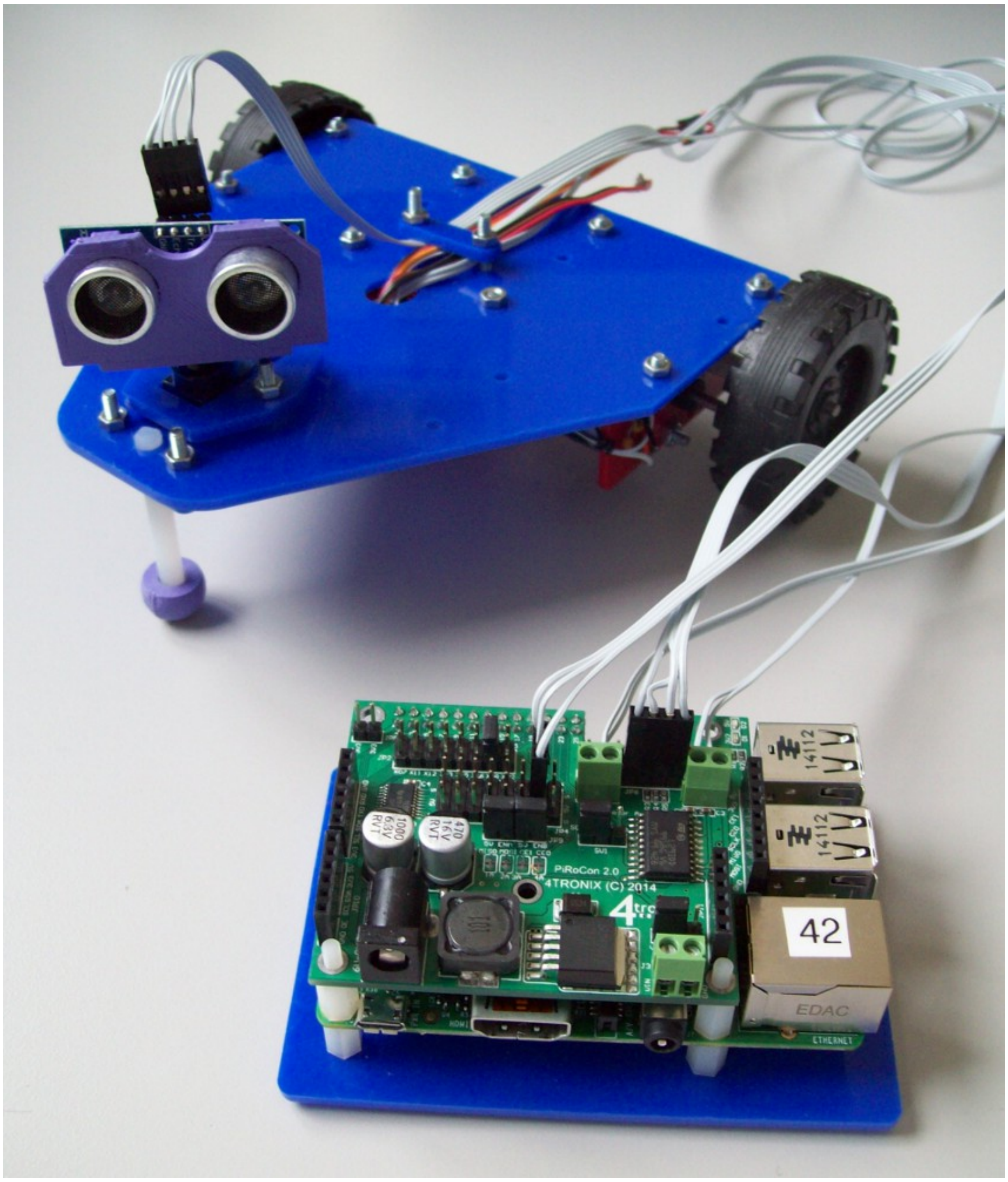
Scratch the Robot



THE UNIVERSITY of York
Department of Computer Science

Mike Freeman 15/07/2015

A Robot From Scratch

Introduction

The aim of this laboratory is to construct a mobile robotic platform. This system requires:

- Sensors: electronic components that can convert information about the environment in which the robot is operating into electrical signals.
- Actuators: hardware components that can convert electrical signals into physical actions or movements.
- Control: hardware or software components that can capture and interpret sensor data, generating a sequence of control signals to implement the correct system behaviours.

Stage 1: construction

Using the tools and components provided, construct your robot.

D.C. Drive Motors

The robot uses two D.C. drive motors (actuators) to move and steer the platform. The D.C. motors used contains two permanent magnets and three wire coils, as shown in figure 1.

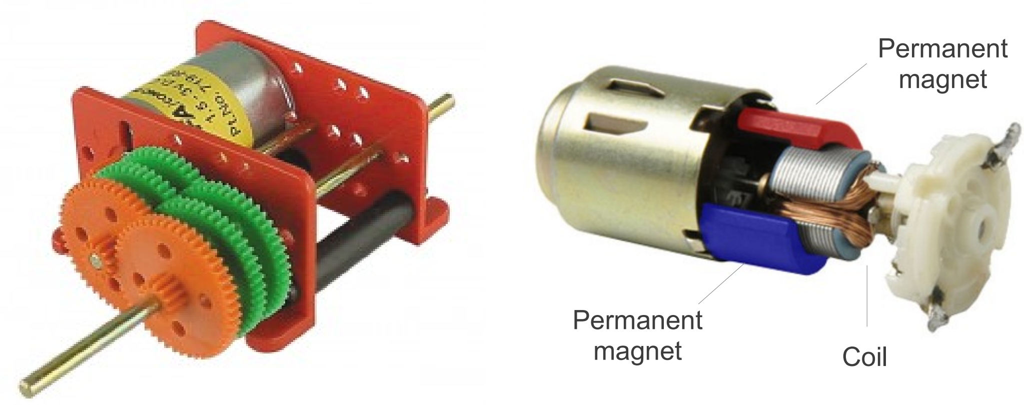


Figure 1: motor and gearbox (left), motor internals (right)

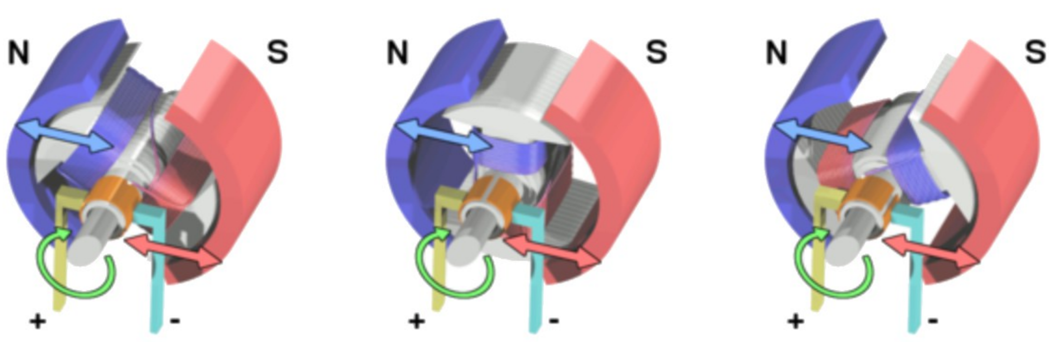


Figure 2: magnetic field interaction

When a voltage is connected across a coil a magnetic field is produced. This field opposes the permanent magnet's field, as shown in figure 2, i.e. the two North poles (blue) and South poles (red) generate a force that pushes the electromagnet (coil), rotating the drive shaft. To continue this rotation a mechanical switch (commutator) reverses the voltage on the coil, reversing the electromagnets field.

