ESCUELA TÉCNICA SUPERIOR DE INGENIEROS
INDUSTRIALES Y DE TELECOMUNICACIÓN

UNIVERSIDAD DE CANTABRIA

Trabajo Fin de Grado

Learning Platform for remotely controlled electrical drives based on Raspberry PI
(Plataforma educativa para el control remoto de motores eléctricos basado en Raspberry PI)

Para acceder al Título de

Graduado en
Ingeniería de Tecnologías de Telecomunicación

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Acknowledgements

Now that the journey is almost over, a thank you to everyone who has helped (and occasionally forced) me to walk this path is in order.

Mario, thank you for making this possible and being so helpful and understanding.

Alberto, thank you for all your help, for answering my obvious questions and then explaining the obvious answer again so I could understand it.

Dad, thank you for being there. And thanks for letting me know every single team in the world had scored while I was studying. Thanks.

Carmela, thank you for dragging me over the finish line. I sincerely could have not done this without you. Thank you for helping me overcome myself and get the job done. Can we chill now?

And Bueli, I did it.

CONTENTS

STARTING GUIDE

Contents

Starting Guide (for Beginners)

In this guide, we will quickly cover all the basic steps in order to have an operative car, all of which will be covered with more detail during the entirety of this document.

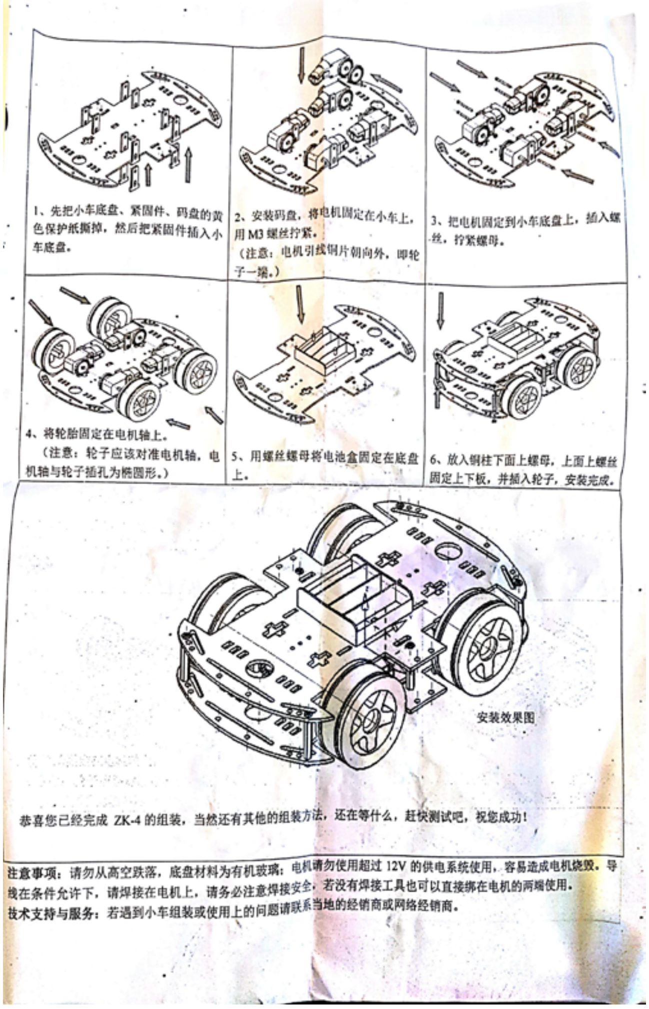
First off, the chassis of the car will need to be assembled. The tutor will provide a chassis but the teams can choose to design and print their own chassis; more details on how to approach this will be discussed in documents *Introduction to Freecad* and *3D Printing*.

All components needed for the assembly of the car are included in the bag provided by the tutor, with a guide (in Mandarin though) on how to assemble them properly; this is explained in detail in document *Inventory*.

Once this is done, the next step will be to connect the car and the Raspberry PI/Gertbot duo that will control it.

Two batteries will be needed (each one powers two wheels) and a power supply to power the Raspberry PI and Gertbot.

Introduction to Gertbot explains in detail how to connect the Gertbot to the four wheels.



1、先把小车底盘、紧固件、码盘的黄色保护纸撕掉，然后把紧固件插入小车底盘。

2、安装码盘，将电机固定在小车上，用 M3 螺丝拧紧。
（注意：电机引线铜片朝向外，即轮子一端。）

3、把电机固定到小车底盘上，插入螺丝，拧紧螺母。

4、将轮胎固定在电机轴上。
（注意：轮子应该对准电机轴，电机轴与轮子插孔为椭圆形。）

5、用螺丝螺母将电池盒固定在底盘上。

6、放入铜柱下面上螺母，上面上螺丝固定上下板，并插入轮子，安装完成。

恭喜您已经完成 ZK-4 的组装，当然还有其他的组装方法，还在等什么，赶快测试吧，祝您成功！

注意事项：请勿从高空跌落，底盘材料为有机玻璃；电机请勿使用超过 12V 的供电系统使用，容易造成电机烧毁。导线在条件允许下，请焊接在电机上，请务必注意焊接安全，若没有焊接工具也可以直接绑在电机的两端使用。
技术支持与服务：若遇到小车组装或使用上的问题请联系当地的经销商或网络经销商。

Figure 1: Set up instructions

In order for the Gertbot to work properly, the Raspberry PI will have to be operational. To do this, a SD card is needed.

Format the SD card and then install an Operating System in the Raspberry PI, this is explained in detail in *Introduction to Raspberry PI.*

As working with the Raspberry PI can be a bit uncomfortable, *Remote Connection to Raspberry PI* explains how to remotely connect to the PI; which will make programming and testing code much easier.

If you are using a Raspberry PI 3, you might need to activate the UART to get the Gertbot to work (supposedly you don't, but when we tried it, it turned out that you did). This is explained at the end of documents *Introduction to Raspberry PI.*

Introduction to Gertbot explains how to set up the Gertbot and try out the DC motors (the same ones that will make your wheels spin).

Once all is correctly set and ready to go, the Gertbot will need instructions regarding what it is that we want it to do. To do this, a Python script will be needed.

The official Gertbot website has a Python source code for two brushed motor vehicle on/off control which can be the foundation for a functional script for this prototype. *Programming* includes an example of fully operative code for four motors, including reverse, two different speeds going forwards and the ability to turn right and left.

Attached is the Flow Chart on how to set a functional prototype from scratch.

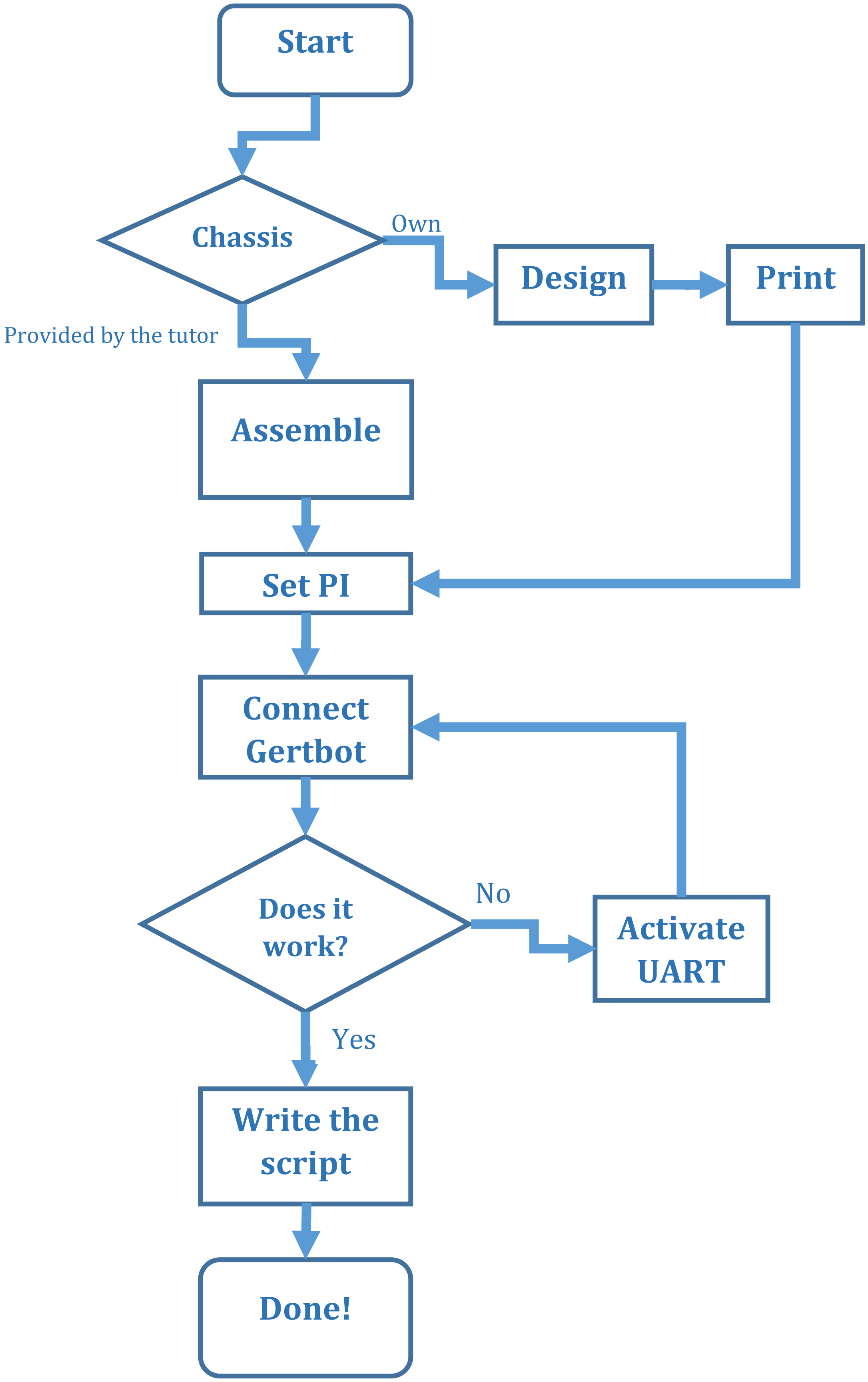


Figure 2: Project flowchart

RULES OF THE COMPETITION

Contents

1. General Requirements

1.1 Circuit Dimensions

The circuit used in the competition is shown in the figure below (Figure 1)

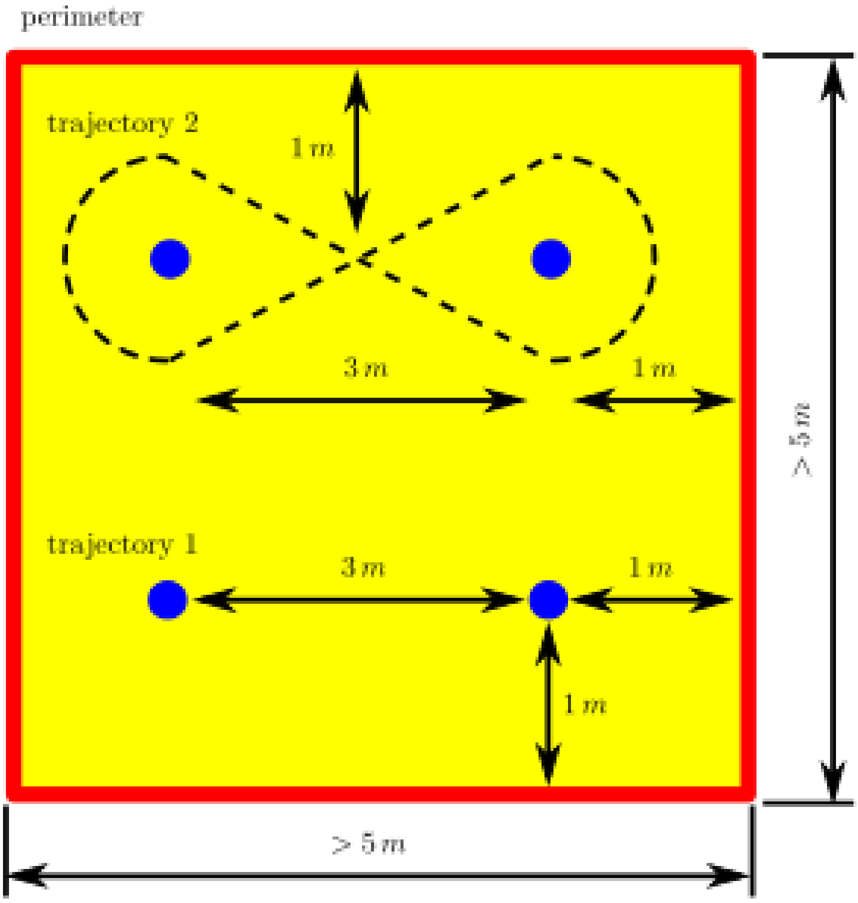


Figure 1: Top view of the race area including trajectories 1 and 2

The field will have the following minimum measurement:

The field must be at least 5 metres long, and 5 metres wide.

There will be two different tracks, each one with their unique measurements:

Trajectory 1: A straight line between two points; A and B. Both points will be 3 metres apart.

Points will be placed one metre away from the edge of the circuit.

Both speed between points A and B and accuracy to stop exactly in the ending points are considered in the evaluation.

Trajectory 2: An infinity loop figure around two points; C and D. Both points will be 3 metres apart.

Points will be placed one metre away from the edge of the circuit.

The centre of the infinity loop will be a metre away from the edge of the circuit.

Both speed (both forward and steering) and adaptability to the trajectory are considered in the evaluation.

2. Requirements for the vehicles

2.1 General Robot Specifications

The vehicle must be able to be placed inside a cube of 22 centimetres in length, 17 centimetres in width and 22 centimetres in height.

The vehicle will weigh less than 2 kilogrammes.

The propulsion system must be electrical.

All the necessary components needed to build the vehicle will be provided by the tutor.

The following list of components is an example of the type of materials that will be available to complete this task:

- Raspberry pi computer board.

- Small DC motors.

- IC drivers.

- Cables.

- Power Bank (5 V).

The tutor will provide each team with a chassis; however teams will have the right to design their own chassis using a 3D CAD software. Students are encouraged to use Open source applications such as FreeCAD (http://www.freecadweb.org/).

Once the chassis has been designed and approved by the tutor, the students will be allowed to synthesise it with a 3D printer.

A Witbox 3D printer (http://www.bq.com/gb/witbox) will be available. The printer file can be generated with the Open Source software Cura (https://ultimaker.com/en/products/cura-software).

2.2 Class Specifications

The vehicle can be autonomous or it can be manually controlled by the student. Any control mechanisms can be employed.

Computational power can be either on board or on an external computer, which will communicate wirelessly with the robot. Additional navigational aids can also be used; these can include a dashed-line on the floor, active or passive navigational aids inside the race area, or additional guides.

Active navigational aids (e.g. infrared beacons) must run on battery; there will be no power outlets available.

Setup of navigational aids must take place within the established preparation time. Navigational aids shall be removed residue-free within two minutes after the race time.

2.3 Security and Safety

Failure to comply with the security and safety rules will lead to disqualification of the team.

Equipment and operations must comply with Spanish law.

Only electric propulsion vehicles are allowed to participate in the competition. The vehicle must always be clearly identified with the starting number obtained during its registration.

Vehicles may not have sharp or potentially dangerous parts. A human safety pilot must be able to take over control of the vehicle at any time in case of an emergency.

Entrance to the race area is only permitted for one team member of the scheduled team after clearance by the judge.

Teams must always follow the instructions of the judge. The judge can abort the race at any time should it be necessary.

2.4 Certification

In order to compete, all vehicles must first be certified by the judges. This check will be performed before the first race and covers all points listed below.

1. The robot must show its ability to adapt to the race track.

2. The ability to safely control the vehicle has to be shown by the team member who will operate the robot (robot operator) during the competition.

3. The vehicle must comply with all security and safety requirements.

3. Game

3.1 Aim of the Game

The vehicle has to complete both tracks within a specified time frame of 10 minutes.

3.2 Start of the Game

Each team is allocated a preparation time slot of up to 5 minutes. During the preparation time, one team member (robot operator) is allowed to enter the race area in order to prepare for the start of the game. When preparation is complete or the preparation time is over, the judge will signal the start of the 10-minute race time and the robot operator can start the robot.

The start has to be performed at the starting line, which will be indicated by the judges.

During the race the robot operator must leave the race area for safety reasons.

3.3 Restart

A race ends when the robot touches the external perimeter or the robot operator decides to abort the race.

Multiple starts are allowed during the moving time.

The robot operator may reenter the race area after the judge clearance and restart the robot.

During the race the robot operator must leave the race area for safety reasons.

3.4 End of the Game

The race finishes when the 10-minute mark is reached or when the judge aborts the race.

3.5 Scoring System

1. The vehicle has to move from point A to point B according to figure 1. Completing this for the first time will be awarded with 10 points.

2. The robot has to move around the two poles (C and D) in the way shown in figure 1. Completing this for the first time will be awarded with 20 points.

3. Each additional lap to each trajectory (A to B or C and D) will be awarded with one point.

4. The lightest robot will be awarded with 5 points.

3.6 Declaring Objections

No objections shall be made against the decisions of the judges after the end of the competition.

All teams must choose a spokesperson who will present objections to the judge, always before the competition is over, if there are any doubts regarding the implementation of these rules.

3.7 Flexibility of Rules

As long as the concept and fundamentals of the rules are observed, these rules shall be flexible enough to encompass the changes in the number of players and of the contents of the matches.

Modifications or abolition of the rules may be made by the local event organisers as long as they are published prior to the event, and are consistently maintained throughout the event.

3.8 Liability

Participating teams are always responsible for the safety of their robots and are liable for any accidents caused by their team members or their robots.

The SEVC organisation and the organising team members will never be held responsible nor liable for any incidents or accidents caused by participating teams or their equipment.

INVENTORY

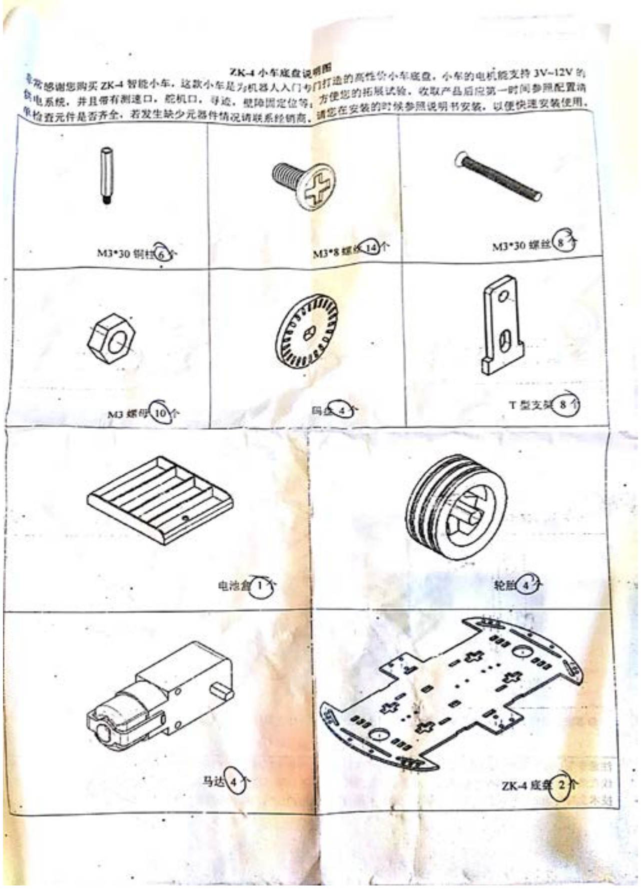
Contents

1. Assembling the vehicle

1.1 Inventory

In order to assemble our vehicle, a number of parts will be given to the student.

This is the assembly guide that will be presented to the student.



ZK-4 小车底盘说明图

非常感谢您购买 ZK-4 智能小车，这款小车是为机器人入门专门打造的高性价小车底盘，小车的电机能支持 3V~12V 的供电系统，并且带有测速口，舵机口，寻迹，壁障固定位等，方便您的拓展试验，收取产品后应第一时间参照配置清单检查元件是否齐全，若发生缺少元器件情况请联系经销商，请您在安装的时候参照说明书安装，以便快速安装使用。

M3*30 铜柱 6 个
M3*8 螺丝 14 个
M3*30 螺丝 8 个
M3 螺母 10 个
码盘 4 个
T 型支架 8 个
电池盒 1 个
轮胎 4 个
马达 4 个
ZK-4 底盘 2 个

Figure 1: Components of the chassis

As can be seen, the instructions are in Mandarin; so this will be a tutorial on how to put the vehicle together.

1.2 The pieces

The following pieces will be needed to assemble the car.

First, the smaller parts:

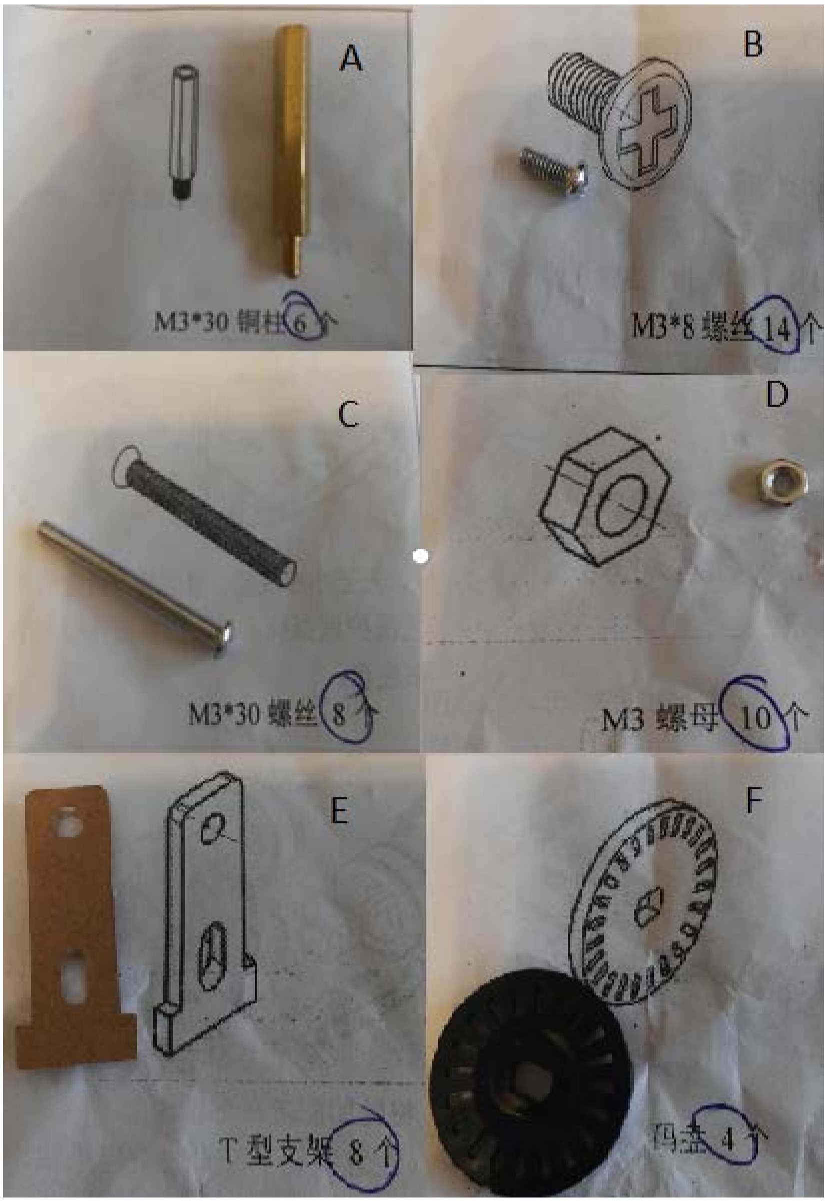


Figure 2: Detailed parts

In order to make the explanation easier, each part has been given a letter.

