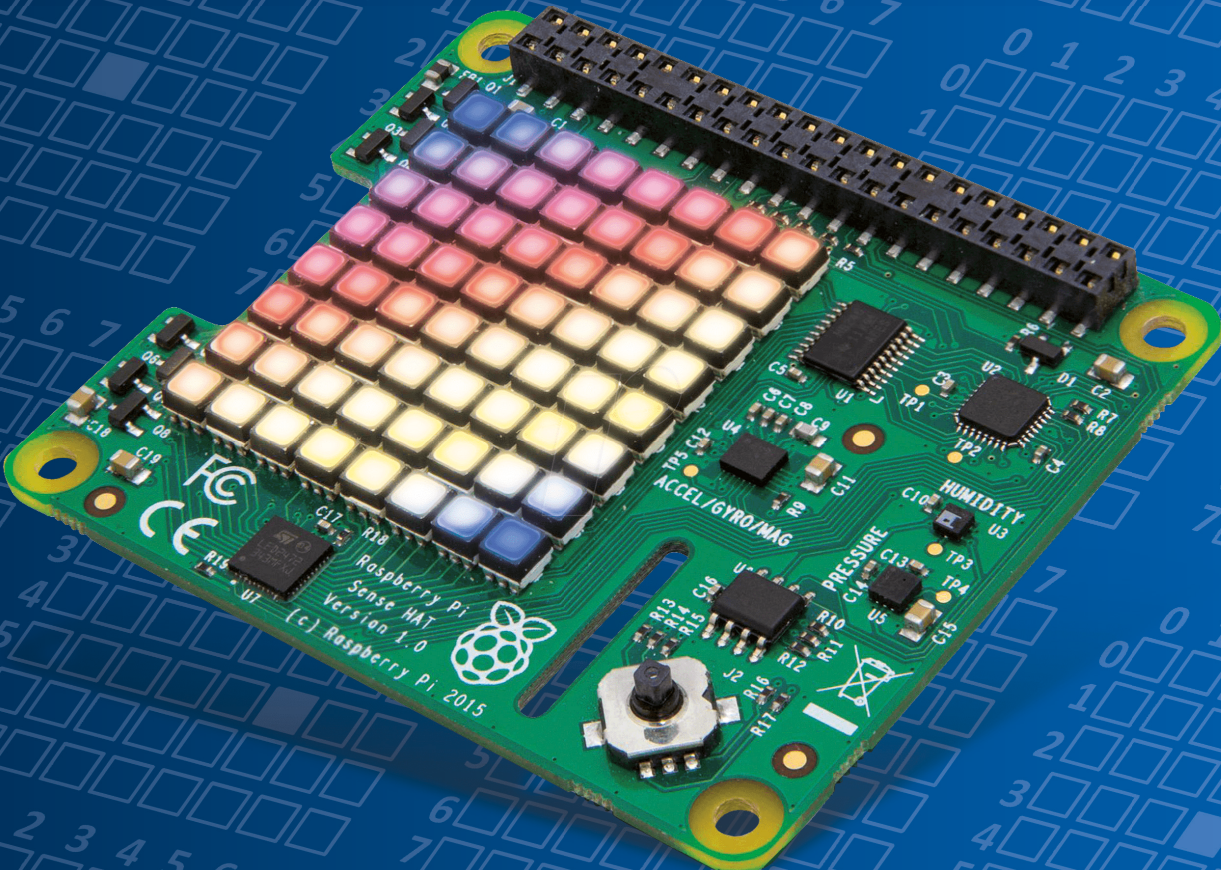
45 Sensor Projects in Python

Innovate with Sense HAT for Raspberry Pi



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Preface

The Raspberry Pi is a credit-card sized computer that can be used in many applications, such as in audio and video media centers, as a desktop computer, in industrial controllers, robotics, and many domestic and commercial applications. In addition to its many features, the Raspberry Pi also has Wi-Fi and Bluetooth capability, making it highly desirable for remote and internet-based control and monitoring applications.