Using eight 10mm M3 bolts (shorter bolts) connect the two D.C. drive motors to the platform, as shown in figure 3. The base is symmetrical so the motors can be attached on either side. The bolt heads go onto the motor bracket, you may wish to place these into position first, as shown in the top right frame of figure 3. The bolt's nut goes on the top of the base, use the long nose pilers and screwdriver to GENTLY tighten, finger tight is fine.

Tip Don't tighten the bolts until all bolts are in position, checking that the motor (wheel) is square to the base.

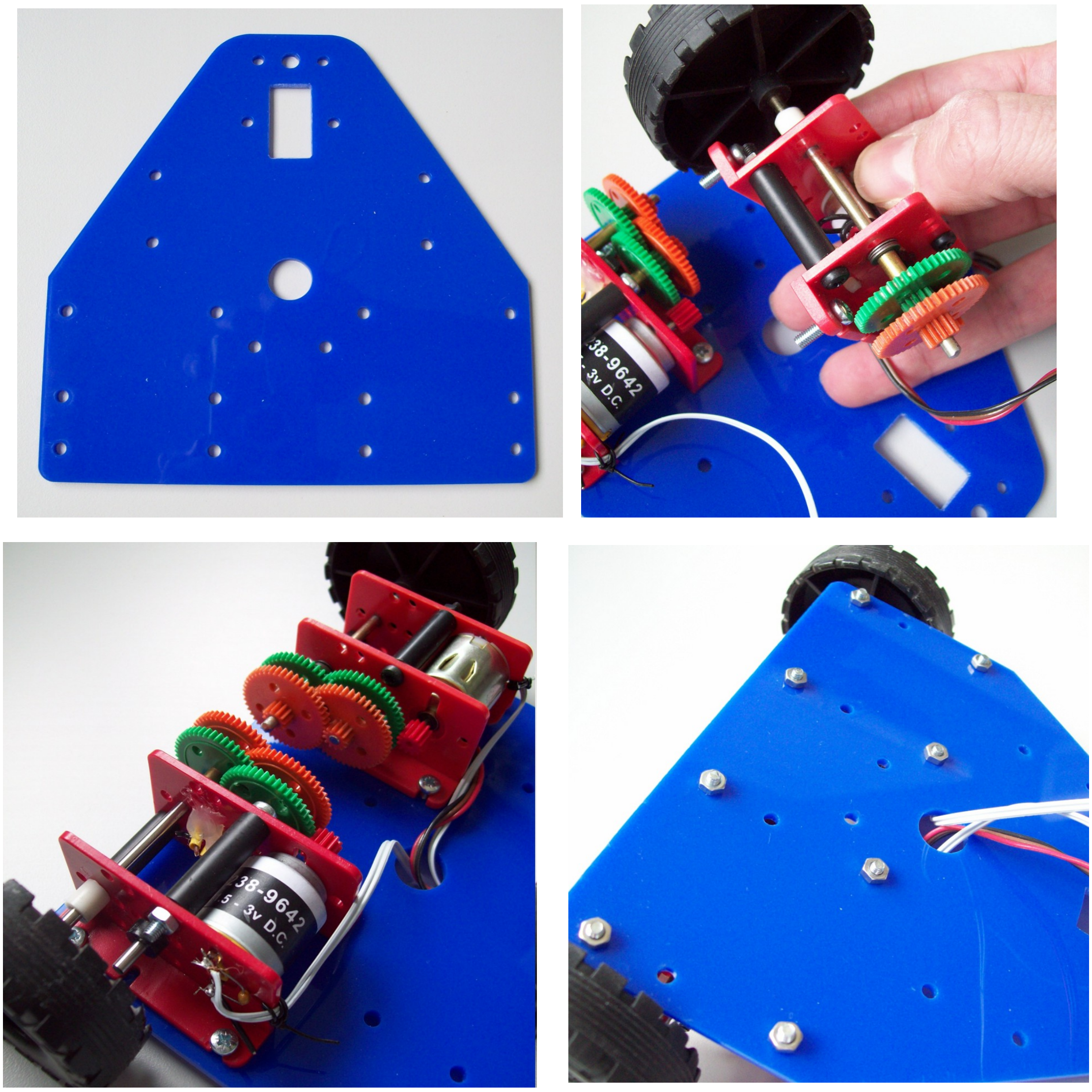
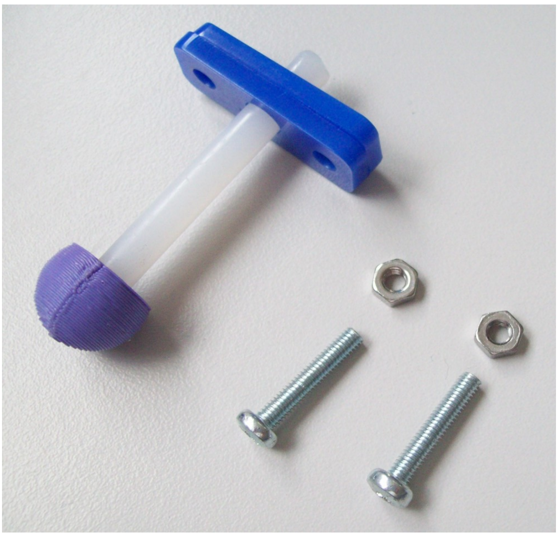


Figure 3: mounting drive motors

The front of the platform is supported by a skid. Using two 15mm M3 bolts (longer bolts) connect the skid to the platform, as shown in figure 4.



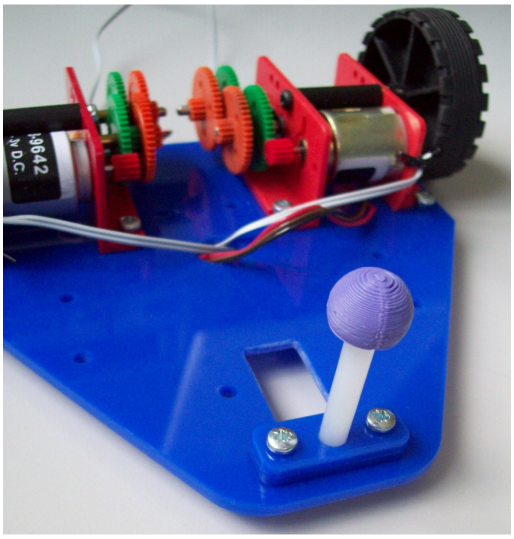


Figure 4: front skid

Servo Motor

A servo motor contains a small D.C. motor, a gearbox and control hardware, as shown in figure 5. Unlike the previous D.C. motors, when a voltage is applied the on-board hardware controller determines the position of the drive shaft i.e. 180 degrees rotation. To set the motor's position the servo is sent a voltage pulse every 20 ms (every 0.02 seconds), the width of the pulse determining the drive shaft's position, as shown in figure 6. A short pulse e.g. 0.6 ms wide, will cause the drive shaft to move to its maximum anti-clockwise position. A long pulse e.g. 2.4 ms wide, will cause the drive shaft to move to its maximum clockwise position.

