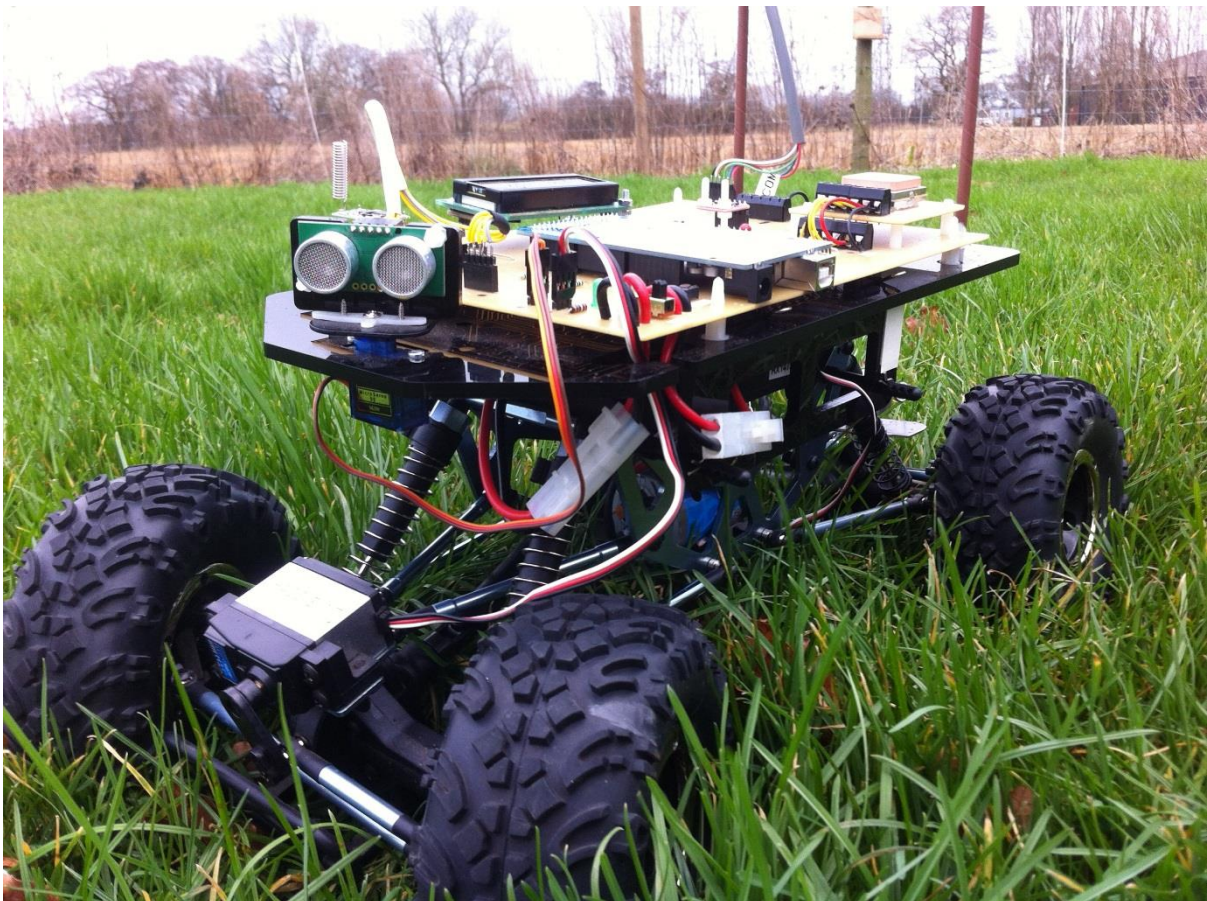# Welcome to Programming a GPS enabled robot using the Arduino.

Presented by Sam Wane, Senior Lecturer

swane@harper-adams.ac.uk

Harper Adams University

Contents

Make it move, then make it perfect – **David Tseng, CAVEDU Education**

The robot hardware

The robot car is built from a standard radio control all-terrain vehicle known as a Maverick. It is a four wheel drive, independent suspension vehicle allowing it to cope with rough terrain.

- **Examine the chassis. Discuss why this vehicle is so well suited to rough terrain.**

The chassis has two motors, a drive motor and a steer motor. These are connected to the microcontroller board through the 'servo motor interface' plugs. The drive motor also has its own separate switch (for safety-we don't want it zooming off the table!) on the chassis close to the interface plug.

- **Locate the motor interfaces, ensure they are plugged in correctly. Locate the drive motor switch and ensure it is switched off!**

Note that the motors are driven from the onboard battery and will only work when the switch (bottom left) is on. Leave it off for now.

There is a variety of sensors on the microcontroller board, these are all connected to the microcontroller.

- **Identify the items below on your vehicle. Discuss how you think the information from the sensors is passed to the microcontroller.**
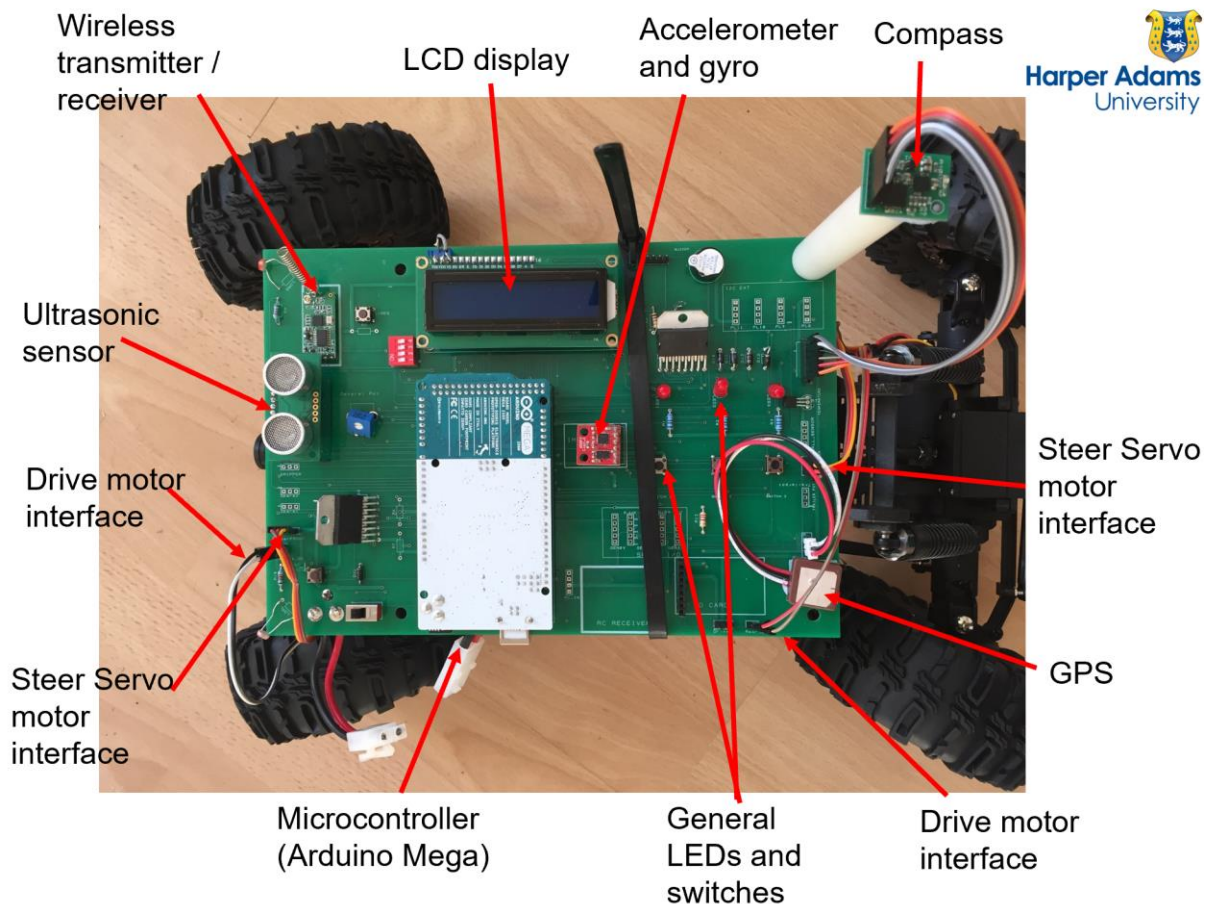
Figure 1 The Robot Hardware

