Msc Project Proposals: 2023 - 2024

PID	Supervisor	Description
1803311	**Abu Ebayyeh,A.** **Machine Learning for Industrial Applications** **Offered to: AML** **From:**	The fourth industrial revolution (industry 4.0) is concerned towards applying smart manufacturing techniques and automation in different industries. In order to do that, machine learning techniques can be implemented in the data-drive approaches for automating the industrial processes. This includes predictive maintenance, computer vision, quality management and anomaly detection. The aim of this project is to utilise machine learning approaches in industrial use-case in order to improve the production performance. Different topics are expected to be dealt with in this project such as big data, computer vision, data augmentation, and deep learning. It is desirable for students who are interested in this project to have the following skills: 1- Good analytical thinking. 2- Knowledge in image processing. 3- Knowledge in data pre-processing and cleaning. 4- Good Python programming skills. References: Ahmad, H.M. and Rahimi, A. (2022) "Deep learning methods for object detection in Smart Manufacturing: A Survey," Journal of Manufacturing Systems, 64, pp. 181–196. Dengler, S. et al. (2021) "Applied Machine Learning for a zero defect tolerance system in the Automated Assembly of Pharmaceutical Devices," Decision Support Systems, 146, p. 113540. Mangal, A. and Kumar, N. (2016) "Using big data to enhance the Bosch production line performance: A kaggle challenge," 2016 IEEE International Conference on Big Data (Big Data). https://aws.amazon.com/solutions/implementations/predictive-maintenance-using-machine-learning/
1803268	**Angeli,D.** **Economic Model Predictive Control of Wind Turbines** **Offered to: Control** **From:** **CAP**	We will study and design feedback strategies for optimizing energy capture from wind turbines, by suitably regulating their operating speed and blades' pitch angles. This will be carried out by solving on line a dynamic optimization problem rather than a static one. Simulations could be performed on Matlab or on any other platform chosen by the student. The issue of plant-model mismatch will be studied. BACKGROUND: model predictive control, optimization

PID	Supervisor	Description
1803269 **Data-driven Model Predictive Control in Noisy Environments** **Offered to: Control** **From: CAP**	**Angeli,D.**	Model Predictive Control is a control synthesis methods that translates a control performance objective into a suitable optimisation problem to be repeatedly solved on-line. As the name suggest the basic idea is that, availability of a model, allows to predict future trajectories and shape them in order to meet control objectives. A recent trend is however to replace availability of a model with availability of historical data, which can be used directly to make inference of future solutions in order to design control actions. The aim of this project is to develop so called data-driven MPC algorithms in the presence of noisy historical data, so that particular care should be used in the way the data is treated in order to find a good solution to the control design problem. Desirable Background: Optimisation, Predictive Control, MATLAB
1803270 **Social optimization without trust: a case study** **Offered to: Control** **From: CAP**	**Angeli,D.**	Social optimization aims at choosing the value of a variable that affects multiple agents so as to optimize overall performance of a system. Normally we would like to do this under the assumption that each agent knows his own cost function and cooperates with the rest to seek the solution to an optimization problem involving a separable objective function. Typically agents only exchange information with their neighbours and might not have knowledge of other agents' objectives. While this is useful in a set up where agents trust each other, such as in a multiprocessor computer system, it might not be directly applicable to contexts where agents are physically distinct entities who might not trust other agents' goals, (for instance in a smart grid). We will investigate the possibility of algorithms where trust is recovered by introducing incentives and payments to a central entity on the ground of the damage each agent is causing to society. We will try a case study where some of the agents are malicious and attempt to disrupt the optimization protocol. For more information see: David Angeli, Sabato Manfredi, Gradient-based local formulations of the Vickrey–Clarke–Groves mechanism for truthful minimization of social convex objectives, Automatica, Volume 150, 2023
1803271 **Learning to control a pendulum with data-driven predictive control.** **Offered to: Control** **From: CAP**	**Angeli,D.**	Pendulums are examples of very non-linear and unstable processes and serve as a toy model of more complicated devices in real-world applications. The goal of the project is to device a Predictive Control algorithm that gradually adapts and learns the dynamics of the pendulum (nonlinear and hence "new" each time a different region in state-space is explored) in order to balance it in the upwards position, viz. around an unstable equilibrium, or dampen it around the downwards position. This can be challenging even in the presence of a model due to potential uncertainties and disturbances and we would like to compare the traditional approach with one where the model is not assumed to be known, while the pendulum is treated as a black-box, with as little prior information as possible. Desirable Background: Control Engineering, Model predictive Control, Optimisation, MATLAB

PID	Supervisor	Description

1802905   **Bannon,A. (with Constandinou,T.)**

Unobtrusive in-home sensing using radar for dementia care and research: assessing coverage of different radar-on-chip platforms

Offered to: Control ADIC AML FPN CSP

From: **CAS**

The UK Dementia Research Institute (UKDRI) Care Research and Technology (CR&T) Centre's core mission is improving dementia care by using new technologies. This is uniquely challenging in dementia, particularly relating to people living with dementia (PLWD) using and engaging with technology. It is therefore essential to co-create with key stakeholders (PLWD, carers, clinicians, scientists) and adopt a user-centred design strategy. This has helped define our focus to create technologies that encourage deployability (low cost, scalability) and good compliance (uptake and adherence).

Our research aims to create novel bioelectronic systems that will enable continuous, unobtrusive monitoring and new interventions to improve outcomes in PLWD. More specifically, we are developing a new wall-mounted radar technology to sense human physiology and behaviour in a completely remote, unobtrusive manner that respects privacy. We are currently working towards integrating our radar device within the Minder smart home infrastructure and deploying this in the homes of 100 PLWD to assess their health and wellbeing longitudinally. This will enable the observation of disease progression by providing new physiological and behavioural measurables unobtrusively at home, improving the assessment of therapeutic interventions such as pharmacological efficacy, behavioural adjustments for sleep, and facilitating further research in dementia.

This MSc thesis project will assess key performance parameters (e.g. coverage, sensitivity to sensing breathing signals) in real-world settings between different radar-on-chip configurations. This will involve experimental (designing and conducting a trial) in addition to computational aspects (signal analysis/processing). A successful project conclusion will contribute to our ongoing research -- with the possibility of publication.

1803097   **Barria,J.A.**

Data Stream evolution analysis using Multiresolution Wavelet Transform

Offered to: Control ADIC AML FPN CSP

From: **ISN**

This project will investigate a wavelet based classification algorithm that implements and early warning scheme as well as being able to track the evolution of the anomaly in time and space.

For the specific case of vehicular traffic, it combines the spatiotemporal changes in the variability of microscopic vehicular traffic variables, namely, relative speed, inter-vehicle time gap, and lane changing. In this context, a micro-simulation tool will be used and implemented in MATLAB environment. Then the performance of the classification algorithm and evolution of the anomaly on several scenarios will be assessed (in rural as well as urban environments). Different early warning mechanisms will be investigated.

Once the algorithms have been developed and tested their performance will be validated using real world data from, e.g., microscopic trajectory data extracted from CCTV cameras (NGSIM: http://ops.fhwa.dot.gov/trafficanalysistools/ngsim.htm)

Note that other real-world data stream will also be available to test the developed algorithms and schemes.

If time permits, decentralised anomaly detection and evolution algorithms will be developed and assessed.

1803100   **Barria,J.A.**

Time series anomaly detection using contrastive learning

Offered to: Control ADIC AML FPN CSP

From: **ISN**

In real world scenario, the performance of the classification algorithms degrades when there is little difference between the classes. Contrastive learning, a representation learning technique, is able to learn a new feature space with a closer distance for data coming from the same class; therefore, it can enhance the algorithm's performance. In this project, different loss functions for contrastive learning will be assessed; the new feature representation will be used for different anomaly detection algorithms. The performance of the proposed algorithm on several anomaly scenarios will be assessed and validated using real-world datasets.

PID	Supervisor	Description
1803103	**Barria,J.A.** **Early warning algorithms using Wavelet probabilistic Neural Networks** **Offered to: Control ADIC AML FPN CSP** **From: ISN**	This project will investigate anomaly detection algorithms that could combine complementary classifiers in order to enhance the robustness of the developed algorithms. The project will start with a literature review of existing hybrid classification approaches, assessment of the most promising ones and if possible add further enhancements. The algorithm will be simulated in Matlab and will be evaluated using benchmark datasets.
1803107	**Barria,J.A.** **Traffic anomaly analysis and congestion precursor detection** **Offered to: Control ADIC AML FPN CSP** **From: ISN**	This project will investigate a novel anomaly detection and classification algorithm that combines the spatiotemporal changes in the variability of microscopic vehicular traffic variables, namely, relative speed, inter-vehicle time gap, and lane changing. First a micro-simulation tool will be used and implemented in MATLAB environment. Then the performance of the classification algorithm on several anomaly scenarios will be assessed (in rural as well as urban environments). Different early warning mechanisms will be investigated. Decentralised anomaly detection mechanisms will be developed and assessed. Once the algorithms have been developed and tested their performance will be validated using real world data from, e.g., microscopic trajectory data extracted from CCTV cameras (NGSIM: http://ops.fhwa.dot.gov/trafficanalysistools/ngsim.htm)
1803293	**Bhandari,A.** **Audio Source Separation from Modulo Samples** **Offered to: Control ADIC AML FPN CSP** **From: CSP**	The goal of this project is to develop signal processing algorithms for audio source separation using modulo non-linearities. Please see the following page for description of MSc projects and from the list, select the appropriate project. https://docs.google.com/document/d/1-Fvad89qrr82MtHL7lBGpOg1OBsI8ljFOYXUmcaZaJo/edit?usp=sharing

PID	Supervisor	Description

1803294   **Bhandari,A.**

Inverse Problems with Folding Non-linearities.

Offered to: Control ADIC AML FPN CSP

From: CSP

In recent years, we've been actively advancing our groundbreaking sensing and imaging technology called "Unlimited Sensing."

http://alumni.media.mit.edu/~ayush/usf.html

This innovative technology enables the simultaneous capture of high-dynamic-range and high-digital-resolution information through hardware-based modulo folding. This exciting development has sparked the creation of various novel signal processing algorithms.

This announcement serves as an open invitation. We welcome interested students to reach out and engage in a conversation to learn more about this cutting-edge technology.

Skills:

Functional knowledge of signal processing and related topics. Excellent programming skills (Matlab/Python etc.). The research work will be based on mathematical analysis and the implementation of algorithms. Where possible, we will also verify the algorithms on the hardware data. Deliverables include project reports and code.

Exceptional students who can potentially convert this research into a top-quality conference/journal paper can continue with doctoral work.

1803295   **Bhandari,A.**

Hardware Testbed for Unlimited Sampling Architecture

Offered to: Control ADIC AML FPN CSP

From: CSP

Signal saturation or clipping is a fundamental bottleneck that limits the capability of analog-to-digital converters (ADCs). The problem arises when the input signal dynamic range is larger than ADC's dynamic range. To overcome this issue, in the last 2-3 years, we have been developing a new framework for high dynamic range (HDR) signal acquisition known as the Unlimited Sensing Framework (USF).

In the previous FYP, we have developed a hardware prototype for implementing this idea. More information is below.

-- LIVE DEMO here: https://youtu.be/i1mdqrxS5cU

-- Check out the Imperial New Coverage on our work here: https://www.imperial.ac.uk/news/230093/unlimited-digital-sensing-unleashed-imaging-audio/

The goal of this project is to develop an electronic hardware testbed that can advance the technological frontiers for digital sampling of signals. Current implementation of the circuit suffers from some severe limitations. The goal is to go beyond such limitations and push the limits of acquisition.

Background in circuit design and familiarity with prototyping is a must.

PID	Supervisor	Description

1803296 **Bhandari,A.**

High Dynamic Range Thermal Imaging and Reconstruction

Offered to: Control ADIC AML FPN CSP

From: **CSP**

Current thermal imaging sensors are limited in their dynamic range. To overcome this omnipresent bottleneck, recently, we have proposed an alternative digitial acquisation pipeline which is based on a joint design of hardware and algorithms. On the hardware front, the conceptualized imaging sensor acquires modulo of the input signal. This folds the High Dynamic Range signal into Low Dynamic Range measurement. There after, new signal processing algorithms recover the HDR signal/image.

In the previous FYP, we have developed a hardware prototype for implementing this idea. More information is below.

-- LIVE DEMO here: https://youtu.be/i1mdqrxS5cU

-- Check out the Imperial New Coverage on our work here:
https://www.imperial.ac.uk/news/230093/unlimited-digital-sensing-unleashed-imaging-audio/

In the current project, the goal is to develop reconstruction algorithms for thermal images. We have recently acquired a thermal imaging sensor. As a part of the project, we will be validating our algorithms on real data.

Skills:

Functional knowledge of signal processing and related topics. Excellent programming skills (Matlab/Python etc.). The research work will be based on mathematical analysis and the implementation of algorithms. Where possible, we will also verify the algorithms on the hardware data. Deliverables include project reports and code.

Exceptional students who can potentially convert this research into a top-quality conference/journal paper can continue with doctoral work.

1803297 **Bhandari,A.**

Photoplethysmogram Modelling and Recovery via Unlimited Sampling

Offered to: Control ADIC AML FPN CSP

From: **CSP**

A photoplethysmogram (PPG) is a valuable optically acquired plethysmogram used to detect changes in blood volume within the microvascular tissue bed. PPG data is typically collected using a pulse oximeter, which emits light through the skin and measures variations in light absorption. A traditional pulse oximeter primarily monitors blood perfusion in the dermal and subcutaneous tissue layers of the skin.

In each cardiac cycle, the heart pumps blood to the peripheral areas of the body. Despite some attenuation of this pressure pulse as it travels to the skin's surface, it is still sufficient to dilate the arteries and arterioles in the subcutaneous tissue. When a pulse oximeter is applied without exerting excessive pressure on the skin, it can also detect a pressure pulse originating from the venous plexus, manifesting as a minor secondary peak.

The overarching objective of this project is to formulate mathematical models for the PPG signal when sampled using the Unlimited Sensing Framework. Additionally, the project aims to develop innovative recovery algorithms tailored to this unique sensing framework, thereby advancing our understanding and capabilities in PPG signal analysis and processing.

PID	Supervisor	Description

1803298   **Bhandari,A.**

High Dynamic Range Lightfield Imaging in Fourier Domain

Offered to: Control ADIC
             AML FPN CSP

From: **CSP**

The light field representation can be demonstrated as a collection of layers that can be effectively generated in the Fourier domain using a sparse set of viewpoints. These layers can subsequently be utilized to reconstruct intermediate viewpoints without the need for a disparity map.

The primary objective of this project is to delve into the Fourier structure of light fields, leveraging it to facilitate high-dynamic-range (HDR) sampling and recovery. This approach aims to enable applications such as "capture first, focus later," revolutionizing the way we capture and interact with visual information.

1803299   **Bhandari,A.**

Acoustic and Audio Logging using a New Digital Sensing Principle

Offered to: Control ADIC
             AML FPN CSP

From: **CSP**

This project is centered around leveraging our initial hardware design to revolutionize audio measurements by introducing a completely innovative approach. The objective of this project is to create an affordable, comprehensive acoustic logger capable of capturing sounds within the audible frequency range and extending its range into the ultrasonic frequencies.

The new part of the project is how the audio is captured. We will be using basing ourselves on the Unlimited Sensing framework, (patent US10651865B2) introduced by our group. It represents a groundbreaking technology that revolutionizes the recovery of high dynamic range signals from a constant factor oversampling of their low dynamic range samples. What sets this innovation apart is its remarkable feature: the oversampling factor remains independent of the maximum recordable voltage.

Traditional sensing systems, such as analog-to-digital converters, face limitations when a signal surpasses the maximum recordable voltage, leading to saturation or clipping. In sharp contrast, the unlimited sensing approach adopts an entirely novel sampling architecture that not only overcomes these limitations but also comes with guaranteed signal recovery capabilities. This advancement promises to reshape the landscape of signal processing and acquisition by enabling the capture of exceptionally high dynamic range signals with unprecedented fidelity.

1803300   **Bhandari,A.**

Image Feature Extraction in Computer Vision with Folded Images

Offered to: Control ADIC
             AML FPN CSP

From: **CSP**

In the realm of computer vision, the ability to detect and differentiate features such as edges, corners, blobs, ridges, and textures is paramount for interpreting scenes. Nevertheless, when confronted with high-dynamic-range scenes, a practical challenge emerges since "features" cannot be reliably extracted from overexposed or clipped images.

To overcome this saturation issue, we have introduced a novel imaging technique called the Unlimited Sensing framework, which involves folding the image prior to capture. This raises an intriguing question: Can we still extract meaningful image features from these folded representations?

The primary aim of this project is to lay the groundwork for addressing this challenge. Successfully addressing this question holds the potential to significantly advance the capabilities of vision and computational imaging tasks. For instance, it could pave the way for the creation of single-shot, high-dynamic-range (HDR) image panoramas, thereby enriching the possibilities and adaptability of computer vision applications.

PID	Supervisor	Description

1803301 **Bhandari,A.**

Coded Exposure Time-of-Flight 3D Imaging

Offered to: Control ADIC AML FPN CSP

From: **CSP**

Motion deblurring is a key source of bottleneck in 3D imaging. In this project, the main goal is to develop a novel strategy for time-of-flight based 3D imaging using coded exposures. This work is based on computational imaging and requires mathematical modelling and design of recovery algorithms.

1802979 **Bouganis,C.**

Mapping CNNs to FPGAs - Semantic segmentation

Offered to: Control ADIC AML FPN CSP

From: **CAS**

Convolutional Neural Networks or CNNs, is a class of neural network that has recently attracted the interest of many researchers and practitioners in image processing due to its excellent performance in object recognition tasks. However, its computational requirements has challenged the community in applying it under real-time constraints and low-energy consumption requirements.

The project focuses on the efficient mapping of Convolutional Neural Networks onto FPGAs and builds on an existing tool that has been developed in our group, fpgaConvNet. The tool takes as input a CNN and a target FPGA platform and automates the mapping of the CNN to the target FPGA optimising its performance.

The project aims to extend the tool to target semantic segmentation algorithms with the objective to produce customised architectures that accelerate the computation of the algorithm.

The project will involve a research stage for identifying a suitable algorithm for an FPGA implementation, a highly parameterised hardware architecture design and its implementation using RTL/Chisel/HLS, and a resource and performance model development to allow a design space exploration to be performed in order to identify a design that maximises performance given the workload and the target FPGA board.

The student should be familiar with FPGAs and the design of digital systems, as well as to be familiar with hardware design programming (RTL/Chisel/HLS)

1802983 **Bouganis,C. (with Wang,Sen)**

Accelerating Visual Simultaneous Localisation and Mapping (SLAM) System using FPGA

Offered to: Control ADIC AML FPN CSP

From: **CAS**

Visual Simultaneous Localisation and Mapping (SLAM) is a critical technology for autonomous robotics, enabling robots to navigate their environment in real-time. However, the computational demands of visual SLAM algorithms often limit their deployment on resource-constrained robotic platforms, e.g., aerial and underwater robots. This project aims to accelerate a Visual SLAM system using Field-Programmable Gate Arrays (FPGAs) to enable more efficient and cost-effective robotic navigation and mapping solutions. The project will involve design and implement FPGA hardware architectures for accelerating a chosen Visual SLAM algorithm while maintaining its accurate localisation and mapping performance.

A state-of-the-art visual SLAM system (programmed in C++) will be provided along with some test dataset collected from an on-board stereo camera. A physical robot platform can also be provided for testing if interested.

The project will focus on the hardware design aspect and more specifically on the design of an accelerator unit that will be placed in the FPGA and accelerate the computationally heavy parts of the algorithm. An initial faithful implementation of the system will be considered, and time allowed, numerical approximations will be explored to further accelerate the overall system considering the impact on the accuracy.

The project offers an opportunity for students who would like to delve into the intersection of hardware acceleration, robotics, and computer vision. Good knowledge of C++ and RTL is required.

PID	Supervisor	Description

1803174   **Bouganis,C.**

Revisiting the Exit-Policy of Dynamic Deep Learning Models

Offered to: Control ADIC AML FPN CSP

From: CAS

As deep learning models are becoming increasingly efficient by design (e.g. through the use of Neural Architecture Search methodologies that yield architectures with minimal computational redundancy), paving the last mile towards efficient DNN deployment increasingly relies to the concept of dynamic inference. In this setting, driven by the fact that not all inputs (images) are equally difficult to recognize, a different computational budget is assigned to each input in a dynamic manner (at runtime), according to its perceived difficulty. Although several different solutions have been proposed adhering to this principle (e.g. Early-exit neural networks, model cascades etc), commonly a confidence criterion is applied to act as an exit-policy, i.e. determine how much computation needs to be spent on each sample.

The main objective of the project is to implement and compare different such criteria (based on uncertainty estimation or learnable approaches) previously proposed in the literature, to better understand the pros and cons of each approach, as well as try to draw conclusions about the characteristics of "easy" and "hard" input samples. Potentially, this investigation can lead to the introduction of a new exit-policy, aiming to push the current speed-accuracy trade-off provided by current dynamic-inference paradigms for CNNs and Transformers.

Early-exit DNN overview:
Laskaridis, S., Kouris, A. and Lane, N.D., 2021, June. Adaptive inference through early-exit networks: Design, challenges and directions. In Proceedings of the 5th International Workshop on Embedded and Mobile Deep Learning (pp. 1-6).

Example of Early-Exit CNN:
Kaya, Y., Hong, S. and Dumitras, T., 2019, May. Shallow-deep networks: Understanding and mitigating network overthinking. In International conference on machine learning (pp. 3301-3310). PMLR.

Example of Early-Exit Transformer:
Wang, Y., Huang, R., Song, S., Huang, Z. and Huang, G., 2021. Not all images are worth 16x16 words: Dynamic transformers for efficient image recognition. Advances in Neural Information Processing Systems, 34, pp.11960-11973.

1803260   **Bouganis,C.**

Build a UAV interfaced with an embedded system

Offered to: Control ADIC AML FPN CSP

From: CAS

This is a design and build project, where the objective is to build a drone (UAV) platform that has the flexibility to be interfaced with embedded platforms such as embedded GPUs/CPUs/FPGAs and to demonstrate its capabilities. The emphasis of the project would be firstly on the design of the architecture of the system, as the platform should be able to operate remotely and autonomously using the on-board compute platform, and secondly on the demonstration of certain actions (like hovering, or autonomous navigation).

Interested students should have a passion and prior experience on building small UAVs, as well as some understanding of the software stack used in drones and on communication protocols. When it comes to the embedded platform, the emphasis can be either on the software or hardware design aspects.

PID	Supervisor	Description

1803365 **Bouganis,C.**

What's that sound

Offered to: Control ADIC
AML FPN CSP

From: **CAS**

The project focuses on the problem of sound source localisation in an urban environment. The objective of the project is to develop a system that uses an array of microphones and signal processing techniques that can a) classify the type of sound, and b) infer its source location and possible direction. The first part of the project will focus on the signal processing side and the performance evaluation of the current approaches, followed by a stage where an attempt to improve over previous results will be made using knowledge of the environment and AI. An final (but optional) step of the project would be to map and optimise the derived algorithm on an embedded system maintaining adequate sampling rate.

The student should have a good background on signal processing and software engineering skills. Some understanding of Machine Learning techniques would be beneficial.

1803367 **Brahma,D. (with O'Malley,M.)**

Data-driven Nodal Inertia Estimation

Offered to: Control ADIC
AML FPN CSP

From: **CAP**

The adverse impacts of depleting inertia due to the transition from synchronous to non-synchronous power generation are well documented. This has primarily led to extensive research in the estimation of power system inertia in various spatial and topological levels, like system-wide inertia (or simply system inertia), and area-wide inertia (or regional inertia).

However, the distribution of these aggregated inertia for a practical power system is non-uniform, which can be mainly attributed to (a) diversified power generation technologies of varying capacities distributed nonuniformly in the grid, and (b) zero, low or varying inertial contribution from inverter-based resources (IBRs), depending on their control methodologies. This locational unevenness in inertial distribution affect both local and global dynamic behaviour of the system, like rate of change of frequency (ROCOF), and inter-area power oscillations. Hence, rather than an aggregated inertial estimation, accurate estimation of inertial distribution at node or bus level, also known as nodal inertia, becomes more critical and necessary, especially as the generation portfolio changes due to increasing penetration of IBRs.

Existing methods of nodal inertia estimation are limited to either ambient (normal) or transient (ring-down) conditions of the power system. Although a unified approach of online estimation of nodal inertia for any power system condition was recently proposed, it still requires network topological and model parametric information. Using existing data sets and some preliminary work to date this project will develop a fully data-driven approach to estimate nodal inertia which would (a) make the estimation model-free, and (b) make it immune to event-detection.

PID	Supervisor	Description

1803006 **Charalambous,C.**
          (with Pike,W.T.)

Real-Time Earthquake Detection
Utilising Polarization Analysis and
Signal-to-Noise Ratio

          Offered to: Control ADIC
                     AML FPN CSP

          From: OSD

 In regions prone to seismic activity, the ability to detect earthquakes in real time is critical for public safety and disaster preparedness. These systems rely on rapid and accurate analysis of seismic data to provide timely alerts. An earthquake early warning system (EEWS) should therefore be included in smart cities to preserve human lives by providing a reliable and efficient disaster management system.

In this project, we aim to develop a new single-station earthquake detection algorithm that operates in real-time by harnessing sophisticated polarisation tools developed in MATLAB and Signal-to-Noise Ratio (SNR) measurements. The polarisation tools can compute critical parameters such the expected ground motion enabling more precise and timely alerts. This has the potential to form the foundation of a new earthquake early-warning system.

The algorithm will be optimised to distinguish between seismic events and background noise through a combination of SNR-based event detection and polarisation attributes, characteristic of earthquakes. The directionality information will enhance our understanding of seismic events and aid emergency response efforts. Rigorous testing and validation of the algorithm using historical seismic data will ensure its accuracy and reliability, making it a robust tool for real-world applications. Machine-learning approaches may be used to enhance detection and the overall system using attributes computed from ground acceleration time series in the temporal, spectral and cepstral domains (e.g., [1]), but it is not a prerequisite of the project.

