

# Project List for Final Year BSc (CSIT) and BE (ECE) 2024/25

School of Computer Science, University of Galway

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**Enda Barrett (EB)**

**Code: EB1**

**Title: Open-Source Threat Intelligence**

A mechanism through which cybersecurity companies gather intelligence about whether assets or organisations under their protection are compromised is by searching online for evidence. This can involve searching through social media, online forums or on the dark web. Hackers will aim to sell items relating to the compromised organisation. This may be access to data such as email addresses, personal information about customers or even login access. This project involves building a search engine which indexes social media, hacker forums and blogs for evidence of compromises. The data must be analysed and classified according to a threat taxonomy, i.e., sale of login details, password bank etc. This will involve some Machine Learning and possibly NLP.

**Code: EB2**

**Title: Adaptive Deception Technology**

One way in which defenders can learn an attacker's strategy is to dupe them into attacking a honeypot. The attacker believes they are attacking a production system but in actual fact it's a fake entity designed to trap the attacker. As the attacker attempts to compromise the honeypot we can learn about their attack strategy, i.e., what vectors they are using to attack, what commands they are executing and in what order. Learning the attack motivation and the strategy can enable cybersecurity experts to harden their defences against attacks. If an attacker realises they are interacting with a honeypot they will immediately stop, building a system that emulates a real system is an open challenge. The goal is to keep them interacting but also to learn their strategies.

**Code: EB3**

**Title: Anomaly Detection**

Anomaly detection is one of the primary tools for detecting malicious activity on an organisations system or network. Recent work by published in ICML:

- <http://www.gatsby.ucl.ac.uk/~balaji/udl2021/accepted-papers/UDL2021-paper-033.pdf>

and with the corresponding dataset:

- <https://www.kaggle.com/datasets/katehighnam/beth-dataset>

aim to address this by utilising machine learning to establish a baseline and spot out of distribution anomalies. This project involves continuing this work, recreating the results within the paper and examining new techniques such as Recurrent Neural Networks for anomaly detection.

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**Code: DC1****Title: Classification of Online Behaviour using Analysis of NetFlow Data**

NetFlow is a feature available on network routers that provides the ability to collect information about IP network traffic as it enters or exits an interface. By analyzing the data provided by NetFlow, a network administrator can determine things such as the source and destination of traffic, class of service, and the causes of congestion. The primary goal of the project is to research and implement mechanisms to provide analysis of the collected NetFlow data to implement classification of online behavior for individual IP addresses. The first challenge will be to develop a NetFlow data collection and monitoring system that filters, aggregates and saves NetFlow data into a suitable structure for analysis. The project can use and augment existing NetFlow data collection and analysis tools e.g. nfdump to help collect and filter the raw dataset.

**Code: DC2****Title: IPv4 and IPv6 Routing and Usage Analysis on Mikrotik Routers**

The goal of the project is to research and design a system that analyses the allocation and usage of both IPv4 and IPv6 address blocks within a network of Mikrotik routers. The idea is to use the Mikrotik API to access the OSPF routing table and static DHCP allocations on a network of routers. From this information the subnetting and usage of an address block can be analysed and presented. The system can also show what IP address blocks are still available for allocation within a network. A test network will be built using the GNS3 open-source network simulator which provides a graphical user interface to design and configure virtual networks consisting of devices such as switches, routers and interconnects. The system can be extended to present graphical information about a network of routers.

**Code: DC3****Title: Energy Usage Monitoring and Recommendation System**

Relatively cheap hardware is now available that can be used to collect energy usage in a typical home or business premises and then transmit this data to cloud-based systems for presentation and analysis. The related IoT sensor data is often transmitted using a protocol called MQTT which is a lightweight, publish-subscribe network protocol that transports messages between devices. This project will concentrate on the development of a cloud-based web application and a related mobile app that can be used to present and analyse energy usage data. It could include a dashboard type presentation and make specific energy saving recommendations.

**Code: DC4****Title: Driving Efficiency App**

The goal of the project is to create a mobile app that can be used by anyone driving a car to evaluate how efficiently they are driving. Driving efficiency can be improved by accelerating gently, maintaining a steady speed, avoiding high speeds and more controlled deceleration. The app will use the sensors on a smartphone to collect related data and it will then present a trip summary, and it will also be able to provide historical analysis. Fuel economy and potential savings can also be incorporated into the data presented.

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I'm happy to discuss any projects in the area of Human-Computer Interaction (HCI). I'm specifically interested in HCI projects related to sustainability and social justice (e.g., addressing greenhouse gas emissions or food poverty). Projects might focus on, for example, "smart" interactions with e.g., buildings, energy, or transport, interaction design for the provision of services, online platforms for supporting communities and organisations, or interacting with data.

**Code: AC1**

**Title: Analytics and visualisation of public transport in Ireland**

Various APIs exist that provide live and forecasted data about public transport modes in Ireland (buses, trains, Luas). This project will explore how this data can be captured, analysed, and presented in a dashboard for analysing services, exploring trends, and developing insights.

**Code: AC2**

**Title: Getting to know non-human neighbours**

An app using social networking and/or gamification that encourages the exploration and sharing of non-human neighbours such as plants, animals, and insects. One relevant metaphor might be the curation of diverse observed species in a gallery for a local area (e.g., your garden or local park) that can be shared with others. There's scope to use the app to build a citizen-science produced map of species in different localities. Features might include friend lists, setting challenges, using geolocation to create groups of users, etc.

**Code: AC3**

**Title: Crowdsourcing activities for parents / Crowdsourcing public walks**

Play areas and activities parents of young children are not well documented. This project will focus on the design and development of an app for parents to search for, tag, and review things like walks and playgrounds. As well as mapping them on a geographic map, some of the properties of interest might be availability of seating, appropriateness for different age groups, buggy-friendliness, and nearby amenities and facilities like toilets. A formative study of parents /walkers might be beneficial to understand the app requirements.

**Code: AC4**

**Title: A locality information platform for house buyers and renters**

Finding an appropriate house to buy or rent is just one aspect to consider when finding a home. Finding the right locality is often a prerequisite to this. However, there aren't many tools available that consolidate information about a locality in one place. Information could be sought in two directions – localities in a travel time radius from a place of interest (e.g., what localities would be suitable for commuting to a workplace). In the other direction, it might include a travel time radius from a locality to nearby towns, cities, and amenities, information on local amenities and services, and web and social media data across, for example, Instagram and Twitter and local news sites.

**Code: AC5**

**Title: Thermal comfort app**

Thermal comfort is often approached as a single building or room setpoint temperature (22C). However, personal thermal comfort is complex and varies from person to person, and even across time for a particular person. This project would design and develop a mobile app that allows a user to capture their thermal journeys using fixed and wearable wireless temperature sensors. The app would allow a user to view their data in meaningful ways, and also record relevant aspects of their thermal comfort experiences. There is scope for the data of individual users to be consolidated in e.g., a building or room dashboard interface.

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**Code: FG1**

**Title: NUI Galway Campus and Services Explorer**

*“Gamification is the process of taking something that already exists – a website, an enterprise application, an online community – and integrating game mechanics into it to motivate participation, engagement, and loyalty”*

This project would involve developing a system (Android app or web based) which would use gamification to encourage new NUI Galway students to explore the full extent of facilities and services that are available to them both throughout campus and online. Users register for an account and then earn points by carrying out activities in the app and compete with fellow users through a global leader board. The goal of the app is to familiarize new students with different locations on campus as well as the many services and supports that are available to them (which often go unnoticed).

**Code: FG2**

**Title: GroupXercisE: An Organisational and Motivational Fitness App**

The 10 most common reasons adults cite for not adopting more physically active lifestyles are (Sallis and Hovell, 1990; Sallis et al., 1992)

- Do not have enough time to exercise
- Find it inconvenient to exercise
- Lack self-motivation
- Do not find exercise enjoyable
- Find exercise boring
- Lack confidence in their ability to be physically active (low self-efficacy)
- Fear being injured or have been injured recently
- Lack self-management skills, such as the ability to set personal goals, monitor progress, or reward progress toward such goals
- Lack encouragement, support, or companionship from family and friends, and
- Do not have parks, sidewalks, bicycle trails, or safe and pleasant walking paths convenient to their homes or offices.

The purpose of this app will be for users to create exercise groups in which members complete daily physical tasks (such as walking, cycling, core, stretching etc.). Each user can view a summary of their own progress as well as the progress of the other members. Task schedules can be automated, manually constructed or set depending on a user- specified fitness level. The app can include daily goals, achievement badges and push notifications to remind users. The overall goal of the app is to motivate users to be more active in an enjoyable way.

**Code: FG3**

**Title: Face and Emotion Recognition for 3D Animated Characters using Deep Learning**

Human facial recognition and emotion classification have been studied with great success for many years. Another interesting, and more challenging, task is in identifying faces and detecting emotions in animated characters. These characters are not necessarily just representations of humans and can include animals, mythological creatures, and toys with facial features etc. Part of this project would involve curating and annotating a new animated character dataset.

This would involve streamlining an approach for acquiring and annotating the images from sources such as motion picture frames. The dataset would then be used to test the performance of a series of state-of-art algorithms in face detection and emotion classification. This project would suit a student that is keen to upskill on computer vision approaches and image classification techniques.

**Code: FG4**

**Title: An Adaptive Teaching Platform using Conversational Learning and User Profiles**

This project would involve developing a prototype application for teaching the user a particular topic (for example Java programming). The application uses a chatbot to interact with the user by asking a series of questions to determine their current proficiency. Using this information, a user profile is constructed, and this profile is used to recommend lessons and exercises which are tailored to the user's current knowledge. The user's profile is updated with real-time statistics from application interactions, and this

will determine the most suitable learning path.

