Noah Harvey's Portfolio

PROFILE

I am a final year master's student studying Robotics at Plymouth University with experience in multiple disciplines surrounding electronic, hardware, and product design. I set out to solve the answer to the questions of what, how and why? Within teams, my role is often that of the communicator, as I can competently and clearly convey information to those with varying degrees of understanding.

I enjoy developing projects that enhance our day to day lives. These have often focused on electronics, software development and computer vision. I have conducted research into multiple fields relating to neural networks, agricultural farming and autonomous air and ground vehicles. Furthermore, I have developed UAVs and drones from conceptual design to field testing and requirement verification.

I have completed individual short-term projects, managed and contributed to long-term projects for a variety of fields. I have taken ownership of my work, and have presented my findings/developments to students, colleagues and stakeholders . I have contributed to monthly innovation talks both in industry and in the educational sector. I am keen to continue my personal and professional growth throughout the rest of my career.

I can make decisions that determine the outcome of a project and will prioritise vital elements and essential maintenance for a product or system to function correctly. For example, I have previously provided the Ministry of Defence with short-term solutions to ensure operation of their assets with immediate effect. I have then created teams of engineers from electronics, mechanics and architectural design backgrounds to provide a long term solution, given my analysis of failure reports. I have in turn managed resources, time and product requirements while encouraging the sharing of knowledge and support of others.

It is worth noting that my work developed throughout placements with Babcock cannot be discussed. Instead, I have compiled my own personal projects, degree highlights and extracurricular projects in this document.

I am available from June 2023 and willing to relocate.

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1 INDIVIDUAL PROJECT – ENTERPRISE AWARD

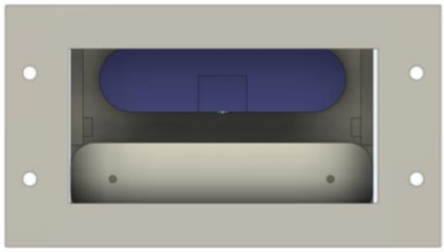
The *Enterprise Award* was for demonstrating an outstanding project with the following qualities: Entrepreneurial endeavour, initiative, innovation, creativity, and collaboration.

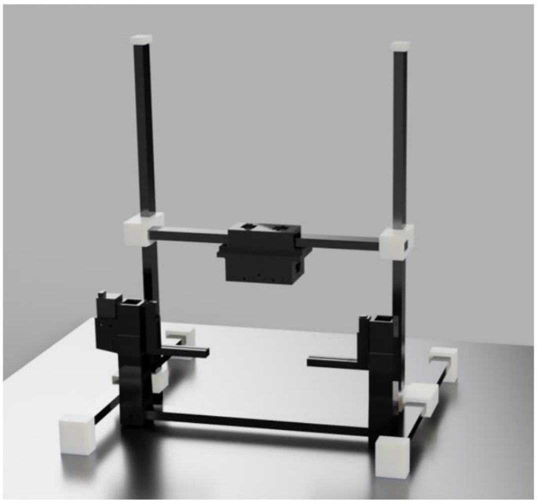
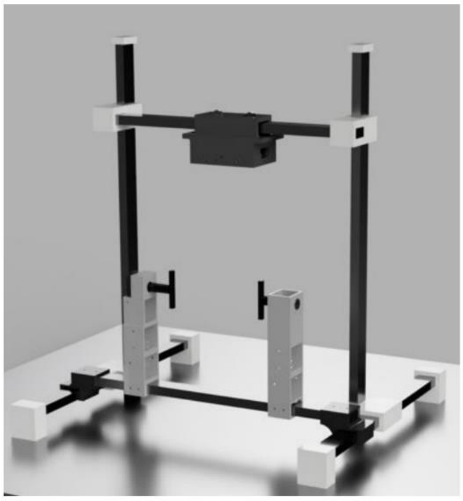
The abstract below has been taken directly from my project report, which can be found in the GitHub portfolio repository.

Engineers within Babcock's Electronic Repair Facility (ERF) reverse engineer Printed Circuit Boards (PCBs) by hand and manually read integrated circuit values to be entered into Electronic Design Automation (EDA) software. PCBs are often damaged during operational use, at which point they are returned to Combined Weapons and Electrical Workshop (CWEW) for maintenance and repair. The information detailing the problems with the PCB's functionality can often be insufficient, making a diagnosis of the issue more difficult. This is time consuming, subject to human error and challenging when the documentation required is unavailable.

