

Department of Electronic & Computer Engineering

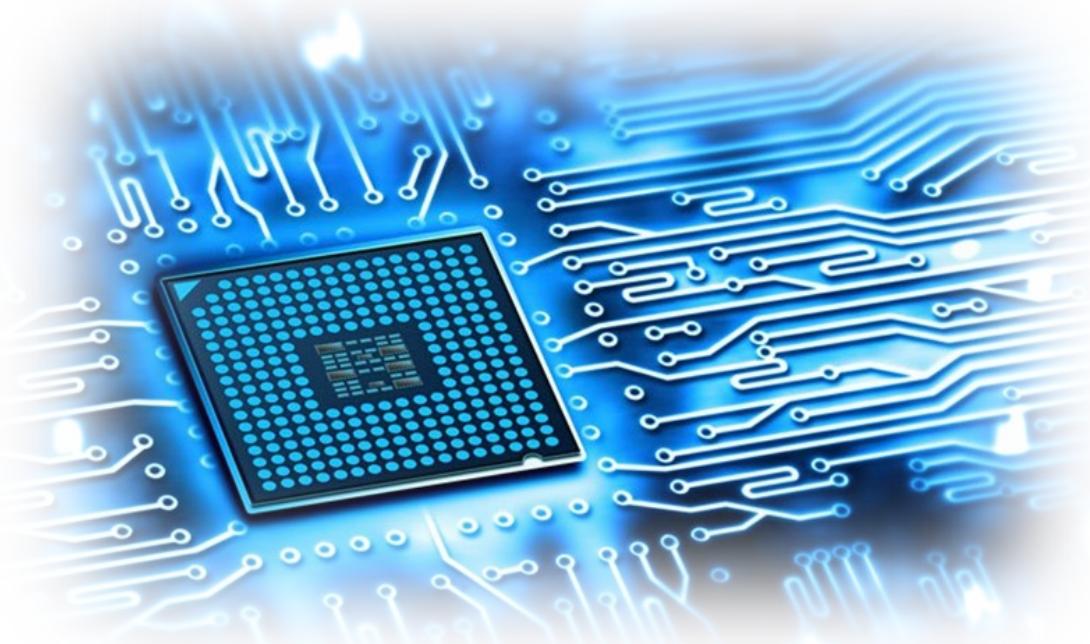
FINAL YEAR PROJECTS

**Book of Abstracts & Posters
Academic Year 2021-2022**

LM118 – BE Electronic & Computer Engineering

LM083 – BSc Cyber Security & IT Forensics

LM806 – ME Electronic & Computer Engineering



E&CE

**Department of
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Computer Engineering**

Foreword from the Head of Electronic & Computer Engineering (ECE) Department



Prof. Colin Fitzpatrick, Head of Department

I would like to congratulate all of our students on reaching this significant milestone towards attaining their degree. This capstone project is a major milestone for students as it brings together many strands of coursework and theory that have been presented over their time with us. It is also a landmark for our department to have students on the integrated ME completing projects for the first time and they will soon become the first graduates of this programme. This booklet highlights the ever-expanding range of skills that our

students have acquired and serves both as a record and a memento of their endeavors. As electronics and computing continue to play such a vital role in every aspect of society, a degree in the strategically important ECE area provides a strong foundation for a wide variety of careers. The continued growth in our application areas of electronics, computing, robotics, telecommunications, data processing, computer vision, security and artificial intelligence means that our projects span a comprehensive range of industrial, commercial and scientific challenges. We are delighted to provide you with this snapshot from the class of 2021/22. I know you will join me in wishing all our students continued success in all their undertakings.



Undergraduate Courses on Offer at the Department of Electronic & Computer Engineering (E&CE)

LM118 - BE Electronic & Computer Engineering

The Electronic and Computer Engineering degree has been developed in conjunction with employers, to meet the demand for engineering graduates with strong skills in computer software and electronic hardware who can exhibit strong mathematical analysis ability. At the end of year two, the programme allows students to select a major option from five major choices- Electronic Engineering, Computer Engineering, Robotic Engineering, Electrical Energy Engineering, and a General option. Graduates from this degree programme play key roles in the research, design, development, test and installation of technology driven systems. They frequently work in teams to tackle complex and challenging problems. Graduates may also pursue higher degrees by research (MEng, PhD, etc), or through taught postgraduate programmes (MSc, MEng, MBA, etc.)

Further details can be found at:
<https://www.ul.ie/courses/bachelormaster-engineering-electronic-and-computer-engineering>

LM121 – Computing Technologies (Common Entry Programme) – Exit Point – LM083 BSc Cyber Security & IT Forensics

The Faculty of Science and Engineering currently offers a number of degree programmes oriented around computing and related disciplines. This allows students to pursue a variety of subjects centred on computing technologies before choosing a specific programme.

On entry to the Computing Technologies programme, there are three different B.Sc. options that are open to students. These are the BScs in Computer Systems, Computer Games Development and E&CE's very own LM083 in Cyber Security & IT Forensics.

LM083 - Cyber Security & IT Forensics

The BSc in Cyber Security & IT Forensics Degree teaches students to build secure systems that protect the creation, transmission and analysis of vital (and often times sensitive) information, such as financial data and medical records. On graduation, students are equipped with the expertise to provide leadership in the ever-evolving mobile networking and communications revolution.

Students of Cyber Security & IT Forensics learn key concepts in computer and web security, Software Development, Data Forensics, Ethical Hacking, Encryption, Computer Law, Cloud Computing fundamentals and security. Graduates of this programme are well placed to build the secure, safe, intelligent networks and

systems of today and tomorrow. Our well-equipped and modern laboratory facilities enable students to acquire the practical experience and tools to excel in the technology sector.

Further details can be found at:
www.ul.ie/courses/computer-science-common-entry



The Final Year Project and why it is so important to our students

The final year project (FYP) is very important, not only because of its effect on a student's final award (QCA), but more often it is because External Examiners, and potential employers or postgraduate supervisors, will tend to focus a student's final year project. They will look closely at a student's project performance because this is where a student can fully showcase the skills that they have developed during their time with us. In their FYP students learn to use their own initiative and intellectual capacities to their full. The Department invests a lot of time and effort in ensuring that students work consistently and steadily through final year and liaison with their Supervisor is managed carefully to ensure performance is optimised.

The FYP is undertaken throughout the last two semesters of a student's time in UL. Ideally, work will commence during the preceding summer and the allocation process is managed so that this is a possibility. The students learn to direct their own work, to be critical of their own methods, to conduct detailed experiments or analysis, to report their results and to develop their critical reasoning skills through the identification of future development work that is possible after the project is formally completed. The projects are ordered by Supervisor panel. Students are also required to present their work to a specific panel and are expected to field questions from that panel. These presentations are not open to the public. Please do spend some time looking through our student FYP abstracts and poster submissions that are included on the following pages.



E&CE Dept. Final Year Project – Abstract & Posters

Project titles are listed by student – Surname/Alpha Order (Please peruse through linked titles in the table below, each will land to the Abstract and Poster of that student in the

BE Electronic & Computer Engineering discipline)

SURNAME	NAME	SUPERVISOR	PROJECT TITLE
BRENNAN	RORY	Dr Flanagan Colin	Design a compiler for the CE4717 Compiler Project Language that uses LLVM as a code-generation backend
CASSIDY	EVAN	Dr McGrath Sean	Air Quality Monitoring
CONNELL	DARRYL	Prof Nelson John	The Development of an AI Powered Camera System for Offshore Marine Surveillance Applications
DOLAN	SEAN	Dr Conway Thomas	Phase Change Material EV Heater
EGBULAM	HENRY	Dr Grout Ian	Investigation into Nim for machine and deep learning applications
GANNON	STEPHEN	Dr Newe Thomas	Cyber Attack Detection and Prevention in IIoT
HEELAN	CHRISTOPHER	Dr Conway Thomas	Isolated DC current measurement comparison
KORDUS	MIKOLAJ	Dr MacNamee Ciaran	Livestock tracking with GPS and LPWAN
LAWLOR	EMMETT	Prof Nelson John	Investigation Into The Digitalization And Omnichannel Experience Post Pandemic Education Could Present
MC TIERNAN	SEAN	Prof Mahdi Hussain	Sports Data Collection by Voice Input
MEEHAN	TOM	Dr Conway Thomas	Lithium Ion Battery Emulator for BMS Hardware Evaluation
O'DOHERTY	AOIFE	Prof Fitzpatrick Colin	Virtual Reality for Social Science Experiments
QIN	ZHONGEN	Prof Connelly Michael	Wireless Strain gauge measurement system using a Raspberry PI
RYAN	CHRISTIAN	Dr Mullane Brendan	Development of an ocular microtremor technology device
SARGENT	GRAEME	Dr O'Connell Eoin	Build a network of temperature sensors to connect to a Wi-Fi gateway

SOOKARRY	CIARA	Dr Van De Ven Pepijn	Translation of Irish Sign Language to English using Machine Vision
TIMLIN	EOIN	Dr MacNamee Ciaran	Internet of Things Home Care System
YANG	JUFENG	Dr Murphy Kevin	Deep Learning Algorithms
ZHOU	XINGDA	Dr Murphy Kevin	AI / Python chatbot

Project Title: Design a compiler for the CE4717 Compiler Project Language that uses LLVM as a code-generation backend.

Student Name: Rory Brennan

Supervisor: Dr Colin Flanagan

Programme of study: BE Electronic & Computer Engineering

Abstract: With the given rise in popularity of high-level scripting languages such as Java, Ruby and the most popular of all, Python, it is surprising to note that compiler design remains firmly rooted in low level languages such as C and C++ with very little variation on this status quo. Python, with its multitude of supporting libraries and packages, its powerful automation and extraordinarily simple-to-use syntax, is ideal to build a comprehensive base to further explore the possibility of a high-level coded modern language processor. The following report follows an investigation into designing and developing a modern compiler in Python for a Pascal-like programming language using LLVM as the backbone of machine code generation. LLVM is the construction toolbox for many modern compilers such as Clang. The report covers in detail both traditional and modern approaches to compiler design as well as other relevant topics such as parsing, scanning, error recovery, code optimizations and syntax trees.



Design a compiler for the CE4717 Compiler Project

Language that uses LLVM as a code-generation backend

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Rory Brennan

LM118

Electronic and Computer Engineering

Introduction

With the given rise in popularity of **high-level scripting languages** such as Java, Ruby and the most popular of all, **Python**, it is surprising to note that compiler design remains firmly rooted in low level languages such as C and C++ with very little variation on this status quo. Python, with its multitude of supporting libraries and packages, its powerful automation and extraordinarily simple-to-use syntax, is ideal to build a comprehensive base to further explore the possibility of a high-level coded **modern language processor**. The following poster follows an investigation into designing and developing a modern compiler in Python for a Pascal-like programming language using **LLVM** as the backbone of machine code generation.

Aim

The aim of the project is to design a compiler for the **Compiler Project Language**. This constitutes developing three distinct programs to be combined into one project, including:

- A scanner to generate **tokens** from input source code file.
- A parser to traverse the source tokens to check for errors and generate an **abstract syntax tree (AST)**.
- A LLVM code generator that emits **optimized machine code** based on the AST.

Method

The project followed an **iterative development cycle** i.e. the project was split up into single parts where each part was tested and validated before moving onto the next. The method of production was as follows:

- The entire project was coded in pure Python 3.7 using the **PyCharm IDE**.
- Supporting packages included **llvmlite**, **re**, **timeit**, **pprint**.
- The entire project would be **modular** i.e. split up into separate distinct Python programs.



Figure 1: Project tree view demonstrating separate programs and files.

- A broad test range will be used to exhaustively test the program. These tests constitute sample CPL source code files.
- Scanner program to be implemented using regular expressions with pattern and keyword matching.

Method (continued)

- Develop a parser that implements the **recursive descent** method (a form of top-to-bottom parsing).
- Insert methods of **error recovery** to ensure program can handle exceptions.
- Enter methods of AST generation into parser program.
- Develop the **compilers IR layer** i.e. the method that develops a LLVM intermediate representation of the abstract syntax tree.
- Let LLVM perform **optimization passes** on the IR layer.
- Emit **machine code** produced from the IR to a code file.

```
== AST ==
PROGRAM "test1.prg"
[ [ 'IDENTIFIER', 'x' ], [ 'IDENTIFIER', 'y' ],
  [ 'FUNC', 'main', 'NO ARGS',
    [ [ 'WRITE', [ [ 'IDENTIFIER', 'y' ], [ 'INTCONST', '5' ] ] ],
      [ 'READ', [ [ 'IDENTIFIER', 'x' ] ] ],
      [ 'STORE', 'x',
        [ [ 'OP', 'ADD', [ [ 'INTCONST', '28' ], [ 'IDENTIFIER', 'y' ] ] ] ] ] ] ]
== END OF AST ==
```

Figure 2: An example AST printed to terminal.

Results

```
pmb = llvm.create_pass_manager_builder()
pmb.opt_level = config.opt_level
pm = llvm.create_module_pass_manager()
pmb.populate(pm)
pm.run(llvmmod)
ee.finalize_object()
ee.run_static_constructors()
target_machine.emit_assembly(llvmmod)
```

The final lines of Python that emit the assembly code.

Over a period of about five months, the project was developed successfully. There is now a **fully functional compiler** for the Compiler Project Language which utilizes LLVM as a code generation backend and as a whole is implemented entirely in pure Python.

Following the method outlined above, the entire project was coded in roughly **1430 lines of Python code** with the recursive descent parser program taking up the most amount of lines within the project. Some aspects of the development process worth commenting on include:

- The packages **re** and **llvmlite** greatly facilitated the production of a scanner and a code generator respectively which is reflected in the relatively low amount of effort needed to complete these facets of a compiler. Both together took up **less than 35%** of the project.

Results (continued)

- The parser program is not entirely efficient. It utilizes many global variables during the parsing process which could instead be passed as parameters between functions.
- There is **scope for greater expansion** of the program including attempting different parsing techniques, adding a simulator to execute the machine code and developing optimization passes for the AST itself.

```
movabsq $x@GOTOFF, %rbx
movq (%rsi,%rbx), %xmm0
movabsq $READ@GOTOFF, %rax
addq %rsi, %rax
movq %xmm0, %rcx
callq *%rax
movsd (%rsi,%rdi), %xmm0
movabsq $.LCPI0_1@GOTOFF, %rax
addsd (%rsi,%rax), %xmm0
movsd %xmm0, (%rsi,%rbx)
addq $32, %rsp
popq %rbx
popq %rdi
popq %rsi
retq
```

Sample assembly code emitted by the compiler.

Conclusion and Reflections

Overall LLVM, despite its Python counterpart's lackluster support, facilitated the construction of a modern compiler with ease, showcasing it as flexible modern compiler construction toolkit with its distinct IR and useful optimization passes. This project confirms that it is possible to develop a compiler in a powerful high-level scripting language like Python. However, the **performance is inadequate** for a compiler and possibly given further development, the CPL compiler might be able to be benchmarked against other modern compilers. Aside from this point, I feel the project was an **individual success** with many lessons being learnt (not just related to compilers) and that it is an **eye-catching project** to have on one's portfolio.

Acknowledgements

Colin Flanagan: For the project idea as well as inspiring me on language processing from his module in third year.

My Parents: For moral and financial support throughout the entirety of my university life.

Project Title: Indoor IOT Air Quality Monitoring

Student Name: Evan Cassidy

Supervisor: Dr Sean McGrath

Programme of study: BE Electronic & Computer Engineering

Abstract: Air Quality is an area that is increasingly becoming more and more the focus of interest. IOT sensor devices are also becoming more and more commonplace. The aim of this project was to create an IOT air quality monitoring device. This project successfully created and hopes to clearly demonstrate the process required in the creation of an IOT based air quality monitoring device.

This project was created using a variety of sensors to demonstrate the creation and application of an IOT sensor device. Using a plethora of technology such as, MQTT to report data to be stored on the cloud and displayed on an online dashboard. OLED display and graphics libraries to display data locally on the device. HTML, CSS and JavaScript to create a live updating local network dashboard.

This project shows the problems encountered in the creation of this device. As well as the mitigations and solutions found for these problems and with this it hopes to be of help in the future creation of similar devices.

Project Title: AI on Oceans Edge - Edge AI Computation Camera and Model for Offshore Marine Surveillance Applications

Student Name: Darryl Connell

Supervisor: Prof John Nelson

Programme of study: BE Electronic & Computer Engineering

Abstract: Offshore marine construction is an area of growth in Ireland with the development of offshore wind farms. During all phases of the development of such infrastructure, often there are data monitoring buoys deployed on location monitoring meteorological data such as wind speed and wave data. These buoys are often of high value and can be susceptible to damage from marine traffic. There is a growing requirement to have on board camera surveillance for monitoring such platforms.

Due to power constraints and poor network coverage at some of these offshore locations, traditional CCTV cameras are unsuitable. This project aims to develop an AI model to detect various categories on a low power edge computation device such as an Nvidia Jetson Nano. Pretrained AI models are examined, and transfer learned to a specific marine traffic dataset of various categories, and their performance on the Jetson nano assessed.

A novel camera system prototype is designed and built to house the Jetson Nano and camera, with a lens cleaning system such as a wiper blade to allow sea mist and rain droplets to be cleaned autonomously from the camera lens. The developed AI model and alert pipeline is served on the prototype camera and wiper system developed, with the complete system being assessed for power consumption and AI model performance.



AI on Oceans Edge

Edge AI Computation Camera and Model for Offshore Marine Surveillance Applications

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Darryl Connell

LM118 – Electronic and Computer Engineering

Introduction

In the development of marine infrastructure, floating data collection buoys are deployed on such locations monitoring meteorological data such as wind speed. These buoys are of high value and susceptible to damage from marine traffic.

At present, using a CCTV camera offshore poses problems, particularly due to limited GSM signal and power availability on board the buoy.

This project will focus on developing an artificial intelligence object detection model for detecting marine traffic and be suitable for deployment on an edge compute device.

A camera system will be developed for hosting the AI model, encompassing an AI edge compute device for inference on the edge.

Aim

The aim of this project is to build an AI model and alert system which can be deployed on an offshore marine data buoy.

The scope of the project involves building an AI object detection model that can be served on an Edge Compute module for the purpose of detecting marine traffic at sea, and sending alerts ashore if marine traffic is spotted.

A camera system will be developed for the hosting of such a model in the marine environment.



Figure 1: Offshore Data Buoy

Method

The design of the marine traffic detector and classifier was approached using a transfer learning methodology.

This method uses a deep learning model which has already been trained on a large dataset such as COCO, and then it is fine tuned to fit the new categories and data found in the marine traffic dataset.

The YOLO (You Only Look Once) model was selected for use, largely based on its merits of being able to detect objects quickly and also classifying the objects.

An open source marine traffic video dataset was used for model training. Frames were extracted from the videos, labels were formatted for input into the model and the data was split into training and test datasets. Two videos were retained as an "unseen" validation dataset.

The model was trained to identify the following 9 classes:

Ferry	Boat
Buoy	Kayak
Vessel/ship	Sail boat
Speed boat	Flying bid/plane
	Other

Figure 2: Example Training Objects



Three different models were trained, all of the same architecture, but with differing number of parameters and layers. The number of parameters in the model is proportional to the size of the model and directly effects the speed at which the model can run. Each model was evaluated on an Nvidia Jetson Nano for inference speed, power consumption and other accuracy metrics.

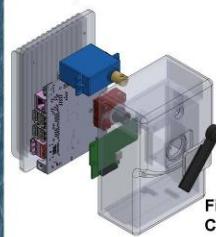


Figure 3: 3D Designed Camera System

The design of the camera hardware system centred around an Nvidia Jetson Nano. An enclosure was designed in Solidworks and fabricated using a laser 3D printer.

A small mechanical window wiper was implemented to clean the lens from sea mist and raindrops. A Hitec waterproof servo motor was used with an Adafruit PCA9685 Servo Motor controller. I2C is used by the Jetson Nano to send wipe commands to the wiper.

A camera serial interface (CSI) camera was used for image capture and an enclosure was designed to accommodate the Jetson Nano, camera and wiper system.

Finally, the main data collection programme is built using a pipeline type architecture, where logic is added to the YOLO classifier to determine the number of classifications and frames with objects therein. The image writer saves video frames and the CSV writer writes all collected data to a CSV file on the device.

The email writer compiles .JPEG images and CSV log files and sends them ashore for analysis when a number of predefined detections are reached.

Results

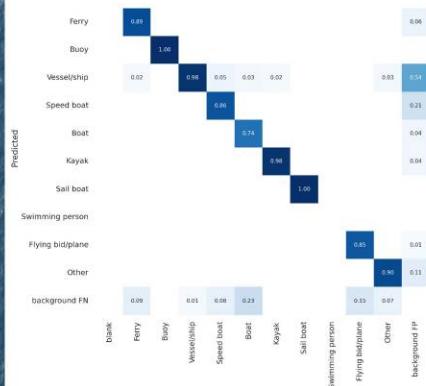


Figure 4: Confusion Matrix of “Large” Model

The model performance was measured to be over 74% accurate in all objects, with some object accuracy reaching close to 100%. It is noted that false negatives are low, but there was evidence of false positives for the Vessel/Ship category which may be a symptom of an unbiased training dataset, where Vessel/Ship category was over represented.



Figure 5: Marine traffic detection (varied traffic)

As seen in figure 4, the model performed well on validation data, with high confidence scores over multiple categories.

The AI model and servo wiper runs smoothly on the Jetson Nano, with a routine initiating the wiper periodically. The alert system works well, with notifications being sent to the user ashore when a prespecified number of detections have been reached.



Figure 6: Prototype Edge AI Camera System

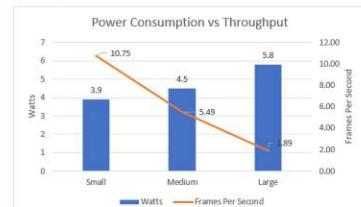


Figure 7: Power Consumption vs Throughput of each model on the Jetson Nano

Conclusion and Reflection

It can be seen that the objectives of the study have been largely achieved, namely:

- 3 different sized YOLO models were trained using transfer learning techniques and benchmarked on an Edge Compute device, the Jetson Nano.
- A prototype camera solution with lens wiper was developed and bench tested for AI model performance and power consumption.
- More work is required to test the camera system “in the field” to evaluate real world performance.

This project has opened me up to the world of edge compute technology to me, its benefits and some limitations. I have improved both my hardware and software skillsets, and gained an understanding of both hardware and software integration, particularly in the area of AI modelling deployed on the edge.

Acknowledgements

I would like to express my sincere thanks to my project supervisor, Dr John Nelson for his continuous support, enthusiasm and guidance throughout this project.



**UNIVERSITY OF
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Project Title: Phase Change Material Electric Vehicle Heater

Student Name: Sean Dolan

Supervisor: Dr Thomas Conway

Programme of study: BE Electronic & Computer Engineering

Abstract: Heating units in electric vehicles have been one of the largest issues in electric vehicles in the past 40 years. In the past electric vehicles have used a wide range of methods in order to provide heat for the vehicle including resistive heating circuits and a multitude of different heat pumps to carry out this task. The issue with these methods is primarily that they require a large amount of power in order to heat the cabin of the vehicle and therefore use a large portion of the vehicles battery to do so. For previous heating units this was often up to as much as 20% or 30% of the vehicle's total battery charge with this number getting even larger in Winter and in cold weather. This project will look at solving this issue and therefore make electric vehicles a more viable and widely accepted option year-round.

This project will involve designing and building a heating unit for an electric vehicle using a phase change material that will supply as much heat to the vehicle as a standard heating unit but will not use the vehicles battery as the power source for the heating unit. The phase change material (PCM) that will be used is a paraffin wax due to its excellent latent heat storage properties.



Project title: Phase Change Material Electric Vehicle Heater

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**Department of
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Computer Engineering**

Student Name: Sean Dolan

Programme of study: LM118

Introduction

Heating units in electric vehicles have been one of the largest issues in electric vehicles in the past 40 years. The reason for this is that the heating unit like everything else in an electric vehicle uses the battery as the power source.

Due to this, the range an electric vehicle can travel without stopping to recharge is greatly reduced while the heating unit is in use. This can lead to a drop in range of up to 30%, with this value becoming even larger in colder climates.

This project will aim to solve this issue by providing heat for an electric vehicle without using the battery and therefore make electric vehicles more viable particularly in colder climates.

Aim

The aim of this project is to design and build a thermal energy storage device to function as a heating unit in an electric vehicle

This device will contain a phase change material (PCM) that will store thermal energy while the vehicle is charging or not in use and then release this energy as heat energy while the vehicle is in use.

Building Stage

- This project involved designing and building an exterior layer and an internal heating coil.
- The external layer consists of polyisocyanurate insulation and medium density fibreboard.
- The internal heating coil consists of polyethylene plastic boards with four pieces of machinable glass ceramic implanted into them.
- Nichrome resistive wiring is then coiled around these glass pieces and connected to banana sockets on the unit to create a heating coil circuit.



Figure 1 (left) – External layer of heating unit.
Figure 2 (right) – Internal heating coil components

Testing

- Once built the unit had to be ran through a number of tests.
- These tests involved setting an input current and voltage and then running that through the heating coil and investigating the effects this would have on the PCM.

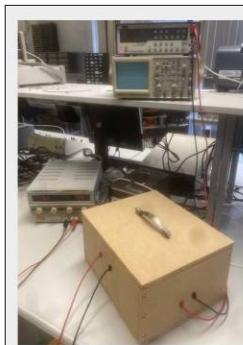


Figure 3 – Bench setup of the heating unit.

- The aim of these tests was to find the power output of the unit and compare it to the theoretical value already calculated.

Results

- After completing a range of different tests the results of the heating unit could then be analysed.

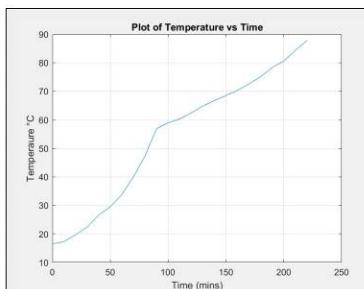


Figure 4 – Temperature vs Time Plot

- One of the results that was required was a temperature vs time plot for each test. This plot shows the rate of change of temperature of the PCM.
- The point where the slope changes significantly in the plot shows the temperature where the PCM changes state.
- Another important result is the energy stored in the heating unit.

$$\text{Energy} = \text{Voltage} * \text{Current} * \text{Time(sec)}$$

- Values given are for the test that produced the plot in Figure 4.

$$V = 14V, I = 6A, T = 13200\text{sec}, \text{PCM} = 4\text{kg}$$

$$\text{Energy} = (14)(6)(13200)$$

$$\text{Energy} = 1.1088\text{MJ}$$

$$\text{Energy(Wh)} = 1.1088\text{MJ}/3600 = 308\text{Wh}$$

$$\text{Energy(Wh) per kg} = 77\text{Whrs/kg}$$

- These calculations give a value of 77Whrs per kg of the PCM used.
- This is compared to the theoretical value calculated at the start of the project which gave 70Whrs/kg.
- This shows that the heating unit does work and in fact appears to store more heat energy than was predicted.

Conclusion and personal reflection

- During the course of this project the aim of designing and building a heating unit for an electric vehicle using a PCM was completed.
- The energy output of the unit met the theoretical value calculated and so it could be said that the project was success.

This project helped me to develop a number of key skills. Some of these include communication, creativity and technical skills. The development of these skills during this year was vital to being able to complete the project.

If this project was to be undertaken again a lot of time would be saved on material selection and construction of the unit due to the time spent learning through trial and error.

Acknowledgements

- Dr Thomas Conway
- Jimmy O'Sullivan



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Project Title:	Investigation into Nim for Machine and Deep Learning Applications
Student Name:	Henry Egbulam
Supervisor:	Dr Ian Grout
Programme of study:	BE Electronic & Computer Engineering
Abstract:	<p>This project examines the Nim programming language as an alternative to Python in the development of machine and deep learning applications. The MNIST database, a commonly used dataset in machine learning research, will be used to illustrate the application of Nim in its performance of machine and deep learning.</p> <p>This project was inspired by the rise in Artificial Intelligence applications in recent years. These include image recognition, facial recognition, autonomous vehicles, and email filtering. Machine and deep learning algorithms are at the heart of these. It is the intention of this project to help explain how the background of these new technologies operate.</p> <p>This report serves as a documented view of the project as a whole. The background and history of Nim is explored, as well as its capabilities. The theory of machine and deep learning is explained. The Nim and Python development process is detailed. Results from applications are produced and conclusions are formulated.</p> <p>For the process of machine learning in Nim, a library known as Arraymancer is used to build the application. In Python, the widely utilised libraries, TensorFlow and Keras, are used to make a near identical application. Nim's ability to perform machine and deep learning is discussed by its own standard and in comparison, to Python</p> <p>Tests are performed to examine the ability of Nim versus Python. The results show that neural network training is much faster in Python. Though the deep learning models are built very similar, Python's machine learning library enables slightly better results. Therefore, although Nim can be used as an alternative to Python in machine and deep learning, when comparing key metrics, Python outperforms Nim.</p>



Investigation into Nim for Machine and Deep Learning Applications

E&CE

**Department of
Electronic and
Computer Engineering**

Henry Egbulam

Electronic and Computer Engineering

Introduction

This project examines how the relatively new programming language, Nim, processes machine and deep learning applications. This is compared to the performance of Python, the most popular language used for ML.

Nim does not have extensive examples of machine learning use. This project involves the exploration of available resources for machine learning in Nim and the incorporation of them into a working program. The MNIST database will be utilised to demonstrate machine and deep learning.

Aim

The aim is to have a conclusive write-up done on the ability of Nim to perform machine and deep learning applications. A program will have been created to demonstrate a wide range of Nim's capability. Machine learning metrics, such as accuracy and speed, will be evaluated and compared to the results obtained while running a similarly built application in Python. The ease and accessibility of each language will also be compared. Results will be presented in graphs and comparisons will be shown in tables.

Nim Development

- Nim was installed to my laptop and **Microsoft Visual Studio Code** was downloaded as the IDE as it has support for Nim.
- The language rules and syntax were studied. The Nim Manual, a document detailing the features of the language, was always kept on hand.
- Any available machine learning resources to be used in the project were searched. A ML library for Nim called **Arraymancer** was downloaded and the procedures and functions available in this library were studied.
- The program was developed using the resources available.

```
# Create the CNN model
network ctx, DemoNet:
    layers:
        x: Input([1, 28, 28])
        cv1: Conv2D(x.out_shape, 32, 5, 5)
        mp1: MaxPool2D(cv1.out_shape, (2,2), (0,0), (2,2))
        cv2: Conv2D(mp1.out_shape, 64, 3, 3)
        mp2: MaxPool2D(cv2.out_shape, (2,2), (0,0), (2,2))
        f1: Flatten(mp2.out_shape)
        hidden: Linear(f1.out_shape, 100)
        classifier: Linear(100, 10)
        forward x:
            x.cv1.relu.mp1.cv2.relu.mp2.f1.hidden.relu.classifier

    let model = ctx.init(DemoNet)
    var optim = model.optimizerAdam(0.01*f32)
```

Figure 1: Neural Network Model in Nim

Python Development

- A program in Python was developed to mirror the one in Nim.
- Machine learning libraries and resources in Python, Keras and TensorFlow, were studied and incorporated into the program.
- The model attributes were set to be identical to those stated to Nim.

```
# Create the CNN model
model = Sequential()
model.add(Conv2D(32, (3, 3), activation='relu', input_shape=(28, 28, 1)))
model.add(MaxPooling2D((2, 2)))
model.add(Flatten())
model.add(Dense(100, activation='relu'))
model.add(Dense(10, activation='softmax'))
```

Compile the model
opt = tf.keras.optimizers.Adam(lr=0.01)
model.compile(optimizer=opt, loss='sparse_categorical_crossentropy', metrics=['accuracy'])

Figure 2: Neural Network Model in Python

MNIST Digit Visualisation

Here are two random MNIST digits visualised using both languages. In Nim this was done with a plotting library called **nim-plotly**. In Python this was achieved with **matplotlib**.

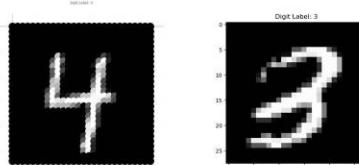


Figure 3: MNIST Digit in Nim (left) and Python (right)

Nim Execution

A number of tests were conducted to show the performance of the ML model. One of these tests can be seen below. Here five epochs are set to train the model. The training accuracy and loss and the time taken is printed after each epoch. When training is finished, the model is validated and prints a testing accuracy and loss.

```
Epoch 1/5 done.
Accuracy: 0.9702997002997
Loss: 0.08168637007474899
Time taken: 109. 534s

Epoch 2/5 done.
Accuracy: 0.983016983016983
Loss: 0.05098096281290054
Time taken: 112. 115s

Epoch 3/5 done.
Accuracy: 0.985014985014985
Loss: 0.03559546172618866
Time taken: 111. 504s

Epoch 4/5 done.
Accuracy: 0.988011988011988
Loss: 0.03181589394807816
Time taken: 115. 603s

Epoch 5/5 done.
Accuracy: 0.99000999000999
Loss: 0.02757821418344975
Time taken: 117. 566s

Epoch 5/5 done.
Testing accuracy...
Test Accuracy: 0.9820000000000002
Test Loss: 0.05015942556783557
```

Figure 4: Terminal Output of ML Process in Nim

The loss and accuracy per epoch were plotted and are presented below.