[1] Pablo Lara, Quentin Bletery, Jean-Paul Ampuero, et al. Earthquake Early Warning using 3 seconds of records on a single station. ESS Open Archive . February 27, 2023.
doi: 10.22541/essoar.167751595.54607499/v1

PID	Supervisor	Description
1803341	**Charalambous,C. (with Pike,W.T.)**	

Unveiling the interior of Mars using signal analysis

Offered to: Control ADIC AML FPN CSP

From: OSD

NASA's InSight mission on Mars has unveiled a wealth of seismic data from over 1300 recorded marsquakes during its four years of surface operations. These include signals from up to ~9000 km away from InSight, probing deep into Mars—from its shallow crust to the boundary of the core. Mars offers a unique laboratory for the detailed seismic exploration of the layers of an archetypal planet, without the complications which come from plates tectonics when we study Earth.

This project represents a convergence of optimization, signal processing, and planetary seismology, with a focus in exploring the Martian subsurface structure. From its shallow, highly-fragmented crust to the primordial deep mantle—a time-capsule of the planet's early formation stages—this project offers the opportunity to use signal analysis to explore Mars' largely unknown interior.

The goal of this project is to try to fit the recorded energy of marsquakes by applying a simple diffusion model to the propagation of seismic energy as it travels through the layers of the planet [e.g., 1-2.]. This should allow us to group quakes based on how their energy is shaped by Mars. For instance, the analysis of the frequency-dependent energy envelopes is allowing us to examine Mars' mantle composition, offering a glimpse into the geological history imprinted within the Martian interior.

The result is a comprehensive insight into the Martian interior's properties and their origin, from the complexities within the crust to the largely unknown structures buried within the deep mantle. To achieve this, you will design and implement global optimization algorithms for fitting the energy profile in time-series signals derived from numerous marsquakes from different locations on Mars. These sources include large meteorite impacts [3], magmatic activity deep in the planet [4], faults, avalanches and rockfalls [5], and other yet-to-be-understood phenomena, such as possibly liquid groundwater systems deep within the crust [6].

Beyond these potential findings, the project extends its reach to seismic hazards. Marsquakes are potential critical hazards for future human exploration [7]. Analysing the energy envelopes contributes crucial insights to how the seismic energy propagates and weakens before its arrival to the future potentially habitable site, enabling us to assess and predict seismic risks—pivotal information for the planning and safety of future missions.

This project, therefore, offers an opportunity to go beyond simple data analysis by decoding the geological story told by Mars' seismic signals, contributing to our understanding of the Red Planet's past, present, and future.

[1] Menina, S. et al. (2021). Energy envelope and attenuation characteristics of high‐frequency (HF) and very‐high‐frequency (VF) Martian events. Bulletin of the Seismological Society of America, 111(6), 3016-3034.

[2] Karakostas, F. et al., (2021). Scattering attenuation of the Martian interior through coda‐wave analysis. Bulletin of the Seismological Society of America, 111(6), 3035-3054.

[3] Posiolova, L. et al., (2022). Largest recent impact craters on Mars: Orbital imaging and surface seismic co-investigation. Science, 378(6618), 412-417.

[4] Broquet, A. & Andrews-Hanna, J. C. (2023). Geophysical evidence for an active mantle plume underneath Elysium Planitia on Mars. Nature Astronomy, 7(2), 160-169.

[5] Lucas, A. et al. (2022, September). InSight for seismically detectability and seismically triggered avalanches on Mars. In Europlanet Science Congress 2022 (pp. EPSC2022-366).

[6] Manga, M., Zhai, G., & Wang, C. Y. (2019). Squeezing marsquakes out of groundwater. Geophysical Research Letters, 46(12), 6333-6340.

[7] Kalapodis, N. et al. (2020). A review towards the design of extraterrestrial structures: From regolith to human outposts. Acta Astronautica, 175, 540-569.

PID	Supervisor	Description
1803342	**Charalambous,C. (with Pike,W.T.)**	For over three Earth years, NASA's InSight mission has returned data from the Seismic Experiment for Interior Structure (SEIS) on Mars with over 1300 recorded marsquakes leading to numerous breakthroughs in determining the planet's structure. However, many marsquakes are hidden in or contaminated by the background noise injected by the Martian atmosphere. Local winds interact with the lander and seismometer system, couples into the seismic signal and generating noise levels that fluctuate throughout the Martian day and regularly exceeding typical event amplitudes, making marsquake detection and analysis challenging. This interaction between the wind and the lander is seen through the excitation of sensitive lander resonances which are measured by the seismometers through vibrations on the ground.
	Denoising the seismic record of Mars	
	Offered to: Control ADIC AML FPN CSP	This project will develop a Machine Learning (ML) approach to denoising the seismic signal, with the aim of decoupling it from the background environmental noise and improving its quality. With the recent developments in deep learning, based on complex models of artificial neural networks, the process of learning a mapping function between a noise-corrupted signal to clean signal can be applied successfully. Inspired by speech-enhancement approaches, the ML approach here will be based on Spectral Subtraction, wherein the dynamic estimation of the background noise from the continuous excitation of wind-driven lander modes can be subtracted to achieve the cancellation of the environmental noise and the effective isolation of the seismic signal power in time-frequency space. The inputs required for the machine learning model will therefore mainly be the continuous excitation of several lander resonances over the Martian time of day. Clean parameters can be predicted from noisy parameters by combining complex neural network architectures and deep learning procedures.
	From: OSD	
		This project would best suit a student interested in Machine Learning and time-series analysis. It is essential to have strong skills in programming of MATLAB or Python.
1803247	**Chaudhuri,B.**	A power grid with a high fraction of inverter-based resources (IBRs) such as wind, solar PV, battery storage etc. is vulnerable to poorly damped (or unstable) oscillations [1] which are difficult to analyse and foresee. This has been a problem in Scotland (and elsewhere in the world where the fraction of IBR is high) in recent years forcing the grid operators to limit the fraction of IBRs at a given point by curtailing wind or PV generation. It is crucial to identify which components in the grid are causing such oscillations (i.e., the source or root cause) [2] to allow effective mitigation. This is particularly challenging for IBR-dominated power grids [3] and will be the focus of this project.
	Locating source of power grid oscillations	
	Offered to: FPN	You would develop the algorithm for locating the source of oscillations in MATLAB and build a simulation model of IBR-dominated power grids in MATLAB/Simulink to validate the performance of the algorithm.
	From: CAP	1)https://ieeexplore.ieee.org/document/9740416 2)https://ieeexplore.ieee.org/document/9132669 3) https://www.techrxiv.org/articles/preprint/Oscillation_Source_Detection_for_Inverter-Based_Resources_via_Dissipative_Energy_Flow/22178966
1803248	**Chaudhuri,B. (with Jaimoukha,I.M.)**	Control of inverters that interface renewables (e.g., wind turbines, solar panels), grid-scale batteries etc. to the power grid is crucial for their performance (e.g., reference tracking) and stability of the grid. This control design involves some difficult trade-offs between conflicting objectives and must be robust across a wide range of operating conditions due to the volatility of renewables. In this project, you would apply multi-objective robust control techniques to design the controller for grid-interface inverters to strike an appropriate balance between reference tracking, control effort (due to limited headroom of inverters) and robustness. The control performance would be validated in both frequency and time domains using case studies on an inverter-dominated test power grid.
	Robust control of grid-interface inverters of renewables	
	Offered to: Control FPN	You would build the dynamic model of an inverter-based power grid in MATLAB/Simulink, develop a methodology for robust control design in MATLAB and compare the performance of the designed robust control against classical control.
	From: CAP	The spring-term elective module 'Design of multivariable control system' would be very helpful for this project.

PID	Supervisor	Description
1803249	**Chaudhuri,B.** **Dynamic stability assurance for offshore DC grids** **Offered to: FPN** **From: CAP**	More than 50 GW of offshore windfarms are planned around the UK by 2030. A 'meshed' offshore DC grid is better suited to transmit this power to the onshore grid rather than multiple radial DC cables from the offshore wind farms as outlined in National Grid's pathway to 2030 holistic network design [1]. The project would investigate how to guarantee the dynamic stability of such an offshore DC grid when subject to a wide range of power exchanges due to the volatility of offshore wind and transmission bottlenecks on the onshore grid. Use of adaptive droop control will be investigated to ensure dynamic stability [2]. You would develop the optimisation framework with stability constraints in MATLAB and then build a dynamic model of an offshore DC grid in MATLAB/Simulink for performance validation. 1)https://www.nationalgrideso.com/document/262676/download 2)https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6242419
1803250	**Chaudhuri,B.** **Digital twin for inverted-based power grids** **Offered to: FPN** **From: CAP**	Analysing and mitigating stability problems in power grids with high fractions of inverter-based resources (IBRs) such as wind, solar PV, battery storage etc. is challenging. This is primarily due to the lack of availability/transparency of IBR models which are often proprietary and only available in black box form. Although generic IBR model structures are available (but evolving), parameterisation remains a major problem. This project would investigate the use of a data-driven digital twin of IBRs whose parameters are continuously updated [1] to reflect their operating point dependency. Such digital twins would be used for stability assurance of IBR-dominated power grids which to minimise unnecessary curtailment of wind and solar PV generation. You would develop IBR parameter estimation algorithm in MATLAB and build a dynamic model of IBR-dominated power grids in MATLAB/Simulink to drive and validate the digital twins. 1)https://ieeexplore.ieee.org/document/9761159
1803185	**Chen,K. (with Franco,E.)** **Modelling and control of soft robotic manipulators for surgery** **Offered to: Control** **From: CAP**	Soft robotic manipulators are a promising solution for surgery because of their inherent safety. However, controlling soft manipulators is challenging because they have many degrees of freedom. In this project you will explore the following aspects. 1. constructing a dynamical model of a soft robotic manipulator using beam theory or equivalent. 2. developing a reduced-order model that can be used for control. 3. formulating a control law and assessing its effectiveness in simulations and experiments. This is a great opportunity to learn about dynamical modelling, model reduction, and model-based control. Desired Skill Set: Linear control theory (Control Engineering) Mechatronics (Modelling and Control of Multi-body Mechanical Systems) signal processing, Arduino (C++)/MATLAB/Python (Real-time Digital Signal Processing) This project is a collaboration between the CAP group, EEE, and the Hamlyn Centre. Interested students are encouraged to approach the supervisor, Dr Enrico Franco, Lecturer in Hamlyn Centre (Room 414B, 4th floor Bessemer building) for further information. For initial discussion, please contact the second supervisor Dr Kaiwen Chen (Room EENG 1109. Email: kaiwen.chen16@imperial.ac.uk)

PID	Supervisor	Description

1803241 **Clarke,T.**

A Novel Digital Simulation Algorithm for Issie

Offered to: Control ADIC AML FPN CSP

From: CAS

Issie [1] is an innovative open source desktop tool which facilitates block-level hierarchical Digital Design and Simulation. It is used for university teaching, but productive with experienced users and large designs, so could be used in many other scenarios.

Currently Issie uses static analysis of code to determine a strict evaluation order for every component in the simulated design. Components are then evaluated with outputs placed directly into arrays shared with inputs - leading to a highly efficient reduction loop.

This project looks at how the Issie simulation algorithm works and will identify and evaluate one or more of various extensions to the core algorithm, which change the preprocessing before the Issie simulator reduction engine. These extensions all involve static analysis of the circuit as a directed dataflow graph:

** Identification and simulation of pseudo-synchronous circuits that contain potential (but not actual) asynchronous loops.

** Performance improvement through chunked reduction. Compile combinational logic into a set of lookup tables not unlike (but more general than) FPGA LCUs. These will be implemented with a novel lookup table Issie component in the simulation engine which can implement multiple logic functions.

** Performance improvement through conditional reduction. In any circuit with multiplexors (or indeed and or or gates) the hardware that needs to reduced, in any clock-cycle, depends on the data. Find a way to exploit this for faster simulation through better static analysis and a small enhancement to the simulation engine.

The implementation of new algorithms will be done in F#. This is an efficient language for this work, and it will allow successful algorithms to be incorporated and tested in Issie.

Project deliverables would be an improved Issie simulator, and an evaluation of concept of algorithms used.

The project would suit a student interested in novel research on digital simulation techniques. It is flexible because the exact algorithm extensions investigated can be changed to fit preferences and time available.

Skills Required

The project work will be approximately:
50% - innovating and evaluating novel simulation algorithms
50% - programming to implement the above.

Programming Prerequisites

This project involves additions to a large open-source software project. It is expected that a successful deliverable will add at least one large new module to Issie. Programming competence is therefore a prerequisite.

F# is a functional-first (Hindley-Milner) functional language currently taught to 3rd year EEE students. The overhead required to learn F# (which is very well supported with tooling and easy to learn) is approximately 30 hours and expected within this project. However Issie is written in a pure declarative style without mutable data (with some very small exceptions). Those not used to this paradigm will benefit from learning it, since most languages now have FP elements which if used properly increase productivity. Some students find the conceptual switch from imperative to declarative programming challenging.

Having said that, the declarative coding in Issie coding means that making additions is easy, so the problems typically found in adding to existing large software projects are much smaller than would be expected.

For more information on F# and the resources available to learn it quickly see the High level Programming web pages [2].

[1] https://tomcl.github.io/issie/
[2] https://intranet.ee.ic.ac.uk/t.clarke/hlp/

1802903   Clemow,P.R.

EV motor control simulation hardware - A dyno for EV motor development with closed loop EV dynamics simulation

Offered to: FPN

From: CAP

When developing EV motor control algorithms, it is crucial to test your new setup with appropriate load to represent the real world.

Often this is achieved by connecting your test motor to a second one (the same or larger than the test motor) which presents a resistance torque to represent the real world load. This means you can test the dynamic performance of your motor under controlled and repeatable conditions.

For this project we are going to be developing an EV motor test rig and simulator. Two motors will be connected by a shaft front to front, one will represent the EV drive motor under test and the other will represent the load. The loading will be programmed to represent a drive cycle, or a pre-determined route. This will be achieved with a simulink model calculating the aerodynamic drag, rolling resistance, gradient changes etc for a driving cycle and command the load motor to apply that resistance torque to the test motor.

Building this motor test rig will be good practice for a student in developing control algorithms and hardware test setups that are realistic and relevant to real world engineering (this kind of test rig is regularly used for testing motors). The test setup will also be used for a hardware coursework in a future revision of the Electric Vehicles 3rd year module so an additional goal is to make it as reliable, student proof and easy to use as possible!

If you want to meet to discuss this project, please get in touch via email or teams. Depending on the level of interest I will set up one-to-one meetings or a group chat as needed

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1803017   Clemow,P.R.

Virtual Wattown - Power Systems Education Game

Offered to: FPN

From: CAP

In order to enact change in the way people perceive and use energy we first must get everyone on the same page about where their energy comes from and how it gets to them. The latter is critical to get across as it helps people understand why the push to renewable energy is more than just building a lot of wind turbines and may even require interaction between consumers and the grid.

To achieve this we often make use of the Wattown energy demonstrator model town, which currently resides in the Hitachi Digital Energy Demonstrator off the foyer. This model is used in events for the Energy Futures Lab and for a large amount of outreach work like the Imperial Festival and Lates events and visits from school children/prospective students/government officials ... anyone who could benefit from an understandable explanation of the energy system.

This project would be to develop a new Wattown but realised virtually so it can be used in the current situation and taken to any events we need in the future. I am particularly keen to use a virtual version to reach people that wouldn't normally find themselves on the IC campus. This requires rebuilding the energy modelling backend and developing a whole new frontend to represent the workings underneath in an understandable and approachable manner.

I see this project as a builder/tycoon game where the player is presented with challenges (structured as levels) designed to introduce issues found in real grids, particularly when integrating a lot of renewable energy.

If you would like to discuss this project with me, get in touch via Teams or Email and we can set up a meeting.

PID	Supervisor	Description

1803199 Clerckx,B.

Computer Vision and Sensing-Aided 6G Wireless Communications

Offered to: AML CSP

From: CSP

Description: Future wireless communications will be characterized by a massive number of antennas, useful to perform efficient beamforming, i.e., to steer the electromagnetic signal toward the intended direction. In this way, future networks will be able to support the increasingly high data rates requested by future applications. However, accurate beamforming typically requires a large control overhead, that prevents the networks from unlocking their full potential. To solve this problem, a novel paradigm has been recently proposed, namely vision-aided wireless communications. In vision-aided networks, communication benefits from side information, derived from sensors available in the communication environment, such as cameras, radio detection and ranging (RADAR), light detection and ranging (LIDAR), and global positioning system (GPS).

The objective of this project is to understand how to exploit sensory data to support future wireless communications. The student will explore intelligent solutions to extrapolate useful information from sensory data, based on computer vision and deep learning techniques.

The following references are helpful:

•Klautau, N. González-Prelcic and R. W. Heath, "LIDAR Data for Deep Learning-Based mmWave Beam-Selection," in IEEE Wireless Communications Letters, vol. 8, no. 3, pp. 909-912, June 2019, doi: 10.1109/LWC.2019.2899571.

•M. Alrabeiah, A. Hredzak and A. Alkhateeb, "Millimeter Wave Base Stations with Cameras: Vision-Aided Beam and Blockage Prediction," 2020 IEEE 91st Vehicular Technology Conference (VTC2020-Spring), 2020, pp. 1-5, doi: 10.1109/VTC2020-Spring48590.2020.9129369.

•M. Nerini and B. Clerckx, "Overhead-Free Blockage Detection and Precoding Through Physics-Based Graph Neural Networks: LIDAR Data Meets Ray Tracing", arXiv preprint arXiv:2209.07350, 2022.

Skills required (or willing to learn): strong interests in communication, signal processing, MIMO, deep learning, simulations, Matlab and Python (knowledge of Tensorflow or Pytorch libraries) programming.

1803200 Clerckx,B.

Signal Design and Optimization for Integrated Sensing and Communication in 6G

Offered to: CSP

From: CSP

Description: Integrated sensing and communication (ISAC) performs sensing and communications simultaneously sharing the same hardware, frequency band or signals. Research has shown its great potential to enhance hardware efficiency and to solve the problem of spectrum shortage that arises from the explosion of the number of sensors in the emerging wireless networks. Consequently, ISAC has been regarded as a key technique for many future wireless scenarios in the 5th generation (5G) or beyond (6G), such as autonomous vehicle, extended reality or the Internet of Things.

This project will explore how signals should be designed in ISAC to improve the joint performance of radar and sensing without additional hardware implement. Towards that, we start from studying the fundamental limits of sensing and communications in different ISAC systems (multi-carrier/MIMO), and then design the corresponding signal towards achieving the best performance. The project aims to lead students to gain insight into the start-of-art ISAC signal design technologies, get aware of the technology gaps, and explore the ISAC signal design under new architectures/criteria.

The following references are helpful:

•Sturm, Christian, and Werner Wiesbeck. "Waveform design and signal processing aspects for fusion of wireless communications and radar sensing." Proceedings of the IEEE 99.7 (2011): 1236-1259.

•A. Liu et al., "A Survey on Fundamental Limits of Integrated Sensing and Communication," in IEEE Communications Surveys & Tutorials, vol. 24, no. 2, pp. 994-1034, Secondquarter 2022, doi: 10.1109/COMST.2022.3149272.

•C. Xu, B. Clerckx, S. Chen, Y. Mao and J. Zhang, "Rate-Splitting Multiple Access for Multi-Antenna Joint Radar and Communications," in IEEE Journal of Selected Topics in Signal Processing, vol. 15, no. 6, pp. 1332-1347, Nov. 2021.

•S. Aditya, O. Dizdar, B. Clerckx, and X. Li, "Sensing using Coded Communications Signals," IEEE Open Journal of the Communications Society, pp. 134-153, vol. 4, Dec. 2022.

Skills required (or willing to learn): strong interests in wireless systems and signal processing, radar, communications, statistical analysis, optimization, matlab programming

PID	Supervisor	Description

1803201 **Clerckx,B.**

Signal Processing for 6G Reconfigurable Intelligent Surfaces

Offered to: CSP

From: CSP

Description: Reconfigurable Intelligent Surfaces (RIS) (or intelligent reflecting surface (IRS)) are an emerging technology that will enhance the performance of future wireless (communications, power, sensing) systems. This technology relies on large surfaces comprising reconfigurable scattering elements, each of them capable of inducing a change to the incident electromagnetic wave, to engineer the wireless propagation. By smartly coordinating the reflection coefficients of its elements, RIS can passively beamform the reflected signal toward the intended direction, reduce interference, combat blockage, increase range, security. RIS has several advantages: passive elements with low power consumption; no active additive thermal noise or self-interference; low-profile and cost-effective solution; no expensive radio frequency (RF) chains. RIS is considered as the next frontier in the multi-antenna/MIMO technology.

The Project's Aim is to leverage promising results to identify the full potential benefits of new architecture called Beyond Diagonal RIS https://sites.google.com/view/ieee-comsoc-rcc-sig-bdris for next generation wireless networks and develop the foundations of BD-RIS aided network design.

The project will look at new BD-RIS architecture, control, optimization, and signal processing.

The following references are helpful:
•M. Di Renzo, A. Zappone, M. Debbah, M-S. Alouini, C. Yuen, J. de Rosny, and S. Tretyakov, "Smart radio environments empowered by reconfigurable intelligent surfaces: How it works, state of research, and the road ahead," IEEE J. Sel. Areas Commun., vol. 38, no. 11, pp. 2450-2525, Nov. 2019.
•Q. Wu and R. Zhang, "Towards smart and reconfigurable environment: Intelligent reflecting surface aided wireless network," IEEE Commun. Mag., vol. 58, no. 1, pp. 106-112, Jan. 2020.
•S. Shen, B. Clerckx, and R. Murch, "Modeling and architecture design of reconfigurable intelligent surfaces using scattering parameter network analysis," IEEE Trans. Wireless Commun., vol. 21, no. 2, pp. 1229-1243, Feb. 2022.
•H. Li, S. Shen, and B. Clerckx, "Beyond Diagonal Reconfigurable Intelligent Surfaces: From Transmitting and Reflecting Modes to Single-, Group-, and Fully-Connected Architectures," IEEE Transactions on Wireless Communications, vol. 22, no. 4, pp. 2311-2324, April 2023.
•H. Li, S. Shen, and B. Clerckx, "Beyond Diagonal Reconfigurable Intelligent Surfaces: A Multi-Sector Mode Enabling Highly Directional Full-Space Wireless Coverage," IEEE Journal of Selected Areas in Communications, vol. 41, no. 8, pp. 2446-2460, Aug. 2023.
•M. Nerini and B. Clerckx, "Pareto Frontier for the Performance-Complexity Trade-Off in Beyond Diagonal Reconfigurable Intelligent Surfaces," IEEE Communications Letters, vol. 27, no. 10, pp. 2842-2846, Oct. 2023.

Skills required (or willing to learn): strong interests in signal processing, communication and optimization, algorithm development, analysis, simulations, matlab programming

PID	Supervisor	Description

1803202 **Clerckx,B.**

Electromagnetic Modelling of 6G Reconfigurable Intelligent Surfaces

Offered to: ADIC CSP

From: **CSP**

Description: Reconfigurable Intelligent Surfaces (RIS) (or intelligent reflecting surface (IRS)) are an emerging technology that will enhance the performance of future wireless (communications, power, sensing) systems. This technology relies on large surfaces comprising reconfigurable scattering elements, each of them capable of inducing a change to the incident electromagnetic wave, to engineer the wireless propagation. By smartly coordinating the reflection coefficients of its elements, RIS can passively beamform the reflected signal toward the intended direction, reduce interference, combat blockage, increase range, security. RIS has several advantages: passive elements with low power consumption; no active additive thermal noise or self-interference; low-profile and cost-effective solution; no expensive radio frequency (RF) chains. RIS is considered as the next frontier in the multi-antenna/MIMO technology.

The Project's Aim is to leverage promising results to identify the full potential benefits of new architecture called Beyond Diagonal RIS https://sites.google.com/view/ieee-comsoc-rcc-sig-bdris for next generation wireless networks and develop the foundations of BD-RIS aided network design.

The project will look at new physical and electromagnetic compliant BD-RIS modeling.

The following references are helpful:
•M. Di Renzo, A. Zappone, M. Debbah, M-S. Alouini, C. Yuen, J. de Rosny, and S. Tretyakov, "Smart radio environments empowered by reconfigurable intelligent surfaces: How it works, state of research, and the road ahead," IEEE J. Sel. Areas Commun., vol. 38, no. 11, pp. 2450-2525, Nov. 2019.
•Q. Wu and R. Zhang, "Towards smart and reconfigurable environment: Intelligent reflecting surface aided wireless network," IEEE Commun. Mag., vol. 58, no. 1, pp. 106-112, Jan. 2020.
•S. Shen, B. Clerckx, and R. Murch, "Modeling and architecture design of reconfigurable intelligent surfaces using scattering parameter network analysis," IEEE Trans. Wireless Commun., vol. 21, no. 2, pp. 1229-1243, Feb. 2022.
•H. Li, S. Shen, and B. Clerckx, "Beyond Diagonal Reconfigurable Intelligent Surfaces: From Transmitting and Reflecting Modes to Single-, Group-, and Fully-Connected Architectures," IEEE Transactions on Wireless Communications, vol. 22, no. 4, pp. 2311-2324, April 2023.
•H. Li, S. Shen, M. Nerini, M. Di Renzo, and B. Clerckx, "Beyond Diagonal Reconfigurable Intelligent Surfaces with Mutual Coupling: Modeling and Optimization," submitted to IEEE Communications Letters. https://arxiv.org/abs/2310.02708

Skills required (or willing to learn): strong interests in communications, microwave theory, antenna theory, electromagnetism, analysis, simulations.