This project, comprised of both hardware and software, aims to automate the analysis of circuit boards and supply diagnostic feedback to engineers. This device can inspect the board using machine vision techniques while maintaining a component library.

Circular economy and design lie at the forefront of this project. In essence, it is the practice of designing products with component rotation in mind, rather than disposal, to create more sustainable products with smarter methods of recycling electronic materials. This product allows for not only reverse engineering the PCB, but to provide an accelerated health check of the board and its components to aid refurbishment and the means to repurpose components.



The image on the left shows the first complete design of the hardware, and the image on the right shows the final design. A modular design was used to adjust the height of the PCB with 3D printed blocks. The stepper motor was encased within the prints to manipulate the board beneath the cameras. The class I wrote for the stepper motor allowed the user to manipulate the board by 5 degree increments manually or initialise a routine in which images would be captured from all angles automatically. An emergency stop button was used to switch cease power to the motor.

The microcontroller used (NUCLEO-L432KC) was tested on a breadboard first, and then a PCB was designed. This provided the user with lights to understand the systems state, screw terminals to implement multiple switch points, and buttons to interact with the system.

The image capture class was written to initialise the 4K camera and ensure that high resolution images were captured in various environments. It included image rectification, sharpness, auto-focus and exposure. It could also determine frame width, height, contrast and hue to adjust them accordingly. A laplacian operator was used to detect edges and the outlines of shapes, and a function was made to obtain the image with the highest degree of focus. If the defined standard of image was not captured, the user would be alerted and the system would attempt to capture the image again.

The library management class would initalise a new folder for the board being assessed. The boards ID could be input by the user or automatically generated with the QR code Babcock often placed on their circuitry. Upon creation of said folder, a library of IC's and text was formed. Images of ICs were separated, and the text from them was added to an excel spreadsheet for that board. Any information from other QR codes was also stored.

The image processing class removed spacial alisasation of false patterns, and image smoothing techniques were applied to improve optical character recognition. This class worked alongside the board comparison class, using the data obtained to determine whether the system had seen this type of board before. Various methods were trialled during the development of this class and histograms representing the images were used as a comparative tool. The difference in the results was used to compare the changes in colours and intesnity distributions. This was then used to produce a likeliness score. The implementation and application of such methods allowed me to understand how the environment impacted illumination levels, and in turn my image processing approach adapted to overcome such tasks.

The project's testing was divided into individual unit testing, which was successful, and the development of each component quickly evolved into a coherent system. I used a Gantt chart to define my own milestones and predict when I should place orders for certain components and materials. The performance of the image capturing, processing and comparison greatly impacted each other and so I chose to focus on explorative testing that allowed me to use my instinct and existing image processing knowledge. I had to be able to implement changes as it was developed, as I had to 12 weeks to develop the project. GitHub was used to track my changes and implement branches throughout the project. I had meetings every week with Babcock to ensure that the system was meeting their requirements and expectations.

If I had more time, I would have designed an automated feeding tray to remove the human element entirely. Additionally, I would explore image compression and the effects of more powerful hardware and sensors. It would have been great to use IoT enabled sensors to remove the physical wiring element and process the images elsewhere.

Keywords: Design Lifecycle, NUCLEO L43KC, PCB Design, KiCAD, Visual Studio, GitHub, Depth Perception, Intel RealSense SDK, OCR, Machine Vision, and Image Processing.

2 Robot 'Buggy' Competition

A competition consisting of two tasks was held in the robotics laboratory in Plymouth University to make a design and build module more exciting. The first task required you to design a robotic buggy that could push beads from one side of an arena to the other, over a raised bump in the centre. We were provided with two servos, two microswitches, an ultrasonic sensor and a H-Bridge *Plymouth Shell* to assemble. Assembling the Shell consolidated my understand of circuitry, and was used as a means to test our ability to configure the board correctly. The rules defined the maximum buggy dimensions and weight. The buggy was to operate independently without any interference from the moment it began operation.

My design process focused on creating quick protypes so I could conduct as much experimental testing as possible. I used a basic MDF chassis designed to give plenty of clearance from the beads and mounted the equipment within an encased 3D printed box on top. The front of the MDF chassis had a designated lip to mount various 'scoop' designs. I tested card, paint brushed and sponges to see which material managed to guide the beads over the raised bump successfully. The sponges performed the best and prevented beads from going under the chassis our around the wheels. The rear drive wheels did not have much grip, so I cut rings from bike inner tube and place them over the tyres. The front of the buggy had caster wheels attached so the beads could not get caught or alter its path. I then made protective bumpers around the rear wheels to deflect beads away from them.

