MEng Group Project - Initial Report

Saad Aamir, Ahmed Egal, Chee Heing Gan, Tze Bey Lim, Jin Liu,
Nursyahirah Mohd Ghazali, Alex Wardle

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Chapter 1

Executive Summary

This report discusses the initial progress of researching, analysing, and designing a system, which can balance a vertical upright and inverted sweeping brush by itself without the need of human input.

1.1 Mission Statement

To design, prototype and demonstrate a system which is able to balance vertically upright an inverted sweeping brush on a movable platform using a real time multi-view active vision system and make the brush do small oscillations whilst remaining balanced.

1.2 Aims and Objectives

- To gain research and analysing skills from using new hardware, libraries, Internet and books.
- To develop team working and communication skills to overcome any difficulties in the process.
- To learn problem solving by taking initiative in finding solutions for unexpected obstacles.
- To improve the practical skills that is needed in engineering industry.
- To attempt to use “hard science” with nominal guidance.

Chapter 2

Introduction

As third year students, we are required to use the skills learnt from previous years and apply them to design and build a new system as a group with nominal guidance. This year the groups are assigned to build a “Dancing Sweeping Brush”. This means building a system, which can balance a sweeping brush vertically upright on moveable flat surface. Unlike, the inverted pendulum, which is restricted to one plane, the sweeping brush will not be restricted to any plane. The Dancing Sweeping Brush system will be built using sub-systems such as;

- The Vision system: This will be when the camera collects information and data to form an image, which is then interpreted by the microprocessor. The microprocessor used in this project is Raspberry Pi.
- The control system: The information collected by the micro processor will then go to the control logic which will direct what movement will the platform take.
- The movement system: This consists of the motor and Omni-directional wheels, which will allow us to steer the platform in X, and Y planes.

The system should not exceed a budget of £1200 and should comply with the United Kingdom laws and regulations.

Chapter 3

System Architecture

3.1 Design

A crucial section of our project is the system architecture. Essentially, this is an overview of all the sub-systems that exist as part of the structure of our overall system and how they all behave and communicate with each other. We have a total of three sub-systems that we're using, all of which will have to communicate with one another in order to keep the broom balanced. These are:

- Vision sub-system
- Control sub-system
- Movement sub-system

Figure 3.1 shows the block diagram for our initial system architecture.

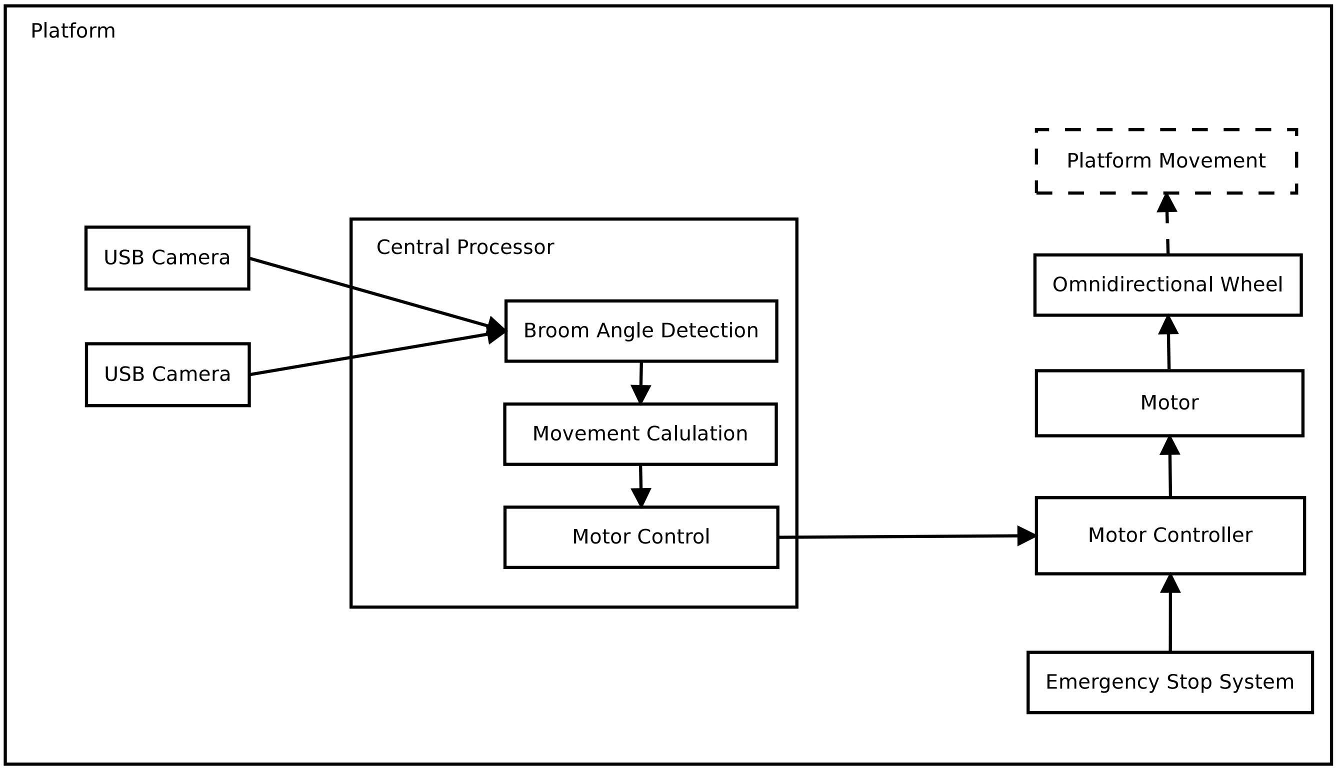

Figure 3.1: Initial System Architecture

We initially set out to use a single processing system with the two USB HD web cameras connected to it. This would mean the system should be capable of processing the images from the two cameras. However, we found that the processing system we're using – the Raspberry Pi – was not powerful enough process real-time images from both cameras simultaneously, which we needed as we would require an angle given from each of the cameras. We connected on of the USB HD web cameras to our Raspberry Pi which was connected to a monitor and found that real-time imaging shown required usage of more than half the CPU in order to obtain a reasonable frame-rate. This deemed it impractical to process both the cameras on the Raspberry Pi and hence required a different approach.

Our solution to this problem is to use two Raspberry Pi's instead, both of which function independently from each other. They will each be linked with a single camera and the control of a pair of motors. In essence, they will each control the movement of the cart on a single plane – one Raspberry Pi controls the movement in the X plane, and the other controls the movement in the Y plane. Figure 3.2 shows the block diagram for the revised system architecture.

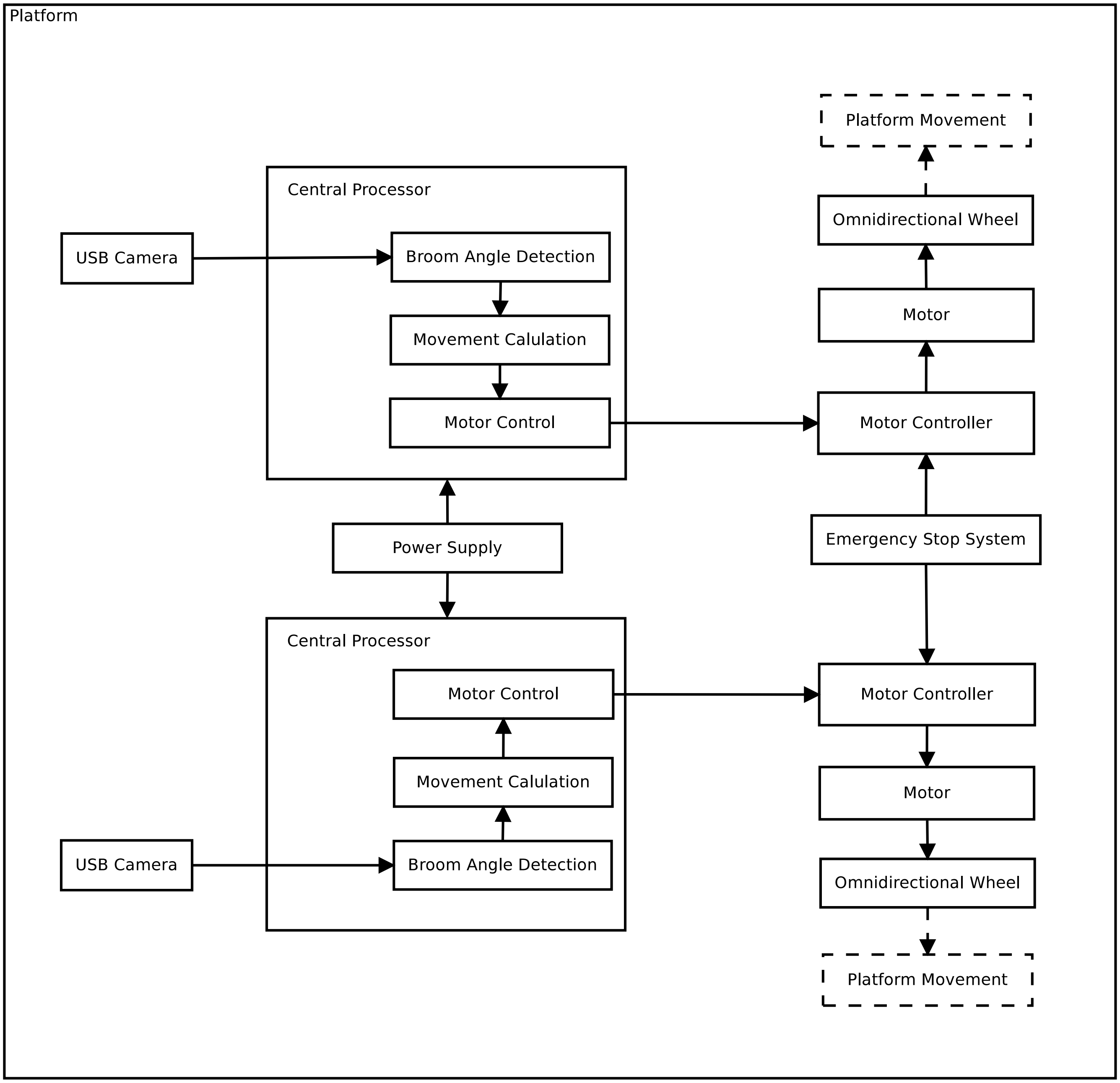

Figure 3.2: Revised System Architecture

One particular software package that may have been useful in our project is LabVIEW, which may have enabled us to combine the simulation and the implementation of the motor control in a more straight-forward manner. However, we decided against using this as the libraries that would be useful to us are over our budget.

Below is a summary of the architecture and how the subsystems will interact together:

- The HD web cameras are connected to the Raspberry Pi via USB
- The vision system will produce the angle detected
- This will be input into the PID controller function as a variable

- This will in-turn produce an acceleration and the Raspberry Pi will thus generate a sequence of outputs into the motor driver
- The motor driver will be connected to the Raspberry Pi via wiring from the motor driver circuit into the GPIO pins
- The circuit will be connected to the motors and will thus rotate the omnidirectional wheels

Each subsystem will be explained in more detail in their respective sections on our report.

3.2 Future

Our next step is to implement both of the Raspberry Pi's onto our system. We also plan to switch the use of USB HD web cameras with that of Raspberry Pi cameras which may eliminate the issues we faced with the speed at which images were being processed from the previous cameras connected to our Raspberry Pi. We plan to use infra-red cameras, explained further in the vision section of our report, and will hence opt to acquire the infra-red Raspberry Pi cameras.

We will also look further into integrating the vision and control systems once we're able to solve some of the issues we've faced with detecting the angle, explained further in the Vision section on the following page.

Chapter 4

System Design

4.1 Vision

In building the project, we use two cameras to find the angle of deviation of the sweeping brush in real time in x and y direction.

4.1.1 Design

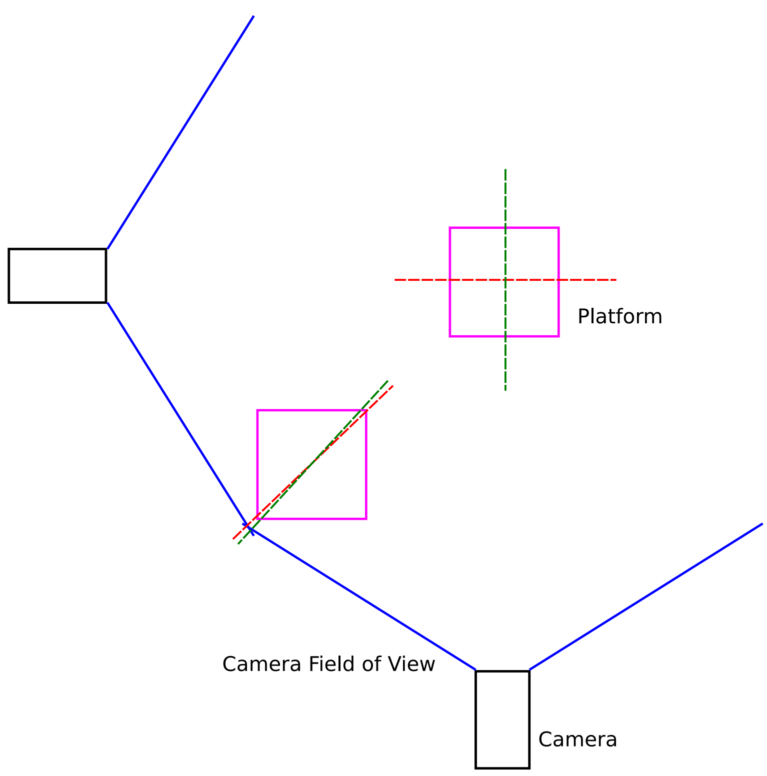

Figure 4.1: Parallax Error

Figure 4.1 shows what happens if we were to mount the cameras off the platform. When the platform is situated in front of the two cameras, angle of deviation can be calculated in both x and y direction. As the platform moves to the side of both cameras, the angle of deviation calculated is bound to have high parallax error.

Therefore, we will mount the cameras on the platform to reduce parallax error. We will also put them reasonably close to the broom so that the broom will take the majority image of the cameras, thus less background. The pole of the broom is the only region that will be detected. This will not be a problem as it does not interfere the measuring of the angle.

The angle of deviation calculated will be the input which will then determine the changes of the position of the platform. Figure 4.2 shows the algorithm used to find the angle of the broom.

Figure 4.2: Flowchart of method to find the angle of deviation of the broom

4.1.1.1 Edge detection

There are many types of edge detection which are Canny, Sobel, Robert Cross and others. It is necessary to know the advantages and disadvantages of each technique before deciding to use it. Table 4.1 shows the differences between them.

Classical (Sobel, Prewitt)	Gaussian (Canny)	Zero Crossing (Laplacian)	Marr-Hildreth
The approximation to the gradient magnitude is simple (but more complex than Laplacian operator) Sensitive to noise, thus can easily degrade the magnitude of edges Inaccurate as the magnitude of the edge decreases	Low error rate (good detection of only existent edges) Good localization (distance between edge pixels detected and real edge pixels have to be minimized) Minimal response (only one detector response per edge) Less likely to be fooled by noise Time consuming as the computation of gradient calculation to generate the angle of suppression is complex.	The approximation to the gradient magnitude is simple Fixed characteristics in all directions Sensitive to noise, thus can easily degrade the magnitude of edges Operation gets diffracted by some of the existing edges in the noisy image.	Tested and established among the wider area around the pixels therefore making it easy to find the correct places of edges Reduce the accuracy to find the orientation of edges and malfunctioning at the corners, curves, where the grey level intensity function varies.

Table 4.1: Comparison of Edge Detectors

Weighing the advantages and disadvantages of each type, we decided to use Canny Edge Detection Technique as it is not as sensitive to noise.

4.1.1.2 Hough Transform

Hough transform is useful to detect straight lines, circles or other parametric curves. It is conceptually simple and easy to be implemented. Furthermore, it handles missing and occluded data very gracefully. For object that has many parameters, applying Hough transform can be computationally complex. The disadvantage of it is it can be "fooled" by apparent lines. Prior to applying Hough transform, edge detection needs to be implemented first.