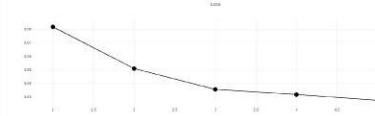


Figure 5: Plot of Training Loss Per Epoch

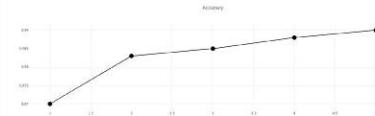


Figure 6: Plot of Training Accuracy Per Epoch

Python Execution

The Python version of the program was run. Similar to Nim, it shows the time taken per epoch, and the training accuracy and loss. After validation, the test loss and accuracy is obtained.

```
Epoch 1/5
Epoch 2/5
Epoch 3/5
Epoch 4/5
Epoch 5/5
Test Loss: 0.03607582673430044
Test Accuracy: 0.9820000000000002
```

Figure 7: Python's Terminal Output

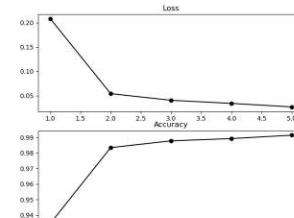


Figure 8: Loss and Accuracy Plots in Python

Comparison

The results from testing the model three times in each of the languages are below.

Classification Accuracy

Nim	Python
0.983	0.9869
0.9853	0.989
0.9842	0.9876

Cross Entropy Loss

Nim	Python
0.0378	0.0394
0.0502	0.0361
0.0513	0.0415

Average Speed in Seconds Per Epoch

Nim	Python
112.6706	19.6
113.2644	20
114.4888	19.6

Conclusion

The results of this program show why Python is the favoured language used for machine and deep learning. The speed is much better than in Nim. Though the models are built very similar, Python's libraries still tends to train slightly better. The ease of writing code is similar and truly depends on one's own preference. With more development into the backend of Nim its performance could still dramatically increase, however, as Python's popularity grows, Nim is unlikely to reach its level.

Acknowledgements

Thank you to Dr Ian Grout for his guidance and time and all the other help he gave me in the development of this project.

Project Title:	Cyber Attack Detection and Prevention in IoT
Student Name:	Stephen Gannon
Supervisor:	Dr Thomas Newe
Programme of study:	BE Electronic & Computer Engineering
Abstract:	<p>The purpose of this project is to investigate the combination of device-type fingerprinting and machine learning to implement an effective Intrusion Detection System for IoT devices. The basis for this project is centred around the concept that the network traffic of a specific device can be monitored in order to derive important information about the device such as its type and its operating state. This information can then be used to detect changes in the devices operation, that may be due to a cyber-attack, by using Statistical and ML based detection models.</p> <p>In this project, the network traffic of two IoT devices, an Amazon Echo, and a Philips HUE Light bulb are analysed in order to derive information that can be used to flag anomalous behaviour in each device. Certain statistical features are calculated from the network packet header data in order to represent the benign operation of a device at any moment in time. Feature Selection is then used to reduce the feature set in order to improve accuracy and reduce training time. Finally, Statistical and Machine Learning based detection models are implemented in order to predict whether incoming data is benign or whether the device is under attack.</p>



Cyber Attack Detection and Prevention in IoT

E&CE

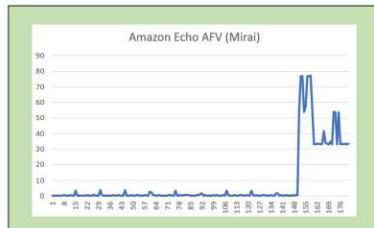
**Department of
Electronic and
Computer Engineering**

Stephen Gannon

Electronic and Computer Engineering

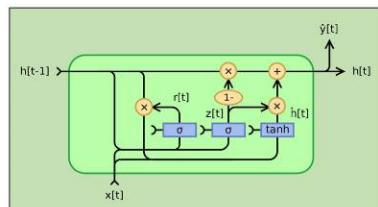
Introduction

- The Internet of Things (IoT) refers to a global mesh of interconnected machines that have sensing, computing or service capabilities that can exchange information with each other and other systems via the internet or other communication networks.
- There could be as many as 64 billion connected devices by 2025 producing zettabytes of useful and private information.
- IoT devices have very limited computing power due to their low power architectures and as such, common on-device security methods such as firewalls are not practical for use.
- As such, novel approaches need to be taken in order to secure IoT networks.



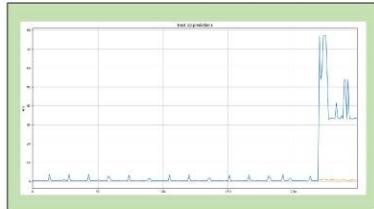
Amazon Echo AFV change due to Mirai Attack

- From here, the Statistical and Machine-Learning based prediction models were implemented.
- The ML model consisted of **GRU** and **LSTM Time-series prediction systems**.
- Time series prediction systems operate on the assumption that patterns in temporal data can be identified and analysed in order to make assumptions about the future value of a variable.



Gated Recurrent Unit (GRU) Neuron

- The ability to predict benign activity allowed effective predictions to be made about the current operation of the device and if the current data could be considered anomalous or not.



Philips Light operation prediction vs. Attack

- Overall, the GRU outperformed the LSTM in prediction accuracy and speed.

Prediction Accuracy	Philips Light	Amazon Echo
GRU	98.9%	97.8%
LSTM	97.3%	97.7%

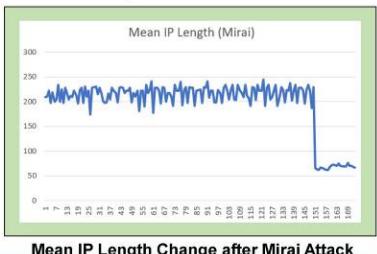
GRU vs. LSTM Accuracy for both devices

Aim

- The aim of this project is to utilise the network traffic being generated by IoT devices in order to extract a **fingerprint** identifier for each device.
- These fingerprints can be leveraged to design an intrusion detection system (IDS) capable of detecting cyber attacks via changes in this fingerprint value.
- The IDS will be implemented using both **Statistical** and **Machine Learning** based models.

Method

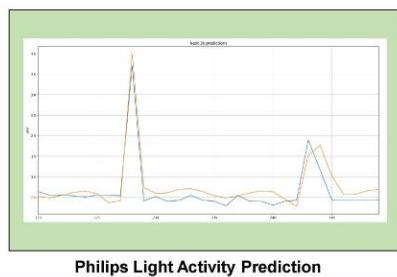
- The first step was to use Wireshark to extract certain network traffic data samples from each device such as IP Length, IP Protocol, SRC Port, DST Port and IAT.
- These values were used to calculate 24 features that represent the **benign** operation of a device at any moment.
- Relief Feature Selection and Univariate F-Test selection were used to attempt to reduce the feature set by identifying features that varied the most during an attack. However neither method returned a useful set of features.
- Instead, a custom feature selection method using values called **AFV** and **DIV** were used in order to identify changes in device behaviour based on the features that changed the most during an attack.



Mean IP Length Change after Mirai Attack

Results

- The creation of the univariate fingerprint feature known as the **Aggregated Feature Value (AFV)** allowed for fast and effective identification of anomalies in the network traffic of a device.
- The AFV allowed the reduction of the initial 24 features that described the benign operation of the device, down to 1 univariate feature that was derived from the best 7 feature values.
- The statistical based IDS performed with **98%** accuracy when **identifying anomalies** and **100%** when **identifying the device type**.
- The time-series based model was found to be able to predict the future network operation of the device via its AFV with extreme accuracy.



Philips Light Activity Prediction

Conclusion and personal reflection

- Overall, the project was a success and the aims and objectives of the project were all met.
- I became more knowledgeable in the fields of IoT security and Malware which will stand to me as I pursue a career in Cyber-Security.
- During the course of the project I greatly improved my network analysis and machine learning skills. I also learned how to take a proactive approach to carrying out my own work and research and how to set my own deadlines in order to get all of the work complete in time.

Acknowledgements

I would like to acknowledge and thank Dr. Thomas Newe and Dr. Subir Halder for their supervision and advice over the course of this project.



**UNIVERSITY OF
LIMERICK**
OLLSCOIL LUIMNIGH

Project Title: Isolated DC Current Measurement Comparison

Student Name: Christopher Heelan

Supervisor: Dr Thomas Conway

Programme of study: BE Electronic & Computer Engineering

Abstract: This project's aim is to compare methods of isolated DC current measurement. The isolated aspect of the project means that there is no electrical connection to the primary circuit that is being measured. The measurement techniques used in this project can be any method of current measurement but must not break the primary circuit as it will be drawing power from the circuit.



Isolated DC Current Measurement Comparison

E&CE

**Department of
Electronic and
Computer Engineering**

Christopher Heelan

Electronic and Computer Engineering

Introduction

This project's aim is to compare methods of isolated DC current measurement. The isolated aspect of the project means that there is no electrical connection to the primary circuit that is being measured. The measurement techniques used in this project can be any method of current measurement but must not break the primary circuit as it will be drawing power from the circuit.

The accuracy of measurement and cost are to be considered in the results section of the final report once the circuits have been built and tested. The testing of the circuits will be undertaken using the Analog Discovery 2 device and the Waveforms software. These two electronic tools are accurate and have a broad range of operation. Components for the project will be gathered from the labs on campus or ordered from ie.rs-online.com.

Aim

A primary circuit will be built with a power supply connected through a known resistor to give us a desired current. Then a secondary circuit will be constructed separately to use the various current measurement techniques.

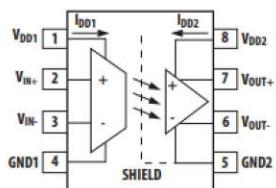
This is the main aspect of this project to ensure that the measurement circuit is not electronically connected to the primary circuit. The use of isolated current measurement components is the structure of this project.

Method

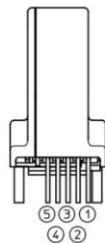
The Opto-Coupler uses a Light Emitting Diode within an Integrated Circuit chip to activate a Light Dependant Resistor or another type of component to complete a circuit to display a voltage.

As seen below, voltage is passed through the LED through legs 2 and 3, the LED lights up and the LDR is activated and closes the secondary circuit which allows a voltage to pass which is delivered through legs 6 and 7, then displayed using the Analog Discovery 2 device and Waveforms program. Legs 1, 4, 5 and 8 are supply rails for the IC.

Functional Diagram



Opto-Coupler Functional Diagram



Current
Transducer Pin
Layout
Diagram



Photo of
Current
Transducer



Opto-Coupler Pin Description

Table 1. Pin Description

Pin No.	Symbol	Description
1	V _{DD1}	Supply voltage for input side (4.5 V to 5.5 V), relative to GND1
2	V _{H+}	Positive input (± 200 mV recommended)
3	V _{H-}	Negative input (normally connected to GND1)
4	GND1	Input side ground
5	GND2	Output side ground
6	V _{OUT-}	Negative output
7	V _{OUT+}	Positive output
8	V _{DD2}	Supply voltage for output side (3 V to 5.5 V), relative to GND2

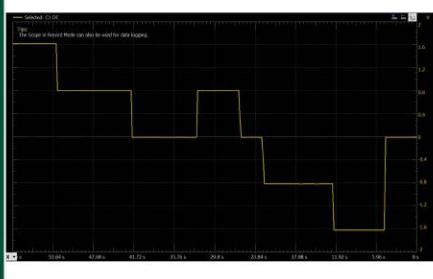
Results

In this section we have voltage results for different currents through the primary circuit. This was done across a certain value of resistor to create the current that was desired. The range of -3 to 3 Amps was used in intervals of 1 Amp as seen below.

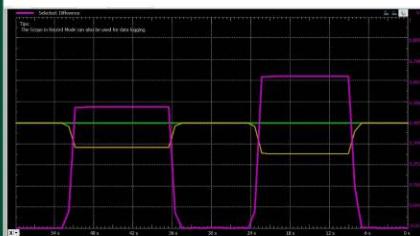
Based on the circuit diagram and proportional equation from Dr. Thomas Conway, the below values for the voltage on pin 7 for the Opto-Coupler are equal to 0.82 multiplied by the primary current across the load resistor.

I went from the positive to negative through the primary current to show any offset that may happen and to also reduce the amount of graphs needed within the report.

Below are results for the Opto-coupler circuit going in the positive and negative direction from 2A to -2A



The below image contains the voltage output of the current transducer with 4 and 5 turns of wire through the transducer while being in proportion to 70/80mV/A as specified on the datasheet provided.



Graph of current transducer with 2A in the primary circuit with 4 turns on the left and 5 on the right

The basic calculation is 70-80 multiplied by the number of turns by the voltage across the resistance of the primary circuit all over the resistor used in the primary circuit.

There is an offset to be expected based on slight deviation from voltage supplies, resistor values and also any small resistances from the wires or measuring devices.

Conclusion and personal reflection

This project was quite tricky to get working initially as there was a large amount of information on the datasheets and often difficult to understand without some guidance from my supervisor.

The Opto-Coupler and DC/DC converter also took some time to set up but worked perfectly in the end after some brainstorming. I thoroughly enjoyed doing this Final Year Project as it was in line with the area of the course that interests me the most.

Acknowledgements

My FYP supervisor Dr. Thomas Conway was instrumental in the completion of this project. Incredibly accommodating and always willing to help at a moments notice.

Jimmy O'Sullivan was also very helpful with the ordering of parts online and enabling access to the laboratory whenever needed.



UNIVERSITY OF
LIMERICK
OLSCOIL LUIMNIGH

Project Title:	Livestock Tracking with GPS and LPWAN
Student Name:	Mikolaj Kordus
Supervisor:	Dr Ciaran MacNamee
Programme of study:	BE Electronic & Computer Engineering
Abstract:	<p>Knowledge of the movement of livestock can be valuable in agriculture, for reasons as diverse as locating lost animals in difficult terrain to detecting illness or when an animal is in heat.</p> <p>This project uses GPS technology, accelerometer readings, temperature sensor data and LPWAN interfaces to provide a proof-of-concept device to detect animal behaviour and body temperature and send this information to a cloud service. The data is then aggregated, analysed and visualised and alerts are sent out to notify of anything concerning or animals that might require attention.</p> <p>The project succeeded in producing a fully functioning device whose low power operation supports extended battery life. The LoRaWAN interface was used to implement the LPWAN aspect of the module. The low power functioning of the module was established by analysis and measurement and it was found that the GPS module was the most power intensive component in the design. A useful element of the project is the ability to link to Google maps, thereby allowing a user to see the location of a lost animal.</p> <p>This livestock tracker is suitable for use with livestock or can be adapted to track different types of animals including the location tracking of domestic pets. It could even be modified further and used as a care device for vulnerable or disabled people such as those with dementia.</p>



Livestock Tracking with GPS and LPWAN

E&CE

**Department of
Electronic and
Computer Engineering**

Mikolaj Kordus

BEng Electronic & Computer Engineering

Introduction

In Ireland alone, 517 cattle were reported missing and 29 reported stolen from the 1st of January to the 20th of July 2021. Out of the total 546 lost or stolen cattle, only 12 were recovered as of the 6th of August 2021.

The livestock tracker provides a proof-of-concept that an all-in-one solution can be created to help ease the above issue and other concerns of Irish cattle farmers. The use of GPS makes it possible to locate stolen or missing cattle to help solve the problem of extremely low recovery rates. The tracker also shows that it is possible to detect a cow in heat thanks to its accelerometer and temperature sensor. In addition, the tracker can send alerts to notify farmers of when cattle become ill or uncomfortable by processing data from the various sensors.

Aim

The main goal of the project was to create a livestock tracker that uses GPS technology and LPWAN interfaces to detect animal behaviour and store a record of their movements in the cloud for further analysis. The following aims were set out at the start:

- Implement LPWAN connectivity.
- Achieve basic location tracking.
- Implement a temperature sensor.
- Track behaviour using an accelerometer and GPS.
- Set up a cloud solution for data handling.
- Use GPS data to display location on a map.

Method

An Arduino MKR WAN 1310 device is used at the core of the livestock tracking system. It receives power from a 10,000 mAh capacity power bank. The power consumption was tested and low power operation was achieved. The tracker is able to operate for over 8 days on this single power bank. The following sensors are used to gather the necessary data:

- Adafruit BME680 temperature, humidity, pressure and gas sensor.
- Adafruit Ultimate GPS Breakout v3.
- Analog Devices ADXL345 accelerometer.

These sensors are implemented with the Arduino which takes readings every 10 seconds. It then converts and formats the data which is sent via LoRa to a gateway. The gateway receives the data and uploads it to The Things Stack using an internet connection. A simple JavaScript decoder then converts the data back into the values read on the Arduino and formats the payload.

The correctly formatted payload is then sent to the ThingSpeak in JSON format in a HTTP request. This is all handled through a webhook integration. Once on ThingSpeak data can be stored, analysed and visualised using MATLAB.

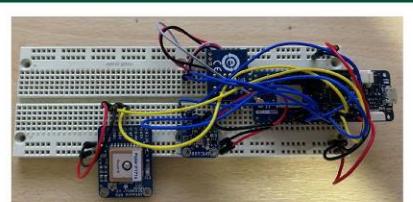
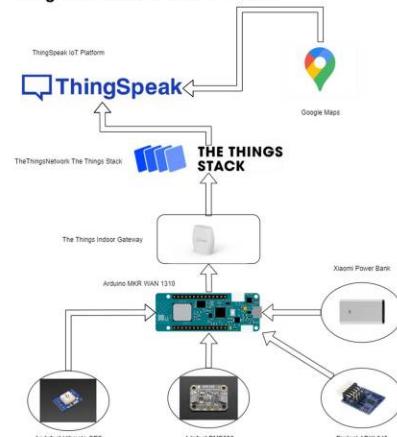


Image of livestock tracker device.

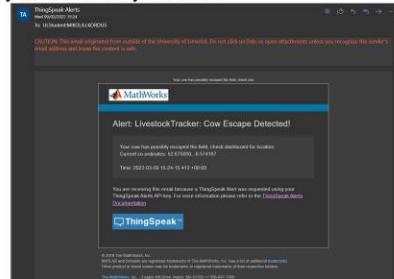


Project structure overview diagram.

Results

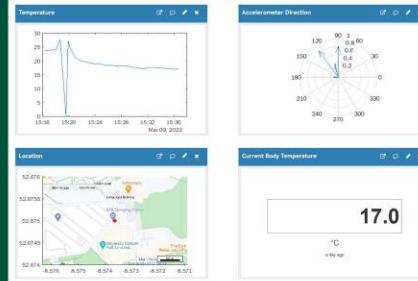
All project aims were successfully achieved within the timeframe provided. The livestock trackers successfully tracks behaviour, temperature and location and communicates it using LoRa.

MATLAB Analysis is run on the data incoming to ThingSpeak in order to detect anything of concern such as a rise in temperature or a cow wandering outside the field. Alerts are then sent by email to notify the user.



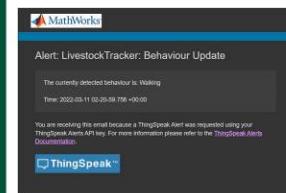
Cow escape alert.

Through the use of MATLAB Visualisation and existing code it is possible to display the location on Google Maps. Accelerometer data is converted to vectors and displayed on a compass plot. A graph of temperature over time as well as the current temperature are also displayed.



ThingSpeak web dashboard using MATLAB visualisation.

Through testing on a human subject it was also possible to successfully detect three distinct behaviour patterns: resting, walking and running. A TimeControl can be configured to send an e-mail every 15 minutes updating the user as to which behaviour is currently being detected.



E-mail alert notifying that the walking behaviour pattern has been detected.

Conclusion and Personal Reflection

Overall, the project was a great success as a fully functioning proof-of-concept livestock tracking device was developed.

I personally feel that undertaking this project was of great benefit to me in developing my UL graduate attributes. I have demonstrated capacity to bring my discipline knowledge to bear on real world problems and challenges in creating a device that solves the problem of missing cattle. I also have a drive to discover, create and to innovate as this project has brought me great enjoyment and motivated me to undertake more IoT projects at home in my free time.

Acknowledgements

I would like to express my gratitude to my supervisor, Dr. Ciaran MacNamee, for all his guidance, support and supervision during these two semesters. I would also like to thank Darryl Connell for his cattle expertise. Finally, I want to thank my friends and course mates, Graeme Sargent and Evan Cassidy for all their moral support.



**UNIVERSITY OF
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Project Title: Investigation Into The Digitalization And Omnichannel Experience Post Pandemic Education Could Present

Student Name: Emmett Lawlor

Supervisor: Prof John Nelson

Programme of study: BE Electronic & Computer Engineering

Abstract: This project builds on the recent shift the education industry underwent in result of the pandemic. By introducing blended learning to third level education, institutions will face problems never seen before; as more people apply to college, the more technology and automation we will need.

As the demand for digital resources rise, students can contribute using university frameworks or data by creating web applications. I created a webapp compiled from UL course timetables, students visit <http://unical.ie> to get a custom downloadable calendar of their courses timetabled events.

As more people enrol in university, I wanted to help making a course easier by creating a tool which people could input a body of text and get recommended courses, removing the typical keyword search process seen today. Using the course directory of Qualifax, we can derive a training set to use in Machine Learning applications such as the recommendation tool.

This project also investigates some trends in Irish education according to CAO, Qualifax and UL.



Investigation into omnichannel experience of Third Level education in a Post Pandemic Era

E&CE

**Department of
Electronic and
Computer Engineering**

Emmett Lawlor

General Electronic and Computer Eng.

Introduction

As blended learning allows institutions to accommodate more people and give more offers, a need to digitize and automate the education sector becomes more necessary for alumni and staff.

This project focuses on the information students need before and during the attendance of their third level. It also provides a foundation for databases and webapps that could potentially assist both, students and professors, throughout their academic lives.

To do this, we used Spiders to extract and gather large amounts of data from websites and existing databases. The textual part of the data was then parsed for information retrieval and categorisation for potential ML/AI modeling.

Aim

1. Collect data relevant to students applying to third level (A) and students already in third level (B).
2. Collect and parse Qualifax data to help machines understand it and to build a cleaner directory and a better experience for finding courses. (A)
3. Collect and parse UL data, for creating web applications for UL students.(B)
4. Create a web-application for UL students to help in streamlining the beginning of the semester. (B)
5. Investigate the data retrieved and detail points of interest and trends that currently exist in third level education in Ireland.

Method

Using frameworks available for Python (a programming language), we extracted data from sources like timetable.ul.ie, bookofmodules.ul.ie, and qualifax.ie. We then deployed crawlers onto websites to extract more information and save it in a usable format.

With 300 timetables and 800 modules extracted from UL sources, we facilitated the webapp, which uses information submitted by students to create a calendar that displays the timetable of the modules they're enrolled in. It can then be downloaded to their devices.



Figure 1: Web app flow on MacOs

The entire stack was built from HTML, JavaScript and Python for free and is explained in this report so students can create APIs of their own.

With textual data on 15k courses extracted from qualifax.ie (course content, subjects, etc.), we created a method to analyse the text and derive important words and meaningful phrases.

By calculating the importance of each word and its rarity among the data itself and similar documents, we can make educational documents easier for computers to interpret, by preparing a training set for its application in fields like artificial intelligence and semantics analysis.

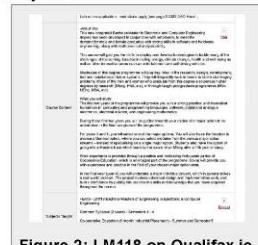


Figure 2: LM118 on Qualifax.ie

The analytical report is based on Data from CAO, UL and Qualifax. We use it to investigate how the Pandemic affected education, such as through UL module delivery changes, number of courses listed on Qualifax, and trends of CAO points, offers and acceptances.

Results

1. Two kinds of Spiders were created to overcome challenges arising from how the spiders interact with webpages. One automated a Chrome browser to crawl dynamic websites and the other simply requested and read HTML documents. 15k Qualifax courses and 800 UL modules were extracted.

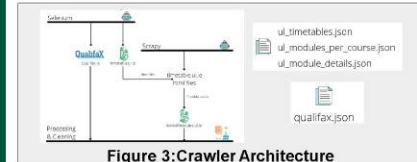


Figure 3:Crawler Architecture

2. In SEM1/21, 43% of the 600 visitors to the webapp submitted their course details, showing that students are open to utilising apps built by other students. This research can encourage students to create tools and institutions to provide resources/data to support creators.

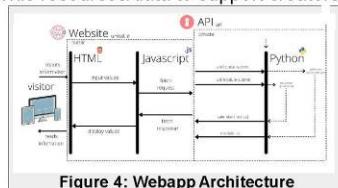


Figure 4: Webapp Architecture

Students creating apps for fellow students would relieve institutions of the competitive development of useful tools. Institutions should embrace this and allow students to utilise their APIs to create better, more integrated applications.

3. Textual analysis reveals the most popular keywords, their frequencies, rarity and importance in documents.

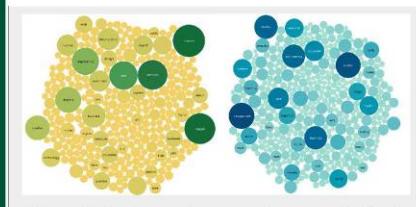


Figure 5: Most prominent words among UL (left) and Qualifax (right) course names.

4. In 2020, 28.1% of modules in UL increased tutorial hours. In CAO, there was a 6.7% increase in acceptances, but only a 3% increase in population. There was no real change in required points for courses on Qualifax. As more people qualify for third level, more institutions will need to rely on self & blended learning, especially with housing and campus space becoming more limited.



Figure 6: Asking requirements remain static while increases in CAO Applicants and Quality of Results.

Conclusion and personal reflection

I explored applications which could assist institutions to adapt in the future;

1. Spiders to find and aggregate relevant information for current and potential students.
2. A template for people to build APIs for students providing useful resources for their institutions alumni and staff.
3. Creating textual training sets for AI and Machine Learning modelling.

I found I have improved my technical skills and have overcome my first ever personal project to be used publicly. I demonstrated creativity, by overcoming problems and seizing opportunities

I hope to continue building a suite of useful tools and resources for current and aspiring students and staff.

Acknowledgements

FYP Supervisor: John Nelson

Frameworks: Selenium, Scrapy, FastAPI, Pandas

Code sites: geeksforgeeks, stackoverflow

Sources: UL, CAO, Qualifax

Project Title: Sports Stats Collection by Voice Input

Student Name: Seán McTiernan

Supervisor: Prof Hussain Mahdi

Programme of study: BE Electronic & Computer Engineering

Abstract: This aim of this project was to create a program which could collect sports statistics by voice input. Voice input is preferable to pen and paper or touchscreen as the user does not have to look away from the game to input events which could lead to them missing subsequent events. Voice input is also more intuitive and requires less training time than touchscreen apps where the user must learn where the buttons for each function are.

Google Speech Recognition API deals with the speech recognition while Python code parses the text received from the API, updates dataframes and displays and runs the GUI.

The final program can collect sports statistics from voice input in real-time to a high degree of accuracy and can deal with all the possible events that can occur during a game.



Sports Stats Collection by Voice Input

E&CE

**Department of
Electronic and
Computer Engineering**

Séán McTiernan

Electronic and Computer Engineering

Introduction

The right statistics in the right hands can be the difference between winning and losing a game. These statistics are currently recorded either with pen and paper or on a mobile or tablet app. The drawback of these systems is that the user must look away from the game in order to input an event, during which time they may miss a subsequent event.

A system in which the user can input statistics by voice input overcomes this flaw in the other systems and also has the benefit of being more intuitive.

Aim

The aim of this project is to create a program to allow users to record stats in real time without looking away from the game.

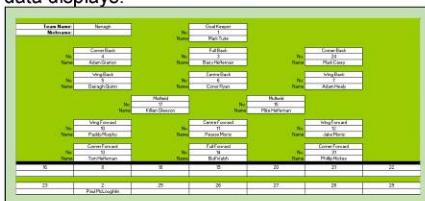
The program must handle substitutions, timing and when the user does not know which player completed a certain action.

It must allow users to undo commands quickly if they have made a mistake so that they don't miss the next statistic to be recorded.

It is also important to display the data in a clear, easy to read, intuitive way to create a seamless user experience.

Method

This program is written in Python. It uses the Google Speech Recognition API for speech recognition, NumPy and Pandas for data operations and PySimpleGUI to make the GUI. It also uses Matplotlib and Seaborn to create the data displays.



Players Input Page

On the above screen, the user inputs player names, numbers and positions, along with team names and which statistics they want to track.

The program then starts with the below screen showing team totals. The user presses the spacebar to begin recording, speaks a command, and presses the spacebar again to end recording.



Team Totals Page

The recording is then passed to the speech recognition API which returns its top five guesses as to what was said.

A function then searches each of these guesses for event names, team names and player names and numbers.

The team totals dataframe and the single team dataframe for the team in question are updated.

Then the data display in the GUI window is updated to show the new values.

The command is added to the command feed on the side of the screen where the user can check that the command was understood correctly.

The user can navigate to other pages showing the individual player totals for each team.

The user can also export the data to an excel file to save for future analysis and can export a timeline of the game.

Results

The program can accurately record statistics from voice input. It works well with short commands like "Goal Cork 7", and works even better with longer sentences like "Number 7 for Cork scored a goal". This is because Google Speech Recognition uses the context of the sentence when predicting words so is more likely to predict "goal" if it comes after "scored".

The program tracks the game clock and can handle half time, full time etc. and puts the time on every command in the command feed.

It can also handle substitutions, moving players off the display when they are taken off and vice versa.

If the player who performed an action is unknown, the user must simply say "Unknown" in place of the player name and the event will only count towards the team total and not to any player's total.

By saying "Undo", the user can wipe the previous command from the display if they have made a mistake. If player names have been input they can be used in place of the player's number, which can also still be used. If the user uses the player's name in a command, they need not specify the team, so long as there aren't two players with the same name.

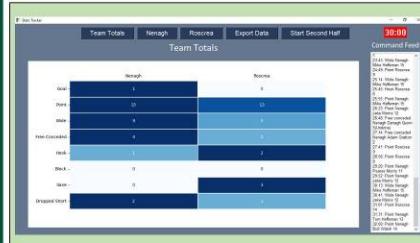
Teams can be referred to by a nickname if their name is too long or unwieldy. The data in the displays is shown in a heatmap format which allows the user to quickly spot the outliers.



Player Totals Page with sample data

The program sounds a warning when a command has not been understood, prompting the user to repeat it. The audible warning means the user doesn't have to look away from the game to know what has happened.

There is also the option to send the data to a manager/coach etc. when exporting.



Team Totals Page with sample data

Conclusion and personal reflection

This program is able to collect sports statistics from voice input in real-time to a high degree of accuracy and can deal with all of the possible events that occur during a game.

I believe it could be very useful to teams who are currently using pen and paper or mobile application systems.

There are very few similar programs which is surprising given the potential for such a system to improve on previous ones.

Future work could involve performing detailed analysis on the data to provide insights for the management team and the ability to compare the current match with previous matches in real time.

The key skills developed over the course of this project were technical skills and creativity.

Acknowledgements

I would like to thank my supervisor, Dr. Hussain Mahdi, for his time and guidance throughout the year.

Also, thanks to friends and family for their advice and support.



**UNIVERSITY OF
LIMERICK**
OLSCOIL LUIVNIGH

Project Title: Lithium-Ion Battery Emulator for BMS Hardware Evaluation

Student Name: Tom Meehan

Supervisor: Dr Thomas Conway

Programme of study: BE Electronic & Computer Engineering

Abstract: As the development of Electric Vehicles (EV's) is accelerating due to the damaging effects combustion engines are having on the environment, the need for a scalable Batter Management System is required to measure the charging capacity of the battery in the EV. The following project will examine how a BMS emulator can be developed to simulate the charging of lithium-ion batteries and examine different circuit configurations to speed up the process.

The system will consist of 4 different circuits which will emulate a cell similar to an actual battery for an EV. The voltages will be measured across the system using a microcontroller which ideally will send the data back to a central location. There are a number of different ways to connect the microcontrollers using both wired and wireless techniques which will all be explored in the design process. Each method has both advantages and disadvantages which will all be taken into consideration when choosing the final design.

The report will outline the purpose of a BMS Emulator and how both the hardware and software for the project was designed and implemented. It will also contain information about personal motivation for the project and also examine other research in this field carried out by other academics. Finally, it will contain a review of the results obtained during the course of the project and examine what was achieved and what could be improved for future work.



Lithium-Ion Battery Emulator for BMS Hardware Evaluation

E&CE

**Department of
Electronic and
Computer Engineering**

Tom Meehan

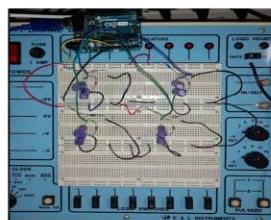
Electronic & Computer Engineering

Introduction

The purpose of the project was to design a Lithium Ion Battery Management System (BMS) emulator capable of simulating the charging and discharging of todays modern lithium-ion batteries used in electric vehicles.

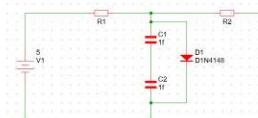
The system will use supercapacitors to simulate the charging and discharging affects of a battery a the system will be monitored using an Arduino Uno programmed in MATLAB.

The system will be able to record and plot the data of 4 different cells in real time in order to determine which cell has the most suitable configuration



Completed BMS System.

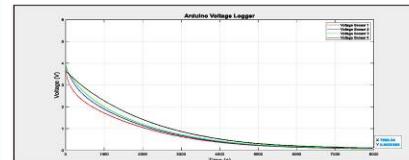
The images above and below show the schematic design for each cell as well as the completed system design on breadboard.



Simple Cell Design Used in the BMS emulator.

During the discharge phase of the system the following results were recorded.

- Cell 1 started off with the highest peak voltage of 4.07V but was the fastest cell to discharge.
- Cell 2 had the next highest peak voltage at 4V and has the second fastest rate of discharge.
- Cell 3 discharged at a similar rate when compared to cell 2 but the cell began discharging at a voltage of 3.86V.
- Cell 4 took the longest to discharge when compared to the other cells. It also had the lowest start voltage at 3.7V.