Installing and setting up the IDE

IDE stands for 'Integrated Development Environment', and this is the place where you write programs and download to the Arduino microcontroller from the PC.
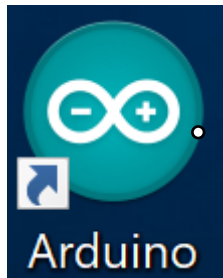
This can be downloaded from www.arduino.cc if not installed already.

Install the Arduino IDE: https://www.arduino.cc/en/software

Arduino Web Editor

Start coding online and save your sketches in the cloud. The most up-to-date version of the IDE includes all libraries and also supports new Arduino boards.

CODE ONLINE   GETTING STARTED
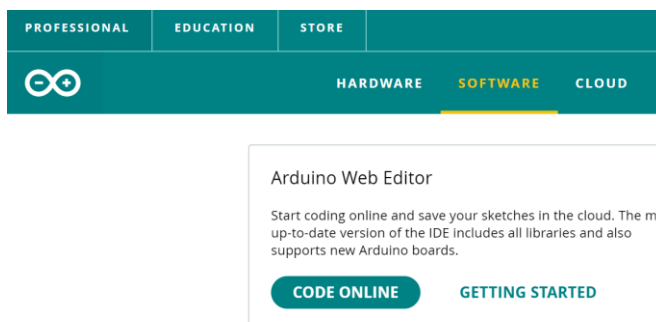
Downloads

The Atlas library

The library is to be installed in the Libraries folder of the Arduino IDE. To find this location, Open the Arduino IDE, select: File→Preferences. Copy the files into the Sketchbook location / libraries folder. E.G. in the example below this would be: C:\Users\00708160\Documents\Arduino\libraries
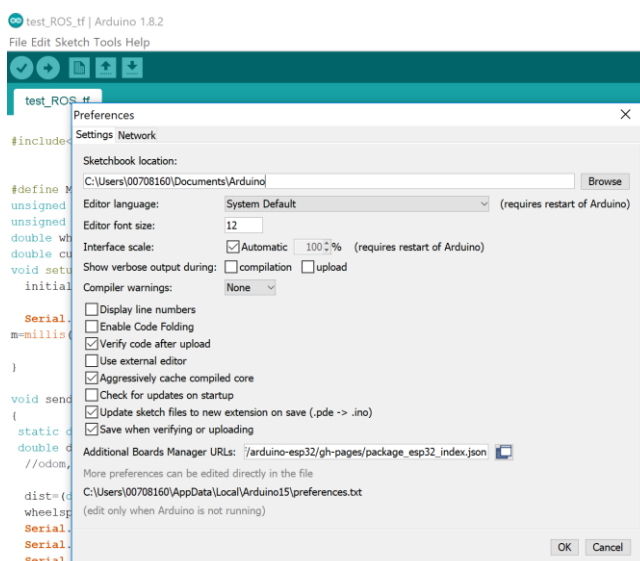
Install the library from the USB stick or from Git Hub location: https://github.com/swane/atlas

Name	Date
📁 examples	15/11
ATLAS.cpp	24/11
ATLAS.h	24/11
deg2utm.cpp	19/03
deg2utm.h	19/03

The library is included in the program and allows easy access to the hardware of the robot.

Now, use the Library manager to search and install the following libraries. To do this, from the menu select: Sketch→Include Library→Manage Libraries. Then enter the following one by one into the search box and click the 'Install' button for each one:

- NeoGPS - https://github.com/SlashDevin/NeoGPS
-
- FreesixIMU ÷ https://github.com/simondlevy/FreeSixIMU2
- VarSpeedServo
- SD (installed already with the IDE)
- SPI (installed already with the IDE)
- LiquidCrystal (installed already with the IDE)
- SoftwareSerial (installed already with the IDE)

1. Close and restart the IDE
2. You can check if the library has installed from the IDE by selecting: Files→Examples→ ATLAS. You should see the example programs.

Connecting the robot to the computer

Connect the microcontroller in the robot to the PC using a suitable USB cable.

Now we will set the IDE to the correct COM port and board.