4.1.1.3 Background Subtraction

We also apply Background Subtraction to eliminate the background so that only the broom is visible in the image. This is an algorithm function uses is described by KaewTraKulPong P. & Bowden R. (2001). By using this method, we subtract current frame with the background model. Using this technique, we will first compute the background model and then apply background update to find any possible changes as the object moves.

4.1.2 Implementation

OpenCV is an open source computer vision library. It is used to help us with vision processing as it has real time vision capabilities. It also has functions that we require to implement the algorithm in the flowchart in order to find the angle of deviation of the broom. In addition, it also runs on Raspberry Pi. We built our first prototype using Python because it is a high level language and a lot simpler as compared to C. We spent more time on algorithm without having problem with memory management hassles. The code written is included in appendix B.

We managed to find the angle of the broom using the algorithm mentioned in the flowchart in Figure 4.2. We first start off by using Background Subtraction to remove the background and leave the broom which is our region of interest. Then, we apply Canny edge detection to get the edges of the broom. Hough Transform is used to work out the angle of line that represents the edge of the broom. This is then the angle where the broom is at. Figure 4.3 below shows the angle of deviation of the broom when it is tilted to the left. This angle is calculated from the vertical.

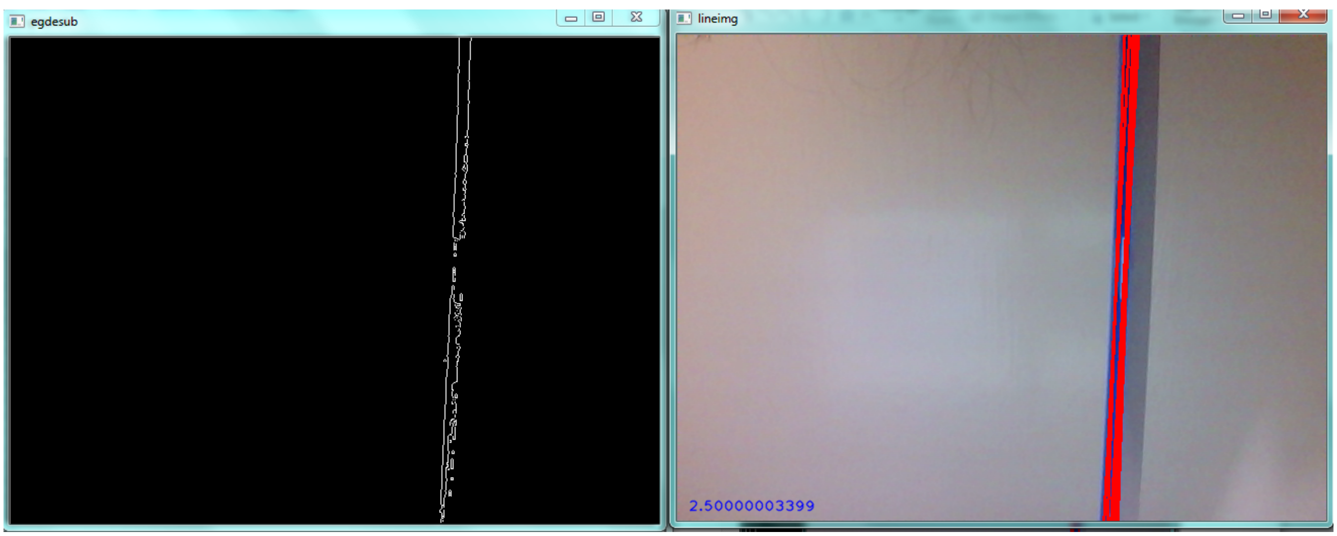

Figure 4.3: A screen shot of the angle measuring system in action

We tested the code by tilting the broom into different angle in both left and right direction. It works fine at any angle and direction. However, if the first frame that has the background model and the background is moving, the angle suffers significantly.

4.1.3 Future Development

There are few problems with current algorithm. Background Subtraction works best when the robot is not moving – as the background does not move. When the robot moves, the angle is no longer right. Canny edge detection that we applied is not as sensitive to noise compared to other types of edge detection. However, it increases computational calculation. We have no problem when we implemented the technique on a computer, but as we transfer the code to the slower Raspberry Pi, we may have to change the edge detection.

To solve the background moving, we will use infra-red light to illuminate the broom and infra-red filter to the cameras. This will leave the background in shadow and therefore only the broom is visible. Thus we can get the angle of deviation of the broom and neglects the background. We will use Pi noIR camera board as it can capture video with a maximum video resolution of 1080p at 30 frames per second.

We will also convert the code into C because C language is much faster compared to Python. Although it is quite low language, there are lots of tutorials on using C with openCV. As for Python, the tutorials are still under development.

4.2 Control

PID (proportional-integral-derivative) is one of the most common control loop feedbacks, widely used in control systems. It calculates the 'error' value between a measured process variable (i.e. actual value) and a desired set point (what we want) and attempts to minimise it by adjusting the control inputs.

Fuzzy-Logic systems are essentially knowledge-based or rule-based systems that contain descriptive IF-THEN rules. They do not need precise mathematical formula as it relies on linguistic variables. It converts inputs into linguistic values. It has better control performance and robustness. Fuzzy controllers have better stability, small overshoot, and fast response.

Fuzzy Logic has more variables to be dealt with in comparison with the PID controller, which makes PID controller easier to be used. Moreover, having studied about PID controllers in the Signal Systems and Control module in the previous year, we were already familiar with the concept of PID and how it functions. This was our deciding factor as we were more accustomed to using PID and had no past-experience with Fuzzy-Logic.

The Figure 4.4 shows how PID controller links in conjunction with the transfer functions of the cart and pendulum that we previously obtained. This is illustrated further in appendix C.

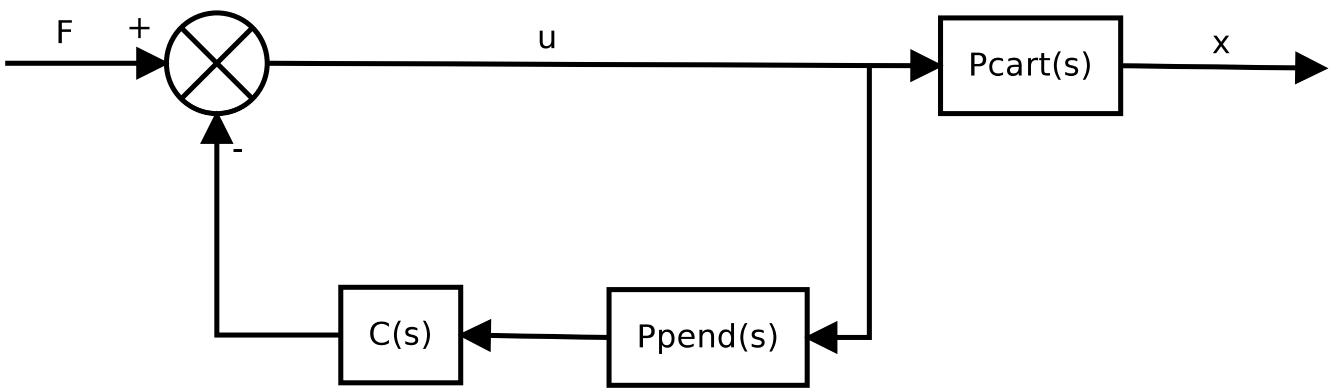

Figure 4.4: Block Diagram of PID Controller

Table 4.2 shows the effects of varying the different PID control parameters

	Rise Time	Overshoot	Settling Time	S-S Error
Kp	Decreases	Increases	No Change	Decreases
Ki	Decreases	Increases	Increases	Eliminates
Kd	No Change	Decreases	Decreases	No Change

Table 4.2: Effects of the PID Control Parameters

- The proportional control is used to improve the rise-time
- The integral control is used to improve the steady-state error
- The derivative control is used to improve the overshoot and the settling time

The Figure 4.5 shows the different waveform characteristics in a PID closed loop system:

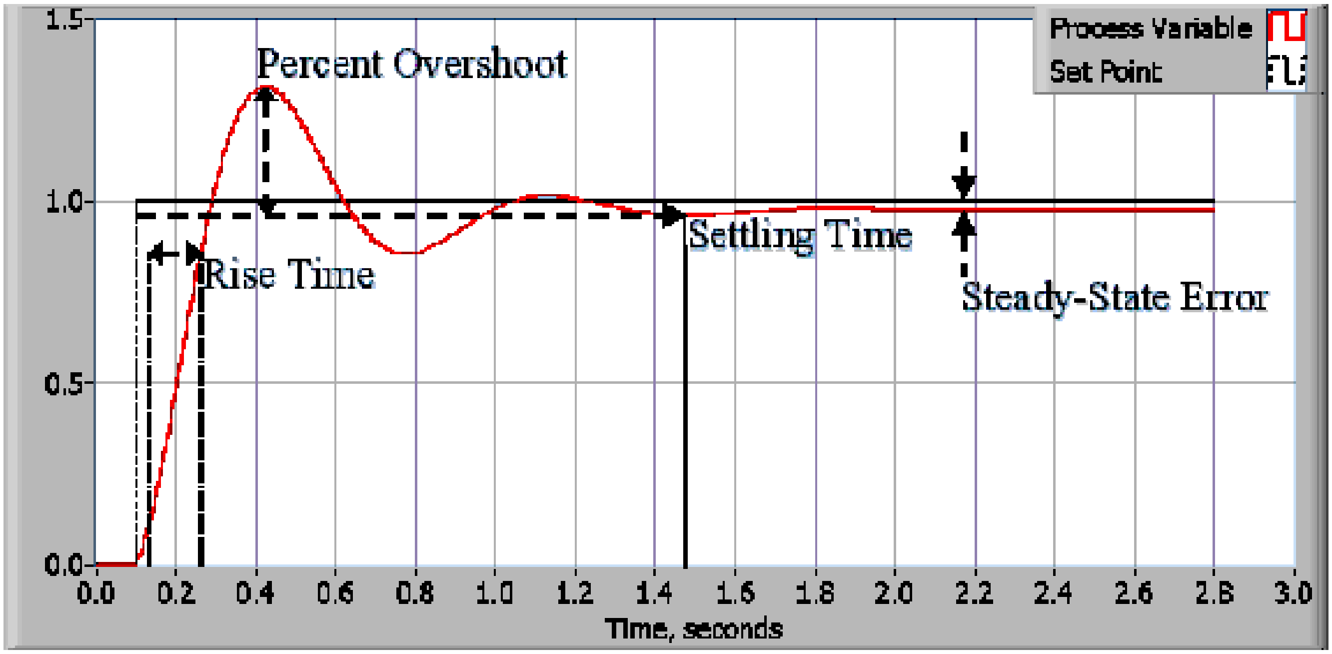

Figure 4.5: Response of a typical PID closed loop system National Instruments (2011)

Ideally, we want a closed-loop system that has minimum overshoot, minimum steady-state error and a fast rise time. After trying different values for the PID control parameters, we found that the optimum response was produced at Kp = 100, Ki = 1 and Kd = 20.

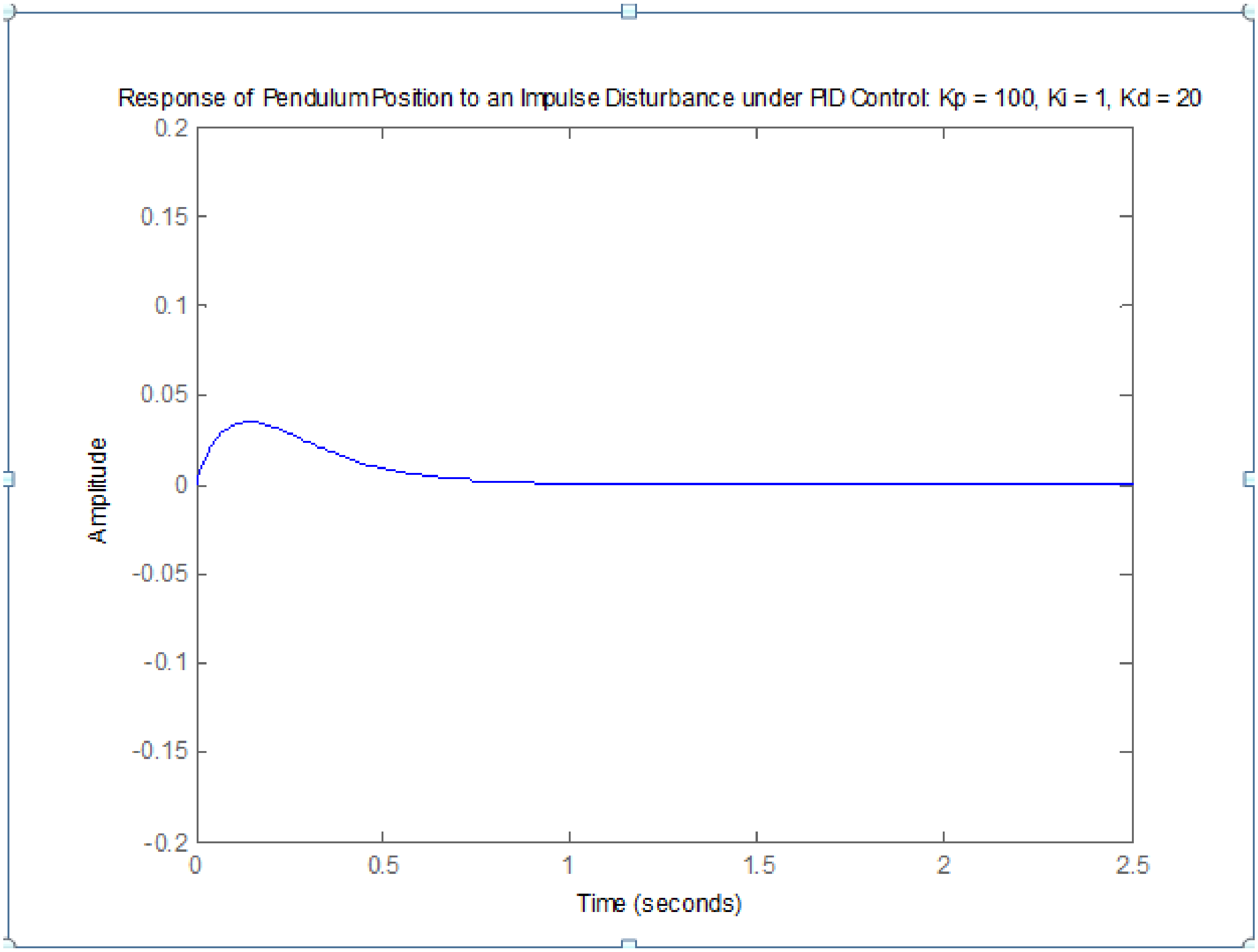

Figure 4.6: Response of Pendulum Position to Impulse

This response gave the minimum overshoot, minimum steady-state error and the fastest rise time.

Having simulated the response on MATLAB, we then decided to create a function of the PID controller in the C programming language. The main purpose of this was because of how quickly C runs – speed is essential for us as we require very prompt feedback from the vision and control systems in order for the motors to react quickly enough to keep balancing the broom. Any (significant) lag time would be detrimental and must be kept to a minimum, hence why we chose to use the C language. Moreover, MATLAB does not run on the Raspberry Pi and would therefore be impractical.

Below is the PID function we're using in C:

```
float PID(float err_ang)
{
        static float err_int = 0;
        static float err_last = 0;

        float PID_out;

        const int Kp = 100;
        const int Ki = 1;
        const int Kd = 20;

    err_int = err_int + err_ang;
```

```
        PID_out = Kp*err_ang + Kd(err_ang - err_last) + Ki*err_int;
        err_last = err_ang;

        return PID_out;
}
```

Looking at the diagram below, θ_1 represents the first angle entered into the function, so the output will be:

$$PID\_out = Kp * \theta_1 + Kd * \theta_1 + Ki * 0$$

θ_2 represents the next angle that is presented to the function. The output now becomes:

$$PID\_out = Kp * \theta_2 + Kd * (\theta_2 - \theta_1) + Ki * \theta_2$$

Kp, Ki and Kd will be the PID control parameters.