**Code: FG5**

**Title: Game Development with Real-time Skill-Matching for Players**

Dynamic Game Balancing (DGB) involves adjusting parameters, scenarios, and behaviours in real-time computer games, based on the player's current performance, in order to avoid them becoming bored with the game. When the computer-controlled opposition is too strong, human players can become frustrated with the gameplay. Likewise, opponents that are too weak result in predictable games in which human players do not feel challenged.

This project would involve the development of an adversarial web game or phone app which incorporates DGB into the NPCs logic in an effort to closely match the current player's skill level. In recent years, students have developed new games using the Unity platform and then incorporated DGB mechanics into the gameplay. Group testing was then carried out to examine the success of the balancing mechanics.

**Code: FG6**

**Title: Academic Profile Website for Career Progression**

It is important for academic staff members to have a presence online, especially those that are actively seeking employment. This project would involve research into existing academic websites to inspire the creation of a blueprint for creating such a site. What works well and what does not? Such websites typically include everything you would find in an academic CV but can also include additional and much more rich content. After the research phase, an academic website will be designed, developed, and deployed online with the objective of having maximum impact. The design should focus on ease of updating, adaptive display, and rich media content.

**Code: FG7**

**Title: Hobby Hotspots: Cataloguing Locations around Ireland**

Many hobbies such as snorkelling, surfing, camping etc. require the participants to have good local knowledge of the area. This project would involve creating a phone app for crowd-sourcing this information for various different activities and allow users to upload photos, reviews, drop map icons, and provide general tips and information. This project would suit students that have a keen interest in app development and those that may already partake in the aforementioned hobbies or similar ones. Ideally, the app should have a map plugin and an easy-to-use seamless interface. After development, the app should be tested from different locations around Ireland to get feedback on the overall design.

**Code: FG8**

**Title: Unity ML-Agents: A Comparative Analysis of AI in Games**

"The Unity Machine Learning Agents Toolkit (ML-Agents) is an open-source project that enables games and simulations to serve as environments for training intelligent agents. We provide implementations (based on PyTorch) of state-of-the-art algorithms to enable game developers and hobbyists to easily train intelligent agents for 2D, 3D and VR/AR games. Researchers can also use the provided simple-to-use Python API to train Agents using reinforcement learning, imitation learning, neuroevolution, or any other methods. These trained agents can be used for multiple purposes, including controlling NPC behavior (in a variety of settings such as multi-agent and adversarial), automated testing of game builds and evaluating different game design decisions pre-release. The ML-Agents Toolkit is mutually beneficial for both game developers and AI researchers as it provides a central platform where advances in AI can be evaluated on Unity's rich environments and then made accessible to the wider research and game developer communities." <https://github.com/Unity-Technologies/ml-agents>

This is an open-ended project where students would carry out a comparative analysis of various different AI algorithms and environments. This project would suit students that are looking to upskill in practical game AI development and deployment.

**Code: FG9**

**Title: Internet Safety and Scam Awareness for Vulnerable Users**

This project would involve carrying out research in the domain of internet safety as well as common scams such as phishing, smishing, and vishing. The goal of the project would be to develop an

interactive website or phone app for raising awareness of the dangers by testing the user's knowledge and providing detailed examples and how to deal with them. After the development, the website or phone app would go through a testing phase in which target groups would provide feedback on its efficacy and suggestions for updates.

**Code: FG10**

**Title: Text Analysis as an Aid for Object and Character Recognition in Feature Length Movies**

This project would involve acquiring the script and closed caption files of a movie and then analyzing this text in order to identify the time stamp at which certain objects or characters might appear on screen. For example, if we wanted to create an image dataset with pictures of Buzz Lightyear from Toy Story, the first pass would be to use the text analysis (of the script and closed caption files) to identify frames of interest and then use either image classification algorithms or human inspection to verify these identifications.

I would also be interested in discussing, and elaborating upon, any student-defined projects. Please email me to arrange a meeting if you would like to discuss any project ideas.

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**Code: JG1**

**Title: Labelling of Memes**

This project will involve building a web app to allow the labelling of online data (in particular memes with image and text) with respect to emotion and sentiment. Sentiment and emotion analysis are areas of analysis which try to capture a person's sentiment (positive, negative or neutral) and emotion (joy, anger, sadness, etc.,) towards a topic, person, or object. Within the area of social media analysis, a common machine learning problem involves building models to automatically classify the sentiment of text and other modalities such as images and videos. Such models generally require a large quantity of labelled data. This project will create a web app to allow the collection or use of memes on a specified topic and to allow people easily, and ideally in a fun way, label the memes with respect to emotion and/or sentiment.

**Code: JG2**

**Title: Identifying Memes and similar memes**

Internet memes have become a common form of expression and are often characterised by having some common component (e.g. the Spongebob character) that is re-mixed and re-used in different situations to convey meaning. Some sites keep track of "meme templates" (e.g., knowyourmeme.com) where the origins, uses and sometimes meaning, of some common memes can be found. The aim of this project is to identify memes and "families" of similar memes based on frequently occurring themes and patterns between memes and those patterns found in online repositories of memes. Some recent research has already considered this approach, where template-based classification of memes is used instead of conventional machine learning and deep learning models.

**Code: JG3**

**Title: Travel and Journaling app**

Many of us use apps to help us stay organised and keep track of important information and memories. The idea of this app is to help us do this in the context of our travel and holidays. This project will involve the design, implementation, testing and evaluation of an app to help us in our planning of a trip (places to visit and where to eat and shop), in storing important information and documents for the trip (boarding cards, train passes, etc.) and in capturing the day-to-day highlights and images of the trip.

**Code: JG4**

**Title: Conversational Recommender Systems**

Recommender Systems are the set of tools and techniques to provide useful recommendations and suggestions to users across a range of application domains. Conventional recommendation systems use content based or collaborative filtering approaches (or a combination) to model user preferences and give recommendations based on existing data stored on user preferences. Newer approaches, such as Conversational Recommender Systems, consider evolving user preferences in different contextual situations. This project will design, implement and test a Context Aware Conversational Recommendation system using a Dialog (Chat) System.

**Note:**

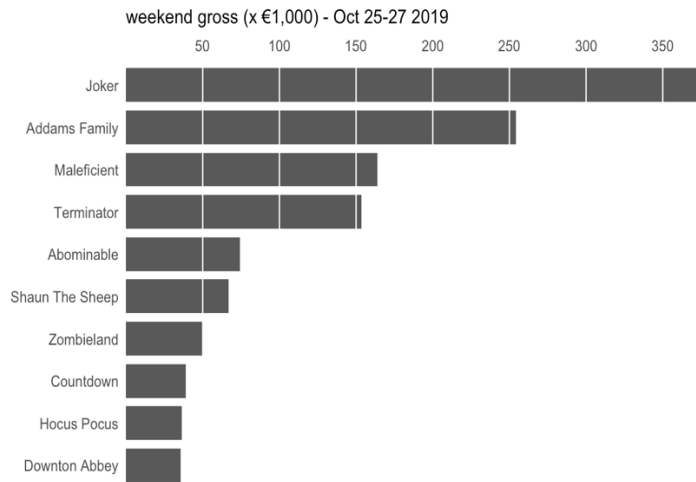
I am also happy to discuss students' own project ideas in the areas of social media analysis, multimodal analysis, recommender systems, ethical recommender systems and other app domains.

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**Code: CH1**

**Title: Visualisation experimental platform**

Visualising Data involves mapping data values to visual properties such as the length of bar, the position of point, shade of colour, area of a circle. For example, the bar chart below uses the length of the bar to encode the revenue generated by films on release in Ireland in October 2019.



The human perceptual system is better at judging some visual properties than others and this determines how we design data visualisations. This project will create an online experimental platform to test how well people can use visual elements to assess quantities. The project will require you to read several seminal papers on experimental design in visualisation (most of which were done in labs under controlled conditions) and recreate some of these experiments for online subjects. The output of this project will be the experimental platform and a set of results showing the results of your experiments. The results should produce a ranking of visual elements in terms of how accurately they were perceived to encode data values.

**Code: CH2**

**Title: Interactive graph visualisation of Irish Biography Data set.**

This project combines graph analysis and visualisation. It involves building an interactive graph of the Irish Biography Data set <https://www.dib.ie/>, which a colleague and I have downloaded. This is a kind of social network of Irish historical figures going back hundreds of years. The idea is to build a platform to allow people to explore the dataset visually, by enabling them to see the patterns of connections between the subjects in the dataset. There are multiple ways to do this, and part of the project will be determining the types of queries people might have and how the results would be visualised. There are several powerful graph visualisation tools available such as <https://cytoscape.org/>

As an example of interactive graph visualisation, you might look at how networks are visualised here: <https://app.litmaps.co/>

**Code: CH3**

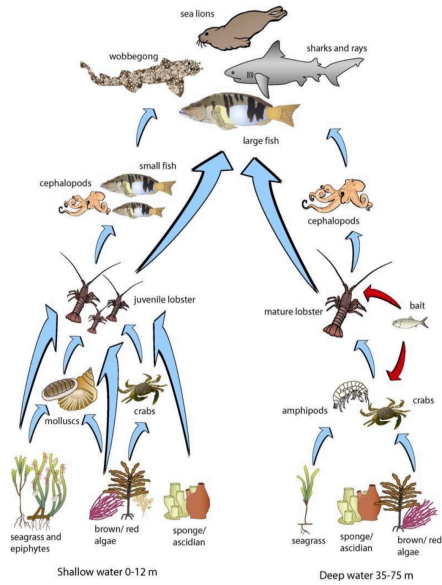
**Title: Simulating the fragility of ecosystem networks using agent-based modelling**

Ecosystems can be modelled as a network of relationships – for example, species can be characterized as either predators or prey or both as in the figure shown below. Removing species from a predation network can have catastrophic consequences on the ecosystem. For example, removing a top predator can cause an explosion in population of its typical prey, which then impacts on the population of prey lower in the network. This project involves creating an agent-based simulation of how human interference (e.g. through over fishing can have huge effect on the overall ecosystem). The project will use data already collected on natural ecosystems. The person taking this project will be expected to design a web site that allows data to be uploaded and modelled as a virtual ecosystem. The site will demonstrate how interference (e.g. through removal or reduction of one species) can harm the overall balance in the ecosystem.