The number of parts needed is specified in the image above, they are:

- 6x Part A
- 14x Part B
- 8x Part C
- 10x Part D
- 8x Part E
- 4x Part F

Besides these smaller parts, we will also need the following:

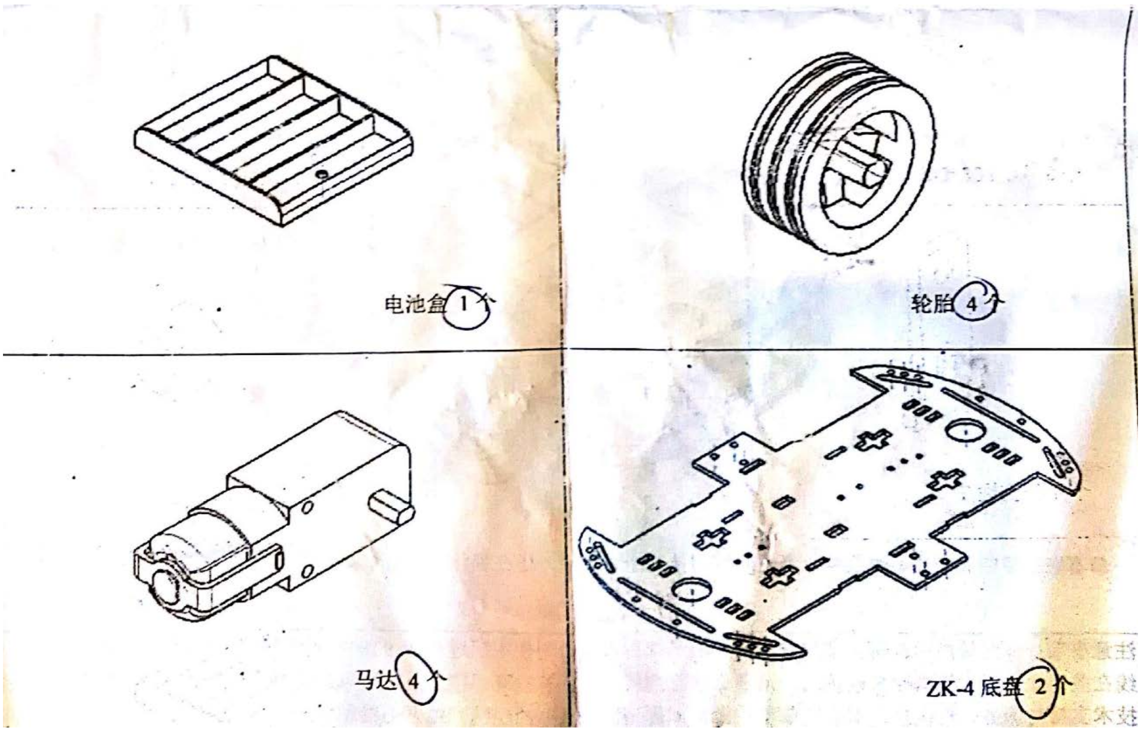


Figure 3: Wheels, motors and covers

- A case for our power source.
- Four wheels
- Four motors
- Inferior chassis
- Superior chassis

With all of these items listed and ready, the set-up is quite easy.

1.3 How to do it

First off, we place the E parts on the chassis, as seen in the image below:

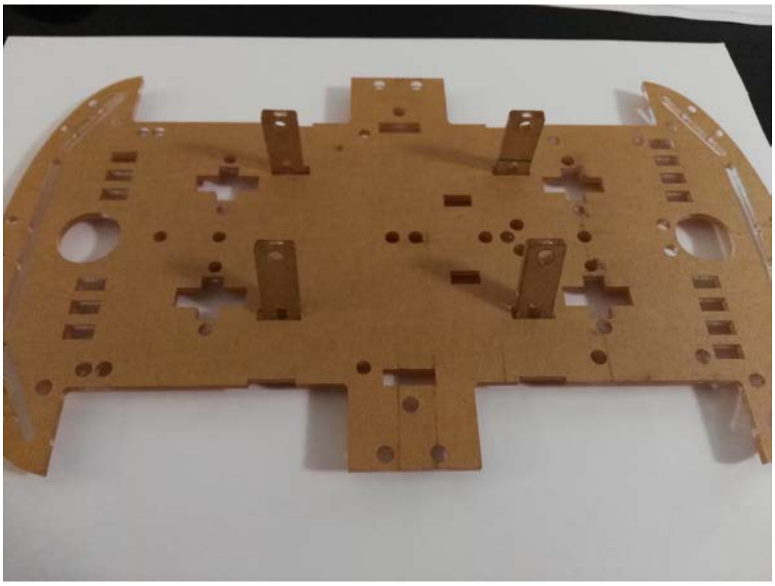


Figure 4: Step 1

Once that is done, we will proceed to place the motors.

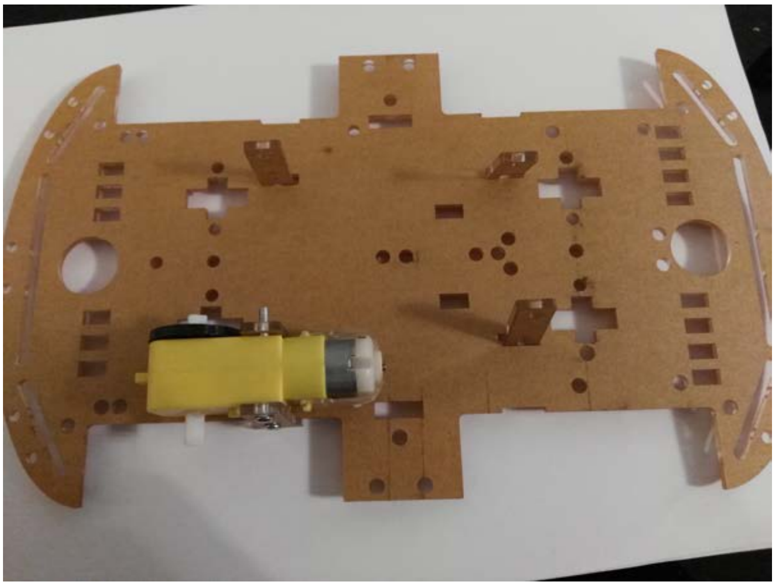


Figure 5: Step 2

Two screws (B part) will be needed, they will be secured with their respective cog (D part).

Then, place the wheel as below:

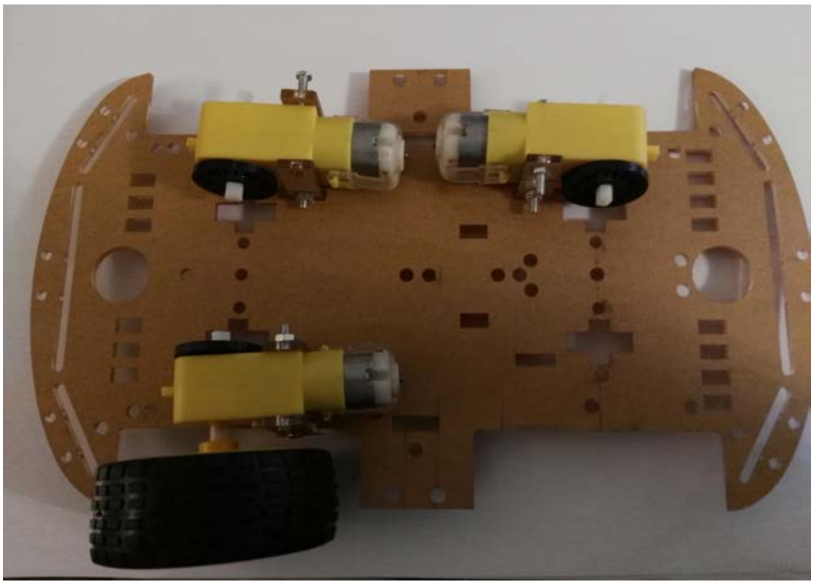


Figure 6: Step 3

Then, the process has to be repeated for the other three wheels, which will end up like the below picture:

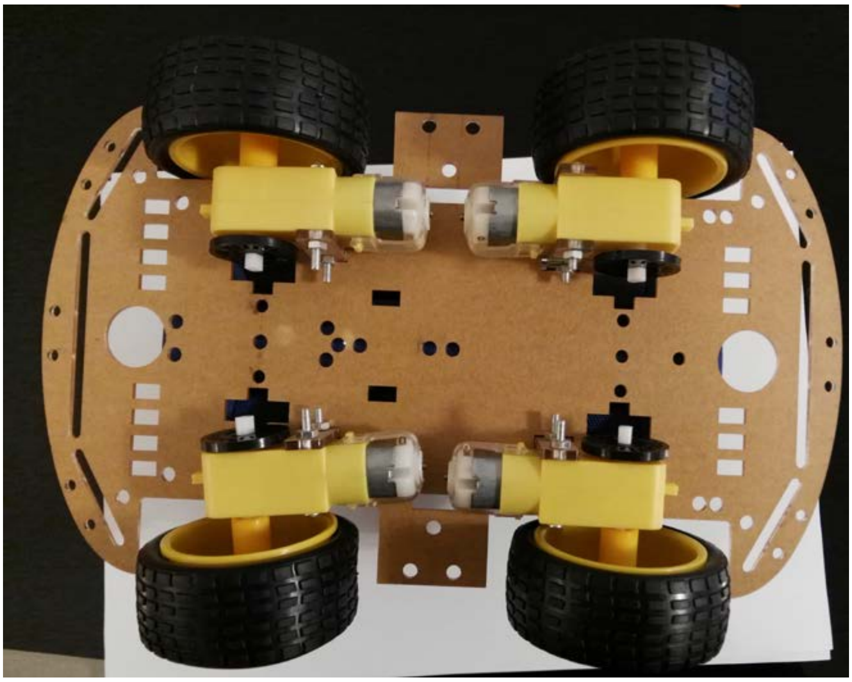


Figure 7: Step 4

To attach the upper chassis, screw pieces A and B together through the holes as shown in the below image:

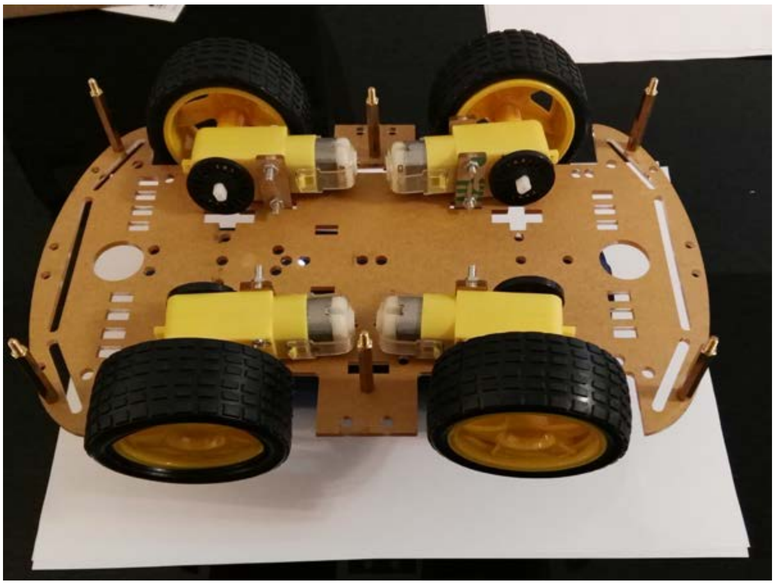


Figure 8: Step 5

Then place the upper chassis and secure with some cogs.

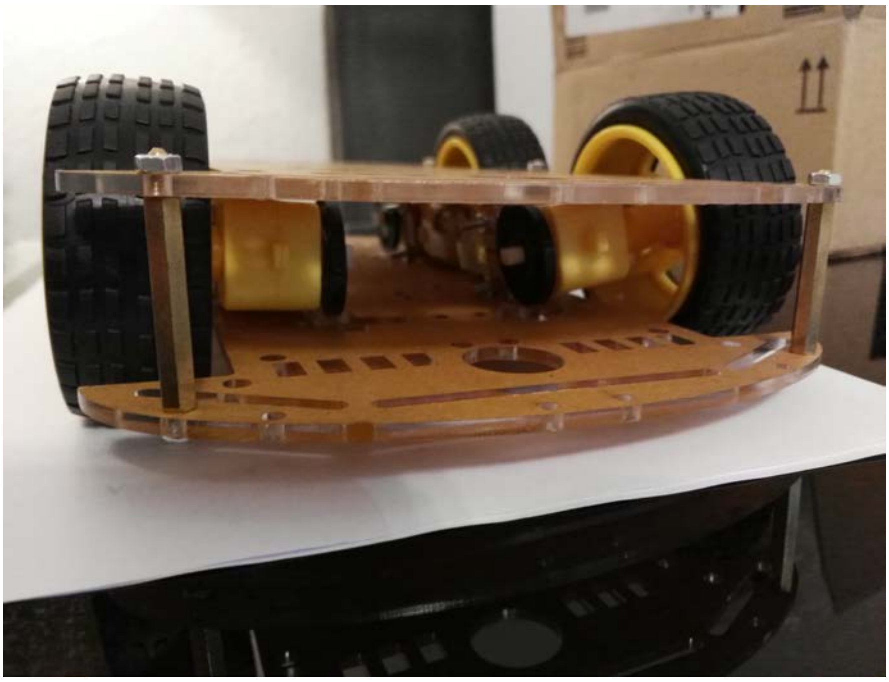


Figure 9: Step 6

Once this has been done, we will then connect the four motors to the Gertbot.

INTRODUCTION TO RASPBERRY PI

Contents

1. What is the Raspberry Pi?

Raspberry Pi is a low-cost, basic computer that was originally intended to help spur interest in computing among school-aged children. The Raspberry Pi is contained on a single circuit board and features ports for:

- HDMI
- USB 2.0
- Composite video
- Analog audio
- Power
- Internet
- SD Card

The computer runs entirely on open-source software and gives students the ability to mix and match software according to the work they wish to do.

The Raspberry Pi debuted in February 2012. The group behind the computer's development - the Raspberry Pi Foundation - started the project to make computing fun for students, while also creating interest in how computers work at a basic level.

Unlike using an encased computer from a manufacturer, the Raspberry Pi shows the essential guts behind the plastic. Even the software, by virtue of being open-source, offers an opportunity for students to explore the underlying code - if they wish.

The Raspberry Pi is believed to be an ideal learning tool, in that it is cheap to make, easy to replace and needs only a keyboard and a TV to run. These same strengths also make it an ideal product to jumpstart computing in the developing world.

2. Setting up the Raspberry PI

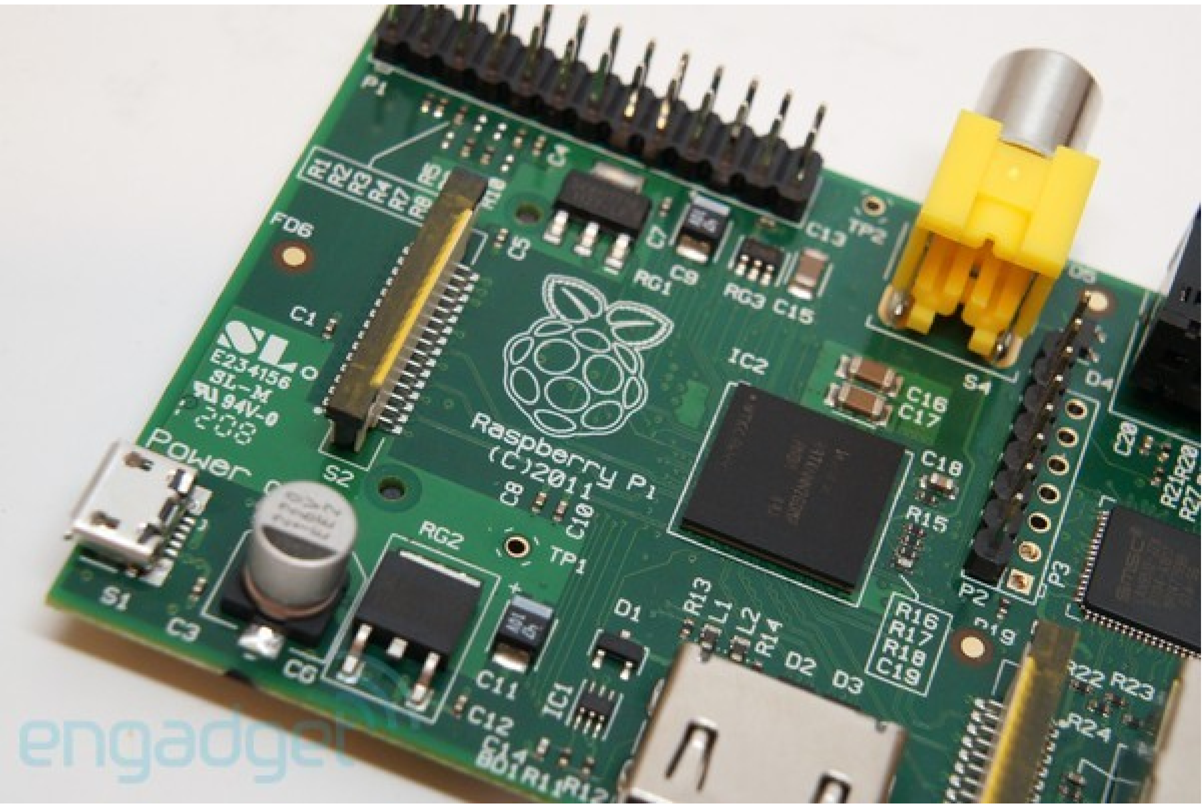


Figure 1: Raspberry PI

The following will also be needed:

- One SD card
- An SD card reader so the OS image can be written onto the SD card
- A means of supplying power to the unit. At the very least, a 5v micro-USB adapter will be needed.
- An HDMI cable and HDMI-to-DVI converter if a monitor is being used instead of a high-definition television.
- A USB mouse and keyboard
- An Ethernet cable

2.1 Formatting the SD Card

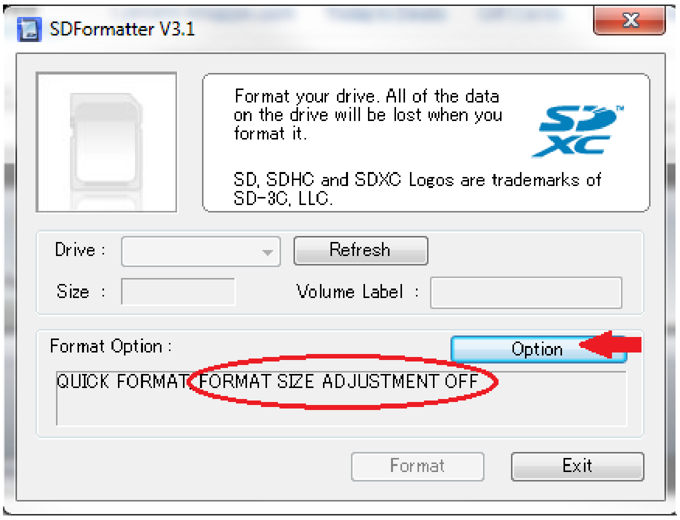
Before installing any operating system in the SD card, it is best to erase all that it might contain as this will mean a smooth installation of the new operating system.

For this purpose, we will use SDFormatter to restore full capacity to the SD card.

The software is available for free on the SD Association website. Once this is downloaded the process is very simple:

1. Run the SD Formatter Application.

2. By default the Format Size Adjustment option is off.



SDFormatter V3.1

Format your drive. All of the data on the drive will be lost when you format it.

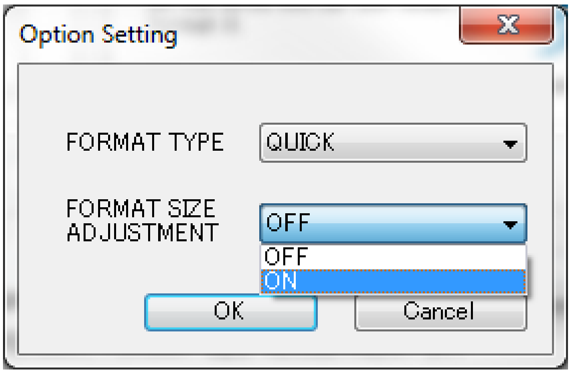
SD, SDHC and SDXC Logos are trademarks of SD-3C, LLC.

Format Option :

QUICK FORMAT, FORMAT SIZE ADJUSTMENT OFF

Figure 2: Format Options

3. Click Options and turn the Format Size Adjustment on.



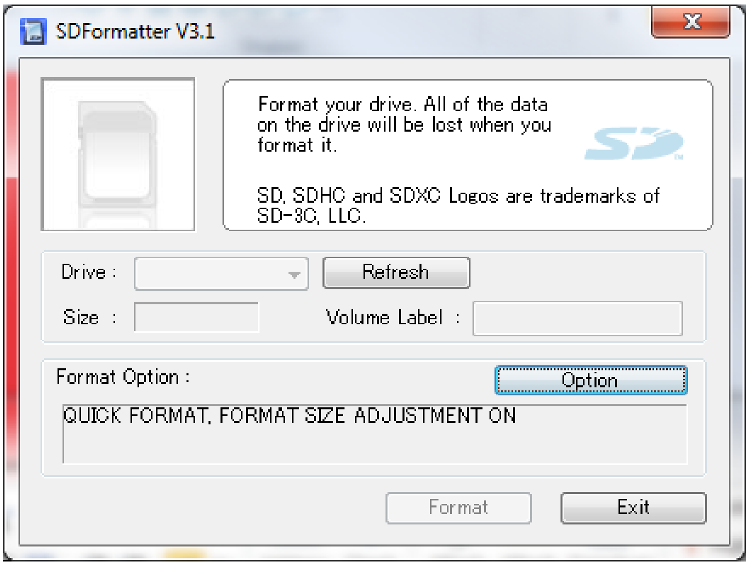
Option Setting

FORMAT TYPE QUICK

FORMAT SIZE ADJUSTMENT OFF

Figure 3: Format Size

4. Select the drive letter for the SD card and then select format.



SDFormatter V3.1

Format your drive. All of the data on the drive will be lost when you format it.

SD, SDHC and SDXC Logos are trademarks of SD-3C, LLC.

Format Option : QUICK FORMAT, FORMAT SIZE ADJUSTMENT ON

Figure 4: Quick Format

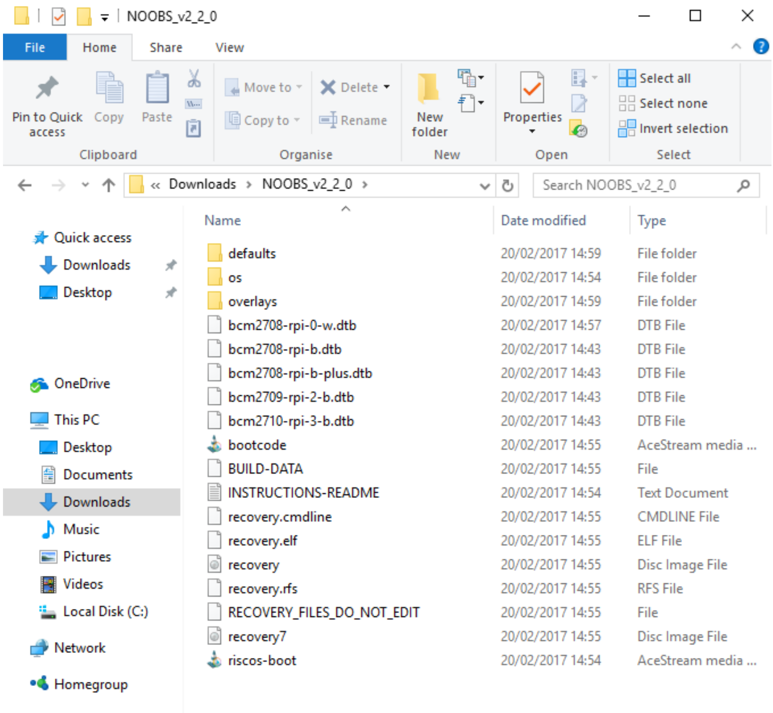
Now the SD card is ready for installation.

2.2 Installing an Operating System in the Raspberry PI

For this tutorial, we have opted for NOOBS (New Out Of Box Software) as the operating system install manager that will install Raspbian in our Raspberry PI. NOOBS also provides a selection of alternative operating systems which are then downloaded from the internet and installed.

NOOBS is very easy to obtain, it is available for download on the Raspberry PI official website, and is not very large in size (around 4GB, although a SD card with a minimum capacity of 8 GB is recommended) which will make most SD cards valid for this installation process.

Once the SD card has been formatted and all NOOBS files have been downloaded, drag all the files in the extracted folder and drop them onto the SD card drive.

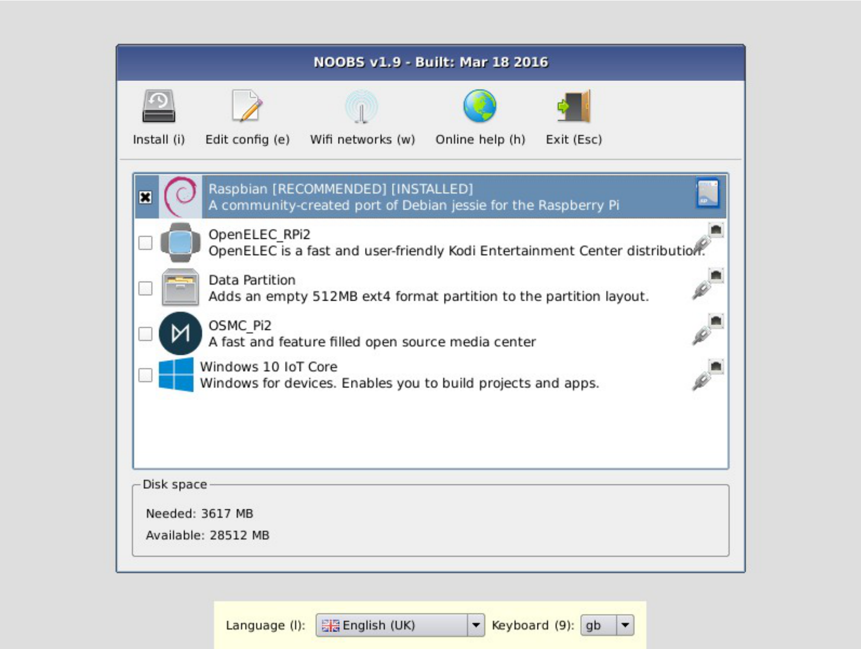


Name	Date modified	Type
defaults	20/02/2017 14:59	File folder
os	20/02/2017 14:54	File folder
overlays	20/02/2017 14:59	File folder
bcm2708-rpi-0-w.dtb	20/02/2017 14:57	DTB File
bcm2708-rpi-b.dtb	20/02/2017 14:43	DTB File
bcm2708-rpi-b-plus.dtb	20/02/2017 14:43	DTB File
bcm2709-rpi-2-b.dtb	20/02/2017 14:43	DTB File
bcm2710-rpi-3-b.dtb	20/02/2017 14:43	DTB File
bootcode	20/02/2017 14:55	AceStream media ...
BUILD-DATA	20/02/2017 14:55	File
INSTRUCTIONS-README	20/02/2017 14:54	Text Document
recovery.cmdline	20/02/2017 14:55	CMDLINE File
recovery.elf	20/02/2017 14:55	ELF File
recovery	20/02/2017 14:55	Disc Image File
recovery.rfs	20/02/2017 14:55	RFS File
RECOVERY_FILES_DO_NOT_EDIT	20/02/2017 14:55	File
recovery7	20/02/2017 14:55	Disc Image File
riscos-boot	20/02/2017 14:54	AceStream media ...