Figure 4.7 shows how the C function of the PID controller works:

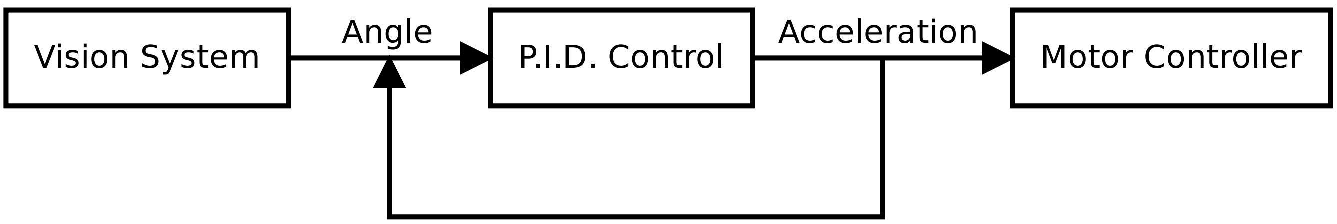

Figure 4.7: Block Diagram of PID Controller in C

Essentially, the vision system will produce the angle deviated from the vertical and this will be the input into the PID controller. This will then generate an acceleration to the motors and loop back around as the process repeats.

4.3 Processor

The processing system is perhaps the most vital part of our project as this is where most of the calculations will take place. Referring to figure 3.2 on page 7, the processing system will be powered by the power supply and connected to the cameras via USB. It will also be linked with the motor driver.

Essentially, we required a processing system that was powerful enough to perform real-time image processing but also small enough to fit on our cart. In our research, the three main types of processing systems we found were the Raspberry Pi, the BeagleBone Black and the Arduino. The Raspberry Pi and the BeagleBone Black are both microprocessors whereas the Arduino on the other hand is a micro controller.

Table 4.3 show a comparison between the two microprocessors.

	BeagleBone Black	Raspberry Pi
Base Price	45	35
Processor	1GHz TI Sitara AM3359 ARM Cortex A8	700 MHz ARM1176JZFS
RAM	512 MB DDR3L @ 400 MHz	512 MB SDRAM @ 400 MHz
Storage	2 GB on-board eMMC, MicroSD	SD
Video Connections	1 Micro-HDMI	1 HDMI, 1 Composite
Supported Resolutions	1280×1024 (5:4), 1024×768 (4:3), 1280×720 (16:9), 1440×900 (16:10) all at 16 bit	Extensive from 640×350 up to 1920×1200, this includes 1080p
Audio	Stereo over HDMI	Stereo over HDMI, Stereo from 3.5 mm jack
Operating Systems	Angstrom (Default), Ubuntu, Android, ArchLinux, Gentoo, Minix, RISC OS, others...	Raspbian (Recommended), Ubuntu, Android, ArchLinux, FreeBSD, Fedora, RISC OS, others...
Power Draw	210-460 mA @ 5V under varying conditions	150-350 mA @ 5V under varying conditions
GPIO Capability	65 Pins	8 pins
Peripherals	1 USB Host, 1 Mini-USB Client, 1 10/100 Mbps Ethernet	2 USB Hosts, 1 Micro-USB Power, 1 10/100 Mbps Ethernet, RPi camera connector

Table 4.3: Comparison of microprocessors Leonard (2013)

Although the BeagleBone Black is perhaps better overall (it runs faster on average and has a significantly larger amount of pins in reference to GPIO capability), it is a much newer design whereas the Raspberry Pi has been around for longer and is thus more widely-used. Consequently, the Raspberry Pi has many more tutorials available than the BeagleBone Black. This meant that these would be beneficial for us if we were to come across any complications with the Raspberry Pi and hence it would be the more efficient choice.

Another alternative was the Arduino. Table 4.4 shows a comparison which summarises the differences between the Arduino and the Raspberry Pi:

	Arduino	Raspberry Pi
Operating System	Custom	Linux
Suited for	Hardware	Software
Number of I/O pins	14 Digital (6 PWM), 6 analogue	8 Digital
Audio/Video output	Basic functionality programmable	Yes
Internet	Via Shield	Yes

Table 4.4: Comparison between Arduino and Raspberry Pi Codeduino (2013)

We found that the Arduino does not have as much processing power as the Raspberry Pi – the Arduino is typically clocked at between 8-16MHz and with 2-8kB of RAM available, whereas the Raspberry Pi can be clocked at 700MHz and may have up to 512MB of RAM. Unlike the Arduino, the Raspberry Pi has GPU and video outputs, as well as Ethernet and USB ports.

We also have members in our group who have past experience with using Linux, which is the default operating system on the Raspberry Pi. Being familiar with this operating system also played a factor in making our decision, hence why the Raspberry Pi is our choice for the processing system we're using for our project.

4.4 Platform

4.4.0.1 Specification

- The platform must be able to withstand the weight of all the components listed in Table 4.5
- The platform must have enough space to place all the components on
- The platform must be mobile
- The platform must be able to move both in the x and y direction at the same time
- The platform must be light enough to accelerate quickly

4.4.1 Physical Platform

4.4.1.1 Design

The platform will be constructed using aluminium sheet with a size of 300mm x 300mm x 1.5mm. The reason why aluminium was chosen, as the materials of robot platform, is that it is easy available, durable, light and is easy to work with. In order to let the robot moving quick and smooth, the weight of the platform needs to be light. At the same time, the platform size should be large enough to fit all the components such as motor circuits, power supply and the broom. The group has also evaluated that 1.5mm thickness aluminium will be strong enough to withstand the shock and impact that might be taken by the robot. Hence, 300mm X 300mm X 1.5mm is concluded as a reasonable size of platform for our robot. Actually, there are some other options of materials for the robot platform such as plastic and wood. However, plastic is very brittle and easy to crack when assembling the robot while wood is heavy and less durable compare to aluminium.

The two cameras will be mounted on the upper layer platform. The cameras will be placed upright so they look directly at the side of the broom. The cameras will be mounted around 5-10cm away from the position where the broom will normally rest. This will allow the broom to take up most of the image, minimising the space for background interference as well as providing a more significant change when the broom moves to the side.

CAD drawings of the robot can be found in appendix D.

4.4.1.2 Implementation

The lower layer of the platform has been created and the motor have been screwed on. The platform has been tested making sure that it can take the weight of all the parts that will have to be placed on it. The platform passed this test.

4.4.1.3 Future Development

In semester 2, the robot platform will have the upper layer of the platform built and installed. The upper layer of platform will be an estimated 200mm x 200mm x 1.5mm. A layer of felt like material may be placed on upper platform to increase the friction of the surface so that the broom is less likely to slip of the platform while it is moving.

The platform may vibrate while it is moving, this could cause a problem for the cameras as picture will not be stable. Therefore we will investigate methods to reduce the effects of the vibrations on the cameras.

4.4.2 Motors

4.4.2.1 Design

In order to make the robot move, motors are required to drive the wheels. In our design we decided to use Stepper Motors, this was because they provided reliable movement each time they were advanced a step. This is different to DC which would require a separate monitoring system see how the inputs to the motors effected the outputs. Stepper motors were also easy to connect to the Raspberry Pi as as long as they are connected to appropriate logic circuits they can be controlled by just 3.3V logic levels.

4.4.2.2 Implementation

We have purchased and installed four stepper motors on our platform. We have managed to get them to interface with the Raspberry Pi and for them to be controllable. Due to a problem with the Raspberry Pi we created a program to help us test and demonstrate the motors working using an Arduino, the code for this program is shown in appendix E. We are currently in the process of testing the performance of these motors.

4.4.2.3 Future Development

While testing the robot, we observed that the robot does not move smoothly at the starting point unless a "kick start" force has been provided. Besides, the robot speed does match the requirement as well. Consequently, we found out that stepper motor is lack of speed and low starting torque. These two problems have raise concern to the team as these factors are very critical in balancing the broom.

In order to solve this problem, we will try to start the robot with a lower acceleration as we suspect that high acceleration at start is the main cause of this problem. If the first method does not give a desired result, we might need to pursue for a higher speed and torque motor.

4.4.3 Motor Controller

Stepper motors can not be controlled directly from a Raspberry Pi. This is because the Raspberry Pi can only output voltages at are 3.3V and 0V with a maximum current of 16mA (van Loo 2012). This is not suitable for the stepper motors as they require a 12V supply with around 160mA current. Therefore we needed to design a circuit that would allow us to control the stepper motors from the Raspberry Pi.

4.4.3.1 Specification

The specification for the stepper motor controller circuits is shown below:

- The motor controller must be able to drive 1 stepper at 12V with a current of 160mA per a coil
- The motor controller must be able to be communicate using 3.3V connections with the Raspberry Pi
- It must be able to drive the motors both backwards and forwards at varying speeds
- It must be able to control the motors given speed
- The controller must have an emergency stop system

4.4.3.2 Design

In order to control the motors at the higher voltage and current an L298 was chosen. The L298 is a full bridge driver, this IC allows separate higher voltage and current source to be used to drive the outputs when input is given. An L298 can support an output of up to 50V and maximum output current of 2A (STMicroelectronics (2000)), this is higher than the required values therefore it meets the above specification. It requires a supply of around 5V to operate the IC.

In addition to this an L297 was included in the circuit. The L297 is a Stepper Motor Controller which generates the required outputs to cause the stepper motor to move one step. This device allows us to control the stepper motor using only two signals. These are a clock signal, which causes the motor to move one step on a rising edge and a direction control signal. The direction control signal sets if the motor will rotate one step clockwise or counter clockwise. This signal will be used to the robot to move forward and backwards.

The advantage to using the L297 is that it allows us to free up 2 pins on the Raspberry Pi per a motor. Another advantage is that the L297 deals with the changing of the outputs to control the motor. This makes the programming of the Raspberry Pi simpler and reduces the computational load of the Raspberry Pi. This will allow the Raspberry Pi to spend more time processing the vision. The L297 contains a system that allows the limiting of the current supplied to the motors, this allows the motors to be run at a higher voltage. This higher voltage decreases the time it takes to reverse the magnetic field producing more torque (Hopkins (2012)). Also to increase the torque the motors are wired in bipolar instead of unipolar mode. the L297 is configured in full step mode, this also increases the torque as both coils within the motor are energised at the same time.

Since the platform is self contained there is a risk if the program controlling the motors has a mistake in it. This could cause the the platform to drive way from us, and we may not be able to stop it. To mitigate against this risk, we have included an emergency stop system into our design. This system consist of a switch which connects a 5V signal to the enable of the L297. This switch has a long cable on it allowing the operator to keep hold of the switch while the robot is operating. The enable of the L297 has a pull down resistor connected to it. If switch is turned off the enable will be grounded and this will cut off all the motors stopping the robot. The system has been designed to be fail safe as if the emergency stop switch is not installed or the wire to switch breaks the enable is grounded and the motors will cut out.

Since each combination of L297 & L298 can control one motor, four will be required in the final system. Each one of these are connected together by the use of a master board. This master board contains connectors for the four motor control boards as well as a power supply connector for the 12V system. The emergency stop system will be connected to this board, as it is common to all the four circuits. To protect the Raspberry Pi from short circuits and over voltage a octal tri state non inverting buffer will be used. This buffer will be connected to the outputs from the Raspberry Pi. If the circuit does develop a fault which causes a short circuit or a over voltage on any of the Raspberry Pi output pins, the buffer should protect. In doing this the buffer maybe destroyed however this is not a particular problem as they are cheap to replace. The buffer that we will be using is the 74LS241.

Completed circuit diagrams for the above circuit are shown in appendix A.

4.4.3.3 Implementation

The circuits above where first tested on breadboard to make sure they worked. Then to make them more sturdy they were moved onto strip board. Strip board was chosen since it was easy to get hold of quickly. A PCB was considered however the time it take to design, get it made and then populate was considered to be longer than using strip board. The other bonus to strip board was that it is easy to change the circuit if the original circuit was found to be wrong. This not as easy to do with PCB and would likely require a brand new PCB, this would take additional time that we did not want to incur.

Each motor drivers were created separately with connectors on them to allow them to be joined together. Figure 4.8 shows the 3 completed motor driver boards. These motor drivers do not have oscillator circuits on them. The oscillator circuits are required for current limiting system. However the L297 allows one oscillator to be used for the other boards, this has the benefit of reducing ground noise problems (STMicroelectronics (2001)). The motor driver including the oscillator is identifiable as it black markings on it. Without this circuit being present the other three circuits will not operate correctly.

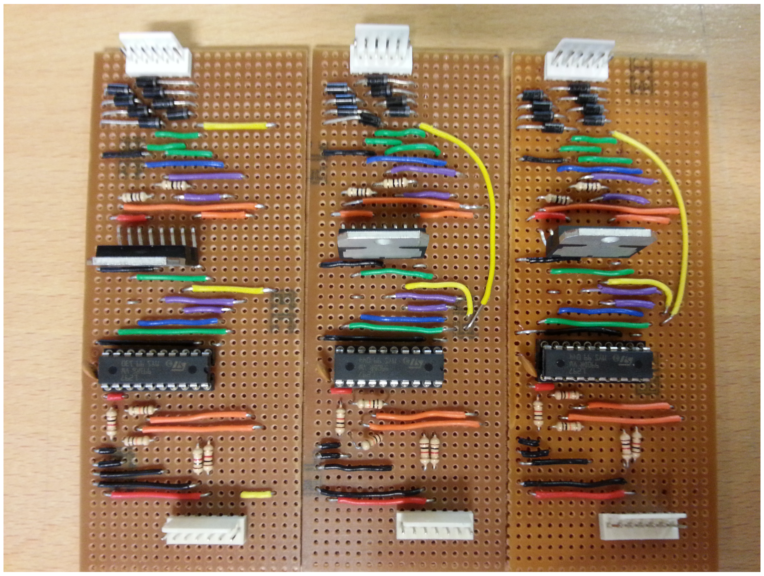

Figure 4.8: 3 Motor Drivers without Oscillator

The final board to be created was the master board. This board contains a ribbon connector that connects to the Raspberry Pi. This provides the input signals to the motor drivers as well as the +5V supply. A barrel connector was also added to the board, this provides the 12V supply required to power the motors. They are four 7 way connectors that connect the separate motor drivers to the master. Finally there is a 2 way connector that the emergency stop switch is connected to. Figure 4.9 shows the completed board.

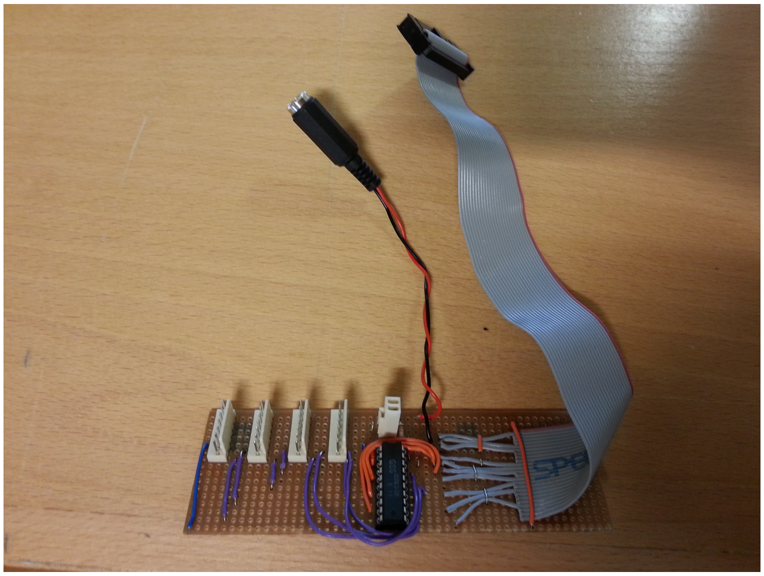

Figure 4.9: The Master Board

4.4.4 Wheels

A balancing robot needs to be moving fast and smooth with less friction. Capability of moving in X and Y direction at the same time is also a must to achieve. Therefore, the wheels will play an important role to help the robot in achieving the balancing and multi directional movement.