PID	Supervisor	Description
1803203	**Clerckx,B.** **Rate-Splitting Multiple Access for 6G: Design and Simulations** **Offered to: CSP** **From: CSP**	Description: Space-division multiple access (SDMA) utilizes linear precoding to separate users in the spatial domain and relies on fully treating any residual multi-user interference as noise. Non-orthogonal multiple access (NOMA) uses linearly precoded superposition coding with successive interference cancellation (SIC) to superpose users in the power domain and relies on user grouping and ordering to enforce some users to fully decode and cancel interference created by other users. In this project, we argue that to efficiently cope with the high throughput, heterogeneity of quality of service (QoS), and massive connectivity requirements of future multi-antenna wireless networks, multiple access design needs to depart from those two extreme interference management strategies, namely fully treat interference as noise (as in SDMA) and fully decode interference (as in NOMA). The objective of this project is to design, optimize, and numerically assess the performance of a novel multiple access framework, called rate-splitting multiple access (RSMA). RSMA is a more general and more powerful multiple access for downlink multi-antenna systems that contains SDMA and NOMA as special cases and is a major candidate for 6G https://sites.google.com/view/ieee-comsoc-wtc-sig-rsma/home . RSMA relies on linearly precoded rate-splitting with SIC to decode part of the interference and treat the remaining part of the interference as noise. This capability of RSMA to partially decode interference and partially treat interference as noise enables to softly bridge the two extremes of fully decoding interference and treating interference as noise and provides room for rate and QoS enhancements and complexity reduction. This project will focus on the design, optimization, and simulations of RSMA. The following references are helpful: •Y. Mao, O. Dizdar, B. Clerckx, R. Schober, P. Popovski, H. V. Poor, "Rate-Splitting Multiple Access: Fundamentals, Survey, and Future Research Trends," IEEE Communications Surveys and Tutorials, vol. 24, no. 4, pp. 2073-2126, fourth quarter 2022. •B. Clerckx, Y. Mao, E. A. Jorswieck, J. Yuan, D. J. Love, E. Erkip, D. Niyato, "A Primer on Rate-Splitting Multiple Access: Tutorial, Myths, and Frequently Asked Questions," IEEE Journal on Selected Areas in Communications, vol. 41, no. 5, pp. 1265-1308, May 2023. Skills required: strong interests in communication and signal processing, MIMO, algorithm development, optimization, analysis, simulations, matlab programming

PID	Supervisor	Description

1803204 **Clerckx,B.**

Rate-Splitting Multiple Access for 6G: Prototyping and Implementation

Offered to: ADIC CSP

From: CSP

Description: Space-division multiple access (SDMA) utilizes linear precoding to separate users in the spatial domain and relies on fully treating any residual multi-user interference as noise. Non-orthogonal multiple access (NOMA) uses linearly precoded superposition coding with successive interference cancellation (SIC) to superpose users in the power domain and relies on user grouping and ordering to enforce some users to fully decode and cancel interference created by other users.

In this project, we argue that to efficiently cope with the high throughput, heterogeneity of quality of service (QoS), and massive connectivity requirements of future multi-antenna wireless networks, multiple access design needs to depart from those two extreme interference management strategies, namely fully treat interference as noise (as in SDMA) and fully decode interference (as in NOMA).

The objective of this project is to implement, prototype and demonstrate the superiority of a novel multiple access framework, called rate-splitting multiple access (RSMA). RSMA is a more general and more powerful multiple access for downlink multi-antenna systems that contains SDMA and NOMA as special cases and is a major candidate for 6G https://sites.google.com/view/ieee-comsoc-wtc-sig-rsma/home . RSMA relies on linearly precoded rate-splitting with SIC to decode part of the interference and treat the remaining part of the interference as noise. This capability of RSMA to partially decode interference and partially treat interference as noise enables to softly bridge the two extremes of fully decoding interference and treating interference as noise and provides room for rate and QoS enhancements and complexity reduction.

This project will focus on the design, implementation, and experimentation of RSMA on software-defined radio.

The following references are helpful:
- Y. Mao, O. Dizdar, B. Clerckx, R. Schober, P. Popovski, H. V. Poor, "Rate-Splitting Multiple Access: Fundamentals, Survey, and Future Research Trends," IEEE Communications Surveys and Tutorials, vol. 24, no. 4, pp. 2073-2126, fourth quarter 2022.
- B. Clerckx, Y. Mao, E. A. Jorswieck, J. Yuan, D. J. Love, E. Erkip, D. Niyato, "A Primer on Rate-Splitting Multiple Access: Tutorial, Myths, and Frequently Asked Questions," IEEE Journal on Selected Areas in Communications, vol. 41, no. 5, pp. 1265-1308, May 2023.
- X. Lyu, S. Aditya, J. Kim, and B. Clerckx, "A Prototype Implementation of Rate Splitting Multiple Access using Software-Defined Radios," submitted to IEEE Trans. on Wireless Commun. https://arxiv.org/pdf/2305.07361.pdf

Skills required: strong interests in communication systems, MIMO, algorithm development, radio system prototyping, software defined radio / USRP, Labview programming

PID	Supervisor	Description

1803205 **Clerckx,B.**

Machine Learning to Optimize 6G Wireless Communications

Offered to: AML CSP

From: CSP

Description:
Conventional receiver architectures are based on algorithms designed for specific mathematical channel models, which may be of statistical or deterministic nature, that aim to define the relationship between the transmitted and received signals. Consequently, estimation of the channel model parameters is necessary as these model-based algorithms rely strongly on accurate prior model knowledge and perform poorly if it is not accurately acquired.

Optimization of communications systems conventionally rely on convex optimization tools. As the dimension of the system increases, e.g. in the presence of multi-antenna systems with hundreds of antennas and users, those tools incur very large computationally complexity and cannot be applied.

In recent years, deep learning (DL) has become an attractive research area and a promising, powerful and purely data-driven tool in wireless communications, e.g. in the design of efficient receivers or as an alternative to optimize resource allocation. A major advantage of receivers based on DL methods is that they are able to directly extract meaningful information from the unknown channel solely on observations. Therefore, DL is naturally suited for scenarios in which the underlying mathematical channel model is unknown, its parameters cannot be acquired with precision, or when it is too complex to be characterized by model-based algorithms with low computational resources. DL has also been used to provide significant computational and performance advantages over convex optimization tools, especially for large scale systems.

The objective of this project is to understand how DL can be used to design and optimize communication systems. Emphasis can be put on the different aspects of the communications system depending on the student interests, e.g. receiver design, optimization, resource allocation, precoder design, etc.

The following references are helpful:
•H. Sun, X. Chen, Q. Shi, M. Hong, X. Fu and N. D. Sidiropoulos, "Learning to Optimize: Training Deep Neural Networks for Interference Management," in IEEE Transactions on Signal Processing, vol. 66, no. 20, pp. 5438-5453, 15 Oct.15, 2018.
•R. Cerna Loli, O. Dizdar, B. Clerckx, and C. Ling, "Model-based Deep Learning Receiver Design for Rate-Splitting Multiple Access," accepted to IEEE Transactions on Wireless Communications, https://ieeexplore.ieee.org/document/10091798
•R. C. Loli and B. Clerckx, "A Meta-Learning Based Precoder Optimization Framework for Rate-Splitting Multiple Access," submitted to IEEE Wireless Communications Letters. https://arxiv.org/abs/2307.08822

Skills required (or willing to learn): strong interests in communication, signal processing, deep learning, simulations, Matlab and Python (knowledge of Tensorflow or Pytorch libraries) programming.

PID	Supervisor	Description

1802904 Constandinou,T. (with Williams,I.)

Developing a wireless intracranial neuromonitoring device for drug-resistant epilepsy: impact of global vs. local referencing

Offered to: Control ADIC
AML FPN CSP

From: CAS

Epilepsy affects around 600,000 people in the UK, with roughly a third unable to control their seizures with medication and subsequently being diagnosed with Drug-Resistant Epilepsy (DRE). This condition results in increased life challenges leading to lower social outcomes and patients suffering disproportionately from traumatic injuries and psychiatric diseases.

Surgery could help many, typically by removing parts of the brain that are involved in initiating seizures. However, in order to identify these parts of the brain and assess whether they can be safely removed, it is often necessary to perform invasive brain activity recordings. This is currently achieved by inserting electrodes into the brain through tiny holes in the skull and connecting them to wires that run through the skull and skin to equipment that records brain signals. Unfortunately, this process has two major downsides:
- The patient has an open wound through to their brain for the monitoring period. The associated risks limit the monitoring period to around 3 weeks and limit the amount of data gathered (or not observing any seizures) which can prevent surgery.
- The patients are tethered to a hospital bed. This can be deeply distressing for patients, (who may be constrained even from trips to the bathroom) and is sometimes not tolerable (e.g. for small children).

A team at Imperial is developing electronics for a new implantable device that will be tiny, and wireless, aiming to massively improve the patient experience, whilst also improving the diagnostic yield of this type of monitoring. The team plan for this to be tested in a first-in-human pilot study in 2025.

This MSc thesis project will specifically assess the impact of global versus local referencing in intracranial SEEG electrode recordings by analysing previous recording data that have been annotated by epilepsy experts. This will be a multi-disciplinary project working with medical professionals, our engineering team, and industry partners. The bulk of the technical work will involve signal analysis/processing methods using tools such as Matlab, and Python. A successful project conclusion will contribute to our ongoing research -- with the possibility of publication.

This project will be co-supervised by Dr Ian Williams.

1802905 Constandinou,T. (with Bannon,A.)

Unobtrusive in-home sensing using radar for dementia care and research: assessing coverage of different radar-on-chip platforms

Offered to: Control ADIC
AML FPN CSP

From: CAS

The UK Dementia Research Institute (UKDRI) Care Research and Technology (CR&T) Centre's core mission is improving dementia care by using new technologies. This is uniquely challenging in dementia, particularly relating to people living with dementia (PLWD) using and engaging with technology. It is therefore essential to co-create with key stakeholders (PLWD, carers, clinicians, scientists) and adopt a user-centred design strategy. This has helped define our focus to create technologies that encourage deployability (low cost, scalability) and good compliance (uptake and adherence).

Our research aims to create novel bioelectronic systems that will enable continuous, unobtrusive monitoring and new interventions to improve outcomes in PLWD. More specifically, we are developing a new wall-mounted radar technology to sense human physiology and behaviour in a completely remote, unobtrusive manner that respects privacy. We are currently working towards integrating our radar device within the Minder smart home infrastructure and deploying this in the homes of 100 PLWD to assess their health and wellbeing longitudinally. This will enable the observation of disease progression by providing new physiological and behavioural measurables unobtrusively at home, improving the assessment of therapeutic interventions such as pharmacological efficacy, behavioural adjustments for sleep, and facilitating further research in dementia.

This MSc thesis project will assess key performance parameters (e.g. coverage, sensitivity to sensing breathing signals) in real-world settings between different radar-on-chip configurations. This will involve experimental (designing and conducting a trial) in addition to computational aspects (signal analysis/processing). A successful project conclusion will contribute to our ongoing research -- with the possibility of publication.

PID	Supervisor	Description

1802908   **Constandinou,T.**

A perimeter interface in neural microsystems to enable wafer-scale quilt packaging

Offered to: ADIC

From: CAS

1802910   **Constandinou,T. (with Rapeaux,A.)**

Evaluation of compression algorithms for neural data on an FPGA-NVM system

Offered to: Control ADIC AML FPN CSP

From: CAS

Problem: As implantable neural interfaces (BMIs) scale their data acquisition capabilities, the power budget for transmitting ever larger amounts of information wirelessly out of the cranium to different storage media for analysis and interpretation is becoming increasingly difficult as battery capacities do not scale in the same way and users require lossless transmission of data. It is therefore essential to reduce power consumption. One strategy is to reduce the amount of data transmitted by first compressing it using a number of lossless compression algorithms. A tradeoff appears between increased power consumption from computing to run the compression algorithm, and power saved from not having to transmit as much data wirelessly. This project aims to characterize this tradeoff using real-world data and hardware platforms to develop a figure of merit capturing compression performance versus power consumption for algorithms implemented on resource-constrained FPGAs (field-programmable gate arrays) connected to NVM (non-volatile memory) storage such as simple flash memories, which combine high storage density and the ability to retain information when turned off, saving power.

The student will use an existing experimental platform consisting of an igloo nano FPGA connected to a 2GB flash memory device to implement different compression algorithms and characterise them in terms of performance (e.g speed, memory requirements, but above all power). The student will also attempt to develop a single figure of merit that captures compression performance versus power consumption, to enable researchers to comparatively evaluate technology combinations for neural signal compression minimising for power consumption. If scope and time permits within the project it will be possible to investigate the use of different FPGAs and memories following the existing scheme, alongside different compression approaches including lossy compression, with the goal of further minimising power consumption.

Essential skills include VHDL/Verilog, experience with signal processing such as filtering and compression (knowledge of general data compression principles highly recommended), electrical measurements in low-noise environments (DC power analyzers, oscilloscopes, logic analyzers).

This project will be co-supervised by Dr Adrien Rapeaux.

PID	Supervisor	Description

1802911 — **Constandinou,T. (with Rapeaux,A.)**

Development of an embedded system for instrumentation control and data capture in ex-vivo heart muscle tissue baths.

Offered to: Control ADIC AML FPN CSP

From: CAS

Problem: heart muscle tissue baths are a powerful means to characterise heart muscle and its response to changes in environmental conditions and injury, as well as being a testbed for pharmaceutical or surgical research. An experimental platform has been developed which uses a collection of loosely connected instruments to stimulate the heart muscle sample and record the pull strength using a load cell. The setup allows the replication of the heart's natural loading cycle, however it is difficult and expensive to replicate, and the operation is currently complex and error-prone. Automating control of the instruments and data acquisition is an essential step towards scaling this platform for parallel experiments.

The student will work both at the South Kensington and Hammersmith campuses of Imperial College in partnership with Dr Cesare Terraciano and their EEE supervisor to develop an embedded system for ex-vivo instrumentation control and data acquisition. An existing system can be used as the starting point. The student needs to have experience in PCB design, embedded system design and programming, with knowledge of embedded C essential. Knowledge of heart muscle models such as Windkessel and heart physiology in general are highly encouraged as they will help the student understand the platform's use context.

This project will be co-supervised by Dr Adrien Rapeaux.

1803289 — **Constandinou,T.**

Unobtrusive balance assessment for people living with neurodegenerative disorders using ultra-wideband radar technology

Offered to: Control ADIC AML FPN CSP

From: CAS

The rapidly growing number of people living with neurodegenerative disorders (NDDs) and the limited hospital resources, highlight the need for advanced and efficient technologies for high-quality patient care. Patients living with NDDs, such as Parkinson's, Alzheimer's and Huntington's disease, commonly suffer from significant motor control abnormalities and postural instability which increase their susceptibility to experiencing falls and sustaining major injuries. Long-term monitoring of balance variables of individuals with neurological conditions can provide healthcare professionals with valuable insights into the health status of patients, which they can use to (a) track disease progression, (b) identify frailty and fall risk, and (c) evaluate medication or treatment (e.g. Deep Brain stimulation) efficacy.
In recent years, ultra-wideband (UWB) radar technology has been extensively utilised in contactless human behaviour monitoring systems and can be therefore considered a promising technology for remote, potentially in-home, assessment of patient balance. Using commercially available UWB radar sensors, our group is currently recording data from both NDD patients and healthy controls while performing balance tests (side-by-side, semi-tandem and tandem stand) as part of the Short Physical Performance Battery (SPPB) assessment. By detecting and quantifying even the most subtle movements in a person's body during these tasks, radar systems can enable a comprehensive analysis of balance sway and related parameters, beyond what traditional assessment can offer.

The student will develop new radar signal processing approaches for extracting clinically relevant parameters for assessing an individual's balance. The student will also validate any developed algorithms using already recorded radar data from both NDD patients and healthy controls in a living-lab setting, against markerless or marker-based motion capture technologies and quantify their accuracy. These methods will offer clinicians valuable supplementary biomarkers to enhance current balance assessments. Moreover, they will enable our research group to extract additional features for distinguishing between healthy participants and patients in classification tasks.

The student needs to have good understanding of advanced digital signal processing (filtering, modulation, demodulation, and spectral analysis) and potentially machine learning techniques, as well as experience with programming languages, preferably MATLAB or Python. Any prior knowledge/experience with radar systems and radar signal analysis is highly encouraged, but not required.

This project will be co-supervised by Charalambos Hadjipanayi

PID	Supervisor	Description

1803310   **Constandinou,T.**

Unobtrusive sleep apnea diagnosis using ultra-wideband radar technology

    Offered to: Control ADIC
                AML FPN CSP

    From: **CAS**

Obstructive sleep apnea (OSA) is characterized by repetitive episodes of apnea and/or hypopnea and various degrees of hypoxia caused by upper airway collapse during sleep. The prevalence of OSA increases significantly with age. However, a large portion of the elderly remains undiagnosed, often unaware of their compromised sleep quality. The gold standard for diagnosing OSA is overnight polysomnography (PSG) in a laboratory setting, which involves multi-channel monitoring. However, PSG requires many attachments to analyze the patterns of sleep in each patient. Thus, some patients have difficulty with achieving satisfactory sleep due to these obstructive circumstances.

Ultra-wideband (UWB) radar technology has emerged as a promising solution for non-contact respiratory and heart rate monitoring, offering an unobtrusive alternative to traditional polysomnography. By employing UWB radar, this project aims to capture critical biometric data necessary for sleep analysis without the discomfort of attached sensors, which can disrupt natural sleep patterns. This project proposes an innovative approach to sleep health assessment using impulse ultra-wideband (UWB) radar technology. The aim is to develop an unobtrusive, accurate method for the detection and diagnosis of sleep apnea among the elderly population.

Data for this study is sourced from an existing dataset in collaboration with the Sleep Research Centre at the University of Surrey, comprising at least 30 participants aged over 65 years, with ongoing efforts to expand this sample. Participants undergo simultaneous sleep monitoring using both the proposed UWB radar system and standard sleep study equipment.

Students will design a radar's signal processing algorithms for the detection of apnea-hypopnea indices and may extend to other sleep quality indicators. Machine learning techniques will be integrated to enhance the diagnostic capability of the UWB system, accommodating to the physiological variances present within the elderly demographic. The ultimate radar system and designed algorithms will be evaluated for its sensitivity, specificity, and overall accuracy in detecting sleep apnea episodes compared to the gold-standard methods.

Essential skills include MATLAB or Python, experience with signal processing and machine learning. The outcome of this study has the potential to deploy in participants' homes, increasing the accessibility of sleep apnea diagnostics. A successful project conclusion will contribute to our ongoing research -- with the possibility of publication.

This project will be co-supervised by Maowen Yin.

1803328   **Constandinou,T.**

Implantable "smartvessel" for monitoring and prevention of thrombosis

    Offered to: Control ADIC
                AML FPN CSP

    From: **CAS**

The 'smartvessel' project aims to develop small diameter vessels (less than 6 mm in diameter) with the functionalities of monitoring blood flow rates and pressure and preventing thrombosis formation. The former will be achieved through the integration of a triboelectric nanogenerator in the vessel while the realization of the latter relies on the controlled and sustained generation of nitric oxide, a simple molecule with potent antithrombotic activity.

This MSc thesis project will develop instrumentation electronics for integration within the implantable "smart vessel". The system will combine design of a highly sensitive electrometer (charge to voltage converter) and picoammeter (picoamp resolution ammeter), at first instance using a PCB-based platform using off-the-shelf components. Once the functionality is confirmed, and specifications identified there will be the opportunity to develop an integrated circuit to miniaturise this capability.

Student is expected to have experience in PCB and analogue circuit design, ideally with Altium designer, knowledge of instrumentation circuits is desirable, techniques for test and measurement. Integrated circuit design will be using the Cadence Virtuouso design suite.

A successful project outcome is expected to deliver a working circuit (PCB based) for test of the smart vessel platform, and (if time permits) and integrated circuit design. Any original contributions may lead to a research publication.

The project will be in collaboration with the Department of Materials.

PID	Supervisor	Description
1803332	**Constandinou,T. (with Rapeaux,A.)** **Development of a smart under-mattress mat for sleep monitoring** **Offered to: Control ADIC AML FPN CSP** **From: CAS**	Sleep quality directly effects health and is as a crucial determinant of quality of life. Disruptions in sleep patterns serve as a risk factor for various health-related issues. Polysomnography (PSG) has long been considered the gold standard for sleep assessment. However, the inherent limitations of PSG, primarily its intrusive nature and the need for a controlled environment, have spurred a growing interest in more user-friendly alternatives. The project aims to design an under-mattress pressure sensor system, which is engineered to unobtrusively capture critical biometric data necessary for sleep analysis without the discomfort of attached sensors. The final system should be able to accurately monitor bed occupancy, respiratory and heartbeat, and movements in real-time. As the project progresses, there is the potential to expand the scope to include more comprehensive sleep monitoring capabilities. This would involve the integration of algorithms development to process the data collected by the sensor array, extracting meaningful insights into the user's sleep health. This involves the detection of sleep stages, identification of potential sleep disorders, and overall sleep quality assessment. This project is in collaboration with the Sleep Research Centre at the University of Surrey. The system's design requires expertise in PCB design, as well as in software tools such as MATLAB or Python. Additionally, a background in microcontroller design and signal processing will be preferred. The ideal candidates for this project will be students with a passion for innovating at the intersection of technology and healthcare. The outcome of this study has the potential to deploy in participants' homes. A successful project conclusion will contribute to our ongoing research -- with the possibility of publication. This project will be co-supervised by Dr Adrien Rapeaux and Maowen Yin.

PID	Supervisor	Description

1803350 **Constandinou,T.**

Unobtrusive multi-person sleep monitoring using ultra-wideband radar technology

Offered to: Control ADIC AML FPN CSP

From: **CAS**

The pursuit of accurate and non-intrusive sleep health assessment has long been a critical focus in sleep medicine. While polysomnography (PSG) is the established gold standard for sleep monitoring, its intrusiveness and the need for a controlled environment pose significant limitations. This project explores the feasibility of using Ultra-Wideband (UWB) radar technology for sleep monitoring, particularly in the context of multi-person environments—a scenario often overlooked in current research.

UWB radar technology has emerged as a promising solution for non-contact respiratory and heart rate monitoring. Initial studies have demonstrated UWB radar's potential in single-user sleep monitoring; however, the dynamics change when considering a bed shared by multiple individuals.

The primary objective of this project is to investigate the feasibility of using single impulse UWB radar sensor for multi-person sleep physiological and movement detection. The challenge lies in the accurate extraction of individual breathing and heart rates in the presence of another person and differentiating between individuals sharing the same bed. As the project progresses, there is the potential to expand the scope to more advanced objectives, such as multi-person sleep stage classification.

Data for this study is sourced from an existing dataset in collaboration with the Sleep Research Centre at the University of Surrey, no need for students to design and collect data.

The system's design requires expertise in signal processing software such as MATLAB or Python. Additionally, a background in signal processing and machine learning will be preferred. The ideal candidates for this project will be students with a passion for innovating at the intersection of technology and healthcare.

The outcome of this study has the potential to deploy in participants' homes. A successful project conclusion will contribute to our ongoing research -- with the possibility of publication.

This project will be co-supervised by Maowen Yin.

1803216 **Constantinides,A.G. (with Sanei,S.)**

Modelling hand movement from multichannel electromyograms (EMGs)

Offered to: CSP

From: **CSP**

Using the available multichannel electromyogram (EMG) datasets, we should be able to model different hand/body movement/posture using a causal model (such as multivariate autoregressive model) to estimate the connectivity between different EMG sensors and how it evolves for each movement.
Given the information about the hand/body position can also help in developing an adaptive cooperative model (or graph) which exploits the connectivity measures, as its combination weights, for mapping EMG to the hand/body movement.

PID	Supervisor	Description

1803217   **Constantinides,A.G. (with Sanei,S.)**

Heart Murmur Extraction from Heart Sound Using Constrained Singular Spectrum Analysis for Murmur Classification

Offered to: Control ADIC AML FPN CSP

From: **CSP**

A heart murmur is a sound produced due to turbulent blood flow within the heart. Heart murmurs are sounds — such as whooshing or swishing — made by rapid, choppy (turbulent) blood flow through the heart. The sounds can be heard with a stethoscope. murmurs are often superimposed on the normal heart sound. The objective here is to use a subspace based method such as singular spectrum analysis followed by a classifier to detect and classify these sounds into systolic, diastolic, and continuous murmurs.

1803077   **Dai,W.**

Array 4D Sensing: Testbed and Demos for New Capabilities

Offered to: Control AML CSP

From: **CSP**

Array 5D Sensing: Testbed and Demos for New Capabilities

Keywords:
Array signal processing, object identification, situation awareness, deep learning for inverse problems

We consider the new capability to not only estimate the location and motion of objects, but also distinguish them by identifying their physical and semantic characteristics. Such capabilities are vital in many scenarios, for example, to differentiate balloons, birds, and UAVs in the sky; discern humans, construction structures, and potential hazards (e.g. gas cylinder) in heavy smoke for fire rescue missions; and distinguish swimmers, marine debris, and surface vessels for maritime applications.

In this project, we target at simple concept-proof demonstrations of the new capabilities. The task involves using hardware systems to collect real data, formulating the inverse problems converting the data to the scene, developing efficient algorithms to solve the inverse problems, and designing convincing demos for potential markets.

Involved Technical Skills:
1. Linear Algebra
2. Signal Processing
3. Optimization
4. Deep Learning for Inverse Problems (NB: This project is not about deep learning!)

The involved optimization techniques are covered by the module Topics in Large Dimensional Data Processing

Meeting Time:
16 Nov (Thursday) 12:00-12:45 Room 811
17 Nov (Friday) 12:00-12:45 Room 811
22 Nov (Wednesday) 12:00-12:45 Room 811

Students who are genuinely interested, please bring a printed copy of your CV to the meeting.

PID	Supervisor	Description
1803079	**Dai,W.**	Keywords:

**Interpretable Learning via
Proximal Optimization**

**Offered to: Control AML
CSP**

From: CSP

Keywords:
Dictionary Learning, Sparse PCA, Protypical Learning, SVM, Medical Dataset

Involved Technical Skills:
1. Linear Algebra
2. Signal Processing
3. Optimization
4. Presentation Suitable for Professionals and Laypeople alike

This project involves optimization techniques covered by the module Topics in Large Dimensional Data Processing

Meeting Time:
16 Nov (Thursday) 12:00-12:45 Room 811
17 Nov (Friday) 12:00-12:45 Room 811
22 Nov (Wednesday) 12:00-12:45 Room 811

Students who are genuinely interested, please bring a printed copy of your CV to the meeting.

PID	Supervisor	Description
1803080	**Dai,W.**	

Automatic Segmentation for Ovarian Cancer via Deep Learning

Offered to: Control ADIC
AML FPN CSP

From: CSP

Keywords:
Deep Learning, U-Net, 40GB Proprietary Data, MRI, Ovarian Cancer, Auto-Segmentation, Explainable Learning, Reinforcement Learning

Early detection and precise delineation of tumor boundaries are crucial for effective treatment planning and improved patient outcomes. Traditional manual segmentation methods are time-consuming, subject to inter-observer variability, and may lack consistency. This project aims to develop an automatic segmentation algorithm tailored for ovarian cancer. By leveraging classic neural networks and the medical imaging data (40 GB unlabelled) from NHS, the student is expected to:

1. implement and improve deep neural medical segmentation networks including U-net, V-net;
2. explore residual, attention, transformer structure;
3. given limited, varied nature of medical images, achieve higher accuracy in tumor boundary segmentation.

The following papers serve as the starting point.