Sense HAT is an add-on board for Raspberry Pi which can be plugged-in to the 40-way connector of the Raspberry Pi. The Sense HAT contains several useful environmental sensors, such as temperature, humidity, pressure, accelerometer, magnetometer, and gyroscope. Additionally, an 8 x 8 LED matrix is provided with RGB LEDs which can be used to display multi-colour scrolling or fixed information, such as the sensor data. A small joystick is provided on the board that can be used in-game programs or in other applications where input from the user may be required. Sense HAT can be used with all models of the Raspberry Pi. This book is about using the Sense HAT multi-sensor and display board in Raspberry Pi Zero W based projects. The book explains in simple terms and with tested and working example projects, how to use the Sense HAT board in interesting visual and sensor-based projects.

The book starts with an introduction to the Sense HAT board and covers many projects using this board with the Raspberry Pi Zero W computer. Although the projects are based on the Raspberry Pi Zero W, they can all be implemented on other Raspberry Pi models without any modifications.

One unique feature of this book is the development of projects using external hardware components in addition to the Sense HAT board. The book explains in detail how to connect the Sense HAT board to the Raspberry Pi using jumper wires so that some of the GPIO ports are free and can be interfaced to external components, such as buzzers, relays, LCDs, motors, other sensors, etc.

Full program listings of all the projects are given in the book together with a full description of each project. All projects in the book have been developed using the latest version of the Python 3 programming language, although they will work with the earlier Python 2 as well. Readers can download the projects from the webpage of the book.

I hope the readers find the book helpful and enjoy reading it.

Prof. Dr. Dogan Ibrahim
January 2020
London.

Chapter 1 • Sense HAT

The Astro Pi is a small computer enclosed in a special case, which has various sensors and two cameras (infrared and visible light camera) used to collect environmental data onboard the International Space Station (ISS). Sense HAT is the main component, and the LED matrix the only form of visual output.

Sense HAT is a small plug-in board developed by the Raspberry Pi Foundation in collaboration with the UK Space Agency and the European Space Agency (ESA). The board includes several sensors, hence its name "Sense". The word "HAT" stands for "Hardware Attached on Top" to indicate that the board is attached or plugged in on top of the Raspberry Pi. Sense HAT gives the flexibility to carry out various environmental measurements using its built-in sensors. The board was specially developed for the Astro Pi challenge and competition. An emulator-based version of Sense HAT is also available, to enable students to carry out experiments without needing the physical board.

Each year, students aged up to 19 from across Europe are encouraged to write code for astronauts to run on the Astro Pis, the aim being to inspire young people to have an interest in space science and coding. The Astro Pi challenge consists of two phases, as explained below: Mission Zero, and Mission Space Lab.

Mission Zero
This is aimed for students up to 14 years old, who are expected to participate in groups of two to four. The students are given the chance to have their code run on the ISS. For example, participants can write codes to display the temperature on the LED matrix so that the astronauts can see as part of their daily tasks. It is guaranteed that all entries to the competition that follow the challenge rules will run in space for the astronauts to see.

Students working in teams are expected to write Python programs that show a message and the air temperature for the ISS astronauts on the LED matrix. No extra hardware is needed and everything can be done using the Sense HAT emulator.

The challenge started on 12 September 2019 and ends on 20 March 2020. The flight status will be confirmed in May 2020, and the certificates to be delivered to the teams in May/ June 2020.

Mission Zero guidelines are available from the following website:

https://astro-pi.org/wp-content/uploads/2019/09/Astro_Pi_Mission_Zero_Guidelines_2019_20_English.pdf

Mission Space Lab
This lab is aimed for groups of two to six students aged 11-19, to give them a chance to have their codes run on the ISS. The participants are asked to develop codes and report their results. Accepted experiments will be deployed by the ISS and ten teams with the best reports will be announced as winners. Mission Space Lab has four phases, including design,

creating, deploying, and analysing the results by writing a report.

Mission Space Lab guidelines are available at the following website:

https://astro-pi.org/missions/space-lab/

This book is about developing projects using the Sense HAT board together with the Raspberry Pi computer. The Raspberry Pi Zero W is chosen as the host computer in this book since it is relatively cheap, widely available, and ideal for running Sense HAT projects. All projects given in this book will also run on the different models of the Raspberry Pi without any modification.