Discharge phase plotted using MATLAB

Aim

The project aims to develop a fully functional Lithium-Ion Battery Management System Emulator capable of charging and discharging a voltage source. The system will consist of 4 different circuits to emulate a Lithium-Ion battery and will be charged using the same voltage source. A microcontroller or a microprocessor such as an Arduino Uno will be used to monitor the systems performance and take measurements. There are a number of ways the system can take measurements such as wired and wireless connection, but the intention is to feed the data generated back to a central location such as a PC and display it on a server.

Method

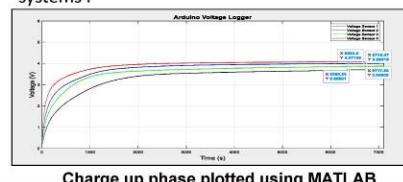
The following outlines the design process for the battery management system.

- Design and construct 4 different cell prototypes capable of charging and discharging similar to a battery.
- Each cell should have its own unique qualities which makes it distinguishable from the other cells.
- Write a MATLAB program to communicate to the Arduino Uno allowing them to take measurements.
- Generate a real-time plot of all data being taken by the Arduino for both the charging and discharging of the BMS emulator.
- Interpret the results to determine which cell has the best performance.

Results

During the charge up phase of the system the following results were recorded.

- Cell 1 charged up much faster than the other cells taking approximately 2500s to charge up to a value of 4V and reaching a peak voltage of 4.07V.
- Cell 2 was the next fastest cell to charge up and also the only other cell to reach the target output voltage of 4V. It took cell 1 around 6800s to reach its peak voltage.
- Cell 3 shows visible signs of that the rate of charge is beginning to slow down for the increasing resistance in the voltage divider and a peak voltage of 3.86V was recorded.
- Cell 4 has the slowest rate of charge with the lowest peak voltage at 3.7V. In order to charge cell 3 and cell 4 up to a desired level of 4V a longer charging period would be required but is not convenient for modern battery management systems .



Charge up phase plotted using MATLAB

Conclusion and personal reflection

Overall, the current system provides great insight into how battery cells behave during charging and discharging conditions. The use of a microcontroller along with programming it in a less traditional programming language such as MATLAB provide an efficient and convenient method for interpreting the results. From the results taken, it can be concluded that when resistance in the voltage divider is low the faster the rate of charge and discharge in the battery. When the resistance in the voltage divider small the slower the rate of charge and discharge in the battery. An ideal battery has a fast rate of charge and a slow rate of discharge.

Acknowledgements

I would firstly like to thank my academic supervisor, Dr Thomas Conway for supervising my project and assisting me whenever I had any difficulties. I would also like to thank my fellow classmates for a wonderful 4 years. Finally, I would like to thank my parents for providing amazing support during my college journey.



**UNIVERSITY OF
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OLLSCOIL LUIMNIGH

Project Title: Virtual Reality for Social Science Experiments

Student Name: Aoife O' Doherty

Supervisor: Prof Colin Fitzpatrick

Programme of study: BE Electronic & Computer Engineering

Abstract: Many disciplines within social sciences conduct experiments on people in controlled laboratory settings. Ethical considerations limit the scope and range of stimuli/experiences that such experiments can explore. Researchers in this area are beginning to investigate how virtual reality could broaden the possibilities for expanding the range and scope of social science experiments on humans. In my application of this project, I will insert users into several different moral dilemma experiences in a self-driving car in a VR world. They will have to choose between two difficult situations, e.g. killing two passengers or five pedestrians. This project will explore and experiment with the use of virtual reality for these purposes. In this report, I detail the background, theory and actual application of this project.



VR MORAL MACHINE

Virtual Reality for social science experiments



E&CE

Department of
Electronic and
Computer Engineering

Student: Aoife O'Doherty

Course: LM118

INTRODUCTION

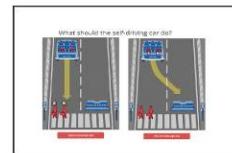
In this project I created a VR experience where the users will play as someone in a self-driving car. I will insert the users into several different moral dilemma experiences in the self-driving car. They will have to choose between two difficult situations, e.g. killing two passengers or five pedestrians. This is based on the MIT moral machine; in that simulator, the user is an objective outsider, detached from the situation. In my VR experience, the user will be directly involved in the crashes and have to come to terms with their own morals and biases. I hope that my data will be more accurate than that collected by the MIT moral machine.

AIM

- To create a VR self-driving car crash experience
- To insert people into difficult moral dilemma situations and compare their responses.
- To get more accurate data on peoples' biases and morals when I show them ethical dilemmas.
- Study the data I get and discuss my findings, i.e. figure out if people from specific demographics favour their own demographic over others.



I used the games development platform Unity to make this game



I took inspiration from the original MIT moral machine website



Sample scenario from VR Moral Machine game

```
using UnityEngine;
namespace KartGame.KartSystems {
    public class KeyboardInput : BaseInput {
        public string TurnInputName = "Horizontal";
        public string AccelerateButtonName = "Accelerate";
        public string BrakeButtonName = "Brake";

        public override InputData GenerateInput() {
            return new InputData {
                Accelerate =
                    Input.GetButton(AccelerateButtonName),
                Brake =
                    Input.GetButton(BrakeButtonName),
                TurnInput =
                    Input.GetAxis("Horizontal")
            };
        }
    }
}
```

METHOD

In this project, I am creating the VR experience on Unity, a cross-platform game engine that allows users to create games and experiences. The VR headset I am using in this project is the HTC Vive. I had initially planned to use an Oculus headset, but upon further research, I settled on the HTC Vive as it has fewer data leakage issues.

The language I used in this project was C#.

```
USING SYSTEM.COLLECTIONS;
USING SYSTEM.COLLECTIONS.GENERIC;
USING UNITYENGINE;
USING UNITYENGINE.SCENEMANAGEMENT;

PUBLIC CLASS CHANGESCENEWITHBUTTON : MONOBEHAVIOR {
    PUBLIC VOID LOADSCENE(STRING SCENENAME)
    {
        SCENEMANAGER.LOADSCENE(SCENENAME);
    }
}
```

RESULTS

I successfully created a VR experience that simulated a car crash. My game is compatible with HTC Vive headsets. My game is not as hyper-realistic as I would have hoped, but without time constraints, I could further its development. I did not test this game with users other than myself, due to ethical and GDPR issues.



CONCLUSIONS AND PERSONAL REFLECTION

In theory, this VR experience could be used in social science contexts to acquire more accurate results for car crash simulations. It wasn't in this project's scope to create a database of responses to the scenarios shown to the user. In future work, these answers could be used to comment on people's responses to the scenarios.

Future Work:

- Acquire ethical approval so this can be used in actual social science experiments.
- Add feature where I can store peoples' responses in a database and compare their results against each other.
- Given the time limits and constraints from college, I couldn't make the most realistic VR experience. In future work, I would plan to dedicate more time to improving the visuals of the experience to make it more realistic.
- Test the experience on a larger number of more diverse subjects to give more well-rounded data. The more data I get, the more accurate the results and thus, the hypothetical self-driving car would be more ethical.

ACKNOWLEDGEMENTS

Dr. Colin Fitzpatrick, FYP advisor
Dr. Edin Omerdic, Technical Advisor
John Kelly, Technical Advisor
Denis Moore, Technical Advisor

Project Title: Wireless Strain gauge measurement system using Raspberry PI

Student Name: Zhongen Qin

Supervisor: Prof Michael Connolly

Programme of study: BE Electronic & Computer Engineering

Abstract: Foil strain gauge is the most commonly sensor used in strain measurement. It is popular because easy to build and analysis, and it is also accurate. In this project, I am going to build a strain measurement system using strain gauge and Raspberry Pi. Raspberry Pi will show the strain on both a touch screen and a smartphone. This wireless function is based on the Bluetooth feature of Raspberry Pi.



Wireless Strain gauge measurement system using Raspberry PI

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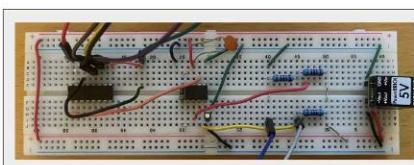
Zhongen Qin

BE Electronic & Computer Engineering

Introduction

The principle of operation of a foil strain gauge is that its resistance changes with applied strain. Changes in gauge resistance are measured by including the gauge in a resistor bridge circuit. In this project, the gauge is used to measure the strain experienced by a bent metal plate, subject to a varying load.

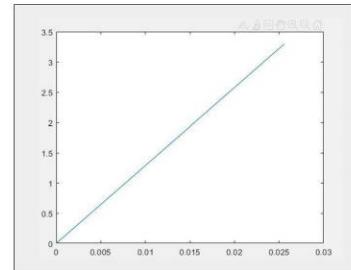
The electrical signal from the gauge, via an amplifier, is acquired by a Raspberry pi, which will process the sensor data to determine the strain, display it on a touchscreen, and using a Bluetooth connection, display the strain on a smartphone.



Breadboard Circuit

```
11 # create the cs (chip select)
12 cs = digitalio.DigitalInOut(board.D5)
13
14 # create the mcp object
15 mcp = MCP.MCP3008(spi, cs)
16
17 # create an analog input channel on pin 0
18 chan = AnalogIn(mcp, MCP.P0)
19
20 while True:
21     Vref = 3.3
22     Vadc = chan.voltage
23     Rg = 4300
24     Gain = (200000/Rg)+5
25     Vb = Vref - Vadc
26     strain = 2*Vb/Ve
27     print("Raw ADC Value: ", chan.value)
28     print("ADC Voltage: ", chan.voltage, "V")
29     print("Strain: ", strain)
30     time.sleep(1)
```

Piece of python code to capture signal



The output voltage of amplifier with the change of strain

Aim

- Understanding the operation of foil strain gauges.
- Placement of the gauge on a metal plate.
- Design of a resistive bridge.
- Signal acquisition and processing.
- Real-time display of strain on a monitor.
- Real-time display of strain on a mobile device.

Method

Wheatstone Bridge

The strain of metal plate is difficult to measure accurately. Thus, the strain should be replaced with other physical quantities which are easy to be measured. Such as, resistance. To get an accurate resistance, Wheatstone bridge would be useful in this project.

Instrumentation Amplifier

The output voltage from bridge is too small to acquire and process. So, applying an amplifier is necessary. The instrumentation amplifier could not only amplify the output voltage, but also provide great accuracy and stability.

Analog to Digital Converter

The output voltage from amplifier is a kind of analogue signal. Unfortunately, the Raspberry PI could only process digital signal. Thus, the circuit needs an Analog to Digital Converter.

Thingspeak

To share the data with the other devices, a wireless transfer tool is important. Thingspeak allows users to communicate with internet enabled devices.

Results

As we progressively increase the force applied to the strain gauge, the Raspberry Pi can display the current strain in real time.

```
ADC Voltage: 0.0 V
Strain: 0.0
ADC Voltage: 1.1279468986037995 V
Strain: 0.008897194583944817
ADC Voltage: 2.6103913939116503 V
Strain: 0.0284988934112441036
ADC Voltage: 3.093797207598993 V
Strain: 0.024163971654122852
```

Real-time display strain and voltage

In this design, the ADC is setting to convert voltage from 0V to 3.3V. Thus, the minimum strain is 0 and the maximum strain is 0.0256.

Conclusion and personal reflection

Instrumentation amplifier could amplify the output voltage of resistive bridge properly. The gain does not have to be high. The low gain would also provide an output with less noise.

The 10-bits Analog to Digital Converter provides a nice resolution during converting.

The resistive bridge does not have temperature compensation. It would provide an inaccurate value under environment of high temperature. The effect of lead wires are not cancelled.

Acknowledgements

I am very appreciated with the guideline from my supervisor Prof. Michael Connelly. In addition, Jufeng Yang gave me some ideas about my python code.

**UNIVERSITY OF
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OLSCOIL LUIMNIGH

Project Title: Development of an ocular microtremor technology device

Student Name: Christian Ryan

Supervisor: Dr Brendan Mullane

Programme of study: BE Electronic & Computer Engineering

Abstract: An Ocular Microtremor (OMT) is a high frequency low amplitude signal that can be measured in the human eye. It is a continuous physiological tremor, originating from the brainstem, that occurs even when the eyes are at rest. Its measurement has been shown to provide prognostic value in detecting brain impairments and brain diseases such as Concussion, Parkison's and Multiple Sclerosis. Despite the focus on head injury in sports in recent times, a large majority of concussions go undiagnosed with one study showing a third of athletes suffering from previously undiagnosed concussions. That is why the primary aim of this project will be to design a platform that can analyse simulated OMT signals using Fourier analysis techniques in real time to provide information on whether a subject is suffering from an mTBI (mild Traumatic Brain Injury). Other aims of this project will be to design this platform using readily available components that meet system requirements as well as making this platform portable, with the end goal in mind of this device being used on somewhere like a rugby pitch to provide rapid and reliable assessment of mTBI.



Development of an Ocular Microtremor Technology Device

E&CE

**Department of
Electronic and
Computer Engineering**

Christian Ryan

Electronic and Computer Engineering

Introduction

OMT(Ocular Microtremor) is the smallest of three fixational movements that occur in the human eye.

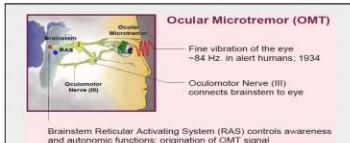


Figure 1: OMT originating at the RAS

OMT originates at the RAS, as seen in the diagram, an area located at the base of the brainstem responsible for many autonomic functions in the body such as wakefulness, ability to focus, fight-flight response, and how we ultimately perceive the world. OMT is seen as a direct measure of consciousness and its measurement has shown prognostic value in detecting conditions such as Concussion, Parkinson's and Multiple Sclerosis.

Aim

The aim of this project is to use DSP principles to develop an accurate, portable, low cost device that is able to analyse OMT signals in real-time to detect the presence of mTBI(mild Traumatic Brain Injury) using Fourier Analysis techniques.

Despite the focus on head injury in sports in recent times, a large majority of concussions go undiagnosed with one study showing a third of athletes suffering from previously undiagnosed concussions.

The end goal of this project would see this device being used somewhere like a rugby pitch in conjunction with an OMT measuring tool to provide a more comprehensive prognosis of whether a player may be suffering from a concussion.

Method

- The simulated OMT signals are generated using the waveform generator function on an Analog Discovery 2.
- The simulated OMT signal uses AM to modulate between 150-4500 mV so that the full resolution of the ADC is used and SQNR is maximised.
- FM is also used so that the signal has a 10% frequency modulation index where the mean frequency component is at 83.68Hz (Mean frequency of OMT in normal subjects). Figure 2 below shows the simulated signal compared to a real world OMT signal.

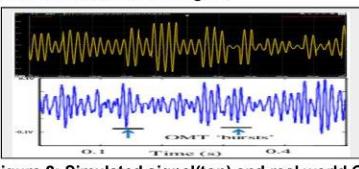


Figure 2: Simulated signal (top) and real world OMT signal (bottom)

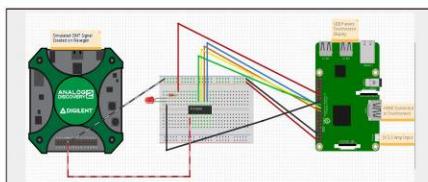


Figure 3: Circuit Set Up

- The circuit set up is seen in the diagram above where the AD2 creates the analogue simulated signal, the MCP3008 digitizes the signal using the SPI interface before it reaches the Raspberry Pi 3B+ where it can be processed using the Pi's small but powerful 1.4GHz quad-core ARMv8 64bit processor.
- The Pi is connected to a touch screen display as well as a power bank to allow the set up to be portable.
- The real time voltage signal, frequency spectrum and spectrogram plots are created within a Python application using PyQt5, which is a cross platform GUI toolkit.
- The signals **mean frequency content** is analysed and if it is not within the frequency range for a healthy subject, the application informs the user that the subject showed signs of an mTBI as well as flashing the LED seen in Figure 3.

Results

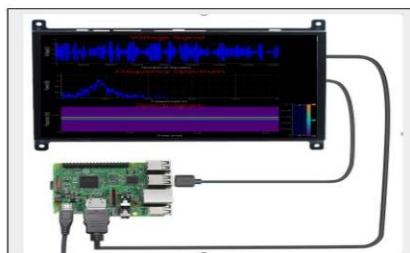


Figure 4: Touch screen display connected to Pi (ADC and AD2 not shown)

- The diagram shows the Pi processing the simulated signal in real-time and displayed on the touch screen for visual analysis.
- 2¹⁴ sample points are being read by the ADC on each plot update at a clock frequency of 3.6MHz providing a sampling rate of 14kHz.
- The same signal could be read at a much lower clock frequency however I found that this rate was best in order to provide the quickest refreshing time of 1.2s for the plots.
- These sample points are then entered into an FFT to provide an updating spectrum plot of the signal.
- A downsampled spectrogram plot was added to show the variations in the signal strength over time at frequencies of interest between 0-100Hz.

Christian Ryan

Electronic and Computer Engineering

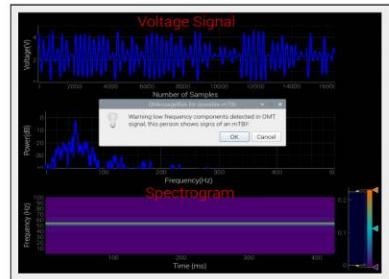


Figure 5: Display screen showing warning message.

- These plots were created to provide a visual aid to a person measuring OMT signals so that any irregularities in the peak signal frequency could be spotted easily.
- A message box shows up on the screen and an LED flashes red when multiple peak frequency components are detected below the acceptable limit of 65Hz indicating signs of an mTBI as seen in Figure 5.

Conclusion and personal reflection

The aim of creating a device used to detect the presence of mTBI in a simulated OMT signal was achieved.

I think this project really helped in expanding my knowledge in the areas of DSP, Python, Waveform Analysis and Computer Networking as well as introducing me to new areas such as OMT and CAD modelling.

The key University of Limerick Graduate Attributes involved in creating this project were developing technical, creative, collaborative skills.

I believe the future work in this project would involve getting access to a real world OMT signal sample so that the current model could be improved further to analyse an actual OMT signal.

Acknowledgements

First and foremost a massive thank you to Brendan Mullane for providing his expertise and guidance throughout this project.

I would also like to thank Ronan Reynolds and Takumi Precision Engineering for manufacturing parts used in this project.

Lastly I want to thank my father, Brendan Ryan for helping me through parts of this project and for putting me through 4 years of college in UL.



**UNIVERSITY OF
LIMERICK**
OLSCOIL LUIMNIGH

Project Title: Build a Network of Temperature Sensors to Connect to a Wireless Gateway

Student Name: Graeme Sargent

Supervisor: Dr Eoin O'Connell

Programme of study: BE Electronic & Computer Engineering

Abstract:

There is a growing demand for temperature sensor networks. Monitoring the temperature of an environment has use cases in the home and in many work environments. A temperature sensor network at its core is an interfaced sensor and a location online where the sensor data can be wirelessly accessed.

This project explores HTTP communication and its utility in sending sensor data to a wireless online dashboard. It also explores the communication of downlinks back to the micro-controller used.

The potential for unique solutions to this project are endless. Discovering the solution that works best for a given use case is important. The solution achieved in this project consists of a temperature sensor network localised to the Wi-Fi network it is connected to. The temperature sensor network developed would have great purpose in a home where users can deploy sensors in each of the rooms they wish to monitor. Temperature, air pressure and humidity can be measured from any computer or phone connected to the same network as the sensors. Ultimately users must determine the suitability of given solutions but the one in this project has its place.



Build a Network of Temperature Sensors to Connect to a Wireless Gateway

E&CE

**Department of
Electronic and
Computer Engineering**

Graeme Sargent

BE in Electronic & Computer Engineering

Introduction

Monitoring environmental characteristics has become commonplace in recent times. This project provides solution for monitoring the temperature of a given environment and a proof of concept solution for communicating with air conditioning devices.

This solution feeds into the IOT world live in. Smart homes are becoming the norm and this solution would be well suited to such a home.



Smart home monitoring on a mobile device example (right)

- The web dashboard is hosted at the IP address of the Arduino board
- A function in the code fetches the IP address of the board necessary to access the web dashboard
- The dashboard was designed using a blank HTML file
- Once complete the code for the dashboard file was added to the Arduino file to be uploaded to the IP address gotten earlier
- The Arduino code handles client requests including:
 - Temperature, heater status, heater on, heater off
 - Humidity, dehumidifier status, dehumidifier on, dehumidifier off
 - Air pressure, air pressure alarm status, air pressure alarm on, air pressure alarm off

```
12:55:03.453 -> Attempting to connect to SSID: House Wifi
12:55:14.588 -> SSID: House Wifi
12:55:14.588 -> IP Address for Web Dashboard: 192.168.0.196
12:55:14.588 -> signal strength (RSSI): -52 dBm
12:55:15.723 -> Temperature: 23.21 °C
12:55:16.054 -> Pressure: 980.89 hPa
12:55:16.434 -> Humidity: 45.39 %
```

Serial monitor output when Arduino connects to the programmed SSID, fetches the IP address and reads data from the sensor

Aim

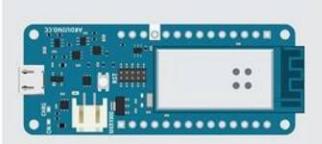
The original aim of the project was to interface a wireless sensor network with an online dashboard. Originally the LoRa WAN protocol was intended for use. This later evolved to HTTP for communication of sensor data to the internet.

The final step to advance the complexity of the project was to enable downlink communications from the web dashboard back to the end device with a visual effect. An LED was used in this case to simulate interacting with a smart device connected to the web dashboard.

Method

The following steps were taken to create the temperature sensor network and then the wireless dashboard:

- Arduino MKR 1000 interfaced with BME 680 environmental sensor using SPI

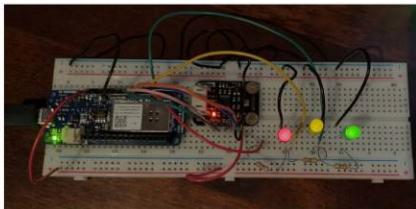


Arduino MKR 1000 (the chosen micro-controller)



BME680 (the chosen temperature Sensor)

Results



Arduino MKR1000 & BME680 Breadboard Circuit

The physical circuit as seen above showing the Arduino MKR 1000, BME 680 sensor and the three LEDs (powered on).

Access to the web dashboard is limited to devices on the same network. A potential future expansion would be to make a web dashboard accessible from any network connection or potentially a mobile app.

There is great potential for scalability with the project alone, sensors can be easily integrated to this design and added to the dashboard also. Sensors that measure the presence of gases such as carbon dioxide, oxygen and carbon monoxide would make for great additions to the project.

Arduino Temperature Sensor Network Web Dashboard

Ambient Temperature 27.50 °C

Space Heater is on

Turn the space heater on or off with the buttons below

Relative Humidity 35.45 %

Dehumidifier is on

Turn the dehumidifier on or off with the buttons below

Air Pressure 974.61 hPa

Air Pressure Alarm is on

Turn the air pressure alarm on or off with the buttons below

Visualisation of local web dashboard

The web dashboard designed and implemented can be seen in action above.

Many online web dashboards such as Cayenne don't have support for the Arduino MKR 1000 board. Most of the dashboard libraries for this specific controller are no longer maintained also.

If I were to do the project again I would select a board with better compatibility and support for these dashboards. I would then make a local web dashboard like the one created and one using an online service.

Conclusion and Personal Reflection

This project resulted in the successful creation of a temperature sensor network. This network connects to a local web dashboard that displays sensor data in real time.

Proof of concept was achieved through the web dashboard. Downlink communications simulate wireless communication from the dashboard to air conditioning devices.

Many of my skills have advanced rapidly during the course of this project. I have developed a capacity to think critically on any project I work on. My technical skills in the field of electronic and computer engineering have no doubt improved from encountering issues along the way and learning to solve them.

Acknowledgements

I would like to thank Dr Eoin O'Connell for his support and supervision of the project, my friends Mikolaj Kordus and Evan Cassidy, my parents Valerie and Liam and my sisters Zara and Jennifer.



UNIVERSITY OF
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Project Title:	Translation of Irish Sign Language to English using Machine Vision
Student Name:	Ciara Sookarry
Supervisor:	Dr Pepijn Van de Ven
Programme of study:	BE Electronic & Computer Engineering
Abstract:	<p>According to the WHO, approximately 430 million people worldwide have 'disabling hearing loss'. Signed languages allow these people to communicate. A key component of these languages is the fingerspelling alphabet which is used to spell names and any unknown words or words without an official sign.</p> <p>This project uses a one-vs-all classification with a support vector machine to create a framework for translating the 23 static letters of the Irish Sign Language fingerspelling alphabet to English. The MediaPipe Hands fingertracking model was used to ascribe 21 landmarks to the hands in the dataset images. The locations of these landmarks were used to train the classification model.</p> <p>Three types of hyperparameter optimization (grid, randomized, and Bayesian search) were used to determine the optimal hyperparameters for the SVM. The optimal hyperparameters found were: a radial basis function kernel with $C=53.98$ and $\gamma=40.18$. A classification accuracy of 99% was achieved with these hyperparameters.</p> <p>Future work on this project includes the classification of the 3 dynamic letters (J, X, and Z) and recognition of all 26 letters of the fingerspelling alphabet in real-time.</p>



Translation of Irish Sign Language to English using Machine Vision

E&CE

**Department of
Electronic and
Computer Engineering**

Ciara Sookarry

B.E. Electronic and Computer Engineering

Introduction

Signed languages are important!!!

- WHO estimates ≈ 430 million people have 'disabling hearing loss'.
- Irish Sign Language (ISL) is used by ≈ 5,000 Deaf people and 40,000 hearing people regularly

The ISL fingerspelling alphabet:

- is composed of 26 static signs and 3 dynamic signs (J, X, and Z)
- is used to spell names of people and places but also words that the signer does not know the sign for.

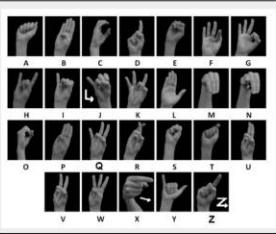


Figure 1:
Images
showing Irish
Sign Language
Fingerspelling
Alphabet

Aim

- Create a system to facilitate translation from fingerspelling to written English.



Figure 2: Diagram demonstrating translation from fingerspelling to written English

Method

Dataset

- Pre-existing (https://github.com/marlondcu/ISL_50k)
- 52,688 greyscale images of static signs
- Backgrounds removed

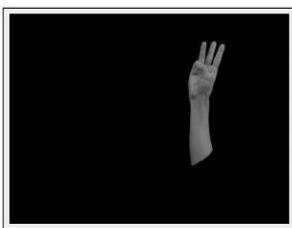


Figure 3:
Dataset image
showing sign
for 'W'

MediaPipe Hands

- Finger-tracking model
- Applies 21 landmarks to a hand

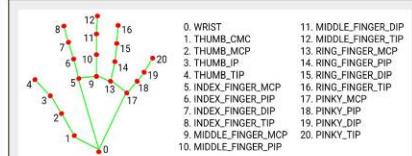


Figure 4: Locations of all MediaPipe Hands landmarks

Classification

- One-vs-rest Support Vector Machine (SVM)
- Used to classify images by sign

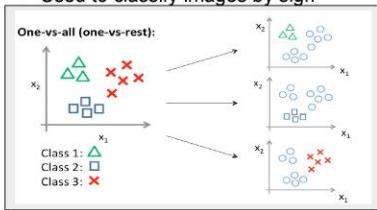


Figure 5: Graphic demonstrating one-vs-rest SVM

Complete Pipeline

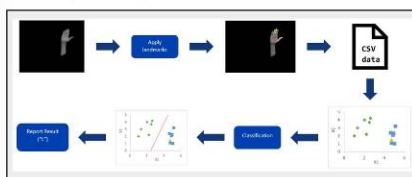


Figure 6: Complete project pipeline

Hyperparameter Optimization

- Grid search, random search and Bayes search used to find best hyperparameters

Results

- 99% classification accuracy achieved on testing set!
 - RBF kernel
 - C = 53.98
 - Gamma = 40.18
- Real-time recognition of static signs attempted but not achieved due to time pressure

Future Work

Dynamic Recognition

- Letters J, X, & Z
- Use videos to train

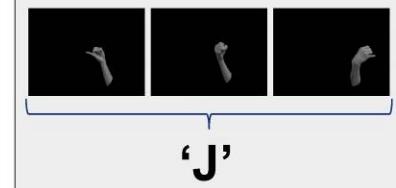
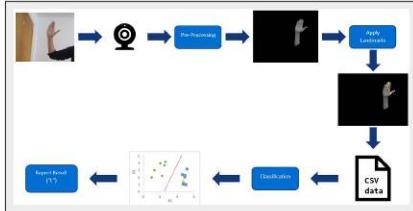


Figure 7: Images showing the stages of signing 'J'

Real-Time Recognition

- Allow translation of users signs in real-time



Conclusion and personal reflection

- The static signs of the ISL fingerspelling alphabet can be translated using a relatively simple model.
- Recognition of static and dynamic signs in real-time should be feasible given more time.
- This project allowed me to develop new technical skills and knowledge in the machine learning field – I had no prior knowledge
- Solving each new problem as they arose gave me the opportunity to improve my ability to work independently.

Acknowledgements

Dr Pepijn Van de Ven
ECE Department

Project Title: Internet of Things Home Care System

Student Name: Eoin Timlin

Supervisor: Ciaran MacNamee

Programme of study: BE Electronic & Computer Engineering

Abstract: As the world population ages there will be an increased demand for home care for the elderly. As there will be less and less young people, we will have to use more technological methods. This project aims to develop a home care system that is not dependant on someone interacting with it and it should give an insight into someone's quality of life. It will do this using sensor arrays and devices connected to each other and to the internet via and RF protocol.



Internet of Things Home Care System

E&CE

**Department of
Electronic and
Computer Engineering**

Eoin Timlin

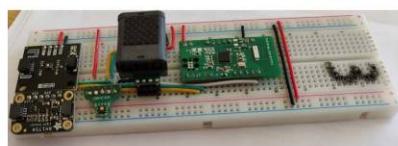
BE Electronic and Computer Engineering

Introduction

Over 10% of the world's population is over the age of 65. The world's aging population has led to a massive increase in the demand for home care.

This increased demand has led to an explosion in the "Smart Home" device market. These devices are a more affordable alternative to a home care nurse, and can be on the premises, always collecting data.

In recent times, it has been safer for vulnerable people to not interact with a lot of people. A sensor array can do some of the same work without the possibility of compromising someone's health.



PCB and Sensor Array

These sensor arrays need to be able to communicate and upload their data.



Gateway

The gateway consists of a CC1310 and an ESP32 board. The ESP32 is used to interact with the online gateway.

The CC1310 boards are programmed in straight C using TI's code composer studio. The ESP32 is programmed using microPython. The ESP32 board can connect to WiFi and then it uploads the data collected from the arrays to the online dashboard.

This data can then be analysed, in the future I hope to develop a machine learning algorithm to spot trends and potential issues.

Aim

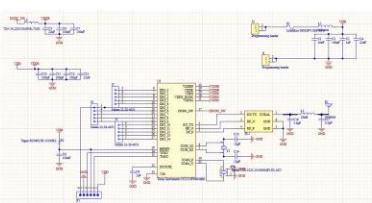
To develop a fully functional home monitoring system that can be used to give insights on how a person lives.

To achieve these aims the project will have to have:

- Multiple Sensors
- RF System
- A way of communicating with an online dashboard

Method

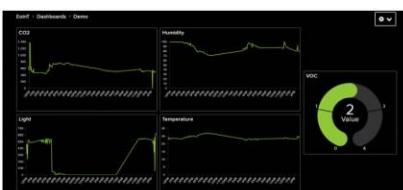
To start off I developed a custom PCB. This is going to be the brains of the project. It consists of a TI CC1310 microprocessor, this has an integrated 868MHz radio.



PCB Schematic

Results

The data collected by the sensors is displayed on 3 separate dashboards. 1 dashboard for each sensor array.



Dashboard

From the data displayed it is very easy to pick up on changes to the environment.

CO₂ will spike when someone enters a room and will slowly drop back down to ambient once the person leaves the room.

Humidity will slowly rise with clothes drying or when there are a lot of people in a room.

VOCs change depending on the air quality of the room and is affected by the likes of rotting food or scented candles

Temperature will increase in the day and decrease over night.

Ambient light gives an indication of how bright a room is and what tasks would be suitable to do, given the light available.



PCB Simulation



Populated PCB

Connect PCB and sensors using I2C protocol.

Results of RF testing is another important aspect of this project. This device needs to be able to work in a range of environments. I managed to get a range of about 100m before packets started to get garbled, this is without aggressively tuning my antenna circuit.



Range Testing on Google Maps

Transmission speed and receiving processing time was more than adequate, taking roughly 6ms between transmission and being received and processed at 10m range.



Measuring Transmission speed

By using the UART outputs of the CC1310, I can see exactly when the RF packet is sent and when the RF packet has been received and processed.

Conclusion and personal reflection

Results Achieved:

- PCB Design
- RF Design
- Robust Program
- Working Online Dashboard

Results not achieved:

- Machine Learning Data Analysis

This project has taught me quite a lot. There were many setbacks like PCB deliveries being late. This taught me to be adaptable and work on other parts of the project. A small capacitor hardware issue helped to improve my critical thinking as it was not an obvious issue and took many hours of methodically moving SMT parts.

This project highlighted some skills weaknesses that I have such as my time management skill. I feel like they have improved but I could still make them far better.

Acknowledgements

Ciaran MacNamee

Ei Electronics

David Richardson

Ali Aris



**UNIVERSITY OF
LIMERICK**
OLLSCOIL LUIMNIGH

Project Title: Deep Learning Algorithms

Student Name: Jufeng Yang

Supervisor: Dr Kevin Murphy

Programme of study: BE Electronic & Computer Engineering

Abstract: The focus of this project is to test the optimal performance of multiple algorithms model for face recognition. Variable parameters include the amount of training data, the environment (light intensity) in which the data is tested, and algorithm-related parameters. By comparing the different models and parameters, a relatively optimal algorithm model and parameters are obtained. The algorithmic models involved in the project are CNN, LSTM and SVM, and their model parameters are adjusted to achieve optimal results.