1. Under the menu **Tools→Board**, select 'Arduino / Genuino Mega or Mega 2560' (figure 2)
2. Under the menu **Tools→Port**, select the COM port with the 'Arduino / Genuino Mega', (this will be a port number higher than COM1), figure 3.
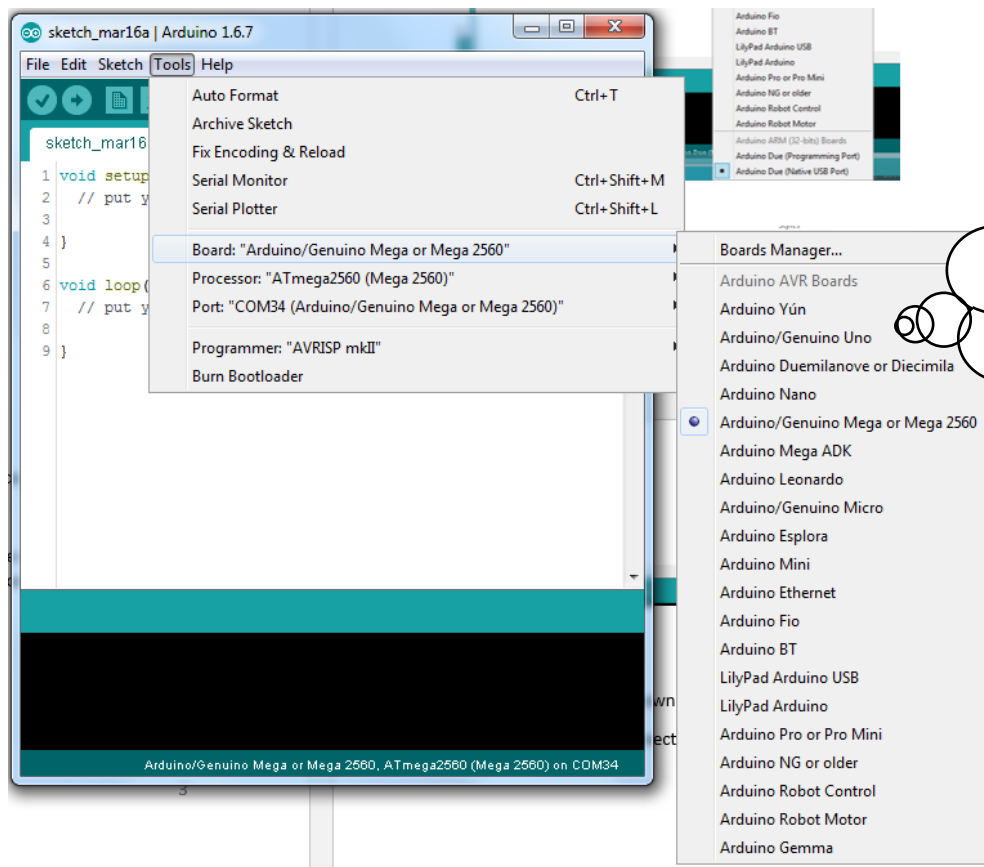
Figure 2 Selecting the Arduino type
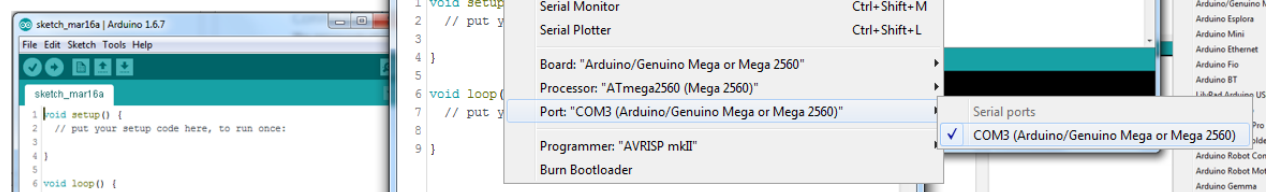
Figure 3 Selecting the Com port

3. Select **File→New**.

An empty program with 'void setup()' and 'void loop()' will be shown as in fig 3. This is where you will write your program.
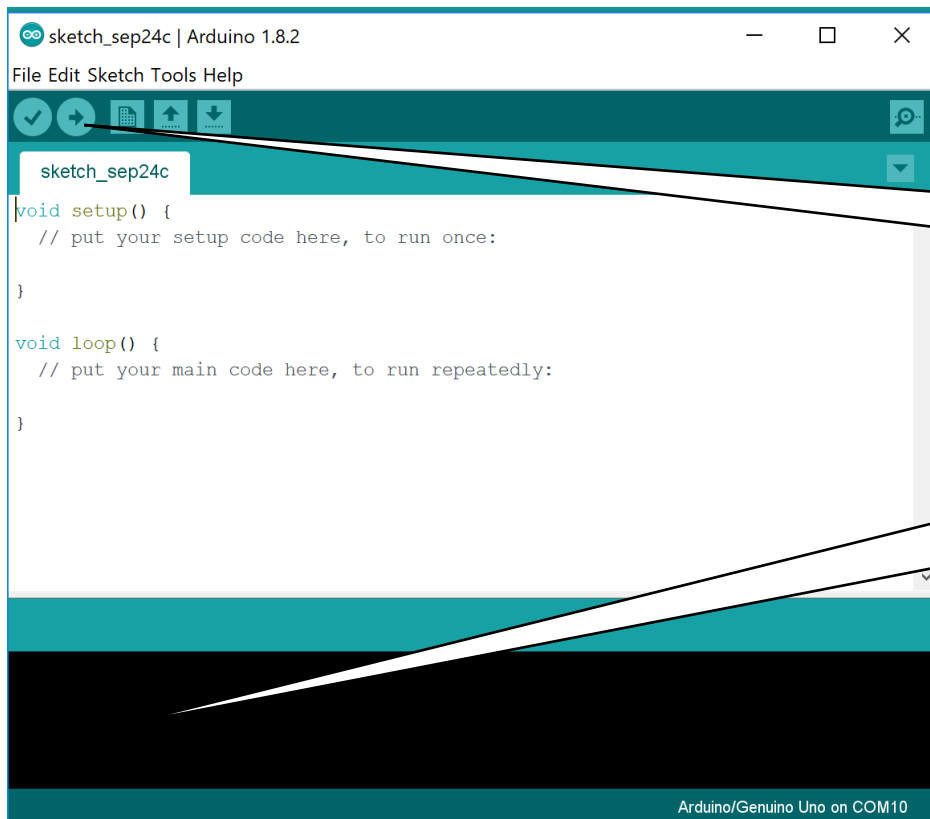
Figure 4 Empty program and how to upload

You can now write your program in here. Press the right-arrow icon to upload and run once you have entered your program.

The 'setup()' section is used to initialise the hardware of the robot (it runs once and sets things up).
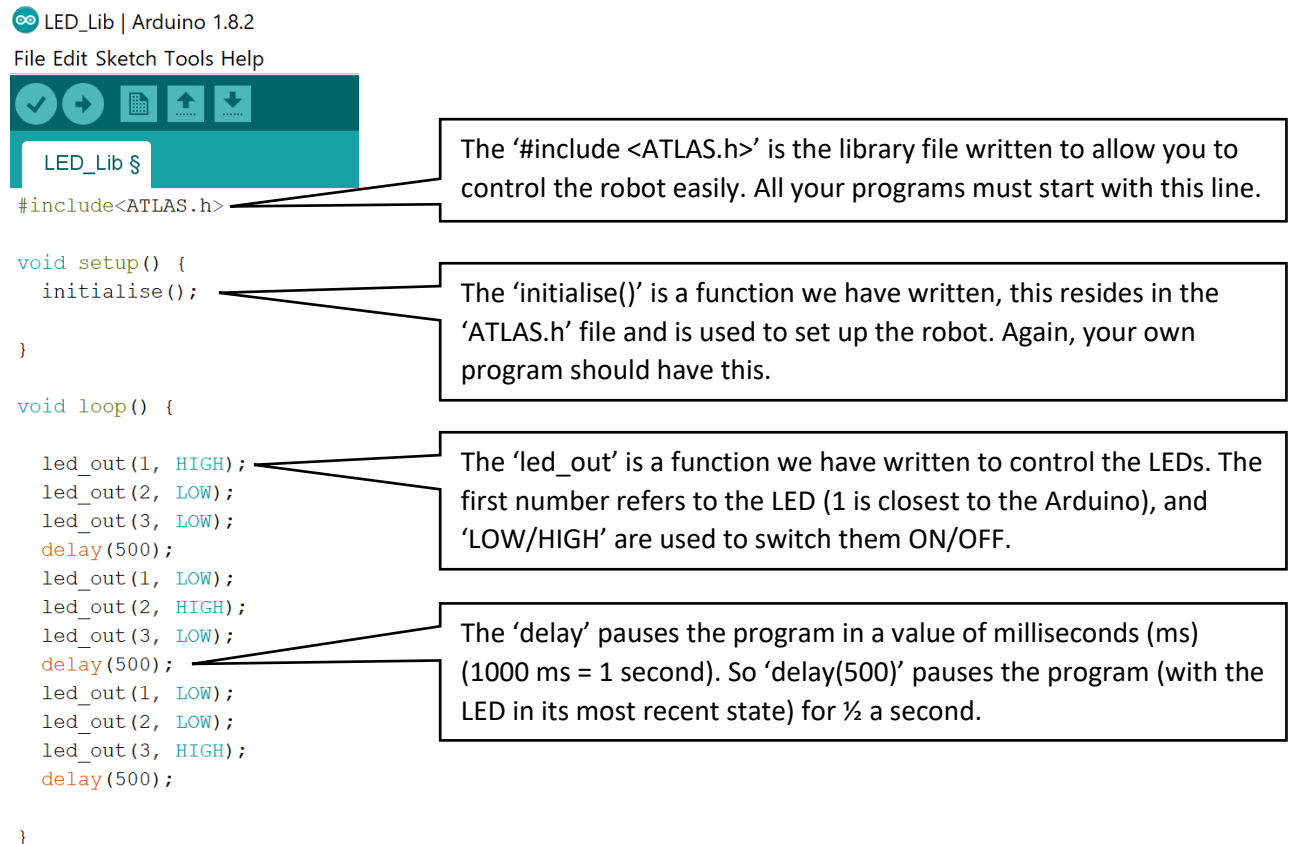
The 'loop()' runs continuously and is where your program runs in a loop.