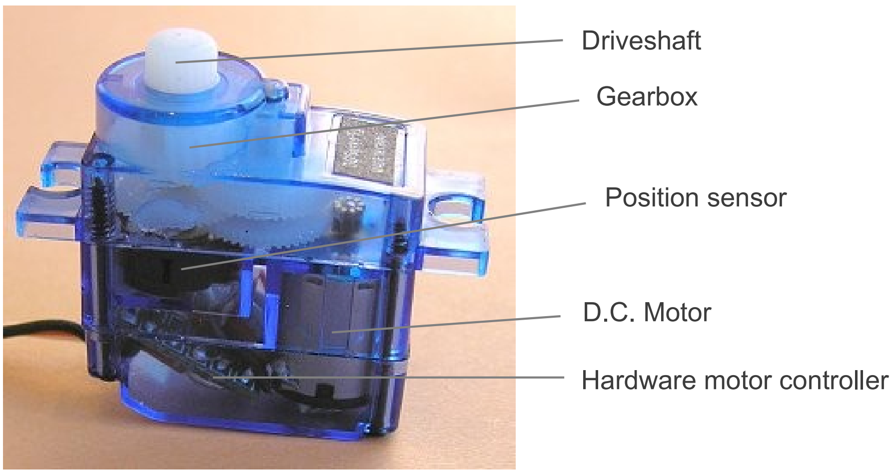


Figure 5: servo motor

Using the two blue plastic washers, clamping plate and two 15mm M3 bolts (longer bolts) connect the servo motor to the platform, as shown in figure 7.

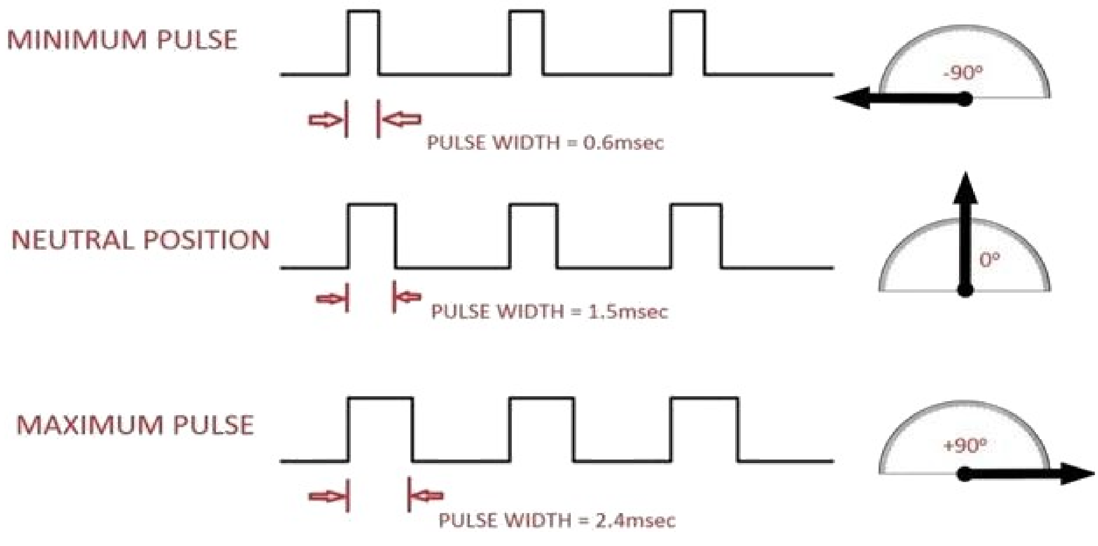


Figure 6: servo control signal (left), drive shaft position (right)

Tip Place the servo motor's wires through the rectangular hole first, then angle the motor housing down into the hole, it's quite a tight fit.

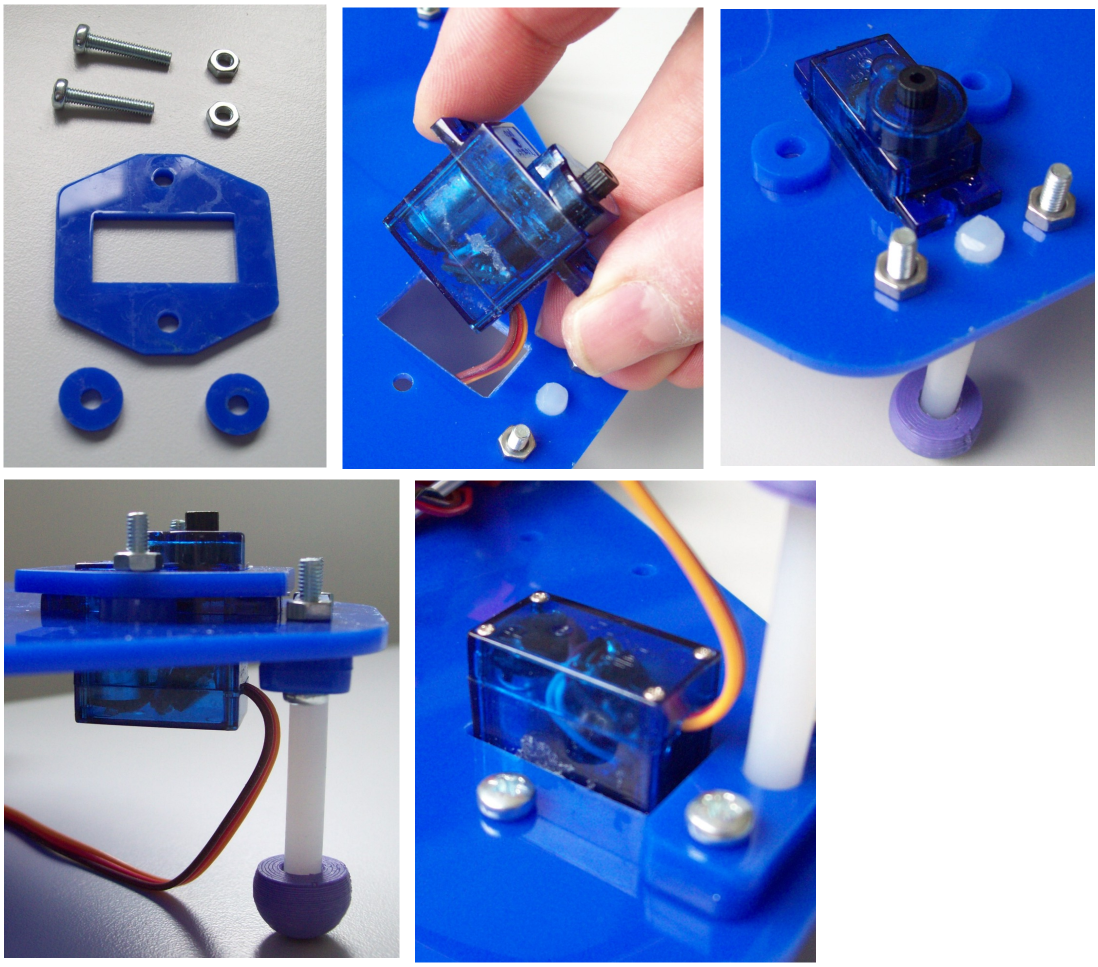


Figure 7: mounting servo

Ultrasonic Distance Sensor

To measure the distance to an object the robot has an ultrasonic sensor, as shown in figure 8. This sensor has a loud speaker that transmits an ultrasonic pulse, 40KHz, twice the frequency humans can hear. Knowing the speed of sound, the on-board hardware measures how long it takes for this sound wave to be reflected off an object and to travel back to its microphone, as shown in figure 9. This time is then converted into an output voltage pulse, its width is proportional to this distance, as shown in figure 10.