In the next section, we will briefly remind ourselves of the basic features of the Raspberry Pi Zero W computer.

1.1 The Raspberry Pi Zero W

The Raspberry Pi Zero W is the smallest model of the Raspberry Pi family of computers. Launched at the end of February 2017, Raspberry Pi Zero W is very similar to the Raspberry Pi Zero, but it includes wireless LAN and Bluetooth connectivity on the board. Figure 1.1 shows a picture of the Raspberry Pi Zero W.

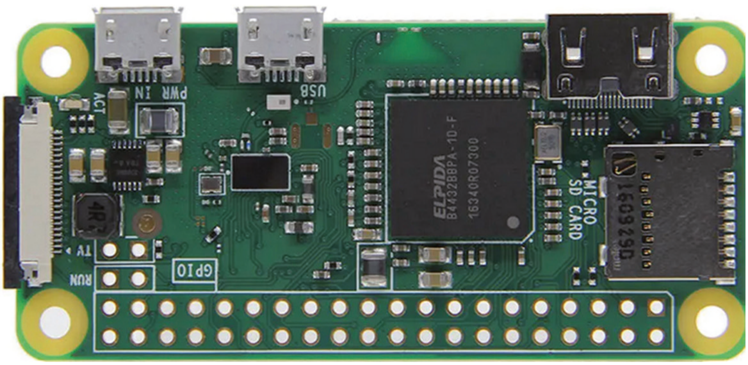

Figure 1.1 Raspberry Pi Zero W

The basic features of the Raspberry Pi Zero W are:

- 1 GHz single-core processor
- 512 MB DDR RAM @ 400 MHz
- Mini HDMI port
- Micro USB power port
- Micro USB data port
- 40-pin standard connector
- 802.11 b/g/n wireless LAN
- Bluetooth 4.1
- Bluetooth Low Energy (BLE)
- CSI camera interface

- Composite video and reset headers
- Micro SD card slot for the operating system
- UART, SPI, I^2C, GPIO
- Small size: 65 x 30 x 5 mm
- Raspberry Pi Zero W is powered from a 5 V, 2 A power supply.

In the next chapter, we will see how to load the latest Raspbian operating system onto the micro SD card ready for the Raspberry Pi Zero W.

Chapter 2 • Installing the operating system on Raspberry Pi

2.1 Overview

The Sense HAT board is compatible with all models of the Raspberry Pi. In this book, we will use the *Raspberry Pi Zero W* which is a cheap model with a small footprint, but it includes Wi-Fi and a reasonable amount of memory. This model does not have USB ports or Ethernet port, which makes it difficult to start using the Raspberry Pi Zero W. In this chapter we will learn how to install the latest operating system (Raspbian Buster) on the Raspberry Pi Zero W, and also learn the different ways that the Python programming language can be used with this processor.

2.2 Raspbian Buster installation steps on Raspberry Pi Zero W

Raspbian Buster is the latest operating system of the Raspberry Pi. This section gives the steps for installing this operating system on a new blank SD card, ready to use with your Raspberry Pi Zero W. You will need a micro SD card with a capacity of at least 8 GB (16 GB is even better) to install the new operating system on.

The steps to install the Raspbian Buster are as follows:

- Download the Buster image to a folder on your PC (e.g. C:\RPIBuster) from the following link by clicking the Download ZIP under section **Raspbian Buster with desktop and recommended software** (see Figure 2.1). At the time of writing this book the file is called **2020-02-13-raspbian-buster-full.img**. You may have to use the Windows 7Zip software to unzip the download since some of the features are not supported by older unzip software.