The project will require you to become familiar with the basic ideas in what are known as ‘Food Webs’, agent-based modelling and you will need to use your software development skills to put



together the interactive website.



**Code: CH5**

**Title: App for Anomic aphasia**

Anomic aphasia is a language disorder that is characterized by difficulty in word-finding, or naming objects and items.

This project involves designing a phone app that will help people with anomic aphasia who may not be able to say or write the word for a concept they wish to express but are able to make a drawing. For example, a person might not be able to say or write the word 'dog', but they may still be able to draw a dog. The project requires you to design a doodle recognition system that can recognize a doodle and submit the word to an image search engine to return a real picture of a dog and an audio clip of its pronunciations. The person can then confirm that this is the concept they intended to express.



The doodle recognition system is based on the Quick Draw Dataset - a collection of 50 million drawings/doodles across 345 categories, contributed by players of the game Quick, Draw!.

Google has made the data available as well as several excellent tutorials on how to train a deep learning system to recognize new doodles and drawings (see links below).

<https://github.com/googlecreativelab/quickdraw-dataset/blob/master/README.md>  
[https://github.com/tensorflow/docs/blob/master/site/en/r1/tutorials/sequences/recurrent\\_quickdraw.md](https://github.com/tensorflow/docs/blob/master/site/en/r1/tutorials/sequences/recurrent_quickdraw.md)

This project will require interest in designing a intuitive user interface, software engineering (designing a client-server system and interest in learning how to use deep learning to classify doodles correctly).

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**Code: EH1**

**Title: Development of advanced Reinforcement Learning Methods.**

Reinforcement Learning is an approach that allows an agent to learn optimal actions over time from receiving rewards for what are considered good choices and punishments for bad choices. This project will examine various mechanisms whereby this technique can be extended and applied to a range of problems.

**Code: EH2**

**Title: Development of a Tool for Modelling of Transportation Networks**

Transport simulation is becoming an increasingly important analysis technique in traffic engineering and urban planning. Realistic simulations require detailed models of transportation networks, and the purpose of this project is to develop a tool for modelling and editing transportation networks. The networks produced using this tool may then be used for simulations. The proposed tool will GUI based, and will allow visual editing of the networks, as well as having its own project file format that will allow users to save their work for future editing. Importing data from a variety of common GIS sources and file formats (e.g. AutoCAD, Ordnance Survey, OpenStreetMaps) will allow users to develop models quickly, which can then be fine-tuned in the editor. A layer-based approach will be adopted to represent different types of transportation links (e.g. national routes, regional routes, bus lanes, rail links, cycleways and pedestrian routes), and allow flexibility when selecting which information is to be edited or exported. The finished tool will allow users to export completed networks in a variety of formats suitable for use in common traffic simulation packages.

**Code: EH3**

**Title: A Study of population health through social network analysis**

The speed of epidemics is directly linked to a number of key factors, which include the virus infectivity and the connectivity of the infected species. This project involves a study of various forms of social networks and various parameters which influence the spread of a virus in a population. The project involves the simulation of agent populations and their behaviour under certain experimental scenarios.

**Code: EH4**

**Title: Multi-Agent approaches to managing resources on the Cloud**

Determining how better manage cloud services raises a range of significant challenges. Some of these involve limited access to resources at certain peak times, or the arbitrary pricing plans of cloud providers. With these in mind, it is possible to put in place hybrid cloud mediators, which can determine stable and low cost cloud service plans from a range of providers. There is increasing need for cloud services, which can support highly flexible and adaptive requirements and this is now a key challenge for the Cloud Computing Industry. This project will involve the development of a multi-agent simulator, which reflects these challenges and offers insights into the complex world of cloud services.

**Code: EH6**

**Title: Complex Topologies in PSOs**

A Study of neighbourhood topologies in PSOs Particle Swarm Optimization has been shown to be a highly effective computational method that optimizes a problem by iteratively trying to improve a solution with regard to a given measure of quality. It has been shown that through alternative topologies or neighbourhoods significant improvements can be achieved in the performance of the PSO. Therefore in this project a number of alternative approaches will be examined and evaluated using various problems. Possible improvements will also be explored.

**Code: EH7**

**Title: A Study agent interactions in a game theoretic environment.**

Through a number of intuitive games a range of quite complex social behaviours can be studied that include cooperation and coordination. This project will examine a number of these games using a simulation of an agent environment. It is intended to explore the effects of certain social interactions on the resulting game dynamics.

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## Michael Madden (MM)

*Note: I am happy to discuss other project ideas in the broad areas of machine learning and deep learning.*

### **Code: MM01**

#### **Title: A Bot to Fix Code Bugs**

The idea of this project is to develop a bot that interacts with a code repository such as GitHub, and pulls down programs and analyses them to find lines that must be bugs. It would then push a change, along with a helpful message. It may also keep track of the bug changes via a twitter account and/or a web page.

In particular, it will focus on bugs that will not lead to compiler errors/warning. Part of the work will involve collecting a good set of candidate bugs in one or more programming languages. Here is an example to begin (Java):

```
int f = (int) Math.random() * 100; // Error: cast is higher priority than multiply
```

This program will use pattern matching to identify bugs, with pattern templates specified by the owner, that could be extended. It is essential that it avoids false positives, as it would ruin its credibility if it sets out to fix a bug and introduces one instead.

Ideally, it should work with more than one programming language. It might also interface with existing "lint" programs that do static analysis of programs.

### **Code: MM02**

#### **Title: Google Scholar and H-Index Graphs**

A researcher's H-index is a measure of how many citations their papers tend to get. A H-index of 20 means that the researcher has published at least 20 papers, each of which have 20 or more citations. (The researcher will have published more than 20 papers in total, and some will have many more than 20 citations, while others have fewer.) However, it has been criticized as being a poor measure of research impact, and prone to manipulation.

In this project, the student will build a tool to allow academics to examine their full distribution of publications and see how it relates to the H-index, by web-scraping Google Scholar or using an API. For an academic, it should be possible to generate a plot of their citation distribution and see how well it aligns with H-index. From here, it will be possible to look at broader questions about whether the H-index really summarises the distribution well, or whether other metrics are better.

### **Code: MM03**

#### **Title: Simple Algebra in Deep Learning**

Current generation deep learning models are surprisingly poor at basic mathematical calculations, including counting. For example, prompting DALL-E or Dream Studio with "five penguins" or "ten penguins" will generate images that do not have the correct number. The fact that most approaches involve scaling inputs to a fixed range, and that activation functions are inherently non-linear, may create challenges for deep learning systems to perform linear algebra in the range  $\pm\infty$ .

The goal of this project is to investigate the limitations of current deep learning systems for performing algebra, and then identify a set of tasks and seek to develop a deep learning system that can tackle them.

### **Code: MM04**

#### **Title: Discrete Simulation of Irish Elections**

The Irish general election process is complex by international standards, with a single transferrable vote and multi-seat constituencies with differing numbers of seats. As such, it poses an interesting challenge for simulation. Some of our past research in probabilistic data mining could be adapted for this application.

The goal of this project is to develop a software model for simulating Irish general elections, using a discrete simulation approach, where the simulation models individual voters or voter cohorts in individual constituencies, and includes behaviours such distributing votes when a candidate is elected or eliminated. The system should also be able to use polling data as an input. A final step could be to combine this simulation with our recent work on probabilistic inference, to evaluate the range of possible outcomes from elections, based on polling data.

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## Patrick Mannion (PM)

My research interests are mainly in artificial intelligence and machine learning; specifically in reinforcement learning, autonomous agents and multi-agent systems, game theory, multi-objective optimisation and evolutionary computation, with applications to areas such as game-playing agents, multi-robot systems, autonomous vehicles, intelligent transportation systems and energy systems / smart grid.

Please see <https://scholar.google.com/citations?hl=en&user=zjX2dVcAAAAJ> for an overview of my recent work. I am happy to discuss thesis ideas for prospective students (including for projects other than those listed below) via email or in person.

### **Code: PM1**

#### **Title: Visualising Agent Behaviour in Sequential Decision-Making Problems**

Developing autonomous agents is one of the main goals of AI research. An agent is a piece of software which takes sensory information as input and selects an action as output. A policy is a mapping between different system states and action selections, i.e. an agent's policy determines how it will act in a given situation. Policies may be derived using many different methods, e.g. hard coded, probabilistic, learning, planning, evolution etc. When developing agent policies, or demonstrating completed ones, visualisations of agent behaviour are useful as an aid to understand the decision-making process. This project will develop methods to visualise agent behaviours in 2D (using e.g. Scalable Vector Graphics) and/or 3D (using e.g. Unity game engine). To facilitate the production of animations based on the output from simulations, an appropriate data format will be defined which will specify the positions of agents and features during each frame of the animation.