The NUCLEO F429ZI was used to control the motors and serve the additional peripherals so the buggy could be aware of its surroundings. The H-Bridge was placed on top of the microcontroller. The buggy followed various paths and determined its position on the board by using the ultrasonic sensor on the front. The micro-switches were used on the back to tell the system when it had reached the back of the section containing beads, and that it was to manoeuvre to collect beads from the next 'row'.

The second tasks required using LEDs to calibrate a colour detector. The buggy had to locate coloured cones and react accordingly, depending on whether they were blue, green or red. The buggy's designed remained the same, I just attached the colour detection PCB to the front instead. The buggy's code was updated to vary speed to perform circular laps around cones.

My buggy came 4th place overall, having performed exceedingly well in each task. I even programmed the buzzer to play various tunes once it had completed individual tasks.

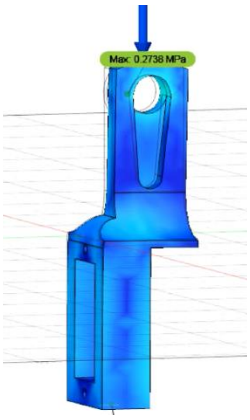
Keywords: NUCLEO-F429ZI, Servos, Prototyping, LabVIEW, Fusion360, SolidWorks, C.

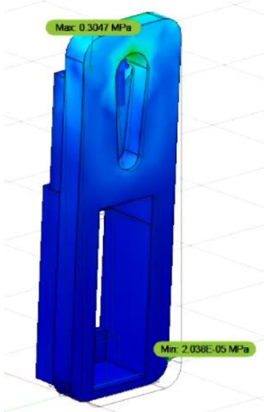
3 HUMANOID ROBOTICS – QUADRUPEDAL ROBOT

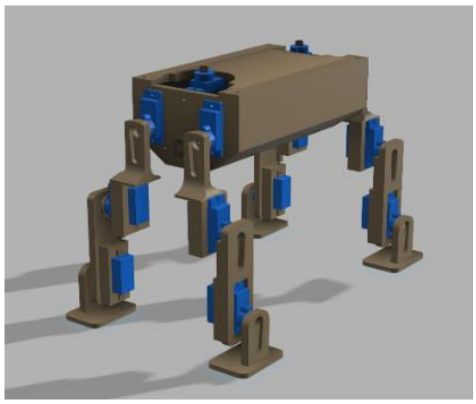
My project partner and I designed and created a quadrupedal triceratops robot using an Arduino Nano, servos and PWM modules. The project was designed as a flatpack kit that children could assemble to teach them robotics. It was presented to several classes of primary school students as an educational tool. The robot itself replicated the walking gait of a triceratops, with a combination of servo-controlled angles and free-pin rotating angles which required precise motion study analysis.

The design plan followed the five stages of development. Requirements, research, plan, test and improve. The requirements define the limitations and capabilities of the project. We had to work in pairs, design our own robot and then produce a final design that combined our ideas. My partner and I both designed dinosaurs, and so we chose to develop a dinosaur with a unique complex walking gate. This decision was based on our own knowledge from a shared interest of the show 'Walking with Dinosaurs'. We both knew that ceratopsian dinosaurs, the family in which the triceratops resided in, had intriguing walking gaits. Their front legs had elbows that bent inwards, as opposed to outwards, and were shorter than the rear. We felt as though this would be a unique gait to replicate, and present a challenge that could be approached from various angles.

We began prototyping and experimenting with the size of the design using cardboard and paper. This is what gave us the idea of a flatpack design, and inspired us to keep the material used down to a minimum. The final design had plates in which the servos were attached to, instead of encasing them completely. Stress tests were conducted to ensure adequate strength with forces exerted in a typical manner relating to the walking gait.







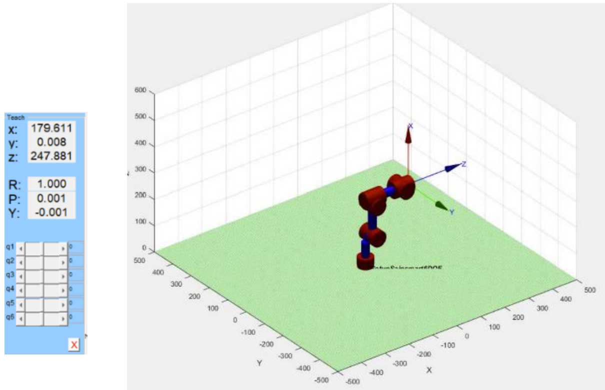
Shock absorbing plates of foams were placed in between the joint contacts and furniture feet covers were used on to provide grip on the base of the feet. You can watch the walking gait motion study and the walking test here.