From Table 4.5, total weight of components for robot will be around 2.83kg. The load capacity of each wheel is 20kg per wheels. Since the motor is mounted below the platform, a large wheel is required to lift the platform to prevent the motors from touching the ground. As such, 4 inch diameter of wheels will be strong enough to withstand the platform weight and also provide the robot platform clearance from the ground.

There are other size and material of Omni-directional such as 60mm, 6 inch, 8inch and aluminium Omni-directional wheel. Yet, we evaluated that 4 inch plastic Omni-directional wheel will be sufficient for our project as it meets the basic requirements.

Components	Weight
Platform	367g
Circuits	400g
Camera	455g
Motors	880g
Broom	500g
Power Supply	224g
Total	2.83Kg

Table 4.5: Weight Budget for Robot

When we assemble stepper motors with Omni-directional wheels, the centre of wheels are in square shape (size of 3.2mm) while the shaft of stepper motors are in round shape (size of 5mm). The shaft size and shape of motors are not compatible with the wheels which then causes a problem.

After gathering some information and suggestion from the workshop supervisor, we tackle this problem by drilling a 4.9mm diameter circular hole in the centre of wheels. The stepper motor shafts are fixed tightly into the hole as shown in Figure 4.10.

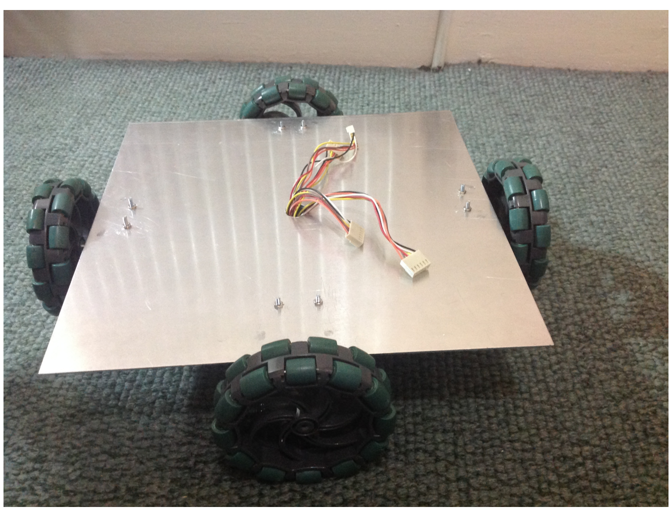

Figure 4.10: Lower Platform

4.5 Power Supply

What are the power requirement for this project? There are several components which needed power supply in the project, which are the raspberry pi, USB cameras, L297, L298 and the stepper motors. Table 4.6 shows the voltage and current required for each of the components.

Component	Quantity	Voltage Required	Current Required for Each Component	Total Current Required
Raspberry Pi	2	5V	350mA	700mA
USB Camera	2	5V	216mA	432mA
L297	4	5V	36mA	144mA
L298	4	5V	80mA	320mA
Stepper Motor	4	12V	320mA	1280mA

Table 4.6: Voltage and current required for each components

Based on the Table 4.6, we can see that the total current required at 5V is approximately 1.6A whereas at voltage of 12V, current of approximately 1.3A is required. As the components we using operate at different voltage, therefore we need different power supply as voltage which is too high may burn and damage the microchip. To solve this problem, we managed to find a portable chargeable battery which have multiple output ports and can provide maximum voltage of 19V at 3A.

We choose portable battery as our power supply for this project. The reason that we choose using portable battery is to ensure that the platform can move easily without having to place the bigger size and heavier power supply onto the platform. This will be an advantage as this can lessen the load on the platform and smooth out the movement of the platform. There are several option when choosing the battery as power supply. Among all the options, we found that the Energizer XP8000 is a better choice for our project. This is because Energizer XP8000 has multiple output ports that can supply different value of voltage at maximum current of 3A which is sufficient for our project. The portable battery that we choose has 3 output ports which supply 5V, 12V and 19V.

Figure 4.11: Energizer XP8000

Chapter 5

Time Management Plan

5.1 Design Method

In this project we are using a rapid prototyping design method. In this method prototypes are created of the design constantly and then improvements are made where problems have been found. Only minimal theoretical work is done before including a part as if it turns out later not to be suitable a new updated part will be purchased. This method was chosen as it allows quick experimental verification of ideas. This contrasts to a theoretical approach where the design is verified theoretically, the problem with this method is that theoretical models are often simplified and therefore when the design is actually built and tested in the real world unexpected effects can occur. One of the downsides to rapid prototyping is the increased budget spend as parts are brought that turn out not be be useful. However in this project we have a budget of £1200, this is a large budget compared to what we will need to send therefore we can afford to spend money on parts that may turnout to be not suitable.

5.2 Future Plan

Throughout this document references have been made to our plans for the future of each of the sub systems. We have not created a detailed time plan or Gantt Chart as we do not know how long tasks will take or what tasks we will have to do. Therefore we thought it wasn't a good use of time as very quickly the plan would need updating, this could end up being time consuming.

5.2.1 Method

The method that we have to finish the project is as follows. We will carry working in one plane only using some method to constrain the broom so it can only falls in one direction. We will also try to balance the broom using the platform, but with manual control instead of using the vision system. This will allow us to check that the platform works in the design and is not the limiting factor. Once we have verified the platform works we will then move onto balancing the broom using the vision. Once we have this working we can progress onto balancing the broom in both directions by replicating what we have previously done.

5.2.2 Milestones

However we felt it was important to create some form of plan to give us goals to reach. This important as it can be hard to motivate ourselves to work when the goal seems hard to reach and a long time away. So we created a list of goals that were quite wide but we felt achievable. These are listed below:

- Week 2 - All parts assembled onto Robot

- Week 3 - Robot can balance broom with manual control
- Week 7 - Robot balancing broom in one direction
- Week 9 - Robot balancing broom in both directions

The milestones refer to the end of the week.

Using these milestones we can see how the project is progressing and it gives us something to work towards. We can also use these to make sure we are not lagging behind.

Chapter 6

Conclusions

In this report we have seen the basic design of the robot and the reasons for the various choices of design that have been made. Some initial implementation work of the design has been completed. This is a prototype of the vision system as well as bottom half of the platform. The PID controller has been created and initial tuning values set, however in the future these are likely to change.

As we are using the rapid prototyping method some of these design decisions may turn out to be inappropriate and therefore maybe changed. We have discussed our aims for the future and have set some initial milestones to meet. We believe that we are on target to complete the project as long as we continue working at the same rate. Our main areas of focus will be the vision system as this has a problem when the camera moves, which it will with current design.

Chapter 7

References

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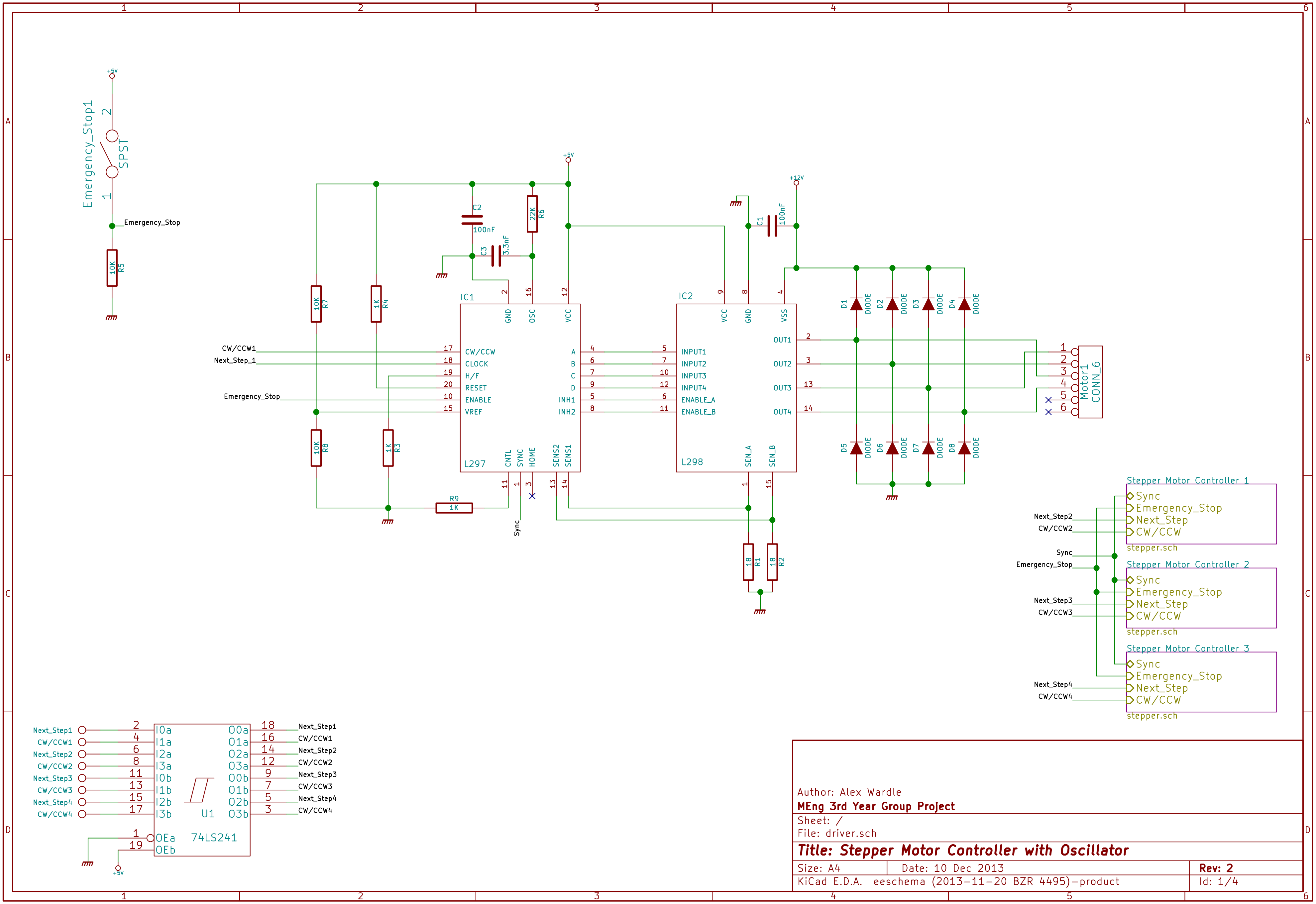
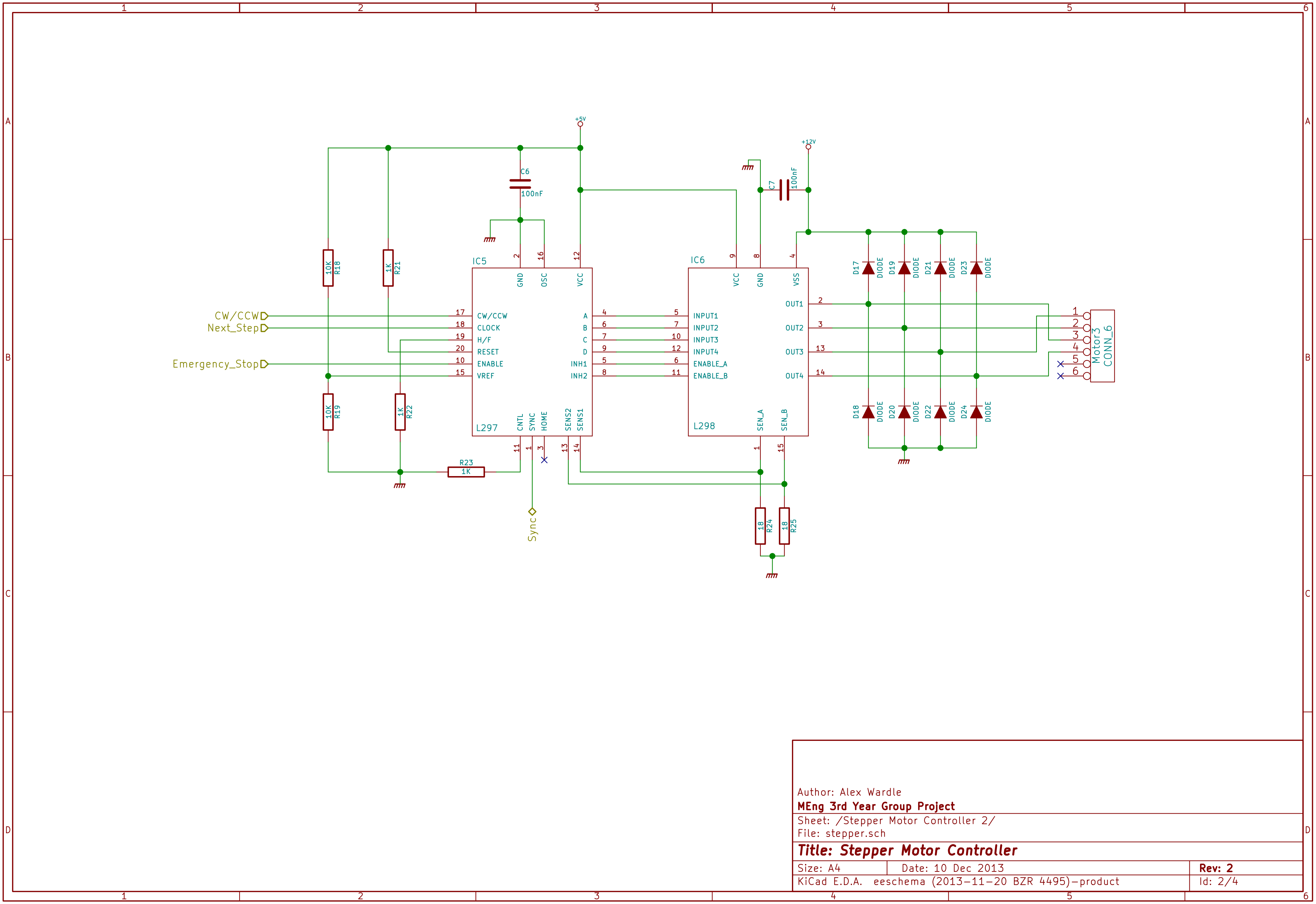
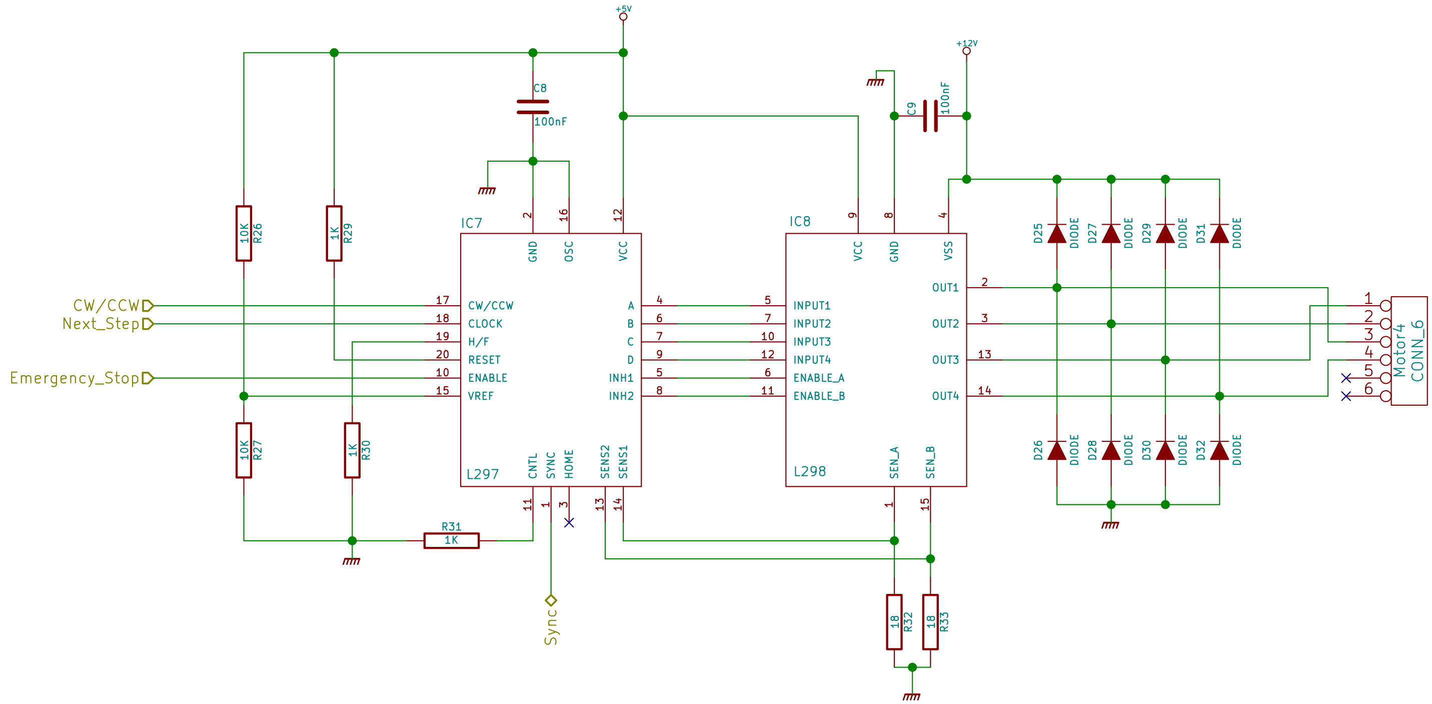
Appendix A