Figure 5: NOOBS Files

When this process has finished, safely remove the SD card and insert it into your Raspberry Pi. Connect your Raspberry PI to a monitor and then to a power cable.

The Raspberry PI will then boot and a window will appear with a list of different operating systems that you can install. Select Raspbian and click on Install.



☒ Raspbian [RECOMMENDED] [INSTALLED]
A community-created port of Debian jessie for the Raspberry Pi

☐ OpenELEC_RPi2
OpenELEC is a fast and user-friendly Kodi Entertainment Center distribution.

☐ Data Partition
Adds an empty 512MB ext4 format partition to the partition layout.

☐ OSMC_Pi2
A fast and feature filled open source media center

☐ Windows 10 IoT Core
Windows for devices. Enables you to build projects and apps.

Disk space
Needed: 3617 MB
Available: 28512 MB

Language (l): English (UK) Keyboard (9): gb

Figure 5: Selecting Raspbian

Raspbian will then run through its installation process. Note that this can take a while.

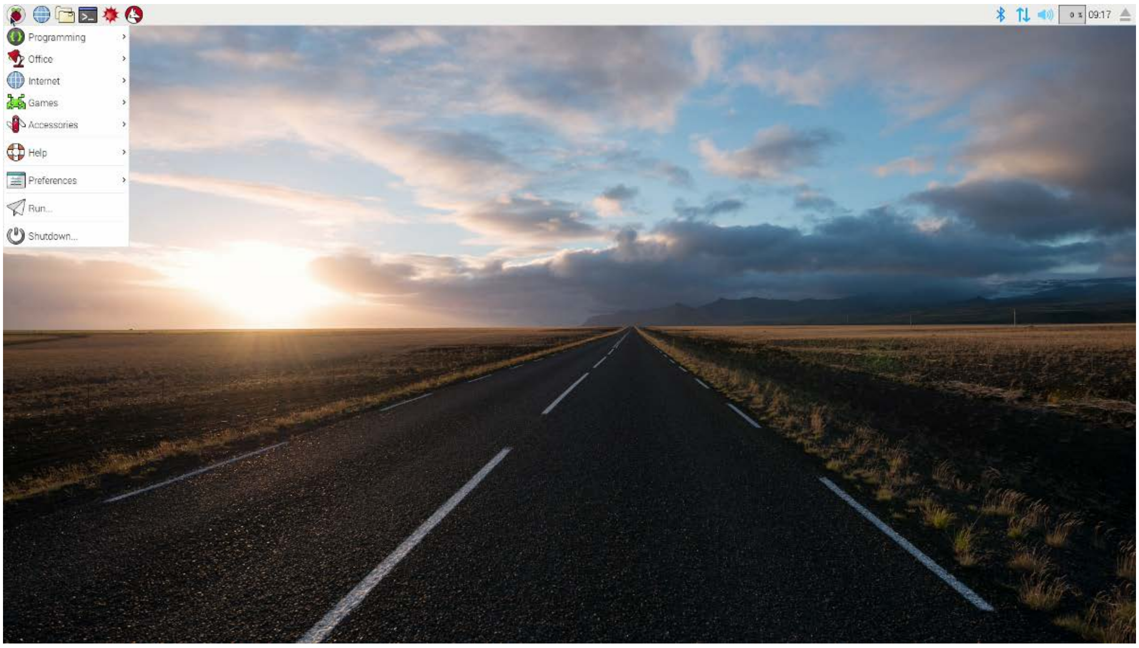


Figure 6: Raspberrry PI's Desktop

When the install process is complete, the Raspberry Pi configuration menu (raspi-config) will load. Here you are able to set the time and date for your region, enable a Raspberry Pi camera board, or even create users. You can exit this menu by using Tab on your keyboard to move to Finish.

The default login for Raspbian is username *pi* with the password being *raspberry*. This will be needed when you connect remotely to the Raspberry.

2.3 Updating and upgrading Raspbian

As we keep using the Raspberry PI, updates of the software will be released over time; and it will be in our best interest to upgrade our system with these updates.

To do this, start by updating your system's package list by entering the following command in LXTerminal or from the command line:

sudo apt-get update

After that, upgrade all your installed packages to their latest versions with the command:

sudo apt-get dist-upgrade

Doing this regularly will keep your installation up to date. However, there are occasional changes made in the Foundation's Raspbian image that require manual intervention, for example a newly introduced package. These are not installed with an upgrade, as this command only updates the packages you already have installed.

When running *sudo apt-get dist-upgrade*, it will show how much data will be downloaded and how much space it will take up on the SD card.

It's worth checking with the command *df -h* that you have enough disk space free, as unfortunately the command *apt* will not do this for you. Be aware that downloaded package files (.deb files) are kept in /var/cache/apt/archives. You can remove these in order to free up space with the command *sudo apt-get clean*.

2.4 Activating UART

In order to control our car, we will use the Raspberry PI and a motor/power controller board for the PI called Gertbot.

To use the Gertbot, we first have to activate the UART interface for the Raspberry PI; even though this step is supposedly not needed work with Raspberry PI 3, we had to activate it manually.

To do this, type the following commands in the command prompt:

```
sudo raspi-config
```

Then, disable the serial console. From the main menu, select option 7 (Serial), then select 'No' to disable shell and kernel messages via UART.

Now, enable UART. First, edit config.txt by typing the following command in the command prompt:

```
sudo nano /boot/config.txt
```

And remove the line: *enable_uart=0* if it exists. And add at the end of the file the following line:

```
enable_uart=1
```

Save the file and reboot the Raspberry PI, freeing UART in the process.

REMOTE CONNECTION TO RASPBERRY PI

Contents

1. Connecting remotely to the Raspberry PI

Setting up the Raspberry for remote access is something very helpful. There won't always be an extra screen and keyboard available nor even a local network to connect. There is also the chance that you may not even have physical access to it.

The following steps will provide with a solution to this by explaining how to set up a SSH connection and a remotely connect to the Raspberry without the need of screens or a keyboard or even a power supply.

First, access the network adapter configuration on your computer by right clicking on the connection icon in the system tray and selecting *Open Network and Sharing Centre*.

Follow *Figure 1* and *Figure 2* to reach it.

In case a power supply is not available; you can also power the Raspberry through a USB port from the computer. USB 3.0 is recommended as 2.0 may not be sufficient to power the Raspberry.

Connect the Raspberry to the Ethernet connector of your computer.

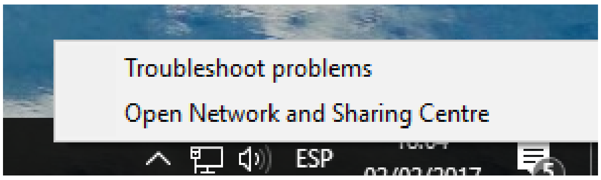
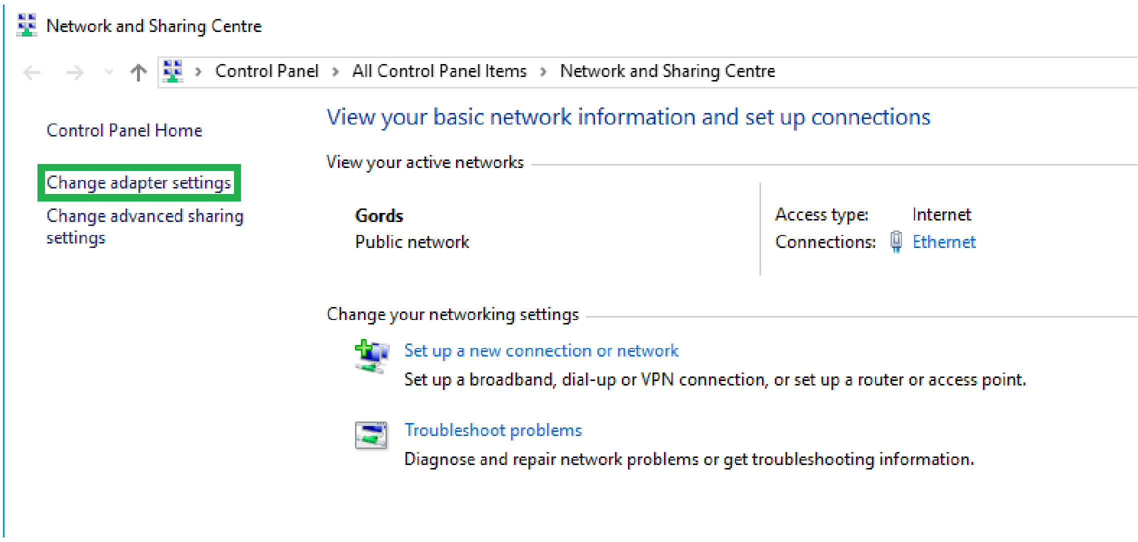


Figure 1: Open Network and Sharing Centre


Network and Sharing Centre
Control Panel › All Control Panel Items › Network and Sharing Centre
Control Panel Home
Change adapter settings
Change advanced sharing settings

View your basic network information and set up connections

View your active networks

Gords
Public network

Access type: Internet
Connections: Ethernet

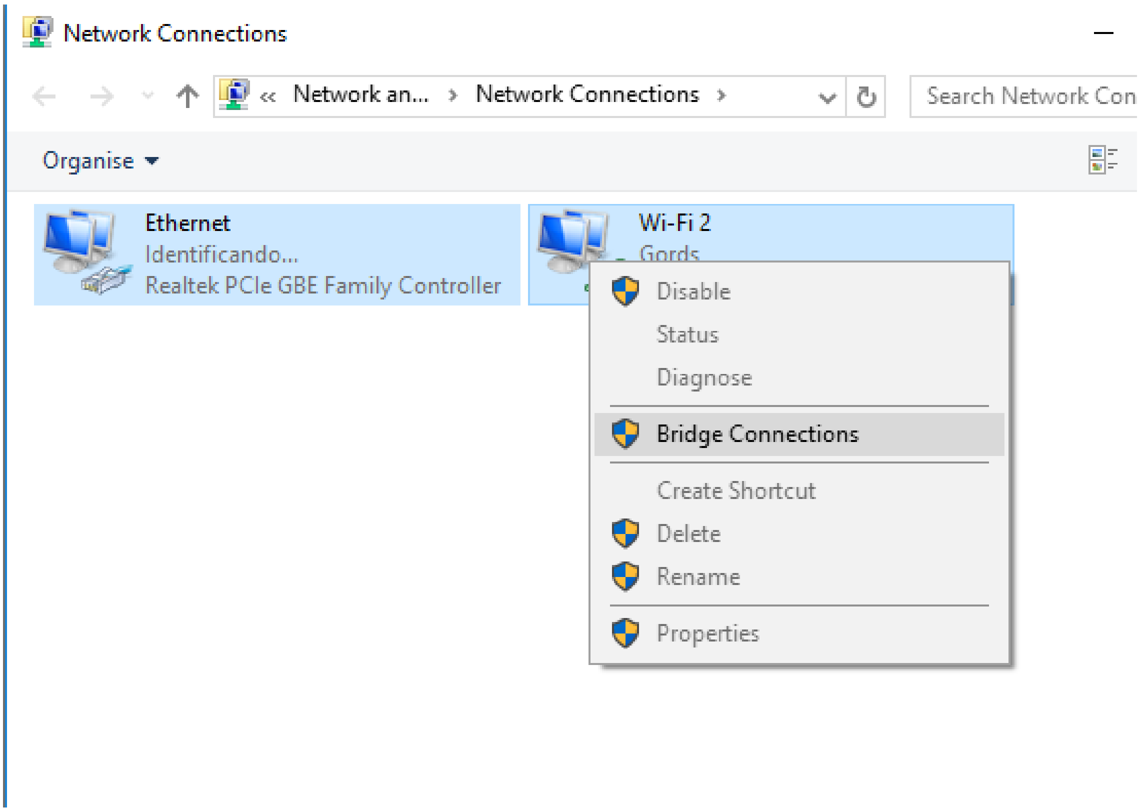
Change your networking settings

Set up a new connection or network
Set up a broadband, dial-up or VPN connection, or set up a router or access point.

Troubleshoot problems
Diagnose and repair network problems or get troubleshooting information.

Figure 2: Change adapter settings

Now, we need to create a bridge connection Next step is creating a bridge connection between the Wi-Fi connection and the Ethernet adapters as shown in *Figure 3*.



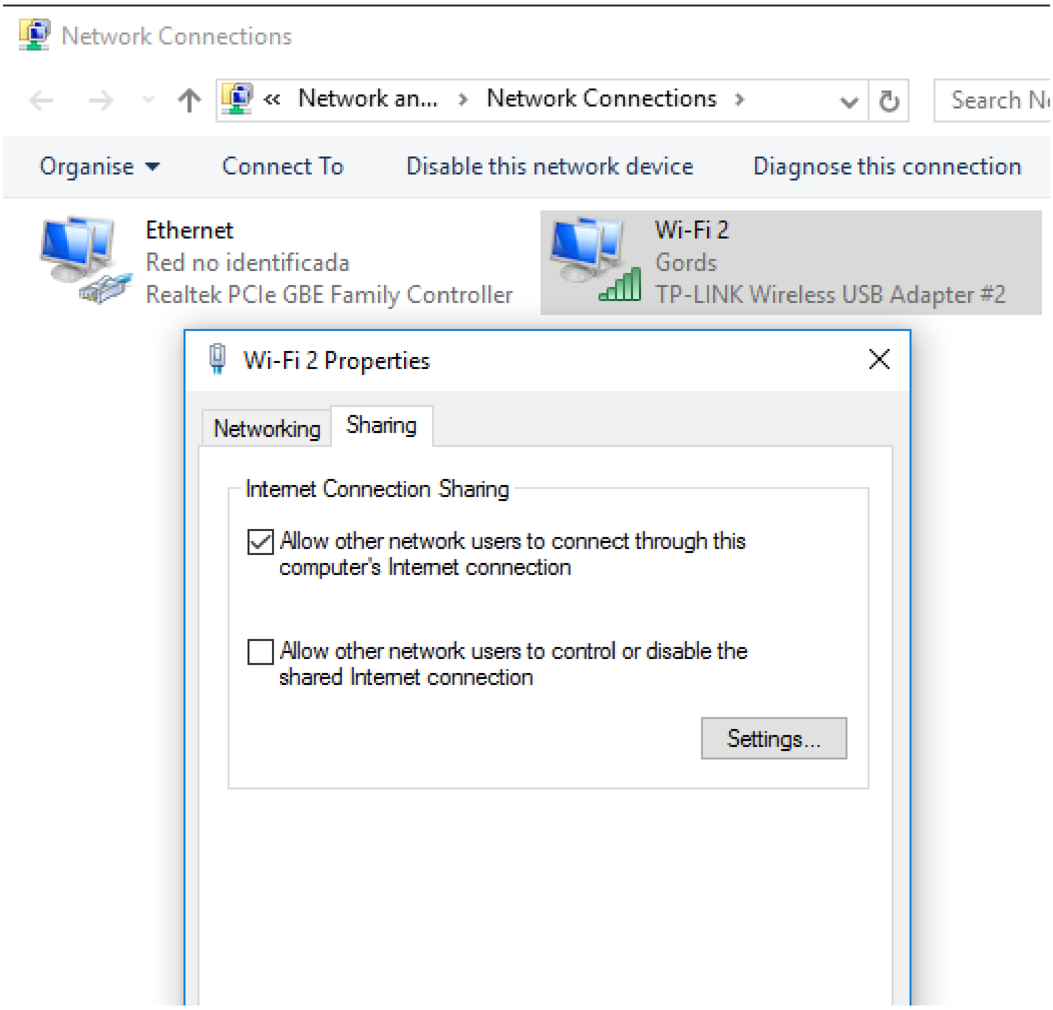
Ethernet
Identificando...
Realtek PCIe GBE Family Controller

Wi-Fi 2
Gords

Figure 3: Bridge Connections

Once the bridge is ready (it might take a couple of minutes) disconnect the Wi-Fi adapter from the bridge. To do this, right click on the Wi-Fi adapter and click on *Remove from bridge*.

Then, right click on the Wi-Fi adapter enable the shared Internet connection within the Properties menu.



Internet Connection Sharing

☑ Allow other network users to connect through this computer's Internet connection

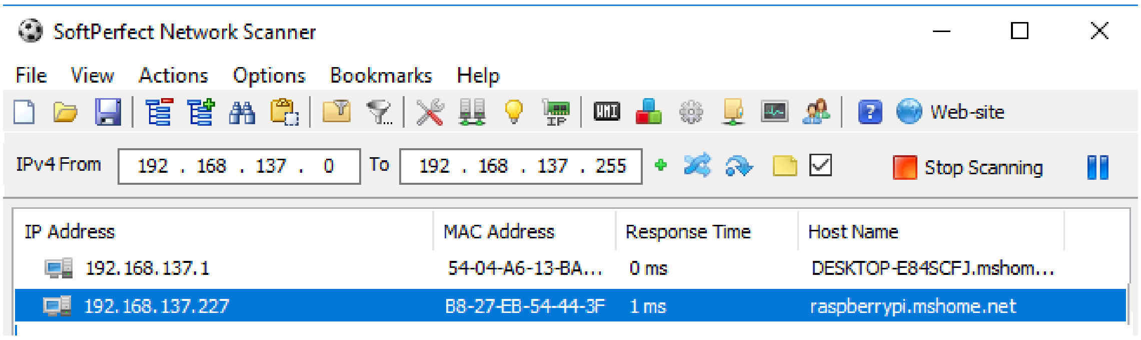
□ Allow other network users to control or disable the shared Internet connection

Figure 4: Internet Connection Sharing

Now that all this has been done, the Raspberry will have an IP address similar to the template 192.168.137.XXXX. We are missing the last part of that address, so we need to obtain it.

Download and install Network Scanner which is available at the SoftPerfect website.

After installation is complete enter the complete IP range for the search (the address we had can only go from 0 to 255) and click the Start Scanning icon.


SoftPerfect Network Scanner
File View Actions Options Bookmarks Help
Web-site
Stop Scanning

IPv4 From 192 . 168 . 137 . 0 To 192 . 168 . 137 . 255

IP Address	MAC Address	Response Time	Host Name
192.168.137.1	54-04-A6-13-BA...	0 ms	DESKTOP-E84SCFJ.mshom...
192.168.137.227	B8-27-EB-54-44-3F	1 ms	raspberrypi.mshome.net

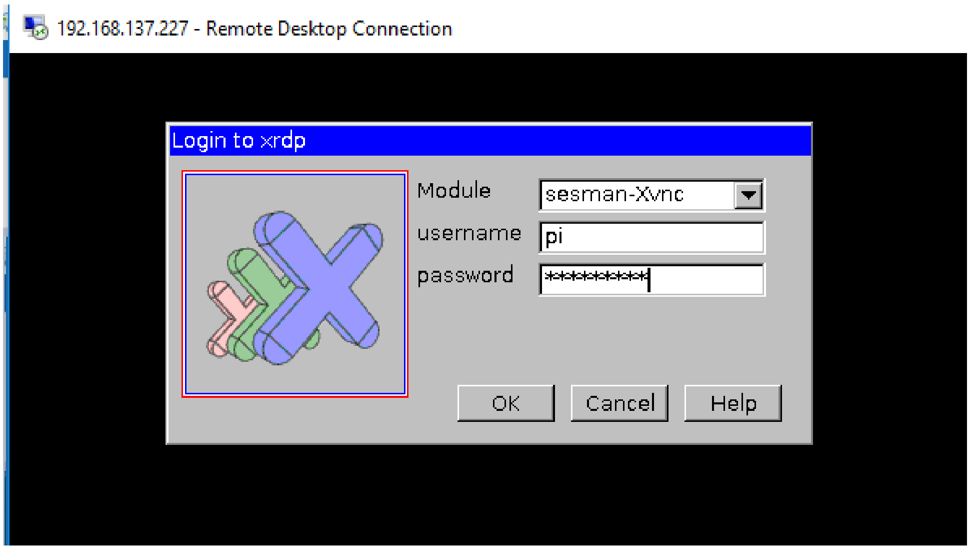
Figure 5: Searching for the IP

Now that we know the Raspberry's IP, SSH connection is possible. Every time the Raspberry is rebooted, this search will need to be repeated.

If working within a LAN, setting a fixed IP can be an option. Searching *ifconfig* can help with this matter.

The SSH connection is activated by default on Raspbian so everything is ready to execute *putty.exe*; available at the Putty website.

Set the right IP and click *open*. Disregard the security warning if it appears. Once the password is accepted, full access to the Raspberry will be granted although GUI interface is not available. Internet connection will be shared with the Raspberry.



Module: sesman-Xvnc
username: pi
password: **********

Figure 6: Accessing the Raspberry PI

If GUI interface is required, the following steep will need to be followed in the <u>exact same order.</u>

First thing to install is *tightvnc* server which requires an Internet connection:

sudo apt-get install tightvncserver

We will be connecting using Windows Terminal Server (also known as Remote Desktop) as it is available in all Windows OS.

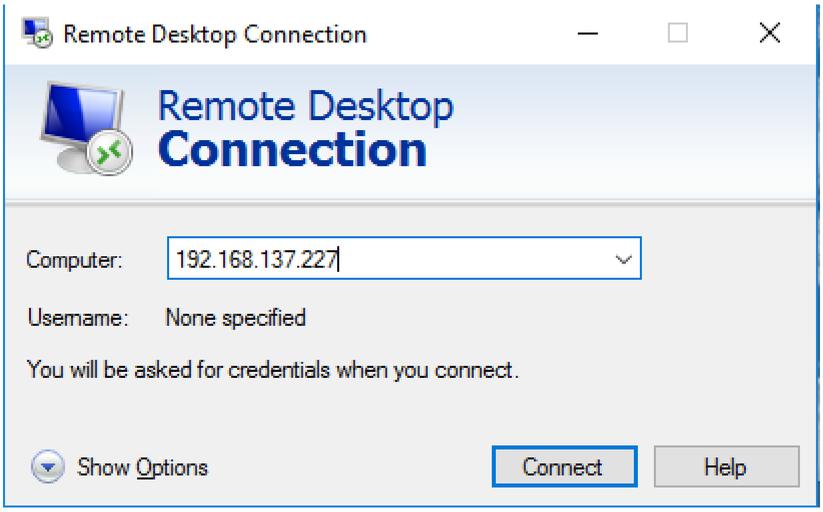
For this to work, xrdp software is required, which also requires an Internet connection:

```
sudo apt-get install xrdp
```

After the installation, start the service:

```
sudo /etc/init.d/xrdp restart
```

Remote connection with GUI will now be available. Note that this creates a new session on the Raspberry.



Remote Desktop Connection

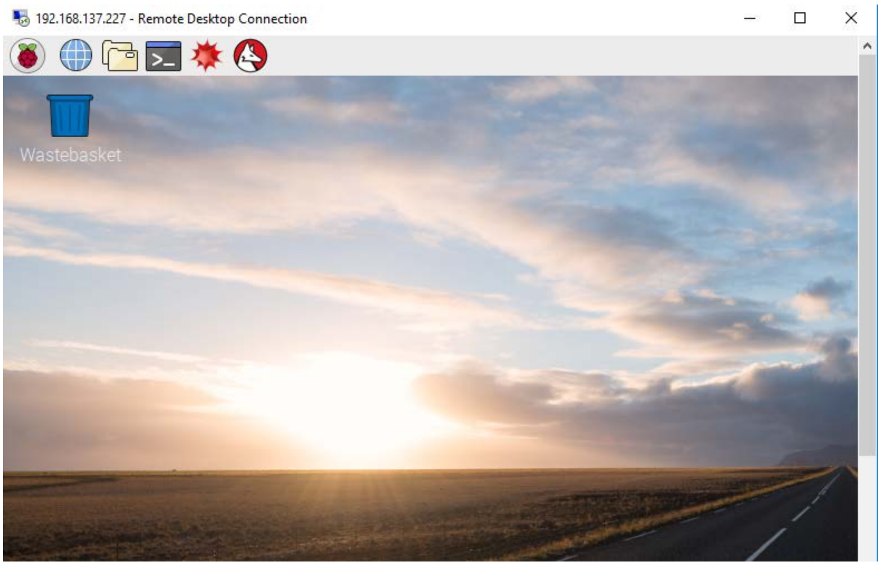
Remote Desktop Connection

Computer: 192.168.137.227

Username: None specified

You will be asked for credentials when you connect.

Figure 7: Remote Desktop Connection



192.168.137.227 - Remote Desktop Connection

Figure 8: Raspberry PI's Desktop

INTRODUCTION TO GERTBOT

Contents

1. The Gertbot

1.1 What is a Gertbot?

The Gertbot is a motor/power controller board for the Raspberry-Pi. The strength of the board is that it has its own CPU which frees up the Raspberry-Pi from a lot of intense computations and will take care of all the real-time requirements.