Now, time to put in your first program, so let's start…

First program-Flashing LEDs

Select 'File→Examples→Atlas→LED'.

Your program should look like this:

LED_Lib | Arduino 1.8.2

File Edit Sketch Tools Help

LED_Lib §

```
#include<ATLAS.h>

void setup() {
  initialise();

}

void loop() {

  led_out(1, HIGH);
  led_out(2, LOW);
  led_out(3, LOW);
  delay(500);
  led_out(1, LOW);
  led_out(2, HIGH);
  led_out(3, LOW);
  delay(500);
  led_out(1, LOW);
  led_out(2, LOW);
  led_out(3, HIGH);
  delay(500);

}
```

The '#include <ATLAS.h>' is the library file written to allow you to control the robot easily. All your programs must start with this line.

The 'initialise()' is a function we have written, this resides in the 'ATLAS.h' file and is used to set up the robot. Again, your own program should have this.

The 'led_out' is a function we have written to control the LEDs. The first number refers to the LED (1 is closest to the Arduino), and 'LOW/HIGH' are used to switch them ON/OFF.

The 'delay' pauses the program in a value of milliseconds (ms) (1000 ms = 1 second). So 'delay(500)' pauses the program (with the LED in its most recent state) for ½ a second.

Figure 5 Flash LEDs Program

You will find a list of the functions in the Appendix.

- **Now, upload the program to the Arduino by using the 'Upload' button as shown below:**

File Edit Sketch Tools Help

Upload
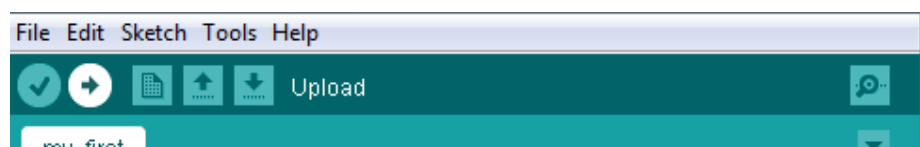
my first

The robot should flash the LEDs as in the program.

In order to understand the program, let's make some changes, but first, save it under a new name:

- **Now, use 'save as' to save the program under 'Documents' and give it the name 'my first'.**
- **Try changing the program, for example, you can change the delay time, or delete which LEDs are accessed.**
  Note that the end of each line has to have a semi-colon (;), this is a C programming standard.

More basic programs

There are many commands which are defined n the Atlas library, a full list is in the Appendix. This section is here to introduce and to whet your appetite for what the robot can do.
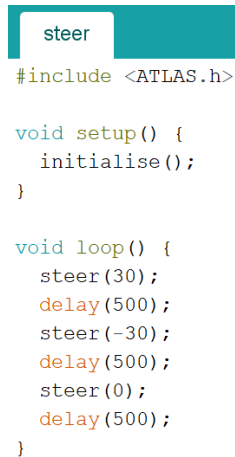
Steer

The robot can steer to an angle, this is called with:

steer(*angle*);

where *angle* is a value between -40° to 40°. Positive angles are turning to the right, 0° is straight ahead.

Try this program, either from the 'Examples→Atlas→Steer', or you can type it in:

```
steer
#include <ATLAS.h>

void setup() {
  initialise();
}

void loop() {
  steer(30);
  delay(500);
  steer(-30);
  delay(500);
  steer(0);
  delay(500);
}
```

Upload the program as before and ensure the main robot power is ON.

Drive

The robot will drive the motors:

drive(*speed*);

where *speed* is in m/s and is approximate. Positive values drive forwards, negative values are backwards, zero is stop. The maximum value is 1. There is a minimum value that is needed to get the robot moving due to friction, and this is approximately 0.5.

The example below is under 'Examples→Atlas→Drive':

```
#include <ATLAS.h>


void setup() {
  initialise();

}

void loop() {
  drive(1);
  delay(2000);
  drive(0.7);
  delay(1000);
  drive(0);
  delay(1000);
  drive(-0.7);
  delay(1000);
  drive(-1);
  delay(1000);
  drive(0);
  delay(1000);
}
```

Reading sensors

The ultrasonic distance sensor is accessed through:

read_distance();

and returns the distance to the robot in cm.

This can be shown on the LCD screen and the example in 'Examples→Atlas→distance' shows this.

This can also be shown on the PC if it is still connected via the USB, and the following demonstrates how:

Upload the 'distance' program on the Arduino.

Open up the Serial Monitor:
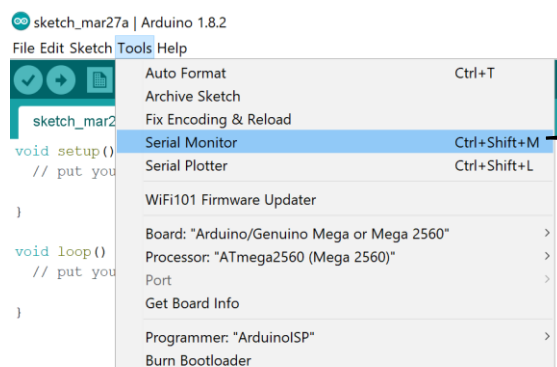
This opens up a new window where you can see data coming from the Control Rig/Arduino.

You should see the values on the PC.

You can close the Serial Monitor and open Serial Plotter if you'd like a graphical display.