[1] Olaf Ronneberger, Philipp Fischer, Thomas Brox. U-Net: Convolutional Networks for Biomedical Image Segmentation[C]// International Conference on Medical Image Computing and Computer-Assisted Intervention. Springer International Publishing, 2015.
[2] F. Milletari, N. Navab and S. Ahmadi, "V-Net: Fully Convolutional Neural Networks for Volumetric Medical Image Segmentation," 2016 Fourth International Conference on 3D Vision (3DV), Stanford, CA, 2016, pp. 565-571
[3] Vaswani A, Shazeer N, Parmar N, et al. Attention is all you need[J]. Advances in neural information processing systems, 2017, 30.

Involved Technical Skills:
1. Linear Algebra
2. Deep Learning
3. Technical Reading and Understanding in both Engineering and Medicine
4. Presentation Suitable for Professionals and Laypeople alike

Meeting Time
16 Nov (Thursday) 12:00-12:45 Room 811
17 Nov (Friday) 12:00-12:45 Room 811
22 Nov (Wednesday) 12:00-12:45 Room 811

Students who are genuinely interested, please bring a printed copy of your CV to the meeting

1803081 **Dai,W.**

Deep Reinforcement Learning for Breast Cancer Personalized Treatments

Offered to: Control ADIC AML FPN CSP

From: **CSP**

Keywords:
Breast Cancer, Survival Rate, Quality of Life, Personalized Treatment, Reinforcement Learning, Proximal Policy Optimization

Reinforcement learning (RL) is propsed to solve the sequential decision-making task which is a vital topic in machine learning and covers a wide range of possible applications such as autopilot, healthcare, quantitative finance and more. The main idea is that an artificial agent may use the experience lerned by interacting with its environment to optimize some objective, i.e., maximize the rewards. Recently, thanks to the notable capacity of deep learning to acquire diverse levels of abstraction from data, the combination of RL with deep learning, called deep RL, has demonstrated great success in tackling complicated tasks with high dimensional state-space and limited prior knowledge. A famous instance is AlphaGo Zero, the first artificial agent to defeat world champions at the ancient Chinese game of Go.

In this project, the student is encouraged to develope an AI medical agent using Deep RL to assist medical professionals in making diagnoses on breast cancer. The agent is expected to make decisions that increases patients' survival rates and improve their quality of life. The following links and papers are provided for reference.

Involved Technical Skills:
1. Linear Algebra
2. Deep Learning
3. Technical Reading and Understanding in Both Engineering and Medicine
4. Presentation Suitable for Professionals and Laypeople alike

Meeting Time:
16 Nov (Thursday) 12:00-12:45 Room 811
17 Nov (Friday) 12:00-12:45 Room 811
22 Nov (Wednesday) 12:00-12:45 Room 811

Students who are genuinely interested, please bring a printed copy of your CV to the meeting.

PID	Supervisor	Description

1803371 **Dai,W.**

Integrated Sensing and Communications for 6G

Offered to: Control ADIC AML CSP

From: **CSP**

Keywords:
Massive MIMO, Resource Allocation, Tradeoff, Constrained Optimization

Integrated sensing and communication (ISAC) enable hardware, resources (e.g., spectra), and waveforms sharing between the sensing and the communication functions. It is becoming a key feature in future-generation communication systems. In this project, the student is expected to work on waveform design problems under several practical considerations such as model uncertainties, different performance metrics, and computational efficiency. The mathematical techniques involved may include applied statistics and applied optimization such as Frequentist and Bayesian statistics, and non-convex and global optimizations. The following three papers serve as the starting point.

[1] Zhang, J. A., Liu, F., Masouros, C., Heath, R. W., Feng, Z., Zheng, L., & Petropulu, A. (2021). An overview of signal processing techniques for joint communication and radar sensing. IEEE Journal of Selected Topics in Signal Processing, 15(6), 1295-1315.
[2] Xiong, Y., Liu, F., Cui, Y., Yuan, W., Han, T. X., & Caire, G. (2023). On the fundamental tradeoff of integrated sensing and communications under Gaussian channels. IEEE Transactions on Information Theory.
[3] Liu, F., Zhou, L., Masouros, C., Li, A., Luo, W., & Petropulu, A. (2018). Toward dual-functional radar-communication systems: Optimal waveform design. IEEE Transactions on Signal Processing, 66(16), 4264-4279.

Involved Technical Skills:
1. Linear Algebra
2. Signal Processing
3. Wireless Communications
4. Optimization

Meeting Time:
16 Nov (Thursday) 12:00-12:45 Room 811
17 Nov (Friday) 12:00-12:45 Room 811
22 Nov (Wednesday) 12:00-12:45 Room 811

Students who are genuinely interested, please bring a printed copy of your CV to the meeting.

PID	Supervisor	Description

1803372 Dai,W.

Deep Network Training via Proximal Optimization

    Offered to: Control ADIC AML FPN CSP

    From: CSP

Keywords:
Deep Learning Training, Proximal Algorithms, Newton Methods, Fast Convergence, Local Optimality

Training a deep and large scale neural network is not always straightforward. Conventional training algorithms are based on acceleration of gradient back-propagation, which do not scale well, suffer from slow convergence and poor local optimality.

This project explores an unconventional optimization method developed very recently by our group. The proposed method enjoys the convergence rate of Newton type methods and much better local optimal point, when tested for some well-known nonconvex and nonsmooth optimization problems. The task is to adapt the new approach for neural network training, and hopefully make a fundamental and significant impact in the arguably over-hyped area of deep learning.

Involved Technical Skills:
1. Linear Algebra
2. Optimization

This project involves optimization techniques covered by the module Topics in Large Dimensional Data Processing

Meeting Time:
16 Nov (Thursday) 12:00-12:45 Room 811
17 Nov (Friday) 12:00-12:45 Room 811
22 Nov (Wednesday) 12:00-12:45 Room 811

Students who are genuinely interested, please bring a printed copy of your CV to the meeting.

1803327 Demiris,Y.K.

Social Navigation for an Intelligent Robot Wheelchair

    Offered to: AML

    From: ISN

In this project you will be developing algorithms for enabling a smart robot wheelchair to navigate in a human-populated environment. Using cameras and/or LiDAR sensors (e.g. Intel L515) mounted on the robot wheelchair, you will write algorithms to detect people in the mobile robot's environment, predict their trajectories, and plot a trajectory for the robot to move among them.

A review article outlining several methods (and the underlying challenges) for robot social navigation: https://arxiv.org/pdf/2103.05668.pdf

You can see examples of our robot wheelchairs at the personal robotics lab website: www.imperial.ac.uk/personal-robotics/robots or /videos.

In the core phase of the project, you can treat the human on the wheelchair as a passive component in the trajectory planning (essentially treating the whole human-wheelchair system as a mobile robot). In a potential extension, the user's preferences (as specified by their joystick movements) can be incorporated in the social trajectory planning.

Required skills:

- Substantial software engineering skills (e.g. C++/Python under Linux for controlling the robots, and for signal processing (vision and/or LiDAR data)); knowledge of ROS would be useful, but can be picked up quickly by a person with good software skills. I would suggest you don't pick this project if you haven't developed substantial pieces of software, and are not comfortable juggling multiple software libraries and programming environments.
- Strong interest in AI, computer vision, navigation, and human signal processing (e.g. human detection, pose tracking). You should be strongly interested in working with real research robots.
- Good Time management: you should put continuous effort on this project throughout the year (and not just the last term) since there are multiple software components involved on real robots

PID	Supervisor	Description

1803329   **Demiris,Y.K.**

Robot affordances determination using Large Language Models

    Offered to: AML

    From: **ISN**

In this project, you will be working on a combination of computer vision, robotics and large language models (LLMs) to automatically determine what is possible (what can be "afforded") in an environment with a mobile robot (with one or more robot arms). You will be designing and implementing a system that receives images from cameras onboard a robot, recognises objects in the environment (semantic segmentation), and determines how the robot can interact with them (for example, an object is grasp-able, push-able, …) taking into consideration the robot's capabilities (size, arm reach) and the object's 3D location. Once the basic affordances are determined, you will be investigating whether LLMs can be used to determine longer-horizon plans (for example, "grasp the bottle, fill it with water, and bring it to me"), and investigating the latencies associated with using onboard (e.g. on Jetson Orins) or remote commercial LLMs.

Papers on a related research project in the Personal Robotics Lab, where augmented reality headsets (MS HoloLens) were used to display the affordances (this is not needed in this project, but can be done as an extension if the student is interested) can be found below; note that in that paper, symbolic planning (PDDL) was used to determine longer horizon actions; in this project you will be investigating whether LLMs can do a good job replacing and improving that component in real time.

Relevant Paper: Proactive robot assistance: affordance-aware augmented reality user interfaces, https://spiral.imperial.ac.uk/handle/10044/1/95958
Relevant videos: https://www.imperial.ac.uk/personal-robotics/videos/ (see video with the same title as the paper above)

Required skills:

- Substantial software engineering skills (e.g. C++/Python under Linux for controlling the robots, for interfacing with the LLMs, and for signal processing (vision); knowledge of ROS would be useful, but can be picked up quickly by a person with very good software skills. I would suggest you don't pick this project if you haven't developed substantial pieces of software, and are not comfortable juggling multiple software libraries and programming environments, especially under Linux.
- Strong interest in AI, computer vision, and LLMs. You should be strongly interested in working with real research robots, and embedded devices such as Nvidia Jetson ORIN.
- Strong time management skills: you should be willing to put continuous effort on this project as soon as it assigned and throughout the year (and not just the last term) since there are multiple software components involved on real robots.

1802998   **Dragotti,P.L.**

Invertible Neural Networks and diffusion models

    Offered to: AML CSP

    From: **CSP**

Invertible Neural Networks (INN) are a specific class of deep networks that are perfectly invertible making them an ideal instrument for imaging applications. In particular they can be used to implement non-linear wavelet-like transformations.

The goal of this project is to explore variations of a recently proposed INN for image synthesis. We will explore the combined use of diffusion model and INN for image generation. Students interested in this challenging project are expected to take the module "Wavelets and Applications".

PID	Supervisor	Description

1803239   **Dragotti,P.L.**

Reconstructing activity of neurons in 3-D using lightfield microscopy

Offered to: CSP

From: **CSP**

Light Field Microscopy (LFM) is an imaging technique that maps a 3D scene into a single 2D image in a single snapshot. LFM enables the study of fast dynamics in 3D biological systems due to its rapid 3D imaging rate. Since LFM skips time-consuming 3D scanning, it is particularly attractive to studying the fast dynamics of cells, such as networks of neurons in the brain. The reconstruction of 3-d volumes from a lightfield image remains a very challenging computational task. Even though computational reconstruction methods have been proposed to ease these problems they operate on a frame by frame basis when trying to reconstruct functional activities of neurons from video ligthfield. This approach is suboptimal since it disregards temporal dependency. The aim of this project is to develop methods able to reconstruct 4-D data (3-D volume plus time) from lightfield sequences in the context of microscopy for neuroscience. We will consider both model-based and learning-based approaches. We will leverage data already acquired at Imperial college and available in Dragotti's laboratory.

1803240   **Dragotti,P.L.**

Implicit Neural Representation for signal reconstruction

Offered to: ADIC AML CSP

From: **CSP**

Implicit neural representations (INRs) have recently been successfully used in a variety of applications. INR learn a function tat maps pixel coordinates to pixel values. INR performance
depends strongly on the choice of activation function employed. The goal is to study alternative activation functions leveraging wavelet theory. We will also explore applications in image inpainting and in signal reconstruction from time-based samples.

1803254   **Evangelou,S.A. (with Jaimoukha,I.M.)**

Tube-Based and Robust Model Predictive Control (RMPC) for uncertain systems

Offered to: Control

From: **CAP**

Model Predictive Control (MPC) is a model-based advanced control scheme that is applied in real time, incorporates optimal control and handles hard constraints.

The aim of the project is to design state and output feedback Robust MPC (RMPC) controllers that are efficient to implement online. Traditionally, RMPC schemes require the online solution of a semidefinite program (SDP), which is computationally very expensive. The aim of this project is to approximate the SDP by a less computationally demanding quadratic program. This will be achieved by transferring the most demanding part of computations from online to offline without violating state and input constraints. The controller will be applied in the Oil and Gas drilling industry.

The project uses robust control theory techniques, linear matrix inequalities and game theoretic approaches. All algorithms will be developed using Matlab and Simulink.

PID	Supervisor	Description
1803261	**Evangelou,S.A.**	This project will look into the optimal control of a vehicle, with the objective to minimise the travel time and energy used during the safe execution of an overtaking manoeuvre. The compromise between travel time and energy used will also be investigated.

Optimal control of the vehicle overtaking manoeuvre

Offered to: Control

From: CAP

| 1803262 | **Evangelou,S.A.** | Due to the compatibility with vehicle electrification and autonomy, and the high demand in driving comfort, stability, and safety, nowadays the development of active suspension systems becomes a thriving topic in both academic research and industrial application. Recently, the series active variable geometry suspension (SAVGS) has been proposed and found to be a promising solution, which enables both vehicle vibration attenuation and chassis attitude control in a car. |

Active suspension control for improved vehicle lateral stability

Offered to: Control

In this project, a high-level control strategy of the SAVGS will be synthesised to additionally improve the lateral stability of a road vehicle.

From: CAP

| 1803267 | **Evangelou,S.A.** | The objective in the subsea oil and gas business is to maintain the high productivity of hydrocarbons at a low operation cost without any interruption. Thus, the subsea production systems are becoming increasingly complicated and extensive to achieve the above-mentioned objective. On the other hand, the chances of system failures are more and more in this complex control designed system. Despite of well-designed systems and best practices, the failures in subsea system are noticed during the operational phase than during the production phase due to a) the ageing effect of the systems, and b) the environmental conditions. To capture these failures on the seabed, a comprehensive failure monitoring system is required, which is the main objective of this project, to avoid the faults in the system by introducing fault detection and isolation techniques. |

Fault detection and isolation in subsea hydraulic system

Offered to: Control

The aims of this project are as follows:
1) Improve an existing mathematical model (nonlinear) of the subsea hydraulic system
2) Apply Kalman filtering and/or other techniques for the nonlinear model to detect faults in the subsea hydraulic system
3) Apply Kalman filtering and/or other techniques for the nonlinear model to isolate faults in the subsea hydraulic system

From: CAP

1803276	**Evangelou,S.A. (with Jaimoukha,I.M.)**	The aim of this project is to investigate and synthesise a novel multi-objective controller for road vehicle active suspension systems to enable further improvements for ride comfort and road holding performances, as compared to existing control schemes. The existing methods require the design of weighting matrices to specify the frequency ranges associated with the various performance objectives. Usually such as design is not only hard to tune and not universally applicable, but also tends to increase system complexity. In addition, even if the solution is found, there is no guarantee for its optimality. Combined with some recent breakthroughs in applying the Generalized KYP lemma with the projection lemma, this nonlinear problem can now be solved with Linear Matrix Inequalities. This leads to a possibility of incorporating a generalised regulator structure and therefore it enables multi-objective control synthesis. Moreover, with an accurate description of the frequency interval, frequency weighting functions can be completely replaced. Overall, this project aims to design one centralised controller K such that for multiple frequency intervals, the performance is optimised. In addition, this project also aims to take into account realistic system disturbances and uncertainties that exist in the problem, and demonstrate the advantage of the newly developed method against existing methods, such as MPC and other well-tuned controllers.
	Finite frequency active suspension control design for road vehicles	
	Offered to: Control	
	From: CAP	
		The student is expected to have a good background both in optimisation and control theory, and be able to apply the theoretical knowledge to the car suspension control problem. All programs will be developed in Matlab and Simulink.
1803021	**Fobelets,K. (with Georgiou,P.)**	Exhaled breath is naturally produced by the human body through breathing. It can be collected via gas condensation into a liquid in a non-invasive way. The pH of this liquid can be monitored using Ion Sensitive Field Effect Transistors (ISFETs). Prof. P. Georgiou's group of the Bio-inspired Metabolic Technology Laboratory has developed CMOS technology compatible ISFET arrays. The group of Prof. K. Fobelets has developed graphene transfer processes onto these arrays to change their functionality.
	Breath analysis using CMOS ISFET Sensor Arrays	
	Offered to: ADIC	In this research project we want to find out whether the ISFET arrays covered and non-covered with graphene will detect pH changes in breath condensate. This is a feasibility study, extending current knowledge in the field of graphene covered ISFET arrays into breath analysis. It is multidisciplinary and involves collaboration between different groups.
	From: OSD	The tasks to be completed in this project are:
		Literature study on breath condensate analysis using ISFETs arrays
		Training on ISFET readout and interpretation of acquired data
		Training on graphene transfer processes onto the ISFET arrays
		Development of techniques to create liquid condensate from exhaled breath.
		Setting up of testing protocol
		Data analysis – analyse response with and without graphene + response under different triggers – drinking an acidic/neutral fluid/base; walking in a traffic heavy street vs walking in nature.

PID	Supervisor	Description

1803185   **Franco,E. (with Chen,K.)**

Modelling and control of soft robotic manipulators for surgery

     Offered to: Control

     From:

Soft robotic manipulators are a promising solution for surgery because of their inherent safety.
However, controlling soft manipulators is challenging because they have many degrees of freedom.
In this project you will explore the following aspects.
1. constructing a dynamical model of a soft robotic manipulator using beam theory or equivalent.
2. developing a reduced-order model that can be used for control.
3. formulating a control law and assessing its effectiveness in simulations and experiments.
This is a great opportunity to learn about dynamical modelling, model reduction, and model-based control.

Desired Skill Set:
Linear control theory (Control Engineering)
Mechatronics (Modelling and Control of Multi-body Mechanical Systems)
signal processing, Arduino (C++)/MATLAB/Python (Real-time Digital Signal Processing)

This project is a collaboration between the CAP group, EEE, and the Hamlyn Centre.
Interested students are encouraged to approach the supervisor, Dr Enrico Franco, Lecturer in Hamlyn Centre (Room 414B, 4th floor Bessemer building) for further information. For initial discussion, please contact the second supervisor Dr Kaiwen Chen (Room EENG 1109. Email: kaiwen.chen16@imperial.ac.uk)

1802968   **Georgiou,P.**

Wireless Portable Electrochemistry Platform for Point-of-Care Diagnosis

     Offered to: ADIC

     From: **CAS**

Point-of-care diagnosis devices have been getting increased attention in the past decades. This is driven by the miniaturisation of diagnostic technologies and new sensor technologies such as aptamer-based biosensors.

Our group at Centre for Bio-Inspired Technology have developed an electrochemistry platform and has validated its use in continuous lactate and cortisol monitoring scenarios. We are migrating the platform to a more powerful wireless enabled MCU to facilitate rapid diagnostics on-the-fly. This is a multi-disciplinary project that will see collaboration with clinical partners.

The objective of this project includes:
Developing and validating the embedded system firmware.
UI/UX design.
Developing communication protocols to interface with device over BLE.
Efficient power management to prolong battery life.
(Plus) Integrating the platform with existing sensors.

Desirable skills: Embedded systems (C), Python, PCB design, BLE

PID	Supervisor	Description

1802969   **Georgiou,P. (with Moser,N.B.G.)**

Advancing rapid diagnostics for infectious diseases using AI classifiers

    Offered to: AML CSP

    From: **CAS**

The ion-sensitive field-effect transistor (ISFET) is a pH sensor that can be used to achieve diagnostics at the point-of-care, with a technology that is similar to PCR but without the requirement for complex machinery in a lab. The possibility to fabricate ISFETs in unmodified CMOS technology allows for array integration of the sensor [1], resulting in large amounts of spatio-temporal data. At the Centre for Bio-Inspired Technologies, we have developed a complete system design to achieve infectious disease diagnostics [3], which involves an ISFET array chip and its circuit integration for readout. The most recent iteration of the array is a 290x204 sensor array that allows to run up to 10 simultaneous experiments. The data from the ISFET array presents sources of noise specific to the technology that can only partly be compensated for [2]. This sets particular challenges in the interpretation of the data and opens the door to the development of innovative signal processing algorithms to achieve sensor characterisation. We have recently published a paper demonstrating that classification can be achieved by transforming the signal to the time-frequency domain, and using the image processing DNN classifiers for diagnostics [4].

This project will be focused on the classification of data from DNA amplification experiments run on ISFET arrays for diagnostics of infectious diseases and cancer. More specifically, the final aim of the project is to evaluate alternative transforms for chemical image analysis, and their integration with a classifier.

References
[1] N. Moser, J. Rodriguez-Manzano, T. S. Lande and P. Georgiou, "A Scalable ISFET Sensing and Memory Array With Sensor Auto-Calibration for On-Chip Real-Time DNA Detection," in IEEE Transactions on Biomedical Circuits and Systems, vol. 12, no. 2, pp. 390-401, April 2018.
[2] N. Moser, T. S. Lande, C. Toumazou and P. Georgiou, "ISFETs in CMOS and Emergent Trends in Instrumentation: A Review," in IEEE Sensors Journal, vol. 16, no. 17, pp. 6496-6514, Sept.1, 2016.
[3] Jesus Rodriguez-Manzano, Kenny Malpartida-Cardenas, Nicolas Moser, Ivana Pennisi, Matthew Cavuto, Luca Miglietta, Ahmad Moniri, Rebecca Penn, Giovanni Satta, Paul Randell, Frances Davies, Frances Bolt, Wendy Barclay, Alison Holmes, and Pantelis Georgiou, "Handheld Point-of-Care System for Rapid Detection of SARS-CoV-2 Extracted RNA in under 20 min" in ACS Central Science 2021 7 (2), 307-317
[4] P. Tripathi, C. Gulli, J. Broomfield, G. Alexandrou, M. Kalofonou, C. Bevan, N. Moser, and P. Georgiou, "Classification of nucleic acid amplification on ISFET arrays using spectrogram-based neural networks," Computers in Biology and Medicine, vol. 161, 7 2023.

PID	Supervisor	Description

1802970 **Georgiou,P.**

Deep Learning at the Edge for SoC Blood Glucose Prediction

Offered to: ADIC

From: CAS

Leveraging continuous glucose monitoring (CGM) systems, real-time blood glucose (BG) forecasting is essential for proactive interventions, playing a crucial role in enhancing the management of diabetes. Pioneering studies have deployed trained deep learning models on software-based computation platforms, such as smartphones. However, these platforms suffer from lack of wearability and battery life constraints. As a result, edge computing hardware based on BLE SoCs has been proposed [1], where deep learning models (e.g., RNN and Transformer) are deployed to perform dedicated glucose monitoring and prediction.

This project aims to the develop the next generation edge computing hardware for future model deployment which potentially including the following objectives:

1)Firmware
a.Establish BLE communication to access glucose data from remote sensors.
b.Peripheral development, e.g., UART, SPI and PWM.
c.Library investigation, e.g., CMSIS-DSP and CMSIS-NN
d.Low-level C function implementation and optimization
2)Hardware
a.Miniaturization of the edge computing hardware using nRF52840 SoC.
b.Power management, e.g., power-gating circuit with rechargeable li-poly battery
c.PCB design and layout
3)Software
a.Implement Python trained deep learning model using C at the numerical level.
b.Investigate tools for analysis of Flash and RAM usage.

Skills needed: Prior experience in embedded systems (hardware & firmware), Python programming (numpy) is mandatory.

[1] T. Zhu, L. Kuang, J. Daniels, P. Herrero, K. Li and P. Georgiou, "IoMT-Enabled Real-Time Blood Glucose Prediction With Deep Learning and Edge Computing," in IEEE Internet of Things Journal, vol. 10, no. 5, pp. 3706-3719, 1 March1, 2023, doi: 10.1109/JIOT.2022.3143375.

1803019 **Georgiou,P.**

A Wireless-Powered Programmable Lab-on-Chip for Swarm based BioSensing

Offered to: ADIC

From: CAS

Bioreactors are biologically active devices that are well-known for their wide range of healthcare applications, such as detecting food safety and vaccine production quality. Lab-on-Chip devices, on the other hand, leverage CMOS integrated circuit chips to provide small form factor solutions for exploring active chemical phenomena. By utilizing sensors such as the ISFET, chips in contact with the electrolyte can directly sense and transmit their active pH values.

This project aims to design to build a swarm sensing platform that integrates a wireless powering strategy for our ISFET sensors, along with a wireless data transmission link. This integration will allow us to significantly reduce the size of the device, down to a millimeter-scaled chiplet, and implement a swarm of these that can be placed inside a beaker for monitoring biochemical reactions in real time.

1.The scope of the project includes the following objectives:

2.Embedded system development, including SPI, on-chip ADCs, Bluetooth (BLE low power), using C.

3.PCB design, integrating the front-end sensing chip, NFC antenna, microcontroller, Bluetooth chip, and Bluetooth antenna.

4. Software programming for Bluetooth host device linking, data retrieval, and plotting, using Python.

Skills required: Prior experience in embedded systems, Python, and PCB design is mandatory.