All the user will have to do is give it high level commands. For example: Board 2, Motor 1, take 2432 steps at 67 Hz. But even that is taken care of by using the Gertbot Debug GUI which is available on the Gertbot website.

1.2 Getting started with the Gertbot

In order to have our Gertbot up and running as quickly as possible, these steps are a good guide to follow:

1. Connect a DC-brushed motor or stepper motor to the Gertbot. In our case, one of the four motors of our car.

2. Those motors will need a power supply that must be connected to the Gertbot. The controller need a minimum of 8 volts in order to work, for safe operation do not connect more than 18 volts.

In order to connect motors and power supplies use the following diagram:

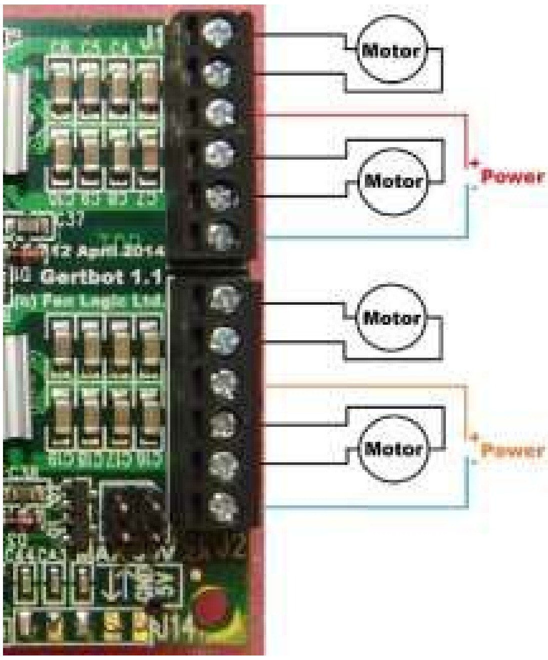


Figure 1: Gertbot connections

The Gertbot can manage up to four motors, and needs two power sources for this.

3. Plug the Gertbot board on top of a Raspberry-Pi board which must be powered down. Then boot the device.

4. As explained earlier, you can remotely connect to the Raspberry PI. This guide will continue explaining as if the student is using this method.

5. Login to the Gertbot website and download the Gertbot Debug GUI executable. (You might want to make a directory to put all the Gertbot data into). Extract the executable and run it.

6. Press the Connect button. A log window will pop-up and show the search for boards. Default from the factory the board has ID 3 so you should see this:

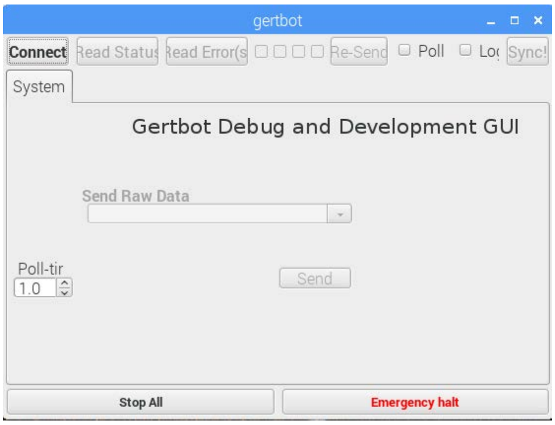
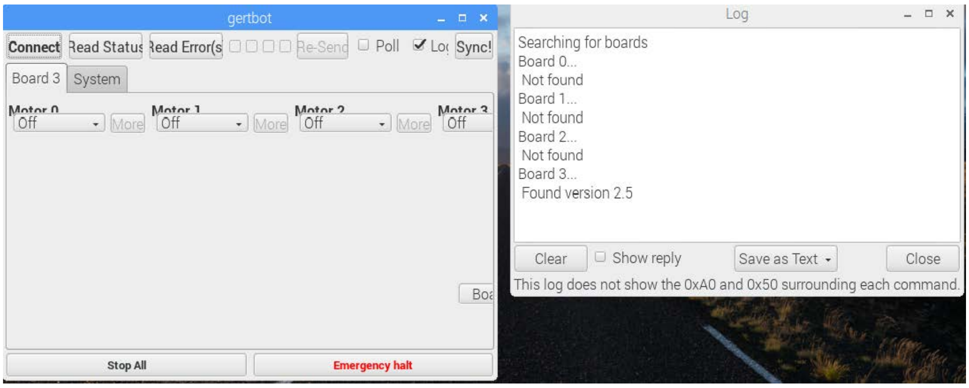


Figure 2: Gertbot GUI

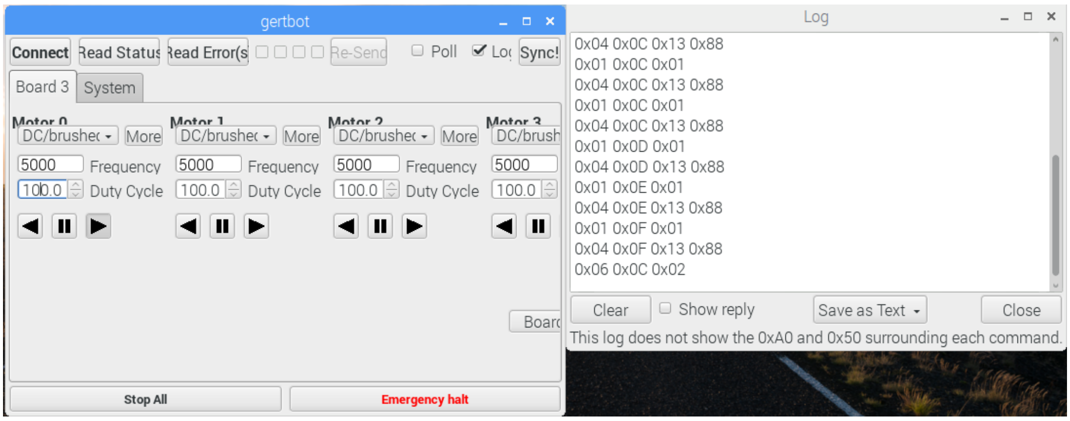


```
Searching for boards
Board 0...
 Not found
Board 1...
 Not found
Board 2...
 Not found
Board 3...
 Found version 2.5
```

This log does not show the 0xA0 and 0x50 surrounding each command.

Figure 3: Searching for boards

7. Use the control under "Motor 0" to select the operating mode. In this guide, we are using DC/brushed motors.



```
0x04 0x0C 0x13 0x88
0x01 0x0C 0x01
0x04 0x0C 0x13 0x88
0x01 0x0C 0x01
0x04 0x0C 0x13 0x88
0x01 0x0D 0x01
0x04 0x0D 0x13 0x88
0x01 0x0E 0x01
0x04 0x0E 0x13 0x88
0x01 0x0F 0x01
0x04 0x0F 0x13 0x88
0x06 0x0C 0x02
```

This log does not show the 0xA0 and 0x50 surrounding each command.

Figure 4: Testing the motors

As can be seen, we can alter the frequency and its duty cycle to adjust it to our needs.

You can now play with the buttons and your motor should run.

PROGRAMMING

Contents

1. Programming the car

1.1 Driving the car

Now that the Raspberry PI is connected and the car is ready to go, there is only one step missing: driving the car.

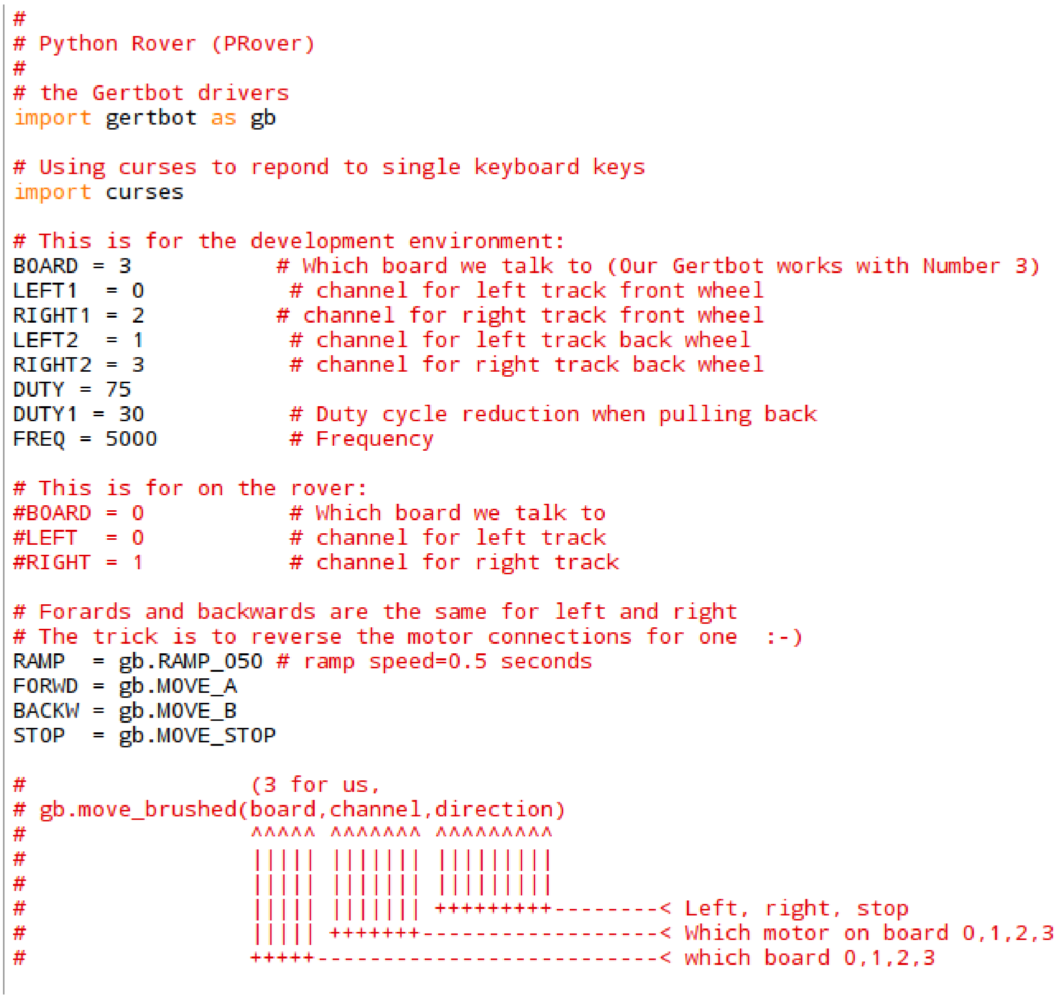
To do this we are going to use the Gertbot, which should be connected as explained before, to drive our motors as we command it to. In order to communicate with the Gertbot, we will use Python as our language.

The official Gertbot website has a Simple Rover example we can download, which is a Python source code for two brushed motor vehicle on/off control that can then be modified to meet our requirements.

1.2 Programming

Using the Simple Rover example as a template, it is quite easy to add the lines that we need to transform this example to a fully functioning 4 wheeled remote controlled car.

There are several ways to write a script that can achieve this. Attached is one of them:

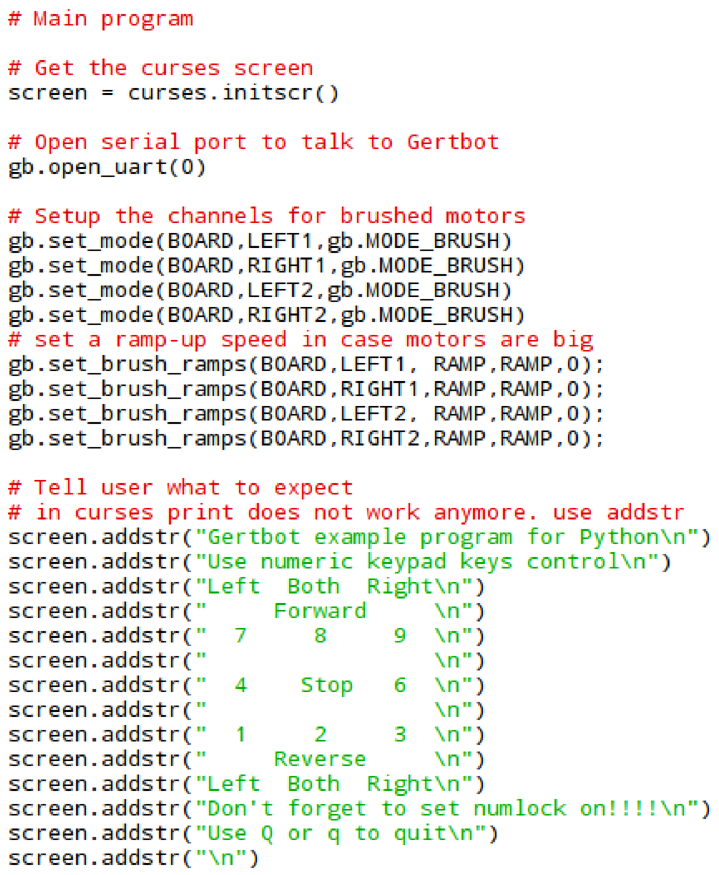


```
#
# Python Rover (PRover)
#
# the Gertbot drivers
import gertbot as gb

# Using curses to repond to single keyboard keys
import curses

# This is for the development environment:
BOARD = 3           # Which board we talk to (Our Gertbot works with Number 3)
LEFT1   = 0          # channel for left track front wheel
RIGHT1 = 2          # channel for right track front wheel
LEFT2   = 1          # channel for left track back wheel
RIGHT2 = 3           # channel for right track back wheel
DUTY  = 75
DUTY1  = 30          # Duty cycle reduction when pulling back
FREQ = 5000          # Frequency

# This is for on the rover:
#BOARD = 0           # Which board we talk to
#LEFT   = 0          # channel for left track
#RIGHT  = 1          # channel for right track

# Forards and backwards are the same for left and right
# The trick is to reverse the motor connections for one  :-)
RAMP   = gb.RAMP_050 # ramp speed=0.5 seconds
FORWD  = gb.MOVE_A
BACKW  = gb.MOVE_B
STOP   = gb.MOVE_STOP

#                 (3 for us,
# gb.move_brushed(board,channel,direction)
#                 ^^^^^ ^^^^^^^ ^^^^^^^^^
#                 ||||| ||||||| |||||||||
#                 ||||| ||||||| |||||||||
#                 ||||| ||||||| +++++++++--------< Left, right, stop
#                 ||||| +++++++------------------< Which motor on board 0,1,2,3
#                 +++++--------------------------< which board 0,1,2,3
```

Figure 1: Development Environment

The Board ID of the Gertbot is 3, so that is the first thing to change in our code. As we want to have four wheels, we will have to add two of them to our code (see above Right1, Right2, Left1 and Left2).

In the event that different speeds are required, different duty cycles will have to be declared (duty and duty1 in this example), as well as the frequency that will be used.



```
# Main program

# Get the curses screen
screen = curses.initscr()

# Open serial port to talk to Gertbot
gb.open_uart(0)

# Setup the channels for brushed motors
gb.set_mode(BOARD,LEFT1,gb.MODE_BRUSH)
gb.set_mode(BOARD,RIGHT1,gb.MODE_BRUSH)
gb.set_mode(BOARD,LEFT2,gb.MODE_BRUSH)
gb.set_mode(BOARD,RIGHT2,gb.MODE_BRUSH)
# set a ramp-up speed in case motors are big
gb.set_brush_ramps(BOARD,LEFT1, RAMP,RAMP,0);
gb.set_brush_ramps(BOARD,RIGHT1,RAMP,RAMP,0);
gb.set_brush_ramps(BOARD,LEFT2, RAMP,RAMP,0);
gb.set_brush_ramps(BOARD,RIGHT2,RAMP,RAMP,0);

# Tell user what to expect
# in curses print does not work anymore. use addstr
screen.addstr("Gertbot example program for Python\n")
screen.addstr("Use numeric keypad keys control\n")
screen.addstr("Left  Both  Right\n")
screen.addstr("     Forward     \n")
screen.addstr("  7     8     9  \n")
screen.addstr("                 \n")
screen.addstr("  4    Stop   6  \n")
screen.addstr("                 \n")
screen.addstr("  1     2     3  \n")
screen.addstr("     Reverse     \n")
screen.addstr("Left  Both  Right\n")
screen.addstr("Don't forget to set numlock on!!!!\n")
screen.addstr("Use Q or q to quit\n")
screen.addstr("\n")
```

Figure 2: Setting channels

This is the main program setup for our two new wheels will have to be added (as seen above).

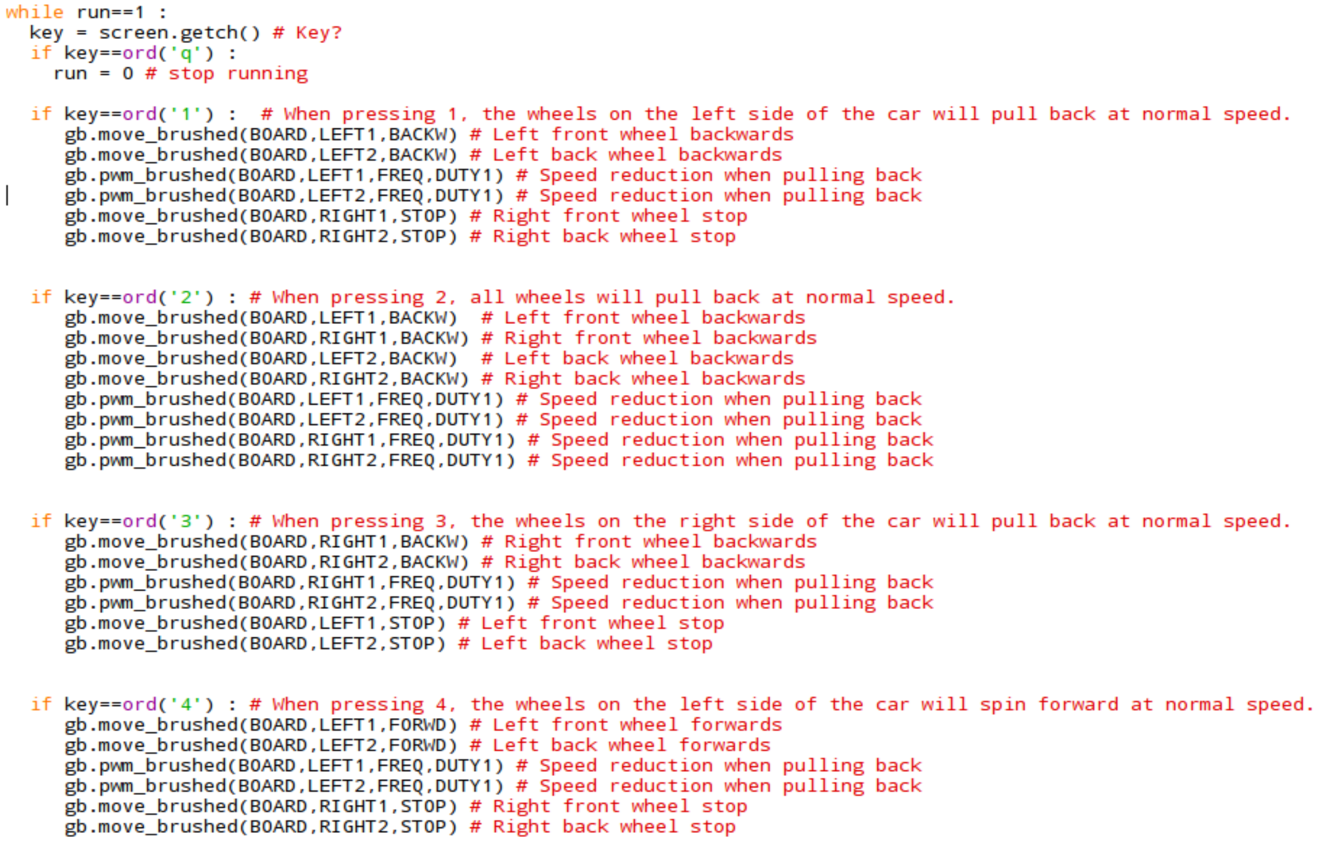
The following attached figures will set up how the car can be driven and the speed that it will have depending on the action being performed.

As there are nine keys in the numeric keypad, there are nine actions that our car will perform; which in this example are:

- By pressing number 1: Both left side wheels will rotate backwards at normal speed.
- By pressing number 2: All wheels will rotate backwards at normal speed.
- By pressing number 3: Both right side wheels will rotate backwards at normal speed.
- By pressing number 4: Both left side wheels will rotate forwards at normal speed.
- By pressing number 5: All wheels moving will stop.
- By pressing number 6: Both right side wheels will rotate forwards at normal speed.

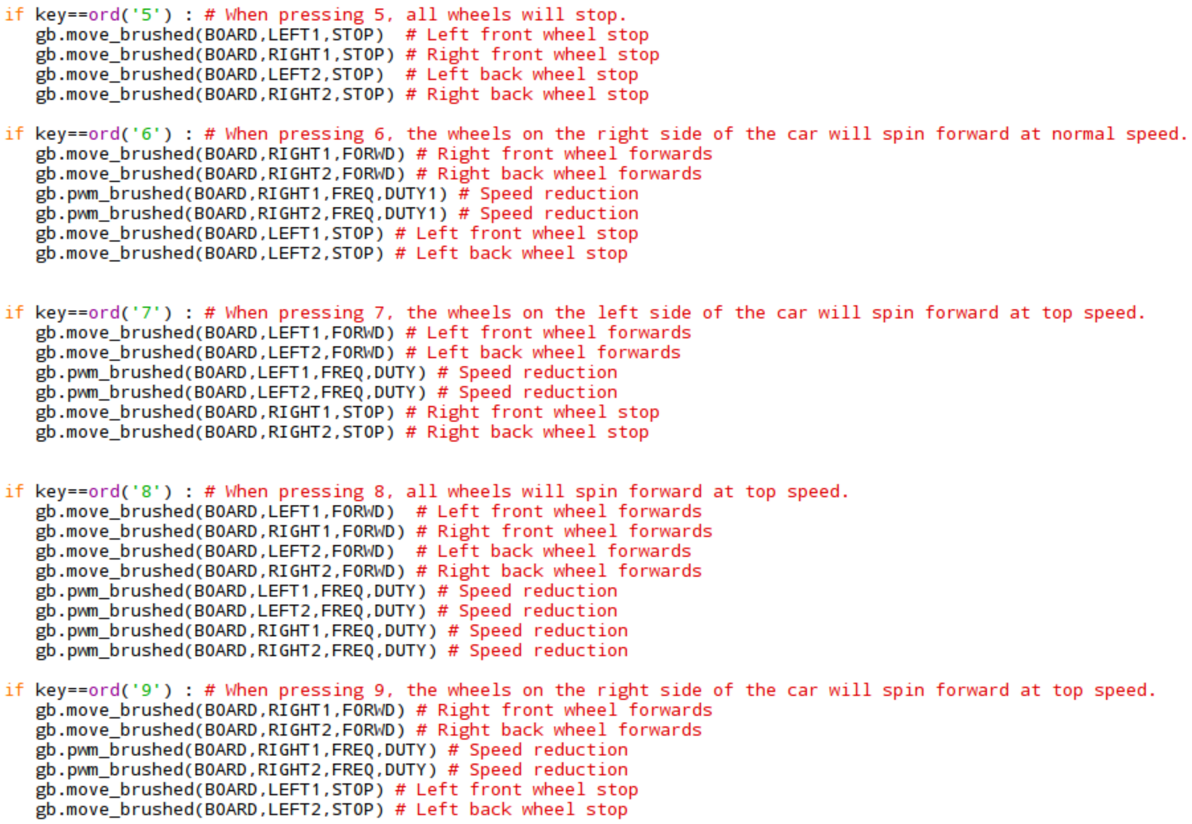
- By pressing number 7: Both left side wheels will rotate forwards at top speed.
- By pressing number 8: All wheels will rotate forwards at top speed.
- By pressing number 9: Both left side wheels will rotate forwards at top speed.