Compass connection

The compass is read in 'Serial' mode. The device is a CMP12 available at https://www.robot-electronics.co.uk

The Tx and Rx are swapped on the PCB. The compass is to be mounted away from motors and any other magnetic interference.
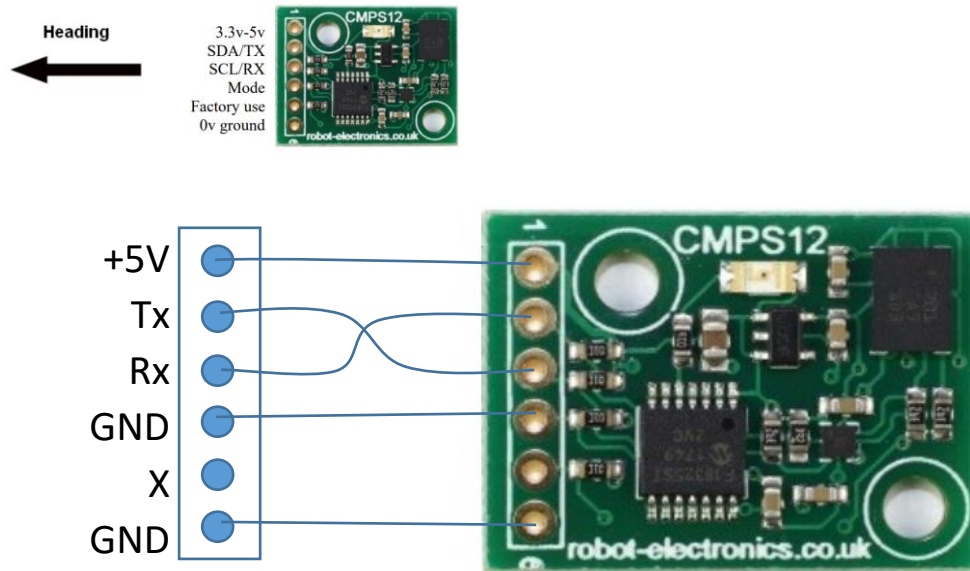
Connections as shown

The command 'read_compass()' returns the heading in 0-360.

Temperature

The temperature sensor is type TMP36.

The command 'temp()' returns a floating point value of the temperature. This is converted from an analogue voltage as in the datasheet diagram below:
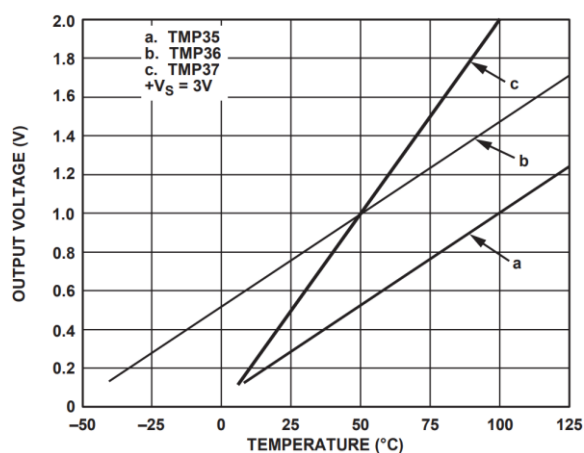
Wireless communication

HC-11

The wireless device uses a HC-11 wireless RS232 transceiver connected to Serial 2 at 9600 baud.

It is set up using AT commands and there is an example program to do this. It can also be set in the Atlas test program. When setting it up, the CON button to the right must be held during this procedure.

Data is send by using Serial.write(data) and read using Serial.read().

e.g.

```
Serial2.write("1");
and:
if (Serial2.available()) {
    c=Serial2.read();
    Serial2.flush();
    lcd.setCursor(0, 1);
    if (c=='1') {led_out(2, HIGH);lcd.print("ON ");delay(200);}
     {lcd.setCursor(0, 1);led_out(2, LOW);lcd.print("OFF");}
More examples are in:
HC-11_Setup
HC-11_Send_AB
```

Note, the HC-11 can be prone to hang. To reset, remove all power, then connect power whilst holding the CON button. Then the AT commands can be sent to set it up.

RC Control

The slot for the RC receiver can allow two signals from a remote control receiver to send data to Atlas. RC receiver pulses are received from a paired transmitter. The pulses vary in length from 1-2ms depending on the control stick position.

These are read using the commands: RC_steer -data on channel 1, and RC_speed-data on channel 2. These functions return a double value in the range of -1 to +1, with 0 being the resting position of the control sticks.

The receiver is connected to the +7.2V, GND, channel1 and channel2. It operates even when only USB power is applied to the Arduino.

 For speed on channel 2, +1=fastest, 0=stop, -1=reverse

For steer on channel 1, +1=full right, 0=straight, -1=full left

 It has a 50 ms timeout, so if communication is lost, it will not halt the program. A 2.0 is returned if communication is lost.

General I/O

Analogue ports are referred to as GENA*portnumber* and range from GENA1 to GENA5

e.g. a=analogRead(GENA1);

Digital ports are referred to as GEND*portnumber* and range from GEND1 to GEND5.

e.g. a=digitalRead(GEND1);

digitalWrite(GEND1,HIGH);

They are set as inputs with internal pull up resistors, but this can be changed with:

pinMode(GEND1,OUTPUT);

pinMode(GEND1,INPUT);

pinMode(GEND1,INPUT_PULLUP);

Pin name	Actual pin
GENA1	A11
GENA2	A12
GENA3	A13
GENA4	A14
GENA5	A15
GEND1	30
GEND2	33
GEND3	32
GEND4	23
GEND5	3

Calibration

The steering angle zero offset along with other values can be fine-tuned for each vehicle once built. These offset values are stored in the EEPROM of the Arduino.

The EEPROM is addressed from 0 onwards and can store bytes only. The first value (at address 0) is set to 170 (10101010 in binary) if calibration has occurred, otherwise, standard pre-programmed values (in the ATLAS.cpp) file are used. The following table states the EEPROM values:

0	Notification if calibration has occurred
1	Front zero angle offset
2	Rear zero angle offset
3	Front max left
4	Front max right
5	Rear max left
6	Rear max right
7	Compass offset

Programs to accomplish calibration:

Calibrate_steer	Allows the front and rear steer servos to have a zero and min / max angles
Calibrate_compass	Allows the compass offset to be calibrated

Using Calibrate_steer

The program is found under Examples/Atlas/Calibrate_steer

This allows the min / max steering angles and the zero (straight ahead) offsets to be defined.

The DIP switches are used to define the function of the program. These are all raised when OFF (0) and ON (1) when pressed down.

DIP Switch operation

1-nearest top of PCB, 4-closest to Arduino 1234

0000-MIDDLE BUTTON DRIVES FORWARDS

1000-CENTRE FRONT STEER (btn1, btn3 -adjust left/right, btn2=store new offset)

1100-MAX/MIN RIGHT FRONT STEER (btn1, btn3 -adjust left/right, btn2=store new min or max)

0001-CENTRE REAR STEER (btn1, btn3 -adjust left/right, btn2=store new offset)

See YouTube video: https://youtu.be/mPYK9m0PjBs

Using Calibrate_compass

The program is found under Examples/Atlas/Calibrate_compass

The LCD shows the current bearing. Button 1 increases the bearing, Button 3 decreases the bearing, Button 2 resets the offset to zero.