Circuit Diagram



Emergency_Stop1
SPST
Emergency_Stop
R5 10K
IC1 L297
IC2 L298
CW/CCW1
Next_Step_1
Emergency_Stop
Sync
R1 18
R2 18
R3 1K
R4 1K
R6 22K
R7 10K
R8 10K
R9 1K
C1 100nF
C2 100nF
C3 3.3nF
D1 DIODE
D2 DIODE
D3 DIODE
D4 DIODE
D5 DIODE
D6 DIODE
D7 DIODE
D8 DIODE
Motor1 CONN_6
Stepper Motor Controller 1
Stepper Motor Controller 2
Stepper Motor Controller 3
stepper.sch
U1 74LS241
Author: Alex Wardle
MEng 3rd Year Group Project
Sheet: /
File: driver.sch
Title: Stepper Motor Controller with Oscillator
Size: A4
Date: 10 Dec 2013
Rev: 2
KiCad E.D.A. eeschema (2013-11-20 BZR 4495)-product
Id: 1/4


+5V
+12V
C6
100nF
C7
100nF
IC5
L297
IC6
L298
CW/CCW
Next_Step
Emergency_Stop
Sync
CW/CCW
CLOCK
H/F
RESET
ENABLE
VREF
GND
OSC
VCC
A
B
C
D
INH1
INH2
CNTL
SYNC
HOME
SENS2
SENS1
INPUT1
INPUT2
INPUT3
INPUT4
ENABLE_A
ENABLE_B
VCC
GND
VSS
OUT1
OUT2
OUT3
OUT4
SEN_A
SEN_B
R18 10K
R21 1K
R19 10K
R22 1K
R23 1K
R24 18
R25 18
D17 DIODE
D19 DIODE
D21 DIODE
D23 DIODE
D18 DIODE
D20 DIODE
D22 DIODE
D24 DIODE
Motor3
CONN_6
Author: Alex Wardle
MEng 3rd Year Group Project
Sheet: /Stepper Motor Controller 2/
File: stepper.sch
Title: Stepper Motor Controller
Size: A4
Date: 10 Dec 2013
Rev: 2
KiCad E.D.A. eeschema (2013-11-20 BZR 4495)-product
Id: 2/4



Author: Alex Wardle

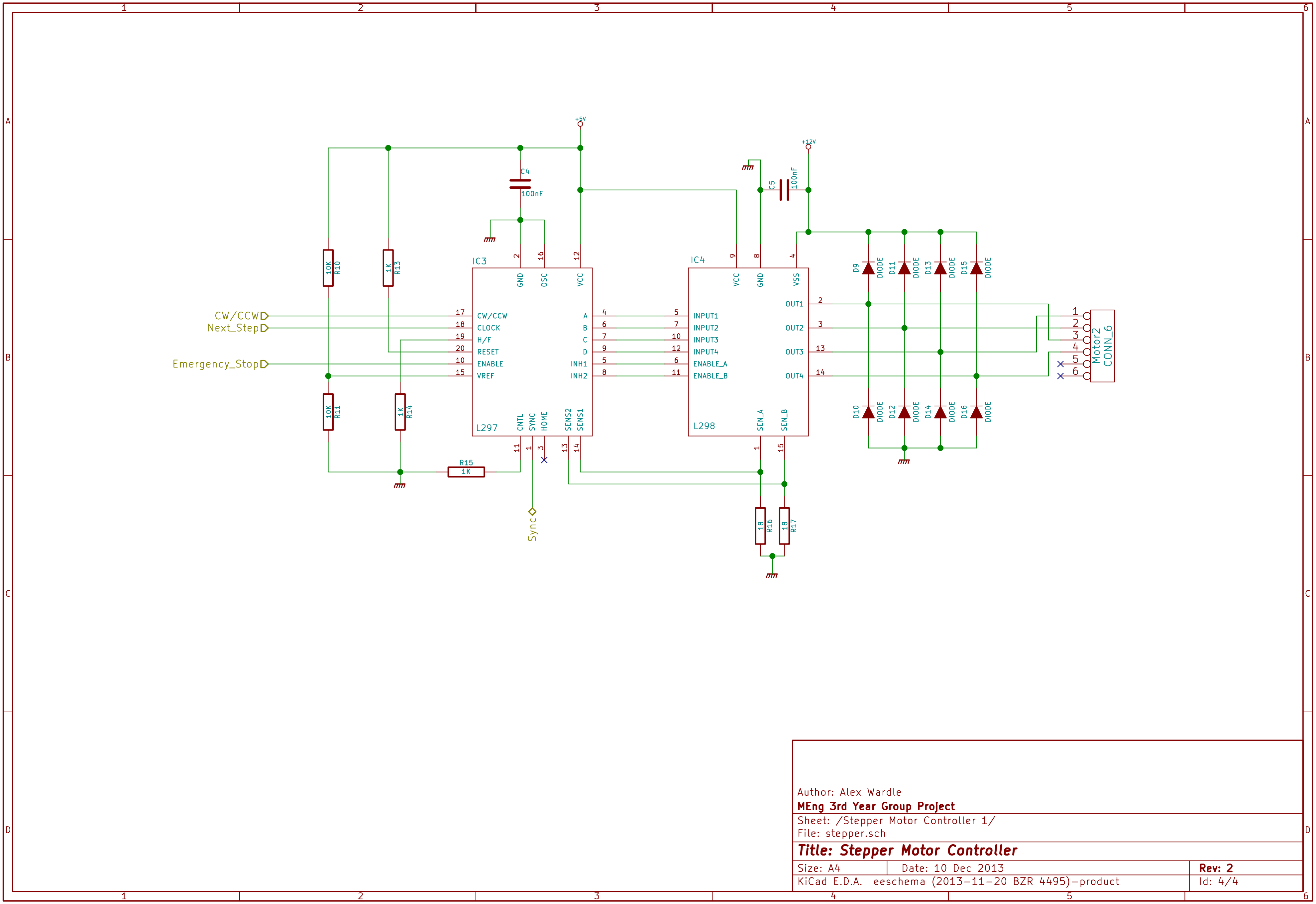
MEng 3rd Year Group Project

Sheet: /Stepper Motor Controller 3/

File: stepper.sch

Title: Stepper Motor Controller

Size: A4	Date: 10 Dec 2013	**Rev: 2**
KiCad E.D.A. eeschema (2013-11-20 BZR 4495)-product		Id: 3/4



Author: Alex Wardle
MEng 3rd Year Group Project
Sheet: /Stepper Motor Controller 1/
File: stepper.sch
Title: Stepper Motor Controller
Size: A4
Date: 10 Dec 2013
Rev: 2
KiCad E.D.A. eeschema (2013-11-20 BZR 4495)-product
Id: 4/4
IC3
L297
IC4
L298
CW/CCW
Next_Step
Emergency_Stop
Sync
Motor2
CONN_6
+5V
+12V
C4
100nF
C5
100nF
R10
10K
R11
10K
R13
1K
R14
1K
R15
1K
R16
18
R17
18
D9
D10
D11
D12
D13
D14
D15
D16
DIODE

Appendix B

Python Vision Code

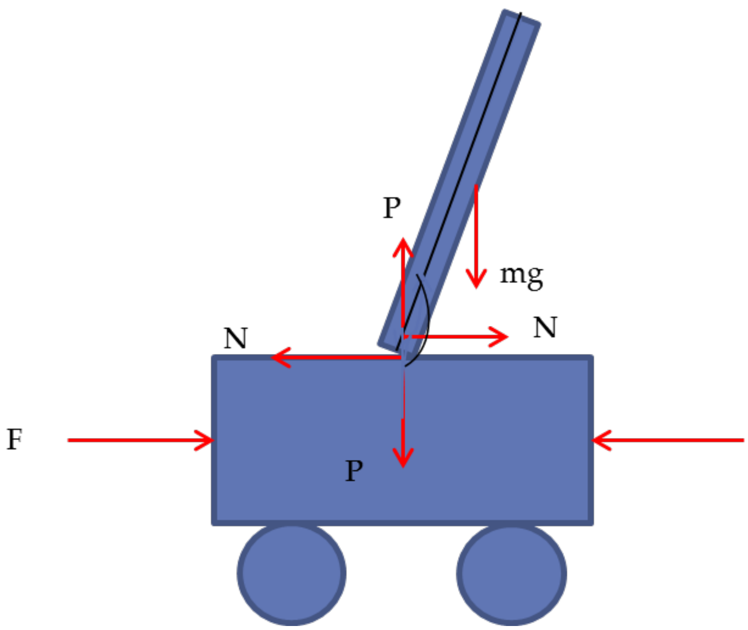
```
# Author: Alex Wardle
#
# Gets a stream from a video camera. Detects
# moving lines. Gives average angle of all
# detected lines.

from __future__ import division
from math import pi
import numpy as np
import cv2


# Setup camera
camera = cv2.VideoCapture(1)

# Setup background subtractor
fgbg = cv2.BackgroundSubtractorMOG()

while(True):
    # Capture frame-by-frame
    ret, frame = camera.read()

    # Get size of frame
    width = np.size(frame, 1)
    height = np.size(frame, 0)

    #gray = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)
    gray = frame

    # Apply background subtractor
    graysub = fgbg.apply(gray)

    # Apply edge detection
    edgessub = cv2.Canny(graysub,100,200)
    edges = cv2.Canny(gray,100,200)

    # Detect lines in picture
    lines = cv2.HoughLines(edgessub,1,np.pi/180,50)
    lineimg = gray

    # Set postion and colour of text. Text in bottom left hand corner
    x = 10
    y = int(height-10)
    text_color = (255,0,0)


    # If lines are found
    if lines != None:
```

```
        average_angle = 0

        # For each detected line
        for rho,theta in lines[0]:

            # Create line
            a = np.cos(theta)
            b = np.sin(theta)
            x0 = a*rho
            y0 = b*rho
            x1 = int(x0 + 1000*(-b))
            y1 = int(y0 + 1000*(a))
            x2 = int(x0 - 1000*(-b))
            y2 = int(y0 - 1000*(a))

            # Convert angle so 0 is vertical. Angles to the right are positive and the left are negative
            if theta > pi/2:
                theta = -(pi/2 - (theta - pi/2))

            average_angle += theta

            # Add line to picture
            cv2.line(lineimg,(x1,y1),(x2,y2),(0,0,255),2)

        # Calulate average angle
        average_angle = average_angle / len(lines[0])
        angle_deg = average_angle * 180 / pi

        # Add text showing angle to picture
        cv2.putText(lineimg, str(angle_deg), (x,y), fontFace=cv2.FONT_HERSHEY_PLAIN, fontScale=1.0, color=text_color, thickness=1, lineType=cv2.CV_AA)



    # Display the resulting frame
    cv2.imshow('grey',gray)
    cv2.imshow('greysub',graysub)
    cv2.imshow('egdesub',edgessub)
    cv2.imshow('egde',edges)
    cv2.imshow('lineimg',lineimg)

    # Wait for 1ms and quit if q is pressed
    if cv2.waitKey(1) & 0xFF == ord('q'):
        break

# Release the capture
camera.release()

# Close windows
cv2.destroyAllWindows()
```

Appendix C

Mathematical Derivation

Based on information from http://ctms.engin.umich.edu/CTMS/index.php?example=InvertedPendulum&section=SystemModel



Force Analysis and System Equations

Firstly, we look into the forces in the horizontal direction of the platform, and get the following equation:

$$M\ddot{x} + b\dot{x} + N = F$$

And summing the forces around the pendulum to get the reactive force N

$$N = m\ddot{x} + ml\ddot{\theta}cos\left(\theta\right) - ml\dot{\theta}^{2}sin\left(\theta\right)$$

If you substitute this equation into the first one ,you will get one of the two governing equations shown as follows

$$\left(M+m\right)\ddot{x} + b\dot{x} + ml\ddot{\theta}cos\left(\theta\right) - ml\dot{\theta}^{2}sin\left(\theta\right) = F$$

Furthermore, we sum the forces perpendicular to the pendulum to get the second equation,

$$Psin\left(\theta\right) + Ncos\left(\theta\right) - mgsin\left(\theta\right) = ml\ddot{\theta} + m\ddot{x}cos\left(\theta\right)$$

Similarly, we sum the moments about the centroid of the pendulum to eliminate the P and N

$$-Plsin\left(\theta\right)-Nlcos\left(\theta\right)=I\ddot{\theta}$$

Then, we get the second governing equation

$$\left(I+ml^{2}\right)\ddot{\theta}+mglsin\left(\theta\right)=-ml\ddot{x}cos\left(\theta\right)$$

However, we must linearise the system, because the controller (PID controller) is only suitable to the linear system, let θ stands for a small angle from equilibrium, and generate the following approximations:

$$cos\left(\theta\right)=cos\left(\pi+\varphi\right)\approx-1$$

$$sin\left(\theta\right)=sin\left(\pi+\varphi\right)\approx-\varphi$$

$$\dot{\theta}^{2}=\dot{\varphi}^{2}\approx0$$

Substitute them into our governing equations, arriving at two linearised equations of cart-pendulum system

$$\left(I+ml^{2}\right)\ddot{\varphi}-mgl\varphi=ml\ddot{x}$$

$$\left(M+m\right)\ddot{x}+b\dot{x}-ml\ddot{\varphi}=u$$

Transfer function

Turn the system equations into the Laplace form assuming zero initial conditions, and get the result:

$$\left(I+ml^{2}\right)\phi\left(s\right)s^{2}-mgl\phi\left(s\right)=mlX\left(s\right)s^{2}$$

$$\left(M+m\right)X\left(s\right)s^{2}+bX\left(s\right)s-ml\phi\left(s\right)s^{2}=U\left(s\right)$$

Solving the X(s) from the first function and substitute into the second one , and we get transfer functions of the system:

$$P_{pend}\left(s\right)=\frac{\phi\left(s\right)}{U\left(s\right)}=\frac{\frac{ml}{q}s}{s^{3}+\frac{b\left(I+ml^{2}\right)}{q}s^{2}-\frac{\left(M+m\right)mgl}{q}s-\frac{bmgl}{q}}$$

$$P_{cart}\left(s\right)=\frac{X\left(s\right)}{U\left(s\right)}=\frac{\frac{\left(I+ml^{2}\right)s^{2}-gml}{q}}{s^{4}+\frac{b\left(I+ml^{2}\right)}{q}s^{3}-\frac{\left(M+m\right)mgl}{q}s^{2}-\frac{bmgl}{q}s}$$

$$q=\left[\left(M+m\right)\left(I+ml^{2}\right)-\left(ml\right)^{2}\right]$$

Firstly, we measured the detail of the system and get the following quantities:

(M)mass of the cart 1.5kg

(m)mass of the pendulum 0.7kg

(b)coefficient of friction for cart 0.6N/m/sec

(l)length to pendulum centre of mass 0.7m

(I)mass moment of inertia of the pendulum 0.099kg.m^2

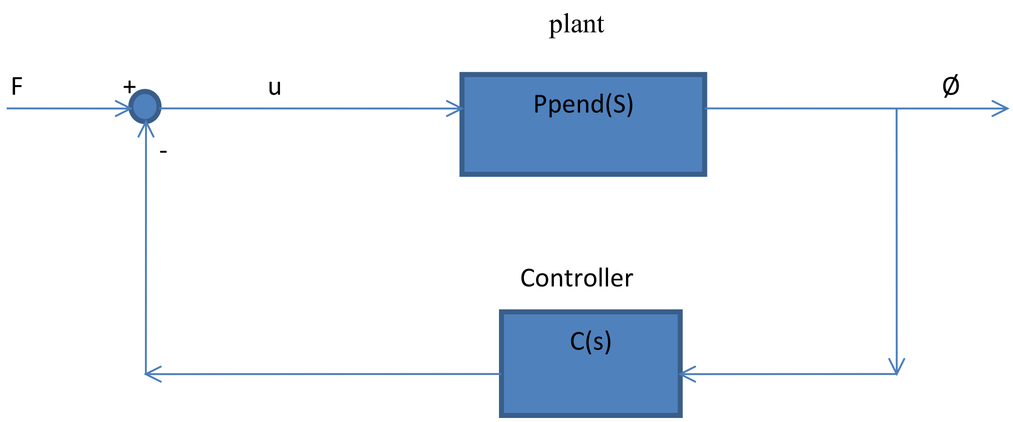
Then we input the following codes into MATLAB to calculate the continuous-time transfer function

```
M = 1.5;
m = 0.7;
b = 0.6;
I = 0.099;
g = 9.8;
l = 0.7;
q = (M+m)*(I+m*l^2)-(m*l)^2;
s = tf('s');

P_cart = (((I+m*l^2)/q)*s^2 - (m*g*l/q))/(s^4 + (b*(I + m*l^2))*s^3/q - ((M
+ m)*m*g*l)*s^2/q - b*m*g*l*s/q);

P_pend = (m*l*s/q)/(s^3 + (b*(I + m*l^2))*s^2/q - ((M + m)*m*g*l)*s/q -
b*m*g*l/q);

sys_tf = [P_cart ; P_pend];

inputs = {'u'};
outputs = {'x'; 'phi'};

set(sys_tf,'InputName',inputs)
set(sys_tf,'OutputName',outputs)

sys_tf


sys_tf =

  From input "u" to output...
                   0.237 s^2 - 2.575
   x:  ---------------------------------------------
       0.3927 s^4 + 0.1422 s^3 - 5.665 s^2 - 1.545 s

                       0.2628 s
   phi:  -----------------------------------------
         0.3927 s^3 + 0.1422 s^2 - 5.665 s - 1.545

Continuous-time transfer function.
```

Next we will define a PID controller

PID control

Model a PID controller in MATLAB using the closed-loop function above , copying the following code to the end of m-file .initially , we define the proportional, the integral and derivative values to 1, structure a controller using pid object within MATLAB, and apply the feedback command to provide a close-loop showed follows:




```
Kp = 1;
Ki = 1;
Kd = 1;
C = pid(Kp,Ki,Kd);
T = feedback(P_pend,C);
```

and generate a response plot using the following command:

```
t=0:0.01:10;
impulse(T,t)
title('Response of Pendulum Position to an Impulse Disturbance under PID
Control: Kp = 1, Ki = 1, Kd = 1');
```

Obviously, this response is not stable, so we begin to tune our controller(Figure1)

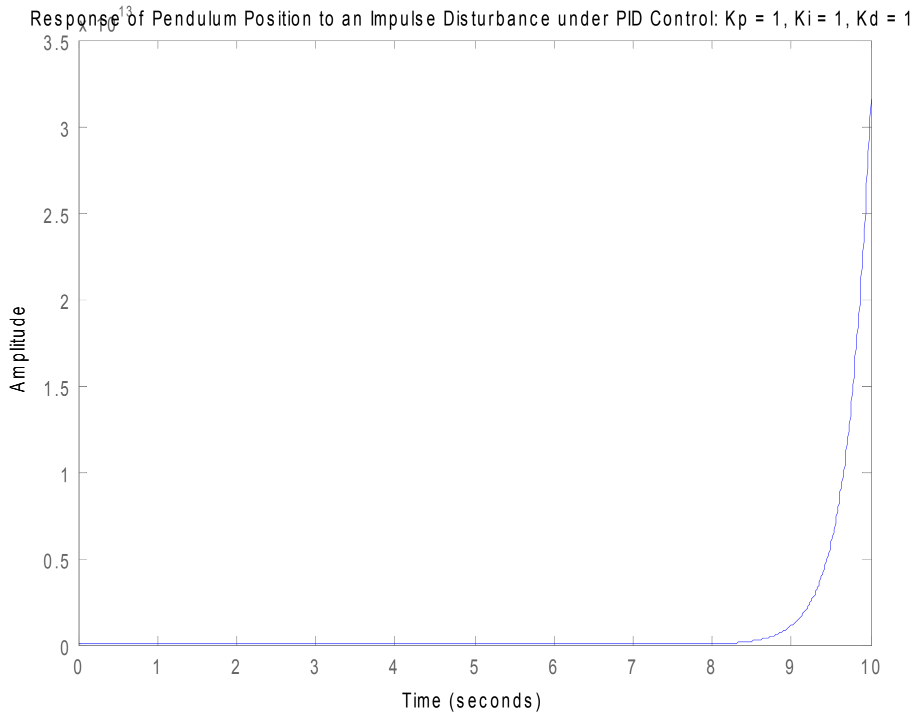


Figure1

Enter the following code and get the response plot shown below(Figure2)

```
Kp = 400;
Ki = 0;
Kd = 1;
C = pid(Kp,Ki,Kd);
T = feedback(P_pend,C);
t=0:0.01:10;
impulse(T,t)
axis([0, 2.5, -0.2, 0.2]);
title('Response of Pendulum Position to an Impulse Disturbance under PID
Control: Kp = 400, Ki = 0, Kd = 1');
```

To perfect the system,we change the Kd to 20,and get the response plot

```
Kp = 400;
Ki = 0;
Kd = 25;
C = pid(Kp,Ki,Kd);
T = feedback(P_pend,C);
t=0:0.01:10;
impulse(T,t)
axis([0, 2.5, -0.2, 0.2]);
title('Response of Pendulum Position to an Impulse Disturbance under PID
Control: Kp = 400, Ki = 0, Kd = 25');
```

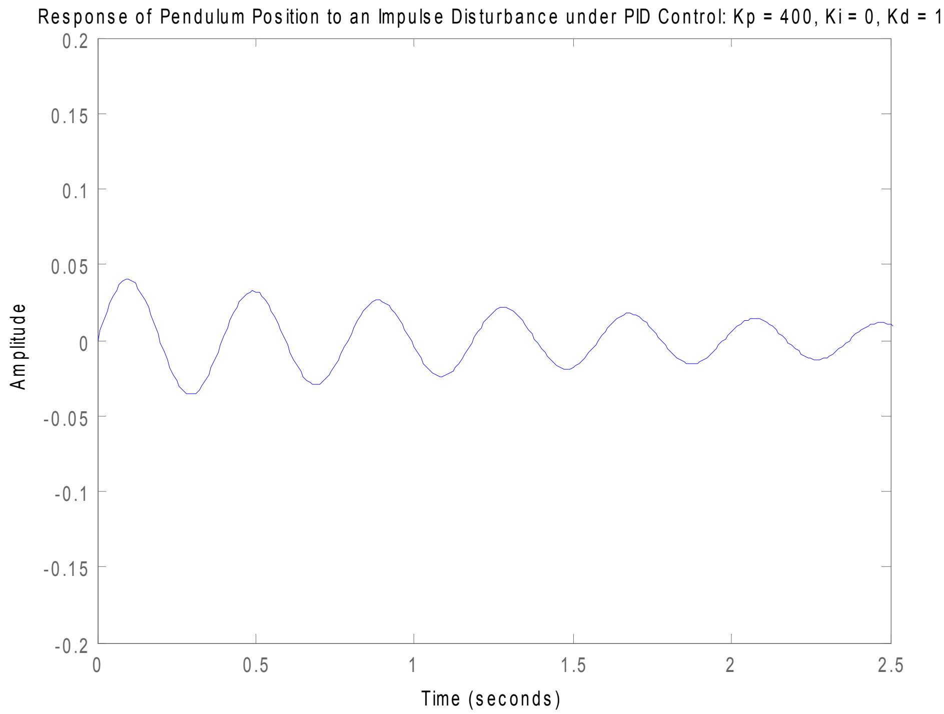


Figure2

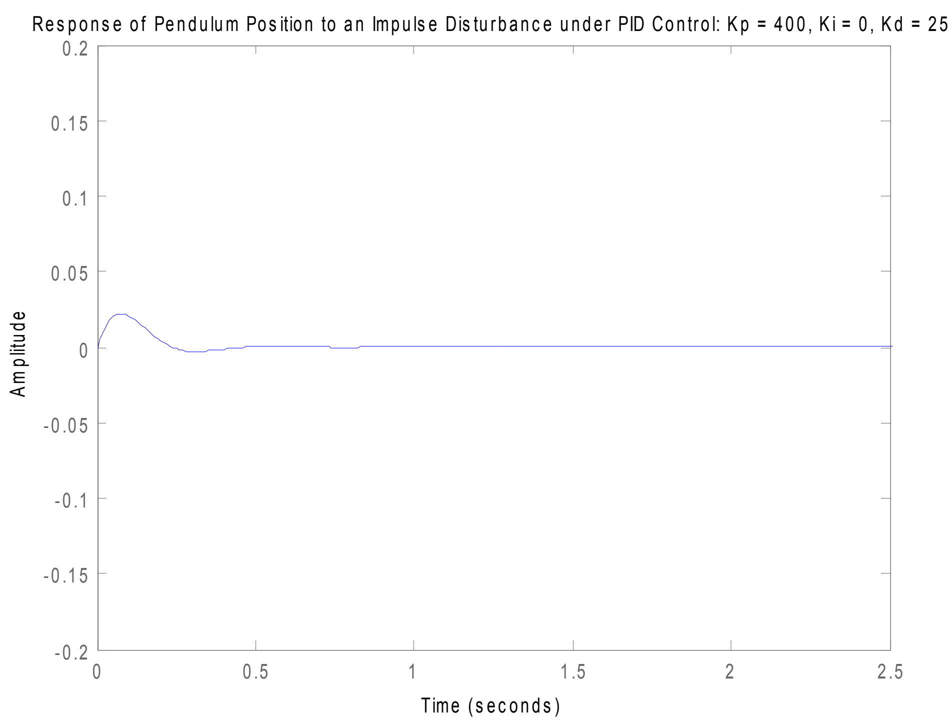
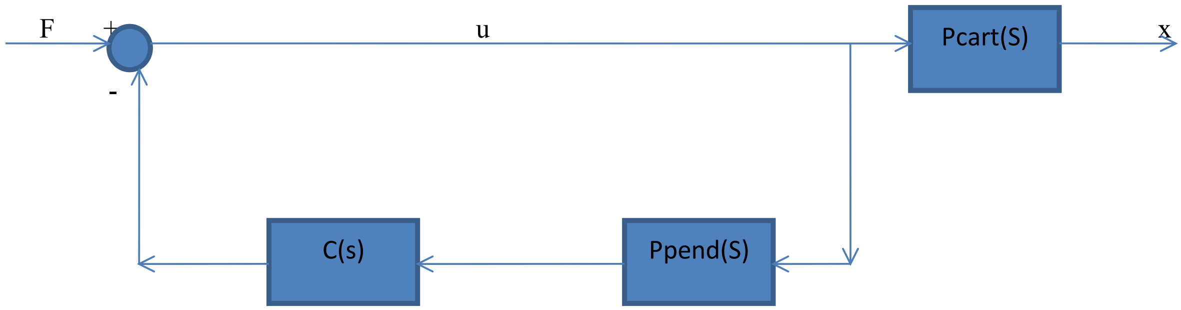


Figure3

Position of the cart

then we look into cart's position, so draw a block diagram shown below for the full system



The close-loop transfer functionT2(s) which is the relationship between force applied and position of the cart is given as follows:

Adding the following command to our m-file will get the response of the cart's position(Figure4)

```
P_cart = (((I+m*l^2)/q)*s^2 - (m*g*l/q))/(s^4 + (b*(I + m*l^2))*s^3/q - ((M
+ m)*m*g*l)*s^2/q - b*m*g*l*s/q);
T2 = feedback(1,P_pend*C)*P_cart;
t = 0:0.01:5;
impulse(T2, t);
title('Response of Cart Position to an Impulse Disturbance under PID
Control: Kp = 400, Ki = 0, Kd = 25');
```

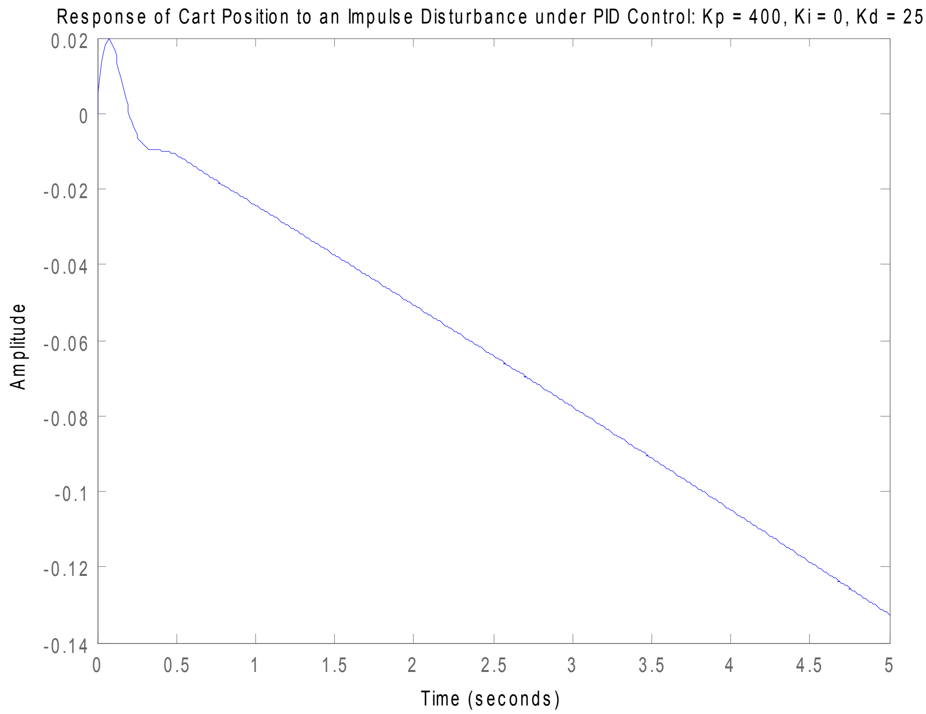
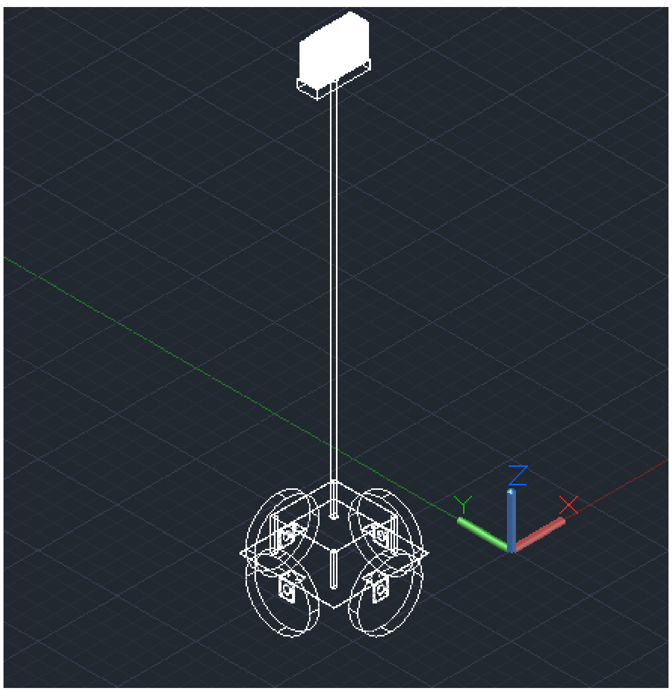
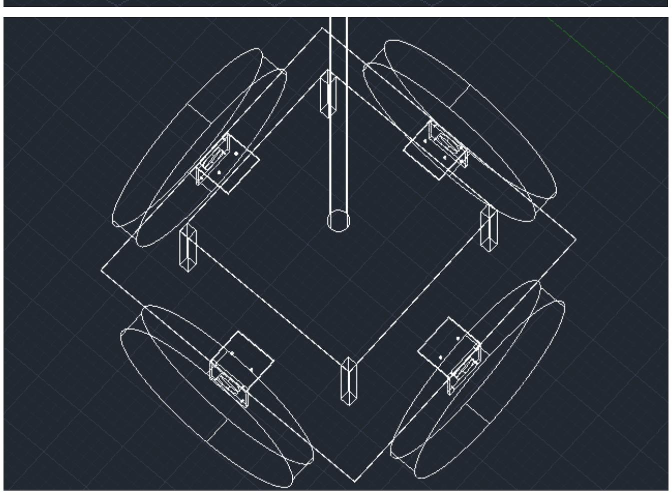

