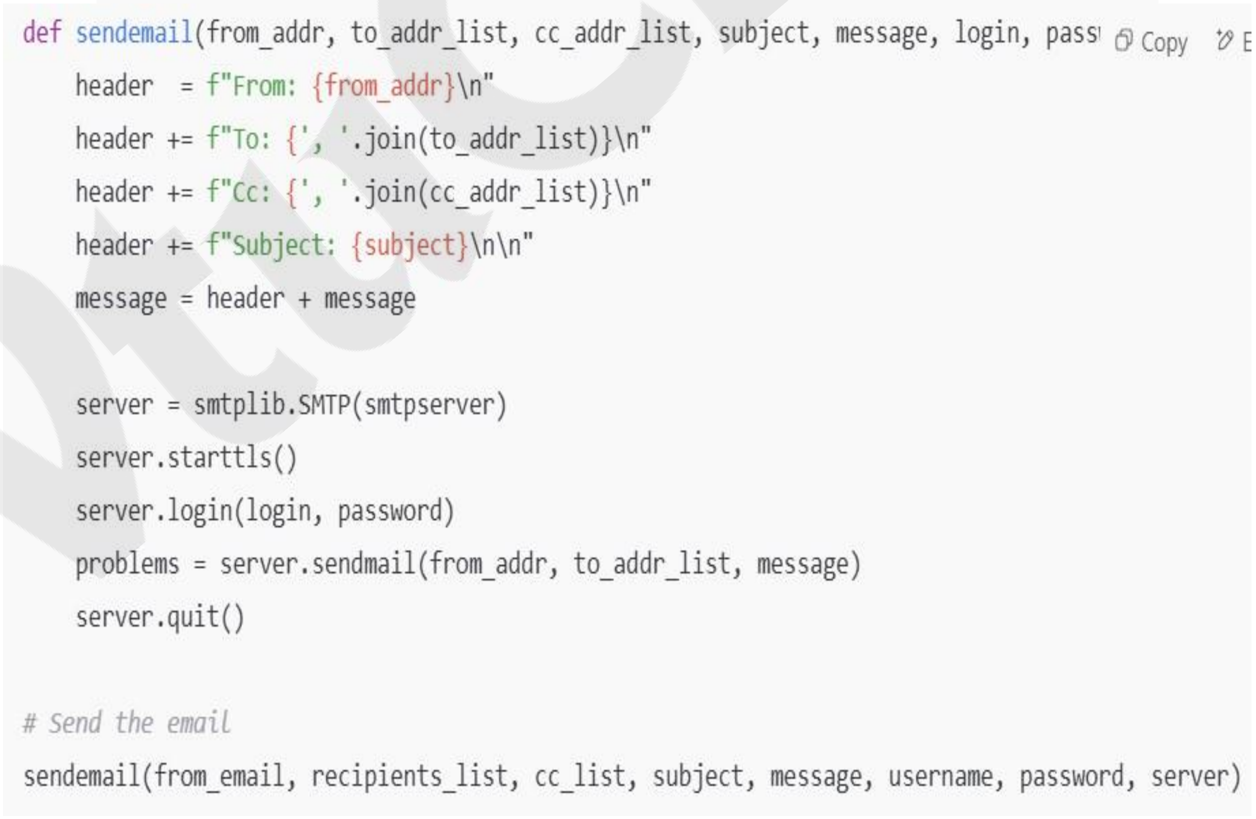
```
>>> import urllib
>>> import urllib2
>>>
>>> url = 'http://www.htmlcodetutorial.com/cgi-bin/mycgi.pl'
>>> values = {'title' : 'Cloud Computing',
...           'language' : 'Python'}
>>>
>>> data = urllib.urlencode(values)
>>> req = urllib2.Request(url, data)
>>> response = urllib2.urlopen(req)
>>> the_page = response.read()
>>> the_page
'<HTML>\n<HEAD>\n<TITLE>Idocs Guide to HTML: My CGI</TITLE>\n</HEAD>'
```

3.13.4 SMTPLib

Simple Mail Transfer Protocol (SMTP) is a protocol which handles sending email and routing e-mail between mail servers. The Python smtplib module provides an SMTP client session object that can be used to send email.
Box 6.44 shows a Python example of sending email from a Gmail account. The string message contains the email message to be sent. To send email from a Gmail account the Gmail SMTP server is specified in the server string.
To send an email, first a connection is established with the SMTP server by calling smtplib. SMTP with the SMTP server name and port. The user name and password provided are then used to login into the server. The email is then sent by calling server. send mail function with the from address, to address list and message as input parameters.



```
import smtplib

from_email = '<your-gmail>'
recipients_list = ['<recipient-email>']
cc_list = []
subject = 'Hello'
message = 'This is a test message.'
username = '<your-username>'
password = '<your-password>'
server = 'smtp.gmail.com:587'
```



```
def sendemail(from_addr, to_addr_list, cc_addr_list, subject, message, login, pass
    header  = f"From: {from_addr}\n"
    header += f"To: {', '.join(to_addr_list)}\n"
    header += f"Cc: {', '.join(cc_addr_list)}\n"
    header += f"Subject: {subject}\n\n"
    message = header + message

    server = smtplib.SMTP(smtpserver)
    server.starttls()
    server.login(login, password)
    problems = server.sendmail(from_addr, to_addr_list, message)
    server.quit()

# Send the email
sendemail(from_email, recipients_list, cc_list, subject, message, username, password, server)
```

Module 3 Question Bank

1. What is the difference between a physical and virtual entity?
2. What is an IoT device?
3. What is the purpose of information model?
4. What are the various service types?
5. What is the need for a controller service?
6. What is the difference between procedure-oriented programming and object-oriented programming?
7. What is an interpreted language?
8. Describe a use case of Python dictionary?
9. What is a keyword argument in Python?
10. What are variable length arguments?
11. What is the difference between a Python module and a package?
12. How is function overriding implemented in Python?