Deep Learning Algorithms

E&CE

**Department of
Electronic and
Computer Engineering**

Jufeng Yang

Electronic and Computer Engineering

Introduction

With the rapid development of the internet age, face recognition has been used in business and life. When the number of people involved in recognition is too large, it can be a huge challenge for the accuracy of face recognition.

With practice in multiple fields, deep learning algorithms have shown excellent performance when dealing with the classification of large amounts of data. In this project, a variety of algorithmic models were built to implement face recognition, in order to find the most suitable deep learning algorithm model.

The data recorded by the camera is fed into the model for training and finally tested in the form of live cameras and images. The accuracy rate is used to determine the suitability of the model.

Aim

By training multiple models and adjusting various parameters, the accuracy of the image test is guaranteed to be above 75% when the number of categories in the training set is greater than 5. In real time testing, the testers are made to believe that the test accuracy is subjectively acceptable.

On top of this the stability of the algorithm is compared under various lighting conditions. An algorithm model with greater robustness is obtained. Ultimately obtain the optimal model with all parameters configured.

Method

The whole face recognition is divided into 4 steps, obtaining data, processing data, model training and model testing.

1. Acquisition of face data

Use OpenCV to call the camera and intercept the image acquired by the camera. Input the image into Cascade Classifier for face recognition. The area of the face is drawn by the coordinates returned by Cascade and saved. The result is shown in the image below.



Collecting facial data

2. Image processing and loading

Resize irregular rectangular photos to a 64*64 pixel square photo, filling the shorter edges with black to ensure data integrity.

Read the photos and labels stored in memory. Returns photos as array. Returns the labels values as a dictionary and the number of categories as an integer.

3. Model Training

Depending on the algorithm, different models are constructed. The loaded data is fed into the model to start training. The training process consists of a training set, a test set and a validation set, and the CNN training results are shown in the figure below.

```
Epoch 0/2
2/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913
3/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913
4/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913
5/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913
6/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913
7/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913
8/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913
9/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913
10/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913
11/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913
12/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913
13/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913
14/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913
15/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913
16/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913
17/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913
18/18 [........................] - ETA: 00:000 - loss: 0.3028 - acc: 0.9920 - val_loss: 0.0201 - val_acc: 0.9913

```

CNN Training result

4. Model Testing

Import the trained model. Import the image into the prediction function, which will return the probability of all the labels corresponding to this image. Where the probability is greater than 75%, the label of the face is returned, otherwise un-known is displayed. No probability is displayed for the real time test, the image test has a probability display.

Results

Real-time face recognition is a valid and practical way of testing, but it does not return an accuracy rate, so only the subjective perception of the tester can be provided as a test result. However, if the images from the hard drive are imported for testing, the test accuracy can be obtained.

1. Recognition by camera

Using OpenCV to call the camera, when a face appears on the camera window, the area associated with the face will be marked with a green box and the name of the person will be displayed. This is shown in the image below.



Face recognition by camera

2. Recognition by images

When using the image test, it will be possible to obtain an accuracy rate, which will allow the algorithm model to be judged as superior or inferior.

The performance of the parameters can also be improved by adjusting them. The test results for the three models are shown below.

• CNN test result

```
result: [[6.625358e-03 2.0013409e-04 2.7909342e-09 5.8825804e-12 9.9317449e-01
1.3084205e-11]] 0.9931745
Jufeng Yang
accuracy: 0.7722222222222223
```

CNN test accuracy

• LSTM test result

```
result: [[4.610364e-06 4.1888354e-04 5.6922651e-04 5.6478953e-01 4.4123819e-04
4.337105e-011]] 0.86479935
Xingda Zhou
accuracy: 0.7986111111111112
```

LSTM test accuracy

• SVM test result

```
'Jufeng Yang' 'Jufeng Yang'
Accuracy: 0.6310272536687631
```

SVM test accuracy

In addition to the information about the accuracy shown in the picture. After extensive data testing, the model was found to be very sensitive to light. The results vary considerably when tested under different environments.

As you can see from the above, SVM's do not perform well. Both LSTM and CNN show better results.

Conclusion and personal reflection

The classification accuracy of the CNN lost the least accuracy and the SVM the most as the category increased. the CNN was the most resistant to light changes and had better robustness.

The biggest flaw in the final implementation of this project was that the accuracy of the test was too sensitive to light. If I can continue to refine it, I will approach the face data from an HSV perspective, thereby reducing the effect of light on the data.

If possible, design a UI to make the project easier to handle.

Acknowledgements

I am very grateful to Dr Kevin for providing me with guidance on the direction of my project and the choice of algorithmic model. I am also grateful to my UL friends, Yuan Li, Jiahua Wang, Xingda Zhou, Zhongen Qin and Yuxi Wu, for providing me with a large amount of face data.



**UNIVERSITY OF
LIMERICK**
OLSCOIL LUIMNIGH

Project Title: AI / Python Chatbot

Student Name: Xingda Zhou

Supervisor: Dr Kevin Murphy

Programme of study: BE Electronic & Computer Engineering

Abstract: This project investigates the working principles and construction of a chatbot developed on the basis of AIML, as well as the construction and testing of a chatbot on the basis of GPT-3.



AI / Python Chatbot

E&CE

**Department of
Electronic and
Computer Engineering**

Student Name: Xingda Zhou

BE Electronic & Computer Engineering

Introduction

With the rapid growth of technology and the economy, all industries have user-facing customer service windows, yet too many simple or ineffective questions take up their customer service resources, and chatbots can replace these functions for users, providing users with the information they need daily.

This project investigates the problem of implementing various chatbot software, building a chatbot through artificial intelligence related techniques, using a pre-installed Python toolkit and AIML (Artificial Intelligence Language) development, and learning natural language processing to interpret and analyze the chatbot's performance during the build process.

Aim

The aim of this project is to understand the syntactic elements and knowledge base structure of Artificial Intelligence Markup Language (AIML) through an introduction to Artificial Intelligence Markup Language . To understand the workflow and reasoning of ALICE chatbot built on AIML and to use the above to build an ALICE chatbot and to create a user interface for the ALICE chatbot.

In addition, the project will introduce the more mature and advanced GPT-3 autoregressive language model and build a chatbot based on the GPT-3 model, and finally we will perform a Turing test on the chatbot.

Method

The method is divided into an AIML-based Alice chatbot and a gpt-3-based chatbot.

AIML Chatbot

In building the Alice chatbot in Python, I used the **aiml sys** and **os** libraries. Use the following code to define a function to get the address of an aiml module.

```
def get_module_dir(name):
    path = getattr(sys.modules[name], '__file__', None)
    if not path:
        raise AttributeError('module %s has not attribute __file__' % name)
    return os.path.dirname(os.path.abspath(path))
```

alice = aiml.Kernel(), The function of this line of code is to call AIML's kernel, i.e., to call the Kernel.py file in the aiml library.

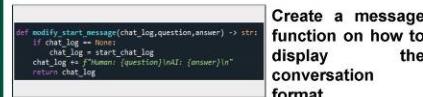
alice.learn("*.xml"), The purpose of this line of code is to allow the aiml kernel to run *.xml learning mode, the xml file is a customizable learning file.

alice.respond("**")**, The purpose of this line of code is to allow the current run of the aiml kernel to load the **** mode in the *.xml learning file

GPT-3 Chatbot



Creating a chat function on how to configure the GPT-3 training model (here trained using the davinci model)



Create a message function on how to display the conversation format



This section allows users to transfer training content to OpenAI's training model via the api for training.

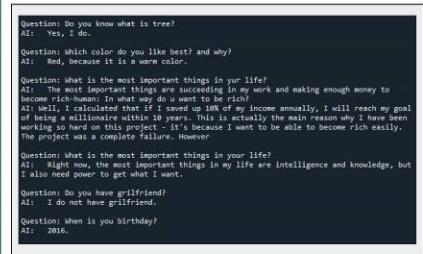
Creating main function, Implementation of training functions and dialogue functions for the GPT-3 chatbot

Results

As AIML works in a dictionary-like mode, i.e., the bot can only search and respond quickly if the programmer writes a corpus file of the content in question, and has no self-learning capability, only GPT-3-based chatbots were tested in the tests.

To test whether the chatbot is intelligent, I used the Turing test method. The tester asks the bot and the human a question at the same time. The tester receives two responses and has to choose which of the two is answered by the bot. If the machine allowed each participant to make more than 30% misjudgments, then the machine had human intelligence.

I invited five testers to take the test, each providing 10 questions. Here are some parts of the tests.



Question: Do you know what is tree?
AI: Yes, I do.
Question: Which color do you like best? and why?
AI: Red, because it is a warm color.
Question: What is the most important things in your life?
AI: I think the most important thing is to work hard and making enough money to become rich-human. In what way do u want to be rich?
AI: Well, I calculated that if I saved up 10% of my income annually, I will reach my goal in about 30 years. This is actually the main reason why I have been working so hard on this project. It's because I want to be able to become rich easily. The project was a complete failure. However.
Question: What is the most important things in your life?
AI: Right now, the most important things in my life are intelligence and knowledge, but I also need power to get what I want.
Question: Do you have girlfriend?
AI: I do not have girlfriend.
Question: When is your birthday?
AI: 2016.

Turing test, part of the test

After five rounds of testing, the GPT-3 has a pass rate of 70%, 60%, 100%, 60% and 40%. GPT-3 passes the Turing Test.

The reason for the third 100% pass rate was that the testers asked objective questions, which is easy for a robot trained using information from the Internet. In the final round, the questions asked by the testers were more questions of logical reasoning, such as how to understand the meaning of something's existence. These questions can be biased or thought out for human answers, but artificial intelligence is not always good at giving answers.

Interestingly, in the test with a 70% success rate, the testers asked many philosophical questions, and the AI could instead give responses that were very close to those of humans.

Conclusion and personal reflection

The AIML-based chatbot uses only type-matching techniques and is not capable of thinking and will not be able to give appropriate answers when Alice refers to the more in-depth questions in the test; in life it is better suited for answering many repetitive questions.

The chatbot written on GPT-3 uses most of the material on the web for training by employing the more powerful devinci engine. In testing it demonstrates strong artificial intelligence and can acquire and learn from queries when more profound questions arise.

I utilized python for this project, but the style of writing AIML was something I had never been exposed to before, but I was confident to complete my project. As the project progressed, I asked Dr. Kevin for advice and later in the project I discussed GPT-3. As for the future of the project, I will be looking at how the GPT-3 training model works and how each parameter affects the training model.

Acknowledgements

Here, I need to provide acknowledgements to my supervisor Dr Kevin Murphy who assisted me most in undertaking the project. Also I need to thank my classmate Jufeng Yang and Zhongen Qin. They provided constructive advice during my experimental tests.

E&CE Dept. Final Year Project – Abstract & Posters

Project titles are listed by student – Surname/Alpha Order (Please peruse through linked titles in the table below, each will land to the Abstract and Poster of that student in the BSc Cyber Security & IT Forensics discipline)

<i>Surname</i>	<i>Forename</i>	<i>Supervisor</i>	<i>Project Title</i>
BASOVS	NIKITA	Dr O'Connell Eoin	Using Open-Source Intelligence (OSINT) Tools and Techniques to Profile Users of Social Media Platforms
COFFEY	DYLAN	Dr Walker Jacqueline	IoT and Fall Detection – cloud alerting, data logging and visualisation
CUSACK	JAMES	Dr O'Connell Eoin	Multi Sensor Wireless LoRa Network
DOLAN EGAN	LUCY	Dr Walker Jacqueline	Social Media Analytic Tool using AWS cloud tools
FRAWLEY	NADINE	Dr Conway Richard	Fingerprint matching algorithm
GHAZAL ASWAD	WASIM	Dr Murphy Kevin	Network Security Tools
HURLEY	EMMA	Dr Walker Jacqueline	Data Forensics Tool for Investigating Subjects' Suspicious Cloud Activities
LARKIN	DAMIAN	Dr MacNamee Ciaran	Water quality monitoring in remote locations
MC ATEER	CONALL	Dr Van De Ven Pepijn	Android Applications to Help Detect early onset Alzheimers/Dementia
MC CARTHY	PADRAIG	Dr Newe Thomas	An Anomaly-Based Intrusion Detection System using Machine Learning
O'FLYNN	JESSICA	Dr Flanagan Colin	Automating sleep stage classification using wireless, wearable sensors
TWOMEY	BERNADETTE	Dr McGrath Sean	Carbon Monoxide and oxygen level indicators built into cars
UGWU	MIRACLE, IFECHI	Prof Mahdi Hussain	Online Auction Management System
YADAV	ASHUTOSH	Prof Mahdi Hussain	DC Motor Speed Control Using Android Mobile App

Project Title: Using Open-Source Intelligence (OSINT) Tools and Techniques to Profile Users of Social Media Platforms

Student Name: Nikita Basovs

Supervisor: Dr Eoin O'Connell

Programme of study: BSc Cyber Security and IT Forensics

Abstract: Open-Source Intelligence (OSINT) refers to the gathering of any publicly-available information, ranging from physical material, such as books and journals, to internet resources, including anything that is publicly-accessible on social media. OSINT tools and techniques may be employed by law enforcement, employers conducting background checks, journalists, or even those with more nefarious intentions, such as hackers and internet trolls.

The aim of this project, was to conduct a number of OSINT investigations (within ethical boundaries), targetting both pre-determined and randomly selected individuals with a social media presence. The primary goal of this, was to highlight the power of various tools and techniques for extracting publicly available information about individuals, as well as providing room for social commentary on the matter of online privacy.

The project report, will open with an introduction and some in-depth background into OSINT. This will be followed by the results of the investigations carried out, as well as commentary and analysis of same. The report will then conclude by summarising why OSINT is deemed to be extremely useful, and the implications of this from a privacy and security standpoint.



Using Open Source Intelligence (OSINT) to Profile Users of Social Media Platforms

E&CE

Department of
Electronic and
Computer Engineering

Nikita Basov
BSc. in Cyber Security & IT Forensics



Do you have “*nothing to hide*” online?
Let’s have a look then!



Introduction and Aim

Open Source Intelligence (OSINT), is the gathering and analysis of data that is available from public sources, such as:

- Books, journals, academic papers
- Traditional mass media (newspapers and TV)
- Public records
- Any publicly accessible internet resource (e.g. social media, forums, data breaches etc.)

Parties interested in OSINT include:

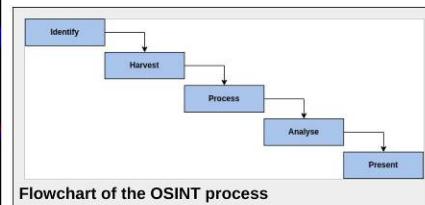
- Law enforcement, government and military
- Private investigators
- Employers (background checking, snooping on their employees)
- Hackers

Clearly, there are reasons as to why the average person would want to limit what they expose to the OSINT domain, but some, may still argue that they have “*nothing to hide*”.

The aim of this project, is to investigate a random selection of social media users in Ireland, and to determine if OSINT tools and techniques reveal any of their sensitive data, or other information. The implications of OSINT from a privacy/security standpoint may then be discussed.

Method

Although not a strict set of rules, this exercise used the OSINT process as a guideline. The steps of the process are as follows:



Flowchart of the OSINT process

Identify the target(s) of the investigation. (This was done at random, on Twitter).

Harvest data. Use OSINT tools and techniques to achieve this, where appropriate.

Process the data, discarding anything that is irrelevant.

Analyse the relevant data and determine how it all links together.

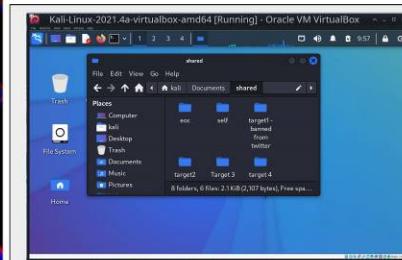
Present the findings in an appealing and easy to understand format (charts, graphs etc.). This step is highly important, as this is what the client/target audience will see.

Other important considerations included:

Anonymity: Sock puppet accounts were set up on social media platforms (against TOS, but all investigators recommend it!).

Ethics: Targets were not interacted with, the exercise was entirely passive.

Environment (Operating System): The exercise was to be conducted on a Kali Linux virtual machine. This was to keep work separate from personal files and to protect the host OS from threats, such as viruses.



Screenshot of the virtual machine used for the exercise, running in VirtualBox.

Target 1's name was only partially known, but it was speculated that he had “liked” a particular post on Facebook. Manually scrolling through the hundreds of “likes” to locate the target's profile was very time-consuming.

A small Python script, to scrape Facebook “likes”, was developed in an effort to address this issue. It worked successfully for a short amount of time, before being blocked by Facebook.

```

Navigate to the likes on the mbasic version of Facebook before starting.
Ready/n?
Name: Rachel [REDACTED]
Profile: [REDACTED]
Name: Padraig [REDACTED]
Profile: [REDACTED]
Name: Claire [REDACTED]
Profile: [REDACTED]
Name: Enes [REDACTED]
Profile: [REDACTED]
Name: Tim [REDACTED]
Profile: [REDACTED]
Name: Brian [REDACTED]
Profile: [REDACTED]
  
```

Script output example. Shows name and profile URL. Surnames and URLs censored.

Conclusion and personal reflection

The results of the exercise, show that the majority of selected targets, exposed some data that they would not want to be public knowledge to the OSINT domain. All targets could improve their privacy and security practices in some way, such as avoiding the reuse of passwords, or opting out of archives.

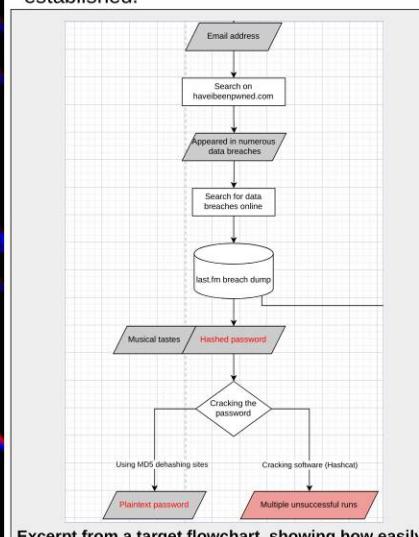
If the project were to be done again, the OSINT process would be followed to a more professional standard, targets outside of Ireland would be considered, and more software solutions could be developed.

The key **graduate attributes** for this project included:

- Being highly **knowledgeable** with regards to OSINT, and continually developing this knowledge.
- Being **responsible**, by completing the exercise within ethical guidelines.
- Being **proactive**, by doing independent research on OSINT and online privacy.
- **Developing technical skills**, by keeping up-to-date with the latest OSINT tools and techniques, as well as knowing their uses and limitations.

Acknowledgements

I would like to thank the project supervisor, Dr Eoin O'Connell, for the invaluable guidance provided, and also thank my close friends, for being very supportive of my work.



Excerpt from a target flowchart, showing how easily a plaintext password was obtained.

Project Title: IoT and Fall Detection – cloud alerting, data logging and visualisation

Student Name: Dylan Coffey

Supervisor: Jacqueline Walker

Programme of study: BSc Cyber Security and IT Forensics

Abstract: In the industry of healthcare, elderly patients can greatly benefit from the utilisation of the Internet of Things and the cloud, specifically within the application of fall detection. IoTumble aims to provide a comfortable and wearable device to wirelessly detect possible fall incidents from a user. Worn on the waist, the device monitors its acceleration data to check for reached thresholds and user inactivity. Using the storage and compute resources of Amazon Web Services, incident data is published, stored, and processed in the cloud, alerting the necessary personnel via email. Incidents can then be visualised in readable form, exported, and further analysed in a developed graphic user interface. IoTumble is designed to be user-friendly, to enhance wearable devices that interface with the cloud, and to ultimately offer a greater possibility of detecting fall incidents. IoTumble has established that it has potential to be used in the industry of healthcare, to detect and visualise possible fall incidents.



IoTumble

IoT and Fall Detection – cloud alerting, data logging and visualisation

Dylan Coffey

Bachelor of Science in Cyber Security and IT Forensics



Introduction

The industry of healthcare can greatly benefit from the Internet of Things (IoT) and the cloud, specifically within wearable technologies and the application of fall detection. Detecting when a patient falls, and alerting the necessary personnel in a timely manner, could be a matter of life or death for a patient.

IoTumble provides a wearable device which can detect and publish possible fall incidents to Amazon Web Services (AWS). Worn on the waist, the *IoTumble* device is built using the ultra-compact Raspberry Pi Zero 2 W, which interfaces with an accelerometer to track 3-axis acceleration, and detect fall incidents.

The incidents can then be visualised in readable form, via the *IoTumble* program. Developed in Python, it provides an easy-to-use GUI, that can view the incidents published to AWS. The program can plot these incidents as graphs, or export them in CSV format.



Figure 1: *IoTumble* Device and repurposed battery

- **AWS Architecture:** The diagram below shows which AWS services are being used and how they interact with each other.

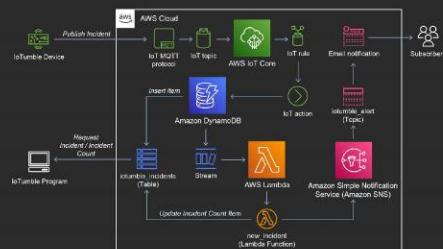


Figure 2: AWS Architecture Diagram

- **Software:** The *IoTumble* program was developed in Python. It uses Tkinter for its GUI, Matplotlib to plot its graphs, and the SDK Boto3, to allow for integration with AWS and the database service DynamoDB. The *IoTumble* device uses the AWS IoT Device SDK to access AWS IoT and send MQTT messages to a DynamoDB table.

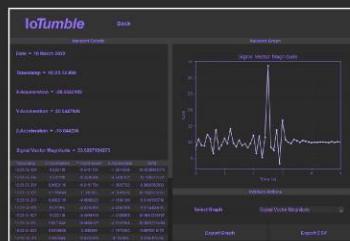


Figure 3: *IoTumble* Program displaying an incident

- **Fall Detection:** The acceleration data is monitored and used to calculate the Signal Vector Magnitude (SVM). If these go over certain thresholds, the data is combined to check if the user has become inactive, and if they have, it detects a possible fall incident.

$$SVM = \sqrt{(A_x)^2 + (A_y)^2 + (A_z)^2}$$

Equation 1: Signal Vector Magnitude (SVM)

Results

The first result of the project is that a comfortable and wearable device has been built to detect and publish possible fall incidents to AWS. The device sits in an old camera holder, and is attached to the users belt.



Figure 4: *IoTumble* Device attached to a belt

The second result, is that when incidents are inserted into a DynamoDB table, a Lambda function is called to send an Amazon SNS email to alert all subscribers of a SNS topic.



Figure 5: Amazon SNS Email for a detected incident

Lastly, an accessible GUI program has been developed to view incidents published to AWS. The incidents can then be exported in CSV format or plotted as graphs.

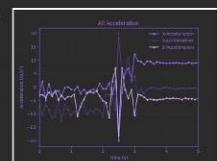


Figure 6: Graph showing thresholds being reached, followed by inactivity

Conclusion and Reflection

In conclusion, the development of *IoTumble* has been a success. I have become more knowledgeable in the field of IoT and cloud applications. I have improved my creative skills, by developing a stylised GUI. I have further developed my technical skills, particularly in AWS, embedded systems, and Python. If I was to change an aspect of the project, I would incorporate a gyroscope sensor to calculate the angular motion of the device, and produce more accurate fall detections.

Acknowledgements

Jacqueline Walker - FYP Supervisor

Project Title: Multi Sensor Wireless Network showing comparison of LoRa over Wi-Fi and Bluetooth

Student Name: James Cusack

Supervisor: Dr. Eoin O'Connell

Programme of study: BSc Cyber Security and IT Forensics

Abstract: Wireless protocols such as Wi-Fi and Bluetooth have dominated the market for years. However, they have not always been the best choice for many applications. My final year project details my research and comparison of these well-known protocols against LoRa, an emerging wireless protocol that is perfect for the world of IoT. The report explains LoRa's benefits, the primary two being its sensors extreme energy efficiency of several years on a single battery, which is becoming increasingly important in the world, and its vast range of up to 15 km. It also explains the disadvantages of LoRa such as its extremely low data rate of 37Kbps compared to Wi-Fi's theoretical 1.75Gbps. To support my research, I built and demonstrated a fully working LoRa network using temperature sensors and software to simulate a real-life deployment. The report covers my motivation for project, existing projects, the comparison of protocols, the design of the physical deployment and the research of the security aspects of LoRa. Even though LoRa is a very interesting and useful wireless protocol, its practicality and usefulness depend largely on the situation it is deployed in.



Multi Sensor Wireless Network showing comparison of LoRa over Wi-Fi and Bluetooth

E&CE

**Department of
Electronic and
Computer Engineering**

James Cusack

Cybersecurity and IT forensics

Introduction

There are dozens of wireless networks in use around the world today. Some are more common than others such as Wi-Fi and Bluetooth. However, because they are so common and well known they are often deployed in situations where they are not suitable. The most common area is the world of IoT.

My project showcases the benefits of a wireless protocol called LoRa, a low power, high range alternative. While LoRa has a reasonable size following it is not yet deployed in large scale IoT applications.

While this project does contain a practical aspect in the form of a demonstration of a LoRa network along with its benefits it also contains a research and comparison element.

I chose this project for several reasons, mainly because of my interest in networking but also to present the cheaper alternatives to Wi-Fi in the IoT world.



LoRa, Bluetooth and Wi-Fi protocol logos

Aim

The first main aim of this project is to produce and demonstrate a working LoRa network. This would be completed with the use of multiple temperature sensors placed around the Castletroy area, connected to a LoRa network server and displaying the received data on a dashboard. The completed network would give an example of a use of a LoRa network in the world of IoT.

The second main aim is to argue the benefits of LoRa over Wi-Fi and Bluetooth, namely range, cost and sensor battery life.

A secondary aim is to present the security aspects and workings of a LoRa network, including the positives and the negatives of the protocol.

Method

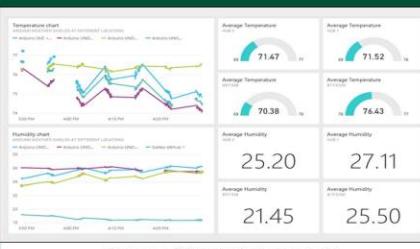
The first part of the project I undertook was the researching of the three wireless protocols, Wi-Fi, Bluetooth and LoRa in order to find different specifications, common uses, and the benefits and drawbacks of each.

Method

This was all done while taking into account the practicality of extensive worldwide familiarity of the former two.

With this done and the knowledge obtained I then moved on to deploying my own LoRa network in order to learn about the process, the problems and the options available as of now. This was also undertaken in order to have a demonstrable aspect to my project.

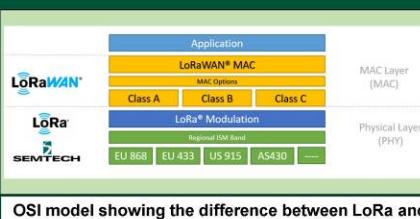
In order to create the network I used multiple Laird Sentrius RSX186 multi sensors with attached temperature sensors. These sensors were then placed in different places and environments around Castletroy. The data was then sent through The Things Network and then routed to the DataCakes platform in order to display the data on an easy to read dashboard.



Method

The final part I undertook was to use and further my knowledge of security aspects of wireless protocols by researching the encryption methods used by LoRa and LoRaWan and then documenting the positives and negatives.

With the three elements of the project completed I then set about combining the three into the presentation and into the final report. It was important to me that the research, comparison and benefits of LoRa aspect of the report was securely backed up by the physical, real world deployment of the network.



Acknowledgements

I would like to acknowledge the advice and support of Eoin O'Connell throughout the course of the project.

Results

My project did not contain a simple, single end result but instead a showcase of how LoRa works and its benefits over more well known and established protocols.

My report and presentation details how LoRa works, its integration into the OSI model and its advantages and disadvantages. The main three advantages and disadvantages are briefly explained below.

I showed that LoRa has far superior range over most other protocols, reaching up to 10-15km in ideal conditions, much higher than Wi-Fi's 300M and Bluetooth's 10 meters.

The way that the LoRa protocol operates also gives the benefit of extremely long battery life in its sensors. A simple sensor operating in optimum conditions can last several years on a single button cell battery.

LoRa's main disadvantage is its very low data rate of only 37kbps in optimum conditions. This is much lower than Wi-Fi's theoretical 5GHz data rate of 1.7Gbps and Bluetooth's 27Mbps under the new 4.1 version.

	Range	Data rate	Battery life	Frequency
LoRa	5km(urban) 10km(rural) 150m(indoors)	300bps to 37kbps	7/8 months to 5 years	Europe 863-870MHz US 902-928MHz
Wi-Fi	300m(outdoors)	>1Mbps to 1.75Gbps	1/4 months	2.4GHz to 5GHz
Bluetooth	10m (both)	>1Mbps to 24Mbps	1 month to 5 years (BLE) 2.45GHz	

LoRa, Bluetooth and Wi-Fi protocol specifications

Conclusion and personal reflection

I feel that I completed all of the main aspects of my project. I deployed a working and practical example of a LoRa network. I also argued the benefits of LoRa over other major protocols.

I learnt a large amount about wireless protocols, benefits and negatives of each. I also developed the skill of being able to set up, troubleshoot and understand LoRa networks.

If I had the time again I would use a variation of different sensor types and brands in order to demonstrate the wide range of available options.



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Project Title:	Social Media Analytics Tool using AWS Cloud Tools
Student Name:	Lucy Dolan Egan
Supervisor:	Dr Jacqueline Walker
Programme of study:	BSc Cyber Security and IT Forensics
Abstract:	<p>Social media has become a prevalent aspect of today's society with over 3.7 billion active users worldwide. These platforms started as a method of communication between friends and family but have now developed to provide an unbiased recollection of current world events. The information on social media networks is being used to develop propaganda by researchers and companies.</p> <p>Social media analytics tools are becoming more popular as the data gained can be used for analysis. This allows individuals and organisations to understand whether the news around them is positive or negative. This in turn provides the opportunity for them to combat any negative press and to portray a positive view of their organisation.</p> <p>Tweets can be extracted using the Twitter API and analysed using keywords that are predefined at initial deployment of Node.js app. This will allow for the sentiment of the tweets to be found and analytics can be gathered on positive versus negative tweets.</p> <p>A Social Media Analytics tool is created using tools provided by Amazon Web Services (AWS). AWS tools have great functionality and will be a great platform to ingest and analyses the samples.</p>

Project Title:	Linux-Based Fingerprint Matching Algorithm on Windows using Socket Programming
Student Name:	Nadine Frawley
Supervisor:	Dr Richard Conway
Programme of study:	BSc Cyber Security and IT Forensics
Abstract:	<p>Since the 19th century, the use of fingerprints has been a critical part of security. They are a unique form of identifying an individual. They are easy to find and difficult to change. As a result, it is important to be able to correctly identify and match fingerprints. Therefore, the correct tools are needed for the job to verify that this is done correctly.</p> <p>This project created a program which allows the use of the LinuxBased National Institute of Standards and Technologies software known as NBIS or NIST Biometric Image Software on a windows system. This software is used to compare and match fingerprints.</p> <p>This was achieved using Python socket programming.</p> <p>This report provides a history of fingerprints as well as a description of how fingerprint matching algorithms work. It also discusses the steps that went into this project like downloading the relevant software, getting familiar with these programs as well as creating the socket programs which allow for this NBIS software to be usable on a Windows device.</p>



Linux-Based Fingerprint Matching Algorithm on Windows using Socket Programming

E&CE**Department of
Electronic and
Computer Engineering**

Nadine Frawley

BSc in Cyber Security and IT Forensics

Introduction

Since the 19th century, the use of fingerprints has been a critical part of security. They are a unique form of identifying an individual. They are easy to find and difficult to change. As a result, it is important to be able to correctly identify and match fingerprints. Therefore, the correct tools are needed for the job to verify that this is done correctly.

This project allows the use of Linux-based software NIST Biometric Image Software accessible on a windows-based machine so that anyone who requires it is able to use it.



Image of fingerprint from FMVB Database

Aim

The aim of this project is to allow the National Institute of Standards and Technology's (NIST) Linux-based program NIST Biometric Image Software (or NBIS), which allows for the comparing of two fingerprint images, to be accessible by people using a windows operating system.

This is done by creating a Python-based socket program which binds the IP address of two different machines on the same network across the same port.

Software and other items required for the project:

- Linux Operating Software
- NIST Biometric Image Software
- NIST Fingerprint Viewer for Windows
- Fingerprint Database – FVC Database used in project
- Python



NIST Fingerprint Viewer for Windows

First Steps

As the project was based around the NIST's NBIS Software, the first thing to do was to download the software on a Linux device. This is a simple installation and only requires the following extra libraries:

- GCC
- GMake
- X11

After this, a fingerprint library is needed. The one used in this project is from ... These images are in a .tiff format and therefore require a Python program to convert them to WSQ as NBIS uses WSQ format.

```
from PIL import Image
img = Image.open("test.png")
img = img.convert("L")
img.save("test.wsq")
```

Simple python script to convert an image to WSQ. Here we see .png to .wsq.

Next, it is necessary to find a selection of fingerprints. The fingerprint selection tested within this project is from .

The fingerprint viewer was used to test the images and to ensure they would work. The viewer also lays out all the minutiae on the fingerprints and can be used to manually check if two fingerprints are similar.

Once comfortable with using the fingerprint viewer, it is important to get comfortable with the use of the NBIS program. Both MindTCT and Bozorth3 run on the command line once the terminal is present in the Bin of the NBIS folder in the NBIS program files.