### **Code: PM2**

#### **Title: Improving Multi-Agent Reinforcement Learning by Incorporating Prior Knowledge**

Multi-agent reinforcement learning (MARL) is a popular distributed AI paradigm, where multiple autonomous agents learn to interact in a common environment. The agents may be cooperative (e.g. multi-robot search & rescue missions), competitive (e.g. adversarial settings such as chess), or may need to learn a mixture of these behaviour types (e.g. team-based games such as robot soccer). One of the main challenges faced by MARL is high sample complexity. Another difficulty is that learning in multi-agent systems is often a "moving target"; as one agent improves its behaviour, its opponents and teammates also simultaneously improve their behaviour. This project will investigate ways to incorporate prior knowledge (e.g. demonstrations from expert humans or agents, reward function shaping, transfer/curriculum learning) to address these challenges and improve MARL performance in an application domain of the student's choice.

### **Code: PM3**

#### **Title: Solution Concepts for Multi-Objective Multi-Agent Systems / Multi-Objective Game Theory**

In multi-objective games, agents must optimise several objectives at once. One example of this setting is negotiations with suppliers, to secure goods at the best possible price, while also minimising environmental impact and delivery times. Solution concepts are interesting groups of outcomes for multi-agent systems (MASs), many of which ensure stable agent behaviours, e.g. the well-known Nash equilibrium occurs when each agent in a MAS has no incentive to change its behaviour, so long as all other agents in the system also don't change their behaviour. Another example is the correlated equilibrium, which allows better and more stable outcomes to be reached when all agents follow a coordination signal (e.g. a traffic light improving safety at a junction). This project will explore how solution concepts from classic single-objective game theory may be adapted for and applied to multi-objective settings.

### **Code: PM4**

#### **Title: Creating Agents with Tunable Behaviours using Multi-Objective Reinforcement Learning**

Typical reinforcement learning approaches train an agent to reach fixed behaviours upon convergence; if the system designer wants to optimise different goals instead, partial or complete retraining of the agent is often required. This project will seek to develop agents whose behaviours are tunable by making use of concepts from Multi-Objective Reinforcement Learning. Each different type of desired behaviour will be rewarded as an individual objective; the agent will then learn about all of the different

behaviours simultaneously during training. Once training is complete, an agent's behaviour may then be modified without the need for retraining by altering the weighting between the different learned behaviours (objectives). This approach could be used to dynamically influence e.g. how cooperative or competitive an agent is, or the aggressiveness/degree of difficulty of a game-playing AI opponent.

**Code: PM5**

**Title: Comparing Procedural Level Generation Methods for Video Games**

In recent years, procedural level generation has become increasingly popular in video games. Procedurally generated levels improve replayability for the player(s), as well as reducing the burden on developers and environment artists. As part of this project, a simple 2D or 3D game will be developed using a game engine (e.g. Unity). The game may be a novel creation, or a clone of a classic (e.g. Zelda, Mario, Sonic etc.). The level components will be constructed in a modular fashion, allowing them to be easily combined in a variety of ways. Several different procedural content generation methods will then be implemented, such as Probabilistic Multi-Pass Generator, search-based approaches, rule-based etc. Finally, a group of non-expert players will evaluate the quality and entertainment value of levels created using each method. Useful references: <http://gameaibook.org>, <http://pcgbook.com/>

Other possible project topics include:

- Benchmarking Sequential Decision-Making Algorithms
  - An Evaluation of Exploration Strategies for (Multi-Objective/Multi-Agent) Reinforcement Learning Quality Diversity Algorithms for Neuroevolution
  - Sequential Social Dilemmas: A Multi-Objective Perspective Generative Adversarial Reinforcement Learning
-

## Karl Mason (KM)

My research generally consists of evolutionary computing, neural networks, machine learning and their applications to a range of problems.

### **Code: KM1**

#### **Title: Ensuring Cooperation Amongst Multiple Robotic Arms**

Manufacturing environments are undergoing a significant shift towards automation, driven by the need for increased efficiency, flexibility, and cost-effectiveness. Traditional rule based controllers have achieved success in controlled environments. AI and machine learning methods are expected to expand the capabilities of robotic arms by facilitating their operation in less controlled environments. Multi-arm coordination involves enabling multiple robotic arms to work together seamlessly in complex and dynamic environments, collaborating to achieve common goals. This project will develop controllers to ensure cooperation amongst multiple robotic arms. This will be done in simulation first, with the possibility to then be evaluated on physical robotic arms outside of simulation. There is also scope to integrate AI/machine learning methods for robotic arm control.

### **Code: KM2**

#### **Title: Autonomous Underwater Vehicle Simulation and Control**

The proposed project will consist of simulating an Autonomous Underwater Vehicle (AUV) using the CoppeliaSim framework. This will involve designing the environment (referred to as a scene in CoppeliaSim) and the AUV. Once this is complete, a control system will be developed to enable the AUV to navigate its environment. The efficacy of the controller will be determined based on its ability to successfully navigate the environment, complete predefined tasks, and move in a safe manner.

### **Code: KM3**

#### **Title: Evolutionary Reinforcement Learning**

Evolutionary reinforcement learning (ERL) combines two prominent fields of Artificial Intelligence research; Evolutionary Computing and Reinforcement Learning. As ERL is an emerging subfield, there are many unanswered research questions, e.g., how can ERL be extended to multi-agent systems? How can ERL be modified to handle multiple objectives? This research project will explore answers to these questions and develop new ERL algorithms for different problem types.

### **Code: KM4**

#### **Title: Evolutionary Controllers for 3D Printers**

Evolutionary neural networks are a promising paradigm for control/decision making tasks. A slightly old but relevant 2017 paper by OpenAI (<https://deepmind.com/wp-content/uploads/2017/10/1703.03864.pdf>) demonstrates its effectiveness when compared to reinforcement learning. This project will consist of developing evolutionary controllers to control the operation of a simulated 3D printer. There is also the scope to apply the developed controller to a physical 3D printer in a laboratory setting.

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**Code: JM1**

**Title: Interactive Evolutionary Computation in Javascript**

Prerequisites: Javascript

Interactive Evolutionary Computation (IEC) is a computer implementation of evolution by artificial selection. It can be applied in engineering, art and music, and many fields of optimisation. The computer generates a “population” of objects, eg artistic images, and the user selects the most aesthetically pleasing. Behind the scenes, the best ones are mated/mutated to give a new population. Over time, the user achieves exploration and optimisation of the space. See <https://nbenko1.github.io/#/evolve/> for an example of the process in action. In this project, the student will implement a reusable Javascript framework for deploying IEC on websites. A user of the framework should be able to plug-in suitable functions in order to re-use the framework for graphical art, music, engineering design, or other problems. A previous student project is available to provide starter code.

**Code: JM2**

**Title: Interactive Multiobjective Search in Javascript**

Prerequisites: Javascript

Search/optimisation methods such as evolutionary computation typically try to minimise some function (called an objective function) of some variables (called decision variables). Sometimes there are multiple objective functions and it is called multiobjective optimisation. An example is optimising the energy production of multiple power plants over the course of a day. Our decision variables are the amount of energy to be produced by each plant per hour. Our objective functions might be the total cost, the total CO2 emissions, and the match between supply and demand.

Because there are multiple objective functions, there are trade-offs between them. There is no single best solution: the right trade-off is subjective. In interactive multiobjective search, there is a human in the loop. The job of the underlying search algorithm is to produce a *Pareto front* of solutions which make different trade-offs, and the job of the human is to focus on the areas of the Pareto front which are of interest. The goal of the project will be introduce a facility for human in the loop. The student will create a simple user interface on top of the multiobjective search. It will visualise the Pareto front that has been created so far as a scatterplot, using objectives as axes. The user will be able to use the UI to select any existing solution and visualise information about it, and choose to either focus on it for further improvement, or move focus to other solutions. The user will also be able to select a direction in multi-objective space, or an area where the Pareto front is weak, for increased focus.

**Code: JM3**

**Title: Zendo with Genetic Programming**

Prerequisites: Python and some exposure to machine learning or optimisation.

Zendo is an interesting board game for 2 or more players. See

<http://superdupergames.wikidot.com/games:zen>. A computer implementation would begin by implementing primitives, eg “on top of”, “beside”, “red”, “pyramid”, and rules by which they can be legally combined to give rules, eg “the red pyramid must be on top of the blue square”. The Artificial Intelligence part of the problem would involve creating a classifier system using program synthesis which tries to guess the correct rule and alters its guess based on feedback. This would be quite different from a statistical/machine learning classifier because the “scene” to be classified would not be represented as a feature vector, but as a graph data structure representing the scene. The program synthesis part would be implemented using Genetic programming, eg Grammatical evolution (resources: see Seán Luke, Essentials of Metaheuristics). Overall it would be a contribution towards artificial intelligence both in the program synthesis and in new ideas for classification on non-feature vector spaces.

**Code: JM4**

**Title: Time Series with Grammatical Evolution**

Prerequisites: Python

Time series data is data where a variable is sampled periodically over many time-steps. Recent work by Mauceri et al. has shown that Grammatical Evolution can extract excellent features for time-series classification problems (see <https://link.springer.com/article/10.1007/s10710-021-09403-x>). In particular, a GE-based system can extract 3-5 features which out-perform the state of the art by 5-7% over a large set of datasets. In this project, the student will propose and test alternatives to the



grammatical representation in order to extend this advantage further.

**Code: JM5**

**Title: Building knowledge graphs to relate tunes and musicians in Irish traditional music**

Prerequisites: Interest in Irish traditional music, web technologies.

*The Session* (thesession.org) is a central online resource for the Irish traditional music community, with over 40,000 tunes and variants, and many more free-text comments and discussions. The tunes are well-structured, with links and metadata. However the free-text comments and discussions are not structured and represent a very valuable resource. The goal of this project is to process this data to extract links between tunes and musicians, and eventually to provide new ways of navigating the website according to this data. The website owner will be involved.