After each button press, the value is stored into EEPROM for access next time it is switched on. The calibration will be fixed and work for any future program.

Aim point to minimise cross track error

In order for the mobile robot to follow a desired path, the robot bearing, path bearing, and the robot deviation from the path need to be considered. The robot bearing is sensed using an onboard compass, the path bearing is calculated from knowing the start and end latitude and longitude coordinates, the position of the robot is sensed using GPS, and the tangential distance from the robot to the desired trajectory line is calculated, referring to fig. 4, and using vectors.
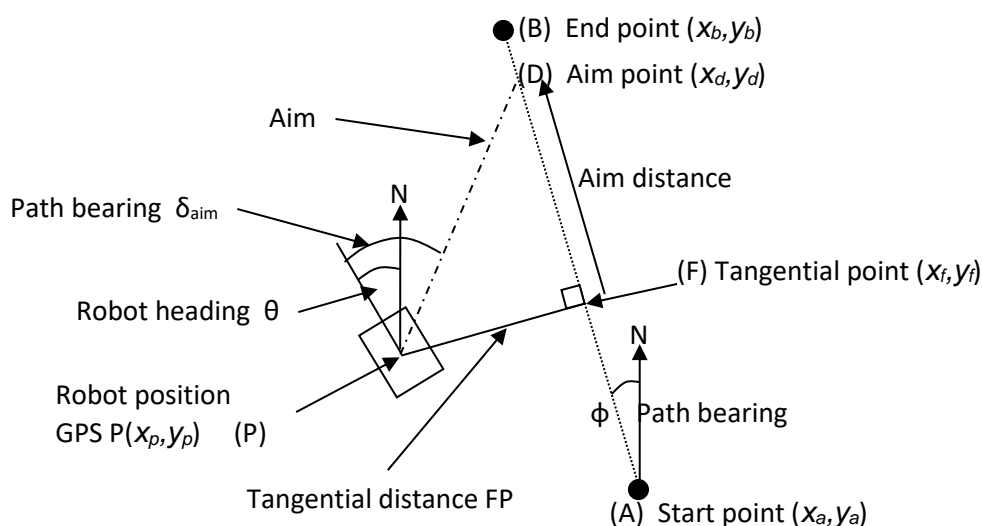
Fig. 6. Heading towards a desired location

The path bearing 'δ_{aim}' is calculated from the latitude and longitude points (equation 2). Points A(xa,ya) – B(xb,yb) define the desired trajectory line. Point P(xp,yp) is the robot measured (GPS) position.

To calculate deviation from the desired trajectory line (FP):

$$AP^2 = FP^2 + AF^2$$

$$\therefore FP = \sqrt{AP^2 - AF^2}$$

$$AP^2 = (xp - xa)^2 + (yp - ya)^2 \tag{1}$$

Find AF:

$$AF = AP \cdot \frac{AB}{|AB|}$$

$$AF = AP \cdot \frac{(xa-xb),(ya-yb)}{\sqrt{(xa-xb)^2+(ya-yb)^2}}$$

$$AF = \frac{(xa-xg)*(xa-xb)+(ya-yg)*(ya-yb)}{\sqrt{(xa-xb)^2+(ya-yb)^2}} \qquad (2)$$

To find the coordinates of the perpendicular point F(xf, yf), we know the equation of the line A-B, and the distance along it, AF, so:

$$AB = \sqrt{(xa-xb)^2-(ya-yb)^2}$$

$$x_f = xa + (xb-xa) + \frac{AF}{AB}$$

$$y_f = ya + (yb-ya) + \frac{AF}{AB} \qquad (3)$$

Then, the displacement from the path (FP) as previously calculated along with knowing the perpendicular point on the path F(xf, yf) are use to find an 'aim point'. This is a point, some way ahead of the ideal point on the path where the robot should be D(xd,yd) and is given as a reasonable point on the ideal path for the robot to aim for. From this, δ_{aim} is calculated and used to control the rotation of the robot.

$$x_d = x_f + (xb-xa) + \frac{Aim\ dist}{AB}$$

$$y_d = y_f + (yb-ya) + \frac{Aim\ dist}{AB}$$

Function

```
void calc_x_track(double* AimN, double* AimE, double S_N,double
S_E,double E_N, double E_E,double CN,double CE,double Aimdist)
```
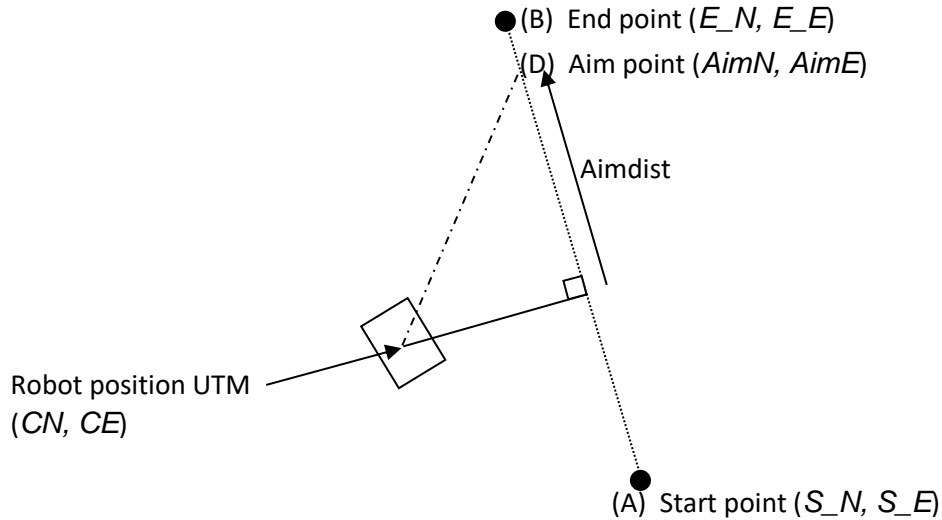

Example file X_track_AB:

double S_N=0,S_E=0,E_N=100,E_E=150, CN=60,CE=50,aimdist=10;

double Aim_N,Aim_E;

calc_x_track(&Aim_N, &Aim_E, S_N, S_E, E_N, E_E, CN,CN,aimdist);

```
Serial.print(Aim_N);

Serial.print(",");

Serial.println(Aim_E);

//Results in 51, 77
```