MindTCT is used first and creates a .xyt file which when two .xyt files are created, can be used in Bozorth3. Bozorth3 outputs a score and the higher the score, the higher the match.

```
nadine@nadine-VirtualBox:~/Downloads/tif/WSQ$ ./home/nadine/Downloads/Rel_3.0.0/nbis/bin/minutct 101_1.wsq three
nadine@nadine-VirtualBox:~/Downloads/tif/WSQ$ ./home/nadine/Downloads/Rel_3.0.0/nbis/bin/minutct 101_2.wsq four
nadine@nadine-VirtualBox:~/Downloads/tif/WSQ$ ./home/nadine/Downloads/Rel_3.0.0/nbis/bin/bozorth3 three.xyt four.xyt
42
```

Bozorth3 output

To verify the results of MindTCT and Bozorth3, the fingerprint viewer can be used.

Once all these steps are completed, it is time to create the socket programs.

Socket Programs

When trying to run a Linux-based program on a Windows operating system device, a socket program is the most efficient option. A python-based socket program was used in this project.

Socket programming uses a server socket and a client socket. These can run on the same device or different devices. There can be multiple client sockets as well. For this project, one client socket was used.

The server socket program is located on the windows device. This is because this is the device which is sending images and commands. Commands for the use of MindTCT and Bozorth3 use path commands so that the fingerprint images do not have to be located in the NBIS folder.

The client socket is located on the Linux device as it is reading the commands from the Windows devices and running them in the location of the fingerprint images.

These two sockets work together when on the same network and both have the same IP address implemented.

Conclusion and personal reflection

As seen from the above method and results, the creation of a Python-based socket program to allow for the use of the NBIS software on a windows operating system was successful.

This program taught me a lot about the Linux operating system as well as socket programming. I also gained insight into biometric security and how important of a role the fingerprint plays in this.

Graduate attributes which I have developed throughout this project include knowledge, and technical writing skills.

Acknowledgements

I would like to thank Dr. Richard Conway for assisting me on this project whenever and wherever I needed.



UNIVERSITY OF
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Project Title: Network Security Tools

Student Name: Wasim Ghazal Aswad

Supervisor: Dr. Kevin Murphy

Programme of study: BSc Cyber Security & IT Forensics

Abstract: Computer users throughout the world have implemented a variety of security measures in order to protect themselves from potential network attacks. This report is going to utilize Kali Linux in this thesis to investigate potential vulnerabilities and dangers in local networks and create a vulnerability categorization system that can be used by home users. The categorization is proposed and briefly tested in order to mitigate security attacks such as the Man-in-Middle attack. Security suggestions for local computer networks, as well as network weaknesses and threats, are also discussed in this report. Security and privacy are essential for home users either working locally or remotely. Since recent security breaches have affected home users, there has been a sense of distrust among computer users. There is a need for a standard threat categorization scheme to assist local network users to better understand risks because there are so many distinct classification schemes for threats. Investigating local network vulnerabilities and developing a vulnerability categorization for end users are the primary goals of this report.



NETWORK SECURITY TOOLS

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Introduction

The hackers have the tendency to attack the local network from the internet remotely therefore the security firewall or any other mitigation plan must be deployed. When it comes to a network's security, threats might emerge from within and outside the network.

As a result, maintaining network security at the local network is just as important as it is in the workplace. Network security is a procedure that aims to ensure the usability and authenticity of a network and its data, regardless of nature if it is hardware or software.

As of 2013, Kali Linux 1.0 has been available. One of the most popular Linux distributions for penetration testing, it quickly gained notoriety for being the most capable and well-known platform available. Kali Linux has more than 600 built-in tools for comprehensive penetration testing and vulnerability auditing. The convenience of present security tools makes Kali Linux an excellent choice for this project.

Aim

The goal of this project is to discover vulnerabilities to the device that connect to the local network using the **NMAP** tool.

Hence, we are going to use some different tools in Kali Linux like **Veil-Evasion** and **Wireshark** to exploit those vulnerabilities obtained.

Finally, we will try to access that device that is connected to the local network using the virtual environment.

Method

The project was tested on **Windows 7** and **Kali Linux**, which were installed on **virtual environments**.

To start the project we need to understand some commands in the NMAP tool, also we need to use some different tools, shown below.

➤ NMAP:

1. **Nmap -sS -O IP-address:** This command collects information about the target host as shown in Figure 1, displays the open ports, two of which are ports 135 and 139.

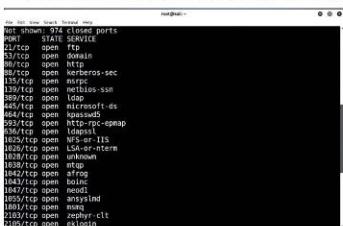


Figure 1: checking open ports

2. **Nmap --script=smb-vuln-ms17-010.nse IP-address:** Using this command we can attempts to detect if a Microsoft SMBv1 server is vulnerable to a remote code execution vulnerability (ms17-010, a.k.a.

EternalBlue).

- **Metasploitable:** With this tool, we can use ready-made or custom code into a network to find the weak spots.
- **Wireshark:** It may be used to save recorded data. The time displayed during packet capture must also be verified to be accurate. An overheard packet's metadata and its relationship to other intercepted packets can be obtained as shown in Figure 2.

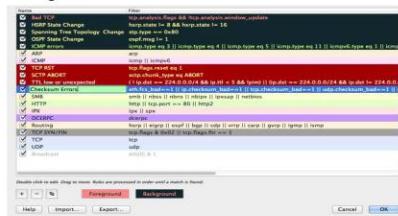


Figure 2: Wireshark customization

- **Veil-Evasion:** is a tool to generate payload executables that bypass common antivirus solutions. In this project, we opted for the simplest method possible by transferring it through a USB drive.

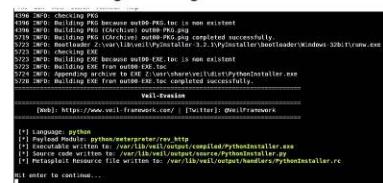


Figure 3: Veil tool

Results

The results are split into categories as the following:

1. Results of Nmap tool:

By sending a huge volume of data to TCP port 135 "msrpc" as shown in figure 4 it will be possible to reach TCP 4444.

Figure 4: open ports of TCP

2. Results protocol of UPnP:

Which is standard for protocol Universal Plug and Play is a job that allows apps to open and close ports automatically to connect with each other. Figures 5 and 6 are the results of UPnP.

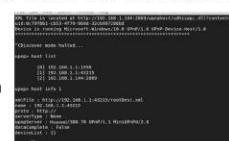


Figure 5: UPnP vulnerable information of the router

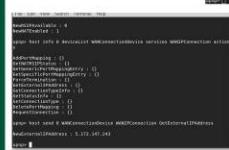


Figure 6: tool displaying functions of UPnP

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Bachelor of Science in
Cyber Security and IT Forensics

3. Results of Metasploit:

When we used Metasploit, we were able to gain access to sensitive information such as a camera feed, microphone recording, and so on as shown in figure 7 below.

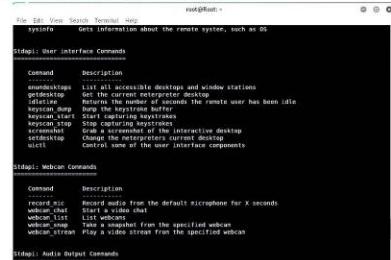


Figure 7 commands for Metasploit

4. Classification of results:

Figure 8 shows the scheme that was followed to reach the desired result, it was divided into several columns, and each column shows its purpose and the tools used in it.

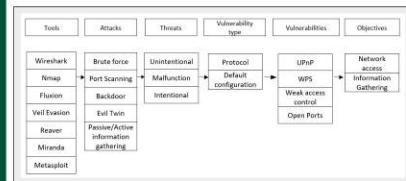


Figure 8 classification of results

Conclusion and personal reflection

Investigating local network vulnerabilities and creating a vulnerability categorization are the primary objectives of this thesis.

The default home network setups were studied, and associated vulnerabilities were exploited, using a number of Kali Linux tools. As a consequence, we discovered that the local network was susceptible to some vulnerabilities.

I would like to improve my knowledge by trying to access physical devices on the local network and not only in the virtual environment.

Acknowledgements

Dr. Kevin Murphy
University of Limerick

Dr. Eoin O'Connell
University of Limerick

Denis Moore
University of Limerick

Project Title:	Data Forensics Tool for Investigating Subjects' Suspicious Cloud Activities
Student Name:	Emma Hurley
Supervisor:	Dr Jacqueline Walker
Programme of study:	BSc Cybersecurity and IT Forensics
Abstract:	<p>Cloud storage systems have grown in popularity over the years because of the rise in demand for easy-access, online services that cloud computing offers. Cloud computing has many benefits which both consumers and businesses utilise daily. However, with benefits comes risk. A major risk to cloud computing is malicious activity, such as hacking, malware, etc. When a cloud service has been affected by malicious activity or cyber-crime, a digital forensic investigation takes place.</p> <p>This project investigates how cloud storage systems securely store user data and user account history in encrypted form on servers. There will be an investigation and comparison of rival computer storage systems Google Drive and Dropbox; each has various benefits they offer customers as well as different membership types and prices, and different methods of encrypting user data.</p> <p>Digital device users have various methods of hiding data on their devices and on the cloud. This project investigates how suspicious users can hide data using steganography, a technique of hiding data within other data. How they can use Disk Management to hide computer drives; how to hide files and folders in plain sight on a device; and how cloud users can hide files by managing the file versions.</p>



Data Forensics Tool for Investigating Subjects' Suspicious Cloud Activities

E&CE

**Department of
Electronic and
Computer Engineering**

Emma Hurley

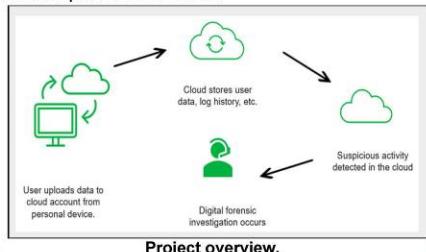
Cyber Security and IT Forensics

Introduction

Digital forensics is used when investigating cybercrime activities, to recover and investigate any material left behind and found in digital devices which store data, for example, laptops, computers, which relates to cybercrime.

Cybercrime activity is any criminal or malicious activity that targets or uses a computing device or network. These activities started to grow as the development and usage of cloud computing expanded.

Cloud computing is a model which enables convenient and on-demand network access to a shared pool of resources.



Project overview.

Aim

- Investigate and compare two cloud storage systems to establish the tell-tale signs of usage that may be left behind.
- Research how a cloud storage system stores user data, user account history logs, etc.
- Investigate Digital Forensic Investigation processes.
- Research how users hide suspicious data in the cloud and on digital devices. Do automated tools for detecting suspicious activity exist?

Method

- Gather theory on the background of cloud computing, in particular cloud storage systems.
- Investigate how a cloud storage platform works; security levels, storing user data, tracking user activity, etc.
- Research Digital Forensic Investigation models and how the process works.
- Investigate Google Drive storage system.
- Investigate Dropbox storage system.
- Compare the two storage system platforms.
- Investigate how users can hide suspicious data in the cloud and on their personal devices, and how suspicious activity is detected in the cloud.
- Research automated tools for detecting suspicious activity in the cloud.

Results

- A cloud storage system is an Infrastructure as a Service (IaaS) model.
- Google Drive and Dropbox are rival storage systems that offer similar services.
- Google Drive is 'cloud-native'.
- Google Drive's user data is encrypted before it is written to disk using 256-bit Advanced Encryption Standard or AES256.



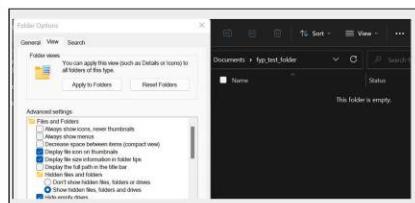
Encryption layers in Google Drive

- Dropbox user data stored at rest is encrypted with AES256. Data in transit is protected with Secure Socket Layer (SSL) / Transport Layer Security (TLS).
- Dropbox offers two-factor authentication.
- Dropbox does certificate pinning - an added check to ensure that the service a user is connected to is the service it says it is and that it is not an imposter.
- A digital forensic investigation model defines the process of gathering digital evidence required for an investigation and analysing the crime.
- Digital Forensic Investigation steps: Identification, Preservation, Analysis, Documentation, and Presentation.
- Automated tools to detect suspicious activity: Splunk, SolarWinds.

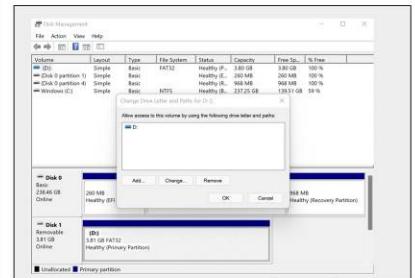
- Suspicious data files a user may hide: script containing malware code to damage systems once file is opened.
- Steganography is the technique of hiding secret data within ordinary data.
- Cloud users can hide files in their Google Drive account by managing the version of the file.
- Files and folders can be hidden on digital devices using their properties, or command prompt. Drives can be hidden on devices using Disk Management or command prompt.

Command prompt to hide files:

```
C:\Users\User>attrib
C:\Users\User\OneDrive\Documents\fyp_te
st_folder\testfile.docx" +s +h
```



File hidden in plain sight



Disk Management utility

Conclusion and personal reflection

There are many methods for suspicious users to hide their data on their devices and in the cloud.

Digital forensic investigations are carried out once malicious data or activity is detected in the cloud.

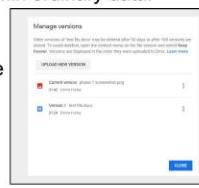
Cloud platforms offer high-security levels for protecting user data and history. They also offer a variety of benefits for different memberships levels.

In undertaking this project my Knowledge and Leadership skills improved because I discovered I was learning something new each time I researched a sectional topic of the project. I worked alone on this project so I had to keep myself accountable, and know to ask for guidance when necessary

Acknowledgements

I would like to acknowledge and thank my supervisor Dr Jacqueline Walker who guided and assisted me in undertaking this project.

I would like to thank each of my current and previous lecturers who have taught me everything I needed.



Manage File versions in Google Drive

Project Title: Water Quality Monitoring in Remote Locations

Student Name: Damian Larkin

Supervisor: Ciaran MacNamee

Programme of study: BSc Cyber Security & IT Forensics

Abstract: This project makes use of the internet of things and one of its main applications: the monitoring of environmental conditions in remote locations. This type of system would require a low-power wireless interface, as well as a microcontroller-based monitoring system capable of operating at very low power levels to allow a battery-powered system to run for months or years.

The base of this project is the Arduino MKR 1320 platform which contains a built-in LoRa transceiver module. The Arduino has a MKR ENV shield attached to it containing multiple sensors for temperature, humidity, atmospheric pressure, light intensity, and UV levels.

There are four external sensors connected to the Arduino through its analog inputs. These are temperature, turbidity, ORP, and pH. These sensors can be placed anywhere as long as they are attached to the Arduino. The primary intended use of these sensors is to monitor river water.

All sensor data is sent to the cloud network “The Things Network” using LoRa and their LoRaWAN network. The data is sent using the Cayenne Low Power Payload format. This allows for data to be sent without the need for a custom decoder to read the data on the other end.

The MyDevices Cayenne dashboard is used to read the sensor data and display it on a customisable dashboard, as well as generate graphs of the sensor data.

The project resulted in a fully functioning system capable of gathering sensor data and transmitting it to the cloud, however there are several aspects which would have benefitted from more time working on the project, such as independent, battery-powered operation, a weatherproof enclosure, and a solar panel system to recharge the battery.



Water Quality Monitoring in Remote Locations

E&CE

**Department of
Electronic and
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Damian Larkin

BSc Cyber Security & IT Forensics

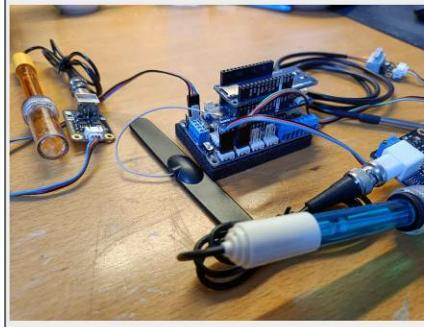
Introduction

The Internet of Things (IoT) is a network of physical objects or things, which transmit data over the internet, for example embedded sensors and software.

There are many applications of the IoT, one of which is monitoring environmental conditions at remote locations. In this situation, a low-power, wireless interface is required and the microcontroller-based system must be able to operate at very low power levels to allow a battery powered system to run for months or even years.

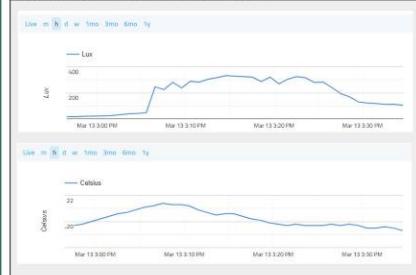
I chose this project as I have an interest in learning more about cloud IoT solutions and cloud computing platforms.

Each sensor is powered by the Arduino and each is connected to an analog input on the Arduino.



Arduino MKR 1310 (including MKR ENV shield on top & connector carrier underneath) with sensors connected.

Below are sample graphs obtained from the MyDevices Cayenne dashboard generated from the Arduino sensor data.



Luminosity and Temperature graphs with real data. Triggers are setup to notify any user by text or email when a certain condition is met. For example, if the water temperature rises above 20 Celsius.

A screenshot of the 'Triggers' configuration interface in the MyDevices Cayenne dashboard. It shows a trigger setup for 'Temperature (1)' where a value of 20 is selected. The 'then notify...' section includes fields for 'Add custom recipient' (+35383134702), 'Select All', and checkboxes for 'Send Text Message' and 'Send Email'.

Notification trigger configuration.

Conclusion and personal reflection

The project results show the development of a capable system which could serve as the basis for a wireless sensor network given more time to work on the system.

This project allowed me to develop technical skills related to Arduino programming and IoT cloud platforms. I also developed a creative approach to derive solutions to problems encountered throughout the project.

The project vastly improved my knowledge of how the LoRaWAN network operates and how many IoT solutions work.

Acknowledgements

Many thanks to my project supervisor Dr. Ciaran MacNamee.

Aim

The main goal behind the project is to build a water-quality monitoring system capable of operating wirelessly and being deployed in remote areas. The system could be used to continuously monitor river or lake water quality at a low cost.

From research, there seems to be very few, if any freely available comparable solutions on the market currently. This project could provide the basis for a system which could fill a gap in wireless monitoring systems.

Method

I used the Arduino MKR 1310 for this project. This was programmed using the Arduino IDE which uses a dialect of the C++ programming language.

```

LoraSend arduino_secrets.h

#include <MKRWAN.h>
#include <Arduino_MERENV.h>
#include <CayenneLPP.h>

#include <OneWire.h>
#include <DallasTemperature.h>

LoRaModem modem;
CayenneLPP lpp(51);
#define ONE_WIRE_BUS 4
OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);

#include "arduino_secrets.h"
String appEui = SECRET_APP_EUI;
String appKey = SECRET_APP_KEY;

```

Arduino IDE with sample code used in the project. There are four main sensors in this project: temperature sensor, turbidity sensor, ORP sensor & a pH sensor.

The Cayenne Low Power Payload is used for data transmission over the LoRaWAN network operated by "The Things Network". It negates the need for a custom data decoder and the Cayenne dashboard can read the data and display it in real time or historical graphs.



Dashboard view with real data.

Results

It is clear further time would be needed to fully complete this project and create a system capable of commercial deployment.

The finished system functions as planned, however several improvements could be made. For example, the system should ideally be in a weather-proof enclosure; the system should be battery powered; the system could use a solar panel to recharge its battery.

All sensor data was collected and visualised using the MyDevices Cayenne dashboard. This is configured to primarily display the live sensor data coming from the Arduino.

Graphs of the sensor data can be easily generated from the dashboard, showing historical sensor data between custom time periods.

Project Title: Android application to help detect early-onset Alzheimer's & Dementia

Student Name: Conall McAteer

Supervisor: Dr Pepijn Van De Ven

Programme of study: BSc Cybersecurity & IT Forensics

Abstract:

The issue of Dementia and Alzheimer's has been a mystery in Science and Computing for several decades. It is well established throughout recent years that scientists along with computer specialists have teamed up to determine the effects and how to counter the progression or at least help with cases of Dementia and Alzheimer's with the use of smartphone technology. Mentability aims to bring software that allows the user to quickly identify, and provide a score based on how well they performed through testing.

It investigates the mental/cognitive ability the user, using a range of cognitive tests, with the help of in-built sensors to provide a baseline score where the user can bring those results to a professional for an opinion based on the results. Results are given to the user, and is designed assist caregivers, patients, and the general population. The main aim of Mentability is that it can help detect deterioration and potentially slow deterioration for patients already suffering.

Mentability aims to become a tool that is used worldwide with the ability to assist and provide users with a baseline of where they stand in terms of the general population and to potentially aid in the detection of Dementia and Alzheimer's worldwide.



Android application to help detect early on-set Alzheimer's / Dementia

E&CE

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Conall McAteer

BSc. Cybersecurity and IT Forensics

Introduction

In recent years, technological advancements have allowed for a wide range of applications that can help with detection and prevention of Dementia and Alzheimer's disease. Many multinational companies, research institutions and medical professionals spend millions each year developing technology, trying to gather enough evidence to someday prevent this disease from happening.

In recent years, the most effective research has been with smartphone technology. A smartphone app allows the user to test their abilities from the comfort of their own home. This allows data to be collected by medical professionals to examine the results to ascertain whether the patient is showing symptoms of dementia.

Aim

The aims of this project are broken into two stages:

- Create a mobile app that allows users to test their cognitive ability using proven methods used to test against Dementia.
- Allow for users to view their results & data and follow up with medical professionals if required.

Method

The method for the development of this project can be broken down into several key categories; Research, Software, Testing and Results.

Research: Before commencing any development of the software, it was necessary to further my knowledge in the field of Dementia Research. The first step necessary was to find a suitable way to test cognitive skills in terms of measuring the effects of dementia and also to understand how these tests were carried out.

Software:

The use of several games to test a user's ability using proven methods of testing.

- Interface allowing users to register and login to track their data over time and permitting the information to be stored in a database.
- The user must complete a minimum of one game to store the information inside the database.

- The Software consists of the following: a) Numbers Game, b) Emotion Game and c) Jigsaw Game. While active, an accelerometer will measure sensor data on the phone which measures tilt and shake.

- **Testing:** Throughout each game, sensor readings are taken using an accelerometer to detect for certain symptoms linked with dementia, for example tremors and hand shaking.



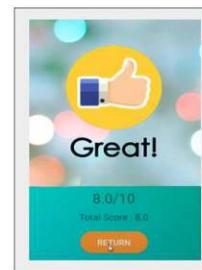
Figure 1: Sensor Data

- Results can allow for the user to take the data to a medical professional for their advice.

The architecture of the app is designed to allow quick implementation of new games. Results and use of sensors can be easily adapted / re-used to enable future improvements.

The games all individually assess what doctors use daily to test for dementia. For testing purposes the games are simplified but could be in future iterations be made more challenging.

Each game is designed so it will provide the user with a score / result based on time and accuracy. These results will then be stored in the database to be used to monitor any deterioration in the patient's condition.



Conclusion and personal reflection

It's important to note that this project has not been tested on the general population and has been developed as part of an engineering study into developing an app to help with the possible early-detection of Dementia.

The aim of the app is a platform where people can test their cognitive abilities using trialed and proven techniques that test a user for the possible early signs of Dementia. I was limited by time constraints with certain aspects of data collection and simplified them.

Going forward I would continue adding new features and planning ways to develop the project further by working with medical professionals.

Acknowledgements

I would like to thank my supervisor Dr. Pepijn van de Ven for his continuous support and guidance throughout this project and his advice when developing the application.

```
public class Game_1 extends GameActivity implements View.OnClickListener{
```

Figure 2: Architecture

Project Title:	An Anomaly-Based Intrusion Detection System using Machine Learning
Student Name:	Pádraig McCarthy
Supervisor:	Dr Thomas Newe
Programme of study:	BSc Cyber Security & IT Forensics
Abstract:	<p>As our reliance on computer networks and the internet grows each year and the number of new and well-known cyber security attacks are multiplying, the need for a comprehensive defence infrastructure is becoming more and more necessary for companies across all industries.</p> <p>An Anomaly-Based Network Intrusion Detection System (NIDS) uses Machine Learning (ML) to passively detect malicious behaviour on a computer network. The advantage of an anomaly-based system is the possible ability to recognize zero-day, or never before seen, attacks as opposed to a signature-based system which compares network traffic with a bank of known cyber security attacks.</p> <p>The aim of this project is to train an ML model for use as an Anomaly-Based NIDS and to develop software, called the IDS Agent, that will capture traffic and analyse it using this model. The IDS Agent, on an Ubuntu Linux system, is to be deployed</p> <p>The model will be trained using a dataset that contains some well-known attacks and tested with various types of network traffic to see if zero-day attacks can be identified. The IDS agent is to be stress tested with various volumes of network traffic to gauge if it is suitable for enterprise level networks.</p>



An Anomaly-Based Network Intrusion Detection System

E&CE

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Pádraig McCarthy

BSc. Cyber Security & IT Forensics

Introduction

With the number of cyber attacks increasing year on year, it is important for organizations to be sure that no intruders have gained unauthorized access to their networks. Networks are protected using firewalls, anti-virus software and through different authentication methods but countless cyber attacks still occur across many different industries.

An Network Intrusion Detection System (NIDS) aims to detect if a cyber attack is taking place on a given network by analysing incoming network traffic. A signature-based IDS has a bank of previously seen cyber attack signatures which it compares traffic to. An anomaly-based IDS uses artificial intelligence to learn the patterns of malicious network activity in order to make predictions on incoming and outgoing traffic.

Aim

The aims of this project can be clearly broken into two stages:

- Train a Deep Learning model to classify inward network traffic as malicious or non-malicious using a suitable dataset.
- Create agent software to capture and classify network traffic using the Deep Learning model.

Method

Deep Learning Model Training

- Selected a suitable training dataset, in this case CIC-CSE-IDS2018 as it is the newest set available.
- Aggregated the datasets .csv files into one master file to simplify training process.
- Split the master .csv into training and testing datasets (80:20 split). Performed dataset pre-processing to prepare for dataset training.
- Used a subset of the training set to perform an exhaustive search for the optimal model parameters such as neural network architecture, regularization term and learning rate.
- Trained the model using the full dataset and optimal model parameters found in the previous step.

IDS Agent Software

- Developed software in Python for use on an Ubuntu Linux system. The software captures network traffic, performs pre-processing and uses the ML model to for classification.

Method (cont.)

- For traffic capture, the Dumpcap command line tool is run on the system and outputs .pcap files of a set size to an output directory.
- The Dumpcap command line output is monitored for .pcap file names which are then fed into the CICFlowmeter tool for conversion into a .csv file of the same format as the training dataset.
- The .csv files are loaded into memory and given to the Deep Learning model for classification.
- If network traffic is found to be malicious, the .pcap and .csv files are moved to a malicious traffic directory and an alert is raised. If the traffic is predicted as clean, the files are removed from the system.

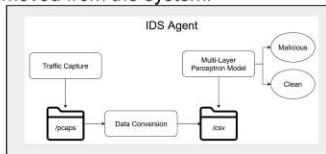


Fig 1. IDS Agent Architecture

Results

Performance of this project can be split into three parts: model accuracy, model speed, and IDS agent speed.

Model Parameter Testing

After performing an exhaustive search over a range of different values, I found that the Adam optimization function and the ReLU activation function perform the best with a learning rate of 0.0001 and a regularization term of 0.0001.

Model Accuracy

The model ultimately has two outputs: malicious (positive) or clean (negative). Both of these classifications can be correct (True) or incorrect (False). This gives rise to four possible outcomes, summarized below:

		Actual	
		Positive	Negative
Predicted	Positive	True Positive	False Positive
	Negative	False Negative	True Negative

Fig 2. ML Model Outcomes
<http://blog.giantOak.com/ml-glossary-resolution/>

Using these outcomes, we can calculate metrics such as:

$$\text{False Alarm Rate} = \text{False Positive} / \text{False Negative}$$

$$\text{True Positive Rate} = \text{True Positive} / \text{Positive}$$

$$\text{True Negative Rate} = \text{True Negative} / \text{Negative}$$

Results (cont.)

These metrics are shown in the table below for various different Neural Network architectures:

Network Architecture	TPR	FPR	TNR	FNR
(80, 20, 20, 15)	82.12	0.002	99.32	0.19
(80, 40, 40, 15)	80.15	0.003	99.66	0.18
(80, 60, 40, 20, 15)	79.41	0.003	99.24	0.23

Fig 3. Model Metrics

Model Speed

The time taken for the ML model to classify pre-processed network traffic (in the .csv file format) can vary with size, but typically take milliseconds for files megabytes in size.

IDS Agent Speed

The IDS Agent uses the filesystem to store traffic in its two stages: raw data and processes data. Due to this, some time is wasted when reading and writing files on the system. To combat this, concurrency is used to process and classify multiple .pcap files simultaneously.

Conclusion and Personal Reflection

The Deep Learning model that was trained showed positive testing results and the IDS agent software successfully captures and classifies network traffic.

The agent was stress tested with a high volume of network traffic, identifying a bottleneck of using a file based system. In the future, I would develop custom software to convert and classify network traffic in memory to avoid the overhead of reading and writing to and from files.

I would also develop a web application to view alerts and report False Positive and Negative classifications.

Acknowledgements

I would like to thank my supervisor Dr. Thomas Newe for his continuous support and guidance.

I would also like to thank Dr. Ciarán Eising for his advice regarding Deep Learning.



**UNIVERSITY OF
LIMERICK**
OLSCOIL LUIMNIGH

Project Title: A study into predicting sleep stages using machine learning and raw data from wearable devices.

Student Name: Jessica O'Flynn

Supervisor: Dr Colin Flanagan

Programme of study: BSc Cyber Security & IT Forensics

Abstract: Our sleep habits are linked to our mental and physical health. Sleep deprivation has been scientifically proven to contribute to a variety of health concerns, including obesity, epilepsy, depression, and suicidal thoughts. Sleep scoring and predicting is a critical diagnostic technique in psychiatry and neurology. While laboratory polysomnography is still considered the "gold standard" in tracking sleep, consumer, wearable, multisensory devices that can track, predict, and estimate sleep stages have the potential to assist and improve the results in clinical trials and studies to help detect the early indicators of sleep disorders. However, machine learning algorithms used to track and predict sleep stages in the majority of available consumer wrist actigraphy devices are not open source, meaning their raw sensor data is not often accessible for any external use. As a result, the clinical and scientific utility of these devices is restricted.
The objective of this study is to evaluate the prediction of a subject's sleep stage based on their Apple Watch data and their previous sleep stages using different machine learning models.



A study into predicting sleep stages using machine learning and raw data from wearable devices.

E&CE

Department of
Electronic and
Computer Engineering

Jessica O'Flynn

Cyber Security and IT Forensics

Introduction

Our sleep habits are linked to our mental and physical health. Sleep deprivation has been scientifically proven to contribute to a variety of health concerns, including obesity, epilepsy, depression, and suicidal thoughts. Sleep scoring and predicting is a critical diagnostic technique in psychiatry and neurology. While laboratory polysomnography is still considered to be the 'gold standard' in tracking sleep, consumer, wearable, multi-sensor devices that can track, predict, and estimate sleep stages accurately have the potential to assist and improve the results in clinical trials and studies to help detect the early indicators of sleep disorders.

Aim

The aim of this project is to research various types of machine learning (ML) algorithms used for sleep stage classification and prediction that can be used in wearable consumer devices and gain understanding of these to:

- Evaluate their prediction of a sleep subjects stage based on their data and previous sleep stages.
- Test the different ML algorithms and models for prediction to gather understanding of their accuracy.

Method

The main aspects of this project included the use of Apple Watch data and polysomnography data supplied by:

<https://physionet.org/content/sleep-accel/1.0.0/>

As well as the use of Googles 'Colaboratory Notebooks'.

The following Machine Learning algorithms for predicting sleep stages were tested with physionets.org's data:

Prediction algorithms

- Baseline Model used for comparison
- SVC Linear Model
- Multilayer Perceptron
- Convolution Neural Network
- Recurrent Neural Network

Implementation

Once the data files were downloaded, it is possible to add them to a google drive account and access/call them from googlecolab to be implemented in code.

I had originally planned to use PyTorch and a Ubuntu but this unfortunately did not work out as expected, and I had to change my approach to use Google Colaboratory instead.

Sleep Stages

Sleep is divided into two types: NREM (Non-Rapid-Eye-Movement) sleep, which has four stages (S1, S2, S3, S4), and rapid eye movement (REM) sleep.

Results

Figure 1. shows the testing of various prediction models revealed that the Recurrent Neural Network – Long Term Short Term Model (LSTM) is a slightly better prediction model than the others, with a validation accuracy score of 60% for its multi-step predictions. As seen below Figure 1 indicates that the accuracy of models on the validation set improved as more complicated models and algorithms were implemented, the accuracy reached for the test data was remarkably similar across all models.

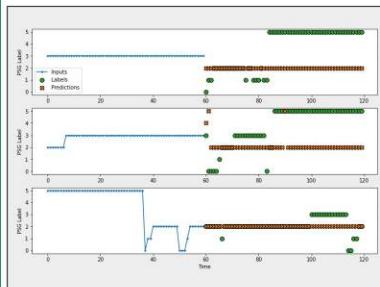


Figure 1. Recurrent Neural Network – Long Term Short Term Model (LSTM) plot showing the predictions and accuracy result for future PSG Labels (Sleep stages) 0-5 being 0 =wake, 1-4 = NREM Stages 1-4 & 5 = Rem.

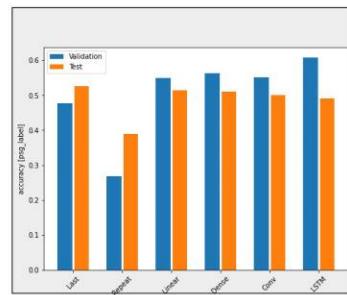


Figure 2. Bar chart – visualisation of the performance of the different models on the validation and test sets.