PID	Supervisor	Description
1803021	Georgiou,P. (with Fobelets,K.) **Breath analysis using CMOS ISFET Sensor Arrays** Offered to: ADIC From: CAS	Exhaled breath is naturally produced by the human body through breathing. It can be collected via gas condensation into a liquid in a non-invasive way. The pH of this liquid can be monitored using Ion Sensitive Field Effect Transistors (ISFETs). Prof. P. Georgiou's group of the Bio-inspired Metabolic Technology Laboratory has developed CMOS technology compatible ISFET arrays. The group of Prof. K. Fobelets has developed graphene transfer processes onto these arrays to change their functionality. In this research project we want to find out whether the ISFET arrays covered and non-covered with graphene will detect pH changes in breath condensate. This is a feasibility study, extending current knowledge in the field of graphene covered ISFET arrays into breath analysis. It is multidisciplinary and involves collaboration between different groups. The tasks to be completed in this project are: Literature study on breath condensate analysis using ISFETs arrays Training on ISFET readout and interpretation of acquired data Training on graphene transfer processes onto the ISFET arrays Development of techniques to create liquid condensate from exhaled breath. Setting up of testing protocol Data analysis – analyse response with and without graphene + response under different triggers – drinking an acidic/neutral fluid/base; walking in a traffic heavy street vs walking in nature.
1803272	Georgiou,P. **A CMOS ASIC Design project for novel Biomedical Applications** Offered to: ADIC From: CAS	Please contact Dr. Junming Zeng to discuss further details : junming.zeng16@imperial.ac.uk

PID	Supervisor	Description
1803312	**Goodman,D.F.M. (with Pitt,J.V.)** **Learning to vote when it matters** **Offered to: AML** **From: ISN**	How can groups of individuals with different interests and expertise work together? One approach is to make decisions by vote, hoping that aggregating individual noisy decisions will lead to a better decision. This has a counterpart in machine learning. Random forest algorithms which feature a voting mechanism have proven to be very robust in practice. Intuitively, this makes sense if all individual decisions are just noisy versions of a correct decision. However, in a world where expertise varies widely (e.g. economists are very expert at handling mathematical models, but have no understanding of the real world problems people face), simply counting up votes might not be the optimal way to aggregate decisions. Previous work has investigated more sophisticated ways to aggregate votes (see references below). In this project, you will investigate the specific case where reaching a consensus or near-consensus is crucially important, may be time critical, and where decisions have immediate and strong consequences. You will use a machine learning, multi-agent model, where each agent has different information and expertise, and agents are allowed to communicate before reaching a decision. In addition to the political, this project has applications to neuroscience. The brain can be considered as a collection of agents with different expertise engaged in continuous communication with each other, and which have a strong incentive to reach consensus quickly. Required skills: strong coding skills, experience in machine learning Useful skills: the "Neuroscience for machine learners" and "Self-Organising Multi-Agent Systems" courses would be good accompaniments Co-supervised by Jeremy Pitt References: - Mertzani et al. (2022) https://pubmed.ncbi.nlm.nih.gov/36200809/
1803313	**Goodman,D.F.M.** **Theseus-bot** **Offered to: AML** **From: ISN**	When designing agents to navigate environments we often focus on two abilities: how agents process sensory inputs and how they can estimate or remember their path. However, many animals also aid their navigation by altering their environment with pheromone trails, markings etc. The aim of this project is to develop agent based models which navigate by both sensing and interacting with their environment, and to then explore optimal strategies which leverage these two abilities. To realise this aim, the student will develop maze solving agents which can leave clues for themselves, and then assess how agents use this ability and what conditions it is beneficial in. This work fits into a larger project in the lab, focussed on evolving navigating agents, and so the student will benefit from additional support and collaborative opportunities. Required skills: strong coding skills in Python, experience of and interest in machine learning Useful skills: prior experience with reinforcement learning and/or evolutionary algorithms Likely to be of interest to students studying the "Neuroscience for machine learners" course. Co-supervised by Dr Marcus Ghosh.

PID	Supervisor	Description

1803314 **Goodman,D.F.M.**

Neural reuse and modularity in resource constrained task families

Offered to: AML

From: ISN

It has long been believed that the brain is highly modular both in terms of structure and function, and that this property might be partly responsible for our ability to reuse things we have learned in one setting in another setting (transfer learning). Machine learning still lags behind human abilities in tasks which require novel reuse of previously learned knowledge, and one reason may be that they do not make use of modularity in the same way as the brain. In previous work in my research group (Bena and Goodman 2023), we showed that moderate amounts of structural modularity aren't sufficient to induce the functional modularity that would be needed to build reusable modules. However, we did find that with increasingly tight resource constraints, the development of modularity was more likely. In this project, you will take this idea further.

Consider a family of tasks with common input and output structure, for example different games where you always have a fixed input set (e.g. visual array) and output set (e.g. set of controls). For each task, find the minimum number of neurons that can do the task at a given performance level. Now do the joint task where you encode the task identity as an extra input. If you can do this task with fewer neurons than the sum of the number of neurons needed for each task separately, then you must be reusing some neurons across tasks, and so they must be modules in some sense.

In this project, you will implement and study this idea. You will build a task family and train neural networks to carry out these tasks individually or jointly. You will then study what common modules have been extracted in the joint task network, and investigate whether or not the development of modules is made more likely by resource constraints.

Essential skills: familiarity with machine learning
Likely to be of interest to students studying the "Neuroscience for machine learners" course.

References:
- Bena and Goodman (2023): http://neural-reckoning.org/pub_sparsity_specialization.html

1803315 **Goodman,D.F.M.**

Brain equivalent of momentum learning rules

Offered to: AML

From: ISN

One of the key innovations in training artificial neural networks is gradient descent based algorithms that make use of some form of 'momentum' (e.g. the Adam learning rule). In practice, these often enable networks not to get stuck in local minima. Human learning is still superior to machine learning, although models of biological learning typically use rules that can be considered as some form of gradient descent. In this project, you will investigate the idea that modelling biological learning as a gradient plus momentum term could lead to a better understanding both of biological learning, and suggest new ideas for machine learning rules.

In the "rate-based models" and "STDP" videos of the "Neuroscience for machine learning" course (links below) you will have seen how changes in synapses take place at a much slower timescale than local changes in gradient. This might be evidence of a momentum-like term in the biological learning rule. In this project, you will investigate modifications to the biological learning rule models that explicitly include momentum-like terms. You will design and implement these models, and check if they allow for more stable learning on tasks that have been shown to be fragile when learned with standard biological learning rules (see the two papers referenced below).

Essential skills: familiarity with machine learning, strong programming skills, good mathematical skills
Prerequisites: The first half of the "Neuroscience for machine learners" course (even if you were not able to take the course for credit)

References:
- Rate-based models: https://youtu.be/UIPn7COOYcg
- STDP: https://youtu.be/fvzzwHKIMzk
- Masquelier et al. (2008): http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0001377
- Hathway and Goodman (2018): http://neural-reckoning.org/pub_re_stdp_repeating_patterns.html

PID	Supervisor	Description
1803302 **Rapid control prototyping for stability study of renewable inverters** Offered to: AML FPN From: CAP	**Gu,Y.**	In the evolving landscape towards a renewable power system, inverters are substituting synchronous generators as dominant sources. To scrutinize the impact of extensive inverter integration on system stability, creating adaptable and easily modifiable lab-scaled inverters is essential. This project aims to employ a Simulink-based Rapid Control Prototyping (RCP) technique on inverters to facilitate effortless control design without any coding. The RCP process will allow rapid testing, iteration, monitoring, and tuning of control strategies. The student of this project will collaborate with the researchers at the Maurice Hancock Smart Energy Lab to develop RCP systems in the lab. This project successfully ran last year with RCP deployed on a low-power (200W) inverter. This year, we will upgrade this to an 11kW inverter and integrate it into the real microgrid system in the lab. The detailed tasks include: 1. To design the PCB interface between an RCP controller and a commercial 11kW Danfoss inverter. The controller and the inverter have been available. 2. To design inverter control algorithms for various control functions, including grid-following, grid-forming, and so forth. 3. To test the inverter control algorithms on real hardware via RCP. 4. To integrate RCP inverters into the microgrid and study inverter-grid interaction and stability. The project can be rescaled depending on the actual progress. The video of the previous project is available at: https://www.youtube.com/watch?v=VnrgIGNwcq8
1803303 **Cloud-based co-simulation** Offered to: Control FPN From: CAP	**Gu,Y.**	Simulation is a very important tool for validating the dynamic stability of a power system. The emergence of inverter-based resources in power systems brings about new challenges for simulation. One of the challenges is that the models of inverters are defined by their control algorithms which are proprietary to inverter vendors. This project aims to develop a cloud-based co-simulation platform to address this challenge. In this cloud platform, the models of the inverters and the models of the power systems are simulated on two different computers, owned by the inverter vendor and system operator respectively. The two computers exchange signals over the cloud to simulate the interactions between inverters and power systems. Such a cloud-based co-simulation approach enables joint simulation among multiple parties without disclosing models from anyone. Candidate of the project needs to have a good knowledge of at least one power system simulation software, like PSCAD, Simulink, and openmodelica.
1803307 **How much overcurrent is needed from inverters for fault recovery?** Offered to: FPN From: CAP	**Gu,Y.**	Inverters are short of overcurrent capacities compared to synchronous generators, which may cause trouble for power systems. Short-term overcurrents are needed to trigger fault protection relays and to provide the surge current needed to bring the voltage back to pre-fault levels. This project will conduct a quantitative analysis of the minimum level of fault current needed to ensure proper voltage recovery after faults. The recovery current may include the in-rush current to re-energies transformers, recharge rectifiers, and restart induction machines. We will use a composite load model for this investigation and illustrate the relationships between load properties and recovery current. This will provide guidance to system operators and inverter vendors for future inverter design and system planning.

PID	Supervisor	Description
1803308	**Gu,Y.** **SiC/GaN ultrafast power amplifier for hardware-in-the-loop simulation** **Offered to: FPN** **From: CAP**	Hardware-in-the-loop (HiL) simulation is a "virtual reality" technology for testing power electronic converters. It allows for real converters to be connected to a simulated virtual environment to test the interaction of the inverter with the wider system, like an electric vehicle, a locomotive system, or a power grid. A power amplifier is the interface between the virtual and the reality. It generates the physical voltages/currents from the virtual model and applies them to the real converter. The power amplifier for HiL simulation needs to have a high bandwidth, up to MHz, to be able to capture the dynamic interaction between the virtual model and the real converter with a very high fidelity. Conventionally, such a power amplifier is implemented by power transistors in linear mode to achieve the high bandwidth needed. A linear amplifier has many drawbacks: it generates very high losses and is therefore huge in size, and it cannot realise bi-directional power flow. Now, with the emerging wide-bandgap devices like SiC and GaN, it is possible to build switching mode power amplifiers with much higher power density and bi-directional energy pump back, without losing the high bandwidth. This project will go from concept design to hardware prototyping for a switching mode ultrafast power amplifier based on SiC or GaN devices. You will start with comparative studies for different solutions and make design decisions from the studies. You will also prototype the amplifier with the help of researchers at the Smart Energy Lab. This project is open to those who are keen on power electronics and hardware design.
1803273	**Gunduz,D.** **Neural Network based Secure Image/Video Transmission** **Offered to: AML** **From: ISN**	In the conventional digital communication pipeline, data sources, such as images or videos, are first compressed into as few bits as possible, and these compressed bits are then transmitted over the channel using modulation and error correction mechanism. The compression and channel transmission blocks are designed independent of each other. Recently, we have introduced the concept of DeepJSCC [1], where the conventional layered pipeline is replaced by a pair of deep neural networks, trained jointly. It is shown that the DeepJSCC approach is more robust to channel variations, does not rely on accurate channel estimation, and achieves better performance then state-of-the-art digital transmission techniques that have taken more than seven decades and many generations of standards (both for data compression and for channel modulation and coding). However, since the DeepJSCC approach does not rely on bits as the common currency between the data compressor and channel coder, well-known digital encryption techniques cannot be used any more. This requires the design of novel encryption and authentication techniques. One initial work in this direction is [2]. In this project, we would like to extend and improve the encryption technique in [2], and also introduce a novel authentication method. This project requires strong background in machine learning, particularly in deep learning. [1] E. Bourtsoulatze, D. Burth Kurka, and D. Gündüz, Deep joint source-channel coding for wireless image transmission, IEEE Transactions on Cognitive Communications and Networking, ‌‌vol. 5, no. 3, pp. 567 - 579, Sep. 2019‌. [2] T. Y. Tung, and D. Gündüz, Deep joint source-channel and encryption coding: Secure semantic communications, IEEE International Conference on Communications (ICC), Rome, Italy, May 2023.
1803248	**Jaimoukha,I.M. (with Chaudhuri,B.)** **Robust control of grid-interface inverters of renewables** **Offered to: Control FPN** **From: CAP**	Control of inverters that interface renewables (e.g., wind turbines, solar panels), grid-scale batteries etc. to the power grid is crucial for their performance (e.g., reference tracking) and stability of the grid. This control design involves some difficult trade-offs between conflicting objectives and must be robust across a wide range of operating conditions due to the volatility of renewables. In this project, you would apply multi-objective robust control techniques to design the controller for grid-interface inverters to strike an appropriate balance between reference tracking, control effort (due to limited headroom of inverters) and robustness. The control performance would be validated in both frequency and time domains using case studies on an inverter-dominated test power grid. You would build the dynamic model of an inverter-based power grid in MATLAB/Simulink, develop a methodology for robust control design in MATLAB and compare the performance of the designed robust control against classical control. The spring-term elective module 'Design of multivariable control system' would be very helpful for this project.

PID	Supervisor	Description

1803252 **Jaimoukha,I.M.**

Fault detection and isolation

    Offered to: Control

    From: CAP

This project aims to investigate fault detection and isolation schemes for linear dynamic systems subject to disturbances and model uncertainties.

The aim of the project is to develop optimization algorithms for the design of a condition monitoring system that attenuates the disturbances, reduces the the sensitivity to model uncertainty and is able to reliably detect and isolate faults.

The student is expected to have a good background in optimization and control theory. All programs will be developed in Matlab and Simulink.

1803253 **Jaimoukha,I.M.**

Fault tolerant control system design

    Offered to: Control

    From: CAP

Control designs for complex systems are vulnerable to possible faults in the sensors and the actuators. The performance may be degraded following such a fault and the closed-loop system may even become unstable.

The aim of this project is to modify control design techniques, such as LQG, MPC, H_infinity, to ensure a minimum level of performance under all potential fault scenarios and to use any remaining degrees of freedom to optimize performance for the nominal, fault-free situation. The emphasis will be on developing fault tolerant controller design strategies that take account of the most likely and realistic fault scenarios.

The student is expected to have a good background in control theory. All programs will be developed in Matlab and Simulink.

1803254 **Jaimoukha,I.M. (with Evangelou,S.A.)**

Tube-Based and Robust Model Predictive Control (RMPC) for uncertain systems

    Offered to: Control

    From: CAP

Model Predictive Control (MPC) is a model-based advanced control scheme that is applied in real time, incorporates optimal control and handles hard constraints.

The aim of the project is to design state and output feedback Robust MPC (RMPC) controllers that are efficient to implement online. Traditionally, RMPC schemes require the online solution of a semidefinite program (SDP), which is computationally very expensive. The aim of this project is to approximate the SDP by a less computationally demanding quadratic program. This will be achieved by transferring the most demanding part of computations from online to offline without violating state and input constraints. The controller will be applied in the Oil and Gas drilling industry.

The project uses robust control theory techniques, linear matrix inequalities and game theoretic approaches. All algorithms will be developed using Matlab and Simulink.

PID	Supervisor	Description

1803255 **Jaimoukha,I.M.**

Approximate robust model predictive control design using off-line computational methods

Offered to: Control

From: **CAP**

Model Predictive Control (MPC) is a model-based advanced control scheme that is applied in real time, incorporates optimal control and handles hard constraints.

The aim of the project is to design Robust MPC (RMPC) controllers that are efficient to implement online. Traditionally, RMPC schemes require the online solution of a semidefinite program (SDP), which is computationally very expensive. The aim of this project is to approximate the SDP by a less computationally demanding quadratic program. This will be achieved by transferring part of the online computation offline.

The project uses robust control theory techniques, linear matrix inequalities and game theoretic approaches. All algorithms will be developed using Matlab and Simulink.

1803276 **Jaimoukha,I.M. (with Evangelou,S.A.)**

Finite frequency active suspension control design for road vehicles

Offered to: Control

From: **CAP**

The aim of this project is to investigate and synthesise a novel multi-objective controller for road vehicle active suspension systems to enable further improvements for ride comfort and road holding performances, as compared to existing control schemes. The existing methods require the design of weighting matrices to specify the frequency ranges associated with the various performance objectives. Usually such as design is not only hard to tune and not universally applicable, but also tends to increase system complexity. In addition, even if the solution is found, there is no guarantee for its optimality. Combined with some recent breakthroughs in applying the Generalized KYP lemma with the projection lemma, this nonlinear problem can now be solved with Linear Matrix Inequalities. This leads to a possibility of incorporating a generalised regulator structure and therefore it enables multi-objective control synthesis. Moreover, with an accurate description of the frequency interval, frequency weighting functions can be completely replaced. Overall, this project aims to design one centralised controller K such that for multiple frequency intervals, the performance is optimised. In addition, this project also aims to take into account realistic system disturbances and uncertainties that exist in the problem, and demonstrate the advantage of the newly developed method against existing methods, such as MPC and other well-tuned controllers.

The student is expected to have a good background both in optimisation and control theory, and be able to apply the theoretical knowledge to the car suspension control problem. All programs will be developed in Matlab and Simulink.

1803306 **Junyent-Ferre,A.**

Technology for decoupling wind energy resource extraction from the instantaneous electrical power output

Offered to: FPN

From: **CAP**

Wind power generation is becoming a key actor in the regulation of the frequency of the power system as more synchronous generation is replaced by wind. This leads to several technical challenges. One of them is how to make wind turbines flexible enough to adapt their power set-point to the instantaneous demand of the grid. This project is to analyse the use of a braking resistor suitable for long-term operation combined with the torque and pitch control of the generator. The idea is to design a controller that enables the wind turbine to implement enhanced Grid Forming (GFM) controls on the wind turbine. This project is suitable for students who are interested in power electronic converter control for generation. The project will involve simulation studies using Matlab Simulink.

PID	Supervisor	Description

1803309   Junyent-Ferre,A.

Seamless transition between AC-grid-tied to islanded-mode of wind farms connected to VSC-HVDC and HVAC

Offered to: Control ADIC AML FPN CSP

From: CAP

There are great incentives to build wind farms in the locations with the best energy resources. However, these are far from load centres, which leads to the need for long-distance transmission with HVAC or HVDC. As wind farms grown larger in size, there's a need to design their transmission to have redundancy and prevent single point of failure. In some locations, an isolated wind farm will be connected by a combination of HVAC and HVDC. This project will look into the control of the HVDC converter to make it possible for the wind farm to continue to operate upon losing the AC connection. The project is recommended for students who are interested in power electronic converter controls applied to VSC-HVDC technology for wind power.

1802876   Kerrigan,E.C.

Dynamic optimisation in the Julia programming language

Offered to: Control

From: CAP

Nearly all optimal control and estimation problems, as well as many system design problems, can be formulated as dynamic optimization problems. These are also often called trajectory optimization problems in the aerospace or robotics communities, where one typically wants to get a dynamical system from one point in space to another, while minimising time, energy or cost. 

In dynamic optimization one seeks to optimize an objective functional to determine the state and input functions of time, subject to differential equations (arising due to modelling the dynamics) and inequality constraints (arising due to safety, performance or physical considerations), while providing guarantees despite modelling uncertainties, disturbances and noise. These problems can be solved efficiently using tailored, structure-exploiting finite-dimensional numerical 
methods. For an introduction to numerical methods for dynamic optimization, see https://doi.org/10.1137/16M1062569 and https://doi.org/10.1137/1.9780898718577.

Julia is a modern high-level language, which employs sophisticated ideas from computer science to allow for rapid algorithm development (similar or easier than Matlab or Python) with an emphasis on high performance (comparable or faster than C). Julia might just one day overtake C/C++ as the language of choice for high-performance scientific computing. See julialang.org and the paper https://doi.org/10.1137/141000671 for more details. If you have not yet heard of Julia, you will certainly hear a lot about it in the future! 

This project will involve contributing towards the development of a user-friendly and efficient package for dynamic optimization in the Julia Language called Interesso. The proposed extensions will build up on past work of the group implementing integrated residual methods.

The student assigned to this project should also choose one or more engineering case studies to which they have to apply and test their code. This list is constantly evolving, but a list of possible case studies include: Formation flight of UAVs; Rocket launch and landing; Spacecraft rendezvous and docking; Aerial communication networks. Other suggestions and ideas from the student are encouraged.

COMPULSORY PRE/CO-REQUISITES: You should have completed the Optimisation module and be familiar with state space control methods. It is essential that you be proficient with more than one programming language (two or more of Matlab, C/C++, Python, etc.) and have experience with object-oriented programming.

PID	Supervisor	Description

1802877   **Kerrigan,E.C.**

Control of a minidrone over a wireless network

     Offered to: Control

     From: **CAP**

This project aims to develop a trajectory generation controller to navigate an Unmanned Aerial Vehicle (UAV) around obstacles in its environment to its target. This will be based on the Mathworks Minidrone Competition (https://uk.mathworks.com/academia/student-competitions/minidrones.html) using the Parrot Mini Drone simulation model, with the possibility of testing the design on hardware. The student will be exploring the capabilities of the MATLAB Model Predictive Control toolbox, including the integration with the FORCES-Pro solver (https://www.embotech.com/products/forcespro/overview/).

PRE/CO-REQUISITES: Interested students should ideally have done the Predictive Control module and be familiar with MATLAB and Simulink.

1802878   **Kerrigan,E.C.**

Computer Vision, Sensor Fusion, and State Estimation for a Parrot Minidrone

     Offered to: Control AML CSP

     From: **CAP**

This project focuses on the development of a state estimation framework for a Parrot quadrotor vehicle. The vehicle is designed for indoor operation, which complicates the problem of position estimation due to the inability to use GPS as a means of correcting for estimator drift. Instead, the quadrotor must process images generated by its onboard camera alongside the data produced by its ultrasonic sensor, inertial measurement unit (IMU), and pressure sensor into a single state estimate that is reliable enough to enable indoor navigation.

The project entails building upon the rudimentary optical flow implementation currently used on the drone and designing a filter framework to combine all of the sensor measurements. Areas of focus include implementing more recent computer vision techniques to improve the quality of the image-based velocity estimation, incorporating loop-closure for position estimation as part of the vision pipeline, and deriving a Kalman filter from the vehicle and sensor dynamics. Work will begin inside a realistic Simulink simulation environment then proceed to deployment and testing on real hardware. As such, any approach developed is expected to work within the constraints of the limited computational power available onboard the quadrotor.

Anyone interested in taking this project should be familiar with MATLAB and Simulink, as well as with the basics of modern computer vision and state estimation.

1803242   **Kerrigan,E.C.**

Algorithmic financial trading in the Julia programming language

     Offered to: Control

     From: **CAP**

Many financial trading algorithms are based on solving optimization problems. The aim of this project is to develop a software package for algorithmic trading in the Julia programming language. The current version of the software package developed by previous students is available at https://github.com/JuDO-dev/AirBorne.jl

Julia is a modern high-level language, which employs sophisticated ideas from computer science to allow for rapid algorithm development (similar or easier than Matlab or Python) with an emphasis on high performance (comparable or faster than C). Julia might one day overtake C/C++ as the language of choice for high-performance scientific computing. See julialang.org and the paper doi.org/10.1137/141000671 for more details. If you have not yet heard of Julia, you will definitely hear a lot about it in the future!

This project will involve integrating existing packages for financial trading, optimization and/or machine learning in Julia with optimization and optimal control solvers developed by my research group. The goal will be to have a software package that can automatically download financial data, analyse the data and make recommendations in real-time as to whether an investor should buy or sell shares. We

COMPULSORY PRE/CO-REQUISITES: You should have completed the Optimisation module. It is essential that you be proficient with more than one programming language (two or more of Matlab, C/C++, Python, etc.) and have experience with object-oriented programming.

PID	Supervisor	Description
1803280	**Kiziroglou,M. (with Wright,S.W.)** **3D-Shaped Magnetic Transducers** **Offered to: Control ADIC** **From:** **OSD**	Supervisors: Steven Wright, Michail Kiziroglou, Eric Yeatman One of the main energy transduction methods for sensing, actuating and powering application is through magnetic fields. Typical mechanisms include magnetic induction, i.e. the induction of a voltage on a conductive loop or coil by the time variation of magnetic flux passing, and the Hall effect. The effectiveness of such devices depends on the available magnetic flux, which for small devices is limited, because it is proportional to the device area. A promising new method for improving magnetic functionalities in small devices is to channel the flux through soft magnetic materials shaped in funnelling geometries [1]. In this project, 3D-shaped magnetic transduces will be developed for use in energy harvesting, high-sensitivity sensing and actuating applications. Custom designs, developed by the student may be fabricated by an external industrial partner as well as by in-house 3D printing of polymer-based magnetic materials. The fabricated shapes will be integrated into functional prototype energy harvesters, sensors or magnetic actuators. The devices will be tested using custom evaluation setups developed for specific aircraft and infrastructure sensing applications, available in the department facilities. It is possible that the work will lead to a scientific publication. [1] M. E. Kiziroglou, S. W. Wright, and E. M. Yeatman, "Power Supply based on Inductive Harvesting from Structural Currents," IEEE Internet of Things Journal, vol. 9, no. 10, pp. 7166 - 7177, 2021.
1803281	**Kiziroglou,M. (with Wright,S.W.)** **Efficiency and Aging of Piezoelectric/Magnetic Energy Harvesting MEMS.** **Offered to: Control ADIC** **From:** **OSD**	Supervisors: Steven Wright, Michail Kiziroglou, Eric Yeatman A major challenge in the development of Internet of Things (IoT) services is powering the distributed microsystems that are used for local sensing and actuation, as required for example in aircraft structural health monitoring. A technology that is underway for addressing this challenge is energy harvesting, i.e. the collection of local environmental energy for local use. In this project, in collaboration with Fraunhofer-ISIT, a hybrid piezoelectric and magnetic energy harvesting transducer concept will be investigated for collecting energy from power lines. The devices are based on a pioneering method for magnetic materials integration in MEMS devices [1] and are already available, provided by Fraunhofer ISIT for tests. The tests will be performed on an existing evaluation setup for inductive power line harvesting transducers. They will focus on evaluating the maximum possible power output, evaluating aging effects of the piezoelectric devices as well as on investigating new methods for device life-extension. Example of wear-reduction methods to be investigated include electrical and mechanical pre-biasing. This study is of broader interest as it addresses the key aspect of aging in piezoelectric transducers. [1] M. T. Bodduluri et al., "Fully Integrated High-Performance MEMS Energy Harvester for Mechanical and Contactless Magnetic Excitation in Resonance and at Low Frequencies," Micromachines, vol. 13, no. 6, p. 863, 2022.
1803282	**Kiziroglou,M. (with Yeatman,E.M.)** **Controlled Actuation of Micro-Robots by On-Board Visual Feedback.** **Offered to: Control ADIC** **AML** **From:** **OSD**	Supervisors: Eric Yeatman, Michail Kiziroglou One of the most exciting technologies emerging in recent years is the combination of rapid prototyping techniques such as 3D printing with microscale actuators and advanced control algorithms to develop precision microrobots. Applications include micro-surgery tools, tethered and un-tethered diagnosis instruments, implants and precision drug delivery and other biomedical devices. A MEMS-actuated, origami-inspired, 3D printed and flexure based delta robot has recently been developed [1]. Various functional features are currently being investigated including mechanical driving of endoscopy probes, micro-lenses and medical scanners and on-board visual feedback by the integration of a camera and micro-location tag systems. A use case of special interest is probe-based confocal laser endomicroscopy (pCLE), which is very promising for supporting informed decisions on removing cancerous tissue during surgery. In the proposed project, updated versions of this robot will be fabricated by 3D printing, and precise motion control will be investigated by applying visual feedback algorithms. The project involves a unique combination of state-of-art hardware prototyping activities and visual motion feedback software implementation. [1] X. Chen, M. E. Kiziroglou, and E. M. Yeatman, "Linear displacement and force characterisation of a 3D-printed flexure-based delta actuator," Smart Materials and Structures, vol. 31, no. 10, p. 104001, 2022/09/05 2022.