Response of Cart Position to an Impulse Disturbance under PID Control: Kp = 400, Ki = 0, Kd = 25
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14
Amplitude
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (seconds)

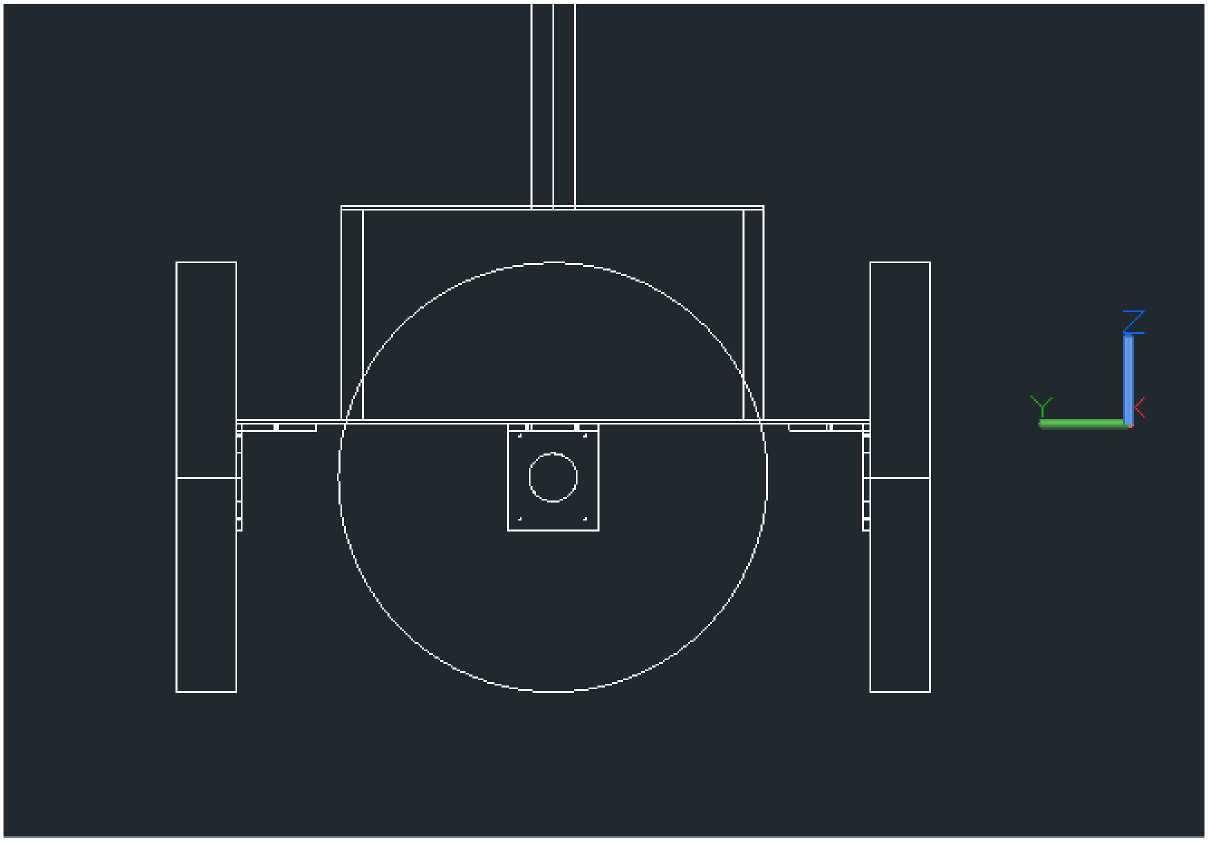
Figure4

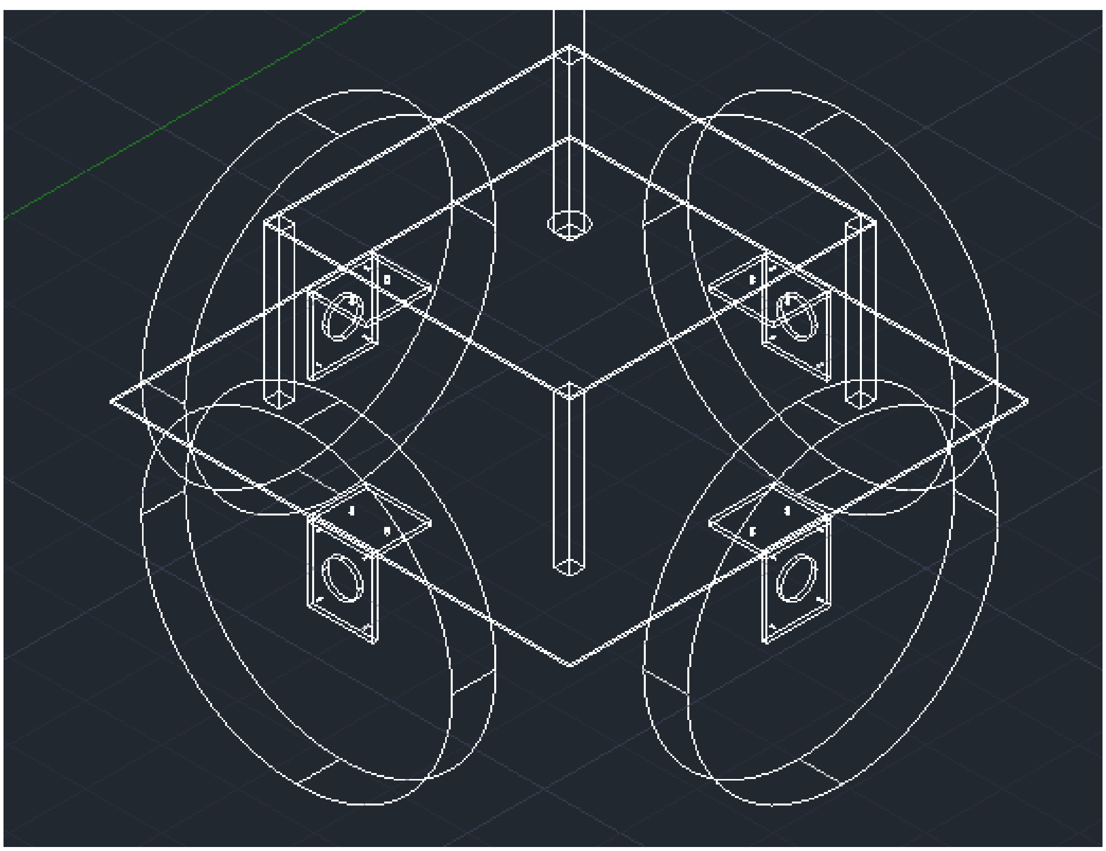
Appendix D

CAD Drawings of Robot






Z
Y



Appendix E

Arduino Demo Code

```
/**
 *  @author Alex Wardle
 *  @date 2013-12-10
 *
 *  Makes robot drive backwards and forwards in one
 *  direction.
 */

// Pins for motor direction
const int motor_dir_n = 2;
const int motor_dir_e = 4;
const int motor_dir_s = 6;
const int motor_dir_w = 8;

// Pins for motor steps
const int motor_n = 3;
const int motor_e = 5;
const int motor_s = 7;
const int motor_w = 9;

// Delay between steps in ms
const int delay_time = 5;

void setup()
{
  // Set Pins to Outputs
  pinMode(motor_dir_n, OUTPUT);
  pinMode(motor_dir_e, OUTPUT);
  pinMode(motor_dir_s, OUTPUT);
  pinMode(motor_dir_w, OUTPUT);

  pinMode(motor_n, OUTPUT);
  pinMode(motor_e, OUTPUT);
  pinMode(motor_s, OUTPUT);
  pinMode(motor_w, OUTPUT);

  // Set all output pins low
  digitalWrite(motor_dir_n, LOW);
  digitalWrite(motor_dir_e, LOW);
  digitalWrite(motor_dir_s, LOW);
  digitalWrite(motor_dir_w, LOW);

  digitalWrite(motor_n, LOW);
  digitalWrite(motor_e, LOW);
  digitalWrite(motor_s, LOW);
  digitalWrite(motor_w, LOW);

}
```

```

void loop()
{
  // Set motors to drive forward
  digitalWrite(motor_dir_n, LOW);
  digitalWrite(motor_dir_s, LOW);

  // Rotate motors 300 times
  rotate_motor_ns(300);

  // Set motors to drive backwards
  digitalWrite(motor_dir_n, HIGH);
  digitalWrite(motor_dir_s, HIGH);

  // Rotate motors 300 times
  rotate_motor_ns(300);

}

/**
 *  @param [in] times number of steps to rotate motor
 *
 *  Rotates the motor x number of steps in the direction
 *  the motor is set in.
 */
void rotate_motor_ns(int times)
{
  for (int i = 0; i < times; i++)
  {
    digitalWrite(motor_n, HIGH);
    digitalWrite(motor_s, HIGH);
    delay(delay_time);
    digitalWrite(motor_n, LOW);
    digitalWrite(motor_s, LOW);
    delay(delay_time);
  }
}
```

Appendix F

Meeting Minutes

Formal meetings were held every week between 1200-1300 on Wednesday. Minutes from some of the meetings are shown below. In the other meetings no formal minutes were made, this was an oversight in the meetings as no person was assigned to record the meetings. A job list was however created and was updated from these meetings. In future meetings an official minuter was appointed and minutes will be created.

Meeting Minutes – 2013-10-11

Minuter: A Wardle

Present: S Aamir (SA), F Egal (FE), C Gan (CG), T Lim (TL), J Liu (JL), N Mohd Ghzali (NMG) & A Wardle (AW)

AW volunteered to be project manager. Project manager was decided to be AW.

Times for a regular meetings were discussed. Regular meetings once a week on Wednesdays between 1200-1300 in the Link were chosen. Everyone to be present at these meetings.

Communication methods were discussed. AW to create mailing list for all communication. CG to look into creating a discussion group on canvas to be used if necessary.

NMG suggested that we should keep a lab book. Group agreed. NMG to get lab book.

It was suggested that we should ask N Cooke to join the weekly meetings.

NMG printed off risk assessment and ethics questionnaire. To be completed in the future.

N Cooke (NC) joined meeting.

Discussion about the sort of things we need to concentrate on. NC suggested that we should find ways to simplify the task. NC also suggested that we should think about what the main problems are.

The group discussed how the platform is going to move in both x and y planes. Group to look at ways to do this and report back next meeting.

It was decided that it would be useful to acquire the broom now. AW to get broom.

Next meeting to be 2013-10-16 1200-1300 in the Link.

<u>Meeting Minutes – Whole Group – 2013-10-16</u>

Minuter: A Wardle

Present: S Aamir (SA), F Egal (FE), C Gan (CG), J Liu (JL), N Mohd Ghzali (NMG) & A Wardle (AW)

TL gives her apologises for not being at the meeting since she is sick.

NMG has got a lab book. She will hold onto the lab book until we have somewhere communal to store it.

Main problems with the project were discussed. Two were finalised on, how to make the robot move in both the x & y directions and how to get the broom to balance.

It was decided that the group will split into two sub groups to focus on these questions.

The first group that is comprised of CG, TL & AW will focus on moving the robot in both the x&y directions. The second group comprised of SA, FE, JL, NMG will focus on getting the machine vision and broom balancing system working.

Discussions took place about the main ways of moving the robot and examples were shown.

CG sent an email to Mike Spann asking him to clarify if the cameras have to be separate to the robot. CG will forward the reply to the mailing list.

NMG is now responsible for getting the broom.

The next whole group meeting to be 2013-10-23 1200-1300 in the Link.

The broom balancing group will meet 2013-10-20 1400 in the Learning Centre.
The robot group will meet 2013-10-17 1130 in the Link.

<u>Meeting Minutes – Robot Sub Group – 2013-10-17</u>

Minuter: A Wardle

Present:C Gan (CG), T Lim (TL) & A Wardle (AW)

Various propulsion methods were discussed. Two methods were chosen to do more research on, these were omnidirectional wheel and a compressed air system which maybe based on a hovercraft or based on wheels. The second method is planned to be a backup if the first method doesn't work.

Group going to research various requirements and parameters for stepper motors and omnidirectional wheels to report at the meeting.

The next whole group meeting to be 2013-10-23 1200-1300 in the Link.

No further separate meetings of the robot sub group scheduled.

Meeting Minutes – 2013-11-27

Minuter: A Wardle

Present: S Aamir (SA), F Egal (FE), C Gan (CG), T Lim (TL), J Liu (JL), N Mohd Ghzali (NMG) & A Wardle (AW)

How to build the stepper motors controllers was discussed. The merits of using PCB or strip board. Strip board was decided on.

AW explained that the circuit diagram for the stepper motor controllers was completed but there was an error with the emergency stop system.

CG reported that the metal for the platform had arrived.

CG showed sample motor mounts and informed that 2 more needed to be made by the workshop. CG was going to go and get the motor mounts created.

SA & CG said they were finishing the platform design and it would be read soon.

N Cooke (NC) joined meeting.

FE explained that they had tried to simulate a virtual version of the inverted pendulum however the software required was not on the school computer. It was agreed that this was not important and the virtual version was not necessary.

System integration was discussed. It was decided that it would be useful to have a dedicated system integrator. FE was chosen as system integrator.

NC advised us that design justification was most of the presentation and report content.

Concerns about the speed of the Raspberry Pi were raised by SA. It was decided that we would need to test the Raspberry Pi to see if it could handle this. If not two Raspberry Pi would be used.

NC suggested that the Raspberry Pi IR camera could be useful.

Next meeting to be 2013-12-04 1200-1300 in the Link.

Appendix G

CVs

12 Barnesville Close
Small Heath
Birmingham
West Midlands
B 10 9LN

Ahmed Egal

axe147@bham.ac.uk
07774697277

Personal Statement

I am a third year MEng student, studying Electrical and Electronic Engineering at the University of Birmingham. I wish to apply the skills I have acquired through studies in an industrial environment and I am willing to learn new skills that may help me adapt in such an environment. I am enthusiastic about working with different people in a team and also confident enough to perform tasks individually.