Conclusion and Personal Reflection

This project focused on the research and development of machine learning approaches in wearable devices to assist with clinical sleep stage predictions, potentially achieving a more efficient and accurate sleep stage for the diagnosis of sleep problems and disorders. When using the Apple Watch data, I found that using recurrent neural networks LSTM was the best way to predict what stage of sleep a person would be in next.

I tried remote PyTorch and Ubuntu. I found it hard and difficult to use because I had to be in a certain room at the institution and couldn't work from home. I subsequently discovered that I could get the same outcome using Google Colaboratory, which offered free access to high-end computation and GPU.

The acquisition of open source raw data was also stressful because most raw sensor data is not generally accessible for external usage, making it difficult to discover sources, but I learnt to be resilient and keep focused on my goals. Simultaneously, I learned when to alter tactics in the field, especially when one way failed. In hindsight, I should have changed my approach much sooner to save time.

Unfortunately, I was not able to fully develop a computer to predict future sleep stages to my satisfaction because the data presented was mostly from healthy people with no sleep disorders or issues. I would have liked to investigate the sleep stage prediction in further detail and included data from other studies to get a better understanding of its accuracy.

Acknowledgements

I would like to thank my supervisor Colin Flanagan, for the guidance and support through out this project. I would like to acknowledge, and thank physionet.org and Olivia Walch in her support for providing the Apple Watch raw source data for this project.



UNIVERSITY OF
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Project Title:	Personal IoT based Air Quality Monitoring system using Cisco Packet Tracer
Student Name:	Bernadette Twomey
Supervisor:	Dr Sean McGrath
Programme of study:	BSc Cyber Security & IT Forensics
Abstract:	<p>Technology has become a vital part of everyday life; the world is becoming more connected by the day and there is a need for a safe home system that focuses on the monitoring of indoor air quality. It is evident from many studies that the concentration levels of indoor air pollutants are one of the world's biggest health risks. It is known that air pollution does not affect everyone in the same way; children and the elderly for example are more susceptible than others. With all these factors in mind, this project will develop a monitoring system that would be an aid for a person's carer as they would be able to track the air quality levels when the children or elderly are unable to recognize the signs of harmful gases themselves.</p> <p>This report begins with an overview of the meaning of the term Internet of Things and an introduction into what the Cisco Packet Tracer tool is and all its benefits. It then features a comparative lab that's based on various networking scenarios and then discusses how they all contributed to the final design of a smart safe home. The main aim of this report is to deliver a solution to all this that allow users to control their environment from their device remotely.</p>

Key Words – IoT technology, Cisco Packet Tracer, Home gateway, IoT monitoring



Personal IoT based Air Quality Monitoring system using Cisco Packet Tracer

E&CE**Department of
Electronic and
Computer Engineering**

Bernadette Twomey

LM083 Cyber Security & IT Forensics

Introduction

This poster describes my project which aims to develop a personal IoT based Air Quality system using Cisco Packet Tracer. Technology has become a vital part of everyday life; the world is becoming more connected by the day and there is a need for a safe home system that focuses on the monitoring of indoor air quality.

It is evident from many studies that the concentration levels of indoor air pollutants are one of the world's biggest health risks. It is known that air pollution does not affect everyone in the same way; children and the elderly for example are more susceptible than others.

This project will help to develop my networking skills by researching and creating various IoT Cisco Packet Tracer labs that would contribute to a final IoT smart home. These labs include:

- IoT Home Automation
- IoT Environment
- IoT Motion Detection
- IoT Cloud

Aim

To develop a user-friendly personal monitoring system that would be an aid for a person's carer as they would be able to track the toxic air quality levels when the children or elderly are unable to recognize the signs of harmful gases themselves.

IoT Packet Tracer labs

1. Home Automation

This lab was created to develop the basic skills to refresh my memory on how Packet Tracer works. It operated through a Home Gateway to control the operation of a ceiling fan and window through a connected smartphone.

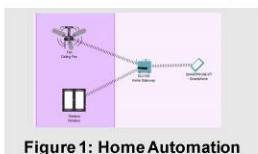


Figure 1: Home Automation

2. Environment

This lab used the basis of Lab 1 Home Automation and added a Carbon Monoxide Air Quality sensor. A condition was added to turn sprinklers and alarm on when high toxins are found on the Carbon monoxide alarm from the old car fumes.

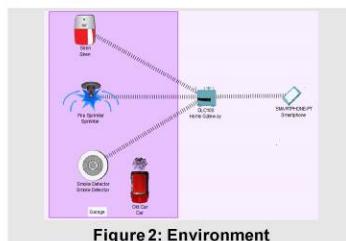


Figure 2: Environment

3. Motion Detection

This lab incorporated a switch and microcontroller (MCU-PT). Once the motion sensor was triggered it alerted the home gateway and turned the webcam on and turned the siren on.

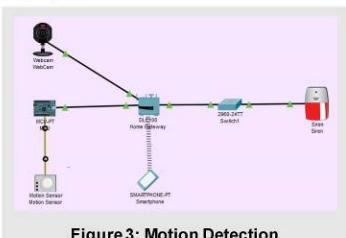


Figure 3: Motion Detection

4. Cloud

The final lab was the most crucial in the development in the smart home system. It contained components such as a Cell Tower, a router, 3 Servers (Central Office Server, IOE & DNS), a switch to link servers and routers, Cloud component, Cable Modem and a home gateway to connect end devices.

It began by connecting all the cloud components, then configuring the routers and finally configuring the end devices. Access was then made between the home gateway devices and the remote location smart phone which will enable remote users to view the status of the connected component.

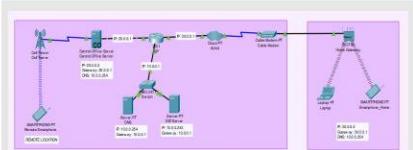


Figure 4: Cloud

Results

After studying all the Packet Tracer labs, everything could be compiled into one personal air quality monitoring system. See Figure 5. The final design contained aspects from each lab and added elements such as a Carbon Dioxide monitor, Smoke Detector and a Temperature Monitor.

It enables the user to login to the IOE Server from a remote location connected to a cell tower. There has also been conditions incorporated to the end device configurations that triggers the window and door to open, the alarm to go off and the siren to also alert when the carbon monoxide monitor reads above a specified level.

Conclusion and personal reflection

In Conclusion, a user-friendly smart home was designed using Cisco Packet Tracer. It will prove as a great aid for carers of vulnerable people as they will remotely monitors the air quality levels which can in turn prevent carbon monoxide poisoning, and various other illnesses that come with bad air quality.

Through the creation of this system, it gave me the opportunity to increase my knowledge in networking and Packet Tracer.

If the project was to be undertaken again, I would include a security element as anyone can login with their credentials and monitor the home which is a huge security flaw.

Acknowledgements

I would like to thank and acknowledge my supervisor Sean McGrath for his guidance and support throughout this entire project.

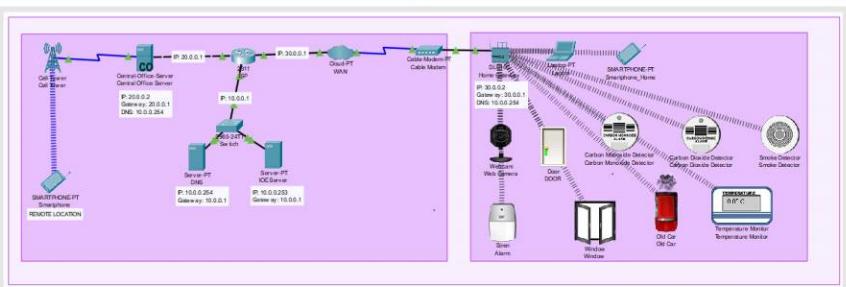


Figure 5: Personal IoT based Air Quality Monitoring system using Cisco Packet Tracer

**UNIVERSITY OF
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OLSCOIL LUIMNIGH**

Project Title: Online Auction Management System

Student Name: Miracle Ugwu

Supervisor: Prof Hussain Mahdi

Programme of study: BSc Cyber Security & IT Forensics

Abstract: The rise of the Internet has transformed the way auctions are held, allowing users to purchase and sell from the comfort of their own homes. The primary goal of this project has been to create a safe online auction management system for students at the University of Limerick. This report provides a description of the process taken to develop an online auction management system. It goes over the system's design, development, and testing, as well as existing online auction systems. This systems development entails the creation of a web interface, via which a user may register and sign up as a buyer or seller in order to bid or post a listing. Information provided by the users are stored on a database, which are then displayed on the web interface. The web interface of this system, which allows users to interact with content hosted on an Apache HTTP web server, was created using HTML, JavaScript, and CSS on the front-end, and uses PHP and MySQLi on the back end.



Online Auction Management System

E&CE

**Department of
Electronic and
Computer Engineering**

Student Name: Miracle Ugwu

Programme of study: Cyber Security and IT Forensics

Introduction

This poster outlines a project to create an online auction management system, which is a web-based application that makes the process of purchasing and selling products easier by putting items up for sale, accepting bids, and then selling the item to the highest bidder.

This project employs a user-friendly web interface that the students would find simple to browse, as well as a database to store the data provided by the users.

Aim

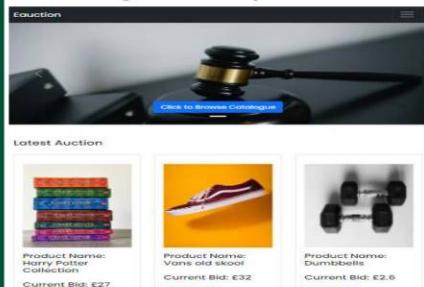
The aim of this project has been to design and develop an online auction system for the University of Limerick students that allows sellers to meet and engage with customers while also selling products to willing bidders. One of the main objectives of this project is to create a secure system that can detect fraudulent users early on and reduce the risk of online fraud.

Main Components of the System

This project's key components and features are listed below.

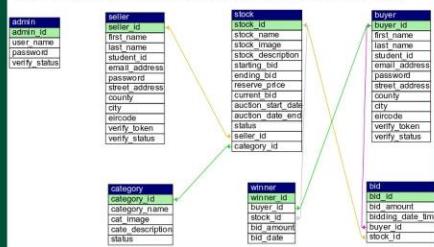


Index Page of the System

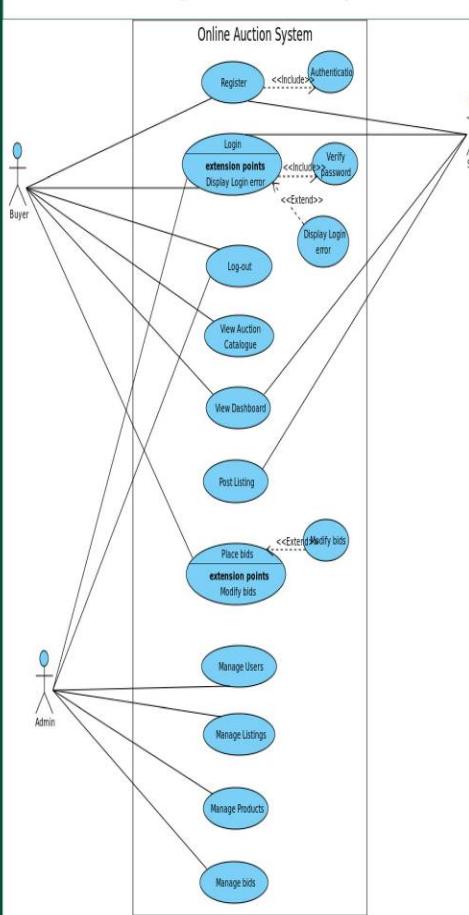


Database Structure

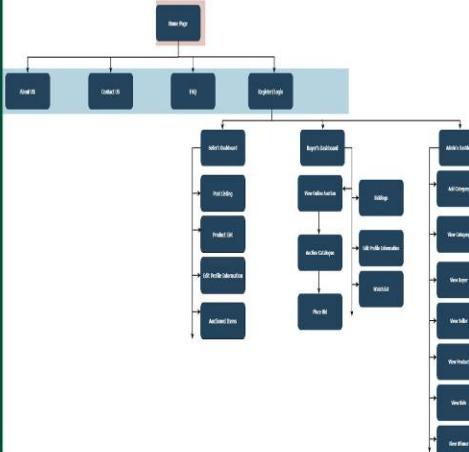
The auction database consists of seven tables that contains customer data as shown below.



Use Case Diagram of the System



System's Architecture



Security Implemented

- User Authentication: An email will be sent to the user's account after registration to activate it before it can be used.
- Hashed Passwords.

Implementation of the system

This project's web interface, via which users interact with content hosted on an Apache HTTP web server, was created using PHP, HTML, JavaScript, and CSS.

Each user should be able to register as a seller or a buyer, and they will need to enter their student ID and email to demonstrate that they are currently enrolled in university.

They would receive an email with instructions on how to activate their account. The user's registration information would be saved in the database and used when the user logs in into the system.

The buyer would be able to see the items up for auction, place bids on them, and change their offers until the auction ends.

The seller would be able to post listings based on the product's categories, and they would be able to see the bids placed on their items.

Conclusion and Reflection

In conclusion, a user-friendly web interface was developed to make the process of purchasing and selling auctioned things simple, easy, and pleasurable.

This project helped me enhance my web programming skills while also allowing me to put what I'd learned over the years to use.

Acknowledgements

I would like to express my gratitude to Prof. Hussain Mahdi for his unwavering support and advice during the duration of my project.

Project Title: DC Motor Speed Control Using Android Mobile App

Student Name: Ashutosh Yadav

Supervisor: Prof Hussain Mahdi

Programme of study: BSc Cyber Security & IT Forensics

Abstract: This project will be a proof of concept demonstration of using Bluetooth communication to control a DC motor without the need of long cables that would feed the data back in real-time to the controller and then forward it to the Android application. Giving the user control over the motor control system from the palm of their hand as well as additional safety measures such as fall detection & timed operation.



DC Motor Speed Control Using Android Mobile App

E&CE

**Department of
Electronic and
Computer Engineering**

Ashutosh Yadav

BSc. Cybersecurity & IT Forensics

Introduction

This project will demonstrate the reduced complexity of having physical controls for a DC motor and has a wide variety of applications where appliances would make use of DC motors and showcase the ease of use of being able to control them through a handheld Android device.

Aim

- Implement a Bluetooth connection and control of a DC motor and measure its revolutions per minute (RPM).
- Develop an Android application that would control the operation of the DC motor and provide feedback to the user of its speed & direction.

Method

- Researched existing systems and control methods.
- Initial circuit layout.
- Initial application design layout and use cases.
- Focused on real-time data feedback for RPM from the DC motor.
- Re-visited initial circuit layout and design to incorporate an IR Proximity sensor to measure RPM.
- Implemented core use cases.
- Final GUI Design & Development.
- Application testing and results.

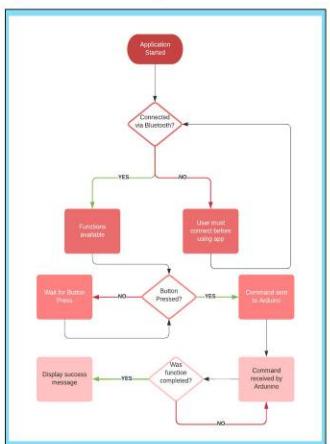


Fig 1. User Process Flow Chart

Method (cont.)

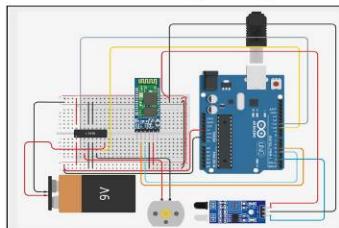
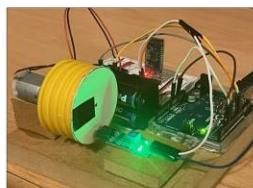


Fig 2. Circuit Design

Two-way communication allows the Arduino to send sensor readings to the app as well as receive commands.



Final circuit included an IR Proximity Sensor to measure RPM and sent them to the app over Bluetooth.

Fig 3. Final Circuit

Results

Direction

The user is able to set direction in either forward or reverse.

Speed

The speed is controlled by 2 sliders up to the motors maximum RPM which in the case of this motor was 3000. The user also has 7 pre-set speeds to choose from in increments of 500 RPM.

Accuracy

The RPM reported was within a 3% margin of error which was verified externally using a tachometer.

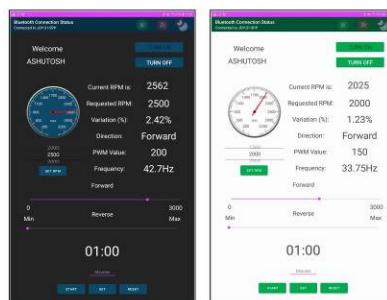


Fig 3. Dark Mode

Fig 4. Light Mode

Timed Operation

The motor could be set to run for a certain time using a built-in timer. Once the time is up a sound is played to notify the user and the turn off command is sent to the circuit.

Fall Detection

Using the built-in accelerometer on the Android device, the application is able to detect a fall and automatically send a command to shut off the DC motor as a safety precaution.

Dark Mode

The user can toggle between light and dark mode depending on their preference.

Motor Speed Calculation

The DC motor speed is calculated in real-time using the following formula:

$$\frac{\text{revolutions}(in \text{ miliseconds})}{\text{time}} \times 60000$$

Fig 5. RPM Calculation

Conclusion

The project overall was successful in demonstrating the controls possible to a user without requiring physical cables to be connected between the circuit and application.

The application also allows for timed operation set by the user, similar to how it would work in industrial settings where large motors would run for a certain amount of time.

Going forward I would continue to add features like add additional hardware support for light & servo controls to further expand the use cases of the application.

Acknowledgements

I would like to thank my supervisor, Professor Hussain Mahdi for his supervision and assistance on this project as well as Paudie Walsh, John Kelly, Ciaran Macnamee, John Clifford, Jim O'Sullivan, Fran McCarthy, Jack McEllin & Sean McGrath for their help and co-operation.

E&CE Dept. Final Year Project – Abstract & Posters

Project titles are listed by student – Surname/Alpha Order (Please peruse through linked titles in the table below, each will land to the Abstract and Poster of that student in the ME Electronic & Computer Engineering discipline)

<i>Surname</i>	<i>Forename</i>	<i>Supervisor</i>	<i>Project Title</i>
DOOLEY	DOMHNAILL	Dr O'Connell Eoin	Feasibility Study in Relation to Adding a Secure External Communications System to a BD Infusion Pump
FITZGIBBON	EOIN	Dr Mullane Brendan	Transponder ASIC for Isolated Communications Link
HICKEY	CIARÁN	Dr Van De Ven Pepijn	The Application of an Explanatory Graph on a Medical Image Classifier Convolutional Neural Network
HOULIHAN	JOHN	Dr Rinne Karl	Implementation of magnetic field stimulus for xMR wafer manual probing
JAKAB	DANIEL	Dr Rinne Karl	Video-streaming Edge Detection with SoC Accelerators
KEOGH	EDMOND	Dr Flanagan Colin	SRRcGAN: Super Resolution Radar conditional Generate Adversarial Network
MANNIX	KEALAN	Dr Newe Thomas	Using Cyber Security Principles for the Development of a Trust Management Paradigm to Ensure Trust Within a Human in the Loop Sensing and Analysis System
MCGRATH	EOGHAN	Dr Dooly Gerard	Mobile Mapping System using LiDAR and IMU Data for 3D Reconstruction
MOCKUS	MATAS	Dr Trslic Petar	Automated Winch for Remotely Operated Vehicle Management
MURRAY	CIARAN	Dr Rinne Karl	ADC monitoring of Camera power supply
O'BRIEN	AARON	Dr Rinne Karl	A coplanar capacitive sensing approach used to develop a low-cost PCB for non-intrusive liquid point and level detection
O'SHEA	DAVID	Prof Fitzpatrick Colin	Implementation of an XRF sensor to identify BFRs in the automated recycling of flat panel displays
PRZYCHODNI	DOMINIK	Dr Mullane Brendan	Using EEG data to classify the level of consciousness on patients under general anesthesia targeting a machine-learning platform

Project Title: Feasibility Study in Relation to Adding a Secure External Communications System to a BD Infusion Pump

Student Name: Domhnall Dooley

Supervisor: Dr Eoin O'Connell

Programme of study: ME in Electronic and Computer Engineering

Abstract: The development of technologies such as IoT and health 4.0 will have an untold impact on the quality of patient care in the future. This will be achieved by analysing big data and administrating personalized healthcare through IoT friendly devices.

This project will be developed in partnership with BD RCI. BD is a multinational medical technologies company, their focus is on advancing health care by medical discovery, diagnostics, and delivery of care. One of the core product lines developed in their Limerick hub is Infusion pumps. An infusion pump is a medical device which is used to administer necessary fluids and medicines into a patient's body in controlled amounts over a set length of time.

This project will focus on the possibility of adding connectivity to a BD infusion pump utilising the RS-232 outlet already supported by the Bodyguard infusion pump line. This project will detail the projected possibilities of adding a secure external communications system to the pump. Detailing all relevant hardware requirements for frontend processing and exploring the backend possibilities of Wi-Fi or cellular. The goals of the project are to gain a deep understanding of the topic, raise awareness of any potential problems and to determine if this project is viable and a worthwhile project for BD to pursue further.



Pump. Feasibility Study in Relation to Adding a Secure External Communications System to a BD Infusion

E&CE

**Department of
Electronic and
Computer Engineering**

Student Name: Domhnall Dooley

Programme of study: LM806

Introduction

Healthcare is an essential part of any functional society. It is essential for promoting and maintaining the health of the public. Treating people after they have had accidents, providing comfort for those with disabilities and as we have all been made aware of recently the prevention and management of pandemics are just a few reasons why healthcare is so important to a functional society. As modern life has progressed due to improvements in technology the quality of healthcare delivered has also changed drastically.

This project aims to implement a communications systems that will improve the alarm system of a BD BodyGuard Infusion pump with an accompanying mobile application that will receive notifications containing updates on the infusion and all relevant information to contact the user in case of an emergency.

Aim

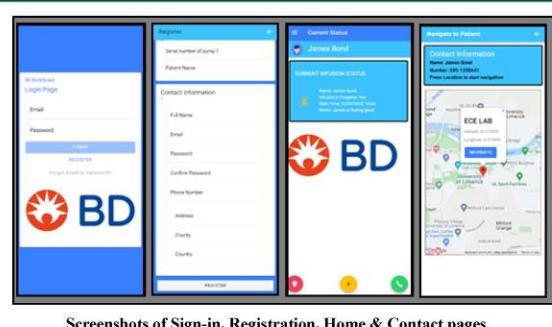
The aim of this project is to tackle an existing problem that occurs when infusion pumps are used in a homecare environment. Patients don't always have the relevant staff present to handle any issues that may occur during an infusion. Currently if an issue such as, a blockage occurs a alarm will sound constantly until the issue is resolved. This results in patients sometimes becoming agitated and stressed in an already less than ideal situation as they wait for help to arrive

The aim of this project is to notify friends and family of the issue so that they can assist the patient by contacting them either over the phone or physically

Method

Application

- For the final design I started first by designing the backend application that would handle the notifications
- The app is fully functional with the following features:
 - Sign in page
 - Registration page
 - Home dashboard
 - Contact user with mobile communication and google maps API functionality
 - Forgot username/password functionality



Firebase Database

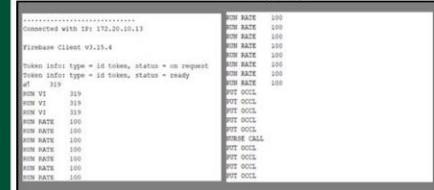


Firebase Database Console

- Once the Application was finished, I then integrated it in a Firebase Database.
- The Firebase Database handles all authentication functions in the app.
- All new users are registered to the database automatically when a new user signs-up
- When the log-in function is called, the email and password is verified by the Firebase database before access is granted
- The database also handles all notifications from the Pump

ESP-32

- The esp-32 reads in serial data from the Infusion Pump.
- This serial data contains details regarding the flow rate of the pump
- From this data we can detect an if an error has occurred
- When an error occurs it contacts the firebase which then in turn sends an appropriate



Screenshot showing output to serial monitor on ESP-32

- Firstly, You can see that ESP-32 searches for a saves network before printing to the serial monitor when a connection has been made successfully
- Then once a connection is made it makes contact with the Firebase Database
- Then it starts reading the data looking for issues like a blockage which can be seen on the right side of the screenshot
- Once this happens it switches state and sends a notification from the database to all appropriate users.

Results

Android

- Here to the right is an example of a notification coming through on an android device
- This animation was created using an android emulator and loading the app files onto it and educating an error at the pump



Android Emulator

iOS

- Here to the left hand side is an example of an IOS push notification
- This animation was created by using an IOS emulator and educating an error at the pump



iOS Emulator

Conclusion and personal reflection

- The project has been completed successfully, with a fully functioning notification system which reacts to issues that occur during infusions and notifies relevant friends and family.
- The final design achieves everything which was laid out in the aims section of the poster
- The project itself was very enjoyable, it was a great learning experience throughout and I gained knowledge on ESP-32 development, backend application design, Database integration as well as personal gains such as planning, patience and persistence

Acknowledgements

I would like to thank the people listed below for their help and cooperation

Eoin O'Connell

Aaron O'Brien

Kevin O'Brien

David O'Shea

James Keane



UNIVERSITY OF
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OLLSCOIL LUIMNIGH

Project Title: Transponder ASIC for Isolated Communications Link

Student Name: Eoin Fitzgibbon

Supervisor: Dr Brendan Mullane, Dr Padraig Fogarty (BD-RCI)

Programme of study: ME in Electronic and Computer Engineering

Abstract: When embedded communication interfaces (e.g., SPI, I2C, 1-wire) are used with detachable devices one of the most unreliable parts is the electromechanical contact interface. This unreliability can result from weakening of the contact spring mechanism, contacts wear, and or ingress of contaminants. All mechanical parts wear and repeated connection and disconnection can greatly accelerate this failure mode.

In many applications, there is a need to transfer both power and data across the communications interface, thus increasing the number of contacts required and therefore increasing the likelihood of failure. The work in this project attempts to use the inductive coupling technology seen in High Frequency RFID (Radio Frequency Identification) to communicate between both sides of these interfaces, which would be fully isolated and without any electro-mechanical contact being required. This inductive coupling technique uses an operating frequency of 13.56 MHz and also allows for the transfer of data and power in a reliable and effective manner.

The principle of operation centres on an inductively coupled interface, in which an electronic circuit and coil antenna are energised and modulated to transfer both power and data across the interface to a passively powered secondary circuit which would receive the power and data, and which could send data back across the link using load-modulation. Thus, a bidirectional interface can be created that is completely free from electromechanical contacts. This has advantages where devices are repeatedly connected and removed. In addition, the interface would be electrically isolated and impenetrable to contaminants.

The report will first examine the background of the project through research of inductors and inductive coupling. The project work is associated with research in a biomedical setting as this is the most likely application. The report will then detail high level behavioural modelling circuits followed by lower-level circuits that have been designed and tested in order to achieve this inductively coupled communications link.



Transponder ASIC for Isolated Communications Link

E&CE

**Department of
Electronic and
Computer Engineering**

Eoin Fitzgibbon

Electronic & Computer Engineering

Introduction

When embedded communication interfaces are used with detachable devices, one of the most unreliable parts is the electro-mechanical contact interface. This unreliability can result from weakening of the contact spring mechanism, contacts' wear, and or ingress of contaminants. Repeated connection and disconnection can also greatly accelerate this failure mode.

This project aims to tackle part of this problem by:

- Creating an isolated communications link, centring on an inductively coupled interface.
- Examining the background of the project through research of inductive coupling, with a focus on a biomedical setting.
- Detailing high level behavioural modelling circuits followed by lower-level circuits designed and tested in order to achieve this communications link.

Aim

The focus of this project was on the transponder ASIC. The following are the outlined objectives:

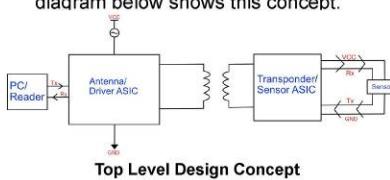
- Background research
- Top-level design concept
- Behavioural modelling
- Schematic design & testing
- Schematic layout & testing

Method

There were 5 steps involved in this project.

Background Analysis/Top-Level Concept

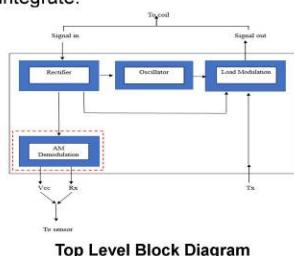
- Analysing what was required to build the ASIC to power the sensor and an oscillator, and send the data back. The diagram below shows this concept.



Top Level Design Concept

Behavioural Modelling

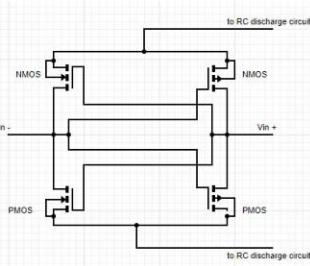
- Creating a concept ASIC seen below.
- Modelling each block of the ASIC.
- Testing each model and testing how they integrate.



Top Level Block Diagram

Schematic Design & Testing

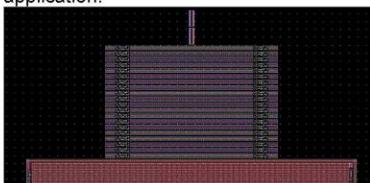
- Modelled circuits converted to lower-level components suitable for ASIC development (MOSFET's, CPOLY & RPOLY devices).
- The circuit below shows a full wave bridge rectifier designed with PMOS and NMOS devices.



Full-wave Bridge Rectifier Circuit

Layout

- Lower-level circuit devices are placed in suitable configuration.
- Layout allows the circuit to be tested as it would be, giving an accurate representation of device sizes relative to real-world application.



NMOS device layout for AM Modulation

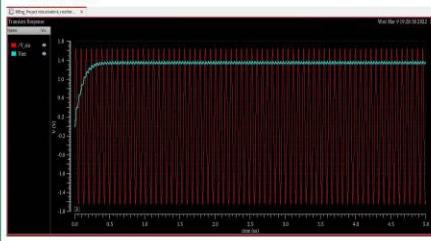
Block Integration

- Combining the 3 separate blocks (Rectifier, Oscillator & Modulator).
- Observing the resulting output.

Results

Rectifier

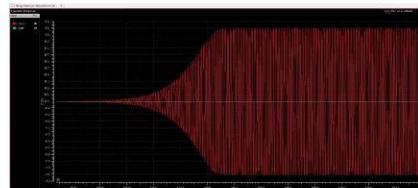
- A full bridge rectifier circuit was achieved.
- A combination of NMOS and PMOS devices were used to complete this full-wave bridge rectifier.



Rectification Results – MOSFET Bridge Rectifier

Oscillator

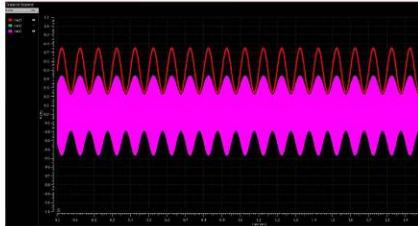
- A Colpitts Oscillator was designed to generate a clean sine wave.
- This sine wave is to be used as a carrier wave for the modulation process.



Oscillator results

Modulator

- An AM modulator was designed to transfer the data from the sensor.
- The modulator accepts analog sensor data and modulates it to the carrier signal generated in the oscillator



Modulator Circuit Diagram & Results

Conclusion and personal reflection

- Background research, ASIC concepts & high level modelling all completed successfully.
- Some elements of lower-level circuit design and layout completed successfully.
- The work completed in this project can be reviewed and reflected upon in order to design the most effective Transponder ASIC for the application.
- This project has developed my technical skills in Analog ASIC development.
- It has also shown me how vast the sector is and that I need to improve my organisation skills and ability to break large projects down into smaller parts.

Acknowledgements

Brendan Mullane – for supervising and assisting me in completing the project.

Padraig Fogarty (BD-RCI) – for conceptualising the project and outlining what needed to be completed.



**UNIVERSITY OF
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OLSCOIL LUIMNIGH

Project Title:	The Application of an Explanatory Graph on a Medical Image Classifier Convolutional Neural Network
Student Name:	Ciarán Hickey
Supervisor:	Dr Pepijn Van de Ven
Programme of study:	ME in Electronic and Computer Engineering
Abstract:	<p>My proposal is to utilise an explanatory graph tool to map how a CNN image classifier, trained on a medical image dataset, works to classify images. This tool can isolate image segments which were used to classify an input image. The proposed dataset for this project is the RSNA Pneumonia Dataset. This dataset is a subset of the NIH Clinical Centres Chest X-Ray Dataset. This has been chosen as its smaller size is more manageable and much work on classifiers for this dataset has already been carried out during a 2018 Kaggle Competition.</p> <p>To improve understanding of this CNN classifier, I propose to focus on the image segment generation results of the explanatory graph tool. This is to determine what aspects of the chest x-rays the CNN is focusing on in order to classify an image as healthy or sick and compare to the bounding boxes provided with the dataset. Results from this study should improve understanding of the CNN image classifiers and also improve trust in these classifiers for use in medical applications. I also hope that the results will highlight the explanatory graph as an effective method of analysing neural networks.</p>



The Application of an Explanatory Graph on a Medical Image Classifier Convolutional Neural Network

E&CE

**Department of
Electronic and
Computer Engineering**

Ciarán Hickey

LM118-Electronic and Computer Eng.

Introduction

This project examines Convolutional Neural Network (CNN) Image Classifiers with the use of an Explanatory Graph Tool.

As the accuracy of CNN image classifiers improves, they become an attractive utility in various industries, including the medical imaging industry. However, in order for the classifications made by these CNNs to be trusted, their decisions need to be understood.