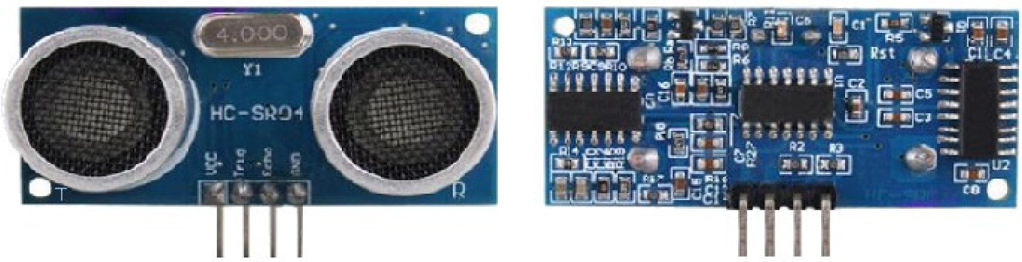


Figure 8: ultrasonic sensor

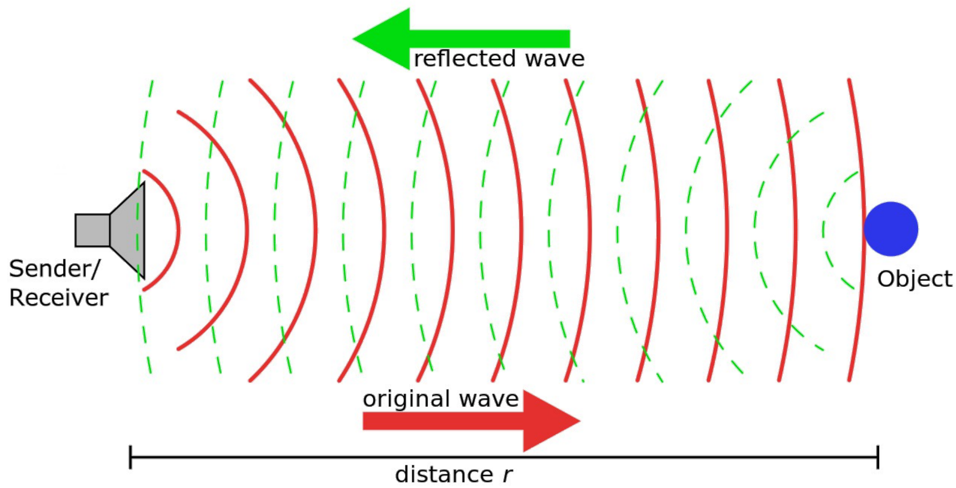


Figure 9: ultrasonic sound wave

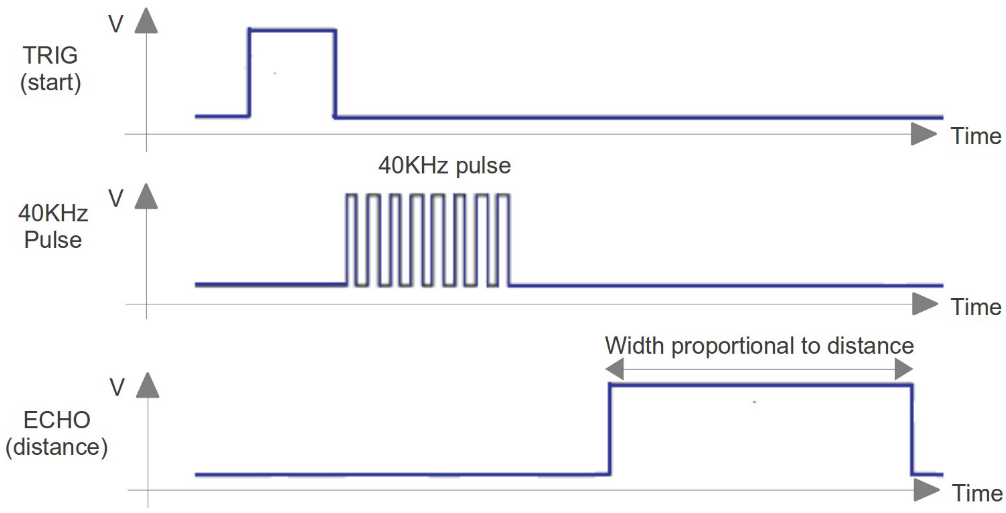


Figure 10: ultrasonic sensor output pulse

Place the ultrasonic sensor into the purple bracket, ensuring the connector (pins) is pointing upwards, then gently push this onto the servo drive shaft.

<u>**Tip**</u> When connecting the bracket to the servo you may need to 'jiggle' it a little until the small drive teeth mesh. Then supporting the bottom of the servo, push the bracket onto the drive shaft. Again finger tight is fine.

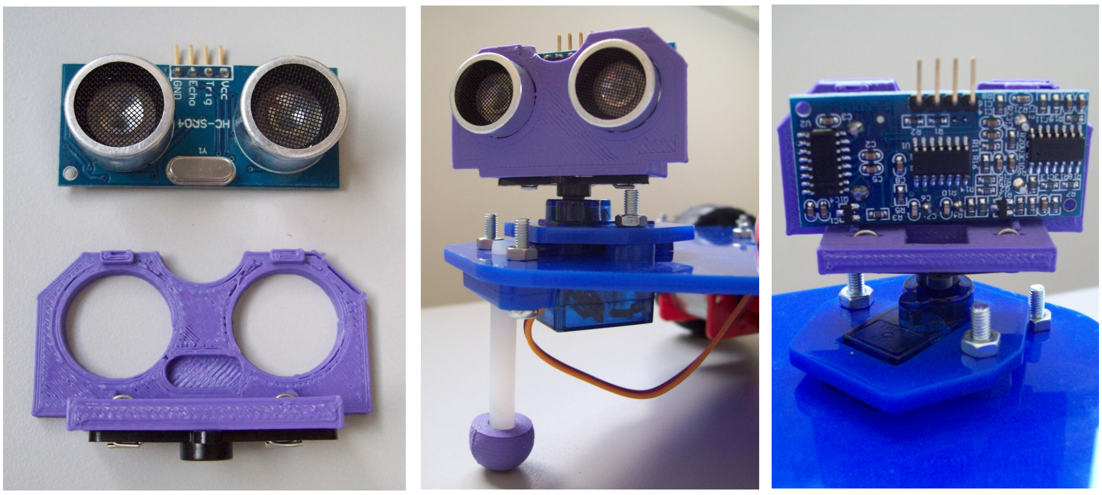
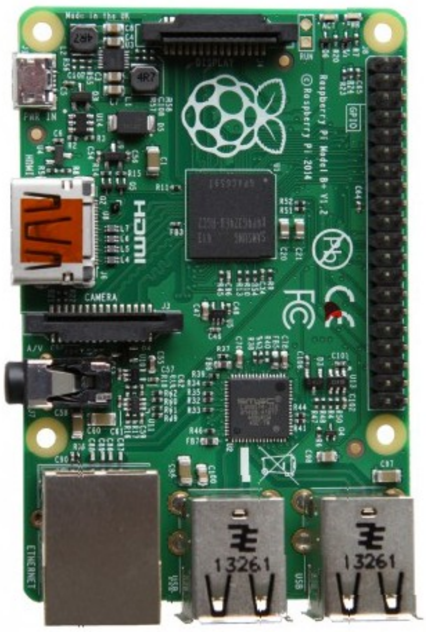


Figure 11: mounting the ultrasonic sensor

Controller

To control the motors and process the ultrasonic sensor data a Raspberry Pi single board computer will be used, as shown in figure 12. The Raspberry Pi has a number of General Purpose Input Output (GPIO) control pins. These are connected through the J8 header to the PiRoCon controller board, shown in figure 13, allowing the Raspberry Pi to be interfaced to the different sensors and actuators.