**Code: JM6**

**Title: Bongard Problems and Language Models**

Prerequisites: Python, machine learning

Bongard problems are very interesting puzzle problems, both for human cognition and AI. Each problem consists of two sets of six images. The task is to understand the rule which distinguishes the two sets. This is similar to the machine problem of *classification*, except that we have very little training data, and the rules are generally quite abstract. See eg [https://en.wikipedia.org/wiki/Bongard\\_problem](https://en.wikipedia.org/wiki/Bongard_problem). In previous work, researchers have not really succeeded in building AI models to solve these problems. The project here is to use a pretrained multi-modal language model to provide captions of the images, and then try to do classification on the captions.

I am also willing to discuss with students their suggestions for variations on the above projects, or new projects proposed by students. Please see the following address for information on my research interests: <https://scholar.google.com/citations?user=nKNOv8oAAAAJ&hl=en>

<https://jmmcd.net/research>

Email: [james.mcdermott@universityofgalway.ie](mailto:james.mcdermott@universityofgalway.ie)

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**Code: MN1**

**Title: Augmented Web Browsing**

Modern web browsers are able to predict surf targets, and various web annotation tools augment web pages with a second layer of information (e.g., notes, ratings or discussion forums). In this project, a novel browser extension should be implemented which augments web pages with automatically discovered additional information, for example background knowledge from online knowledge bases or relevant news articles.

Requirement: Good programming skills and an interest in Web development

**Code: MN2**

**Title: An AI Tool for the Collective Creation of Artifacts**

The purpose of this project is to create a novel tool which uses AI approaches to support its users in the collective creation of shared artifacts, such as images, stories or musical pieces. Users work interactively with (or against?) each other to build and update shared artifacts, supported by an AI (using a suitable existing AI approach, such as Diffusion Models).

Requirements: Good programming skills. Interest in Artificial Intelligence

**Code: MN3**

**Title: Data Analytics Chatbot**

In this project, an intelligent chatbot should be created which is able to perform data analytics tasks in interaction with the user. Instead of specifying the analytics task using a scripting language or a graphical user interface, data sets are processed and analyzed step-by-step in a dialogue with the chatbot, using natural language commands and queries.

Requirements: Good programming skills. Interest in Data Analytics

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**Code: SR1**

**Title: Tactical Pathfinding with visibility and threat analysis**

This project will build on the well-known algorithms for pathfinding in computer games, by assessing and building on approaches that take visibility, threat, and tactical value into account.

**Code: SR2**

**Title: Team-Based Pathfinding in computer games.**

Although pathfinding is a well understood problem in computer games, the automatic production of interesting, believable and challenging pathfinding behaviours for *teams* of AI agents has received little academic interest. This project will evaluate team-based AI in general, and develop+evaluate team-based pathfinding solution(s).

**Code: SR3**

**Title: Procedural (random) map generation in computer games.**

This project will investigate the techniques used for procedural map generation in computer games, and will develop a random map making tool. It will also develop and assess novel steps in this process. The map could be 2D or 3D, could use a game engine if desired, and could use the student's own artwork or open-source artwork. The project would involve investigation of various techniques (Perlin noise, cellular automata, Voronoi maps etc.). The requirement is to be able to specify various parameters, a random seed, and generate a map which can then be scrolled around to view.

There is no requirement for any functioning gameplay. E.g., see <http://pcg.wikidot.com/category-pcg-algorithms>.

**Code: SR4**

**Title: Historical Education Game.**

This project will design and develop a single-player historical education game similar to the famous game The Oregon Trail (which you can play online here: <https://classicreload.com/oregon-trail.html> ). Your work will involve picking an appropriate historical topic, researching the details of this, and then designing and implementing a game which captures the essence of the topic – perhaps involving travel across a map, strategic decision making, random events and hazards, and simple graphics.

**Code: SR5**

**Title: Believable Pedestrian Movement in Crowded Environments.**

This project will research and develop a graphical simulation of pedestrians moving about in a crowded environment (e.g. city centre), probably using a game engine. As we navigate on foot, we not only use simple pathfinding on the static environment to determine the shortest path, but we also take into account other people and moving obstacles, and an implicit shared negotiation of space is used to alter our routes. This project will consider this process and develop a graphical simulation of it.

***I am also generally happy to supervise student-specified projects in the areas of computer games, graphics, and networked/online collaboration tools.***

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**Code: MS1**

**Title: Post Quantum Cryptography**

Emerging quantum computing capabilities will eventually render traditional public-key algorithms based on RSA, finite field and elliptic curve constructions useless. This has led to the development of post-quantum encryption and signature algorithms that take advantage of the hardness of lattice problems over module lattices. Here, standardization efforts, for example by US NIST (<https://csrc.nist.gov/News/2022/pqc-candidates-to-be-standardized-and-round-4>) have made significant progress. This project aims to make a contribution to this emerging domain of cryptography, and may include algorithms' reference implementations (based on <https://openquantumsafe.org/liboqs/algorithms/>), benchmarking, or their integration with cryptographic protocols (e.g. TLS) or concepts (e.g. digital signatures). Therefore, the exact scope of the project will be determined in due course.

**Code: MS2**

**Title: Cellular automaton**

You probably heard about Conway's Game of Life - a well-known cellular automata (CA), which simulates the life cycle of cells in a 2-dimensional grid. In fact, some biological or chemical processes occur—or can be simulated—by cellular automata. In this study you research one of the many types of CA (elementary or n-dimensional), investigate its characteristics, and look for potential applications or biological equivalents. This project requires you to implement a CA editor / emulator.

**Code: MS3**

**Title: AI music composer**

Music composition is a new and interesting application area of Artificial Intelligence. In this project you will research, explore and implement new concepts to algorithmically create music, i.e. rhythms, melodies, sounds and / or compositions.

**Code: MS4**

**Title: Adaptive spell checker**

Many spell checkers, as used in word processors and editors, use the Levenshtein distance to determine possible word corrections. This works well for simple typos, but is not a very satisfactory solution for people that suffer from dyslexia and related issues. In this research you will explore and research spell checkers that are more tailored to an individual's needs, hence creating an adaptive spell-checker.

**Code: MS5**

**Title: Software Synthesiser**

Synthesizers use various methods to generate electronic sounds. Among the most popular waveform synthesis techniques are subtractive synthesis, additive synthesis, wavetable synthesis, frequency modulation synthesis, phase distortion synthesis, physical modelling synthesis and sample-based synthesis. The aim of this project is to prototype a software synth, based on the aforementioned methods or any suitable combination, either as a standalone application, or integrated into dedicated hardware like for example a Raspberry Pi.

**Code: MS6**

**Title: Sonification**

Sonification is the use of non-speech audio to convey information or perceptualize data. In this project you will prototype a system for wearable audio navigation based on a mobile phone for visually impaired users. The system will translate video or still images into audio (and possibly complemented by tactile) stimuli, thereby allowing a person to navigate in a room, or locate an item.

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**Code: FS1**

**Title: Programming Paradigms**

Implement various generic trees (and other data structures) in C, Prolog and Lisp. Compare each of the implementations in terms of speed, size of code and maximum size.

**Code: FS2**

**Title: Dynamic Mandelbrot Sets**

This project will look at initially creating a depiction of a Mandelbrot Set, which is an infinite fractal that can be easily drawn. Once the set has been drawn, variations can be implemented – eg zooming in a certain area or changing the colour palette (the colours are used to indicate the rate of movement away from the boundary). Once these are done, an animation that varies the image based upon a music file. Different aspects of the music could be used to vary the image.

**Code: FS3**

**Title: Qualitative reasoning**

Implement a qualitative reasoning system that can be used to model a range of dynamic systems. The system should be developed in Prolog or Clips for which guidance will be given.

**Code: FS5**

**Title: Programming tool**

Develop a programming tool to help beginners with programming, the tool should help them build the required constructs and be able to be incrementally augmented as they cover new topics – so the tool will only help them with what they have covered.

**Code: FS6**

**Title: Calculation accuracy**

Investigate the accuracy of calculations. Errors can occur from many sources, including measurement tolerance and rounding error. This project should investigate the effect of these errors in calculations. One way of doing this would be to create a new numeric class that incorporates both value and margin of error.

**Code: FS7**

**Title: Very Large Numbers**

Many conventional programming languages have a limit to the size of numbers they can store. With integers, there is usually an absolute maximum, with floating point numbers the limit is more complex (larger numbers tend to become less accurate). This isn't a specific project as there are a wide range of projects that could be undertaken, both in basic principles and applications. For example, comparing the efficiency of different methods of multiplication and division, or finding large prime numbers (useful in cryptography).

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**Code: KY1**

**Title: Healthy App**

Description: This project involves the planning, design, implementation and testing of a mobile app to improve health outcomes for a particular group (first step will involve identifying target audience: weight loss, heart health management, diabetics, fitness improvement etc.). Initial research will identify other apps in this space, and identify core requirements. The app will be iteratively designed and tested and provides scope to incorporate any innovative technical or behavioural elements according to student interests (front or backend).

**Code: KY2**

**Title: BookClub / CookClub / FilmClub App**

Description: This project again involves the planning, design, implementation and testing of a mobile / web-based app to track a Bookclub's "books", CookClub's "menus" or FilmClub's "films". This app should allow tracking of books / menus / films and their reviews, as well as recommendations, and could include links to other "clubs". The possibility of incorporating challenges within the app can be explored. Note: this app could also be used by a single book reader / chef / film goer who wants to keep track of their own books, recipes or films.

**Code: KY3**

**Title: UI's for Cars / Driving**

Description: This project will involve research and development activities in the area of user interaction with automotive vehicles. Initial research will consider the integration of sensing and human agents (CPSS's) as well as existing UI's and develop and test new UI prototypes for driver interaction which will be trialled via defined use cases and scenarios.