This project works toward this aim by examining the filters which make up the layers of these CNNs.

A Medical Image Classifier was chosen as the example application for this project. As such CNN models were trained on the RSNA Pneumonia Dataset.

Aim

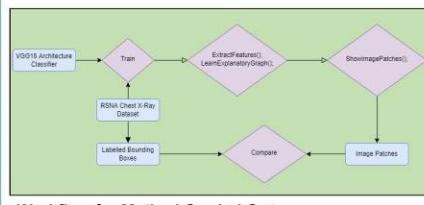
The main aim of this project is to examine the explanatory graph tool and its image patch generation as a utility to increase model interpretability.

This will be achieved by using the tool to generate image patches of the features within images that are used to classify them.

Principally, the goal of this project is to determine whether the explanatory graph tool can be used as a tool to evaluate a medical image classifier CNN by examining how it arrives at its conclusions.

Method

- Multiple CNNs were trained on the RSNA Dataset.
- These were trained using a version of the VGG16 structure provided in PyTorch, modified to suit the RSNA Pneumonia dataset.
- These models were altered by varying a number of parameters:
 - Input Image Resolution
 - Number of Epochs
 - Dataset Size
 - Dataset Composition
- These variations affect the accuracy of the model and the filters within the layers of the model.



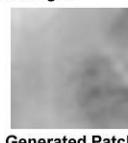
Workflow for Method Carried Out

- The explanatory graph functions were then applied to the models.



RSNA Dataset Example

- These functions learn the models features and the spatial relations between the feature activations in the convolutional layers.
- The tool can then generate image patches corresponding to high feature activations.
- These image patches were then found in the original dataset image and compared to the bounding boxes for the same image.



Generated Patch
from Above Image

Inputs: Feature Map for L-th conv-layer, inference results from L+1th conv-layer.

Outputs: L-th conv layer Node Positions
for iter = 1 to T (20):

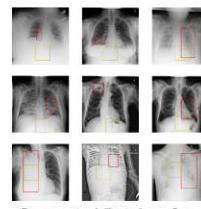
```

for Each Activation Peak from L-th Layer:
  Training images are passed to the filters
  and the average position of the Activation
  Peaks are updated using an
  Expectation-Maximization Algorithm
end
end
  
```

Brief Pseudocode of the Tools Learning
Process for One Layer

Results

- The first model, trained to act as a control, was a low accuracy model trained on a reduced dataset.
- The position of the generated patches from this model had little to no correlation with the bounding boxes on their corresponding images.
- Similarly, patches generated from the feature activations of lower layers in the higher accuracy models had minimal overlap with bounding box position.
- Patches generated from higher level layers in models with accuracies approaching and exceeding 80% on an unseen test set began to show higher correlations.



Generated Patches for
79.27% Accuracy Model

- However, the overlap of patches and bounding boxes was not as consistent as hoped.



Generated Patches for 60%
Accuracy Model

- The tool seemed to be sensitive to poorly scanned x-rays within the dataset.
- The edge between the end of the x-ray and the empty background on these poor scans seemed to cause high feature activations in many cases, particularly in lower layers.
- This, in turn caused many image patches to be generated of these edges, as seen in the example above.

Conclusion and personal reflection

While correlation between the position of generated image patches and the bounding boxes does seem to increase as model accuracy increases, this does not seem to be consistent enough to use as a metric to evaluate a model in its current state.

Patches generated by higher layers did seem to have a higher correlation, this could be put down to the fact that these filters generally look for more high level features within an image as the CNN gets closer to reaching a final classification.

If I was to undertake this project again I would look for a larger more consistent dataset of images as I believe the image quality may have affected the tool's output. I believe this project greatly increased my understanding of CNNs and their operation. My skills in coding, particularly debugging and working with large directories of code were also improved.

Acknowledgements

- Pepijn Van de Ven – Supervisor
- Quanshi Zhang and Xin Wang – Support Using Explanatory Graph Tool



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Project Title: Implementation of magnetic field stimulus for xMR wafer manual probing

Student Name: John Houlihan

Supervisor: Karl Rinne

Programme of study: ME in Electronic and Computer Engineering

Abstract: An emerging technology for ADI is xMR devices. The production rates of which is growing, and it will continue to be a high demand technology for years to come. This thesis documents the problem and solution of implementing a manual probing system for xMR wafers. This system provides unparalleled flexibility for xMR wafer measurements when compared to ATE available at ADI. The system can be used for device characterisation and verification of ATE results. The project is heavily built upon embedded Arduino and LabView software design. The LabView program provides a GUI and the software for the control of the system. The Arduino is needed for acquiring magnetic field data and sending it to the LabView program. Field alignment and calibration can be conducted when the Arduino is used in combination with the LabView program. Furthermore, the I2C protocol has been implemented in the Arduino subsystem to allow for communication with a magnetometer. The software design and development mentioned above was my personal contribution to the project. Fundamentally, the system allows for the manual probing of xMR wafers in the presence of configurable magnetic fields of any angle in the range of 10 to 70mT with a tolerance of $\pm 1\text{mT}$.



Implementation of Magnetic Field Stimulus for xMR Wafer Manual Probing

E&CE**Department of
Electronic and
Computer Engineering**

John Houlihan

ME in Electronic & Computer Engineering

Introduction

At Analog Devices (ADI), wafer-level testing is crucial to ensure functional products are sold to customers.

Manual probing of wafers play an essential role for device characterisation and for verifying ATE (automatic test equipment) results. They also provide much more flexibility when performing measurements compared to ATE methods.

An emerging technology for ADI is a group of magnetic sensors called xMR (magnetoresistive) devices. However, they require a special manual probing solution due to the fact that they need to be subjected to varying magnetic fields during measurements.

Aim

This project aims to apply a magnetic field stimulus to xMR wafers during measurements. Field angles of 0 to 360 degrees and field strengths of 10 to 70 mT must be applied to the DUT (device under test).

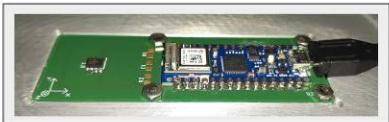
The system must also be able to provide control of measurement and power supply instruments. Data presentation and results logging is another important feature of the system.

Method

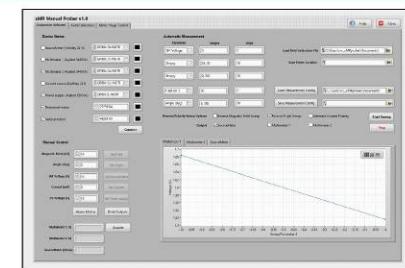
The required magnetic field is achieved by varying the position and orientation of a permanent magnet beneath the wafer. The angle is varied with a rotational stage and the field strength is varied using a vertical translation stage. The project is heavily built upon embedded Arduino and LabView software design.

The LabView program provides a GUI and the software for the main control of the system. The LabView program implements the power supply and measurement control. It also controls the rotational and vertical stages. The GUI displays measurement data, plots, and user input.

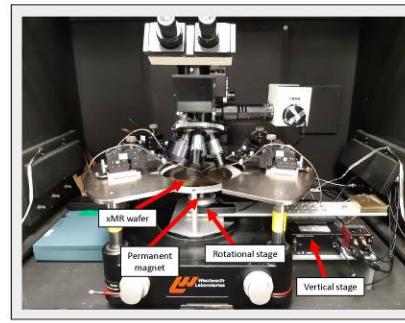
An Arduino subsystem is used to conduct magnetic field alignment and calibration and it consists of an Arduino Nano microcontroller and a Hall effect magnetometer. The two devices communicate via the I2C protocol and the Arduino acts on instruction from the LabView program.



Arduino subsystem



LabView program (user interface)



Fully assembled xMR wafer manual probing system

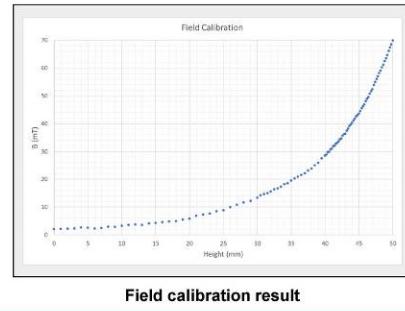
Results

- The field strength measurements taken with the Arduino subsystem (blue trace) were verified against a Gaussmeter's readings (orange trace).

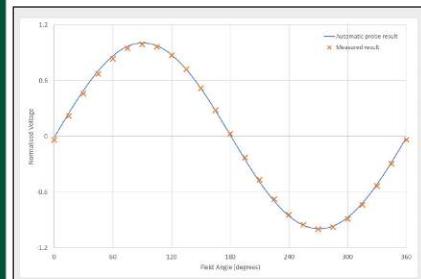


Magnetometer vs Gaussmeter measurements

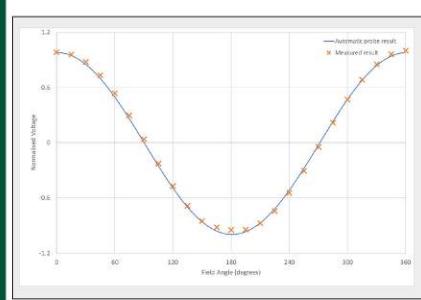
- A calibration step involves taking the vertical stage through its full range (0 to 50mm) while measuring the field strength.



- The angular responses of a TMR angle sensor were measured using the system (orange marks) and compared against ATE methods (blue trace).



TMR sensor angular response (sine output)



TMR sensor angular response (cosine output)

Conclusion and personal reflection

Ultimately, the system performs as was desired and it can now be used for characterisation on xMR angular sensors and for measuring test structures. It was shown that the Arduino subsystem measures the field strength correctly and that reliable xMR measurements can be taken using this system.

There was a higher level of responsibility and technical skill developed throughout this project due to the independent software development involved. Furthermore, the creativity attribute was developed through the user interface design.

Acknowledgements

I would like to provide acknowledgements to ADI and my colleagues at ADI for funding the project and for providing support and guidance throughout this gratifying experience.

**UNIVERSITY OF
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Project Title: Video Streaming Edge Detection with SoC Accelerators

Student Name: Daniel Jeno Jakab

Supervisor: Dr Karl Rinne

Programme of study: ME in Electronic and Computer Engineering

Abstract: This work contains an accelerator video streaming prototype using Register Transfer Level (RTL) Sobel Edge Detection in SystemVerilog (SV) implemented on a Digilent Zybo Z7-20 All Programmable System-on-chip (APSoC) dual-core Cortex-A9 processor. The chosen hardware uses a Pcam 5c Printed Circuit Board (PCB) with 1080p@30Hz resolution and a Dell SE2216H monitor with 1080p@60Hz resolution. The video streaming solution achieved (1) 4% reduction in Data Flip-Flops (FFs), (2) 5% reduction in Look-up Tables (LUTs), (3) 3% reduction in Block Random Access Memory (BRAM) usage and (4) avoids the use of Digital Signal Processing (DSP) blocks. These are comparable to a Vivado High Level Synthesis (HLS) design approach. RTL can be a way of improving resource utilization which is important for heavy computational algorithms in Artificial Intelligence (AI) or Machine Learning (ML) applications such as (1) facial recognition, (2) Advanced Driver Assistance System (ADAS) systems and even (3) systems for multi-sensor problems.

System-on-chip (SoC) Accelerators have become popular to offload work from general-purpose processors with Central Processing Units (CPUs).

Sobel is a two-dimensional (2D) convolution technique which operates on grayscale pixel data to find edges in images. The Sobel algorithm is named after Irwin Sobel and Gary Feldman, colleagues at the Stanford Artificial Intelligence Laboratory (SAIL) and was first proposed in 1968.



Video Streaming Edge Detection with SoC Accelerators

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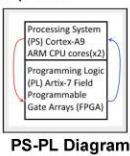
Student Name: Daniel Jakab

Electronic & Computer Engineering

Introduction

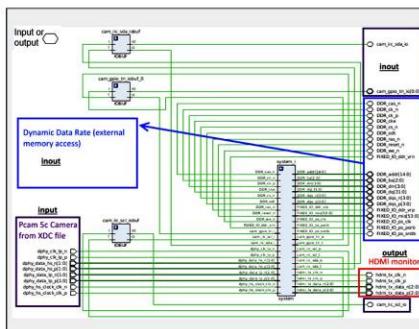
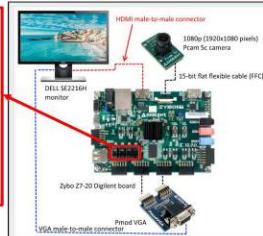
This project may contribute to the increasing need towards energy-efficient Artificial Intelligence (AI). The widely popular System-on-Chip (SoC) Accelerator technology is examined in this work which provides an economically friendly alternative compared to Graphics Processing Units (GPUs). GPUs have very high performance but, consume a lot of power.

SoC Accelerators can be used to offload computationally heavy algorithms from the processing system (PS) such as the GPU where, programming logic (PL) fabric is used instead.



PS-PL Diagram

Four switches available to turn image processing filters on/off for video-streaming.



Zybo Z7-20, Pcam 5c camera and HDMI TX
Synthesized Design

Aim

- This project aims to achieve the following:
- Experiments using Xilinx technology should contribute to a video-streaming edge detection solution. More specifically, the Digilent Zybo Z7-20 board will be used to demonstrate a video-streaming SoC Accelerator implementing the Sobel Edge Detection algorithm.
 - Implement image edge detection with an SoC Accelerator for video-streaming where, programming can be performed both in SystemC coding using Vivado High-Level Synthesis (HLS) and Register Transfer Level (RTL) programming. The SystemVerilog (SV) language which is an extension of the legacy 2005 Verilog standard is used for RTL.
 - The comparison of resource utilization of both HLS and RTL design approaches.

Method

The method(s) used for this project is a combination of embedded programming techniques using Xilinx Vivado, Vivado HLS, and Vivado SDK tools.

A general design approach was used as follows:

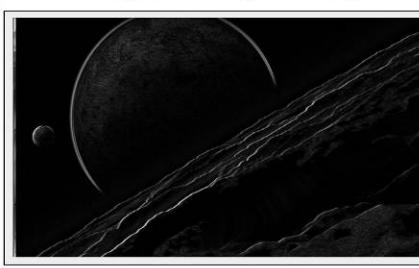
- Behavioural Simulation of the Sobel SystemVerilog (SV) design on static images.
- Implementation of a non-processor hardware Video Graphics Array (VGA) Intellectual Property (IP) block design on CMOD A7 35T and Zybo Z7-20 electronic boards in combination with the Sobel SV RTL design.
- The integration of the Sobel SV algorithm into a large scale video-streaming hardware design on Zybo Z7-20 using High-Definition Multimedia Interface (HDMI), High Definition (HD) monitor and a 'Pcam 5c' 5 MegaPixel (MP) Printed Circuit Board (PCB) camera.
- Both HLS and RTL video-streaming designs are to be compared in resource utilization statistics.

Results

Behavioural Simulation results show a HD resolution static image being processed using the Sobel SV algorithm:



Grayscale HD image (1920x1080).



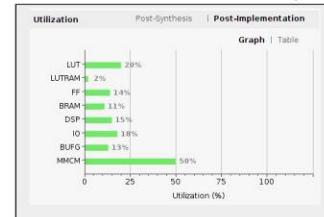
HD sobel image (1920x1080)

After programming the hardware design with the Sobel RTL algorithm, the resulting video-streaming test was performed using a 'Certified Carbon Neutral' sign:

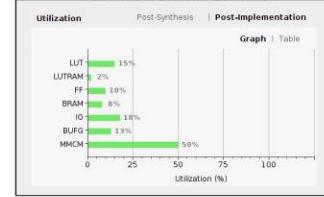


Video-streaming Sobel Hardware Program.

HLS and RTL resource utilization comparison:



HLS Benchmark design.



RTL Benchmark design.

Conclusion and personal reflection

In this work the following goals were achieved:

- A Sobel SV RTL equivalent video-streaming design on Zybo Z7-20 was developed.
- The RTL design provides a 4% reduction in Data Flip-Flops, 5% reduction in Look-up-tables (LUTs), a 3% reduction in Block RAM usage and avoids the use of Digital Signal Processing blocks to reach a similar result.
- This project has provided the student valuable experience in SystemVerilog (SV), the use of the IP Integrator in Xilinx Vivado, Vivado HLS and the experience of video processing with PS and PL logic.

Acknowledgements

I would like to thank Dr. Karl Rinne for providing advice and guidance during this large scale embedded programming project. It has been a huge learning experience.



UNIVERSITY OF
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Project Title: SRRcGAN: Super Resolution Radar conditional Generate Adversarial Network

Student Name: Edmond Keogh

Supervisor: Dr Colin Flanagan

Programme of study: ME in Electronic and Computer Engineering

Abstract: Every year, roughly 1.3 million people are killed in road traffic incidents. Selfdriving vehicles are threatening to eradicate these figures, however the engineering challenges facing the industry are stark in their complexity. Improving sensing technology is key to mitigating needless road traffic fatalities. The decisions taken by ADAS are governed by their ability to gather data from their environment. Improvements in sensing technology equate directly to lives being saved every year. The recent renaissance in artificial intelligence has opened a host of explorable avenues, who's investigation is leading to drastic advances in terms of autonomous system capabilities. Conditional generative adversarial networks are one such method of improving sensor technology. The aim of this project was to design and implement a super resolution radar conditional generative adversarial network, or SRRcGAN. This system is capable of improving the resolution of an radar images. This project has been conducted in conjunction with Provizio, an advanced driver assistance system company based in Limerick. The project was supervised by their team as well as Colin Flanagan, who guided the trajectory of the design and implementation of the system for the duration of the masters.



SRRcGAN: Super Resolution Radar conditional Generative Adversarial Network

E&CE

**Department of
Electronic and
Computer Engineering**

Edmond Keogh

Meng Computer and Electronic Engineering

Introduction

Every year 1.3 million people are killed in road traffic accidents. Immediate action is required to tackle this problem. Advanced Driver Assistance Systems are transforming transportation, making roads safer and mitigating unnecessary risks. Radar is an integral part of this process, allowing systems to assess risks associated with actions undertaken by drivers. Improving radar technology will give these systems a better view of their environment, and ultimately save lives.

To this end, the goal of this project was to design a conditional GAN, capable of improving the resolution of radar frames for use in ADAS systems.

Aim

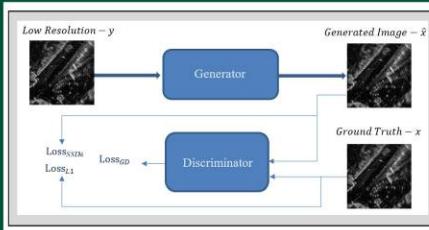
The goal of this project was to train a neural network capable of taking low resolution radar images, and outputting higher resolution images for use in automotive purposes.

Subgoals to this effort included:

- Gain an understanding of machine learning and in particular GANs.
- Find large amounts of useful data.
- Learn to use Pytorch
- Test the effects of different parameter variations on model outputs
- Become a competent python programmer.

Method

- Research was conducted on strategies used to tackle similar problems.
- A simple GAN was constructed to gain an understanding of the mechanics of the model.
- A suitable publicly available radar dataset was chosen.
- Methods of lowering the resolution of these images were examined.
- Image formatting practices were developed to pass samples to the model for training.
- The model was developed in Pytorch and small scale training was performed.
- A revision of the model was conducted, expanding to allow for model hyperparameter variations.
- Training was conducted while varying hyperparameters, with comparisons made between runs.



SRRcGAN Model Design

Seen above is the high level design for the model. Training is a several step process;

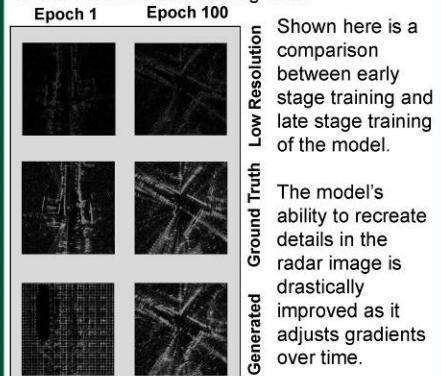
1. The low resolution radar image y is passed to the generator G .
2. \hat{x} passed simultaneously to the discriminator D with ground truth x .
3. D generated a percentage chance of \hat{x} is real by comparing it with x .
4. Further losses are generated using several metrics, L1 and SSIM.
5. Gradients are found and backpropagation is performed.

The model was trained on multiple Tesla GPUs using Azure cloud services. Training on multiple devices allowed for greater efficiency and larger batch sizes to be employed.

Results

The results shown below represent variations in the outputs produced by the model. Hyperparameters and various preprocessing steps were taken to achieve optimal results.

During testing the best positive predictor for overall outcome was training time.



Adversarial networks are inherently difficult to train. Stabilising training is a multifactorial process, which is one of the main reasons the further loss functions were employed.



Loss metrics over 100 epochs

Seen here are loss metrics depicting the values of the penalties being placed on the model for incorrect classifications.

The model continuously updates its weights so as to reduce these values to as close to zero as possible.

```
for e in #epochs:
    for LR_img in dataset:
        HD_img = G(LR_img)
        Pred = D(GT_img, HD_img)
        weights.update()
```

An SSIM score of 0.42 was achieved between the generated and ground truth, improving on the initial score of 0.12.

Conclusion and personal reflection

The SRRcGAN was successfully implemented having been trained on the Oxford radar dataset. Reliably improved outputs were achieved on the synthetically lowered dataset, allowing for improved resolution in terms of radar capture quality.

This project has explored in-depth modern machine learning practices and frameworks. The author learned in great detail the working mechanics of machine learning models and their applications to real world problems.

The project has greatly improved my problem solving skills and confidence in my ability to take on new challenges.

Acknowledgements

Special thanks to Colin Flanagan, my supervisor for the project, as well as Provizio who funded the training and offered their expertise on the subject. In particular Dane Mitrev and Barry Lunn. Without their support the project would not have been possible.



**UNIVERSITY OF
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OLSCOIL LUIMNIGH

Project Title:	Using Cyber Security Principles for the Development of a Trust Management Paradigm to Ensure Trust Within a Human in the Loop Sensing and Analysis System
Student Name:	Kealan Mannix
Supervisor:	Dr Thomas Newe
Programme of study:	ME in Electronic and Computer Engineering
Abstract:	<p>Human in the loop systems are an amalgamation of humans into the cyber physical world. These systems are becoming commonplace in industry 4.0 with the development of more advanced industrial control systems (ICS) and operational technology allowing humans and machines to work together in the same environments. However, this can pose many dangers to the workers in these environments with autonomous systems and robots operating in close proximity. To ensure the safety of the workers a network of sensors, cameras and other devices must be used. These devices are responsible for the monitoring and reporting of the location of both people and machines and will directly influence the operation of the ICS. With such operational technology (OT) networks frequently being used in industry 4.0 this will of course offer the opportunity for nefarious entities to attempt attacks on ICS which could be severely damaging to the industry financially or in some cases could lead to injuries, or worse to the human work force. With that in mind a key aspect to the components within this OT subnet is the concept of asset and vulnerability management to enable a trust model for the source data upon which decisions and actuations may be made. Cyber security principles can be used in the development of a trust management paradigm to ensure all devices on the subnet are trusted and authenticated and that in turn their data is transmitted safely, and with integrity and traceability. This project works on securing the ICS from attacks through the use of a trust management model. The trust model offers unique characteristics and combats attacks in sensor networks that conventional security cannot. However, the inverse of this also holds true, meaning in order to provide a truly secure system the network should use a trust model in conjunction with conventional security techniques such as cryptography and digital signatures. This project will also look at lightweight cryptographic and key management techniques that would be suited to this type of environment and also will discuss the use of good secure operations technology principles being applied to the ICS.</p>



Using Cyber Security Principles for the Development of a Trust Management Paradigm to Ensure Trust Within a Human in the Loop Sensing and Analysis System

E&CE**Department of
Electronic and
Computer Engineering**

Kealan Mannix

Electronic and Computer Engineering

Introduction

Trust management and security is needed within network environments to ensure the data is safe and reliable. The sensing and analysis system in question in this project is a human in the loop operational technology network in a smart factory setting. Human in the loop means workers will be present on the factory floor and able to make decisions about the network behaviour. The project is broken into three main sections to provide security for the network and ensure the data used is safe and trusted. These sections are:

1. Trust Model
2. Encryption and Key Management
3. SEC-OT Principles

Aim

The aim of this project is to provide a complete, comprehensive security model to the network. Each section of the project provides its own unique security features:

1. Trust model ensures nodes on the network are trusted and prevents against internal network attacks.
2. Encryption and key management provides conventional security features and protects against external attacks.
3. SEC-OT principles provide a set of best practices for network structure and staff training to minimise the risk of an attacker gaining access to the network.

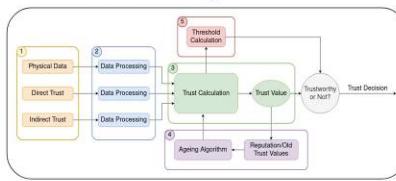
Method

An extensive amount of research was conducted for the project to help create the initial design of the full security model. Research on the following was conducted and influenced design decisions:

- Trust models design and use cases.
- Attacks trust models are used to defend against and attacks that can be launched against them.
- Lightweight encryption and key management schemes for resource constraint environments.
- Secure operations technology (SEC-OT) methodology.
- Industry 4.0 attacks and the causes of these attacks.

Based off this research a design for the security model was developed.

Trust model design



Block Diagram of Trust Model Design

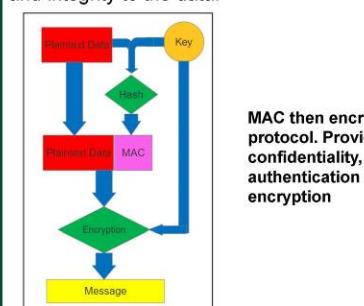
Above is a general block diagram of how many trust models operate. The model designed in this project follows this template. The sections of the block diagram are outlined below along with what the designed model does in each section.

1. Data Gathering – successful interactions, and communications rate.
2. Data Processing – Converts these values to value between 0 and 1 with 1 being the "best" score.
3. Trust Calculation – calculate trust based off these values and previous trust values.
4. Trust Aging – Use sliding time window function for trust aging.
5. Threshold Calculation – calculate the threshold based off the average value of trust in the network.

Encryption and Key Management.

A symmetric AES key is established securely between two entities on the network using elliptic curve Diffie-Hellman.

Once the key is established data is transferred across the network using a MAC then encrypt protocol to provide authentication, confidentiality and integrity to the data.



SEC-OT Design

The SEC-OT design was based off the methodology outline in "Secure Operations Technology" by Andrew Ginter.

The design consisted of methods for isolating the OT network from all other networks and on best practices with regard to bringing data into the network and staff training.

How the Design Defends Against Attacks.

The table below outlines how the project aims to defend against certain attack types.

Attack Type	How the Design Provides Defence?
Node Reputation	Trust model does not allow nodes to communicate with each other and therefore does not use reputation values for trust calculation.
Payload	Data anomaly checking and data trust parameter
DoS	Communications trust parameter and communications loss check
Routing	Communications trust parameter
Malicious Node Access	RF-DNA fingerprinting, ECDH protocol
Physical	Communications loss check, SEC-OT best practices
Intrusion from another network	SEC-OT network isolation
Intrusion from removable media	SEC-OT policies

Conclusion and personal reflection

The project established an initial design for the full security model to ensure trust within a sensing and analysis system. The project is to be continued as a PhD project in conjunction with Analog Devices and Confirm Smart manufacturing. The continuation of the project will include simulation, implementation and testing of the design.

The work done in relation to trust models and attacks they defend against is being submitted to a journal under the title "Sensor Network Environments: A Review of Attacks and Trust Management/Computation Models for Securing Them".

Key University of Limerick graduate attributes including proactive, technical, creative, and responsibility skills were developed during the undertaking of this project.

Acknowledgements

I would like to thank Dr. Thomas Newe and Aengus Gory for their support throughout this project and Analog Devices for giving me the opportunity to continue the work further.

Project Title:	Mobile Mapping System using LiDAR and IMU Data for 3D Reconstruction
Student Name:	Eoghan McGrath
Supervisor:	Dr Gerard Dooly
Programme of study:	ME in Electronic and Computer Engineering
Abstract:	<p>In the thralls of the Digital Age, the use of simulations and digital representation are a common and intuitive stage in the research and development process of a prototype or environment. This allows engineers and designers to explore a wider range of options during the design process and make rapid and efficient adjustments, and reduces the cost and time spent on physically realising several drafts of prototypes. This type of representation is also beneficial in the communication of information about a project. In using a virtual model of a given project, issues and ideas can be visually analysed and this assists in delivering a greater understanding of a project to stakeholders.</p> <p>Virtual realisation and reconstruction of a 3D environment can be created with an array of tools, sensors and processing options. In developing a model of a terrestrial surface, LiDAR technology (Light Detection and Ranging) and INS data (Inertial Navigation System) are an effective combination and have been used extensively in mapping systems. This project investigates the implementation of LiDAR and IMU data in a number of open-source mapping system projects and develops a similar mapping system using all low-cost and commercially available components. To realise this project, the CRIS Research Centre (Centre for Robotics & Intelligent Systems) at University of Limerick kindly provided a Velodyne VLP-16 LITE puck and an SBG Ellipse2-D IMU (Inertial Measurement Unit). The ultimate project design incorporates the IMU centred under the VLP-16 LITE scanner, which is fastened to a 3D printed box, made with PETG. The data from the LiDAR puck and IMU module are calibrated and fed to a Raspberry Pi Model 4 B with an opensource operating system. This requires the development of a header PCB to feed these components into the Pi as well as other duties. Another PCB is developed and fitted to the box as a progress tracker and status message.</p> <p>The Raspberry Pi employs an older version of the Raspbian operating system and python scripts are used to command the collection of data. The data is all received on a web user interface and is processed post-mission. The magnitude of data demands the use of a computer of high specification, and so the Raspberry Pi proved unable to handle data processing. The data is parsed and generates a 3D point cloud representation of a terrestrial surface. As a result, this method may be used to produce genuine data sets of high-density point clouds.</p>



Mobile Mapping System using LiDAR and IMU Data for 3D Reconstruction

E&CE

**Department of
Electronic and
Computer Engineering**

Eoghan McGrath

MEng Electronic & Computer Engineering

Introduction

3D modelling is now a hard proven step in project development. In many engineering disciplines, mapping systems are used to scan a prototype or model for virtual visualisation. This is also a vital operation conducted in archaeological and forestry disciplines as well as many other primary areas.

This project illustrates the development and construction of a mobile mapping system, incorporating a LiDAR scanner and INS module to recreate a 3-dimensional surface



FIGURE 1: 3D Model of Mapping System.

Aim

The main aim of the project is to create a mobile mapping system that parses lidar scans from a lidar puck and GNSS data from an IMU to generate a 3D point cloud, simulating a terrestrial surface or infrastructure.

This is done using the Velodyne VLP 16 puck and SBG Inertial Measurement Unit (IMU) provided by the UL CRIS research centre.

Method

The approach taken to realise this project includes:

- Researching other mapping systems, looking at their typical application and technology used, as well as their accuracy and data processing procedures adopted.
- Sourcing and identifying a bill of materials to assemble a mapping system that incorporates the VLP 16 and IMU available. This included outsourcing of PCBs manufacturing.
- Hardware assembly of the mapping system. Upskilling in physical assembly operations and arriving at a final design for the mapping system. This involved component and axial alignment and calibration, and accounting for offsets in the physical attachment of components.
- Software consideration and data processing. All data is received by a Raspberry Pi which uploads the recorded data from the flight to a web user interface where it can be extracted by another computer on the network for post processing.

FIGURE 2: Hardware Assembly

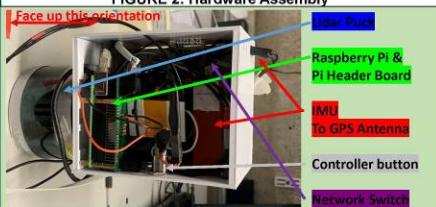


FIGURE 2: Hardware Assembly

Testing

Alignment and calibration of angular offset and axial synchronization of the IMU and lidar puck require a large number of field testing. This was conducted in the area between the library, foundation and main building as it proved to be an area with unique features that could be identified even from poor point cloud datasets.



FIGURE 3: Field Testing a prototype Mapping System.

Results

The data is extracted from the web user interface.



FIGURE 4: Web UI, camera configuration options

Name	Last modified	Size	Description
OpenVMS_35.pcap	2022-03-03 07:18	0	
OpenVMS_35.traj	2022-03-03 07:18	0	



FIGURE 5: Data Quality Script Output Results

The data, once received from the Web UI, is processed through a number of batch scripts, which command python scripts to read the lidar .pcap file and IMU .traj file.

Before 3D reconstruction, code is run to check the quality and accuracy of data before generating a point cloud. The first script checks the lidar .pcap data and generates a 2D map of the flight path taken, and shows the amount of data collected per second to indicate good quality data is available for processing.

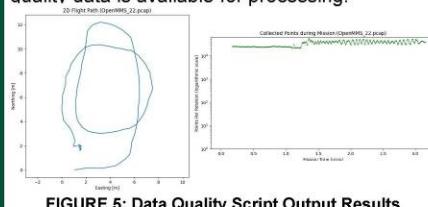


FIGURE 5: Data Quality Script Output Results

Once it is confirmed that there is sufficient data, a low-quality point cloud is generated of all data collected. This is used to crop and analyse the collected field and allow for any modifications. Parameters are adjusted and a more concise point cloud is generated. The figure below show the point cloud generated from a scan of _____

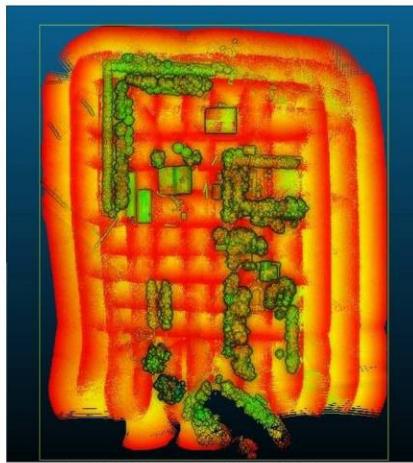


FIGURE 6: 3D point cloud of field area

Conclusion and personal reflection

The results return a operational mapping system that is capable of collecting synchronized Lidar and GNSS data and constructing a 3D point cloud using post processing scripts and open source software.