Below is the script that allows this:



```
while run==1 :
  key = screen.getch() # Key?
  if key==ord('q') :
    run = 0 # stop running

  if key==ord('1') :  # When pressing 1, the wheels on the left side of the car will pull back at normal speed.
     gb.move_brushed(BOARD,LEFT1,BACKW) # Left front wheel backwards
     gb.move_brushed(BOARD,LEFT2,BACKW) # Left back wheel backwards
     gb.pwm_brushed(BOARD,LEFT1,FREQ,DUTY1) # Speed reduction when pulling back
     gb.pwm_brushed(BOARD,LEFT2,FREQ,DUTY1) # Speed reduction when pulling back
     gb.move_brushed(BOARD,RIGHT1,STOP) # Right front wheel stop
     gb.move_brushed(BOARD,RIGHT2,STOP) # Right back wheel stop


  if key==ord('2') : # When pressing 2, all wheels will pull back at normal speed.
     gb.move_brushed(BOARD,LEFT1,BACKW)  # Left front wheel backwards
     gb.move_brushed(BOARD,RIGHT1,BACKW) # Right front wheel backwards
     gb.move_brushed(BOARD,LEFT2,BACKW)  # Left back wheel backwards
     gb.move_brushed(BOARD,RIGHT2,BACKW) # Right back wheel backwards
     gb.pwm_brushed(BOARD,LEFT1,FREQ,DUTY1) # Speed reduction when pulling back
     gb.pwm_brushed(BOARD,LEFT2,FREQ,DUTY1) # Speed reduction when pulling back
     gb.pwm_brushed(BOARD,RIGHT1,FREQ,DUTY1) # Speed reduction when pulling back
     gb.pwm_brushed(BOARD,RIGHT2,FREQ,DUTY1) # Speed reduction when pulling back


  if key==ord('3') : # When pressing 3, the wheels on the right side of the car will pull back at normal speed.
     gb.move_brushed(BOARD,RIGHT1,BACKW) # Right front wheel backwards
     gb.move_brushed(BOARD,RIGHT2,BACKW) # Right back wheel backwards
     gb.pwm_brushed(BOARD,RIGHT1,FREQ,DUTY1) # Speed reduction when pulling back
     gb.pwm_brushed(BOARD,RIGHT2,FREQ,DUTY1) # Speed reduction when pulling back
     gb.move_brushed(BOARD,LEFT1,STOP) # Left front wheel stop
     gb.move_brushed(BOARD,LEFT2,STOP) # Left back wheel stop


  if key==ord('4') : # When pressing 4, the wheels on the left side of the car will spin forward at normal speed.
     gb.move_brushed(BOARD,LEFT1,FORWD) # Left front wheel forwards
     gb.move_brushed(BOARD,LEFT2,FORWD) # Left back wheel forwards
     gb.pwm_brushed(BOARD,LEFT1,FREQ,DUTY1) # Speed reduction when pulling back
     gb.pwm_brushed(BOARD,LEFT2,FREQ,DUTY1) # Speed reduction when pulling back
     gb.move_brushed(BOARD,RIGHT1,STOP) # Right front wheel stop
     gb.move_brushed(BOARD,RIGHT2,STOP) # Right back wheel stop
```

Figure 3: Driving the car



```
if key==ord('5') : # When pressing 5, all wheels will stop.
   gb.move_brushed(BOARD,LEFT1,STOP)  # Left front wheel stop
   gb.move_brushed(BOARD,RIGHT1,STOP) # Right front wheel stop
   gb.move_brushed(BOARD,LEFT2,STOP)  # Left back wheel stop
   gb.move_brushed(BOARD,RIGHT2,STOP) # Right back wheel stop

if key==ord('6') : # When pressing 6, the wheels on the right side of the car will spin forward at normal speed.
   gb.move_brushed(BOARD,RIGHT1,FORWD) # Right front wheel forwards
   gb.move_brushed(BOARD,RIGHT2,FORWD) # Right back wheel forwards
   gb.pwm_brushed(BOARD,RIGHT1,FREQ,DUTY1) # Speed reduction
   gb.pwm_brushed(BOARD,RIGHT2,FREQ,DUTY1) # Speed reduction
   gb.move_brushed(BOARD,LEFT1,STOP) # Left front wheel stop
   gb.move_brushed(BOARD,LEFT2,STOP) # Left back wheel stop


if key==ord('7') : # When pressing 7, the wheels on the left side of the car will spin forward at top speed.
   gb.move_brushed(BOARD,LEFT1,FORWD) # Left front wheel forwards
   gb.move_brushed(BOARD,LEFT2,FORWD) # Left back wheel forwards
   gb.pwm_brushed(BOARD,LEFT1,FREQ,DUTY) # Speed reduction
   gb.pwm_brushed(BOARD,LEFT2,FREQ,DUTY) # Speed reduction
   gb.move_brushed(BOARD,RIGHT1,STOP) # Right front wheel stop
   gb.move_brushed(BOARD,RIGHT2,STOP) # Right back wheel stop


if key==ord('8') : # When pressing 8, all wheels will spin forward at top speed.
   gb.move_brushed(BOARD,LEFT1,FORWD)  # Left front wheel forwards
   gb.move_brushed(BOARD,RIGHT1,FORWD) # Right front wheel forwards
   gb.move_brushed(BOARD,LEFT2,FORWD)  # Left back wheel forwards
   gb.move_brushed(BOARD,RIGHT2,FORWD) # Right back wheel forwards
   gb.pwm_brushed(BOARD,LEFT1,FREQ,DUTY) # Speed reduction
   gb.pwm_brushed(BOARD,LEFT2,FREQ,DUTY) # Speed reduction
   gb.pwm_brushed(BOARD,RIGHT1,FREQ,DUTY) # Speed reduction
   gb.pwm_brushed(BOARD,RIGHT2,FREQ,DUTY) # Speed reduction

if key==ord('9') : # When pressing 9, the wheels on the right side of the car will spin forward at top speed.
   gb.move_brushed(BOARD,RIGHT1,FORWD) # Right front wheel forwards
   gb.move_brushed(BOARD,RIGHT2,FORWD) # Right back wheel forwards
   gb.pwm_brushed(BOARD,RIGHT1,FREQ,DUTY) # Speed reduction
   gb.pwm_brushed(BOARD,RIGHT2,FREQ,DUTY) # Speed reduction
   gb.move_brushed(BOARD,LEFT1,STOP) # Left front wheel stop
   gb.move_brushed(BOARD,LEFT2,STOP) # Left back wheel stop
```

Figure 4: Driving the car

AD HOC WIFI HOTSPOT

Contents

1. Creating an Ad Hoc WiFi Hotspot

1.1 Why do we need this?

It would be rather difficult to drive our car if it were connected through wires to our computer. To solve this, an Ad Hoc Hotspot can be created so we can wirelessly connect our Raspberry PI.

All that is needed is our Windows 10 machine and an Ethernet connection.

1.2 Setting it up in Windows 10

To start, right click on Start button or press the Windows + X keys to open the power user settings panel, and launch Command Prompt (Admin).

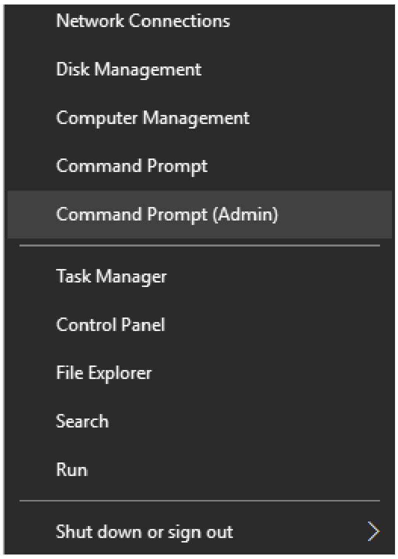
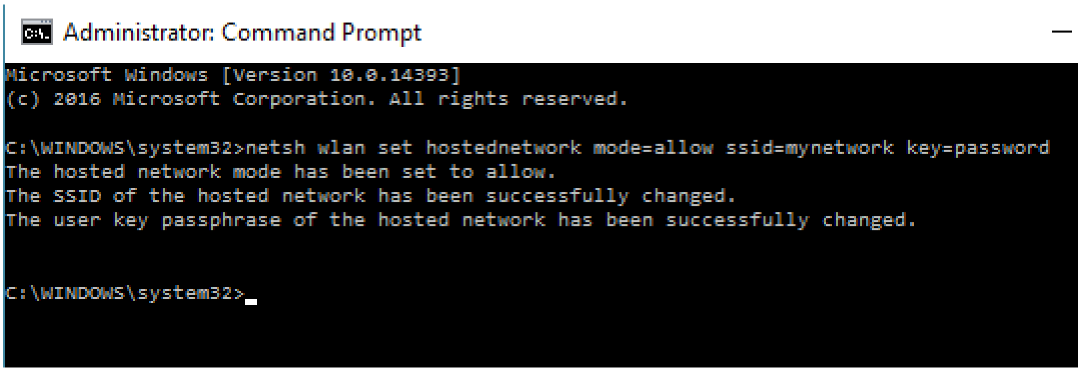


Figure 1: Command Prompt

Enter the following command and hit the Enter key at the end. Name your Ad hoc connection with a name of your choice and change the password to one of your choice:

netsh wlan set hostednetwork mode=allow ssid=mynetwork key=password



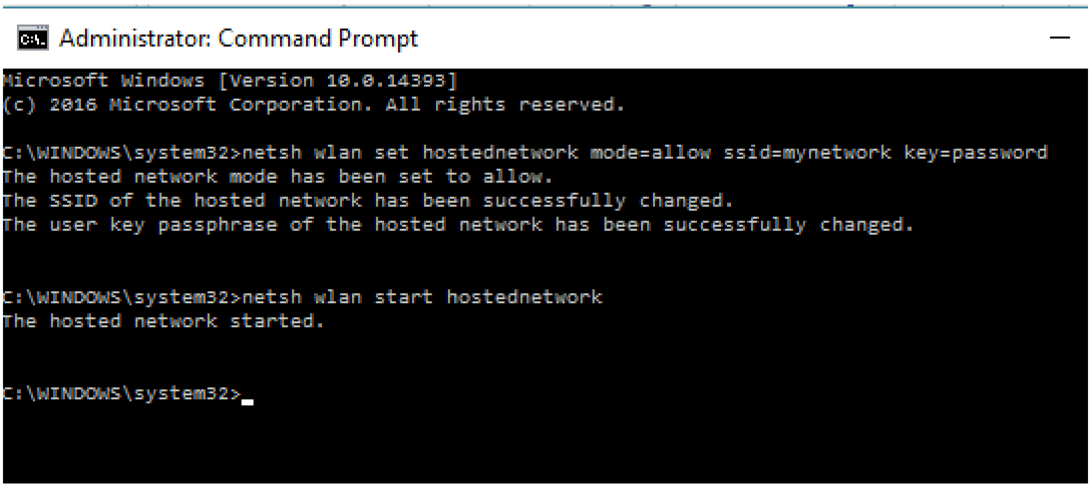
Administrator: Command Prompt

```
Microsoft Windows [Version 10.0.14393]
(c) 2016 Microsoft Corporation. All rights reserved.

C:\WINDOWS\system32>netsh wlan set hostednetwork mode=allow ssid=mynetwork key=password
The hosted network mode has been set to allow.
The SSID of the hosted network has been successfully changed.
The user key passphrase of the hosted network has been successfully changed.


C:\WINDOWS\system32>_
```

Figure 2: Creating the network

Enter the following command and hit the Enter key:

netsh wlan start hostednetwork



Administrator: Command Prompt

```
Microsoft Windows [Version 10.0.14393]
(c) 2016 Microsoft Corporation. All rights reserved.

C:\WINDOWS\system32>netsh wlan set hostednetwork mode=allow ssid=mynetwork key=password
The hosted network mode has been set to allow.
The SSID of the hosted network has been successfully changed.
The user key passphrase of the hosted network has been successfully changed.


C:\WINDOWS\system32>netsh wlan start hostednetwork
The hosted network started.


C:\WINDOWS\system32>_
```

Figure 3: Starting the network

Open the "Network and Sharing Centre" window, then click on "Change adapter settings" which can be found in the Control Panel.

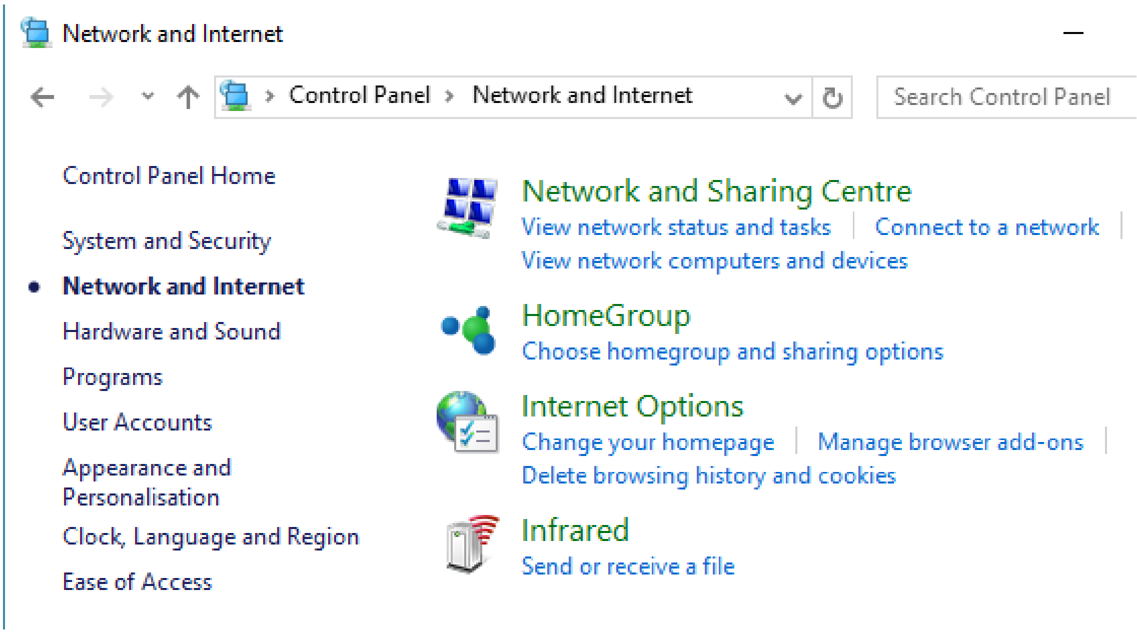

Network and Internet
Control Panel > Network and Internet
Search Control Panel
Control Panel Home
System and Security
Network and Internet
Hardware and Sound
Programs
User Accounts
Appearance and Personalisation
Clock, Language and Region
Ease of Access
Network and Sharing Centre
View network status and tasks | Connect to a network
View network computers and devices
HomeGroup
Choose homegroup and sharing options
Internet Options
Change your homepage | Manage browser add-ons
Delete browsing history and cookies
Infrared
Send or receive a file

Figure 4: Network and Internet

Right-click your Ethernet connection and select Properties and switch to the Sharing tab.

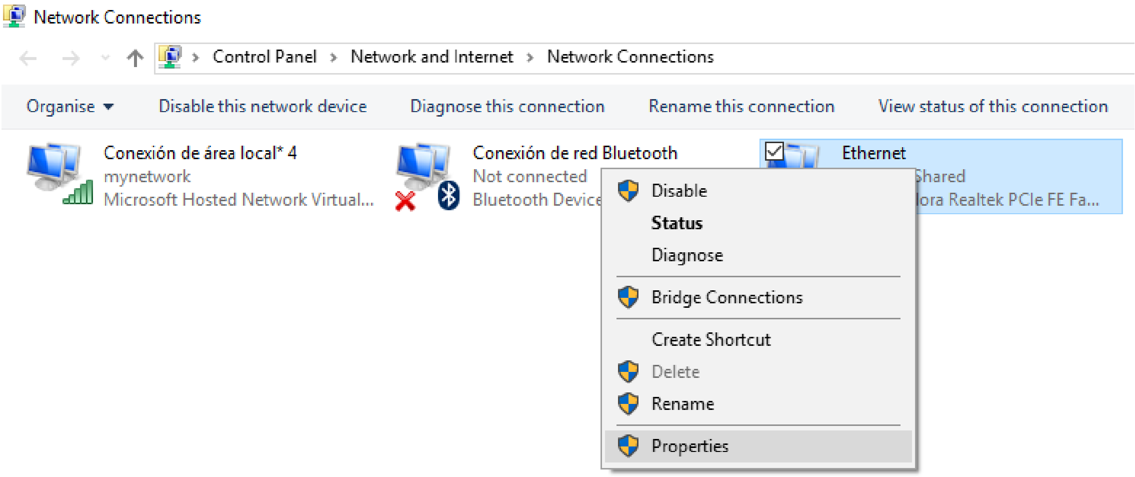
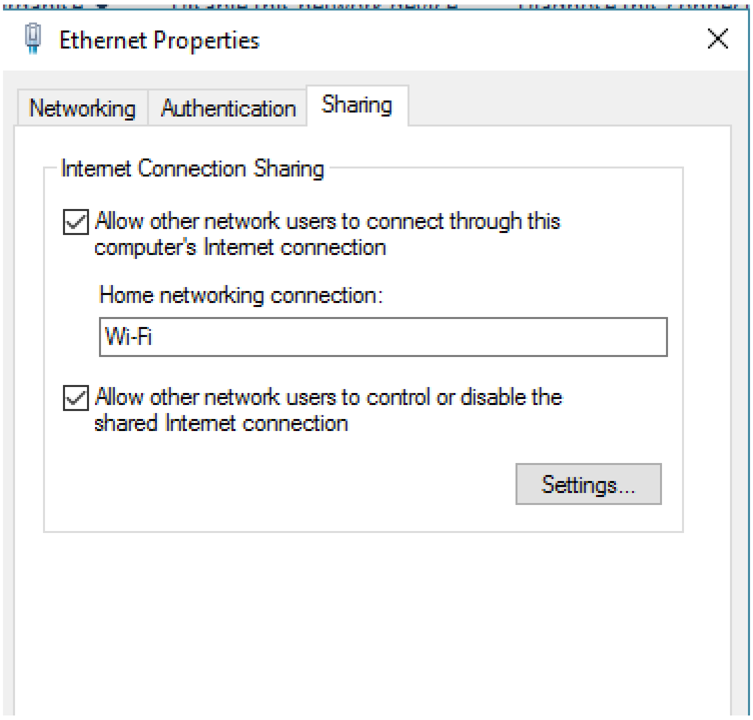

Network Connections
Control Panel > Network and Internet > Network Connections
Organise ▾
Disable this network device
Diagnose this connection
Rename this connection
View status of this connection
Conexión de área local* 4
mynetwork
Microsoft Hosted Network Virtual...
Conexión de red Bluetooth
Not connected
Bluetooth Device
Ethernet
Shared
lora Realtek PCIe FE Fa...
Disable
Status
Diagnose
Bridge Connections
Create Shortcut
Delete
Rename
Properties

Figure 5: Ethernet Properties

Check the *"Allow other network users to connect through this computer's Internet connection"* option, and choose the newly created WiFi connection from the drop down list located under *"Home networking connection"*.



Ethernet Properties

Internet Connection Sharing

☑ Allow other network users to connect through this computer's Internet connection

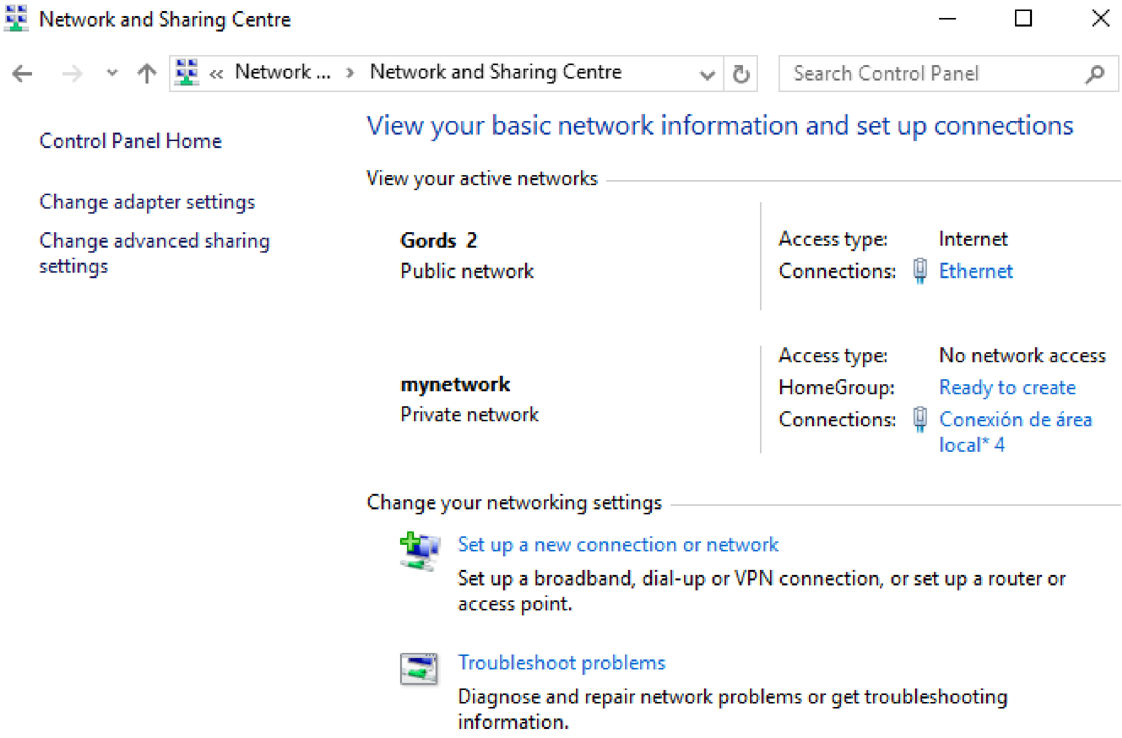
Home networking connection:

Wi-Fi

☑ Allow other network users to control or disable the shared Internet connection

Figure 6: Sharing tab

The Hotspot is now up and running, you can connect your Raspberry PI to it in order to access it remotely and drive your car without any issues.



Network and Sharing Centre

« Network ... › Network and Sharing Centre
Search Control Panel
Control Panel Home
Change adapter settings
Change advanced sharing settings

View your basic network information and set up connections

View your active networks

Gords 2
Public network

Access type: Internet
Connections: Ethernet

mynetwork
Private network

Access type: No network access
HomeGroup: Ready to create
Connections: Conexión de área local* 4

Change your networking settings

Set up a new connection or network

Set up a broadband, dial-up or VPN connection, or set up a router or access point.

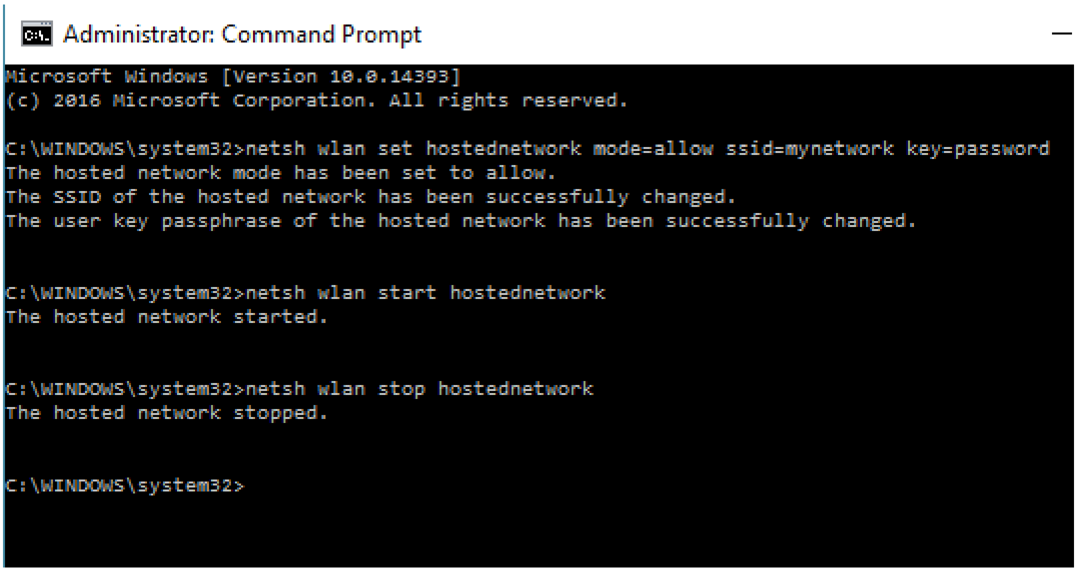
Troubleshoot problems

Diagnose and repair network problems or get troubleshooting information.