Raspberry Pi B+ J8 Header

Pin#	NAME	NAME	Pin#
01	3.3v DC Power	DC Power 5v	02
03	GPIO02 (SDA1 , I2C)	DC Power 5v	04
05	GPIO03 (SCL1 , I2C)	Ground	06
07	GPIO04 (GPIO_GCLK)	(TXD0) GPIO14	08
09	Ground	(RXD0) GPIO15	10
11	GPIO17 (GPIO_GEN0)	(GPIO_GEN1) GPIO18	12
13	GPIO27 (GPIO_GEN2)	Ground	14
15	GPIO22 (GPIO_GEN3)	(GPIO_GEN4) GPIO23	16
17	3.3v DC Power	(GPIO_GEN5) GPIO24	18
19	GPIO10 (SPI_MOSI)	Ground	20
21	GPIO09 (SPI_MISO)	(GPIO_GEN6) GPIO25	22
23	GPIO11 (SPI_CLK)	(SPI_CE0_N) GPIO08	24
25	Ground	(SPI_CE1_N) GPIO07	26
27	ID_SD (I2C ID EEPROM)	(I2C ID EEPROM) ID_SC	28
29	GPIO05	Ground	30
31	GPIO06	GPIO12	32
33	GPIO13	Ground	34
35	GPIO19	GPIO16	36
37	GPIO26	GPIO20	38
39	Ground	GPIO21	40

Figure 12: Raspberry Pi (left), GPIO pins (right)

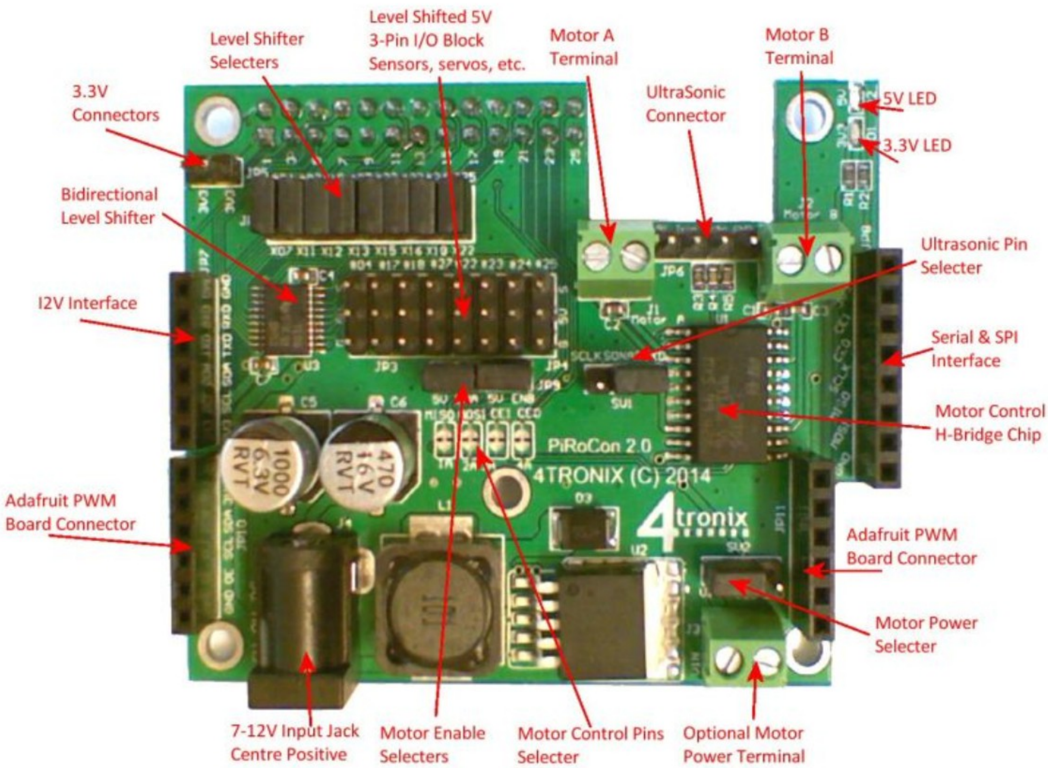


Figure 13: PiRoCon interface board

Connect the three way and four way cables to the ultrasonic sensor and servo motor. Ensure that the connectors are the correct way round. For the ultrasonic sensor the metal pins should be visible from the front. For the servo the yellow cable should be plugged into the pin marked with white paint. Finally secure all wires with the plastic clamp, as shown in figure 14.

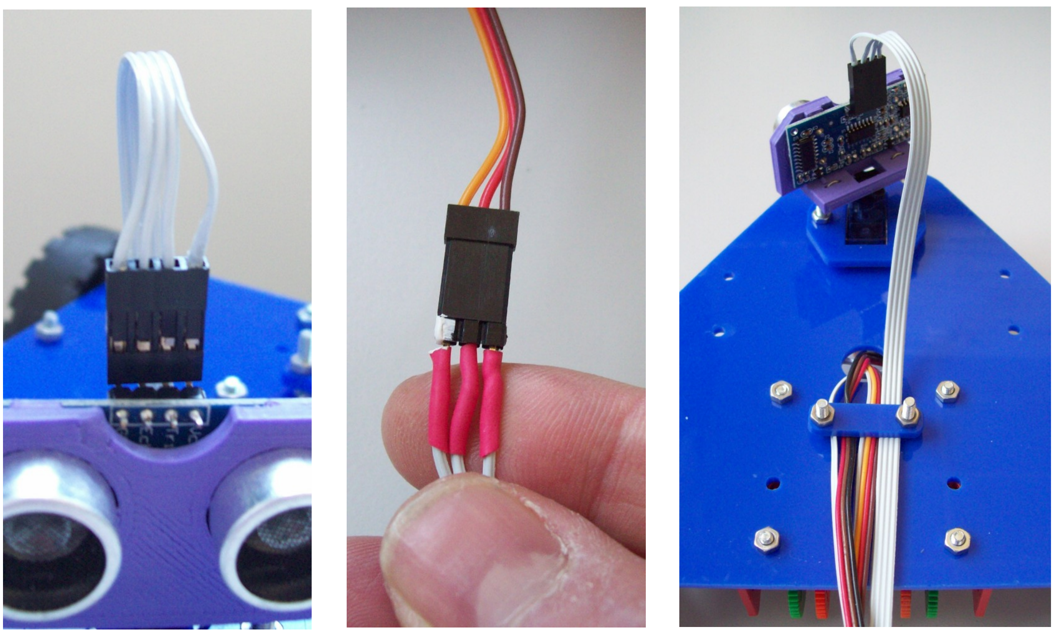


Figure 14: Wiring

The robot will be controlled using a Raspberry Pi, connect the D.C. drive motor wires to motor A & B terminals. Using the small instrumentation screwdriver connect the left motor (looking from below) to the left terminal (B) and the right motor to the right terminal (A). Wire orientation is not important at this time, if needed can be corrected later.

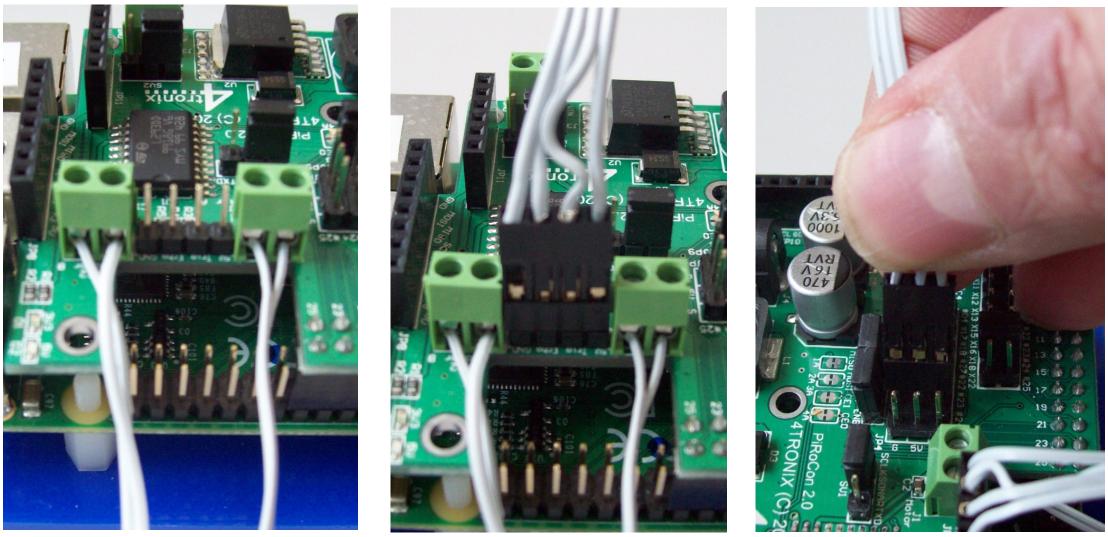


Figure 15: D.C. Drive motors (left), ultrasonic sensor (middle), servo (right)