PID	Supervisor	Description

1803373 **Leung,K.K.**

Efficiency and Data Privacy in Federated Learning

Offered to: Control ADIC AML FPN CSP

From: **CSP**

In mobile networks and large-scale computing infrastructures, data servers, storage, databases and other types of resources are connected by communication links to support a wide range of user applications. Data-driven learning applications have also become popular. Machine learning in mobile computing environments encounters a few key challenges: (1) data is often collected and available at geographically dispersed locations, (2) the collected data may actually be owned by different owners who may not be willing to share their data with each other due to data privacy, and (3) limited communication resources may also prohibit transfer of all data to a central node for the learning purposes. Federated learning has been proposed as an efficient form of distributed learning in such environments.

The goal of this project is to explore and enhance federated learning techniques. By using appropriate datasets such as the Alibaba cluster data and MNIST image data, we aim to develop new federate learning techniques:
1. To maximize the effectiveness of the distributed learning (e.g., in terms of the required learning time for convergence and the accuracy of the learned model), OR
2. To enhance data privacy by use of heterogeneous models for local processing nodes (e.g., through knowledge distillation).
Experimental work will be conducted to illustrate the performance merits of the proposed technique(s).

This challenging research work is part of the extension of the DAIS ITA research project. Additional information and related papers can be found at http://www.commsp.ee.ic.ac.uk/~wiser/dais-ita/index.html Students with possible interest in pursuing PhD study or research-focused career are particularly welcomed to consider this project. Interested students are encouraged to email Professor Kin Leung at kin.leung@imperial.ac.uk to arrange a discussion.

1803374 **Leung,K.K.**

Distributed Reinforcement Learning

Offered to: Control ADIC AML FPN CSP

From: **CSP**

In edge computing and large-scale distributed computing systems, data servers, storage, databases and other types of resources are connected by communication links. Analytics tasks and other applications make use of this large set of distributed resources to support the processing of these applications. Machine learning (ML) and reinforcement learning (RL) in particular have been widely employed for the purpose of allocating such distributed resources to the competing application tasks with the goal of maximizing the overall system reward.

While RL is powerful, RL techniques typically represent a centralized process. That is, a single agent has the responsibility of monitoring the system (or environment). Depending on the system state observed, the agent decides on the optimal actions to take in order to maximize the rewards. Unfortunately, such single-agent RL cannot be applied to many application scenarios. For example, the single agent may not be able to observe the entire system state. As a result, the idea of distributed RL using multiple agents to observe the system and take partial actions becomes important. The goal of this project is to investigate: (1) how distributed RL algorithms with multi-agents should be designed such that the overall performance is identical or close to that of the single-agent RL, (2) the mathematical conditions and requirements for which the RL problem can be solved exactly by the distributed agents, and (3) if the distributed, multiple agents can only provide an approximate solution, study the learning and reward performance and identify the region of applicability for such approximate solution by the distributed agents. Experimental work will be conducted by considering use of distributed RL to allocate networked resources to competing processing tasks.

This research work is part of the extension of the DAIS ITA research project. Additional information and related papers can be found at http://www.commsp.ee.ic.ac.uk/~wiser/dais-ita/index.html Students with possible interest in pursuing PhD study or research-focused career are particularly welcomed to consider this project. Interested students are encouraged to email Professor Kin Leung at kin.leung@imperial.ac.uk to arrange a discussion.

PID	Supervisor	Description

1803256 **Li,G.**

MSc Project: Bayesian Optimisation in UAV Management and Path Planning

Offered to: Control ADIC AML FPN CSP

From: CSP

Black-box optimisation tackles challenging problems with hidden or expensive-to-evaluate objective functions. Bayesian optimisation, a sophisticated method, uses probabilistic machine learning models to efficiently find optimal solutions. It strikes a balance between exploration and exploitation by creating a surrogate model, and iteratively selecting new evaluating points based on uncertainty estimations. Bayesian optimisation efficiently navigates the input space, gradually refining its understanding of the function to ultimately converge upon the optimal solution. Its strength lies in its ability to make informed decisions in the absence of complete information, thereby enabling the efficient optimisation of costly or difficult-to-evaluate functions in various applications, such as hyperparameter tuning in machine learning, experimental design in scientific research, and other complex real-world problems.

This project proposes to design BO-based search and tracking methods in applications related to target searching and sensor scheduling. By modelling the problem as a black-box optimisation problem, BO can be applied to various related problems, including WiFi device localisation, environmental monitoring, and contaminant source identification. It favours search and tracking in an active manner without prior position information. By further extending the surrogate model, it can also be used for scheduling the sensors to track moving targets. However, how to design BO-based sensor scheduling to efficiently search and track highly manoeuvring targets is still challenging. This project can be investigated in the following three directions:

1. Surrogate model design: A more proper model can help characterise the local stationarity of the dynamic block-box function in tracking applications.
2. Unmanned aerial vehicle (UAV) path planning: BO-based path planning can better schedule the UAVs for efficient measurement collection for search and tracking.
3. Exploration-exploitation strategy: The strategy of guiding the optimisation based on the surrogate model remains underexplored in search and tracking. A proper strategy can diminish the myopic property of the search and lead to a more efficient algorithm.

1803257 **Li,G.**

Elastic Resource Allocation with Deep Reinforcement Learning

Offered to: Control ADIC AML FPN CSP

From: CSP

Next generation communication systems are expected to support various data-intensive services and applications such as self-driving cars, augmented/virtual reality, Internet of Everything, and mobile data analytics. To meet the requirements of these emerging services and applications, service providers are expected to provide resources such as radio, storage, and computing at the network edge. To maximize quality of service, these heterogeneous resources should be shared properly among users based on their varying and dynamic demands as well as the environment dynamics caused by the changes in overall workload and internal application/service phases. Unfortunately, conventional optimization approaches cannot efficiently deal with the dynamics and uncertainty of user demands.

Multi-agent deep reinforcement learning (MADRL) is a promising tool to help service providers intelligently and dynamically allocate different types of resources to applications/services in a distributed and real-time manner. This project aims to develop advanced DRL approaches (e.g., federated DRL, deep dueling and GNN based DRL) to obtain the optimal resource allocation policy under the environment dynamics and uncertainty of applications/services to maximize the system performance. The trade-offs between revenue, service delay, and load balancing will also be analysed in the project.

Interested students are encouraged to email Prof. Geoffrey Ye Li at geoffrey.li@imperial.ac.uk to arrange a discussion.

PID	Supervisor	Description

1803258   Li,G.

Neuromorphic Semantic Communication for Future Wireless Systems

Offered to: Control ADIC AML FPN CSP

From: CSP

Semantic communication focuses on task related information transmission, which has the potential to break the theoretic limit of conventional bit-level wireless communication systems. However, semantic communication systems heavily rely on deep learning modules for semantic information encoding. These deep learning models, though powerful, are computationally intensive and power-hungry, which is challenging to be deployed on resource limited mobiles phones or Internet of Things (IoT) devices. Therefore, it is necessary to develop more energy-efficient deep learning algorithms for semantic communications.

Spiking neural network (SNN) provides a brain-inspired solution to the problem. It mimics the dynamics of biological neurons and processes information using time-coded spike trains. SNN features its high energy-efficiency and bio-plausible architecture, which has been envisioned as the third generation neural networks. In light of the promising future of SNN, this project aims to develop SNN-based semantic communication systems, which possibly involves the design of powerful SNN modules and novel spike-based source-channel coding to improve the system performance.

Interested students are encouraged to email Prof. Geoffrey Ye Li at geoffrey.li@imperial.ac.uk to arrange a discussion.

1803259   Li,G.

Deep learning-enabled ISAC System Design

Offered to: Control ADIC AML FPN CSP

From: CSP

With the development of location-enabled services, such as 6 degree of freedom (DoF) virtual reality, smart robotic systems, and vehicle networks, integrated sensing and communications (ISAC) systems have recently been proposed to provide localization abilities in communication systems. In ISAC systems, the sensing systems and communication links share the wireless resources to save bandwidth requirement, which requires joint waveform design for sensing/communications and advanced signal processing techniques for the estimation of targets' parameters and transmitted data.

Despite the success of ISAC systems, existing ISAC systems are mainly designed in a model-based way, whose performance relies on the accuracy of system models. Recent studies have shown that learning from data can help the system better capture the properties of wireless environment and the measurement noises. In addition, deep learning provides a convenient way to jointly design different components in ISAC systems by end-to-end training. Therefore, this MSc thesis project will explore the application of deep learning in ISAC systems.

Interested students are encouraged to email Prof. Geoffrey Ye Li at geoffrey.li@imperial.ac.uk to arrange a discussion.

1803243   Ling,C.

AI image generation based on improved diffusion models

Offered to: Control ADIC AML FPN CSP

From: CSP

Diffusion models have emerged as the state-of-the-art generative models, beating other AI methods such as GAN. A diffusion model is basically a random process where you add more and more noise, then run it backward with the help of a neural network. Amazingly, noise is your friend here. It can be used in image synthesis, computer vision, natural language processing etc. Furthermore, diffusion models have close connections with other research areas, such as information theory, probability and random processes, and statistical physics. This project is focused on the method of stochastic differential equations. Student must have an excellent mathematical background. Knowledge of random processes is essential (student required to take the module Probability and Stochastic Processes). Good programming skill is required.

Reference: L. YANG et al., Diffusion Models: A Comprehensive Survey of Methods and Applications.

PID	Supervisor	Description
1803244	**Ling,C.** **Post-quantum signatures with applications to blockchains** **Offered to: Control ADIC AML FPN CSP** **From: CSP**	In a world where quantum computers exist, current public key cryptographic schemes will become vulnerable to attacks that exploit the nature of quantum mechanics. Standardisation bodies such as the National Institute of Standards and Technology (NIST, USA), ETSI and ISO are in the process of developing standards of post-quantum cryptography. Among the prospective methods which are expected to be implemented for post-quantum cryptography, lattice-based cryptography figures as a front runner. This project will be concerned improved lattice signature protocols. Applications to blockchains may also be considered. Knowledge of cryptography is essential. Good mathematical background and programming skills are required for successful completion of this project. (student required to take the module Quantum Info and Post-Quantum Crypto, even better Cryptography and Coding Theory)
1803245	**Ling,C.** **Post-Quantum Key Exchange over the Internet** **Offered to: Control ADIC AML FPN CSP** **From: CSP**	We use Internet on a daily basis, whose security relies on modern public-key cryptography. However, existing key exchange protocols over the Internet based on RSA and Diffie-Hellman would be totally broken with the emergence of quantum computers. Lattice-based cryptography offers an answer to deal with this disaster. It also appears to be more efficient than existing key exchange protocols. In this project, you will firstly familiarize yourself with key exchange protocols in TLS, then implement in software a new, quantum-safe protocol based on lattices. Some knowledge of cryptography and programming skills are required. (student required to take the module Quantum Info and Post-Quantum Crypto, even better Cryptography and Coding Theory)
1803246	**Ling,C.** **Coding Theory for Post-Quantum Cryptography** **Offered to: Control ADIC AML FPN CSP** **From: CSP**	We use Internet on a daily basis, whose security relies on modern public-key cryptography. However, existing key exchange protocols over the Internet based on RSA and Diffie-Hellman would be totally broken with the emergence of quantum computers. Lattice-based cryptography offers a firm answer to deal with this disaster. It also appears to be more efficient than existing key exchange protocols. In this project, you will firstly familiarize yourself with key exchange protocols, implement in software a new, quantum-safe protocol based on lattices, and use error correction codes to reduce failure probability. Knowledge of cryptography and coding theory, as well as programming skills are required. (student required to take the module Quantum Info and Post-Quantum Crypto, even better Cryptography and Coding Theory)

PID	Supervisor	Description
1803091	**Lucyszyn,S.** **Extremely Low Frequency (ELF) Communications with Machine Learning** **Offered to: Control ADIC AML FPN CSP** **From:** **OSD**	This is a very practical design & build project for a student interested in experimental short-distance communications and machine learning. The project covers the ELF spectrum (from 3 Hz to 3 kHz) using electromagnetics (i.e., not acoustics). Examples of existing systems are used in military sub-maritime communications. Using HiFi amplifiers and modified speakers, the student will experiment with a relatively simple transmitter and receiver, using commercial audio systems. This is a re-run of a 2022 student project. Therefore, the project is more about improving the existing setup and doing lots of cool new experiments using signal processing and machine learning!
1803283	**Lucyszyn,S.** **Microwave radiation exposure sensor array** **Offered to: ADIC** **From:** **OSD**	With the 'perceived' risk of human exposure to excess levels of microwave radiation, from our WiFi to mobile phones to domestic microwave ovens, a student is required to develop a ubiquitous array of tri-axis microwave sensors connected to a smartphone, via a Bluetooth link. This is a challenging project and so the student should have hands-on experience with Raspberry Pi/Arduino interfaces, and a keen interest in RF electronics (and doing lots of experiments).
1803284	**Lucyszyn,S.** **Enhanced Buried Metal and Plastic Detection with Machine Learning** **Offered to: CSP** **From:** **OSD**	This project is for a well-rounded experimentalist (hardware and software). The project of metal and plastic detection builds-on a previous project. This year the student must improve the performance using machine learning and experiment with new applications, which may include biomedical applications.

PID	Supervisor	Description
1803286	**Lucyszyn,S.** **Ultra-sensitive microwave receiver** **Offered to: Control ADIC AML FPN CSP** **From:** **OSD**	This is a highly experimental project. The student must design and build a very low noise receiver for operation from approximately 1 to 2 GHz. The receiver will include antennas, band-pass filter, low-noise amplifier, power detector, integrator and post-detection amplification and ADC interface. In addition, any detected signals must be logged using an Arduino/Raspberry Pi connection.
1803287	**Lucyszyn,S.** **Noise radar simulation** **Offered to: Control ADIC AML FPN CSP** **From:** **OSD**	Conventional radars work on the principle of using pulsed/chirped coherent sinusoidal signals. This project uses thermal noise as the carrier signal, which is pulsed to provide distance measurements. A student is required to investigate previously reported systems that employs this technique and then to simulate an appropriate radar system using the Microwave Office simulator. The student can then compare and contrast the benefits of coherent and thermal noise radar systems.
1803214	**Mandic,D.P. (with Sanei,S.)** **Generation of Surrogate data using generative adversarial networks** **Offered to: CSP** **From:** **CSP**	Surrogate data are very important and useful in places where there are insufficient data available for learning, classification, and recognition. Different methods have been already used for this purpose. In recent years the focus has been on deep learning approaches. In this project, we will investigate the use of tensors for data augmentation (surrogate data generation). Tensors are extension of matrices into multi-dimensional space where various data diversity can be accommodated. The results will be applied to generate new surrogates from a set of gait data to enhance their classification quality. The outcome can also be used for generation of biomedical single- and multi-channel data such as ECG or EEG.

PID	Supervisor	Description

1803345 **Manikas,A.**

Array Uncertainties and Mobile Localisation using both Small and Large Aperture Antenna Array

Offered to: CSP

From: CSP

The purpose of this research project is to formulate a design methodology for smart calibration of antenna-arrays to remove array uncertainties

Array uncertainties/errors (which are the result of a number of factors such as ageing of antenna components, drift, mutual coupling, thermal effects, changes in the environmental conditions, imposed movements, etc.) can degrade significantly the performance of an antenna-array either slowly or even abruptly.
Initially the calibration problem of an array of a general geometry will be investigated with respect to errors/uncertainties in location (geometrical errors), phase and gain (electrical errors), even when all errors are present simultaneously. Furthermore, the
adverse effect of mutual coupling uncertainties between the elements of an array, (especially for small aperture arrays), will be examined, based on the modelling of the Mutual Coupling Matrix (MCM). This depends on the array geometry and the array electrical characteristics, but not on the directions of the incoming signals.

Emphasis will be given on the performance of super-resolution Direction Finding (DF) and localisation array signal processing algorithms. In particular a number of key issues and aspects will be highlighted by applying these algorithms to the mobile location estimation problem using both uncalibrated and calibrated arrays in conjunction with a Xilinx ZCU216 RFSOC software defined radio board

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1803347 **Manikas,A.**

Experimental BISTATIC Radar Using Xilinx ZCU216 RF System-On-Chip (RFSOC) Board

**Offered to: Control ADIC
                    AML FPN CSP**

From: CSP

To design and build an experimental BISTATIC radar supporting a large variety of experiments. Aims and Properties:
▪Real time, Adaptive behaviour
▪Calibration of hardware impairments
▪It should be easy to modify the radar so that to support experiments for specific scenarios.
▪It should be built in modules e.g. for changing frequency, increase output power.
▪To be able to scale up the radar system.
▪The radar should be easy to use, even for people with low knowledge of how it is built.
▪The radar shall not contain secret information and hardware.

Please see
▪https://www.xilinx.com/applications/aerospace-and-defense/digital-radar-ew.html#video and
▪https://www.dropbox.com/s/2oq00380k9hcsdo/L-%20band%20Tx.mp4?dl=0

NB:
▪A group/team of 3 students will be the primary workforce for building this experimental radar (RF units, digitisers, algorithms and antenna array)
▪At the end of the project period: For a working demonstrator, a bonus of £500 will be given to each student member of the team.

1803348 **Manikas,A.**

Cognitive MIMO Radar

**Offered to: Control ADIC
                    AML FPN CSP**

From: CSP

see Slides 10-22 in the following link: https://skynet.ee.ic.ac.uk/notes/Radar_10_other_Radar.pdf

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PID	Supervisor	Description
1803349	**Manikas,A.**	see Professor Manikas

Experimental MIMO radar for localisation and tracking of multi-UAVs

Offered to: Control ADIC AML FPN CSP

From: CSP

| 1803277 | **Mikolajczyk,K.M. (with Spiers,A.)** | In the field of computer vision, the majority of algorithms do not need a particular type of camera and will work comparably between a smartphone camera or the webcam of a laptop. Conversely, approaches to tactile sensing vary greatly by the type of sensor being used, as the sensors themselves vary in terms of transducer type (e.g. capacitive / optical) and resolution. |

Towards Tactile Sensor Agnostic Feature Extraction with a Robotic Arm

This project aims to create a method of comparatively analysing the data between various tactile sensors using machine learning approaches to extract common features. A variety of tactile sensors (DIGIT, Contactile, Xela) will be mounted on a UR5 robotic arm for repeatable data collection. This project builds on work from last year, which dealt with controlling the robotic arm and reading data from some of the sensors using a ROS (Robotic Operating System) framework.

Offered to: AML

From: ISN

| 1803067 | **Mitcheson,P.D.** | Most wireless power transfer technology (such as toothbrush chargers, Qi for mobile phones etc) uses the near magnetic field, i.e. induction. An alternative is to use the electric field via capacitive power transfer (CPT). |

Capacitive Power Transfer

This project will aim to investigate, design and build a CPT based system for mobile phone charging. As the link capacitances of such systems are very small, the operating frequency needs to be very high (MHz).

Offered to: ADIC FPN

The student will need to investigate suitable converter topologies for this work (we use versions of class E in the inductive work, but class DE has been more popular in CPT), design and simulate the system, and build a prototype.

From: CAP

PID	Supervisor	Description

1803378   **Mitcheson,P.D.**

An investigation into the operational and regulatory limits of inductive wireless power transfer

Offered to: ADIC FPN

From: CAP

Inductive power transfer systems are usually operated at 85 kHz (for vehicle charging), 100 kHz (for phones) and 6.78 MHz for medical implants

In this project we will look to see the limits of power transfer at different frequencies, whilst maintaining safety limits (ICNIRP), EMC regulations (including CISPR/IEC) and pacemaker compliance.

We will initially consider the limits based on ideal systems (without harmonics) but will then investigate how difficult the non-idealities of the system make compliance.

This will mainly be a modelling and simulation project, but may have some opportunity for taking measurements in the lab to confirm the models.

1803109   **Moosavi Dezfooli,S.M.**

What do LLMs know about sequence prediction?

Offered to: AML

From: ISN

Prerequisites: Strong math background (particularly Probability and Statistics, Linear Algebra), Machine Learning and Deep Learning modules, excellent time-management skills, and creativity.

This project focuses on the emergent properties of Large Language Models (LLMs), specifically their ability to extrapolate or interpolate a signal based on a series of observations.

1803110   **Moosavi Dezfooli,S.M.**

Robustness to distribution shift

Offered to: AML

From: ISN

Prerequisites: Strong math background (particularly Probability and Statistics, Linear Algebra), Machine Learning and Deep Learning modules, excellent time-management skills, and creativity.

In real deep learning applications, the test distribution usually differs from the training one. So, ensuring the trained models are robust enough to handle discrepancies between the two distributions is essential. This project aims to explore various methods that can be employed to enhance the robustness of models when dealing with common distribution shifts.

PID	Supervisor	Description
1803113	**Moosavi Dezfooli,S.M.**	Prerequisites: Strong math background (particularly Probability and Statistics, Linear Algebra), Machine Learning and Deep Learning modules, excellent time-management skills, and creativity.

How (Un)robust deep networks can be?

It is well-known that deep neural networks are susceptible to adversarial perturbations. Various methods have been proposed to improve their robustness to such perturbations. However, in this project, we aim to explore the opposite side of the spectrum: How can we further reduce the robustness of deep networks and what is the limit to their vulnerability?

Offered to: AML

From: ISN

| 1803114 | **Moosavi Dezfooli,S.M.** | Prerequisites: Strong math background (particularly Probability and Statistics, Linear Algebra; familiarity with Differential Geometry is a plus), Machine Learning and Deep Learning modules, excellent time-management skills, and creativity. |

Understanding the geometry of visual transformers

The geometry of the decision regions of convolutional neural networks (CNNs) has been extensively studied. Here, we compare the geometry of visual transformers (ViTs) to that of CNNs to identify similarities and differences.

Offered to: AML

From: ISN

PID	Supervisor	Description

1802969 Moser,N.B.G. (with Georgiou,P.)

Advancing rapid diagnostics for infectious diseases using AI classifiers

Offered to: AML CSP

From: CAS

The ion-sensitive field-effect transistor (ISFET) is a pH sensor that can be used to achieve diagnostics at the point-of-care, with a technology that is similar to PCR but without the requirement for complex machinery in a lab. The possibility to fabricate ISFETs in unmodified CMOS technology allows for array integration of the sensor [1], resulting in large amounts of spatio-temporal data. At the Centre for Bio-Inspired Technologies, we have developed a complete system design to achieve infectious disease diagnostics [3], which involves an ISFET array chip and its circuit integration for readout. The most recent iteration of the array is a 290x204 sensor array that allows to run up to 10 simultaneous experiments. The data from the ISFET array presents sources of noise specific to the technology that can only partly be compensated for [2]. This sets particular challenges in the interpretation of the data and opens the door to the development of innovative signal processing algorithms to achieve sensor characterisation. We have recently published a paper demonstrating that classification can be achieved by transforming the signal to the time-frequency domain, and using the image processing DNN classifiers for diagnostics [4].

This project will be focused on the classification of data from DNA amplification experiments run on ISFET arrays for diagnostics of infectious diseases and cancer. More specifically, the final aim of the project is to evaluate alternative transforms for chemical image analysis, and their integration with a classifier.

References
[1] N. Moser, J. Rodriguez-Manzano, T. S. Lande and P. Georgiou, "A Scalable ISFET Sensing and Memory Array With Sensor Auto-Calibration for On-Chip Real-Time DNA Detection," in IEEE Transactions on Biomedical Circuits and Systems, vol. 12, no. 2, pp. 390-401, April 2018.
[2] N. Moser, T. S. Lande, C. Toumazou and P. Georgiou, "ISFETs in CMOS and Emergent Trends in Instrumentation: A Review," in IEEE Sensors Journal, vol. 16, no. 17, pp. 6496-6514, Sept.1, 2016.
[3] Jesus Rodriguez-Manzano, Kenny Malpartida-Cardenas, Nicolas Moser, Ivana Pennisi, Matthew Cavuto, Luca Miglietta, Ahmad Moniri, Rebecca Penn, Giovanni Satta, Paul Randell, Frances Davies, Frances Bolt, Wendy Barclay, Alison Holmes, and Pantelis Georgiou, "Handheld Point-of-Care System for Rapid Detection of SARS-CoV-2 Extracted RNA in under 20 min" in ACS Central Science 2021 7 (2), 307-317
[4] P. Tripathi, C. Gulli, J. Broomfield, G. Alexandrou, M. Kalofonou, C. Bevan, N. Moser, and P. Georgiou, "Classification of nucleic acid amplification on ISFET arrays using spectrogram-based neural networks," Computers in Biology and Medicine, vol. 161, 7 2023.

1803062   Naylor,P.A.

Sound source localisation using graph neural networks

Offered to: CSP

From: CSP

In the context of acoustic signal processing, Sound Source Localisation (SSL) is the task of simultaneously processing signals recorded from multiple microphone receivers, also known as a microphone array, to estimate the coordinates of one of more active sound sources, such as a human speaker. Applications of SSL include robot orientation, speech enhancement and separation.
SSL may be divided into two tasks, Positional SSL and Direction of Arrival (DOA) estimation. In the former, the 2D or 3D coordinates of the sources are estimated using spatially-distributed microphones. Conversely, in the latter, the angle between the sources and a single device containing multiple microphones is estimated. An example of device capable of such processing is Amazon Alexa, which possesses 6 embedded microphones.
Recently, Deep Neural Networks (DNNs) have surpassed classical signal processing methods, such as
the Steered Response Power (SRP) approach in terms of localisation performance. However, most neural approaches require for a model to be trained for each microphone topology (number of microphones and their relative positions), hindering their direct adoption in practical scenarios. The project will study the application of Graph Neural Networks (GNNs) for the task of SSL, which have recently been shown to handle a variable number of microphone signals.
As an initial step, a comparison between a GNN and the classical SRP algorithm will be made for the task of localising a single speech source in an enclosed room. A metric to be used for this comparison is the Euclidean distance between the prediction and ground truth of both localisation methods. An extension element of this project is to adapt the existing GNN model for the task of DOA estimation, training and testing the method using microphone arrays of different size and topology.