Keywords: Prototype, Finite Element Analysis, Zero Moment Points, Fusion360, CAD, Motion Study and Simulations, Presentations, Iterative Development, Presentations and Demonstrations.

4 6 Degree of Freedom Robotic Arm

This project used MATLABS's symbolic toolbox and [Peter Corke's robotics toolbox] to simulate the control of the 6DOF robotic arm in Figure 1. The coordinate frames and joint lengths were derived from the measurements of the real arm. I calculated the forward kinematics directly from first principles by implementing the rotations and translations with Corke's toolbox. The symbolic toolbox was used to provide processing ability to simplify mathematical derivations. These were then used to generate the homogeneous transformations for each link and therefore the forward kinematics for the entire arm. Six individual frames were combined to calculate the homogenous transformation that transforms the arm from its sixth frame to its base frame.

The forward kinematics were computed using Denavit-Hartenberg analysis of the mechanism. The robotics toolbox's *Link* command was used to build each individual link. *SerialLink* was used to join each link together. The default configuration of the robot was defined using appropriate control parameters. This configuration is displayed in 3D in Figure 2. This was then developed further using the *teach* member function, to allow the user to interact with the robot by controlling its parameters. The video for this can be found here.



I then configured the robot to follow a trajectory I had plotted, drawing specific shapes. This animation was created using the *ifunc* member function. This function solves the inverse kinematics of the robot through optimization. I then plotted the trajectory angles. The animation video can be found here.

Keywords: MATLAB, Toolboxes, Denavit-Hartenberg, 6DOF robotic arm.

5 Control Engineering

Introduced the concepts in controlling systems that have dynamics to make an unstable system stable and controlling a robot arm to a target without oscillation or overshooting. It involved state space models, observability, controllability, and stability of state space systems. Finalising with state estimation and observers.

An inverted pendulum, a pole pivoted on its end and attached to a cart, has a cart which can travel horizontally along a track. Appropriate movement of the cart can balance the pole and maintain it inverted position. I designed a state feedback controller with integral action that could control the pendulum via the cart. The project consisted of three stages.

The first stage was the theory and design concepts required to design a state feedback controller. By defining the cart as having a specific location, I could design a *Luenberger Observer*. The observer allowed me to use state estimation for stabilising a simulated inverted pendulum in MATLAB. I used a second order differential equation to define the relationship between multiple parameters. A feedback controller was used to find the predicted error, which in turn allowed me to correct its state estimate.

I then implemented, and then ran, the observer in the second stage of the project. It was based on a State Feedback Control (SFC) controller, using a reference of the cart as its input. This input was provided through Euler integration. This provided the ability to implement the system on a microcontroller. The new positional state was computed by integrating the input control velocity. The integral term of the PID was formed through integrating the cart position.

Stage 3 involved the simulation of the inverted pendulum with the SFC controller. I disturbed the pendulum with non-zero initial conditions and recorded multiple runs with different values. The video of the pendulum returning to its upright, inverted state can be found here.

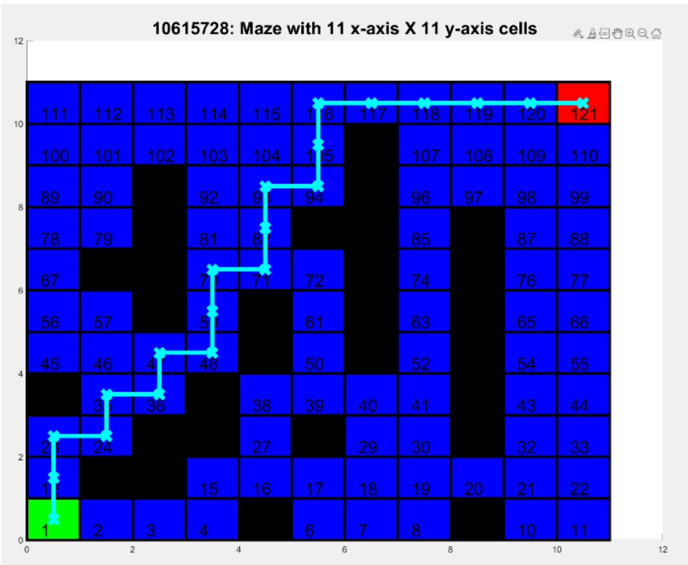
Keywords: MATLAB, Laplace Transforms, Differentiation, PID Control, Microcontroller, State Space Model, State Feedback Control.