https://www.raspberrypi.org/downloads/raspbian/

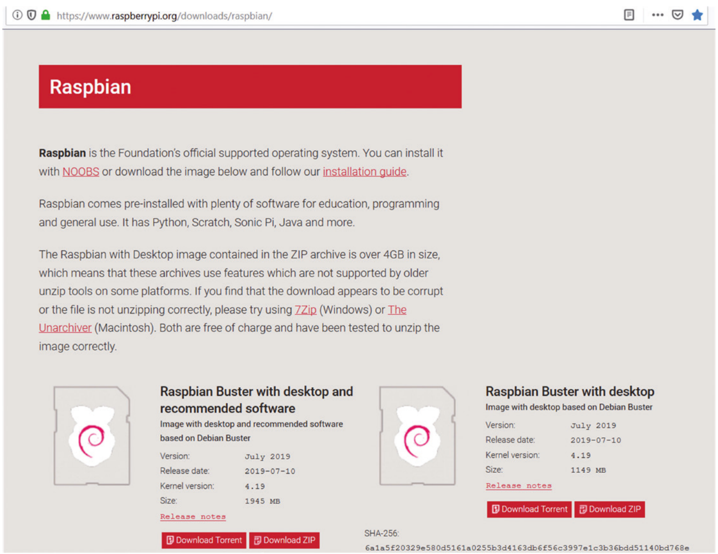

Figure 2.1 Raspbian Buster download page

- Put your blank micro SD card into the card slot on your computer. You may need to use an adapter to do this.
- Download the Etcher program to your PC to flash the disk image. The link is (see Figure 2.2):

  https://www.balena.io/etcher/

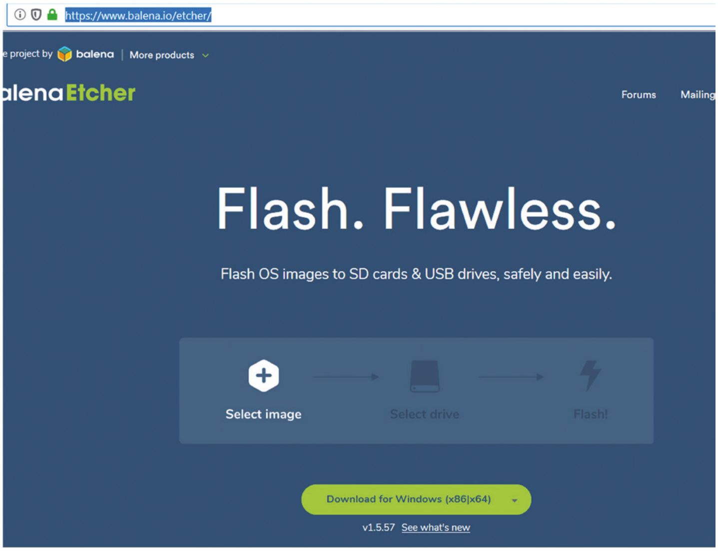

Figure 2.2 Download Etcher

- Double click to Open Etcher, and click **Select image**. Select the Raspbian Buster file you just downloaded and unzipped.
- Click **Select target** and select the micro SD card.
- Click **Flash** (see Figure 2.3). This may take several minutes, wait until it is finished. The program will then validate and unmount the micro SD card. You can remove your micro SD card after it is unmounted.

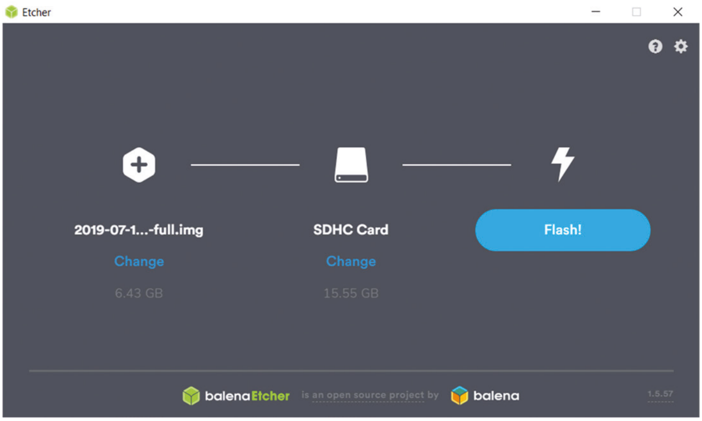

Figure 2.3 Click Flash to flash the disk image

Your micro SD card has now been loaded with the Raspberry Pi operating system. But before we use this card on our Raspberry Pi Zero W, we have to configure the SD card so that the Wi-Fi and SSH are enabled when the Raspberry Pi is started. This way, we can log in using remote terminal software such as Putty. The steps are as follows:

- Install the Nodepad++ software to your PC from the following website:

  https://notepad-plus-plus.org/downloads/v7.8.5/

- Insert the SD card back to your PC and start the Notepad++ software.
- Click **Edit** -> **EOL Conversion** -> **UNIX/OSX Format**.
- Enter the following statements into the blank file (replace the MySSID and My-Password with the details of your own Wi-Fi router):

```
country=GB
update_config=1
ctrl_interface=/var/run/wpa_supplicant

network={
        scan_ssid=1
        ssid="MySSID"
        psk="MyPassword"
}
```

- Copy the file (save) to the boot folder on your SD card with the name wpa_supplicant.conf. In Windows, this is the only folder you will see which contains items like loader.bin, start.elf, kernel.img, etc.

- Create a new empty file with the Notepad++ and save it in the boot folder of the SD card with the name **ssh.** where this file will enable the SSH to be used with your Raspberry Pi Zero W.

- Remove the SD card from your PC and insert it into your Raspberry Pi Zero W.

- Power up the Raspberry Pi Zero W.

Before logging in using the Putty terminal software, we have to know the wireless IP address of our Raspberry Pi Zero W. There are several ways that we can find the IP address of our Raspberry Pi. Perhaps the easiest way is to look at the devices connected to our Wi-Fi router by accessing the router from our PC. You can also get the IP address of your Raspberry Pi using your mobile phone. There are several apps free of charge that you can install on your mobile phone that will show you the IP addresses of all the devices connected to your router. In this section, the Android app called **Who's On My Wi-Fi – Network Scanner** *by Magdalm* was used to show the IP address of the Raspberry Pi used by the author. Running this program will display the Raspberry Pi Wireless IP address under the heading **Raspberry Pi Trading Ltd**. In addition to the IP address, other parameters such as the MAC address, gateway address, IP mask, etc. are all displayed by this app.

- After knowing the IP address of our Raspberry Pi Zero W, we can log in using the Putty software (see next section) with the following default username and password:

  username: **pi**
  password: **raspberry**

- After logging in you are advised to change your password for security reasons. You should also run the **sudo raspi-config** from the command line to enable the VNC, I^2C, and SPI as they are useful interface tools that can be used in your future GPIO based work.

2.3 Remote access

It is much easier to access the Raspberry Pi remotely over the internet, for example using a PC rather than connecting a keyboard, mouse, and display to it. Before being able to access the Raspberry Pi remotely, we have to enable the SSH by entering the following command at a terminal session (if you have followed the steps in Section 2.2 then the SSH is already enabled and you can skip the following command):

pi$raspberrypi:~ $ **sudo raspi-config**

Go to the configuration menu and select **Interface Options**. Go down to **P2 SSH** (see Figure 2.4) and enable SSH. Click **Finish** to exit the menu.

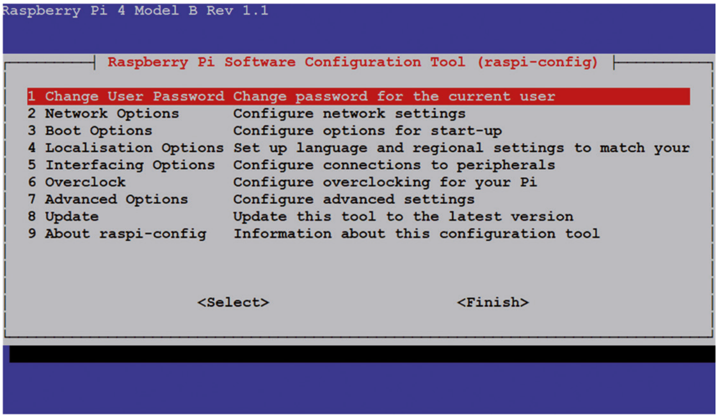

Figure 2.4 Enable SSH

You should also enable VNC so that the Raspberry Pi Desktop can be accessed graphically over the internet. This can be done by entering the following command at a terminal session:

pi$raspberrypi:~ $ **sudo raspi-config**

Go to the configuration menu and select **Interface Options**. Go down to **P3 VNC** and enable VNC. Click **Finish** to exit the menu. At this stage, you may want to shut down your Raspberry Pi by clicking the **Applications Menu** on Desktop and selecting the **Shutdown** option.