Figure 7: Networks

If you wish to disable the hotspot at any given time, simply enter the following command in Command Prompt with Administrator privileges and hit Enter:

netsh wlan stop hostednetwork



```
Microsoft Windows [Version 10.0.14393]
(c) 2016 Microsoft Corporation. All rights reserved.

C:\WINDOWS\system32>netsh wlan set hostednetwork mode=allow ssid=mynetwork key=password
The hosted network mode has been set to allow.
The SSID of the hosted network has been successfully changed.
The user key passphrase of the hosted network has been successfully changed.


C:\WINDOWS\system32>netsh wlan start hostednetwork
The hosted network started.


C:\WINDOWS\system32>netsh wlan stop hostednetwork
The hosted network stopped.


C:\WINDOWS\system32>
```

Figure 8: Stopping the network

INTRODUCTION TO FREECAD

Contents

1. Setup

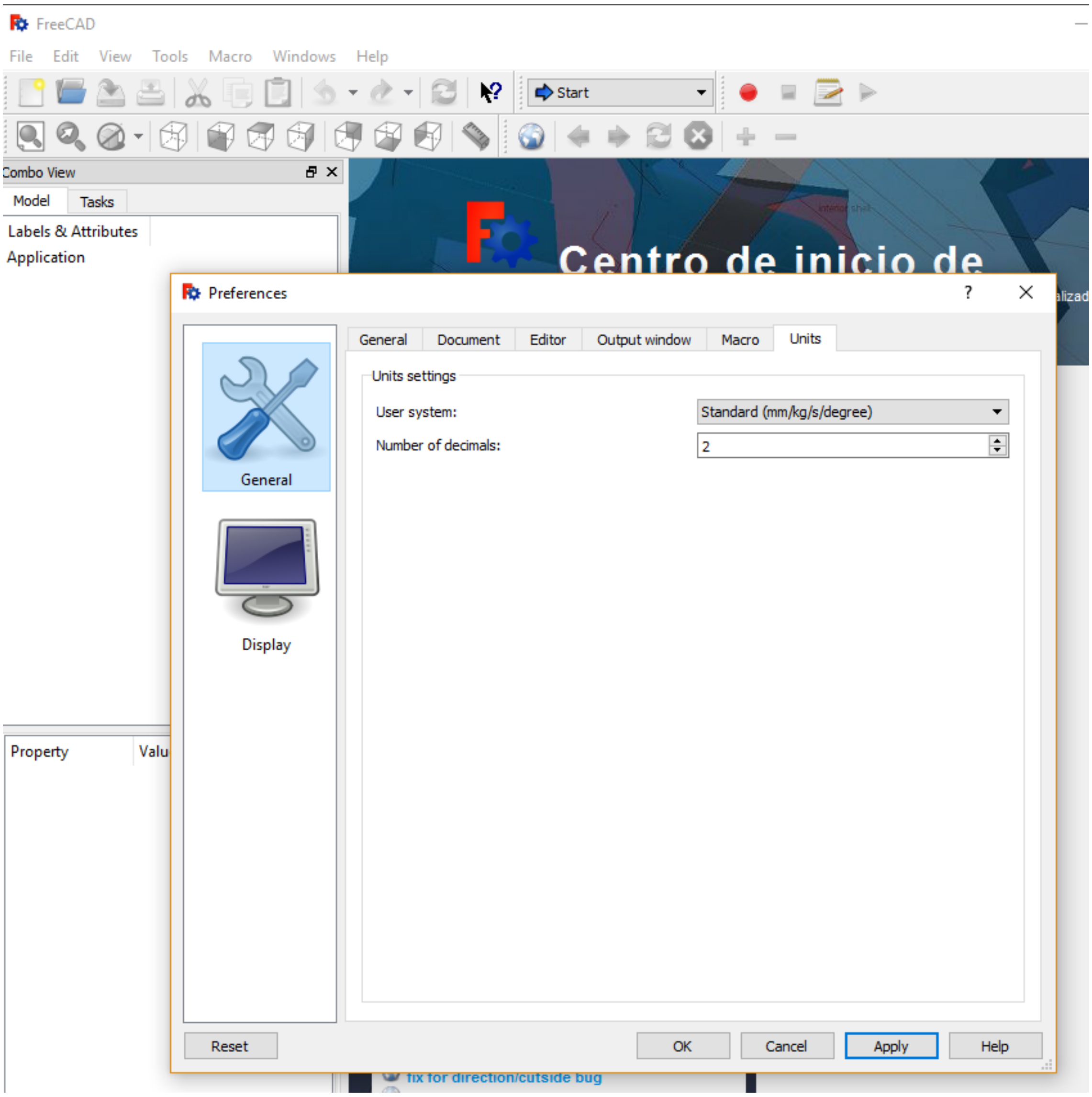
1.1 Download FreeCAD

FreeCAD is a free programme. It can be downloaded from their website https://www.freecadweb.org/ for free. Once it is downloaded, proceed to install it.

1.2 Setting the correct units

Before starting a project, you must decide which units are going to used. The metric system has been employed in all the following processes.

These are the steps to be followed in order to change the units:



Units settings

User system: Standard (mm/kg/s/degree)

Number of decimals: 2

Figure 1: How to change units in FreeCAD

Click on **Edit > Preferences**

Select **General** in the pop up window

Go to **Units** and change the User System to “Standard” and confirm by pressing “OK”.

1.3 Organising the views

Start a new document by pressing **CTRL+N.**

If the Combo View window on the left is already open, the following step can be skipped.

The Combo View is opened by clicking on **View > Panels > Combo View.**

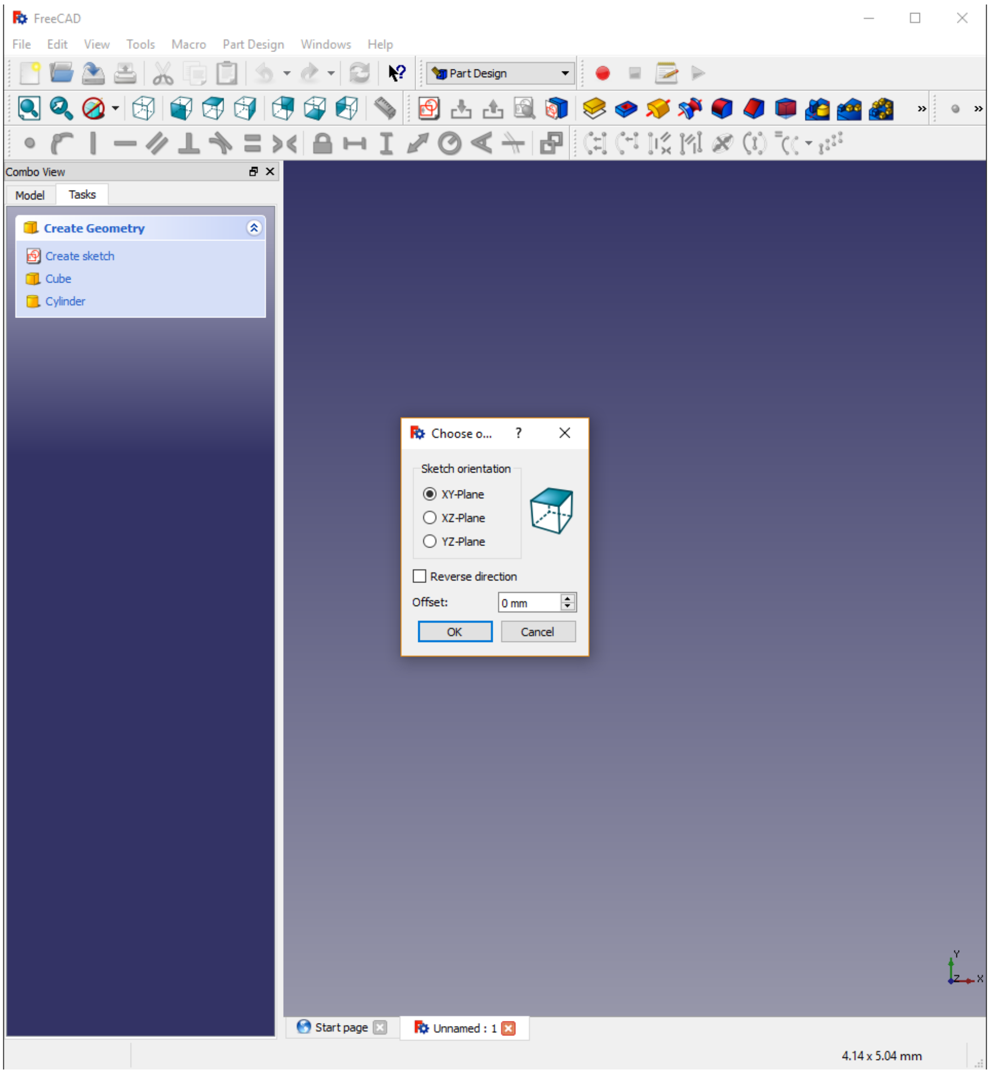
This window is very useful for issuing commands quickly. It also contains the Tree and Property view which allows for a closer look at the structure of the project.

1.4 Sketching a base

To build a three-dimensional object a base must be sketched first.

Change the Workbox from Start to **Part Design**. This will enable the option Create Sketch under the Task slide in the combo view window.

Click on **Create Sketch.** This will pop up a new window to choose the orientation to sketch on.



Choose o...

Sketch orientation

● XY-Plane

○ XZ-Plane

○ YZ-Plane

□ Reverse direction

Offset: 0 mm

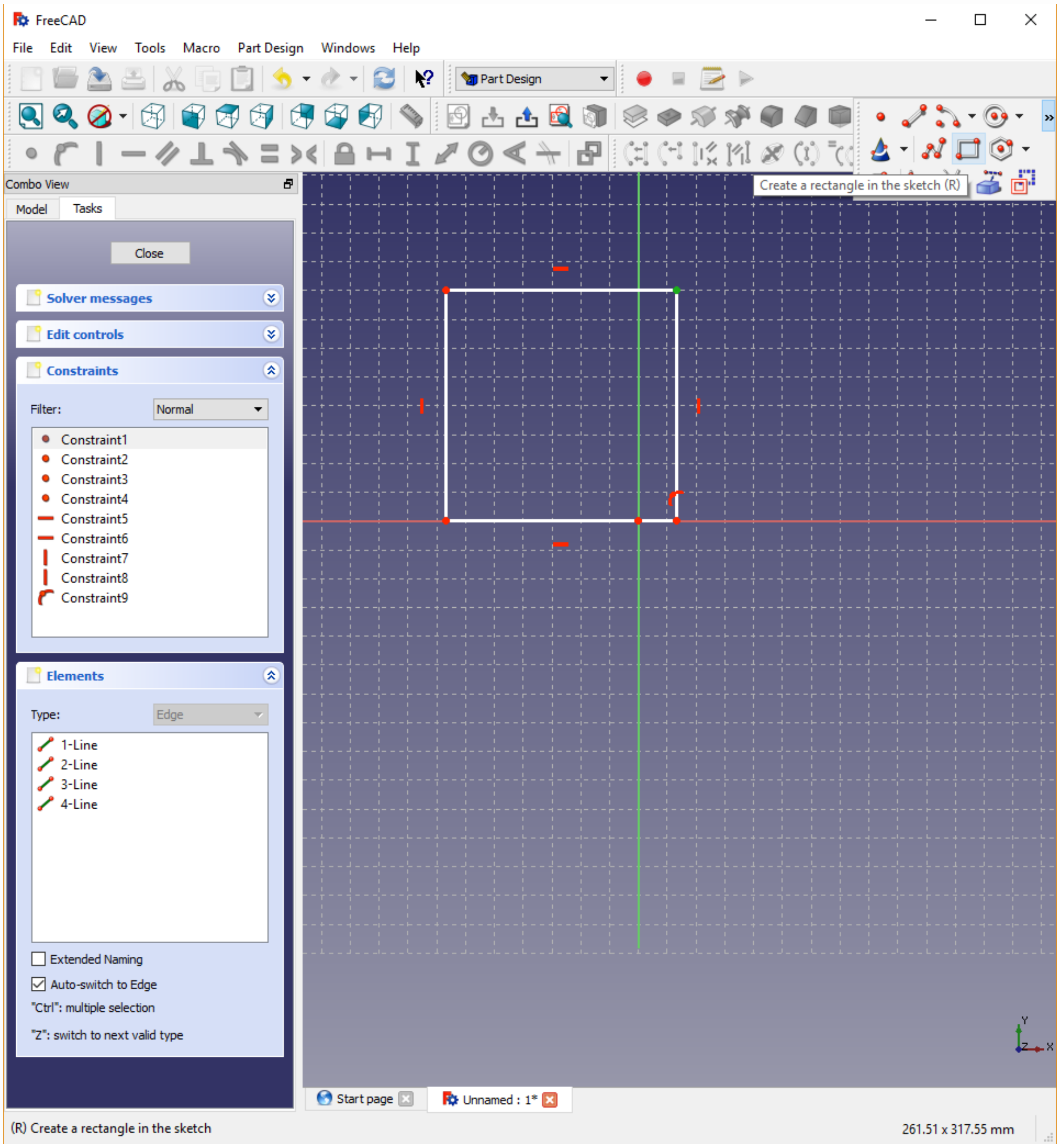
OK Cancel

*Figure 2: First change the Workbox to Part Design. Then click on **Create Sketch**.*

Choose the **XY-Plane**, uncheck **reverse direction** and **zero** the offset. In this window the cube on the right will show the selected plane. The **Reverse Direction** option will switch to the opposite plane. With the option **Offset** the height of the plane can be changed. Press OK to proceed.

Under the **Tasks** bar new options pop up. Here, the **Grids** properties can be changed. **Check all** the grid options and set the **Grid size** to**10mm**. Unchecking **Show grid** will hide the grid and **Grid size** will vary the spacing of the grid. Selecting **Grid Snap** will automatically snap a point to the closest crossing.

Select the sketch tool **Create a Rectangle.** When the cursor moves over the coordinate system the current coordinates will be shown right next to the cursor. Click in the **IV section** of the coordinate system on the point **-40.0, 40.0**. Notice how the points snap to the grid which lets you work with more precision. Create a rectangle **80.0 x 80.0** big. FreeCAD automatically sets constrains to the sketch as can be seen in the **Constrains** window on the left. Click on Close to exit the Sketch. The sketch can now be extruded to a three dimensional object.



Filter: Normal

- Constraint1
- Constraint2
- Constraint3
- Constraint4
- Constraint5
- Constraint6
- Constraint7
- Constraint8
- Constraint9

Type: Edge

- 1-Line
- 2-Line
- 3-Line
- 4-Line

☐ Extended Naming

☑ Auto-switch to Edge

"Ctrl": multiple selection

"Z": switch to next valid type

(R) Create a rectangle in the sketch

261.51 x 317.55 mm

Figure 3: Set Grid options and select draw rectangle

1.5 Setting new points

Select the **Pad** command under the Task section in the Combo View.

Set the **length** to **60mm**, the tab to **Dimension** and uncheck **Symmetric to plane** and **Rewind**. **Length** will determine how far the object is extruded. The option Rewind will extrude the sketch in the other direction. The second length will be enabled by switching the **Dimension** tab to **two dimensions** and will extrude the object on two sides. Confirm by pressing OK.

1.6 Moving objects

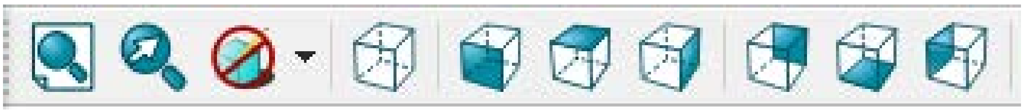


Figure 4: Different points of view. 1 Isometric view, 2 Front view

You can also move the object around and take a look at it from different sides.

Holding the middle mouse button and moving your mouse will move the object.

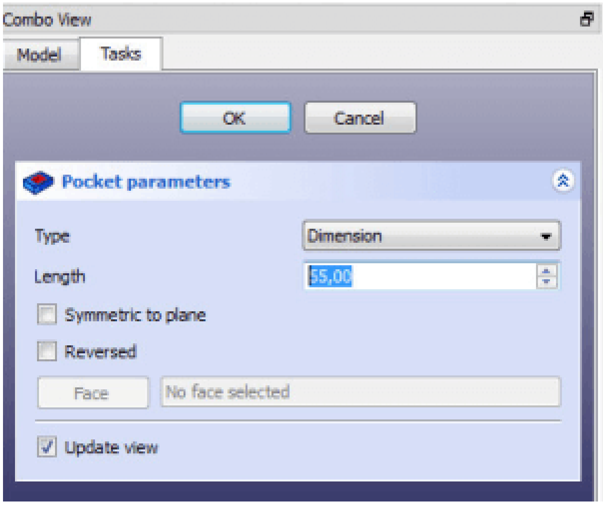
You can also select different angles of view. The different views can be found right in the middle of the FreeCAD toolbar. The axiometric view projects the object in a three dimensional way. You can also choose to look at one specific side.

When you lose track of your object press on the magnifying glass on the left of the view toolbar. This will centre your entire project.

2. How to Cut Objects

To begin with Lesson 2 of this FreeCAD tutorial, open the last lessons project and switch your Workbox to Part Design. At first, we want to hollow out our box with the cut feature.

2.1 Basic Cut Feature



Type: Dimension

Length: 55,00

□ Symmetric to plane

□ Reversed

Face: No face selected

☑ Update view

Figure 5: Set the dimensions of the Pocket feature found in the combo view.

Select the Top plane by switching to the Top view in the view menu and clicking on the visible face of your box. Now create a new sketch under Task in the Combo view window.

Set your grid to 5mm and check Grid Snap. Now draw a rectangle starting at -35.0, 35.0 and make it 70.0 x -70.0 big. It should offset 5mm from the edges of your box. Click to confirm the rectangle and close the sketch.

Go on by clicking on the **Pocket** feature right under the Pad feature in the combo view. This feature will cut everything inside your recently drawn rectangle. You can change the direction and the limit to cut to in the Type selection. Set Type to Dimension and your length to 55.0mm so the floor is 5mm thick. Also rename the created pocket to “Hole” by pressing F2. When you switch to isometric view you can see the hole in the box.

2.2 Offset

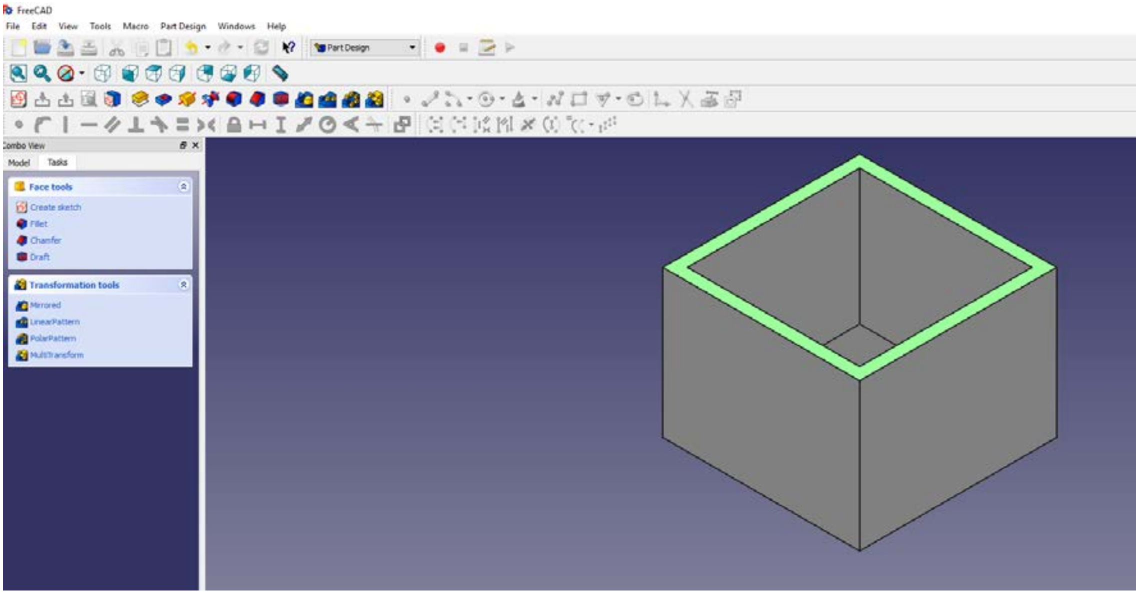
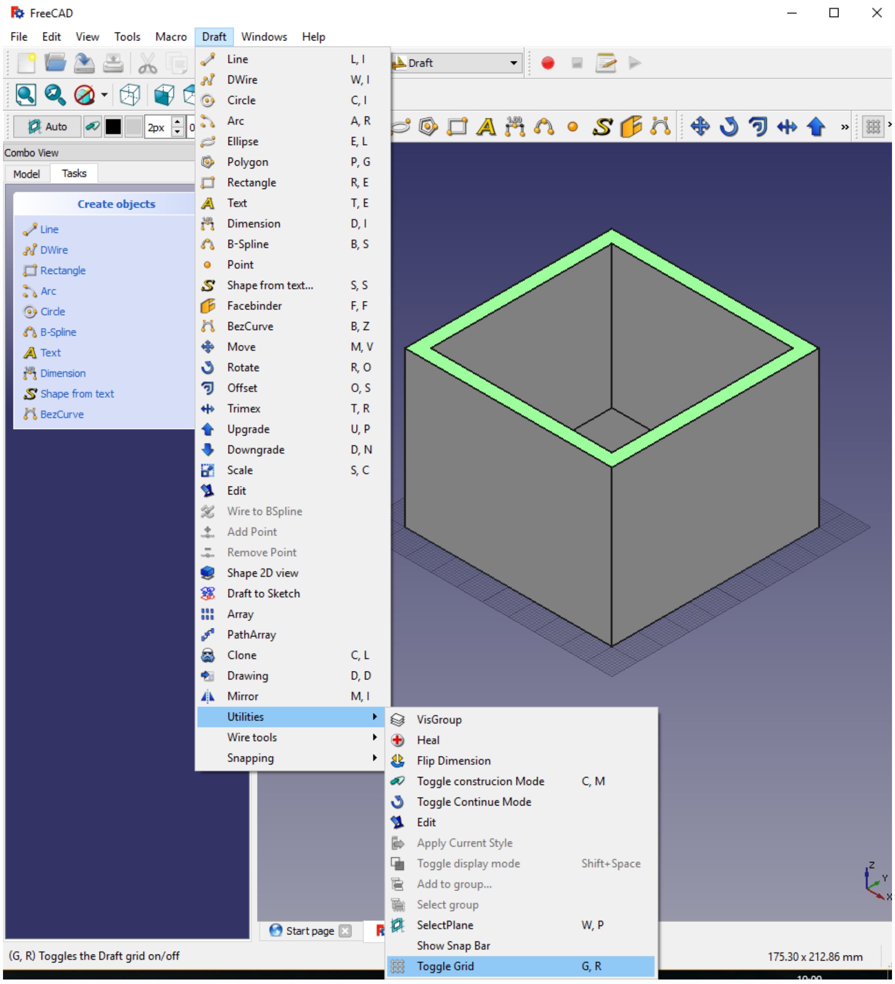


Figure 6: Set the Draft Plane on the top face of the box.

To keep the future lid in place, you will have to create a rim around the top of the box. Switch to the isometric view and select the top plane of the box again. Do not select the floor or walls of your box! Change the grid size to 5mm and enable grid snap. Now create a rectangle aligned with the top edges of your box starting at -40, 40.0., close the sketch when finished and rename the finished sketch to Rim 1. To access the **Offset** tool, switch your Workbox from Part Design to **Draft**.



(G, R) Toggles the Draft grid on/off

Figure 7: Disable draft grid after you finished drafting.

Redefine your working plane by clicking on **Set Working Plane** and then on the top plane of your box. A grid should become visible. To show or hide the grid go to Draft > Utilities > Toggle Grid. The height working plane will determine the drafting level. Drafting on different levels will allow you to extrude the drafts into one object.

Select the sketch "Rim 1" in the Model section and select under Task the **Offset** tool. Check **Copy** so "Rim 1" remains after the offset. When using the offset tool it is very important to move and **keep** your curser in the modeling window. You will notice a rectangle following your curser. Now do not move your mouse, type **-2.5** and press enter. This will offset your sketch by 2.5mm to the inside. Also rename "D Wire001" to "Draft".

Disable your Draft grid as shown earlier and switch Workbox back to Part Design.

2.3 Advanced Cut

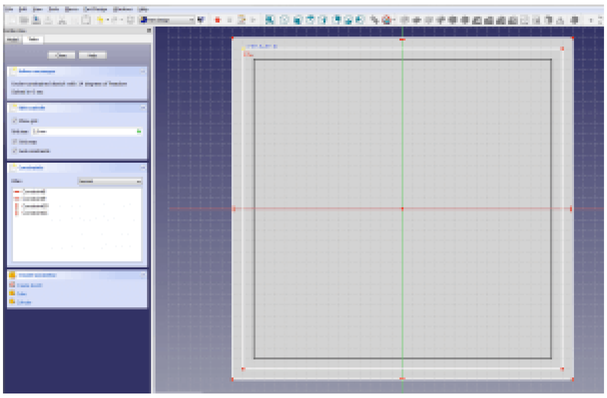


Figure 8: Sketch a rectangle on top of the draft.

Double click on “Rim 1″ sketch to edit it. Set your grid to 2.5mm and check grid snap. Now draw a second rectangle right on top of “Draft” starting at **-37.5, 37.5** and close the sketch.

Now you can also delete “Draft” by clicking on it and pressing the delete button.

Select “Rim 1″ again and cut it by using the Pocket feature. Set Type to Dimension and Length to **5mm**. This will cut the space inside the rectangles.

3. Fillets & Pattern

In lesson 3 of this FreeCAD tutorial, you are going to learn how to multiply a part and make corners round. To begin open the box you created in lesson 2.

3.1 The Pattern Feature

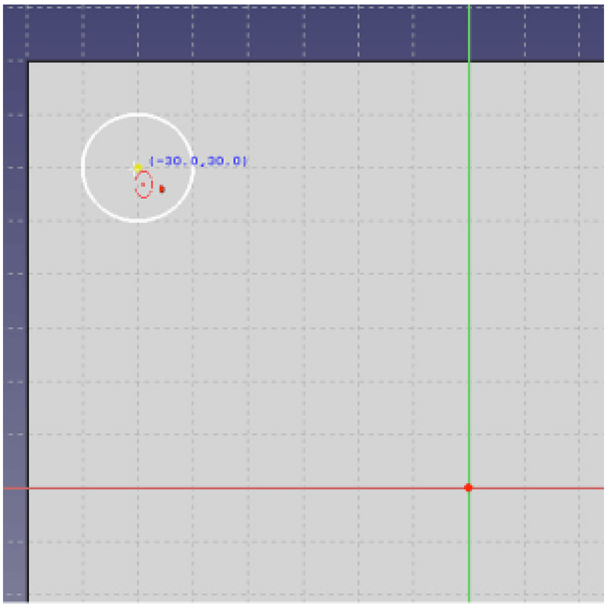


Figure 9: Create a circle on the bottom of your box.

The Pattern feature distributes an object equally. So before you can pattern an object you need to create one. In this step you are going to add little nubs on the bottom of your box. Switch your view to bottom view and select the visible plane. You should see the bottom of your box. Now create a new sketch on this plane and set your grid size to 5mm, also check grid snap. Select Create a Circle and draw a circle in the upper right hand corner of your box at **-30.0, 30.0** with a radius of **5mm.** Now close the sketch.