6 Machine Learning

This project was my introduction to the concepts of machine learning, naming neural networks and reinforcement learning. I was able to use Bayesian classification, a probabilistic model, to predict the classification of new examples. I was presented with a maze in which a supervised learning technique could be applied. Baye's theorem was able to use previous events to predict future events. The previous events were alternative routes taken, and the new events included more efficient routes to the goal.

A forward kinematic model of the arm was used for the animated movement throughout the maze. I implemented the feedforward and training passes of a two-layer neural network, which I then used to solve the inverse kinematics for the arm. The trajectory through the maze was calculated through reinforcement learning.

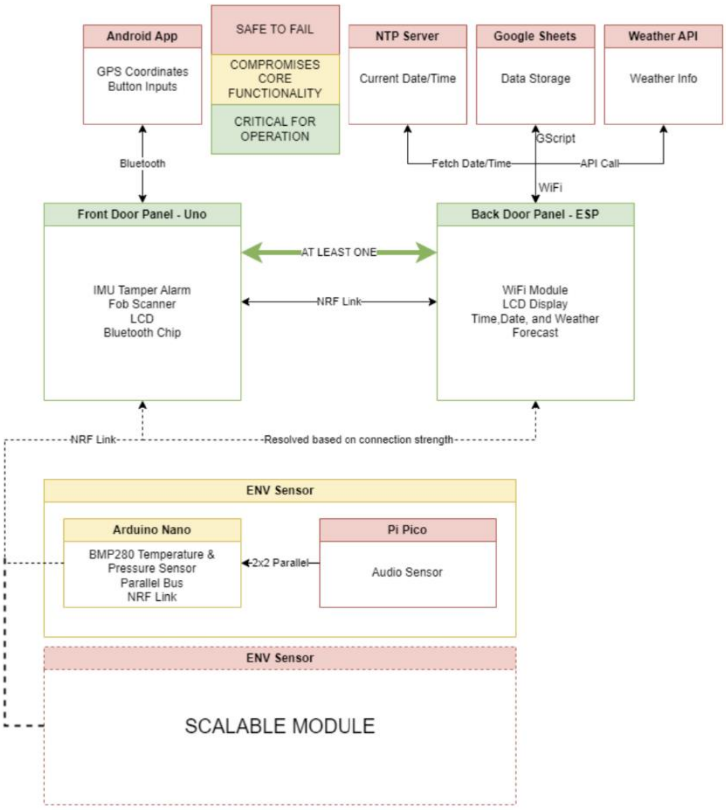
A video of an animated arming moving through the most direct route to the end of the maze can be found here.



Keywords: MATLAB, Machine Learning, Multi-Layer Neural Networks, SARSA Q-Learning, Bayes Classifier.

7 DISTRIBUTED SYSTEM

I have collaborated with three other students to develop a distributed system using four different microcontrollers to create seven individual platforms that can share resources amongst themselves. My role was to design the network topology for all of the nodes within the 'Smart Home Environmental System'. The system was capable of monitoring the environment and concurrently processing the data throughout various rooms, while downloading weather data and uploading the data acquired to Google Sheets.

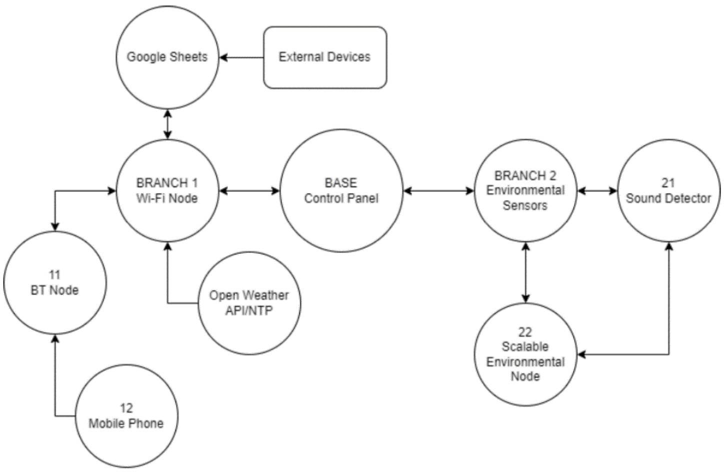


As a group, we decided that no central node should have the responsibility of monitoring the entire network. Therefore, reliability was put at the forefront of the system. The network was designed to have multiple branches with their respective leader node, who would then operate in a Zookeeper manner. I was also responsible for the communication protocol and the development of the control panel, the leader of the environmental branch and the communication protocol used throughout the entire system.