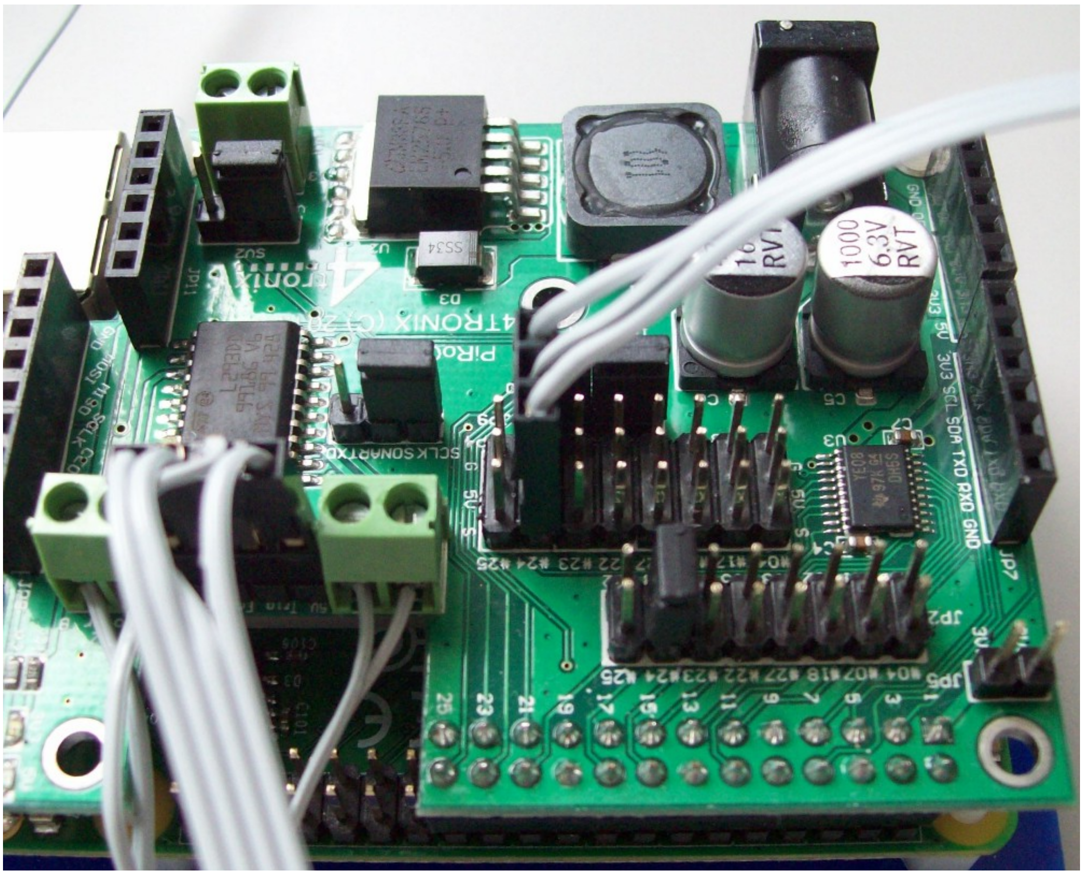


Figure 16: top view of Raspberry Pi + PiRoCon interface board.

Next connect the three way and four way connectors to the board, as shown in figure 15. Make sure that the connectors are orientated as shown.

Stage 2: manual control

When you have finished constructing your robot ask a demonstrator to quickly check your wiring, then turn on the Raspberry Pi. The robot's behaviour will be defined using the Scratch graphical programming language. Double click on the Scratch desktop icon, then click on the OK button, as shown in figure 18.