**Code: KY4**

**Title: Data Dashboard**

Description: This project will initially identify a required data service (e.g., citizen service, energy consumption service, food sourcing service, marine service etc.) and provide an interactive dashboard for public access and use of this data. The project will identify the relevant data required and develop an effective data management service for accessing and querying this data, and design a dashboard to visualise, interact with and explore this data.

**Code: KY5**

**Title: Language Learning (or other education) App**

Description: This project involves the planning, design, implementation and testing of a mobile (or Web-based) app to support language learning for a particular group (e.g., specific age cohort casual holiday makers language for business needs, foreign students etc.). Initial research will identify other apps in this space as well as best practice language learning pedagogy, and enable identification of the core requirements. The app will then be iteratively designed (incorporating auditory elements, challenges and other gamified elements etc.) and tested.

**Note:**

I am also happy to discuss students' own project ideas in interactive systems design in the areas of digital health, data visualisation and analysis, and educational systems design.

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## Mamoona Asghar (MA)

My research interests are mainly in Cyber security, Encryption, Steganography, Image/video processing, attack/Threat Modeling, Malware analysis, and Computer vision.

Please visit <https://scholar.google.com.pk/citations?user=W9brBMQAAAAJ&hl=en> for an overview of my published work for more ideas.

I am happy to discuss thesis ideas for prospective students (including for projects other than those listed below) via email: [mamoona.asghar@universityofgalway.ie](mailto:mamoona.asghar@universityofgalway.ie) or in person.

### **Code: MA1**

#### **Title: Secure File Sharing System Using Blockchain Technology**

This project will create a platform where users can securely upload, share, and access files. Key features include user authentication with public-private key pairs, file encryption for confidentiality, blockchain integration for tamper-proof transaction logging, fine-grained access control, and cryptographic hash functions for file integrity. Decentralized storage solutions like InterPlanetary File System (IPFS) will ensure file availability and redundancy.

### **Code: MA2**

#### **Title: Chatbot for Real-Time Security Monitoring**

This project aims to create a chatbot that interfaces with Security Information and Event Management (SIEM) tools to provide real-time insights into security events and assist with incident response. The chatbot will retrieve and display security alerts, logs, and analytics, enabling security teams to identify and respond to potential threats quickly. The chatbot will notify users of critical security events in real-time. Users can query the chatbot for specific incidents or logs. It will provide detailed information about security events. The developed chatbot can also be deployed on platforms like Slack, Microsoft Teams, or a web interface.

### **Code: MA3**

#### **Title: Lightweight Motion Detector**

A motion sensor project that detects motion, summarised those frames, and may sound an alarm accordingly. This software system will constantly monitors an environment using a Raspi camera and sounds an alarm and records images of the motion taking place as soon as it takes place. Every video frame will be numbered and also take time, so that motion timing can also be recorded. Security codes will also be set up for activating and deactivating alarms.

### **Code: MA4**

#### **Title: Facial Expressions Recognizer and person tracker**

The three most usable expressions will be recognized in this system, such as whether the person is smiling, sad, or shocked. Raspi Camera will be used to get live images and then the software system is designed first to detect and read a person's face. The system then computes o various facial parameters of the person's face. Upon detecting and registering these parameters, the system compares these parameters with default expressions for human sadness, smile, and human expressions. Based on these statistics the system concludes the person's emotional state. And also we can track the person's identity too by their names.

### **Code: MA5**

#### **Title: Image forgery Detector using Machine learning/Hashing**

As social networking services have grown in popularity, the volume of image data has increased. Furthermore, image processing software such as Adobe Photoshop has made it possible to edit images. Inciting violence and spreading false information can be accomplished with doctored images. This image forgery detection project allows students to detect even the slightest signs of forgery in an

image. Two methods can be deployed in this project. (1) image classification through machine learning algorithms, and (2) hashing technique can be implemented to check that either image is forged or not.

**Code: MA6**

**Title: Lightweight Image/video Encryptor**

This project can be implemented on Raspberry pi or also on a standard computer/laptop. The live images can be processed and taken through cameras or using built-in image databases. Similar to encryption on text, it can also be used for images by using different algorithms e.g. AES, DES, RSA, or genetic algorithms. All these algorithms are used for encrypting the images to defend them from a cyber hacker. Student can also design their own encryption algorithm by using permutation, substitution, and eXclusive OR (XOR) rounds. There could be more expansion in this project as per learning of students.

**Code: MA7**

**Title: Arduino based Cyber-Physical Systems**

This project includes the detection of power theft & a management system for the automatic bill. This project will use an Arduino board, voltage sensor & current sensor to discover the power theft & automatic billing system. If the user is connected to overload means, the amount of the bill was considered however the lamp should not turn on. So they need to call the electrical department person compulsory so that they control the load.

**Code: MA8**

**Title: Sandboxing for Malware Analysis**

In the world of cybersecurity, a sandbox environment is an isolated virtual machine in which potentially unsafe software code can execute without affecting network resources or local applications. Cybersecurity researchers use sandboxes to run suspicious code from unknown attachments and URLs and observe its behaviour. Malware is the Swiss-army knife of cybercriminals and any other adversary to the company or organization. In these evolving times, detecting and removing malware artifacts is not enough: it is vitally important to know how they work in order to comprehend the context, the motivations, and the goals of a breach. In this project, studying various malicious files (office documents, executables, emails, etc) as well as mischievous websites under Windows, Linux, macOS, and Android virtualized environments. Tracing the API calls and general performance of the file and distilling it into high-level data and signatures comprehensible by anyone. Scrap Heap and analyze network traffic flow, even when encrypted with SSL/TLS.

**Code: MA9**

**Title: Web Application Firewall (WAF)**

A Web Application Firewall helps protect web applications by cleaning and examining HTTP traffic between a web application and the Internet. It safeguards web applications from attacks such as cross-site forgery, cross-site scripting, file insertion, and SQL injection, among others. A WAF is a protocol layer 7 defense and is not intended to defend against all types of attacks. This method of attack modification is usually part of a suite of tools that all together creates a whole defense against a range of attack vectors.

**Code: MA10**

**Title: Passcode generator and strength checker tool**

In cybersecurity, strong passcode generation is key to surpassing guessing attacks on your accounts. Passcode strength is one of the essential elements. This passcode must include alphabets, digits, and different symbols. In this project, students will generate passcodes using different images, too. You would also create a tool to check its strength, informing you if it is secure to utilize.

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## Ihsan Ullah (IU)

I like to work on any of the following topics among Action/activity Recognition from Videos using Deep Learning, medical image processing, modelling light weight deep neural networks (e.g. CNN, 3DPyraNet), Object Detection and Tracking using deep models, Explainable AI, and Federated Learning.

Some specific projects are listed below:

### **Code: IU1**

#### **Title: Activity/Action recognition using light weight Deep Learning models**

Despite advances in image recognition, action recognition is still challenging as it contains insufficient information for proper classification of an action. Action/Activity recognition in a video has received significant attention because of its wide applications such as visual monitoring (in normal RGB videos, heat videos, and depth videos). Recent progress in deep learning algorithms and convolutional neural networks (CNNs) significantly improve the performance of many action recognition systems. However, these models are heavy (based on depth, width, number of parameters, and time it take). In this project, we intent to utilize and enhance a model that is light weight, fast, and need less time to train and test.

### **Code: IU2**

#### **Title: Person detection and Tracking using Deep learning models**

As the automotive industry progresses toward level four autonomous driving, the need for safety features such as reliable and fast pedestrian detection continues to be in high demand. The rapid growth in AI and its capabilities in recent years empowered researchers and automotive companies, allowing them to develop more performant deep learning models. However, the need for efficient and more accurate solutions in this domain persists. In this project we intend to use depth, thermal, and/or infrared images and videos as input to deep learning models.

### **Code: IU3**

#### **Title: Small object detection using deep learning**

Over the past decade, deep learning (DL) frameworks have achieved impressive success in solving complex problems in the areas of computer vision and image/video processing. Pre-trained networks and the availability of large datasets are making it easier to efficiently implement DL methods for object detection. However, small object detection at a distance is still a challenging area. In this project, the objective will be to propose light weight deep neural network for small object detection.

### **Code: IU4**

#### **Title: Using deep learning for Medical Image segmentation (e.g., MRI, CT, and Xray)**

There are different type of images that are used with machine learning or manually by specialists (cardiologists, radiologists, etc.) for various disease detections (e.g. cardiovascular, covid). One of the most serious cardiovascular events characterized by a growing yearly incidence, and the severity of disease prognosis is type-b aortic dissection. For its diagnosis, computer tomography (CT images) or CT angiography has been widely used. In this project, we will use CT images and deep learning models for segmentation of type-b aortic dissection despite false lumen thrombus which can be find in anywhere along the aorta with irregular shapes.

### **Code: IU5**

#### **Title: Understanding deep learning decision with explainable AI**

Trust and credibility in machine learning models are bolstered by the ability of a model to explain its decisions. While explainability of deep learning models is a well-known challenge, a further challenge is clarity of the explanation itself for relevant stakeholders of the model. In this project, we intend to use explainable AI techniques for understanding bias as well as important features that are impacting the decision of a deep neural network.

### **Code: IU6**

#### **Title: Using deep learning models for EEG signal processing**

The habits of a driver have a significant impact on the environment and sustainability. Poor driving habits can lead to wastage of fuel, affects traffic flow, etc. The objective of this project is to develop an algorithm for detection of multiple driving behaviours (DBs) like alertness, aggressiveness, etc. The

project aims to use electroencephalogram (EEG) data from different scenarios and to apply state-of-the-art artificial intelligence techniques to detect poor driving habits to support sustainable driving.