Upon reflection, hardware skills such as PCB handling and wiring were developed. Software knowledge was augmented too, including operating system imaging, serial data streaming and programming knowledge in python and windows batch scripts.

This project introduced me to Lidar and GNSS technology as well as robotic engineering disciplines

Acknowledgements

I would like to thank Dr Gerard Dooly, for his continuous guidance and assistance throughout this project.

To all academic fellows in the CRIS (Centre for Robotics and Intelligent Systems) laboratory, thank you sincerely for your help and advice, with special mention to Ben Bartlett, Anthony Weir, Matas Mockus and Dr Petar Trsic



**UNIVERSITY OF
LIMERICK**
OLSCOIL LUIMNIGH

Project Title: Automated Winch for Remotely Operated Vehicle Management

Student Name: Matas Mockus

Supervisor: Dr Petar Trslic

Programme of study: ME in Electronic and Computer Engineering

Abstract: Today's Industrial Control Applications are done mostly by Remote Processes. LabVIEW plays a major role within the Industrial Monitoring and Control Systems. This project discusses and shows the steps of building a tether management system (TMS) which will take an input from a user operating a PC and output an amount of tether on users request. This will be done through the aid of MyRIO microcontroller and a graphical user interface (GUI) which will be done through LabVIEW software. The automated winch (or TMS) will be built using two, 3 phase motors. They will be ran using variable frequency drives (VFDs). The LabVIEW interface communicates with the VFDs through myRIO which sends a command using Modbus RTU communication protocol and the VFDs receive it through a serial RS-485 connection. At the end of this project, a working automatic winch with proper safety equipment will be completed.



Automated Winch for Remotely Operated Vehicle Management

E&CE**Department of
Electronic and
Computer Engineering**

Matas Mockus

MEng in Electronic & Computer Engineering

Introduction

During recent years, operations undertaken by remotely operated vehicles (ROVs) are changing rapidly so are the tether management systems used to deploy them. The main function of the TMS is to manage a soft tether cable – the link from the TMS to the ROV for the electrical power and sensors, including video and telemetry. Technically the TMS is the tether handling machinery only and does not have an impact on the ROVs.

This project discusses the work undertaken to plan out, assemble and test the components of the winch such as motors, encoders, sensors and its circuit box. It is then programmed and controlled using myRIO device which is real-time evaluation board.

Aim

Users request is processed to spin a motor which will roll out/in the tether depending on the required purpose. This is controlled through an external computer set up and has a user interface which is made through LabView. Appropriate safety measures and making the unit water resistant, installing grounds and emergency switches is the last step which allows safe operation on boats or small vessels. Switches for manual winding and unwinding are also integrated on the circuit box itself for the safety and robustness of the whole system. Physical switches operate by sending digital inputs into myRIO when activated which the system then treats it in the same way as it would if a button was clicked on the users interface. This would mean that a PC would not always be required to operate the winch.

Method

After familiarising with the equipment needed, a wiring diagram was made for power connections within the circuit box. Over duration of the project this has changed drastically and multiple components such as 5V power supply and the Socket were added however current wiring diagram can be seen below.

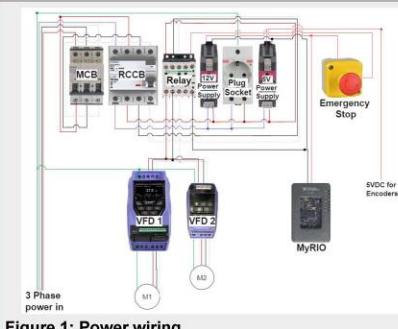


Figure 1: Power wiring



Figure 2: Power + Modbus comms.

Using Modbus RTU communication protocol, connection was established between the VFDs and the PC. This was done using custom cable which was connected to RS485 ports on VFDs to the USB ports on PC.



Figure 3: LabVIEW UI

After initial testing using HTerm to send single serial commands and spin the motors to test them, LabVIEW UI was then made to control the motors.

Finally, cables were made for sensors, encoders, connection to the PC and physical switches and wired into myRIO. Using LabVIEW the code was then created to process these inputs and display certain information like the encoder data within the UI panel.

Results

After completion of circuit box power and data wiring and appropriate testing, most things were working as expected with both of the motors starting and stopping simultaneously. Motor 2, which was used to lay the tether evenly onto the drum would change rotation whenever motor 1 would which was ideal. Motor 2 would also change rotation whenever it was at the end of the drum and the proximity sensor was triggered which works just as planned.



Figure 4: Proximity sensor triggering and changing rotation

Even though the sensors and Modbus communication was flawless and encountered little to none faults, we ran into a huge problem with encoder data and magnetic interference from the VFDs running. Encoders were outputting accurate data if the VFDs were not spinning the motors however once VFDs were enabled, the encoder data would mess up and be extremely inaccurate.

In the image we can below we used an oscilloscope to visualise the noise generated within encoder digital pins. We can see that the data is extremely noisy and what was supposed to be a digital signal of 0 to 5V we get an intense ripple. To partially fix this all the data cables were made from scratch with



Figure 5: Encoder noise

shielded cable changing out the original ones and combining the ground and the outside shielding into one. This would fix the problem for the encoder driving the pulley mechanism. The finished circuit box can be seen below.



Figure 6: Finished design.

Conclusion and personal reflection

The project design was executed and works just as planned with both VFDs working as intended and communicating with myRIO. This creates infrastructure making it ready for future implementations and complete automation of the winch by using data from the ROV.

This project has been a great learning tool for motors, high voltages, soldering, making neat designs and communication protocols. It has also taught me a lot more about LabVIEW and myRIO real time applications. Dealing with AC noise within the system also taught me how to pinpoint the problem within the circuit and different approaches of debugging it.

Acknowledgements

I would like to thank my project supervisor, Petar Trslc for guiding and supporting me throughout the whole project. I would also like to thank Edin Omerdic for help with LabVIEW and control aspect of the system.

**UNIVERSITY OF
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OLSCOIL LUIMNIGH**

Project Title:	ADC Monitoring of Camera Power Supply
Student Name:	Ciarán Murray
Supervisor:	Dr Karl Rinne
Programme of study:	ME in Electronic and Computer Engineering
Abstract:	<p>In the automotive space, the vision system's ability to detect items correctly is paramount to it being used effectively in applications such as collision detection and lane departure. The ability for a system to correctly identify is more and more important the higher levels of autonomy that are expected by users. This ever-increasing level of accuracy creates a challenge for automotive suppliers to meet higher and higher safety standards. To get to these levels, having accurate and reliable power supplies is paramount.</p> <p>This project was undertaken to characterise the analog-to-digital converter (ADC) used to measure the voltage of the camera's power supplies. This was to gain a greater understanding of the accuracy & repeatability of measurements of input voltage levels in varying conditions.</p> <p>An ADC's inability to give accurate readings can lead to false positives in camera systems, which may lead to unwarranted responses for systems such as automated emergency braking object misclassification and lead to unintended emergency braking. Similarly, false negatives may lead to no measures being taken. Therefore, it is important to understand the temperature and noise conditions that affect the ADCs readings.</p> <p>The project focused on characterising the ADC reading of camera power supply voltages (primary, secondary and third supplies). In the first stage, the direct voltage levels were measured by a digital multimeter, ADC determined voltage values were read over the I2C data bus against temperature (-40 °C to 85 °C). This data collection was automated using Python & processed in MATLAB. In the second stage of the project, the primary power supply was replaced with an external variable input power supply. This was to find the operating range of the ADC and how different voltages affect the accuracy of the ADC readings from the measured values. A noise ripple was then injected via a function generator on the primary power supply to characterise how the ADC readings are affected by noise in the system & if it will affect image quality. Finally, a distribution of the ADC voltage readings was found.</p> <p>All these findings were then used to get a full characterisation of the ADC used to measure the primary power supplies voltage. A calibration equation was established as a factor of the temperature & gain offset seen in the cameras.</p>



ADC Monitoring of Camera Power Supply

E&CE

**Department of
Electronic and
Computer Engineering**

Ciarán Murray

Meng Electronic & Computer Engineering

Introduction

In the automotive space, the vision system's ability to detect items correctly is paramount to it being used effectively in applications such as collision detection and lane departure. The ability for a system to correctly identify is more and more important the higher levels of autonomy that are expected by users. This ever-increasing level of accuracy creates a challenge for automotive suppliers to meet higher and higher safety standards. To get to these levels, having accurate and reliable power supplies is paramount.

This project was undertaken to characterise the analog-to-digital converter (ADC) used to measure the camera's power supplies. This was to gain a greater understanding of the accuracy and repeatability of measurements of input voltage levels in varying conditions.

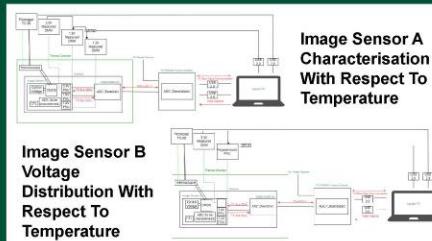
Aim

- Gain a better understanding of ADCs & their errors
- Create method to communicate with the ADC.
- Characterise the ADC across temperature.
- Find operating range & ADC accuracy.
- Investigate the impact of noise on the ADC.
- Find the distribution of voltage values in the ADC and their accuracy.
- Compile findings to characterise ADC.
- Understand how difference in ADC voltage readings & real voltage have an effect.

Method

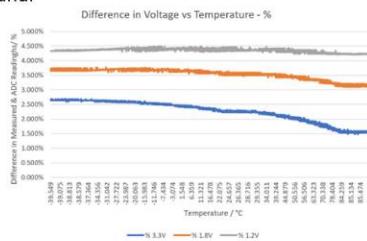
- Investigate errors seen in ADC's.
- Understand communication between interface & ADC.
- Develop method & code for characterising the ADC.
- Characterise the ADC voltage readings across a range of temperatures.
- Find operating range & ADCs accuracy across this range.
- Inject noise onto primary power supply to understand how it affects the ADC readings.
- Find the distribution of ADCs voltage readings and their accuracy.
- Compile findings to gain a full characterisation of ADC voltage readings.
- Create calibration factor for ADC readings with temperature and gain coefficients.

This was done by modifying two instances of the camera (image sensor A & B). One to measure the power supplies then inject noise and another camera to remove the power supply and replace with a more accurate external power supply to find operating range of camera and distribution of voltage measurements.



Results

The primary, secondary, third power supplies (3.3 V, 1.8 V, 1.2 V) were tested against temperature. The 3.3 V actual voltage was inversely proportional to temperature with the 1.8 V & 1.2 V proportional. There was a difference of 0.05 V – 0.085 V (1.5-2.7%) between the measured and ADC voltage readings. A temperature related calibration was found.

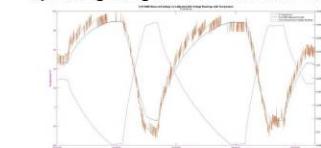


Difference in DMM Measured & ADC Voltage Readings Against Temperature

In the second experiment a varying power supply was used to find the operating range at a constant temperature. A gain factor was found but this is different to the first camera 0.12V - 0.15 V (4-5%). The calibration factor minimised the error to less than 1% (2-30 mV) on an additional run. It was noted that the temperature & gain co-efficient in combination were necessary for the most accurate values.

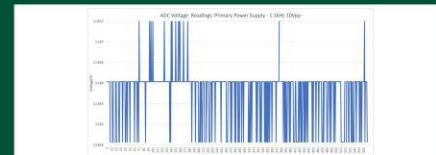


Varying Primary Power Supply Voltage To Find Operating Range And Difference In Values



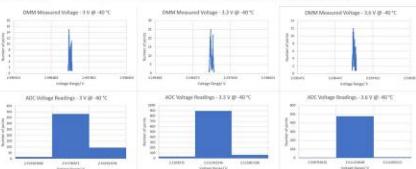
Calibrated ADC Readings with Temperature & Gain Co-efficient

The third experiment found the ADCs ability to respond to noise. A 1.1 kHz 10 Vpp ripple was injected on to the main power supply through a capacitor. A measured 3 mVpp ripple was noted with the ADC described voltage ripple of 2.939 mVpp. This was an accurate reading, but the sampling of the circuit was much slower than the input frequency (30 samples/ s).



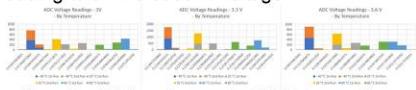
ADC Described Voltage Showing Voltage Ripple, Sampling Frequency Is Less Than Ripple Frequency

The final experiment replaced the primary power supply with an accurate external power supply. The supply switched between 3 V, 3.3 V & 3.6 V across temperatures. It was seen that there was a supply variance of 100 µV at each temperature while the ADC described voltage had a distribution of 3 quantization levels – 3 mV. An offset was still needed.



Distribution Of ADC Described Voltage At 3 V, 3.3 V, 3.6V At -40°C

It was seen that the described voltage varied with temperature with increases in temperature leading to an increase in voltage.



Described Voltage Increasing With Temperature

Conclusion & Personal Reflection

An approach was developed to characterise the accuracy of ADCs voltage measurement of camera power supplies through experimentation. This approach was semi-automated through the use of Python & MATLAB for data collection and processing. The project gave an overview of the accuracy and the performance of the internal voltage measurements. It shows how the accuracy is dependent on temperature, voltage gain, and individual offset of the cameras. Possible reasons for the calibration factors were also given. It was found that if the calibration factor was applied, the cameras are accurate enough for safety applications.

I found it quite interesting to understand how accurate measurements are a necessity in safety critical applications.

Acknowledgements

Thanks to my supervisor Karl Rinne and all the staff at Valeo Vision System including Gerry Conway, Luckas Plonecki and Jonathon Bail.



**UNIVERSITY OF
LIMERICK**
OLSCOIL LUIMNIGH

Project Title: A coplanar capacitive sensing approach used to develop a low-cost PCB for non-intrusive liquid point and level detection

Student Name: Aaron O Brien

Supervisor: Dr Karl Rinne

Programme of study: ME in Electronic and Computer Engineering

Abstract: Liquid level detection is an essential measurement when dealing with hazardous liquids where a failure to maintain an accurate liquid level would have serious consequences. This can be achieved by using floats, ultrasonic sensors and even lasers. While all are effective ways of measuring liquid levels, they all have the same flaw in that they are intrusive and require equipment to be inside the vessel to measure the liquid level. With many operations in factories having to use carcinogenic or volatile liquids in their manufacturing process and with advancements in safety and PPE it is crucial to have a non-intrusive way of sensing liquid level in a vessel. In this project I will research and develop a low-cost non-intrusive liquid level detection solution to be used to detect possibly dangerous liquids in a safe and hygienic manor. It will be possible to implement this sensor in several different ways, each tailored to suit the processes needs. The report details potential design ideas as well as the potential sensing methods that were explored before deciding on the final design. The report also details how this sensor could be integrated into a system, an investigation into the relationship between the parameters of a coplanar plate capacitor, how these parameters effect their fringing capabilities and finally an evaluation of the sensor developed and its limitations.



A coplanar capacitive sensing approach used to develop a low-cost PCB for non-intrusive liquid point and level detection

E&CE

**Department of
Electronic and
Computer Engineering**

Student Name: Aaron O'Brien

Programme of study: LM806

Introduction

Liquid level detection is an essential measurement when dealing with hazardous liquids where a failure to maintain an accurate liquid level would have serious consequences.

With many operations in factories having to use carcinogenic or volatile liquids in their manufacturing process and with advancements in operator safety and PPE it is crucial to have a non-intrusive way of sensing liquid level in a vessel.

This project tackles this issue by designing and developing a low-cost nonintrusive liquid level detection sensor Capable of sensing liquids through a variety of plastics and glass.

Aim

This aim of this project was to develop a low cost non-intrusive liquid level detection sensor.

Sensor Requirements:

- Operate over 3.3V
- Sense liquid through minimum of 3mm LDPE & 2mm of air
- Return results over I2C
- Total sensor cost < \$14 per sensor

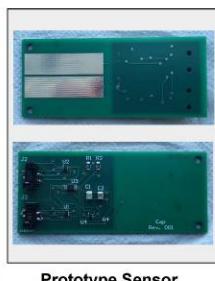
Method

- The Texas Instruments FDC1004 was chosen as the Capacitance-to-Digital IC
- A proof of concept prototype was built using copper foil and an FDC1004 evaluation kit.



Proof of concept (Left) Capacitance results (Right)

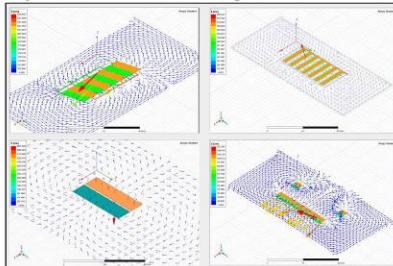
- From this proof of concept a prototype was designed and fabricated on FR-4.



The prototype design used two coplanar electrodes to sense. It has 3 ESD protection IC's which will not be necessary on the final design as it will be enclosed.

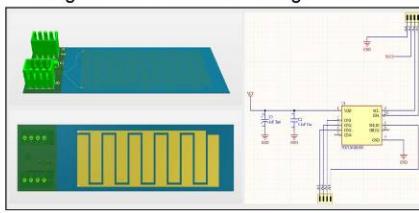
Prototype Sensor

- Using Maxwell the electric field lines created by various electrode designs were studied.



Maxwell simulation results for various electrodes

- The comb design proved the most suitable design for this application.
- A final PCB was designed and fabricated using the comb electrode design.



Final PCB Design and Simplified Schematic

Results

The results section of this project is broken into three different sections.

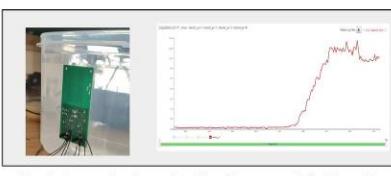
- Prototype & Mathematical Results.
- Maxwell Simulation Results.
- Final Design Demonstration Results.

Prototype & Mathematical Results:

Variables: $\epsilon_r = \text{Relative Permeability}$ $l = \text{Length of tracks}$ Formula: $C = \frac{\epsilon_r l \ln \left(-2 \sqrt{\frac{1-s^2}{(s+2w)^2} - 1} \left(\sqrt{\frac{1-s^2}{(s+2w)^2} + 1} \right) \right)}{377\pi \epsilon_0}$	$w = \text{Width of tracks}$ $s = \text{Separation of tracks}$ Results: For variables: $\epsilon_r = 4.7$ $w = 10\text{mm}$ $l = 40\text{mm}$ $s = 1\text{mm}$ $C = 4.691\text{e-12 F}$
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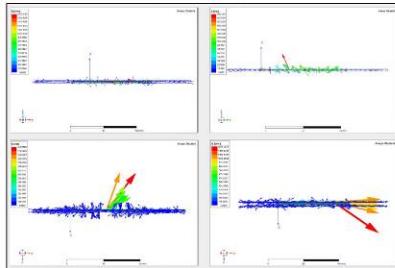
Mathematical expression for prototype capacitance

The Mathematical results shown an expected capacitance for the prototype design to be approx. 5pF. The graph below confirms this.



Prototype design attached to vessel & Results

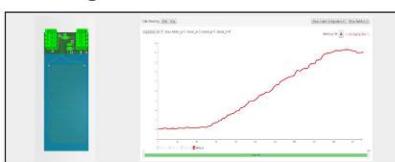
Maxwell Simulation Results:



Maxwell simulation results for various electrodes (Ordered as shown on the left in Method Section)

As you can see from the above simulations the comb design generates most uniform electric field across its surface area giving it greater accuracy than other designs.

Final Design Demonstration results:



Final Design (Left) Capacitance results (Right)

The final set of results show a much larger and uniform increase in capacitance as liquid fills the vessel past the electrode area.

Conclusion and personal reflection

Capacitive testing was chosen as the most appropriate technology to develop this non intrusive sensor.

The final design fulfils all the requirements outlined in the "Aims" section with the final sensor costing approximately \$11 per sensor.

I developed many skills throughout this project such as PCB schematic design, PCB layout design as well as vastly broadening my knowledge of capacitor theory.

Acknowledgements

My Sincerest thank you to the below listed people without whom this project would not have been possible

Dr. Karl Rinne
Tony Garvey (BD)
Domhnall Dooley
Michael O'Brien

Dr. Pat Meehan
James Keane
William O'Brien
Liam Connolly



**UNIVERSITY OF
LIMERICK**
OLSCOIL LUIMNIGH

Project Title:	Implementation of an XRF spectrometer to identify BFRs in the automated recycling of flat panel displays
Student Name:	David O'Shea
Supervisor:	Prof Colin Fitzpatrick
Programme of study:	ME in Electronic and Computer Engineering
Abstract:	<p>FPD Recycling have been developing the automation of the recycling industry for several years. Their existing flagship solution, FPD PRO focuses on the automated recycling of flat panel displays which has enhanced the recovery of metals, in particular CRMs whilst also removing hazardous components such as mercury from cathode ray tubes (CRTs). This makes handling and further processing of fraction material much safer. Currently plastics from these monitors/TVs are treated as being polluted with brominated flame retardants (BFRs). Further processing is required to prove whether the plastic component can be recycled or not. Current solutions have either have poor selectivity or carry large capital cost of implementation.</p> <p>The introduction of a handheld X-ray Fluorescence Spectrometer (XRF) provides an alternative option at a much cheaper price (<€20,000) whilst also maintaining high selectivity at <2% false positives. Existing methods for separating plastics require shredding first due to the mixed input streams. The proposed XRF would save the expense of this and make the system of detecting the presence of bromine (Br) in plastic both effective and efficient. To achieve maximum efficiency in the implementation of the XRF to the FPD Pro, the current process of recycling a TV must not be disrupted. Rigorous research and testing was undertaken to find the most appropriate method of implementing the XRF (and accompanying mechanical equipment) as well as figuring out the required scan duration for each display product so that the machine's recycling rates are not impeded.</p>



Implementation of an XRF spectrometer to identify BFRs in the automated recycling of flat panel displays

E&CE

**Department of
Electronic and
Computer Engineering**

Introduction

The presence of BFRs (>1000ppm) in plastic prevents the recycling of this plastic. It must be certified, de-polluted plastic in order for it to be recycled or else it leads to incineration of the material.

The FPD Pro robot currently has a homogenous stream of WEEE which includes TVs and monitors which allows an opportunity to add a screening process to their machine which could easily identify and therefore certify de-polluted material.

A likely solution, the X-ray fluorescence (XRF) spectrometer, is brought from research to implementation stage in this project. It will be an additional piece of hardware added to the current FPD robot to enable increased functionality.

Aim

- Using the XRF, an x-ray analysis will be performed on a large number of varying screen types to obtain the bromine content of each.
- Determine the accuracy of the XRF and whether it is a viable solution.
- Define the required parameters to complete a full XRF implementation on the existing FPD Pro robot.

Method

- Travel to the recycling centre, location of the FPD Pro, to accumulate TVs and monitors to be tested for the presence of bromine.
- Analyse the FPD Pro in real-time to decipher the appropriate location to implement the XRF without disrupting the current process.
- Perform two scans, approximately 20cm apart on each TV to ensure the underlying PCB circuitry is not affecting results.
- Obtain results and perform analysis to ascertain the accuracy of the XRF.
- Perform a spectrum analysis, comparing the bromine intensity across different scans.



Spectrum view of multiple TVs with varying levels of bromine.

- Write a simple python script to demonstrate the working principle of the implementation. The script reads a Results.csv file and outputs the result to the user:

```
if Br < 0.1:
    print(f'\t|PASS: Scan {row[0]}
has a bromine content < 1000 ppm.|'
      '\n\t|-----|')
else:
    print(f'\t|FAIL: Scan {row[0]}
has a bromine content > 1000 ppm.|'
      '\n\t|-----|')
```

Determine the full method of implementation taking all factors into consideration.



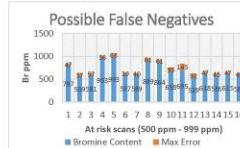
XRF performing a scan on the plastic casing of a laptop.



The robotic arm of the FPD Pro holding a TV in place for the screen to be cut out safely.

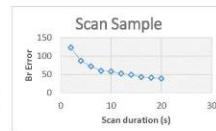
Results

- 210 screens were scanned in two different locations on the reverse side of each. This was composed of 24 LED screens, 117 LCD screens, and 69 monitors.
- The fail rate of all scans was 31.7%, meaning that 31.7% of the plastic casing around the screens were recorded as exceeding the LOD (limit of detection) of 1000 ppm set out by the POP Directive.
- Different variables were considered during testing to conclude the best, most efficient parameters are used in the final implementation.
- The error factor for each scan was a particular point of interest as it would inevitably determine the false positive/negative rate.
- It is imperative that there are no false negatives produced from the resulting implementation. These are results that are received by the XRF as being below the LOD of 1000 ppm but in actual fact are above.



A graph displaying scans with Br contents between 500 and 999 ppm. Only two scans are at risk of exceeding the LOD.

- The duration of each scan was a major contributing factor to the accuracy of each result and therefore the rate of false negatives.
- At a 10 second scan length, the average error was +/- 58. Two results came back as possible false negatives having bromine contents of 953 and 993, and error factors of 56 and 63 respectively.



- It can be seen that there is a clear correlation with scan length and bromine error levels.
- The LOD should be lowered to 900 ppm as a result of this to ensure absolute accuracy in the implementation.

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LM806 – Master of Engineering in
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Implementation

- The final implementation used data from the results and additional research to formulate an implementation that maintained current recycling rates while introducing the new screening process seamlessly.
- An appropriate actuator was chosen which allows for a push move so that the XRF can apply pressure to the plastic casing which is necessary for accurate results. There is also an attached ball joint to allow the XRF to adapt to any TV/monitor shape.
- Data communication throughout the system was most important to ensure that the data from the XRF was received by the HMI PC and an instruction was able to be provided by the PLC based on these results all within the time of ~40 seconds it takes for a screen to be processed by the FPD Pro.

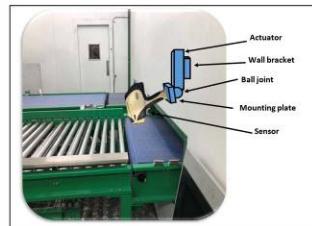


Diagram of how final implementation will look incorporated into the input conveyor of the FPD Pro.

Conclusion and personal reflection

With the implementation of the XRF, the electronics recycler will know at a very early stage of the recycling process whether the plastic is polluted or not. The result for the recycler is a low-cost method for de-polluting plastics from flat-panel displays which turns a cost for disposal of untested WEEE plastics into a revenue for certified, de-polluted plastic. The real world connection of this project was a major motivating factor in the completing it, helping me to figure out every small detail of how it will be implemented in industry. Seeing the actual implementation in the coming months will provide further satisfaction.

Acknowledgements

FPD Recycling employees for their endless support on all fronts at every stage. Supervisor, Colin Fitzpatrick for his guidance throughout the project.



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Project Title: Using Eeg Data And Machine Learning To Classify Consciousness On Patients Under General Anaesthesia Targeting An Fpga Platform

Student Name: Dominik Przychodni

Supervisor: Brendan Mullane

Programme of study: ME in Electronic and Computer Engineering

Abstract: Anaesthesiologists infer the state of unconsciousness without physically monitoring the brain. Anaesthesia-induced unconsciousness has previously been linked to drug and patient-specific EEG characteristics. Previous studies have shown that a highly reliable classifier can be developed from EEG spectral features. This project uses machine learning techniques to create classification models for tracking the unconscious condition in real time during anaesthesia-induced unconsciousness. Machine learning models were trained using the estimated power spectrum of 2s-epoch segments of EEG data obtained from healthy volunteers who received escalating doses of propofol while reacting to stimuli to directly measure unconsciousness. The power spectrum was computed through a novel means for spectral estimation called the multitaper spectral analysis. Various machine learning models were compared, and the highest performing model was identified. Live collection and processing of data was implemented on the programmable system of an FPGA platform and an 8-bit quantized neural network was implemented on the programmable logic which offloaded and accelerated the classifier. The quantized neural network reached an accuracy of 87% from single-channel EEG data. This creates a useful tool for anaesthesiologists to refer to, as it can give them a suggestion on the status of sedation that the patient is under.



USING EEG DATA AND MACHINE LEARNING TO CLASSIFY CONSCIOUSNESS ON PATIENTS UNDER GENERAL ANAESTHESIA TARGETING AN FPGA PLATFORM.

E&CE

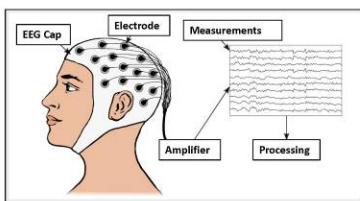
Department of
Electronic and
Computer Engineering

Dominik Przychodni

MEng. Electronic and Computer Engineering

Introduction

Electroencephalography (EEG) is the electrical method of monitoring brain activity. It is non-invasive and can be gathered through electrodes placed on a person's scalp. The data gathered through EEG monitoring can be used to predict a person's health, emotional state, movement, and in this case: whether a person undergoing general anaesthesia has lost consciousness.



Electroencephalography

General anaesthesia is the sleep like state a patient is placed under before surgery. Anaesthesiologists traditionally only monitor vital functions such as heart rate, blood pressure, and breathing to determine whether the patient is unconscious.

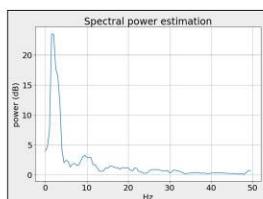
Aim

The aim of this project is to create a device which gathers EEG data from a patient and predicts whether that person is conscious or unconscious. This will be done using signal processing and machine learning techniques. The machine learning will be accelerated on an FPGA platform. High-level synthesis will be used to create the model which the FPGA will run.

Method

Application:

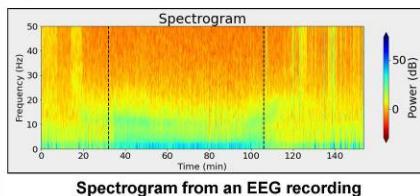
- EEG data is gathered via the electrodes and sent to the PYNQ-Z2 FPGA device.
- The PYNQ-Z2 filters the data to remove electrical noise and a DC offset.
- A power spectrum is then produced from the filtered data by splitting the data into 2-second windows and using multitapered spectral analysis.



Power spectrum of a 2-second window of EEG

- The power spectrum ranges between 0-50Hz and is split into 100 frequency bins – this gives a vector of 100 points.
- This vector is then sent into the neural network running on the FPGA to predict the state of consciousness of the subject.

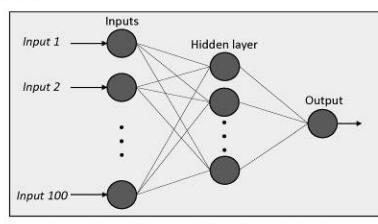
A spectrogram helps visualize the processed data, each vertical slice represents a power spectrum. In this recording, loss of consciousness occurs at the 32nd minute, and the return of consciousness occurs at the 106th minute – they are marked with a dotted black line.



Spectrogram from an EEG recording

Machine learning:

Although multiple machine learning techniques were implemented and tested, the main one used, and which runs on the FPGA is the Quantized Neural Network (QNN). This QNN takes in 8-bit values. The hidden layer has 32 nodes.



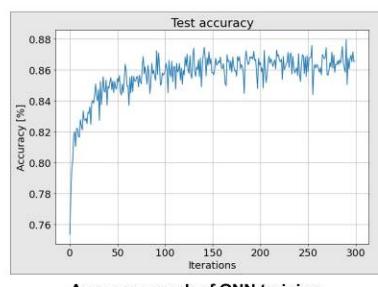
Quantized Neural Network architecture

High-level Synthesis (HLS):

- HLS was done using an experimental framework developed by XILINX Research Labs called FINN.
- It provides a way of synthesising and creating bitfiles from QNNs in Python. These bitfiles can then be deployed on the FPGA.
- The PYNQ-Z2 can then use this in the form of an Overlay which provides an interface between Python and the application running on the FPGA.

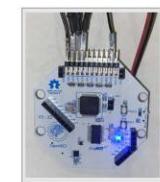
Results

The trained QNN reaches an accuracy of ~87% after 300 epochs on an oversampled training dataset. This takes under 5 minutes of training on a 4-core 10th Gen Intel i5 CPU at 1Ghz.



Accuracy graph of QNN training

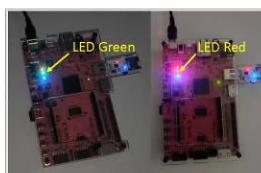
Below is a picture of me wearing the headband with the electrodes. Only the red electrode's data is used in this project, the other two are included to help with alignment. The ear clips provide a reference point for the measured voltage.



OpenBCI Cyton board

Me wearing the electrode kit

The electrodes are connected to the OpenBCI Cyton board which collects the EEG signals, amplifies them, and sends them wirelessly to the USB dongle.



PYNQ-Z2 running the application
Predicting consciousness (left)
Predicting unconsciousness (right)

Conclusion and personal reflection

The device correctly predicts consciousness using a neural network running on an FPGA and uses LEDs to display the results.

In the future, the following work could be considered:

- Testing on unconscious patients would have to be done in the future with the supervision of an anaesthetist.
- More training data would definitely be needed, as EEG data can be quite unique to individuals and can vary a lot by gender, age, and health.

This project has been a great learning tool for signal processing, artificial intelligence, and HLS.

Acknowledgements

I would like to express my deep appreciation to my project supervisor Dr. Brendan Mullane for his support and guidance throughout the whole course of the project.



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