Each message was encrypted, and nodes cannot be added to the system without acknowledgement from the control panel via the IR remote. These security features were used to test the openness of the system. I produced a lightweight version of the TCP/IP protocol as it was highly scalable and could trace packets and their importance throughout the system. This meant that each transmission was represented by a four-digit code specifying the transmitting node, receiving node, its priority and final digit to determine what other nodes should maintain a backup of the same data.

The system demonstrated flexibility, redundancy and scalability. The system costs were minimized by using multiple microcontrollers with single cores for a lower price. Operational reliability was managed through send and receive messages having set maximum latency times. If a node was unresponsive, its leader and all the other branch leaders would be made aware. Such problems, along with the sharing of data throughout the system, was conducted with a degree of transparency. The user was not made aware of delayed data packets unless the node in question was critical for operation.

Quality assurance was a group effort as we switched and verified each-others work between us. I tested the communication protocol across the system with top-down integration, adding more nodes to the system after they had been individually tested. I recorded power consumption and recommended changes to the operation of the system to save power, such as using motion sensor to turn on LCD screens. This also led to my implementation of an IMU and backup power supply in the control panel. The IMU would trigger a 'tamper alarm' if an intruder were to attempt to interfere with the system. Upon sensing movement or having the power lines tampered with, the control panel would discretely alert the system of the interference.



If we were to have developed this project further, we would have replicated the system amongst multiple houses to test the ability of Google Sheets. We would have acquired data from multiple houses and created a means for the user to interact with their system while away from the home.

Keywords: Scalability, Transparency, Fault Tolerance, Reliability, Security, Redundancy, Regression and Verification Testing, Top-Down Testing, Communication Protocols.

8 EMBEDDED SYSTEMS

Introducing time, sequential blocks, and machines to adopt techniques required to develop and validate larger scale embedded systems that can tackle a range of real-world tasks. I can capture, process, and generate signals using hardware and firmware. I can verify and validate the techniques used in each. I can interface FPGAs with the NUCLEO F429ZI to switch operations, move data and execute various instructions.

I can understand requirements for and how to implement GPIO, peripherals, interrupts, and timers at register level. I have completed a project that focused on gaining a deeper understanding of the inside of the Cortex M4, memory devices and NVIC and DMA.

I can design and implement single and multi-threaded applications in an embedded context while developing my knowledge of concurrent programming concepts. I have the ability to manipulate real-time data and respond to asynchronous events when servicing multiple peripherals with a single core.

Keywords: VHDL, State Minimisation, Mealy Machines, ASM Charts, Interrupts, C/C++, SPI, I2C, Controller Datapath Architecture, , RTOS, OOP, Memory Management, Threads and Schedulers, Network Programming, IoT.

9 Electrical Principles

I have completed several projects on digital electronics and computer control, with an overview of the background of the principles, design, and application of combinational and sequential logic circuits. Logic in action was both simulated and constructed with hardware using FPGAs. The theoretical side covered latches, flip flops, Boolean algebra, universal gates, Karnaugh maps and the Quine McCluskey algorithm.
Keywords: Proteus, FPGA – Altera Cyclone IV, Model Sim, VHDL, Quartus.

During my studies I have obtained an overview of analogue circuit characterisation, analysis, and design applications. I can link theory to practice as I examined and constructed analogue systems from elementary components at university and in industrial settings.
Keywords: Oscilloscope, Proteus, Amplifiers, BJTs, Circuit Design.

Magnetism, strain gauges, Wheatstone bridges combined with stepper motors to deepen my understanding of DC motor principles. I have designed a motor from 'scratch' and measured its performance to iteratively improve the design.
Keywords: CAD, Electromagnetism, Testing, Electronic Speed Controllers.

10 Master's Project – Including Grammar Lessons

I am currently developing a bespoke product in a team of four master's students. Until this project is patented, I cannot disclose any more information about it. This module has included a Project Execution Plan and Patent Review. The PEP details the software design and hardware configurations with modularity in mind. The module also includes a linguistics element to maintain grammatical standards. This involves exams and an Executive Summary that gives an overview of the project's intended use and functionality.
Keywords: Hardware, Software, CAD, Simulation and FEA, Project Management, C/C++, PCB Design.