Further examples

More example programs are available under: Files→Examples→ATLAS→

See below:
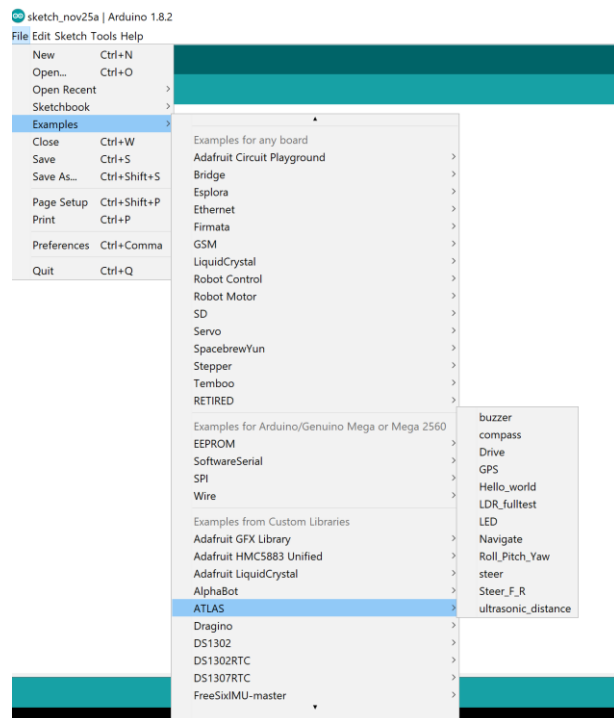
Lessons

Task 1. Robots in Agriculture

Task 2. Robot Chassis

Task 3. Buttons and Logic

Task 4. Variables and Display

Task 5. Distance and Tilt Sensors

Task 5b. Filtering

Task 6. Compass and Steering

Task 7. Drive

Task 8. GPS

Task 9. Bearing and Navigation

Task 10.

Functions

General

initialise();
Input: Nothing
Returns: Nothing
Function: Sets up the robot, called in the setup function. This must be called prior to using any other functions.

approx(a,b,c)
returns true if a is within the range of b with a threshold of c

get_timer(int timer_no);
Input: timer number 0-9
Returns: long milliseconds since the timer was reset
Function:

set_timer(int timer_no, unsigned long timerincrement);
Input: timer number 0-9, value to count down in ms
Returns: nothing
Function: Sets up a countdown time.r Starts a timer counting in ms. There are ten timers which can be accessed. The timer elapsed is checked with timer_elapsed(timer number 0-9)

e.g.

set_timer(0,500);
if (timer_elapsed(0)) Serial3.print("Timer 0 triggered after 0.5 seconds");

timer_elapsed(int timer_no);
Input: timer number 0-9
Returns: true if the timer has passed
Function: Returns a logical TRUE when the timer as set in 'set_timer' is triggered. This does not automatically reset the timer howerver. A '**set_timer**' command must be called to set this again.

bearing_to_point_deg(current latitude,current longitude, goal latitude, goal longitude);
Returns the bearing to a point, in degrees.

double distance_to_point_deg(current latitude,current longitude, goal latitude, goal longitude);
Returns the distance to a point in degrees.

closest_bearing_difference(current_bearing,goal_bearing);
Returns the difference between the current and goal bearing. Solves the problem of the 360 to 0 rollover.
e.g.
steer_angle=closest_bearing_difference(bearing,0);

delay(millisecs);
Pauses the program for the time stated in 'millisecs'

e.g. delay (500);

if (statement) action ; else other action;

Is used to perform an action is the statement is true.

Use a double equals sign (==) to test equality, or a greater than (>) or less than (<) to test if a value is bigger or smaller.

Filter

```
double filter(double input, double f)
Returns the low pass filtered signal, f is the cut-off frequency in Hz, input is the
signal. The sample rate is automatically calculated.
```

void set_veh_length(double v)

void set_veh_width(double v);

Sets the vehicle length and width (in metres), the distance between the axles.

double Output_PID(double Kp, double Ki, double Kd, double error, double maxerror)

```
outputs the PID corrected value within the limits of maxerror. It stops integral
windup if outside these boundaries.

error=Output_PID(0.9, 0, 0.2, error, 45);
```

read_offset_bearing()

Returns the offset bearing as stored in EEPROM

write_offset_bearing(double ob)

Sets the offset bearing, stored in EEPROM

Inputs (sensors)

battery()

Returns a value representing the battery voltage

trailer_angle();

Input: Nothing
Returns: double
Function: Returns the angle of the trailer attached to the potentiometer.

set_trailer_centre();

Input: Nothing
Returns: double
Function: Calibrates the trailer potentiometer to centre.

RC_steer();

Input: nothing
Returns: The steer angle command from the Radio transmitter in the range of +-1. + is right, - is left

getE();
Returns a double
Returns Easting as a type double.

getN();
Returns a double
Returns Nothing as a type double.
e.g.
    E=getE();
    N=getN();

getLat();
Returns a double
Returns latitude as a type double.

getLon();
Returns a double
Returns longitude as a type double.
e.g.
    lt=getLat();
    ln=getLon();

float getAlt();
Returns the altitude in m.

get_Pitch();
Returns int
Reads the pitch of the robot (tilt which occurs when climbing a hill).
e.g.

```
int pitch; //declare variables to hold the pitch value
pitch = get_Pitch(); //assign values by using the provided functions
```


get_Roll();
Returns int
Reads the roll of the robot (side to side movement)
e.g.

```
int roll;
roll = get_Roll();
```

float get_Yaw();
Returns the yaw of the vehicle.

double rightLDR()
Returns the brightness at the right LDR in percentage (0-dark, 100-brightest)

double leftLDR()
Returns the brightness at the left LDR in percentage (0-dark, 100-brightest)

read_distance();
Input: nothing
Returns: double: the distance sensed by the ultrasonic ranger in cm
Function:Reads distance.

Serial2.read
Reads data from the wireless transceiver
e.g.
int i;
while (Serial2.available()){
        i=Serial2.read();
        Serial.print(char(i));
}

read_compass();
Input: nothing
Returns: Double of degrees
Function: Returns the bearing as measured by the magnetometer (compass) in the range 0-360.

float temp();
Input: nothing
Returns: temperature in degrees C
Function: Reads the temperature from the temperature sensor.

int read_button(int button);
Returns a '1' if the button 1,2,3 is pressed.

e.g. if (read_button(1)==1) Serial.print("button on"); else Serial.print("Button off");

edge_rising(1..3)
returns HIGH if a button has just been pressed,
e.g.
void loop() {
  if (edge_rising(2))
  {
    n++;
  clear_LCD();
  Serial3.print(n);
  }

float right_light();
reads the right light sensor

float left_light();
reads the left light sensor

unsigned long read_wheel();
Reads the Hall sensor

void zero_wheel();
Resets the Hall wheel count

double RC_speed()
For speed on channel 2, +1=fastest, 0=stop, -1=reverse

It has a 50 ms timeout, so if communication is lost, it will not halt the program. A 2.0 is returned if communication is lost.

double RC_steer()
For steer on channel 1, +1=full right, 0=straight, -1=full left

It has a 50 ms timeout, so if communication is lost, it will not halt the program. A 2.0 is returned if communication is lost.

These routines are coded by hand to use the micros() timer, as the 'pulseIn' function is unstable due to interrupts used elsewhere in the code.

Outputs (actuators)

steer_radius(double inv_R);
Input: double, inverse radius
Returns: nothing
Function: sets the front steer angle to steer to a radius where a positive value will steer LEFT.