Select the sketch drawn in 1. and extrude it with the pad feature. Set length to **5mm** and uncheck Symmetric to Plane and Reverse. Press OK to finish and rename the Pad to “Nub” by pressing F2.

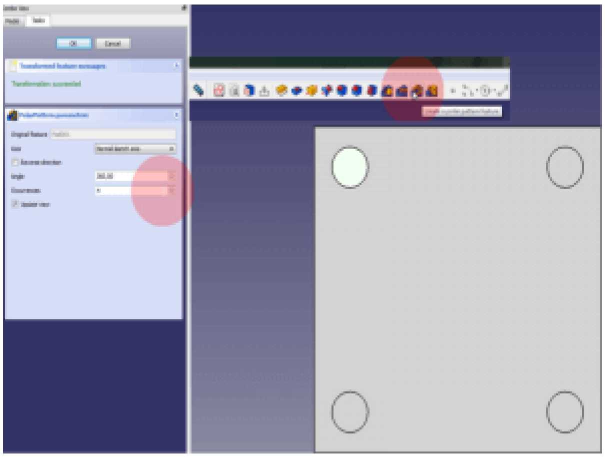


Figure 10: First select the entity you want to multiply and then click on the circle pattern feature. This will arrange the circle equally.

Now click on “Nub” again and select the **Polar Pattern** feature. Set Angle to **360.00**, Occurrences to **4** and uncheck reverse direction. This tool creates a circle pattern of a part with a specific angle and occurrences. The angle determines the size of your pattern. For example, at 360° the objects will be arranged in a full circle, at 90° only inside a quarter of a circle. With reverse direction checked your pattern will go around clockwise.

3.2 The Fillet Feature

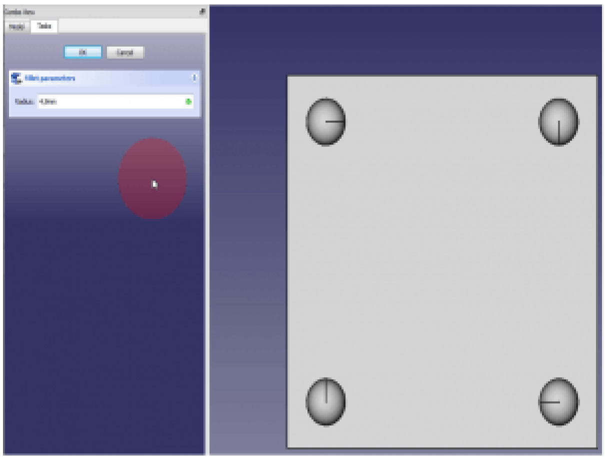


Figure 11: Create a fillet from the circle pads with the radius of 2.4mm.

Switch to bottom view and select all the Nubs. To select many parts hold down CTRL and click on different parts. To unselect a part just click on it again.

Now select the Fillet Feature. The adjustable radius determines the size of your fillet. The radius must be smaller than the entity you create a fillet so set the radius to **4.9mm**. What you get looks just like little nobs. Close the feature and rename the Fillet to “Nub1”.

3.3 How to make corners round

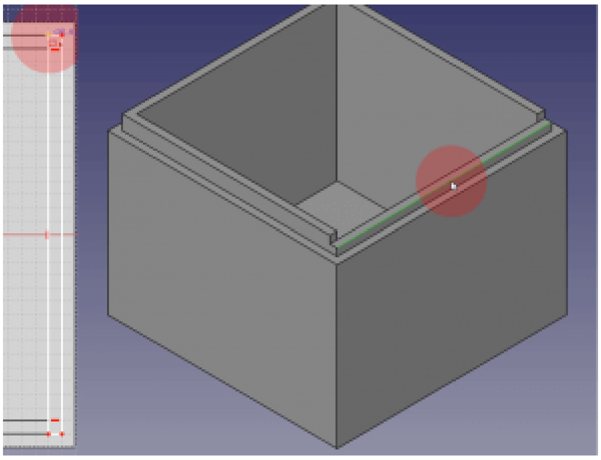


Figure 12: First create a rectangle on the existing rim. Cut it by 2.5mm and then select the outward rim of your box to create a fillet.

Switch to top view and create a new sketch on the rim you created in lesson 2. Now draw a rectangle on the right side starting at **35.0, 37.5** and make it **2.5 x -75.0** big. Exit the sketch and proceed to the next step.

Create a new pocket with the sketch from 1., set the length to **2.5mm** and uncheck reversed. Also rename the pocket to “SmallRim”.

Now click on the outward edge of SmallRim and click on the Fillet Feature. Set the radius to 2.4mm.

4. Sweep Feature & Placement Regulation

In lesson 4 of this FreeCAD tutorial, you will learn how to create a sweep out of two sketches and copy it afterwards. To begin, open your Tutorial Box and switch your Workbox to Part Design.

4.1 Create a Sweep

Switch to your right side view, select the right side of your box and create a new sketch. Set grid size to 2.5mm and sketch a new rectangle at **-35.0, 50.0**. Make this rectangle 10.0 x -2.5 big. This rectangle will be the base for your sweep so rename it to “Hinge Base” by pressing F2.

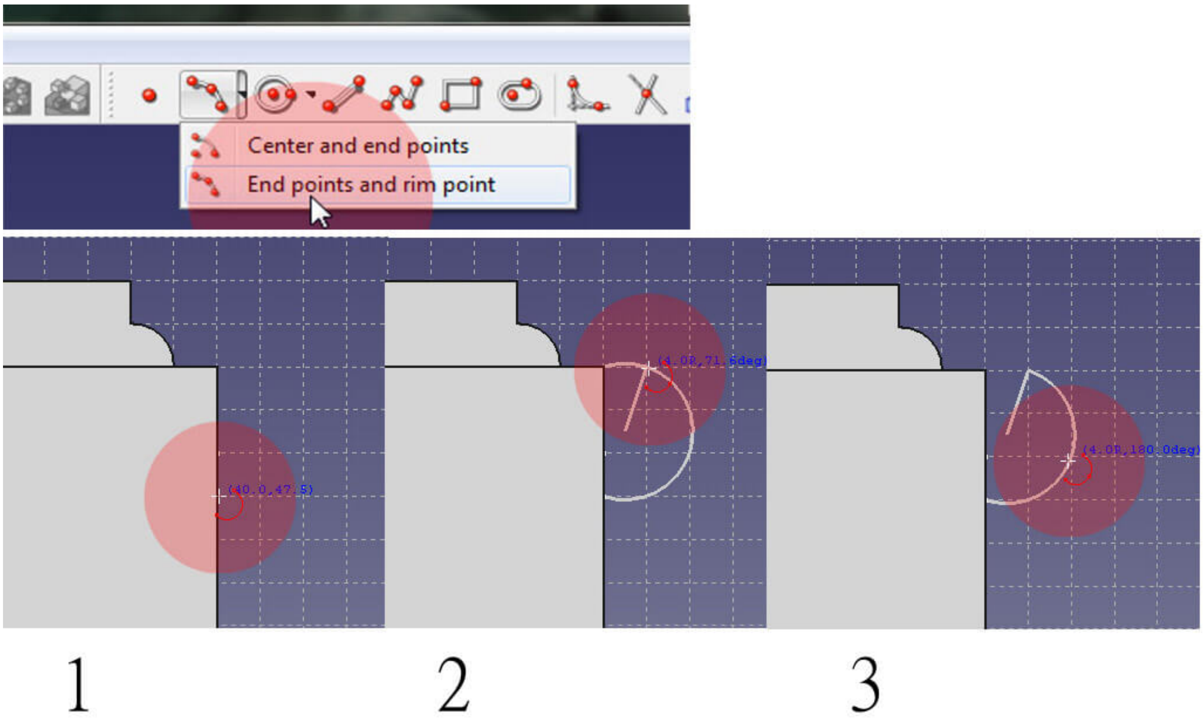
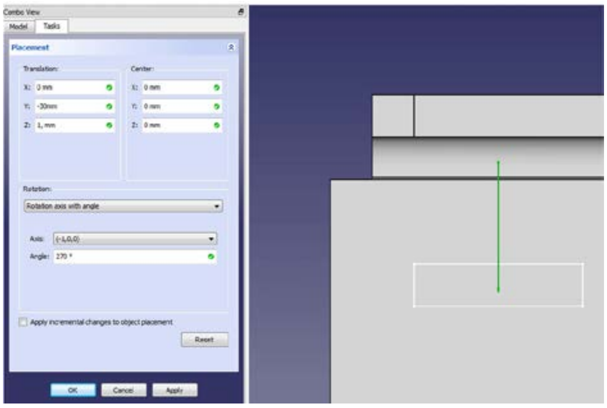


Figure 13: Create the semicircle following these steps.

Now click next to the box into the void to create another new sketch on the XZ-Plane. Zoom in on the right side of your box and set grid size to 2.5mm as well.

Select the sketch tool ‘Ends Point and Rim Point’ circle. You can find it in the sketch section under the semicircles. Sketch a new circle at **40.0, 47.5** (1). Make the diameter of your circle **4.0R**(2) big so the end point aligns with the top edge of your box. To complete the circle set it to **180°** (3). This circle will guide your sweep, so rename it to “Hinge Guide”



Translation:
X: 0 mm
Y: -30mm
Z: 1, mm

Center:
X: 0 mm
Y: 0 mm
Z: 0 mm

Rotation:
Rotation axis with angle
Axis: (-1,0,0)
Angle: 270 °

□ Apply incremental changes to object placement

Figure 14: Move the sketch along the Y and Z-Axis.

When you switch back to right side view, you will notice that “Hinge Guide” does not align with “Hinge Base”. To move it right into the middle of your rectangle click on “Hinge Guide” and after that on the **Data** tab found at the combo view bottom. Click on **Placement** now and then on the [...] box to adjust the positioning of your sketch. Change the values in the Translation box. Set the Y-Axis to**-30mm** and the Z-Axis to **1mm**. When using Translation the programme will use the coordinates of your sketch as 0,0,0 reference. Using the Centre values will use the overall coordinate system as a reference. Rotation gives you the option to rotate your sketch along an axis. Press OK to proceed.

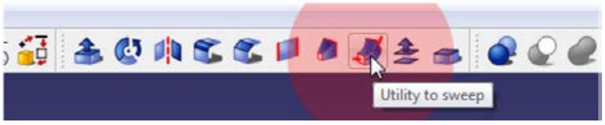
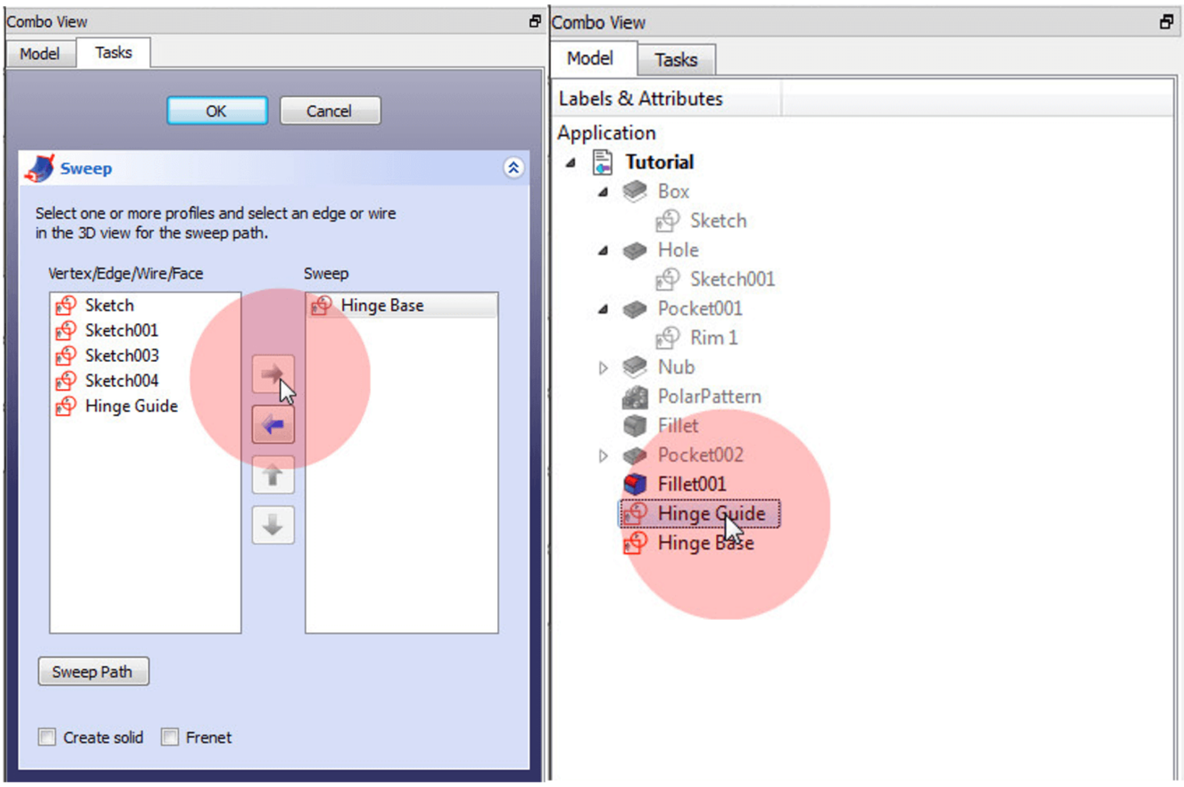


Figure 15: Select the Sweep Feature in the Part section of your Workbox.

Switch your Workbox to Part and click on ‘**Utility to Sweep**‘. This tool extrudes a sketch following a certain path. In the Combo View you can see all of your sketches. Select the sketch “Hinge Base” and move it to the Sweep box by clicking on the arrow facing to the right.



Select one or more profiles and select an edge or wire in the 3D view for the sweep path.

Figure 16: Always follow this order when creating a sweep: Select the base > Click on Sweep Path and select the path > press Done and OK.

Now press **Sweep Path** and in the Model Section select “Hinge Guide” and switch back to Task. Confirm the sweep by pressing done first and then OK. Rename Sweep to “Hinge”.

4.2 Copy the Sweep

Right click on “Hinge”, click on copy and confirm by pressing Yes in the Object Dependencies window. You can also use the shortcut CTRL+C.

Paste the object by either right clicking on “Hinge” again or pressing CTRL+V.

Now the copied object is right on top of the original. To move it, click on the Placement options as shown in Step 1,3. Move the object along its Y-Axis by **60mm.**

Now you have finished the box – congratulations! In the next lesson, you will create the cover for it.

5. The Revolution Feature & How to Cut with Two Objects

In lesson 5 of this FreeCAD tutorial, you will create the cover of your box. The cover will be curved and hollowed out with the Revolution feature. No, you are not going to overthrow any government but you will create a solid curved shape around a sketch. To begin open a new document and save it as “Box cover”. Then switch your Workbox to Part Design.

5.1 The Revolution feature

Create a new sketch on the XY-Plane, draw a rectangle starting at **-40.00, 40.00** and make it 80.00 x -80.00. Rename the sketch to “Base”.

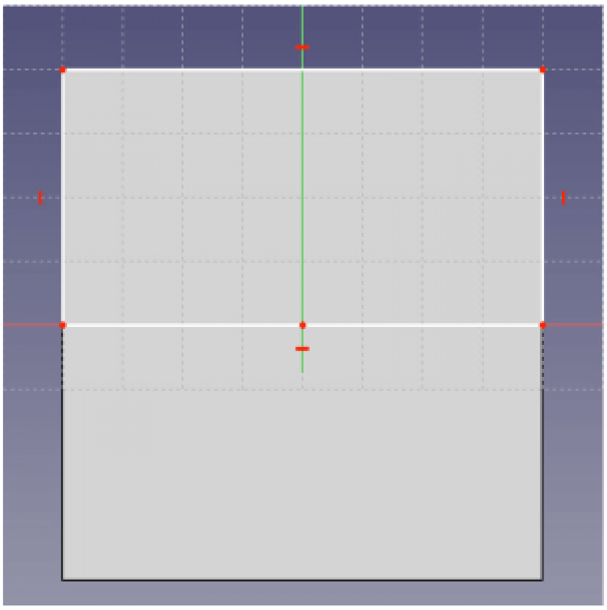
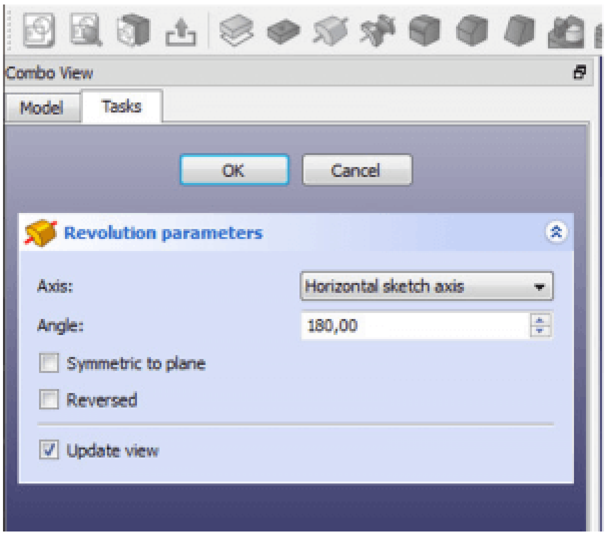


Figure 16: Draw a rectangle on one-half of your base.

Now extrude the sketch to **5mm** height and rename it to “Base” also. When finished, start a new sketch on top of the extruded box. Draw another rectangle starting at **-40.00, 40.00** and make it **80.00 x -40.00**big. Rename it to “Base of Revolution”.



Revolution parameters

Axis: Horizontal sketch axis

Angle: 180,00

□ Symmetric to plane

□ Reversed

☑ Update view

Figure 17: Set Axis to Horizontal and Angle to 180° to create half of a revolution.

To create a revolution, click on ‘Base of Revolution’ first and then on the Revolve a sketch feature. Set Axis to ‘Horizontal Sketch Axis’ and Angle to **180°**. Uncheck Symmetric to Plane and Reversed. Symmetric to plane will distribute the feature on each side of the sketched plane equally.

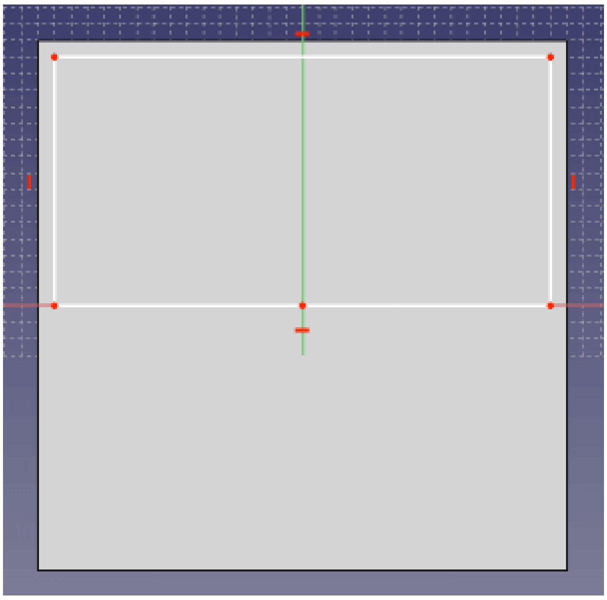
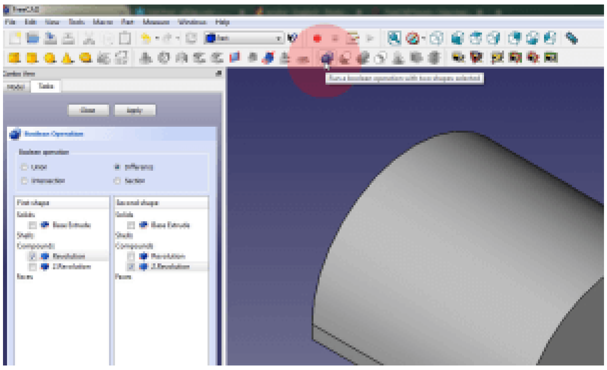


Figure 18: Draw a second rectangle with an offset of 2.5mm to the edges on one-half of your box.

Hide the Revolution you created. by clicking on it in the Model view and pressing spacebar. Now create a new Sketch on top of 'Base' extrude. Set your grid to 2.5mm and draw a rectangle at **-37.50, 37.50** and make it **75.00 x -37.50**big. Rename it to 'Base of the 2. Revolution' and create a new Revolution feature. Rename it to "2. Revolution". Set the Axis to horizontal and Angle to 180° also uncheck Symmetric to Plane and Reversed.

5.2 Cut with two objects


FreeCAD
File Edit View Tools Macro Part Measure Windows Help
Run a boolean operation with two shapes selected
Combo View
Model
Tasks
Close
Apply
Boolean Operation

Boolean operation
○ Union ● Difference
○ Intersection ○ Section

First shape
Solids
□ Base Extrude
Shells
Compounds
☑ Revolution
□ 2.Revolution
Faces

Second shape
Solids
□ Base Extrude
Shells
Compounds
□ Revolution
☑ 2.Revolution
Faces

Figure 19: Subtract with the Boolean command one object from another one.

Switch your Workbox to Part and select Run a Boolean operation. Check Difference in the Boolean operation window. This will subtract the Second Shape from the First Shape. Union will combine two objects, intersection will extract the common part of two objects and section will extract the common part of two objects as a non-solid.

Check as First Shape 'Revolution' and as Second Shape '2.Revolution'. Click on Apply to confirm the subtraction.

To finish we create a new sketch at the bottom of 'Base Extrude'. Draw a rectangle starting at **-37.50, 37.50** and make it **75.50 x -75.50** big. Cut the sketch with the Cut feature by a length of **5mm.**

3D PRINTING

Contents

1. 3D Printing: Printing our vehicle

Before a 3D model output can be implemented on a 3D printer, the model has to be converted into a format that the printer can manage. This process is called slicing as the model is divided into small layers – the slices.

A special software is needed to do the slicing. The software which as been used for 3D printing in this project is Cura. Cura software allows the user to import an STL (or OBJ) file and prepare it for any printer model (each model has its specific settings).

This software package prepares the 3D model into instructions that the specific 3D printer requires to produce an object. Cura is an open source software developed by Ultimaker to make 3D printing as easy and streamlined as possible.

It contains everything that is needed to prepare a 3D file for printing. It is fully preconfigured to work with the BQ Witbox 1 which was available for this project.

Cura has an integrated setup programme that guides the user on the installation of the latest firmware as well as to calibrate the printer.

While the user is making decisions on the look and quality of the 3D object, the slicer engine included in Cura prepares the model in the background.

With Cura it is only possible to copy your print file to an SD card and print from it.

With Cura software, the user sets a number of settings that depend on the printer, model and the print material used. The most important settings are layer height and layer thickness.

Then Cura 3D calculates the outline of the model layer by layer and determines the path the print head has to take in order to print the object.

The Cura software not only slices the model: It creates the commands that the printer interprets and executes while printing.

This code is called the G-code. When Cura 3D is finished, the user will save this code to a file on an SD card that can be fed later into the printer.

2. The Basics

2.1 Installing the Cura software

The first step will be to select the printer model that a G-code will be created for.

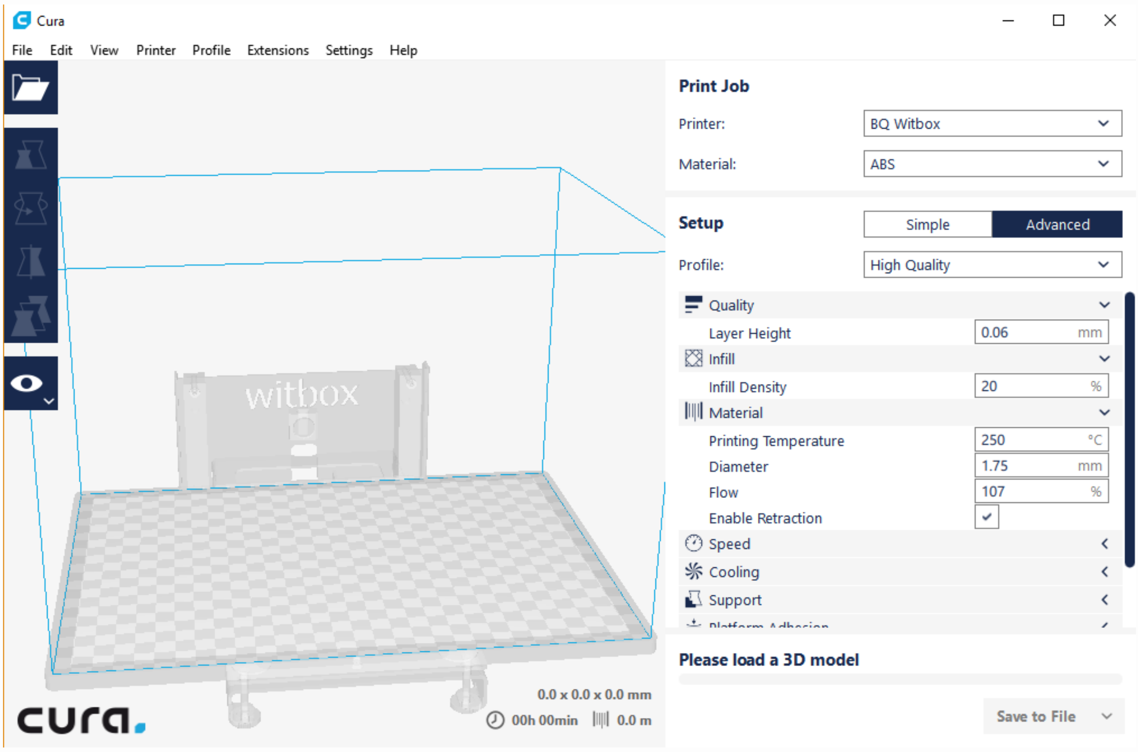
To do this, the installation file for your operating system must be obtained from the Ultimaker website and you must install the latest version of the software.