2.4 Using the Putty

Putty is a communications program that is used to create a connection between your PC and the Raspberry Pi. This connection uses a secure protocol called SSH (Secure Shell). Putty does not need to be installed; you can simply store it in any folder of your choice and run it from there.

Putty can be downloaded from the following website:

https://www.putty.org/

Simply double click to run it and the Putty startup screen will be displayed. Click **SSH** and enter the Raspberry Pi IP address, then click **Open** (see Figure 2.5). The message shown in Figure 2.6 will be displayed the first time you access the Raspberry Pi. Click **Yes** to accept this security alert.

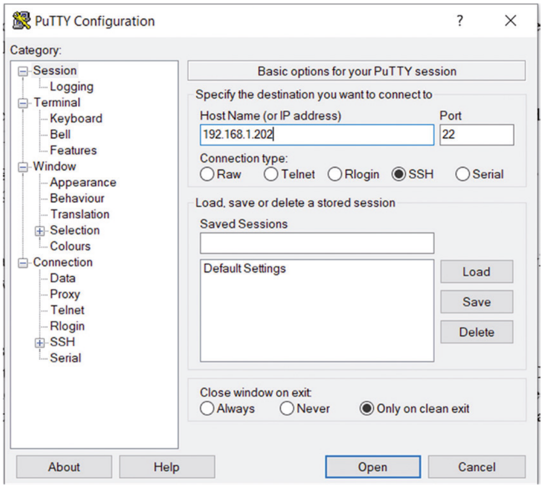

Figure 2.5 Putty startup screen

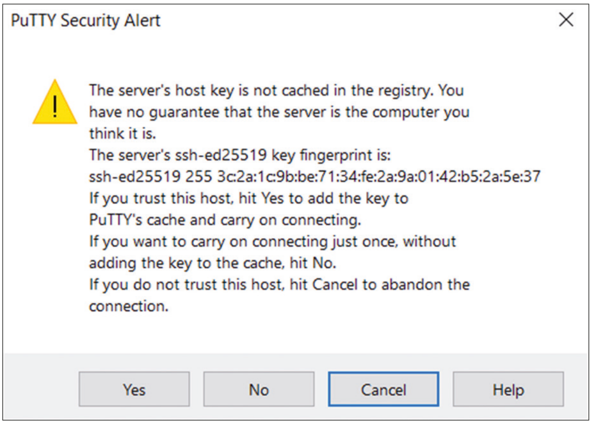

Figure 2.6 Click Yes to accept

You will be prompted to enter the username and password. Notice that the default username and password are:

username: **pi**
password: **raspberry**

You now have a terminal connection with the Raspberry Pi and you can type in commands, including the **sudo** commands. You can use the cursor keys to scroll up and down through the commands you've previously entered in the same session. You can also run programs, although not graphical programs.

2.5 Remote Access of the Desktop

You can control your Raspberry Pi via Putty, and run programs on it from your Windows PC. This, however, will not work with graphical programs because Windows doesn't know how to represent the display. As a result, for example, we cannot run any graphical programs in the Desktop mode. We can get around this problem using some extra software. Two popular programs used for this purpose are VNC (Virtual Network Connection), and Xming. Here, we shall be learning how to use the VNC.

Installing and using VNC

VNC consists of two parts: VNC Server and the VNC Viewer. VNC Server runs on the Raspberry Pi, and the VNC Viewer runs on the PC. VNC server is already installed on your Raspberry Pi and is enabled as described in Section 2.3.