PID	Supervisor	Description

1803064 **Naylor,P.A.**

A Study of Differential Microphone Array Technology

Differential microphone arrays are particularly attractive for devices of small dimension, such as may be encountered in Internet of Things technologies. This project will study differential microphone arrays in comparison to classical array processing to determine the advantages and disadvantages.

Implementation of differential microphone array processing will be performed in either Python, or MATLAB, and performance evaluation carried out for two or three particular use cases to be defined.

Offered to: CSP

From: CSP

1803366 **O'Malley,M.**

Planning for extreme weather events on power system distribution grids

Power systems have constantly confronted extreme weather events. Climate change has increased the rate of such incidents in recent years. Extreme weather events can cause severe power system failures, resulting in widespread blackouts with significant economic impacts. Globally the economic impact is estimated to be of the order of 50 to 100 billion US$ per year. Planning to reduce these impacts cost effectively is the subject of significant research. Here the focus will be on distribution grids that are more prone to damage from extreme weather and the nature of distribution grids is also changing because of the increased penetration of distributed energy resources DER (e.g., wind, solar PV etc.). Cost effectively planning is a trade-off between investment in distribution grids e.g., such simple things as installing more costly distribution poles to carry the network that don't easily blow down in a storm and the cost of a disruption to supplying the consumer in the event of a storm. This trade-off must be analysed into the future for the lifetime of any investments and therefore the problem is a stochastic optimisation problem. Using distribution network data, predicted weather patterns (that may change with climate change) and cost data etc. the project will develop a stochastic optimisation algorithm investigate this trade-off for a test system with increased penetrations of DER.

Offered to: Control ADIC AML FPN CSP

From: CAP

1803367 **O'Malley,M. (with Brahma,D.)**

Data-driven Nodal Inertia Estimation

The adverse impacts of depleting inertia due to the transition from synchronous to non-synchronous power generation are well documented. This has primarily led to extensive research in the estimation of power system inertia in various spatial and topological levels, like system-wide inertia (or simply system inertia), and area-wide inertia (or regional inertia).

However, the distribution of these aggregated inertia for a practical power system is non-uniform, which can be mainly attributed to (a) diversified power generation technologies of varying capacities distributed nonuniformly in the grid, and (b) zero, low or varying inertial contribution from inverter-based resources (IBRs), depending on their control methodologies. This locational unevenness in inertial distribution affect both local and global dynamic behaviour of the system, like rate of change of frequency (ROCOF), and inter-area power oscillations. Hence, rather than an aggregated inertial estimation, accurate estimation of inertial distribution at node or bus level, also known as nodal inertia, becomes more critical and necessary, especially as the generation portfolio changes due to increasing penetration of IBRs.

Existing methods of nodal inertia estimation are limited to either ambient (normal) or transient (ring-down) conditions of the power system. Although a unified approach of online estimation of nodal inertia for any power system condition was recently proposed, it still requires network topological and model parametric information. Using existing data sets and some preliminary work to date this project will develop a fully data-driven approach to estimate nodal inertia which would (a) make the estimation model-free, and (b) make it immune to event-detection.

Offered to: Control ADIC AML FPN CSP

From: CAP

PID	Supervisor	Description

1802930 **Pal,B.C.**

A Stochastic Method for the Operation of Active Distribution Networks

Offered to: FPN

From: CAP

Motivation

The penetration of distributed generators (DGs) in distribution networks could improve the system efficiency, reliability and security. Nevertheless, they could impact the system voltage, power quality, fault level and interact with the operation of capacitors and voltage regulators. The intermittency and variability of renewable DGs (e.g., wind and PV) impose challenges when operating distribution systems.

Objective

A stochastic method for the operation of active distribution network under active management schemes such as coordinated voltage control and adaptive power factor control is proposed in order to evaluate the active and reactive power of renewable and non-renewable DGs considering 1) uncertainties related to solar irradiance and load demand, 2) different operational status of DGs (multi-configurations), and 3) capability curve of PV inverters. Total costs are composed of active and reactive cost of renewable and non-renewable DGs and active power losses cost and the cost of imported/exported power from/to the grid.

Methodology

The simulation software can be MATLAB or GAMS. The first step is gathering load data, renewable and non-renewable DGs and a real distribution network data. The second step is formulating the problem and implementing it in one of the above mentioned softwares.

Learning outcome

Programming in MATLAB or GAMS can be a great learning experience and understanding the challenges of distribution systems operation with integration of renewable DGs.

1802931 **Pal,B.C.**

Impact of FRT capability on DGs penetration level

Offered to: FPN

From: CAP

Title: Impact of LVRT capability on DGs penetration level

With increasing distributed generators (DGs) in power grid, new services have been introduced to increase grid safety, efficiency and reliability. Among such services, low-voltage ride-through capability in IIDERs, such as wind plants and photovoltaic parks, has been the one with most interest, particularly during grid faults. Despite this service being implemented due to the high penetration level of DGs, it is not known to what extent this service can support the increase in DGs penetration.
This study aims to provide an insight of how much more power capacity the LVRT service can allow from IIDGs. This will help power system operators to estimate the penetration level of DGs (with/without of LVRT capability) they can allow within their systems.
The student should have knowledge of energy systems modelling with renewable with matlab.

PID	Supervisor	Description

1802932 **Pal,B.C.**

Optimal Scheduling of Electric Vehicles for charging

Offered to: FPN

From: CAP

The number of Electric Vehicles (EV) and Plug-in Hybrid Electric Vehicles (PHEV) is increasing day by day because of their reduced carbon footprint. However, the charging of a large fleet of PHEV and EV can significantly stress the electrical grid if not managed properly. This problem particularly requires more attention because most of the EV/PHEV owners start charging them right after the day's work which is when the basic load curve is already at its peak. This uncontrolled charging can lead to voltage imbalances at the nodes and violation of line ampacity limits. To overcome these problems, an optimal charge scheduling of EVs need to be developed considering the upcoming trips of the vehicles. This scheduling will be carried out by a third party player, called an aggregator, where many vehicles need to be aggregated. The aggregator will require the day ahead electricity prices and a driving plan for the next day together with the network congestion limits to dispatch an optimal schedule which pursues the minimum cost of charging while removing any grid bottlenecks. The solution of the optimization problem run by the aggregator will consist of a charging schedule of each vehicle so that sufficient energy is available for the upcoming trips.

1802933 **Pal,B.C.**

Suitability of wind farm generator model for dynamic simulation

Offered to: FPN

From: CAP

Power system studies are largely based on modeling and simulations. Dynamic equations and parameters of generators, loads and network are largely based on physical principles and validated using field test. However, wind farms and solar farms are different from conventional generators as a farm may consist of hundreds of individual generators. Including all constituent generators in a power system simulation is not a practical approach. Hence an aggregate model of wind or solar farm is used in grid simulations. These often result in poor accuracy and wrong judgment on stability and capacity of transmission grid.
This project proposes to study the appropriateness of models used in DigSilent PowerFactory and PSSE software by comparing with an EMTP simulation in Matlab or PSCAD.

1802934 **Pal,B.C.**

Modelling and analysis of converter induced instability in power network

Offered to: FPN

From: CAP

Recently the post fault voltage recovery of power network has been found to be associated with oscillatory response in the system voltage . It is suspected that there are interactions amongst various dynamic voltage and VAR support in the network which are converter interfaced. In this project, the dynamic behaviour of converter following fault will be modelled along with is control. In a sample network consisting of at least two DG interfaced through hardware and dynamic loads will be modelled and analysed. The sensitivity study to various control parameter and power output level will be conducted to understand the underlying causes of the interaction.

PID	Supervisor	Description

1802935 **Pal,B.C. (with Ul Nazir,F.)**

Forecasting MW from DG in the UK from weather data

Offered to: FPN

From: CAP

In a particular day in August, 2016 National Grid (NG) experienced lowest demand in their system. This is due to generation from PV in the system that is at distribution level. NG does not have any record of this generation because it is not connected to their system. However, there are plenty of local weather information stations across different areas of UK where temperature, sun index all are measured. The challenge is how such information can be translated to available MW when the installed capacity of PV farm is known. The objective is to estimate the MW from solar to grid for most cost effective reserve planning. The project will explore various estimation/prediction tools used in industry for that purpose. Make a comparison and contrast their performance. A good first class project requires new method to explore.

1803027 **Papavassiliou,C.**

Reservoir Computing using Coupled oscillator networks

Offered to: ADIC

From: CAS

Coupled oscillators develop collective modes. Input signals can cause transitions between these modes, and alter the coupling strengths between the oscillators.

Networks of oscillators are becoming very popular as a candidate technology to make learning circuits known as Reservoir Computing.
In this project we will explore in MATLAB simulation simple couple oscillator learning networks.

Reservoir Computing has emerged as a powerful paradigm in machine learning for processing and forecasting complex temporal data. This project explores a novel approach to RC by harnessing the phase dynamics of coupled oscillators. The concept of coupled oscillators has deep roots in physics and biology, with synchronization phenomena being widely observed in natural systems. Leveraging these principles, we propose a new framework for reservoir computing that utilizes the phase information of interconnected oscillatory units.

In this research endeavor, we investigate the theoretical foundations and practical applications of phase-based reservoir computing. We analyze the dynamics of coupled oscillators and demonstrate how their intrinsic synchronization properties can be exploited to create a reservoir of computational capacity. By carefully engineering the connections and parameters of the oscillator network, we aim to harness the rich temporal dynamics for efficient and effective information processing.

Furthermore, we explore the capabilities of phase-based reservoir computing in various domains, including time-series prediction, pattern recognition, and signal processing.

1803029 **Papavassiliou,C.**

A memristor compact model for circuit simulations

Offered to: ADIC

From: CAS

Memristors are adjustable nano electronic resistors able to remember their resistance value.

The resistance value of a Memristor changes when current pulses are applied to the device and then it relaxes to a final value which persists with very little drift over long periods of time.

In this project we will perform measurements on memristor devices to determine parameters for a compact model recently developed at Imperial to describe the complex behaviour of memristor devices. A compact model is a computationally efficient set of equations which adequately describes the behaviour of a device. A transistor small signal model is an example of compact model.

PID	Supervisor	Description
1803031	**Papavassiliou,C.**	Proposals for electronic design projects in Radio Frequency and/or Instrumentation are invited.

Self-Proposed RF-Instrumentation circuit Design

Offered to: ADIC

From: CAS

| 1803032 | **Papavassiliou,C.** | In this project we will investigate both by simulation and by building circuits using discreet memristors, the possible uses of memristors in analogue and Radio electronics. |

Analogue and RF applications for Memristors

Memristors are electrically programmable, variable resistors. Their resistance can be changed by applying signals on them, and they "remember" their resistance afterwards . Memristors can be used as analogue memories or non-volatile potentiometers. Memristors are a candidate technology for future microelectronics, and consequently the student working in this project will be working at the forefront of microelectronics research.

Offered to: ADIC

From: CAS

| 1803034 | **Papavassiliou,C.** | A capacitance gauge can be used for a great number of industrial applications. Capacitive sensors are used as pressure sensors, microphones, accelerometers, fluid level sensors among many other applications. |

AC capacitance gauge

In this project we will investigate a class of capacitance readout
instruments based on relaxation oscillators. Such instruments can be extremely sensitive (have a resolution of a fraction of a pF) fast

Offered to: ADIC

(can take a reading in a few msec) operate at very low power (a few mW)
and finally are easy to implement monolithically, i.e. ideally suited for
integrated sensor applications.

From: CAS

We will investigate the limitations of such oscillators such as nonlinearity , dynamic range and resolution. Ideally we will build several prototype oscillators which we will test in the laboratory.

PID	Supervisor	Description
1803058	**Papavassiliou,C.**	In this project we will use stochastic gates made out of a True Random number generator we have developed in our lab to implement a reservoir computer.

Reservoir computing using stochastic logic gates

Offered to: ADIC

From: CAS

Reservoir Computing has emerged as a powerful paradigm in machine learning for processing and forecasting complex temporal data. This project explores a novel approach to RC by harnessing the phase dynamics of coupled oscillators. The concept of coupled oscillators has deep roots in physics and biology, with synchronization phenomena being widely observed in natural systems. Leveraging these principles, we propose a new framework for reservoir computing that utilizes the phase information of interconnected oscillatory units.

In this research endeavor, we investigate the theoretical foundations and practical applications of phase-based reservoir computing. We analyze the dynamics of coupled oscillators and demonstrate how their intrinsic synchronization properties can be exploited to create a reservoir of computational capacity. By carefully engineering the connections and parameters of the oscillator network, we aim to harness the rich temporal dynamics for efficient and effective information processing.

Furthermore, we explore the capabilities of phase-based reservoir computing in various domains, including time-series prediction, pattern recognition, and signal processing.

1803059	**Papavassiliou,C.**

Machine learning in memristor programming

Offered to: ADIC CSP

From: CAS

Memristors are electrically programmable, variable resistors. Their resistance can be changed by applying signals on them, and they "remember" their resistance afterwards . Memristors can be used as analogue memories or non-volatile potentiometers. Memristors are a candidate technology for future microelectronics, and consequently the student working in this project will be working at the forefront of microelectronics research.

Memristors are programmed by short voltage or current pulses. Immediately after a pulse the resistance randomly increases or decreases, but it has a definite average and long-time behaviour.
This project will attempt to develop heuristics and/or machine learning for automatic memristor programming.

1803321	**Papavassiliou,C.**

Amplifiers using Memristors

**Offered to: Control ADIC
          AML FPN CSP**

From: CAS

Memristors are electrically programmable, variable resistors. Their resistance can be changed by applying signals on them, and they "remember" their resistance afterwards . Memristors can be used as analogue memories or non-volatile potentiometers. Memristors are a candidate technology for future microelectronics, and consequently the student working in this project will be working at the forefront of microelectronics research.

The memristor I-V characteristic forms a pattern similar to a "figure-eight" so it necessarily includes regions of negative differential resistance.

This project will explore whether it is possible to make an amplifier using his Negative Differential Resistance region.

PID	Supervisor	Description
1803322	**Papavassiliou,C.**	Our group has developed a True Random Number Generator which uses a memristor as a random seed.

Simulated annealing using True Random Number generators

In this project we will design a large scale CMOS array to perform logic computations (eg number factorisation). This circuit will use a selectorless memristor crossbar array as a vector seed generator.

Memristors are electrically programmable, variable resistors. Their resistance can be changed by applying signals on them, and they "remember" their resistance afterwards . Memristors can be used as analogue memories or non-volatile potentiometers. Memristors are a candidate technology for future microelectronics, and consequently the student working in this project will be working at the forefront of microelectronics research.

Offered to: Control ADIC
AML FPN CSP

From: CAS

PID	Supervisor	Description

1803330 **Parbhoo,S.**

Causally-informed Data Augmentation for OOD generalization

Offered to: AML

From: ISN

The reliance of classifiers on spurious correlations can lead to poor generalization at deployment, raising concerns about their use in safety-critical domains such as healthcare. For example, consider a situation where we want to reliably predict a patient's condition, probability of readmission etc. based on clinical text in hospital records. Here, a common issue that arises due to clinical practice is where patients with some conditions are explicitly directed to specific caregivers in the hospital. A classifier that is then trained to predict a patient's outcomes from a single dataset that exhibits correlation between caregiver style and clinical outcomes, may unintendedly rely on the caregiver style to make such predictions; this ultimately leads to failure to generalize to data from unseen hospitals or out of distribution data, due to changes in clinical practice.

In this project, we propose using causally-informed data augmentation (guided by knowledge of the causal structure of the data), to simulate interventions on spurious features and to learn more robust classifiers, particularly for text data. Our goal is to develop causally-driven data augmentation methods, that leverage auxiliary data and domain knowledge to improve model prediction.

The specific objectives are as follows:

1)Survey the existing literature on counterfactual data augmentation and invariant learning, particularly when related to clinical electronic health records and notes.

2)Construct a causal graph for describing the process where a prediction may indirectly be informed by spuriously correlated attribute.

3)Devise a procedure for identifying a reasonable counterfactual distribution and estimating counterfactuals under certain assumptions; assess whether counterfactuals are necessary in comparison to reweighting the original data samples akin to [1]

4)Investigate whether the procedure of augmenting the dataset with counterfactuals improves OOD performance of downstream classifiers and its sensitivity to the choice of counterfactual distribution. How does this compare to editing existing data?

5)If the augmentation procedure indeed improves OOD performance, can we say anything about how to update our causal assumptions downstream and repeat the process for further improvement?

Note that a min mark of 70% is required to take on this project.

You will need excellent statistics, mathematics and software skills (particularly in C++/Python/Linux), and a strong interest in machine learning. You must be comfortable creating, installing and modifying diverse software libraries, and working with scripts, both local and remote. The project also requires commitment to distribute the work throughout the year.

Relevant literature:

[1] Maggie Makar, Ben Packer, Dan Moldovan, Davis Blalock, Yoni Halpern, and Alexander D'Amour. Causally motivated shortcut removal using auxiliary labels. In International Conference on Artificial Intelligence and Statistics, pages 739–766. PMLR, 2022.

PID	Supervisor	Description
1803331	Parbhoo,S.	Counterfactually Augmented OPE

Counterfactually Augmented Off Policy Evaluation

Offered to: AML

From: ISN

When applying reinforcement learning (RL) to high-stakes domains, quantitative and qualitative evaluation using observational data can help practitioners understand the generalization performance of new policies. However, this type of off-policy evaluation (OPE) is inherently limited since offline data may not reflect the distribution shifts resulting from the application of new policies. On the other hand, online evaluation by collecting rollouts according to the new policy is often infeasible, as deploying new policies in these domains can be unsafe. In this work, we will propose a semi-offline evaluation framework as an intermediate step between offline and online evaluation, where human users provide annotations of unobserved counterfactual trajectories. Recent work along the same lines by Tang & Wiens (2023) [1] has shown that simply augmenting existing data with such annotations can lead to biased results; specifically the authors introduce a novel weighting scheme to incorporate counterfactual annotations without introducing more bias.

In this project we will take annotations for OPE one step further. The goal is to perform an assessment of what types of annotations lead to reduction in variance and bias so that we can learn when to collect measurements and how to collect these. The hope is that by basing annotation on human-centered design, we can enable actionable application of OPE in practice.

The specific goals are:

•Survey the current state of the art in OPE, list and understand the underlying and understand and document their advantages and disadvantages

•Devise a strategy for collecting annotations for a medical task. Include what types of information you would need from an annotation

•Conduct a user study with clinicians to collect these annotations

•Perform a bias/variance analysis based on the annotations collected to assess whether certain types of annotation are more likely to worsen these properties; in cases where annotations do not help reduce variance, consider whether there is are alternative measurements or annotations that could be collected to reduce the uncertainty or whether there additional information/expertise is required.

You will need excellent statistics, mathematics and software skills (particularly in C++/Python/Linux), and a strong interest in machine learning. You must be comfortable creating, installing and modifying diverse software libraries, and working with scripts, both local and remote. The project also requires commitment to distribute the work throughout the year and a min grade of 70% to be selected.

Relevant Literature:

[1] Counterfactual-Augmented Importance Sampling for Semi-Offline Policy Evaluation. Shengpu Tang and Jenna Wiens, NeurIPS 2023

PID	Supervisor	Description
1803333	Parbhoo,S.	Shaping Rewards for Counterfactually Augmented Off Policy Evaluation

Shaping Rewards for Counterfactually Augmented Off Policy Evaluation

Offered to: AML

From: ISN

When applying reinforcement learning (RL) to high-stakes domains, quantitative and qualitative evaluation using observational data can help practitioners understand the generalization performance of new policies. However, this type of off-policy evaluation (OPE) is inherently limited since offline data may not reflect the distribution shifts resulting from the application of new policies. On the other hand, online evaluation by collecting rollouts according to the new policy is often infeasible, as deploying new policies in these domains can be unsafe. In this work, we will propose a semi-offline evaluation framework as an intermediate step between offline and online evaluation, where human users provide annotations of unobserved counterfactual trajectories. Recent work along the same lines by Tang & Wiens (2023) [1] has shown that simply augmenting existing data with such annotations can lead to biased results; specifically the authors introduce a novel weighting scheme to incorporate counterfactual annotations without introducing more bias.

Recently, Parbhoo et al (2020) introduced the idea of using reward shaping to learn better model-based control variates for variance reduction in OPE. In practice, these shaped control variates serve as approximations of the true Q function and can help reduce variance of a traditional Importance sampling-based estimator, while being sample efficient. In this project we will take a close look at [1] and assess why certain counterfactuals are better able to lead to variance reduction than others. The hypothesis is that these counterfactuals behave similar to a shaped control variate and provide additional signal to accelerate learning the true value function, while requiring less data than traditional model based control variates.

Our specific objectives are

• Survey the current state of the art in OPE, list and understand the underlying and understand and document their advantages and disadvantages

• Devise a strategy for collecting annotations for a medical task. Include what types of information you would need from an annotation and perform a bias/variance analysis based on the annotations collected to assess whether certain types of annotation are more likely to worsen these properties; in cases where annotations do not help reduce variance, consider whether there is are alternative measurements or annotations that could be collected to reduce the uncertainty or whether there additional information/expertise is required.

• Formulate the annotation collection strategy as a shaped model-based control variate. Compare how this formulation compares to i) the standard use of reward shaping in OPE as in Parbhoo et al [2020}, b) the standard way of collecting counterfactual annotations for data i.e without using the annotations as a model-based control variate of Q.

• Calculate the bounds of each approach and observe which is better

• Apply the new technique for OPE to the clinical task of assessing the performance of treatments in the ICU for patients with sepsis or hypotension

Related literature:

[1] Counterfactual-Augmented Importance Sampling for Semi-Offline Policy Evaluation. Shengpu Tang and Jenna Wiens, NeurIPS 2023

[2] Shaped Control Variates for Off Policy Evaluation. Sonali Parbhoo, Finale Doshi-Velez, NeurIPS 2020. https://scholar.harvard.edu/files/finale/files/shaping_control_variates_for_off-policy_evaluation.pdf, supplement at: https://offline-rl-neurips.github.io/supplement/56supp.pdf

PID	Supervisor	Description
1803334	Parbhoo,S.	Monte Carlo Tree Search for Experimental Design

Monte Carlo Tree Search for Experimental Design

Offered to: AML

From: ISN

Imagine a scientist entering a wet lab to conduct experiments in order to discover the underlying causal relations within the system of interest. The scientist first comes up with some hypotheses, based on prior knowledge and past observations. Then, based on the formed hypotheses, an experimentation protocol to disambiguate between the competing hypotheses is devised. Additionally, because of financial and ethical costs and risks involved in such experimentation, it is in the scientist's interest to minimize the number of batches required. This process is known as experimental design and assuming that the question of interest concerns discovering the causal structure of the system of interest, the process is known as experimental design for causal discovery.

A Bayesian framework for this process has been proposed in prior work which typically consists of updating an approximate posterior with past experimental data and using this updated posterior to compute experiments that are maximally informative, as evaluated by expected information gain - the objective of interest in Bayesian Optimal Experimental Design (BOED). However BOED is very hard and typically not scalable to very high-dimensional problems as required for the creation of genomic atlases. That is why in this project we will focus on the derivation of novel Monte Carlo Tree Search based [1,2] methods.

The project deliveries include:
Investigating advanced MCTS based approaches vs. vanilla MCTS for experimental design.
Including diversity [3] in each tree of MCTS [1] as a first and simple extension
Establishing a benchmark for Experimental Design on simple simulated functions as well as real world evidence [3]
Improving and evaluating MCTS vs. BO for continuous actions spaces for experimental design.

You will need excellent statistics, mathematics and software skills (particularly in C++/Python/Linux), and a strong interest in machine learning. You must be comfortable creating, installing and modifying diverse software libraries, and working with scripts, both local and remote. The project also requires commitment to distribute the work throughout the year and a min grade of 70% to be selected.

[1] Wang, Linnan, Rodrigo Fonseca, and Yuandong Tian. "Learning search space partition for black-box optimization using monte carlo tree search." Advances in Neural Information Processing Systems 33 (2020): 19511-19522.
[2] Song, Lei, et al. "Monte carlo tree search based variable selection for high dimensional bayesian optimization." Advances in Neural Information Processing Systems 35 (2022): 28488-28501.
[3] Lyle, Clare, et al. "DiscoBAX-Discovery of optimal intervention sets in genomic experiment design." (2023).
[4]Nguyen, Tung, Sudhanshu Agrawal, and Aditya Grover. "ExPT: Synthetic Pretraining for Few-Shot Experimental Design." arXiv preprint arXiv:2310.19961 (2023).

PID	Supervisor	Description

1803335   **Parbhoo,S.**

Can we use LLMs to generate reasonable counterfactuals?

Offered to: AML

From: ISN

Counterfactual information plays an important role in causal reasoning and learning about causal relationships. Causal representations can be defined not only by relationships between antecedents and outcomes, but also by counterfactuals—what would have happened if the antecedent had not occurred. In high stake domains such as healthcare, these counterfactuals can be useful for providing both quantitative and qualitative evaluation of various treatment choices to help practitioners understand and assess the generalization of policies to alternative situations.

Traditionally in high stake decision-making situations such as healthcare, machine learning models are assessed using off-policy evaluation where a retrospective batch of observational data is used to learn a treatment policy. Unfortunately off-policy evaluation is difficult to perform in practice and suffers from high variance when the decisions we wish to evaluate differ significantly from those observed in the observational data. Recent work by Tang and Wiens (2023) [1] has shown that augmenting an observational data set with a set of counterfactual annotations of possible trajectories can however help overcome these issues without the introduction of additional bias. However, there is little work on how to generate plausible counterfactuals for such an evaluation to work in practice.

In this project, we will make use of a large language model or generative AI to determine a set of plausible counterfactual annotations that may be used to aid in off-policy evaluation.

The specific goals are

•Survey the current state of the art in OPE, list and understand the underlying and understand and document their advantages and disadvantages

•Train an LLM for collecting counterfactual annotations for a medical task. Include what types of information you would need from an annotation

•Assess the performance of an LLM's counterfactuals in terms of how the distribution of counterfactuals compares to the distribution of factuals and explore the extent of distribution shift, as well as their coverage of the data manifold, their compactness and plausibility

•Perform an in-depth analysis of the cases where LLM-generated counterfactuals may be useful for reducing bias and variance of traditional OPE estimators. Perform a bias/variance analysis based on the annotations collected to assess whether certain types of annotation are more likely to worsen these properties; in cases where annotations do not help reduce variance, consider whether there is are alternative measurements or annotations that could be collected to reduce the uncertainty or whether there additional information/expertise is required.