Launch Cura 3D.

Select the printer model. BQ Witbox 1 is the one being used in this project.

2.2 Quick overview

This screenshot shows the basic features:



Print Job

Printer: BQ Witbox

Material: ABS

Setup: Simple / Advanced

Profile: High Quality

Quality
- Layer Height: 0.06 mm

Infill
- Infill Density: 20 %

Material
- Printing Temperature: 250 °C
- Diameter: 1.75 mm
- Flow: 107 %
- Enable Retraction: ☑

Please load a 3D model

0.0 x 0.0 x 0.0 mm

00h 00min 0.0 m

Figure 1: The Cura 3D interface.

Open file: This option or the **File > Open** command can be used to open the STL or OBJ file.

View Mode: This option allows switching between **Layers** and **Solid view**.

Printer: This option allows the user to open the printer-specific settings.

Setup: In **Simple mode** only very basic settings can be changed, in **Advanced mode** the user will have access to all printer settings.

Save to File: The Gre-code can be saved into the hard disk or directly to an SD card in order to be used by the printer.

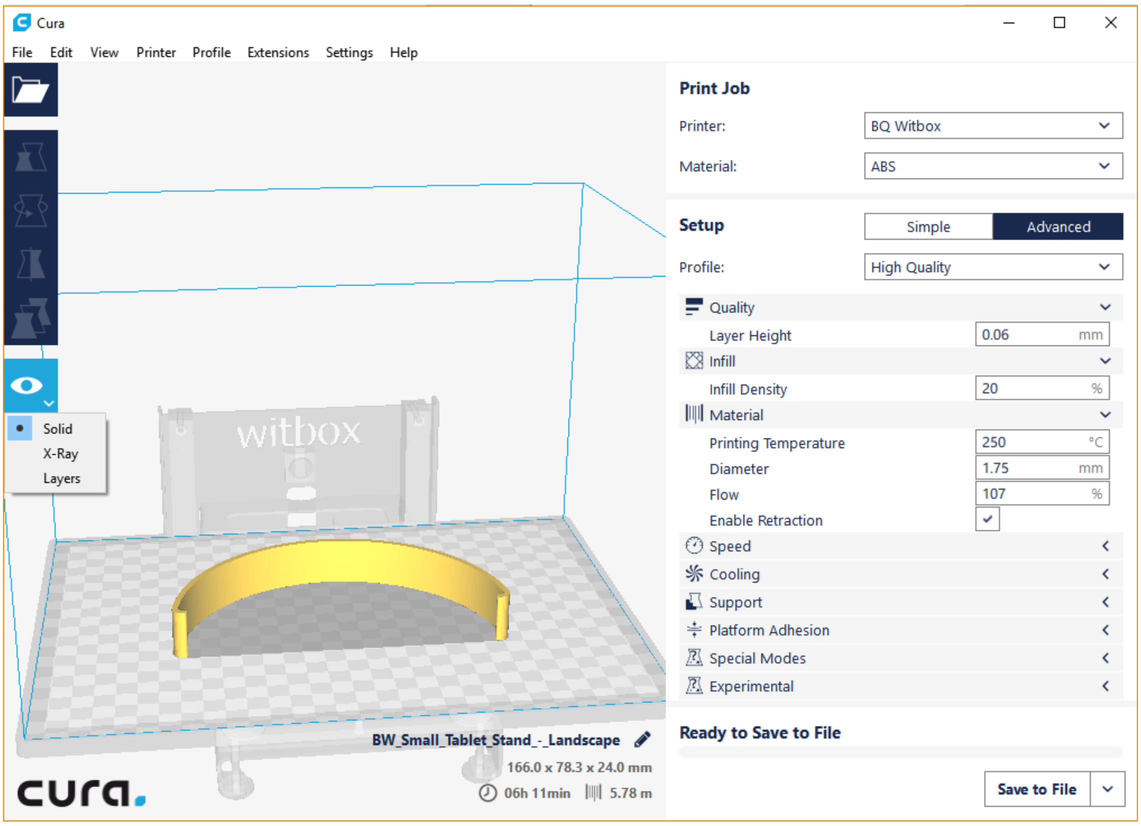
2.3 Handling your model in Cura 3D

A basic stand for a tablet has been used for this project. To load the 3D model, use **Open file** as explained earlier.

There are two views available; **Solid view** and **Layer view**. In **Solid view**, the entire object can be seen as it will look when printed.

In **Layer view**, there is a scrollbar to the right through which an individual layer can be selected; alternatively, the user can go through layer by layer using the **Up/Down arrow keys** on their keyboard.

When switching to **Layer view**, it may take a while before the layers are calculated and displayed (depending on the model and computer hardware).



Print Job

Printer: BQ Witbox

Material: ABS

Setup: Advanced

Profile: High Quality

Quality

Layer Height 0.06 mm

Infill

Infill Density 20 %

Material

Printing Temperature 250 °C

Diameter 1.75 mm

Flow 107 %

Enable Retraction ✓

Speed

Cooling

Support

Platform Adhesion

Special Modes

Experimental

Ready to Save to File

BW_Small_Tablet_Stand_-_Landscape

166.0 x 78.3 x 24.0 mm

06h 11min 5.78 m

Figure 2: Display the model in Layer or in Solid view.

After loading the model, the user can scale, rotate or mirror it on the build platform using the three buttons to the left.

The user should switch to **Solid** view before rotating the model as it takes a while to recalculate the layers in **Layer view** so rotating might be quite sluggish.

When the model is selected, a green and a red arrow will appear. Using these arrows, the user can move the model to the front/back and left/right on the workspace.

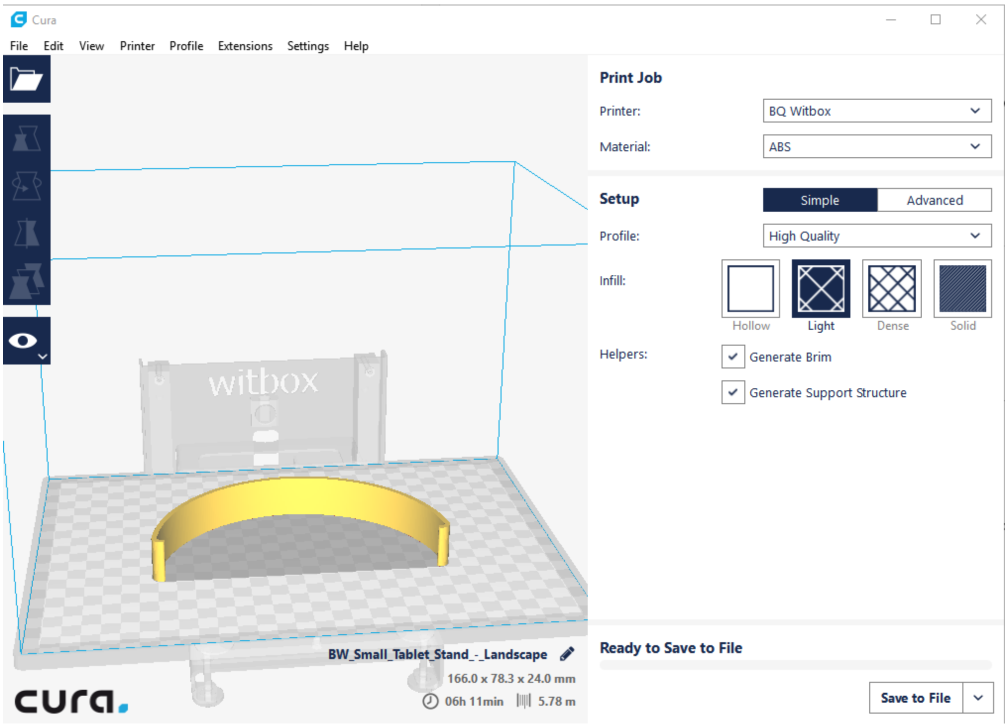
In order to get a more detailed view, user can click the **Scale** button and enter a higher percent value – always maintaining the **Uniform Scaling** setting, otherwise the printed model will be distorted. In order to close the **Scale** dialogue box, the user can click the **Scale** button a second time.

The user can right click the object to undo any changes. This will open the context menu where the user can undo all changes and centre it on the platform.

The model can also be duplicated with this menu.

2.4 Cura 3D settings

When Cura is started, **Simple mode** is activated. Here, there are only two settings available in Cura 3D. The user may select print quality and may have support structures printed together with the model:



Print Job

Printer: BQ Witbox

Material: ABS

Setup: Simple | Advanced

Profile: High Quality

Infill: Hollow | Light | Dense | Solid

Helpers: ☑ Generate Brim

☑ Generate Support Structure

BW_Small_Tablet_Stand_-_Landscape

166.0 x 78.3 x 24.0 mm

06h 11min 5.78 m

Ready to Save to File

Figure 3: Setup modes

In **Simple mode**, select print quality and decide whether to add supports or not.

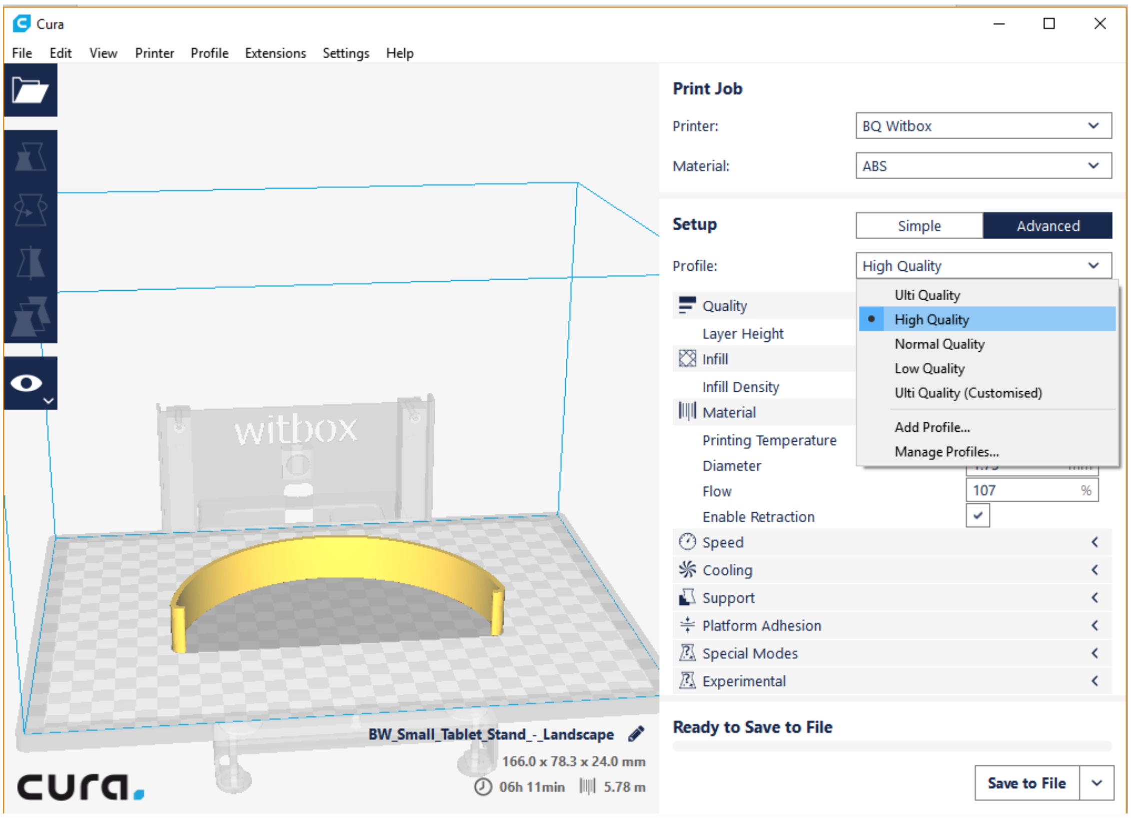
If needed, the **Enable Support** option can be checked (in this project, no supports are needed). Most 3D models require support structures, so it is best to have **Enable Support checked.**

Supports are needed when the model has overhanging parts or parts floating in the air.

To set the **print quality,** chose Advanced and they change to the quality desired. Cura software displays the print duration for minimum and maximum print quality.

The field to the left of the **Save to Disk** button displays estimated print time and material required for the currently selected quality.

For a quick print of a draft, **Low Quality** can be chosen. If you need maximum quality and time is not as important as quality, choose **Maximum Quality**.



Print Job

Printer: BQ Witbox

Material: ABS

Setup

Profile: High Quality

Flow 107 %

Enable Retraction ✓

BW_Small_Tablet_Stand_-_Landscape

166.0 x 78.3 x 24.0 mm

06h 11min 5.78 m

Ready to Save to File

Figure 4: High Quality

Cura 3D now calculates layer height, print speed and other settings according to the quality selected.

Cura 3D remembers these two settings and defaults for later projects.

2.5 Generate a G-code file

The last step is to save the model in a printable G-code file.

The **Save to Disk** option or select **File > Save** can be used.

Enter a file name and the folder where the file is stored. The file may be stored on the SD card used to transfer the file to your 3D printer; but usually it is first stored on the hard disk and then copied to the SD card.

Select **GCode File (*.gcode)** as the type of file and click **Save**.

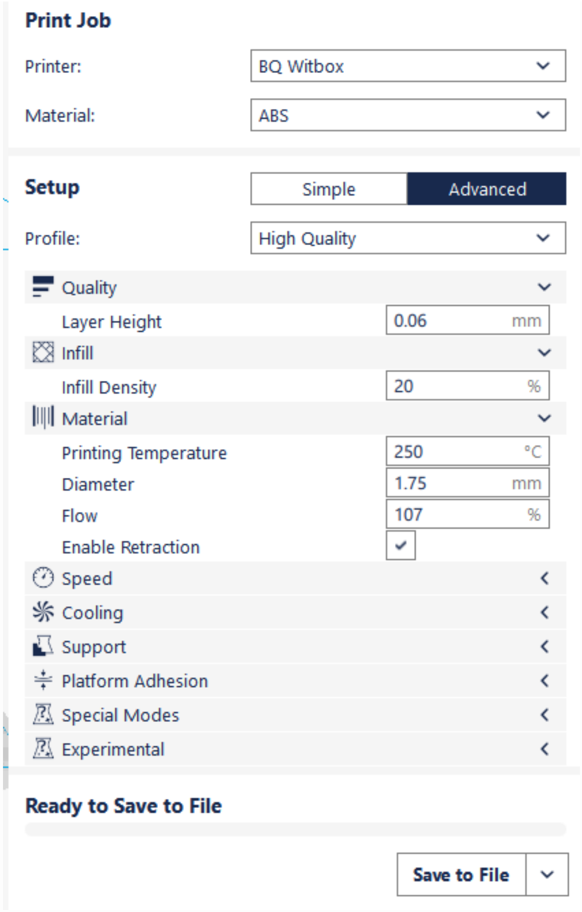
Copy the file on an SD card and insert the card into the 3D printer's SD slot.

3. Cura Software Settings

While the basic print settings of the Cura software are fine to start with, the **Advanced** settings give more control over the output. Basically, there are two ways to access the **Advanced** settings:

1. Through the tabs in the **Print Setup** pane on the right-hand side of the Cura window,

2. Through the **Preferences > Settings** menu.



Print Job

Printer: BQ Witbox

Material: ABS

Setup Simple | Advanced

Profile: High Quality

Quality
- Layer Height: 0.06 mm

Infill
- Infill Density: 20 %

Material
- Printing Temperature: 250 °C
- Diameter: 1.75 mm
- Flow: 107 %
- Enable Retraction: ☑

Speed

Cooling

Support

Platform Adhesion

Special Modes

Experimental

Ready to Save to File

Figure 5: Advanced Setup

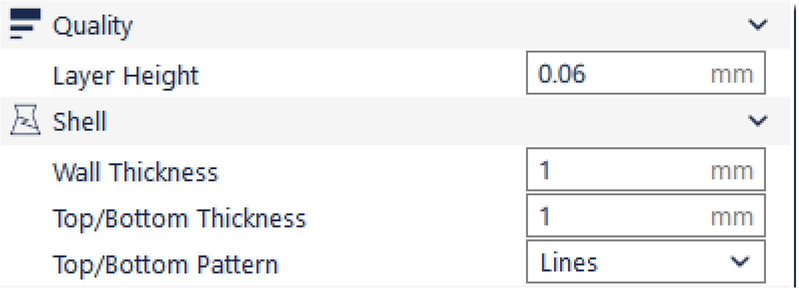
3. The Print Setup pane contains the most relevant settings, while in the **Preferences > Settings** menu the user has access to all the print settings – and the user can select selected which of these settings are displayed on the **Print Setup** pane.

We will start with the **Print Setup** pane.

3.1 Quality settings

In the **Mode** field, select **Advanced** instead of **Simple**. Below **Print Setup**, a number of tabs for **Quality**, **Material** and other settings are displayed.

Click **Quality** to define the surface quality of the 3D printed object.



Quality

Layer Height 0.06 mm

Shell

Wall Thickness 1 mm

Top/Bottom Thickness 1 mm

Top/Bottom Pattern Lines

Figure 6: Cura Quality settings

Layer Height is by default 0.1 mm. If the selected printer supports thinner layers, the height can be decreased to get smoother surfaces, however, that will increase print time.

The **Shell > Wall Thickness** setting of Cura 3D determines the thickness of the walls of the object. It has to be an integer multiple (1x, 2x, 3x, etc.) of the nozzle diameter. A thickness setting of 0.8 mm means that walls will be 2 lines wide (as the nozzle of our Ultimaker 2 printer has a diameter of 0.4 mm).

The **Bottom/Top Pattern** can be either **Lines** or **Concentric**.

The **Bottom/Top Thickness** is usually also set to 0.8 mm. If an object with a large flat top is printed, user may want to print more layers in order to close the top surface completely. This avoids the unwanted "pillowing" effect.

As the **Bottom/Top Thicknes**s setting is not by default in the **Print Setup** pane, the user first has to open **Preferences > Settings** and check **Bottom/Top Thickness** – now the setting will be displayed in the **Print Setup,** so the user can increase the value (again in integer multiples of the nozzle diameter).

3.2 Material settings

Usually, there is only the **Retraction** option in the **Material** section. It is recommended that users leave **Retraction** turned on. Retraction means that the filament will be retracted, i.e., pulled back, when the printer nozzles move over an area that is not printed. This way, no filament will come out of the nozzle. There will be no "stringing" – no thin threads of plastic between the printed parts of the object.

If the user wishes to change other material settings, the **Preferences > Settings** will present all the settings that might need changing.

The recommend temperature settings for PLA are a **Printing Temperature** of **210 Infill Thickness C** and a **Bed Temperature** of **60°C**; for ABS the **Printing Temperature** must be set to **250°C** and the **Bed Temperature** to **90°C**.

Usually, there is no need to change the default **Diameter** and **Flow** values. If user needs to do so, the settings can be enable under **Preferences > Settings**.

Flow is the entire amount of material that needs to be extruded for the object. The **Flow** value is usually set to 100%, so the extruded amount equals the amount of material required. The user will only need to increase this setting if they use very soft materials.

3.3 Speed settings

If the user wishes to print faster than the default (and recommended) **50 mm/s**, the **Print Speed** value may be increased. In this case, it is recommended that the **Print Temperature** value is also increased so that the plastic is properly melted.

The **Travel Speed** setting determines how fast the print head moves when it is not printing (e.g., when moving from one wall to the next). The default **150 mm/s** is appropriate for most cases.

In the **Preferences > Settings** dialogue, there are other speed settings that allow control over the speed for specific parts of the print. In case the user wishes to change any of these speed settings, **Print Speed** is the setting to change; this will make accelerating and decelerating smoother when changing e.g. from infill to shell printing.

3.4 Infill settings

Infill Density determines how much plastic is printed inside the object. A higher value means that more plastic will be printed – which will result in a stronger object. Typically, **10%** to **20%** are sufficient to build strong objects. In case user wishes to print the object completely hollow, the density must be set to **0%**.

If the user wishes to change other infill settings, these must first be selected in the **Preferences > Settings** dialogue to make them accessible on the **Print Setup** panel. The **Infill Thickness** and **Infill Layers** settings allow the user to reduce print time when the quality of the infill is less important: sparse infill is printed in fewer layers to save print time. **Infill Thickness** sets the thickness of the sparse infill; the value has to be a multiple of the layer height. **Infill Layers** allows to combine several layers to form sparse infill.

3.5 Cooling

Turning off the **Enable Cooling Fan** setting is not recommended as it will result in warping and other ugly surface effects.

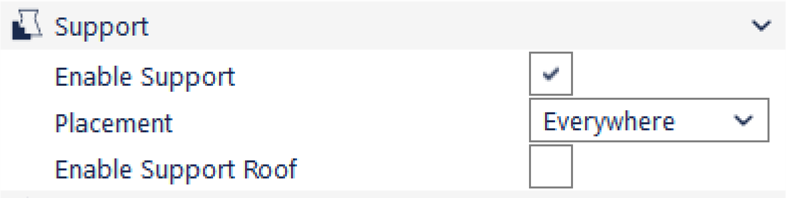
In order to control the cooling fan more precisely with the Cura software, the user must enable the **Cooling** settings in the **Preferences > Settings** dialogue, e.g. the **Fan Speed** settings in order to increase **Maximum Fan Speed** when it is very hot in the office or to decrease it when the fan is too loud.
When the user wants to make sure a layer has enough time to cool before the next layer is printed above it, set the **Minimal Layer Time**. Increasing this value also increases print time.

Through the **Minimum Speed** setting the user can make sure the printer does not slow down too much as that means that the nozzle will be on the same spot for a longer time – keeping the plastic at that spot hot. A **Minimum Speed** below 100 mm/s will reduce print quality.

When an object with a small top is printed, it is recommended to use the Lift Head option. This removes the print head from the object so it can cool down (otherwise, you might end up with a blob at the top of the object).

3.6 Support settings

Do not turn the **Enable Support** option off – otherwise floating or overhanging parts cannot be printed.



Support

Enable Support ☑

Placement Everywhere

Enable Support Roof □

Figure 7: Cura 3D: Support settings

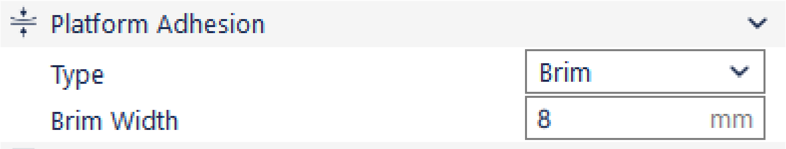
The **Placement** option determines where supports are attached: **Touching Build plate** means the supports are based only on the build plate; **Everywhere** means the support structures can also be built on the model or inside the model.

The **Overhang Angle** value determines how much overhang a part has to be supported; the default is **60°**. Note that setting the **Overhang Angle** to **90°** will create no support structures at all.

There is also the **Use towers** setting. These "towers" are special support structures that have a larger diameter than the supported parts and that are smaller at the top. This way, these supports can be removed more easily and there will be less traces of the supports on the printed object.

3.7 Platform Adhesion settings

In order to improve bed adhesion or in case the object does not have a flat bottom, a brim or a raft can be added. If the user does not do this, Cura software automatically adds a skirt around the object.



Type: Brim
Brim Width: 8 mm

Figure 8: Cura 3D: skirt settings

The skirt is a line around the print on the first layer that helps prime the extruder. A brim is made of a few lines attached directly to the bottom of the object; this increases the bottom surface and minimises warping. A raft is a thick grid underneath the model and helps the object stick to the build plate.

In case the user simply wants the skirt printed, the user must set **Type** to **None** and select the number of skirt lines and the distance to the object.

In case the user wants a brim printed, the user must select **Type: Brim** and set the **Brim Line Count**, i.e., the number of lines to be printed.

To have a raft printed, user must select **Type: Raft** and adjust the margin, the thickness and other settings.

CONCLUSIONS

This project is focused on the study of an implementation of both Raspberry and Gertbot for the operation of electrical drives, as a practical example of the several applications that can be achieved with both Raspberry and the Gertbot.

As has been outlined on each of the documents that make up this study, it is possible to operate a remote-controlled car in a simple and intuitive way, using a Python script and the combination of a Raspberry PI and a Gertbot.

This project aims to help the students of the subject Electrical Drives in the development of the practical side of the subject, serving as a guide or manual for them and providing them with the different references through which they can expand their knowledge on all aspects of the practical side of the subject.

Therefore, several different competitions can be held with the designed vehicle, changing the rules of said competitions and achieving higher levels of complexity, enabling different trajectories and speeds that the vehicle will be able to attain.

The tools employed in this project, such as Gertbot, not only permitted this design, but also made possible all kinds of designs of all levels of complexity; from a personal web server or a home automation system.

On a personal level, this study has allowed me to gain a better understanding of the Raspberry PI and start to familiarise myself with Python, consolidating some concepts I acquired during my degree, this leading to a practical use of the same. This has been a perfect finishing experience; to be able to design and create something and make it work as an engineer.

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