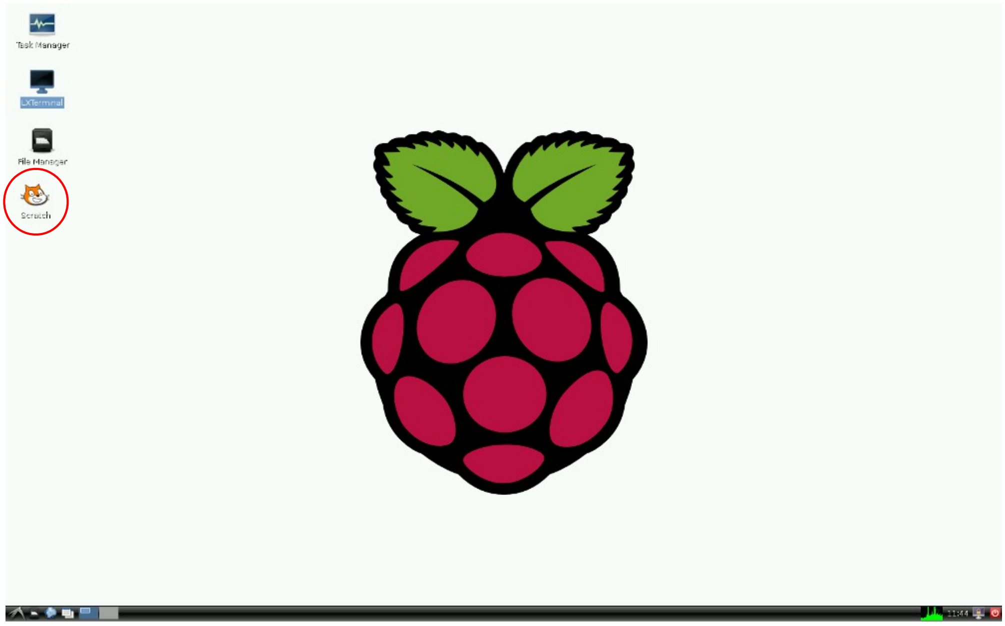


Figure 17: main screen

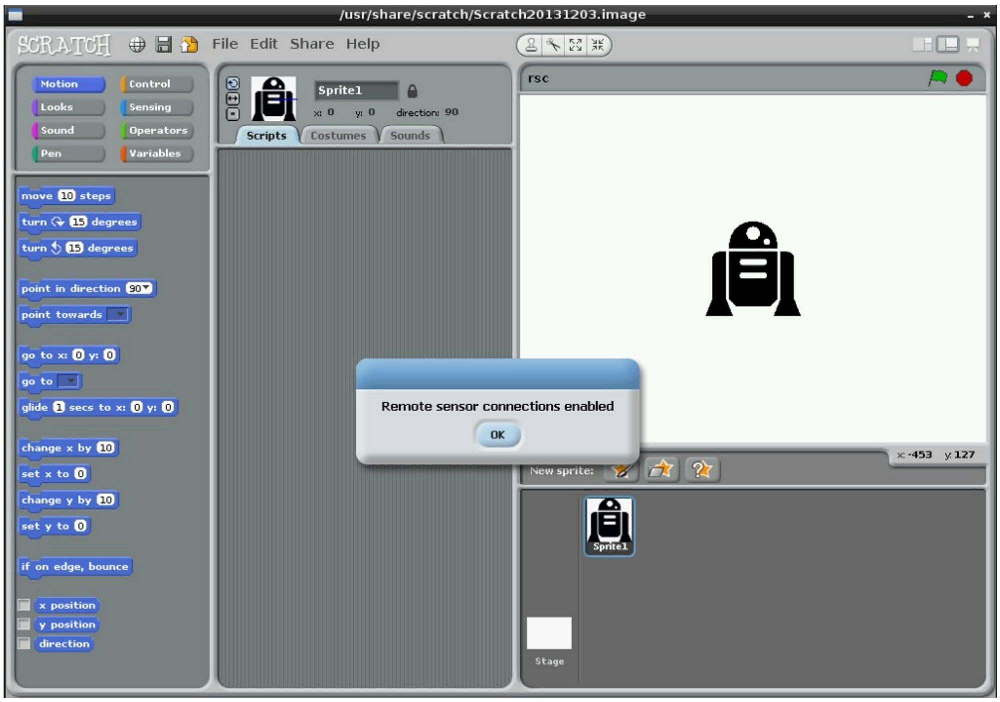


Figure 18: Scratch screen

The Scratch programming style is very similar to the Lego Mindstorm environment used in the other practical. You can select different programming tiles using the main menu in the top left hand corner, as shown in figure 19.

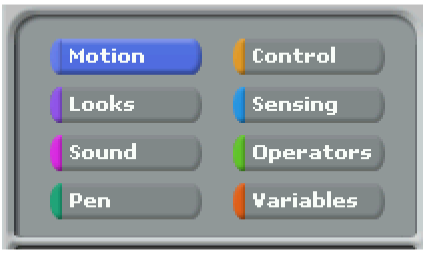


Figure 19: Scratch main menu

To control external components e.g. servo, D.C. drive motors etc, a set of python functions have been written. Scratch communicates with these using predefined variable names, plus the GPIO pin number used. Click on the "Variables" tab Variables on the main menu. This will open the Variables panel. Next select "Make a variable" Make a variable and enter the name `Servo18`. The key word `Servo` tells Scratch to use the python servo control routines on GPIO pin 18.

The servo control software can be assigned a value from +90 to -90 degrees. This will rotate the drive shaft as shown in figure 6. Click on the "Control" tab Control on the main menu. Drag and drop the yellow tiles shown in figure 20 into the centre panel, then use the pull down menu option within the tile to select "up arrow" and "down arrow".

<u>Tip</u> To delete a tile right click on the tile and select delete, alternatively click on the delete icon from the top toolbar.

Figure 20: servo control

Click on the "Variables" tab Variables on the main menu. Drag and drop the orange tiles shown in figure 20 into the centre panel, ensuring that they 'snap' onto the correct control tile. Then use the pull down menu option within the tile to select the `Servo18`, setting the values 0, 10 and -10.

To start this program click on the green Go flag. This will initialise the servo to it centre position. If the sensor bracket is not facing forwards gently remove it from the servo drive shaft and reposition. Pressing the up and down cursor keys will now cause the servo motor to rotate clockwise and anti-clockwise (the active script will flash when triggered).

WARNING telling the servo to move to a position it cannot move to e.g. 100 degrees will cause the motor to burn out. Always ensure you finish a test with the servo in its 0 position i.e. facing forwards.

To stop the `Servo18` variable being assigned an illegal value click on the "Operators" tab 

and select the relational operator >. Add this function and the tiles shown in figure 21 to the "up arrow" script, so that if the value of `Servo18` is greater than 80 it will be reset back to 80.

Tip, the servo should be able to rotate from +90 to -90, but to be safe set the limits to +80 to -80.

Figure 21: servo limit tiles

Repeat this functionality for the "down arrow" script using the < relational operator. If you are not sure what this should look like the answer is in the Appendix at the end.

The two D.C. drive motors are controlled by four control signals, two per motor, as shown in table 1. A `True` indicates that the associated pin outputs a logic '1' i.e. +3 volts, a `False` indicates that the associated pin outputs a logic '0' or 0 volts.

	Pin 7	*Pin 8*	*Pin 9*	*Pin 10*
Forwards	TRUE	FALSE	TRUE	FALSE
Backwards	FALSE	TRUE	FALSE	TRUE
Rotate Left	FALSE	TRUE	TRUE	FALSE
Rotate Right	TRUE	FALSE	FALSE	TRUE
Stop	FALSE	FALSE	FALSE	FALSE

Table 1: motor control signals

Click on the "Variables" tab 

on the main menu. Next, make the variables: `gpio7`, `gpio8`, `gpio9` and `gpio10`. The key word `gpio` tells Scratch to use the python general purpose input output control routines on GPIO pins 7,8,9 and 10. If these variables are assigned a `0` they will output a logic '0'. If they are assigned a non zero value they will output a logic '1'. Drag and drop the yellow and orange tiles shown in figure 22 into the centre panel and configure as previously described.

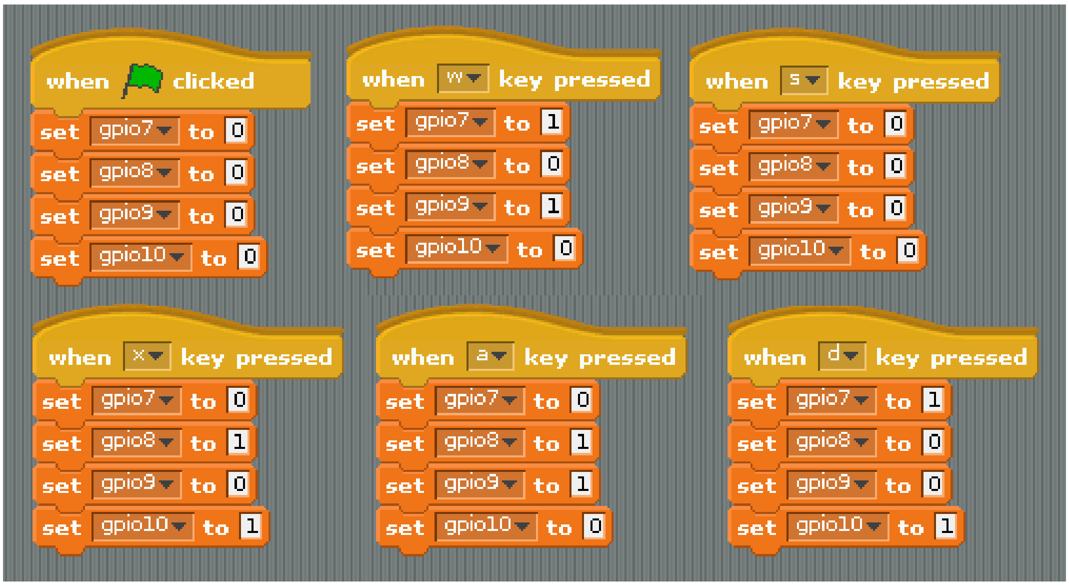


Figure 22: D.C. drive motor control

To start this program click on the green Go flag . This will initialise the D.C. drive motors into the Stop state. Pressing the `W` key should make the robot move forwards. If it rotates one of the drive motors is wired the wrong way round. You will need to unscrew the motor wires for the motor rotating backwards and swap the wires over. If the robot moves backwards both motors have been wired the wrong way round.