The steps to install and use the VNC Viewer onto your PC are given below:

- There are many VNC Viewers available, but the recommended one is the TightVNC which can be downloaded from the following website:

  https://www.tightvnc.com/download.php

- Download and install the **TightVNC** software for your PC. You will have to choose a password during the installation.

- Start the **TightVNC Viewer** on your PC and enter the Raspberry Pi IP address (see Figure 2.7) followed by :1. Click **Connect** to connect to your Raspberry Pi.

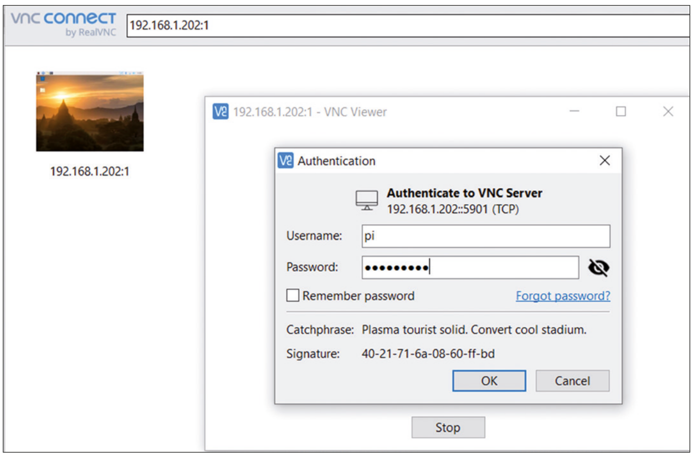

Figure 2.7 Start the TightVNC and enter the IP address

Figure 2.8 shows the Raspberry Pi Desktop displayed on the PC screen.

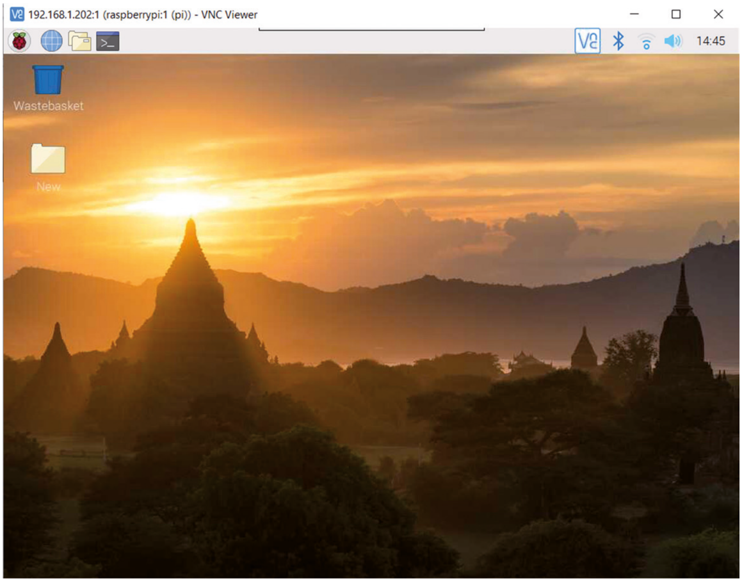

Figure 2.8 Raspberry Pi Desktop on the PC screen

2.6 Using the Python programming language

At the time of writing this book, there are two versions of the Python programming language: Python 2.7 and Python 3.x. Although Python 2.7 is still used by many programmers, it is not supported any longer. There are only a few changes between the two versions. All the programs in this book are based on Python 3.x, which is the latest version.

It is assumed in this book that the reader is familiar with the Python programming language and has developed and run Python programs in the past. Many references, tutorials, and example programs on the Python programming language can be found on the internet.

Python programs can be written and run in three different ways: interactively, using an editor in the command line, and using the Thonny program in Desktop.

Using Python interactively

Python can be used interactively, where the program statements are entered after Python is started. To start the Python, simply enter Python3 while in the command line. This method can only be used for very small programs, such as to test a small code or a function. An example is shown in Figure 2.9, where the area of a rectangle with 5 and 6 unit sides is calculated.