**Code: IU7**

**Title: Creating a Benchmark dataset for segmentation of Underwater objects**

The ocean represents 70% of the earth surface. Various datasets for segmentation have been proposed for in land objects. However, underwater datasets have remained unexplored due to data inaccessibility. It poses distinct challenges; the underwater environment exhibits non-uniform lighting conditions, low visibility, lack of sharpness, low contrast, camouflage, and reflections from suspended particles. Performance of traditional object segmentation, recognition, and tracking algorithms drops rapidly as they are not trained on large scale datasets. In this project, first we would create a dataset for segmentation data and then do benchmarking with various available deep learning models.

In general, I am interested in supervising deep learning and computer vision related projects. You can visit my website to see some past papers and projects that I worked on.

<https://sites.google.com/view/drihsanullah/research?authuser=0>

If you would like to work on any of that, feel free to contact me. Similarly, feel free to contact me to discuss any relevant project or ideas that you might have and on which you want to work.

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## Takfarinas Saber (TS)

### **TS1: An application for the exploration of Net-Zero pathway data**

Unprecedented extreme weather events highlight the critical need for achieving Net-Zero greenhouse gas (GHG) emissions.

This project seeks to make a contribution to addressing this challenge by developing a user-friendly application focused on the Agriculture, Forestry, and Other Land Use (AFOLU) sector for Ireland. The application leverages a large database of scenarios generated by the GOBLIN land balance model (produced at the Ryan Institute, University of Galway). This data, encompassing >26 tables, covers key areas like GHG emissions, economic factors, agricultural inputs, and land-use changes.

The App would include the following features:

- Visualize data: Through clear visualizations, users can understand how livestock reduction impacts the path to Net-Zero.
- Filter scenarios: Users can specify their preferred level of livestock reduction to see relevant pathways.
- Summarize results: The app offers concise summaries of the filtered scenarios.

By making complex AFOLU data accessible and understandable, this application will allow users to explore different scenarios and identify feasible pathways for achieving Net-Zero goals.

### **TS2: Data Analytics and Machine Learning techniques for the Net-Zero scenarios**

Unprecedented extreme weather events highlight the critical need for achieving Net-Zero greenhouse gas (GHG) emissions. This project seeks to make a contribution to addressing this challenge by developing a user-friendly application focused on the Agriculture, Forestry, and Other Land Use (AFOLU) sector for Ireland.

The project will leverage a large database of scenarios generated by the GOBLIN land balance model (produced at the Ryan Institute, University of Galway). This data, encompassing >26 tables, covers key areas like GHG emissions, economic factors, agricultural inputs, and land-use changes.

Objectives:

- Data Analytics: Through clear analytics and visualizations, investigate how GHG reductions could impact the path to Net-Zero.
- Machine Learning: Predict the impact of different mitigation levels relative to pre-mitigation data
- Recommendation: identify optimum combinations of mitigation and land cover change.

### **TS3: Evaluating Source Code Similarity Techniques**

A large number of studies (have and) are looking at automation in computer programming, where the goal is to make the programmers' job easier by providing them with various tools and approaches for generating and improving source code. In this project, you will investigate the assessment of source code comparison techniques. Identifying similar codes will help leverage the large amount of source code available in various software repositories (e.g., github, stackoverflow) to recommend better (i.e., more efficient and clean) code refactoring/substitution.

### **TS4: Evolving Interpretable Traffic Routing Strategies**

With the number of drivers using on-board navigation systems on the rise, drivers get real-time information regarding traffic conditions which enables them to change their routes and avoid closed roads or circumvent major hotspots. However, changing a route based only on current traffic conditions is not a guarantee of a lower overall travel time as traffic conditions can change drastically over time—especially in urban scenarios. In this project, you will use evolutionary algorithms (e.g., Grammar-Guided Genetic Programming algorithm) to devise better traffic rerouting strategies specific to particular road networks (e.g., cities, villages, motorways).

### **TS5: Higher Order Interpretable Regression Models for Economic Data**

Many empirical studies attempt to identify the factors explaining the differences in countries' economic growth rates by regressing GDP growth on a large set of country characteristics that could possibly affect growth. However, for interpretability reasons, these studies focused mostly on linear models--with at-most simplistic hand-crafted features (e.g., square features, multiplication between two features). In this project, you will create various predictive economic growth models (with various complexities) and assess their trade-offs in terms of growth predictive performance and interpretability.

In this project, you will devise techniques to identify engagement and inclusion issues within slides and recommend potential modifications to make them more engaging (e.g., animations, images, infographics) and multi-cultural (more diverse examples/usecases).

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**Code: BC1**

**Title: Identifying inappropriate behavior in online gaming**

The term "massively multiplayer online role-playing games" refers to a type of online computer game that enables players of different ages, genders, nationalities, and cultures to engage in social interaction inside a virtual setting. Users often have a good time when working together to complete missions, construct, or explore; yet, a significant number of players report experiencing some type of abuse. As part of this project, you will investigate potential indications of harassment in a digital gaming environment and report your findings on how to find abuse automatically.

**Code: BC2**

**Title: Zero-Shot Learning and Applications**

The term "zero-shot learning" refers to a revolutionary approach to the process of learning how to recognize new ideas by only being provided with a description of them. For instance, zero-shot learning can be used to solve a classification problem when there are no labelled training examples available for all classes. In this scenario, the classes are separated into two class subsets: training classes and unseen classes. In this scenario, there are only examples of training classes available to be used in the process of constructing a classifier. The purpose of this project is to examine effective zero-shot learning approaches as basic research, as well as their applications in real-world situations such as multi-media information retrieval and multi-task reinforcement learning.

**Code: BC3**

**Title: Multi-task Learning and Applications**

A learning system may be trained in standard machine learning to deal with a specific single task, however humans are able to do several tasks using the same learning technique. Traditional methods of machine learning have their limits, and in order to overcome these, multi-task learning strategies are required for artificial intelligence (AI). A learning system operates for different tasks in AI by sharing relevant information between tasks. This makes it possible to learn a new task in a more time- and resource-effective manner and allows the learning system to generalize more effectively across numerous tasks. This project is going to develop novel learning systems and learning algorithms for multi-task learning. These learning paradigms range from supervised learning to unsupervised learning to reinforcement learning, and their applications to real world problems are going to be researched and developed as part of this project.

**Code: BC4**

**Title: Comparative analysis of ML's capacity for explanation**

There is a lot of conversation going on about making machine learning models more explainable. Although there is a common sense belief that some techniques for generating models are more easily explicable than others (for example, neural networks as opposed to decision trees), there is not much in the way of a comprehensive analysis that compares the various approaches. The purpose of this project is to conduct such a comparison by defining a variety of metrics and criteria and rigorously evaluating a range of methodologies in order to produce data highlighting the differences as well as significant elements and considerations.

**Note:**

I am also happy to discuss students' own project ideas in the areas of chatbot, natural language processing, bias in machine learning, and multimodal machine learning.

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## Owen Molloy (OM)

I am happy to supervise projects of the students' own design also, particularly in the areas of simulation, machine learning, analytics and visualisation.

Analysis, Design and Development Projects

**Code: OM1**

**Title: FoodMiles App**

You are in the supermarket and consider buying beans grown in Africa. There are other organic locally produced alternatives, but they are a little more expensive. With this app, you can find information on how foreign-grown food has reached your local supermarket. Maps can be used to illustrate food journeys and travel times. Information and graphics / videos, and links to journalist articles can be added to information on how food is grown, harvested, stored and shipped. Information on working conditions for those involved in the food industry can also be added.

**Code: OM2**

**Title: Trip Weather Activity Planner**

You are planning a trip covering a number of different locations over a particular period. This app will allow you to see the current weather conditions in each of the places you plan to visit. The app will need to use a weather service API site such as weatherstack, as well as mapping libraries to visualise the trip and the weather along the way. You could also include information on your hobbies and what activities are available at each location, so that suitable activities could be suggested based on the predicted weather conditions.

**Code: OM3**

**Title: Horticultural Services Planner**

You are running a popular gardening service, providing services such as lawn mowing, pruning, weeding, tree cutting etc. Unfortunately, you often find yourself short of time, or having too many lawns to mow too far apart in a very short space of time. This app will allow you to use mapping to specify the location of each customer, and the jobs they want done. You will need to find and apply algorithms to optimise your time, taking travelling into account. It will keep track of what you have done last, and what needs to be done next, based on parameters you decide, such as mowing schedules, time of year etc. The app should enable you to simply keep track of what activities are completed and create simple bills for customers. The app should be able to message or email information to yourself and customers as needed. Weather API's could also be used to provide information on what activities are feasible on given days.

**Code: OM4**

**Title: "Cause and Effect" Modelling and Visualisation**

In all kinds of projects, in all kinds of industries, we experience risks (to the success of the project), and failures. There are numerous ways used to categorise, monitor and control these risks, such as Cause-and-Effect diagrams, Fishbone diagrams, FMEA (Failure Mode and Effects Analysis). Ultimately, the models underlying these tools are directed graphs, linking chains of causes and effects to outcomes (and their severity and risk of occurring). In this project you will undertake research into the different tools used to model and visualise risk / cause and effect. You will design and build a web-based app to allow people to build and visualise cause and effect models, store them in a graph database, and search the database to find linked causes and effects. The app should incorporate drag and drop functionality and display your skills in design and visualisation.

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## Colm O'Riordan (CR)

My research interests are in the domains of game theory, evolutionary computation and information retrieval.

I am happy to discuss project proposals in these, and related, domains.

### **Code: CR1**

#### **Title: Evolutionary Game Theory**

Game theory is the study and analysis of strategic decision making and has a wide range of applications. In our recent work, we have been interested in evolutionary spatial game theory and have focussed on games where players can abstain or where players can move their position to alter their interactions. This project will involve exploring other less studied interaction models with a focus on identifying conditions that lead to beneficial global outcomes. Projects will involve exploring different games, the effects of different topologies and potentially different interaction models.