You should now be able to drive your robot around the desk using the following keys:

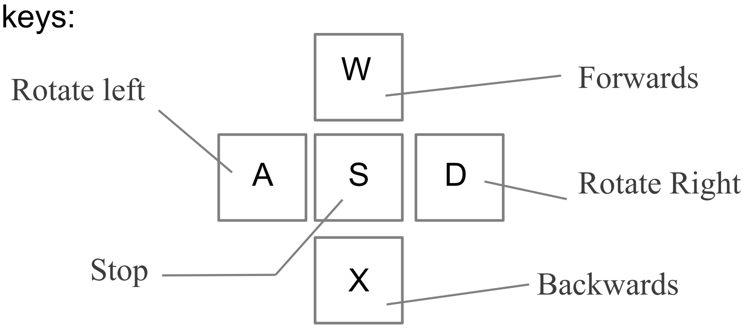


Figure 23: direction controls

To improve the robot's controllability add the scripts to allow:

Turn Left Forwards	-	Q key	-	Left motor stop, Right motor forwards
Turn Right Forwards	-	R key	-	Left motor forwards, Right motor stop
Turn Left Backwards	-	Z key	-	Left motor backwards, Right motor stop
Turn Right Forwards	-	C key	-	Left motor stop, Right motor backwards

In addition to controlling actuators Scratch can also process input data. To print the ultrasonic sensor data to the screen click on the “Looks” tab ,  on the main menu. Drag and drop the purple “Say for” tile into the centre panel. Next click on the “Sensing” tab , selecting the “Sensor value” tile, complete the script show in figure 23.

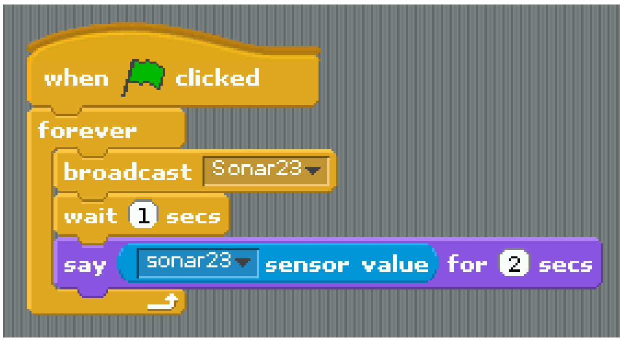


Figure 23: ultrasonic sensor

Within the broadcast tile click on the pull down menu, adding a new broadcast message `Sonar23`. When this message is sent the python software associated with the ultrasonic sensor is triggered, sending out a sound pulse. The system then waits for 1 second, allowing the reflected signal to be received and processed before printing out its distance value.

Tip You may have to run this script once i.e. click on the green Go flag  to be able to select `Sonar23` in the “Sensor value” tile.

The system will now measure the distance from the robot every two seconds.

Stage 3: automatic distance control

Place the plastic box directly in front of the robot, approximately 20cm away. Using the ultrasonic sensor design a scratch program to automatically maintain a fixed distance between the box and the robot. Test your program by moving the box backwards and forwards.

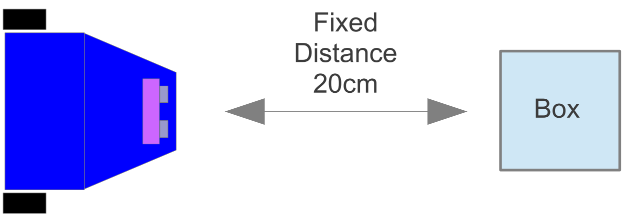


Figure 24: reactive control

Tip to avoid jitter i.e. small movements caused by variations in the distance measurements you may need to define ranges for which readings are considered the same e.g. the robot is in range if the distance is 20cm +/- 1cm.

Stage 4: automatic guidance control

A target (the plastic box) is placed anywhere in the front arc of the robot, approximately 30cm away. Design a scratch program to automatically locate this object and guide the robot to it.

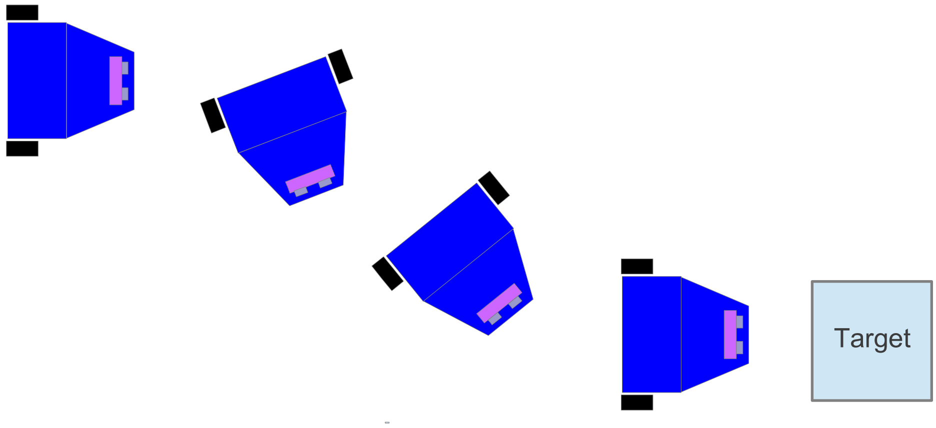
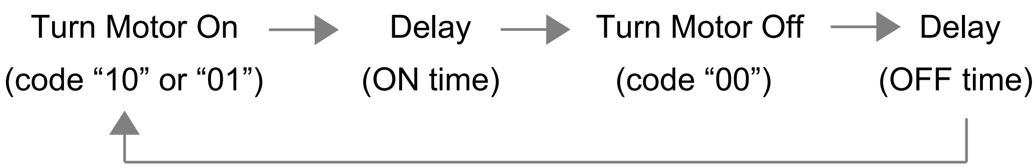


Figure 25: movement control

<u>**Tips**</u> There are a lot of different ways to solve this problem, from the very simple to the more complex. My first attempt was towards the overly complex. Use the servo and ultrasonic sensor to scan 180 degrees, record the maximum and minimum angle at which an object at 30cm was detected. Objects over this range are ignored, you can assume there is only one object. The average of these angles is the direction of travel. Through observations calculate the relationship between motor on-time and angle turned. Using this information the platform can be rotated the required angle, then moved forwards. This process is repeated until the target is reached.

Stage 5: speed control

As a rule of thumb in robotics things that you think will be easy tend to be difficult and things that you think will be tricky are easy e.g. making a robot go in a straight line is very tricky. This is due to random variation in the environment, mechanical and electrical components used. Variations in motor speeds can be compensated for by slowing down the speed of the faster motor to that of the slower. To do this power to the fast motor can be modulated i.e. switched on and off at <u>high speed</u>, now the ratio of ON time to OFF time determines the motor's speed.



Modify your manual control scratch program to use this technique i.e. so that the robot goes in a straight line rather than a curve.

Appendix A : Answers

Perhaps not the best solution i.e. Servo18 is updated, then corrected, but it can just be added to the existing scripts.

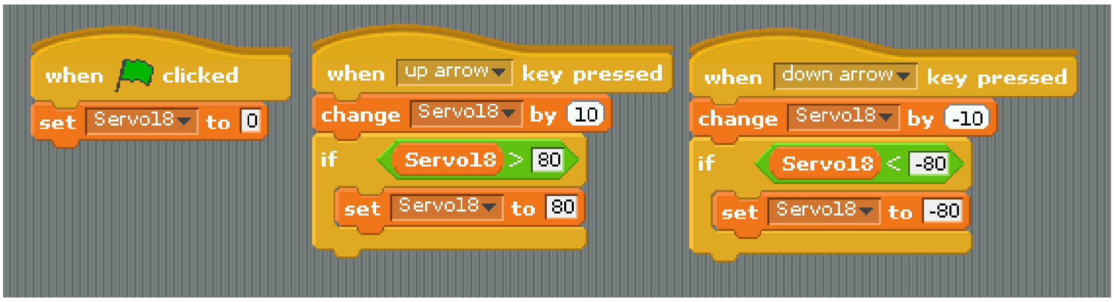


Figure A1: servo limits

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