Qualifications

University of Birmingham

Year 1: 2:1

Year 2: 2:1

A-levels – Joseph Chamberlain College

Maths:	A*	Computing	B
Physics:	A	English Lang/Lit :	C

GCSE – Al-Hijrah Secondary School

Maths :	A	Arabic:	A*
Science DA	A	Islamic Studies:	A
English Lang	A	I.C.T:	B
English Lit	B		

Personal Skills

- Well-organised and hard-working
- I take pride in my punctuality my time-management skills
- Experienced in working in a team as I was a member of a group robot project in my second year at university.
- Communicates effectively and good at assigning tasks to different members of a group based on how they're coping
- Able to think logically to solve problems

12 Barnesville Close
Small Heath Ahmed Egal axe147@bham.ac.uk
Birmingham 07774697277
West Midlands
B 10 9LN

Technical Skills

- MATLAB
- PIC Programming
- C programming language
- Circuit construction and fault-finding
- Active-HDL

Work Experience

La Favorita Restaurant - (February - April 2012)

I worked in this restaurant as a waiter. Speaking to customers was an important part of my job here which helped to improve my communication skills as well as building up my confidence. Being under circumstances whereby we had to do multiple tasks in a short space of time enabled me to work better under pressure and also cooperate and complete tasks efficiently with my colleagues, hence improving my team-working skills

Home Fundraising: Cancer Research UK - (August 2012)

Working for Cancer Research UK helped me enormously in my communication skills as I would speak to around 150-200 people every day. We would also work in groups and this helped with my team-working skills.

Al-Afrah - (September - December 2012)

Working in retail enabled me to work well under pressure as well as my communication skills as I would be talking to customers throughout the day

.

Hobbies and Interests

I love to play football in my spare time. I was captain of my college football team which helped me immensely with my communication and team-work skills. I also like to go skydiving when I have the opportunity. I am currently a member of our Engineering department's society and participate in the different events that are arranged. I organised a charity event in my college which consisted of a talent show, a fashion show and also a play. This helped me improve my organisational and time-management skills and my ability to work under pressure.

References

References are available on request

Gan Chee Heing

Apt 9 Dain Court,488
Bristol Road, Selly Oak,
Birmingham,B29 6BD.

Mobile: 07473848399
Email:cheeheing.0902@gmail.com

EDUCATION AND QUALIFICATION

2013-present	University of Birmingham MEng Electronic and Electrical Engineering All of MEng subjects are accredited by the Institution of Engineering and Technology (IET), providing me with a professionally recognised degree, and one which has a great reputation within the industry.
2011-2012	Taylor’s University Malaysia Bachelor of Engineering (Honours) in Electrical & Electronic Engineering **CGPA of 3.76, Awarded 4 times Dean’s List Award** Part of the team for project Mind Controlled Wheelchair and **awarded bronze medal** in **Malaysia Technology Expo 2012.** Part of the team for project Air Jelly and **awarded Best Mechanical Design in Engineering Fair 2012.** Highly proficiency in Engineering Mathematics provides me a strong foundation in engineering. Demonstrate strong ability in circuit and signal analysing.

2010	Taylor's College Malaysia SAM(South Australian Matriculation): Chemistry A18, Mathematical Studies A18, Physics A17, Specialist Mathematics A17, English as Second Language Studies B15 **ATAR:95.25**

ELECTRICAL RELATED WORK EXPERIENCE

2012 (Feb – April)	ABB Ltd (Malaysia) Electrical Technician Assistant Checked the wiring of circuits for switchgear and circuit breaker in production line Tested the functionality of switchgear by carrying out primary injection test, secondary injection test, Megohmmeters, Electrical and Mechanical Operation Test Setting up values for overcurrent earth fault relay
2013 (Jan – May)	Mahgan Engineering Ltd (Malaysia) Intern 5 months work experience of site jobs together with the company technical team. Possess knowledge about the market of electrical service job and equipment price after helping the company to prepare documents such as quotation, purchase order and invoice

ADDITIONAL WORK EXPERIENCE

2012	Digi Telecommunication Ltd (Malaysia) Clerk- Filing and sorting out data

VOLUENTARY WORK EXPERIENCE

2012

Taylor's University (Malaysia)

Tutorial session for junior on subject Signal and System

Student guide on orientation day

ADDITIONAL SKILLS

Language - Fluent in Chinese and semi-fluent in Malay

ADDITIONAL

- Enjoy trading of stock market in Malaysia

Lim Tze Bey

Mobile: 07842111046 Email: TBL336@bham.ac.uk

Education

2013 – present	**University of Birmingham, UK**
	MEng in Electronic and Electrical Engineering
	Modules included Computer Hardware and Digital Design, Analogue Electronics, Organisation and Management, Electrical Power Transmission and Distribution and Renewable Energy.
	Project: Dance Sweeping Broom
2011 – 2013	**Taylor's University Lakeside Campus, Malaysia**
	BEng in Electronic and Electrical Engineering
	In Taylor's University, every student is required to finish a group project within 14 weeks in each and every semester. Working with other students have let me to understand about teamwork, tolerance and having the will to have more rooms of improvements. Below are some of the project titles:
	Semester 1 project: Shell Eco Marathon project Semester 2 project: Ergonomic plastic bag handle Semester 3 project: Small scale vertical axis wind turbine Semester 4 project: Signal features for cyclists' helmet
2010 – 2011	**Disted College, Malaysia**
	GCE A-Levels
2005 – 2009	**Penang Chinese Girls' High School, Malaysia**
	SPM (Malaysia Certificate of Education): 11 subjects at grades A+ to C+

Working Experience

2010 (Jan – Feb) **Kitschen, Malaysia**

Sales Assistant (Part Time)

- Involved in all aspects of customer service including till work, stocktaking and shelf-filling
- Required high levels of teamwork and the ability to adapt quickly to a range of different circumstances.

Technical Skills

Sound knowledge of basic operating systems like Microsoft Word, Excel and Powerpoint

Familiar with software tools like Assembly language, MATLAB, C Programming, Multisim and VHDL

Extra-Curricular Activities

2008 – 2009 **Young Enterprise Club** – Quality Control Director

Responsible for maintaining the quality of the goods produced.

Achievements: Best Managed Company, Most Profitable Stall and Best Annual Report in AMCHAM Young Entrepreneur Program

2008 **Science and Technology Society** – Vice President

Represented the school in Formula One Technology Challenge

2008 – 2009 **Graduation Magazine Committee** – Vice Treasurer

2005 – 2009 **Board of Librarians** – Member

2005 – 2008 **Olympiad Mathematics Society** – Treasurer (2008), Member (2005 – 2007)

Achievements

2008 Champion in Malaysian Mensa Puzzler's Challenge

Distinction in New South Wales International Competitions for Schools (Mathematics Assessment)

Jin Liu

Room 1, Flat 11, Block 2, Ashcroft, Pritchatts Park,

Edgbaston, Birmingham, B15 2QU

07955 094 154

liujin950@gmail.com

Education:

University of Birmingham **Sep 2013-Jul 2015**

MEng Electronic and Electrical Engineering

Harbin Institute of Technology **Sep 2010--Jul 2013**

Bachelor of Electrical Engineering and the Automatization

Technical Competencies:

C program, VHDL,Protel99se,MATLAB,Lathe,Shaper, Numerically Controlled Discharge Machine, Grinder, Milling

Internship& Experience:

Internship, State Grid Corporation, Harbin, China

Jul 2012-Sep 2012

Examine and repair cables during a summer vacation, visit local power stations and acknowledge some power equipments.

- *Mix the theoretical knowledge and practical working experience*
- *Improve understanding of working process*

The chairman ,computer corporation Harbin institute of Technology

Sep 2010-Sep 2011

Teach computer science to the freshmen in campus and organize a computer science match, improve their computer skills and any provide any electronic service for them.

- *Improve communication skills*
- *Develope team and consulting abilities*

Interest

Play traditional instrument,penmanship

Saad Aamir

Address: 6 Dartmouth Road, Selly Oak, Birmingham, B29 6EA,United Kingdom
E-Mail: saad-aamir@live.com; sxa353@bham.ac.uk
Mobile-UK: +447501300925
Mobile-Kuwait: +96566009458

Education

- **The University of Birmingham, United Kingdom**
  Master of Engineering (M.Eng), Electrical and Electronics Engineering with Industrial Year
  2013 – 2016
  First Class Honours (Expected)
- **Taylor's University, Malaysia**
  Electrical and Electronics Engineering,
  2011 – 2013
  Grade: 3.11/4.0
- **International School & College of Pakistan, Kuwait**
  A-level: Mathematics (A), Physics (B) and Chemistry (C)
  (300 UCAS Tariff Points) 2009-2011

Projects

- **Harvesting Energy Using Piezoelectric Material**
  September 2011 to December 2011.
  To design, build and install aesthetically appealing renewable energy features such as Piezoelectric in the lakeside campus.
- **Stretching Chair**
  March 2012 to June 2012.
  To design and build a stretching chair for our Engineering Design and Ergonomics module, that is capable of stretching all the major muscle groups found in ones upper body.
- **Shell Eco Marathon (2013)**
  August 2012 to December 2012.
  The objective of this project was to design and built an eco friendly electric car, which covers the most distance with the least amount of energy.
- **Managing a Semester 4 Project Team**
  April 2013 to July 2013.
  To work as a project manager of a semester 4 team participating in Taylor's University Engineering Fair July 2013.
- **Dancing Sweeping Brush third year M.Eng Project**
  September 2013 to Present.
  To Design, Prototype and demonstrate a system which is able to balance a vertically upright an inverted sweeping brush on a moveable platform using a real time multi-view active vision system.

Honour

- **Dean's Honours List Awards.**
  Awarded Dean's List by Taylor's University for Semester 1 of the Bachelor of Engineering (Honours) Electrical & Electronic Engineering Programme.

Skills & Expertise

- Able to use modern computational tools for technical problem solving such as:
  - Matlab & Simulink
  - Microsoft office including Visio
  - iWork
  - SolidWorks
  - NI Multisim
  - Ultiboard
  - Photoshop
  - Eagle
  - LabVIEW
  - Proteus
  - Latex
  - C/C++
  - VHDL
  - Assembly
- Able to work in a team not only as a committed individual but also as a leader in achieving common goals in the multi-disciplinary field of Engineering.
- Ability to identify, formulate and solve both well defined and open ended engineering problems.
- Capable of accomplishing given tasks relevant to the field of Electrical & Electronic Engineering independently and presenting the results in written and oral modes with self-reliance and a positive attitude.
- Able to handle challenges, comments and criticisms.
- Languages:
  - English (Professional working proficiency)
  - Urdu (Native proficiency)

Extra-Curricular Activities

- Year 3 Student Representative, University Of Birmingham.
- Floor Leader, Taylor's University Residence.
- University of Birmingham Sports, Free Weights Training.
- University of Birmingham Sports, Squash.
- Voluntary services during the sixth and seventh free Medical Camp held in KUWIAT.
- Photographer at REDBRICK, University Of Birmingham newspaper.
- Sky Diving.

NURSYAHIRAH MOHD GHAZALI

Mobile: 07715458786 ***Email: nbm121@bham.ac.uk***

11A Hubert Road, Selly Oak, Birmingham, WestMidlands B29 6DX

Profile

I am a very committed person with strong interpersonal skills and able to generate love of learning in things that I engage with. I enjoy working with others and I am also able to work on my own. Currently, I am looking for work experience in Electronic and/or Computer area.

Education

2011-present **University of Birmingham, United Kingdom**
MEng Electronic and Computer Engineering
Accredited by The Institution of Engineering and Technology

- Microprocessor System and Digital Logic
- Digital Systems and Embedded Computing
- Advanced C Programming
- Communication Systems
- Object Oriented Software Design
- Computer Hardware and Digital Design
- Analogue Electronics
- Electronic Circuits and Devices

2010 **University of Canterbury, New Zealand**
Engineering Intermediate
A good exposure to various types of engineering before specialising

- Introduction to Computer Programming
- Engineering Mathematics
- Mathematical Modelling and Computation
- Foundations of Engineering
- Engineering Physics

2008-2009 **International Education Centre (INTEC), Malaysia**
Australian Matriculation

- TER 90.7 in Australian Matriculation(AUSMAT)
  Including Chemistry (B), Mathematics (A), Specialist Mathematics (A), Physics (B), and English (B)
- **Special achievement:**
  - Represent INTEC for basketball inter-university where I broaden my network and developed networking skills

2006-2007 **MARA Junior Science College Tun Ghafar Baba, Malaysia**
A boarding school that has trained me to be independent

- **Malaysian Certificate of Eduacation (O level Equivalent)** in ten subjects including Maths (A), Additional Maths (A), Physics (A) and English language (A)
- **Special Achievements:**

- Second Place in Shooting Competition (state level) which I develop interpersonal skills
- Fifth Place in Compass Marching (national level) which I developed leadership and teamworking skills

Voluntary Experience

2013	Member of ISRAA' institution, a charitable organization aimed to help Palestinians
2011-present	Member of IKRAMUKE, a human developmental and training and charitable organization
Feb 2011	volunteer to help earthquake victims in badly affected area in Christchurch with Student Volunteer Army (SVA), University of Canterbury

Achievements

March 2012	Head Facilitator of Spring Camp (SCUK12) for Undergraduate Students in UK
July 2012	Deputy Director of Journey of a Muslim (JOM12) pre-departure program organized for Muslim Malaysian students
March 2013	Activity Coordinator of Spring Camp (SCUK13) for Undergraduate Students in UK

Skills

- Acquire hands on experience for the theories learned in university subjects
- Able to communicate and work in a group of diverse background
- Organized small projects and meet deadlines
- Competent in computer programming (C, Java, C++, VHDL, MATLAB, Python)
- Able to communicate in English and Malay.
- Competent in using Microsoft Word, Microsoft Powerpoint

Interests

Travel
- Planned three trips for Malaysians at University
- Developed organization skills and teamworking skills by planning itinerary for the trip and delegating tasks between travel members

Sports
- Swimming and playing basketball regularly in a week
- Developed time management skills to fit into my study timetable

Group Study
- Held weekly among Malaysians, organized by IKRAMUKE
- Head of a group of six students
- Trained to give full commitment

Baking
- Baked and delivered cupcakes to be donated to the earthquake victims in Christchurch, New Zealand

Referees

Referees are available on request.

Alex Wardle

Flat 3
7 Carlyle Road
Edgbaston
Birmingham
B16 9BH

Telephone: 01142994585
Email: awardle@gmx.com

Education and Qualifications

2011 - Present **University of Birmingham**
MEng Electronic and Computer Engineering (averaging 1st)

Modules include:

- C Programming and Algorithmic Problem Solving
- Object Oriented Software Design
- Digital Systems and Embedded Computing
- Computer Hardware and Digital Design
- Data Mining

Worked on Second Year Group Project designing a line following robot developing important team working skills and independent thinking.

2004 - 2011 **King Edwards VII School, Sheffield**
A-Level: Physics (A*), Chemistry (A*), Maths (A*), Further Maths (A)
11 GCSEs (A*-C) including Maths and English

Work Experience

2011 **Website Design for Smart Maintenance**
Designed and built brand new website for Smart Maintenance. This included finding what the customer wanted, designing the graphics as well creating the underlying system.

- Developed customer relationship skills
- Developed time management skills
- Independent working ability was also required
- Improved understanding of HTML & CSS

2008 **Tribal – Work Experience**

- Developed content for a national website
- Conducted testing of the content management system

Technical Skills

- Experience working with avr chips, avr-gcc and avrlibc

- Proficient in Python, C
- Have experience with Java, C++, VHDL, HTML and MATLAB
- Confident with Office application, email and internet

Other interests

- Worked on Dashboard system for Formula Student
- Volunteer with the University of Birmingham Conservation Volunteers
- Take part regularly in Google Code Jam
- Took part in National Cipher Challenge 2009, 2010 (Joint 1st in 2009)

Additional

- Full clean driver's licence

References

References are available on request