### **Code: CR2**

#### **Title: Graph colouring algorithms**

Graph colouring is a well-known topic in graph theory with a wide range of applications in the domains of optimisation. Projects in this domain will involve exploring distributed algorithms to identify the minimum number of colours need to colour the graph. The algorithms will be tested on a range of different graph types.

### **Code: CR3**

#### **Title: Analysis of sports data**

Data science continues to play an increasingly large role in the domain of tactical and strategic analysis in sport. Increasingly rich data sets taken from training and competitions coupled with more sophisticated and nuanced tactical understandings have led to a growing interest in the extraction of information from these data sets. This project will explore suitable approaches to extract and analyse data from sports events. This project will involve learning and classification techniques to identify important features in the sports events. We will focus on team games as there is often a richer strategic and tactical element.

### **Code: CR4**

#### **Title: Composition of chess puzzles**

This project will attempt to develop algorithms to automatically compose chess problems/puzzles. The project will initially concentrate on end games or mate-in-k situations and attempt to generate puzzles based on difficulty and aesthetic merit. Having achieved this, more complex scenarios and analysis will be undertaken.

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## Malika Bendechache (MB)

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I am interested in projects in the areas of:

- Machine Learning;
- Big Data Analytics;
- Application of AI and ML in Healthcare;
- Data Governance (Data Quality, Data Value, Data Protection/Privacy, Data Ethics);
- Ethics and Trustworthy AI.

I welcome and happy to discuss student ideas and project suggestions aligned to these areas.

### Code MB1:

#### Title: Data value assessment model using data analytics

Data is becoming one of the world's most valuable resources and it is suggested that those who own the data will own the future. However, while companies can collect and store more and more data, they are struggling to assess its value (e.g., in terms of volume, usage, utility, quality, timeliness)—a task called data value. Some recent pioneer works have led to an increased awareness of the necessity for measuring data value. They have also put forward some simple but engaging survey-based methods to help with the first-level data assessment in an organization. However, these methods are manual and they depend on the costly input of domain experts. This project aims to develop an automatic, metric-based data value assessment and visualization framework to help companies quantify the business value of a given database.

### Code MB2:

#### Title: Predict the house pricing in Ireland

The price of buying or renting a house in Ireland is becoming very expensive in the last few years. Since 2013, the prices kept going up and the demands surpass the offers. This project is about using the rent price [dataset](#) published by CSO to build a predictive model to predict house prices in Ireland.

### Code MB3:

#### Title: Bike Sharing App/Website

Thanks to its extensive network of bike paths, Galway is a fantastic city for cycling as it enables both its commuters and visitors to travel easily around the city.

To promote cycling, Galway council has put in place a bike sharing system whereby anyone registered to the scheme can freely pick up, ride and drop off a bike at one of the numerous bike stations across the city.

While the bike sharing system is a huge success, many people still complain about the lack of communication regarding bike availability at some bike stations—particularly during rush hours. The objective of this project is to develop a Web application that improves the bike sharing experience in Galway by providing existing and new users with real-time bike availability information at each bike station as well as enabling them to book a bike online.

### Code: MB4:

#### Title: Student Carpooling

Several University of Galway students are using cars for their daily commute to the university. However, as the cost of owning and driving a car is rising, students are more numerous to turn to alternative solutions such as carpooling; i.e., the sharing of car journeys. In addition to alleviating the hefty cost of owning and driving a car for students, carpooling has the potential to decongest Galway roads and reduce gas emissions. The goal of this project is to design and develop an app to facilitate the carpooling of University of Galway students. The app will enable passengers and drivers to input their details (e.g., location, desired departure time, constraints, etc). It will also connect potential passengers with matching vehicle owners, enable them to book seats and provide a place to rate their reputation.

### Code: MB5:

#### Title: An app to promote seasonal food in Ireland

Buying local and seasonal Irish foods has numerous benefits. Firstly, for your health: you know what you buy as fresh produce that tastes better and that is more traceable. Secondly, for the Irish economy:



the money you spend stays in Ireland and supports our farmers and communities. Lastly, for the environment: more energy is required to transport, refrigerate and store it.

The goal of this project is to design and develop an app to promote buying local Irish seasonal food from Irish farmers and shops. The app will showcase local Irish vegetables during their season (this is particularly useful in winter), give tips (e.g., recipes, calories), and provide some interesting facts about the vegetables (onions are high in vitamin c and a bit of history about it). The app will also connect consumers with local farmers and shops and buy their listed products.

**Code: MB6:**

**Title: Visualisation of Brain Tumor Segmentation: A Graphical Interface using BRATS2020 Dataset**

The project aims to develop a graphical interface for visualising brain tumor segmentation using the BRATS2020 dataset. The interface will integrate advanced image processing techniques and machine learning algorithms to provide medical professionals with a user-friendly tool for exploring segmented brain tumors. By enhancing the interpretation of medical imaging data through detailed visual overlays and annotations, the project seeks to improve diagnostic accuracy and facilitate more precise treatment planning for patients with brain tumors. This project merges interests in computer vision, medical imaging, and software development to contribute to advancements in healthcare technology.

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## Effirul Ramlan (ER)

My research focuses on developing biocomputers that can perform complex molecular-level information processing in biological systems. Alternatively, I'm also interested in applied AI solutions in life sciences and healthcare, and explorative unconventional models for theoretical or applied computing problems. Or anything that you are curious about, we can discuss further.

Note: All titles are tentative and subject to change (to something more appropriate).

### **ER01: Molecular-scale Rubik's**

Develop an intuitive, no-code platform that allows researchers (regardless of their knowledge in biochemistry and molecular biology) to design complex DNA geometrics for molecular information processing.

Ref: <https://phys.org/news/2019-04-molecular-scale-rubik-cube.html>

### **ER02: Find-Me**

Develop an advanced AI-powered assistant, integrating Large Language Models (LLM) with a Retrieval-Augmented Generation (RAG) framework to create a highly responsive and context-aware recommendation system, akin to the Jarvis AI in the Iron Man series.

\*\* Notes – There are a few domains that we explore in terms of application, e.g., electronic products, household products, holidays, music, books, etc. Therefore, you can have multiple Find-Me-\*\* sub-projects.

Ref: <https://www.wired.com/story/fast-forward-tested-next-gen-ai-assistant/>

### **ER03: Help-Me-Code**

Develop an AI-coding assistance with CodeLLaMa to help students tackle programming assignments at the fundamental level. Why? Because GitHub Copilot is not a free service, and because we plan to do better than the other free alternatives (e.g., Captain Stack, GTP-CC, etc).

Ref: <https://ai.meta.com/blog/code-llama-large-language-model-coding/>

### **ER04: What-to-Watch**

Develop an AI-powered application that automatically generates concise and insightful summaries of movies while also evaluating their quality and suitability for individual users. Leveraging advanced language models like GPT-4, the system will analyse movie scripts, subtitles, reviews, and metadata to produce brief summaries and assess factors such as plot coherence, character development, and critical reception.

Ref: <https://unsummary.com/movies>

### **ER05: Slide-Master**

Develop an AI-powered application that helps users create visually appealing presentations using Markdown or Notion pages. This tool will enhance content to improve the overall presentation quality by optimising layouts, formatting text, and generating high-quality visuals. The system will also analyse content structure and style, making suggestions to improve clarity and engagement. Users will have the option to generate entire slide decks automatically based on provided content, making it ideal for both quick drafts and polished presentations.

Ref: <https://github.com/markslides>

**ER06: Zero-Bet**

Develop an AI-powered betting prediction system for Premier League games using advanced reinforcement learning techniques inspired by AlphaZero and MuZero. The model will be trained to predict match outcomes by learning optimal betting strategies through self-play and reinforcement learning. By analysing historical match data, player statistics, and live game metrics, the system will make real-time predictions on win probabilities, scores, and potential betting odds, offering valuable insights to enhance decision-making in sports betting.

\*\* While we're at it, maybe we can explore NFL, NBA, GAA (Why not ?!)

Ref: <https://www.techopedia.com/gambling-guides/ai-sports-betting-predictions-sites>

**ER07: Mr. Scholar**

Develop a research assistant that will search for relevant academic papers across multiple databases like Google Scholar, analyse them, and highlight key findings. The assistant will categorise papers based on relevance to the user's query, provide summaries, and recommend which papers require a detailed review. This tool will help streamline literature reviews, making research more efficient and less time-consuming for scholars across various fields.

Ref: <https://scite.ai/>

**If you have any other ideas, let's explore them together.**

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The broad areas of my research are computer network protocols, network traffic measurement, machine learning, and cybersecurity. I am happy to discuss project ideas in related areas.

**Code: JMZO1**

**Title: Performance Evaluation of QUIC transport protocol**

QUIC is a new transport protocol which was originally designed by Google and recently standardized by the Internet Engineering Task Force (IETF). QUIC has replaced TCP protocol for the web. The aim of this project is to compare the performance of QUIC protocol in various network conditions using new web performance measurement metrics like Core Web Vitals.

**Code: JMZO2**

**Title: Congestion Control in QUIC transport protocol**

The aim of this project is compare the performance of different congestion control algorithms in QUIC protocol, such as CUBIC, NEWRENO, BBR, COPA using simulations.

**Code: JMZO3**

**Title: Anomaly Detection in IoT**

Internet of Things (IoT) is a rapidly expanding field. At the same time, it is also an attractive target for attackers. The aim of this project is to do analysis of the state-of-the-art in IoT anomaly detection and propose new and improved methods using machine learning.

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