All servos were found to suffer interference when not being addressed, this was cured by only attaching them when needed and then detached after a short delay as in:

```
frservo.attach(frontservo);
frservo.write(steer_angle);
delay(50);
frservo.detach();
```

steer(double steer_angle);
Input: double steer angle
Returns: nothing
Function: sets the front steer angle in degrees with 0 – centre, and positive is steer right

rear_steer(double steer_angle);
Input: double steer angle
Returns: nothing
Function: sets the steer angle in degrees with 0 – centre, and positive is steer right

steerslow(double steer_angle);
Input: double steer angle
Returns: nothing
Function: sets the front steer angle moving slowly, in degrees with 0 – centre, and positive is steer right

rear_steerslow(double steer_angle);
Input: double steer angle
Returns: nothing
Function: sets the rear steer angle moving slowly, in degrees with 0 – centre, and positive is steer right

drive(float drive_speed);

Drives the motors. If speed = 0 then it stops, a positive value makes it go forwards, and a negative value backwards. The value is calibrated in metres per second.

The minimum and maximum values for 'speed' are -1 → +1 m/s.

e.g. drive(0.5);   //Drive the vehicle at 0.5 m/s

drive(float drive_speed, byte accel);

If used, acceleration can be in the range +1 to +255. In practice the useful range is around 5 to 10. Usage example

drive(0.7,5); will gently accelerate to 0.7 Metres/Sec. A subsequent instruction drive(0,5); will decelerate to a halt. The program continues to run during the acceleration/deceleration phase.

drive(0.7); and drive(0); will start and stop abruptly as before.

turret(angle);

int angle

Moves the ultrasonic servo turret by 'angle'. Angle is from -80 to +80, with 0 pointing forwards and negative values are to its right.

turret() now has two extra optional parameters: speed, and whether to block program execution until the move is complete. This is very useful when sweeping the ultrasonic sensor in a series of steps, in a for loop for example.

Usage example

turret(30,25,1); will move to angle 30 at constant speed 25. The program will be blocked until it arrives. The third parameter is a Boolean. It can be entered as 1/0 or true/false (or omitted).

turret(30,25); will move to angle 30 at speed 25. The program continues to execute during the move. Speed can be set in the range +1 to +255, but the useful range is around 30 – 60.

turret(30); moves at maximum speed as before.

lcd.clear();

Input: nothing

Returns: nothing

Function: clears the LCD

lcd.print("Text");

Input: Text

Returns: nothing

Function: Sends text to the LCD display.

lcd.print(var, 6);

Input: variable value

Returns: nothing

Function: Sends a number held in 'var' to the LCD display. The number after the comma is how many decimal places to show.

lcd.setCursor(column, row);

Sets the cursor position to the values. These start at 0. So, 0,0 is the top left of the screen.

E.G to send the next text to the bottom row, first column, use lcd.setCursor(0, 1);

display(text) display(top line text, bottom line text)

Clears and displays text on the LCD. If an item is included after the comma, it is displayed on the bottom line. E.g.

display("Harper Adams Uni", "Atlas tests ");

Variables must first be converted into text using 'String(variable)' as in:

display("Bearing", String(bearing));

Serial.print

Sends data to the PC monitor to display or graph.

e.g.
Serial.print("Hello") ;
sends 'Hello' to the serial monitor.
Serial.println("Hello") ;
sends 'Hello' to the serial monitor and goes on to the next line down.
int a=20;
Serial.println(a);
Sends '20' to the serial monitor, or it can form part of a graph on the serial plotter.

Serial2.print

Sends data to the wireless transmitter.
e.g.
Serial2.print("Harper Adams Uni");

led_out(led,state);

int led
int state
Switches the LEDs on or off.
led can be 1, 2, or 3 (1 is closest to the Arduino).
state can be HIGH or LOW.
e.g. led(1,HIGH);

void buzzer_on();

void buzzer_off();

drive(speed metres per second);
double speed metres per second

byte readDIP();

Returns the DIP switch state as a 4 bit byte.
Switches are ON when raised, OFF when pressed in.
Lowest bit is at the top of the PCB.

double gen_pot();

Returns the double value from the PCB mounted potentiometer.
1023.00=fully left, 0.00=fully clockwise

All commands in the library

General

```
void initialise();

unsigned long get_timer(int timer_no);
void set_timer(int timer_no, unsigned long timerincrement);
bool timer_elapsed(int timer_no);

double Output_PID(double Kp, double Ki, double Kd, double error,
double maxerror);
double Output_PID(double Kp, double Ki, double Kd, double error);
double filter(double input, double f);
bool approx(double a,double b,double t);
```

Inputs

```
double trailer_angle();
void set_trailer_centre();
double rightLDR();
double leftLDR();
float right_light();
float left_light();
int read_button(int button);
double gen_pot();
double rev_pot();
double battery();

void imu_init();
float get_Yaw();
float get_Pitch();
float get_Roll();
float temp();
void initSD();
void openSD();
double read_offset_bearing();
void write_offset_bearing(double ob);
byte readDIP();
unsigned long read_wheel();
void zero_wheel();
double read_distance();
```

Navigation

```
double read_compass(void);
float getLat();
float getLon();
float getAlt();
float getN();
float getE();

double closest_bearing_difference(double current_bearing, double
goal_bearing);
double bearing_to_point_UTM(double current_northing, double
current_easting, double goal_northing, double goal_easting);
```

```
double distance_to_point_UTM(double current_northing, double
current_easting, double goal_northing, double goal_easting);

double bearing_to_point_deg(double current_lat, double current_lon,
double goal_lat, double goal_lon);
double distance_to_point_deg(double current_lat, double current_lon,
double goal_lat, double goal_lon);
double drive_target(double goal_northing, double goal_easting,
double offset);
double follow_wall(double des_dist, double gain);
bool edge_rising(int port);
bool scan(int stand_out, int* distr, int* bearr); //Returns 999,999
if not found


void calc_x_track(double* AimN, double* AimE, double S_N,double
S_E,double E_N, double E_E,double CN,double CE,double Aimdist)
```

Outputs

Display
```
void display(String topLine);
void display(String topLine, String bottomLine );
void clear_LCD();
void nextline_LCD();

void buzzer_on();
void buzzer_off();
void led_out(int led,bool value);
```

Steering
```
void steer(double steer_angle);
void steerc(double steer_angle);
double read_steer(double steer_angle);
void set_front_calibrate(int c);
void set_rear_calibrate(int c);
int read_front_calibrate();
int read_rear_calibrate();
void rear_steer(double steer_angle);
void steerslow(double steer_angle);
void rear_steerslow(double steer_angle);
double steer_radius(double inv_R);
void set_veh_length(double v);
void set_veh_width(double v);
void set_max_steerf(double s);
void set_min_steerf(double s);
```

Drive
```
void front_RC(float drive_speed);
void rear_RC(float drive_speed);
void drive(float drive_speed);
void drive(float drive_speed, byte accel);
```

```
void front_drive(float drive_speed);
void rear_drive(float drive_speed);
double RC_speed();
double RC_steer();


void turret(int angle);
void turret(int steer_angle, byte speed);
void turret(int steer_angle, byte speed, bool block);
void sweep(int *scanarray); //returns array of scans 10 deg apart
```