You will need excellent statistics, mathematics and software skills (particularly in C++/Python/Linux), and a strong interest in machine learning. You must be comfortable creating, installing and modifying diverse software libraries, and working with scripts, both local and remote. The project also requires commitment to distribute the work throughout the year and a min grade of 70% to be selected.

Related literature:

[1] Counterfactual-Augmented Importance Sampling for Semi-Offline Policy Evaluation. Shengpu Tang and Jenna Wiens, NeurIPS 2023

[2] LLMs as Counterfactual Explanation Modules: Can ChatGPT Explain Black-box Text Classifiers? Bhattacharya, Amrita et al 2023.

PID	Supervisor	Description

1803336 **Parbhoo,S.**

Understanding and Extrapolating from Latent Spaces

Offered to: AML

From: ISN

Autoencoders exhibit impressive abilities to embed the data manifold into a low-dimensional latent space, making them a staple of representation learning methods. However, without explicit supervision, which is often unavailable, the representation is usually uninterpretable, making analysis and principled progress challenging.

Recently score and consistency based representation learning methods have been rediscovered and achieved state of the art performances in image generation or inpainting. Some of these proposals can be considered drop in replacements for VAE based approaches.

In this project we will investigate:

The application of VAE based methods to modern generative representation learning methods

The scaling of VAE [1,2] based methods to large pre-trained CNN based representations.

Exploration and experimental design [5,6] capabilities as downstream tasks for improving and understanding latent spaces.

Latent space generative models are a focus on the upcoming NeurIPS tutorial [4], which should provide a good starting point for interested students.

You will need excellent statistics, mathematics and software skills (particularly in C++/Python/Linux), and a strong interest in machine learning. You must be comfortable creating, installing and modifying diverse software libraries, and working with scripts, both local and remote. The project also requires commitment to distribute the work throughout the year and a min grade of 70% to be selected.

[1] Notin, Pascal, José Miguel Hernández-Lobato, and Yarin Gal. "Improving black-box optimization in VAE latent space using decoder uncertainty." Advances in Neural Information Processing Systems 34 (2021)
[2] Leeb, Felix, et al. "Exploring the Latent Space of Autoencoders with Interventional Assays." Advances in Neural Information Processing Systems 35 (2022): 21562-21574.
[3] https://github.com/openai/consistencydecoder
[4] https://nips.cc/virtual/2023/tutorial/73957
[5] Nguyen, Tung, Sudhanshu Agrawal, and Aditya Grover. "ExPT: Synthetic Pretraining for Few-Shot Experimental Design." arXiv preprint arXiv:2310.19961 (2023).
[6] Bertrand, Quentin, et al. "On the Stability of Iterative Retraining of Generative Models on their own Data." arXiv preprint arXiv:2310.00429 (2023).
[7] Albergo, Michael S., Nicholas M. Boffi, and Eric Vanden-Eijnden. "Stochastic interpolants: A unifying framework for flows and diffusions." arXiv preprint arXiv:2303.08797 (2023)

1803351 **Parisini,T.**

Interaction-Aware Safe Planning for Autonomous Systems

Offered to: Control

From: CAP

Autonomous systems are systems capable of making decisions and performing actions by themselves, without explicit human control. The development in autonomous systems over the past few years has changed the way we live, e.g., transport and communicate. A fundamental problem for autonomous systems is how to automatically synthesize safe controllers in the dynamic environment. In the context, the autonomous system should be be able to interact with the environment (e.g., the surrounding dynamic systems). The objective of this project is to develop a new interaction-aware safe planning algorithm for autonomous systems. More specifically, the will be asked to: (i) conduct a literature review on the topic; (ii) model interaction between dynamic systems from game-theoretic perspective; (iii) apply known control techniques (e.g., model predictive control) to develop a safe planing algorithm; and (iv) validate the approach via simulations.

PID	Supervisor	Description
1803352	**Parisini,T.** **Model Predictive Control under Temporal Logic Constraints** **Offered to: Control** **From: CAP**	Cyber-physical systems (CPSs) are systems that involves complex interactions between computing components and physical components. Temporal logic formulae have been widely used to specify complex behaviors of CPSs since they are expressive enough to capture many important properties, e.g., safety and liveness, and more complex combinations of Boolean and temporal statements. Traditional control synthesis under temporal logic specifications requires the abstraction of a continuous-space system to a finite transition system, which can be computationally expensive. Some recent works have proposed the notion of temporal logic tree, which enable abstraction-free verification and control. The objective of this project is to develop a new control algorithm by integrating the popular model predictive control and the temporal logic trees. More specifically, the candidate will be asked to: (i) conduct a literature review on the topic; (ii) learn how to transform temporal logic formulae to temporal logic trees; (iii) extend the model predictive control formulation to temporal logic trees; and (iv) validate the approach via simulations.
1803353	**Parisini,T.** **Formal Verification of Neural-Network Controlled Systems** **Offered to: Control** **From: CAP**	Motivated by the great success of (deep) neural networks in classification and perception, neural network controllers have gained increasing interest in the autonomous industry and cyber-physical systems. The main reason is that neural network controllers enable a more flexible data-driven mechanism, different from the traditional model-based mechanism. However, due to the non-linearity and complex architecture of neural network, verifying the property of neural-network controlled systems is challenging. The objective of this project is to design an efficient algorithm to verify the safety property of neural-network controlled systems. More specifically, the candidate will be asked to: (i) conduct a literature review on the topic; (ii) model the neural-network controlled systems; (iii) analyze the uncertainty propagation along neural networks; and (iv) validate the approach via simulations.
1803354	**Parisini,T.** **Truck Platooning in Mixed Traffic** **Offered to: Control** **From: CAP**	Truck platooning is a method for driving a group of trucks together. It can reduce traffic congestion and provide greater fuel economy (due to reduced air resistance between trucks). In the mixed traffic where there are both automated trucks and human-driven trucks, how to handle the possible inconstant driving behavior of human-driven vehicles is crucial to ensure the safety of truck platooning. The objective of this project is to study truck platooning in mixed traffic from a system and control perspective. The candidate will be asked to (i) conduct a literature review on the topic; (ii) model the platoon in the mixed traffic and in particular model the driving behaviors of human driver; (iii) design a control strategy that can guide human-driver to respect the safety constraint and improve the platooning performance; and (iv) validate the approach via simulations.

PID	Supervisor	Description
1803355 **Cyber-attacks Detection Using Networks of Sensors**	**Parisini,T. (with Yang,G.)** **Offered to: Control** **From:** **CAP**	This a research-oriented project deals with designing a distributed estimation scheme by which detecting cyber-attacks on large scale systems in which a networks of sensors is available. Several kind of cyber-attack have to be considered including replay attacks and covert attacks. The algorithms will have to be validated in Matlab/Simulink.
1803356 **Control of Supply-Chain Systems**	**Parisini,T.** **Offered to: Control** **From:** **CAP**	A supply chain is an interaction network involving a company selling a product, its suppliers, the distributors, and other entities up to the final buyer. Variations in the offer/demand of the product may cause oscillations and instabilities leading to economic losses for the company and shortages for the buyers. A prototypical abstraction of such a problem has been proposed in the 60s by MIT's professor Jay Forrester and is known under the name of "Beer Distribution Game" (https://en.wikipedia.org/wiki/Beer_distribution_game). The aim of this project is to study supply chains from a system and control theoretic perspective, identifying the sources of instabilities, and devising possible mitigation strategies. In particular, the candidate will be asked to: (i) model and analyze a supply-chain system; (ii) apply known techniques in the literature of control theory (model predictive control, distributed control, ...) and distributed optimization with the aim of damping the offer/demand oscillations.
1803357 **Distributed State and Parameter Estimation for Large Scale Systems**	**Parisini,T. (with Yang,G.)** **Offered to: Control** **From:** **CAP**	Large scale systems are crucial to daily life but susceptible to faults and attacks. Therefore, it is essential to monitor the system state using provided measurements. According to the communication graph, the measurements (nodes) are distributed over the entire system, and information is exchanged among all the nodes. This project aims to propose a distributed state and parameter estimation scheme to achieve state omniscience. Moreover, the student is encouraged to explore the feasibility of the proposed design, and its robustness against disturbance or fault (e.g. input noise, output noise, and communication link failure). A numerical model (preferably based on some application scenarios) is desired to be built to evaluate the performance of the proposed design.

PID	Supervisor	Description

1803006   **Pike,W.T. (with Charalambous,C.)**

Real-Time Earthquake Detection Utilising Polarization Analysis and Signal-to-Noise Ratio

Offered to: Control ADIC AML FPN CSP

From: OSD

In regions prone to seismic activity, the ability to detect earthquakes in real time is critical for public safety and disaster preparedness. These systems rely on rapid and accurate analysis of seismic data to provide timely alerts. An earthquake early warning system (EEWS) should therefore be included in smart cities to preserve human lives by providing a reliable and efficient disaster management system.

In this project, we aim to develop a new single-station earthquake detection algorithm that operates in real-time by harnessing sophisticated polarisation tools developed in MATLAB and Signal-to-Noise Ratio (SNR) measurements. The polarisation tools can compute critical parameters such the expected ground motion enabling more precise and timely alerts. This has the potential to form the foundation of a new earthquake early-warning system.

The algorithm will be optimised to distinguish between seismic events and background noise through a combination of SNR-based event detection and polarisation attributes, characteristic of earthquakes. The directionality information will enhance our understanding of seismic events and aid emergency response efforts. Rigorous testing and validation of the algorithm using historical seismic data will ensure its accuracy and reliability, making it a robust tool for real-world applications. Machine-learning approaches may be used to enhance detection and the overall system using attributes computed from ground acceleration time series in the temporal, spectral and cepstral domains (e.g., [1]), but it is not a prerequisite of the project.

[1] Pablo Lara, Quentin Bletery, Jean-Paul Ampuero, et al. Earthquake Early Warning using 3 seconds of records on a single station. ESS Open Archive . February 27, 2023.
doi: 10.22541/essoar.167751595.54607499/v1

PID	Supervisor	Description
1803341	**Pike,W.T. (with Charalambous,C.)**	NASA's InSight mission on Mars has unveiled a wealth of seismic data from over 1300 recorded marsquakes during its four years of surface operations. These include signals from up to ~9000 km away from InSight, probing deep into Mars—from its shallow crust to the boundary of the core. Mars offers a unique laboratory for the detailed seismic exploration of the layers of an archetypal planet, without the complications which come from plates tectonics when we study Earth.

Unveiling the interior of Mars using signal analysis

Offered to: Control ADIC AML FPN CSP

From: **OSD**

This project represents a convergence of optimization, signal processing, and planetary seismology, with a focus in exploring the Martian subsurface structure. From its shallow, highly-fragmented crust to the primordial deep mantle—a time-capsule of the planet's early formation stages—this project offers the opportunity to use signal analysis to explore Mars' largely unknown interior.

The goal of this project is to try to fit the recorded energy of marsquakes by applying a simple diffusion model to the propagation of seismic energy as it travels through the layers of the planet [e.g., 1-2.]. This should allow us to group quakes based on how their energy is shaped by Mars. For instance, the analysis of the frequency-dependent energy envelopes is allowing us to examine Mars' mantle composition, offering a glimpse into the geological history imprinted within the Martian interior.

The result is a comprehensive insight into the Martian interior's properties and their origin, from the complexities within the crust to the largely unknown structures buried within the deep mantle. To achieve this, you will design and implement global optimization algorithms for fitting the energy profile in time-series signals derived from numerous marsquakes from different locations on Mars. These sources include large meteorite impacts [3], magmatic activity deep in the planet [4], faults, avalanches and rockfalls [5], and other yet-to-be-understood phenomena, such as possibly liquid groundwater systems deep within the crust [6].

Beyond these potential findings, the project extends its reach to seismic hazards. Marsquakes are potential critical hazards for future human exploration [7]. Analysing the energy envelopes contributes crucial insights to how the seismic energy propagates and weakens before its arrival to the future potentially habitable site, enabling us to assess and predict seismic risks—pivotal information for the planning and safety of future missions.

This project, therefore, offers an opportunity to go beyond simple data analysis by decoding the geological story told by Mars' seismic signals, contributing to our understanding of the Red Planet's past, present, and future.

[1] Menina, S. et al. (2021). Energy envelope and attenuation characteristics of high‐frequency (HF) and very‐high‐frequency (VF) Martian events. Bulletin of the Seismological Society of America, 111(6), 3016-3034.

[2] Karakostas, F. et al., (2021). Scattering attenuation of the Martian interior through coda‐wave analysis. Bulletin of the Seismological Society of America, 111(6), 3035-3054.

[3] Posiolova, L. et al., (2022). Largest recent impact craters on Mars: Orbital imaging and surface seismic co-investigation. Science, 378(6618), 412-417.

[4] Broquet, A. & Andrews-Hanna, J. C. (2023). Geophysical evidence for an active mantle plume underneath Elysium Planitia on Mars. Nature Astronomy, 7(2), 160-169.

[5] Lucas, A. et al. (2022, September). InSight for seismically detectability and seismically triggered avalanches on Mars. In Europlanet Science Congress 2022 (pp. EPSC2022-366).

[6] Manga, M., Zhai, G., & Wang, C. Y. (2019). Squeezing marsquakes out of groundwater. Geophysical Research Letters, 46(12), 6333-6340.

[7] Kalapodis, N. et al. (2020). A review towards the design of extraterrestrial structures: From regolith to human outposts. Acta Astronautica, 175, 540-569.

PID	Supervisor	Description

1803342   **Pike,W.T. (with Charalambous,C.)**

Denoising the seismic record of Mars

Offered to: Control ADIC AML FPN CSP

From: OSD

For over three Earth years, NASA's InSight mission has returned data from the Seismic Experiment for Interior Structure (SEIS) on Mars with over 1300 recorded marsquakes leading to numerous breakthroughs in determining the planet's structure. However, many marsquakes are hidden in or contaminated by the background noise injected by the Martian atmosphere. Local winds interact with the lander and seismometer system, couples into the seismic signal and generating noise levels that fluctuate throughout the Martian day and regularly exceeding typical event amplitudes, making marsquake detection and analysis challenging. This interaction between the wind and the lander is seen through the excitation of sensitive lander resonances which are measured by the seismometers through vibrations on the ground.

This project will develop a Machine Learning (ML) approach to denoising the seismic signal, with the aim of decoupling it from the background environmental noise and improving its quality. With the recent developments in deep learning, based on complex models of artificial neural networks, the process of learning a mapping function between a noise-corrupted signal to clean signal can be applied successfully. Inspired by speech-enhancement approaches, the ML approach here will be based on Spectral Subtraction, wherein the dynamic estimation of the background noise from the continuous excitation of wind-driven lander modes can be subtracted to achieve the cancellation of the environmental noise and the effective isolation of the seismic signal power in time-frequency space. The inputs required for the machine learning model will therefore mainly be the continuous excitation of several lander resonances over the Martian time of day. Clean parameters can be predicted from noisy parameters by combining complex neural network architectures and deep learning procedures.

This project would best suit a student interested in Machine Learning and time-series analysis. It is essential to have strong skills in programming of MATLAB or Python.

1803275   **Pitt,J.V. (with Spiers,A.)**

A self-organising multi-robot system (SObotics)

Offered to: AML

From: ISN

Robotic arms are used extensively in industry for the manipulation of objects and tools. In multi-robot systems these arms collaborate to perform tasks that are outside the scope of the individual (e.g. carrying a heavy object or moving an object beyond the reach of one arm). In this project you will work with three or more desktop robot arms (model: ROBOTIS Manipulator-X) in the framework of self-organising multi-agent systems, using the robots to complete a physical manipulation task while trying to minimise a cost function. An example task (which is subject to modification) could be placing an object (only accessible to robot A) in a container (only accessible to robot B) and passing that container from a start position (accessible to robots A and B) to an end destination (only accessible to robot C). This is to be completed in the framework of minimising time taken, with the goal of creating an efficient object/container production line.

PID	Supervisor	Description
1803312	**Pitt,J.V. (with Goodman,D.F.M.)** **Learning to vote when it matters** **Offered to: AML** **From: ISN**	How can groups of individuals with different interests and expertise work together? One approach is to make decisions by vote, hoping that aggregating individual noisy decisions will lead to a better decision. This has a counterpart in machine learning. Random forest algorithms which feature a voting mechanism have proven to be very robust in practice. Intuitively, this makes sense if all individual decisions are just noisy versions of a correct decision. However, in a world where expertise varies widely (e.g. economists are very expert at handling mathematical models, but have no understanding of the real world problems people face), simply counting up votes might not be the optimal way to aggregate decisions. Previous work has investigated more sophisticated ways to aggregate votes (see references below). In this project, you will investigate the specific case where reaching a consensus or near-consensus is crucially important, may be time critical, and where decisions have immediate and strong consequences. You will use a machine learning, multi-agent model, where each agent has different information and expertise, and agents are allowed to communicate before reaching a decision. In addition to the political, this project has applications to neuroscience. The brain can be considered as a collection of agents with different expertise engaged in continuous communication with each other, and which have a strong incentive to reach consensus quickly. Required skills: strong coding skills, experience in machine learning Useful skills: the "Neuroscience for machine learners" and "Self-Organising Multi-Agent Systems" courses would be good accompaniments Co-supervised by Jeremy Pitt References: - Mertzani et al. (2022) https://pubmed.ncbi.nlm.nih.gov/36200809/
1803358	**Pitt,J.V.** **Stability, Scalability and Sustainability of Social Influence** **Offered to: AML** **From: ISN**	This project is concerned with applying diverse machine learning algorithms to investigate how social influence scales with respect to size and structure of self-organising systems, and what "sort" of stability it produces, and whether or not that stability can be sustained over time, in particular generations. The starting premise is starting premise is Principle 7 of Elinor Ostrom's theory of self-governing institutions for sustainable common-pool resource management [Ostrom90]. This demands "minimal recognition of the right to self-organise", and so sets a lower bound for an external authority to determine the extent to which a sub-system can self-determine its own social arrangements. This was generalised in Josiah Ober's theory of Basic Democracy [Ober17] to set an upper limit on the right to self-organise: thereby defining a Zone of Dignity (ZoD), whereby excessive control produces infantilisation, but inadequate control produces inequality, uncertainty and instability. By specifying a coordinate plane, a "basket" of metrics and indices can be defined that can position an "object" within this plane, the objects in question being a set of self-determined social arrangements. This plane then defines the space in which to locate configurations of social arrangements, and also to evaluate their trajectories, as well as identifying the boundaries on "acceptable" or "permissible" configurations in this space. Using Nowak's Regulatory Theory of Social Influence [Nowak19] and computational models based on this theory [Mertzani23], the questions that can then be asked, as parameters of time and size are varied, are: 1. How does social influence within a sub-system serve to identify and control the trajectory of that sub-system within the ZoD – i.e. is this a form of unsupervised self-learning? 2. How does social influence between peer sub-systems serve to serve to identify and control the trajectory of a sub-system within the ZoD -- i.e. is this a form of social learning? 3. How does social influence between a sub-system and a supra-system serve to serve to identify and control the trajectory of the sub-system within the ZoD -- i.e. is this a form of supervised learning? The project involves inter-disciplinary reading, re-use of (or design and implementation of) a platform for self-organising multi-agent systems, specification and implementation of machine learning algorithms, and experimental design, execution and evaluation. It is well-suited to any student who took ELEC70071 SOMAS.

PID	Supervisor	Description

1803359   **Pitt,J.V.**

Cooperative Reinforcement Learning

Offered to: AML

From: ISN

This project envisions the following scenario: a user is presented with a multi-agent cooperative survival "game", and is asked to use an appropriately-defined interface to (a) select a diverse population of agents with particular characteristics, and (b) select a set of social arrangements for the agents to help them with their survival. The "game" is played and the user gets feedback on the results, but the system also generates data which it can use to learn the relationship between (population & arrangements) and survivability. The game is then repeated, but how the system is (potentially) able to offer guidance or recommendations on the selection of population and social arrangements, which the user can choose to accept (or not). The process is repeated, with both user and system (supposedly) getting progressively more experienced in defining populations which are successful in surviving.

This project aims to combine Machine Learning algorithms, which allow the system to learn from (to begin with) no data and incremental data, with Human-Machine Interaction in order to address issues related with human-ai learning and cooperation.

Therefore, this project will include designing the research methodology, performing human experiments for acquiring diverse data, developing or modifying existing machine learning algorithms and reflecting on the experimental results.

In particular, this project has the aim of investigating questions related with the speed and the feasibility of learning from the side of the user and from the side of the system as well as the interconnection between them (for instance under which conditions does the user learn faster than the system or which is the trade-off for learning faster, is the learning of the system dependent on the user feedback or the intention of the user, and vice versa, etc.), the stability/sustainability of the human-AI system, and the trust (perhaps mis-trust or over-trust) of the user to the system.

The project is suitable for anyone interested in socio-technical systems and human-computer interaction (really: human-Ai interaction), and in particular has taken ELEC70071 SOMAS.

1803360   **Pitt,J.V.**

Machine Learning Plug-ins for PlatformOcean Application(s)

Offered to: AML

From: ISN

PlatformOcean is an open platform for social coordination motivated by the idea of re-empowering people with the tools they require for selection of social arrangements to address local issues. In particular, it allows the inclusion and customisation of specific tools through the use of plug-ins (imagine a Swiss Army knife with blades and tools which can be added-to/replaced/re-configured while the tool is in user: PlatformOcean similarly allows plug-ins to imported, deleted and reconfigures at run-time). Moreover, in PlatformOcean, some of these plug-ins can use machine learning to improve performance over time, i.e. they are self-reconfiguring for continuous systemic self-improvement. This changes the potential dynamic of the plug-in so that rather than just offering a deterministic input-output relationship, it can acquire agency within the system, and offer bespoke functionality which changes over time according to the changing parameters of humans in the system. The aim of this project is to examine a range of use cases for PlatformOcean, for example in football team section and traffic optimisation, health care and well-being, and social arrangements for co-housing.

The project does require relatively strong software engineering skills, but is otherwise suitable for anyone interested in ML applications for socio-technical systems and human-computer interaction (really: human-AI interaction), and in particular has taken ELEC70071 SOMAS.

PID	Supervisor	Description
1803361	**Pitt,J.V.** **Self-Organised Social Arrangements for Mega-Bike** **Offered to: AML** **From: ISN**	The project proposes to use the Mega-bike platform from ELEC70071 SOMAS as a starting point for a deeper investigation into specific issues around democracy, governance and trust, and specifically the role of Machine Learning in advancing: democracy, conceived as the principles underpinning effective and fit-for-purpose self- determination by citizens; governance, conceived as the operationalisation of those principles in specific social arrangements enacted and evaluated by those citizens; and socially-constructed conceptual resources, such trust, but also the codification of deep social knowledge and systems of contributive justice. In particular, this project aims to explore the Aristotelian concept of "flourishing" against the so-called boundary problem for self-organised social arrangements: i.e. between, one the one hand, anarchy (construed properly as voluntary cooperation without political institutions, NOT as disorder, "no rules" or nihilism) and/or "no boss" basic democracy, and, on the other hand, systems of apparent democracy which might be suffering from the circularity involved in the definition of citizenship by those who have, at some historical moment (e.g. at founding), declared themselves to be citizens, to the exclusion of "others". The aim is for agents to learn how to mitigate the risk of getting ``stuck'' in certain forms of hierarchical social arrangements which suppress "flourishing", by devolving into oligarchy or majoritarian tyranny, thereby marginalizing and harming minority populations and/or those who are stranded outside the body of enfranchised citizens, Furthermore, as some studies of participatory budgeting have shown, decisions and decision-making processes can come to be dominated by a self-empowered minority of well-educated citizens who have resources (time and education) to participate in complex procedures. And yet, there are also some problems with un-considered widening of the franchise to include some who might be lacking in domain expertise (as per Condorcet's theorem). The project involves inter-disciplinary reading, a good working knowledge of the Mega-bike platform, specification and implementation of machine learning algorithms, and experimental design, execution and evaluation. Given the base, it is highly dependent on having taken ELEC70071 SOMAS.

PID	Supervisor	Description

1803035   **Qin,C.**

Explainable machine learning for lung cancer nodule classification

Offered to: AML CSP

From: **ISN**

In the past years, there has been a significant improvement in the accuracy of deep learning classification models. Many industries have been fast to adopt them to take advantage of their great benefits. However, 'critical' industries, such as the medical sector, have been more cautious in deploying such models due to their 'black-box' nature. Interpreting deep learning models are therefore gaining importance especially in the safety-critical medical imaging field. This project will build on previous work to create an interpretable model for classifying lung cancer nodules in thoracic computed tomography (CT) scans [1]. It will be based on Prototypical Part Networks [2-4], mimicking the lung nodule diagnosis process by human expert. More specifically, it will aim to improve the explainability of prototypes by 'guiding' them to resemble human-specified characteristics rather than arbitrary network-chosen concepts. The developed model will be expected to serve as a tool that provides additional information during the diagnosis of a nodule rather than having its predictions be trusted blindly.

Requirement: Proficiency in Python and Pytorch/Tensorflow is essential. Knowledgeable in deep learning and computer vision. Experience in processing medical images is desired.

The project is research oriented. Candidates with strong research interest are encouraged to apply.

[1] Shen, Shiwen, et al. "An interpretable deep hierarchical semantic convolutional neural network for lung nodule malignancy classification." Expert systems with applications 128 (2019): 84-95.
[2] Chen, Chaofan, et al. "This looks like that: deep learning for interpretable image recognition." Advances in neural information processing systems 32 (2019).
[3] Nauta, Meike, et al. "This looks like that, because... explaining prototypes for interpretable image recognition." Joint European Conference on Machine Learning and Knowledge Discovery in Databases. Cham: Springer International Publishing, 2021.
[4] Barnett, Alina Jade, et al. "A case-based interpretable deep learning model for classification of mass lesions in digital mammography." Nature Machine Intelligence 3.12 (2021): 1061-1070.
[5] Gallée, Luisa, Meinrad Beer, and Michael Götz. "Interpretable Medical Image Classification Using Prototype Learning and Privileged Information." International Conference on Medical Image Computing and Computer-Assisted Intervention. Cham: Springer Nature Switzerland, 2023.

PID	Supervisor	Description

1803339 **Qin,C.**

Implicit Function Learning on fMRI Motion Correction

Offered to: AML CSP

From: **ISN**

Due to the time scale of Blood Oxygen Level Dependent (BOLD) signal changes, Functional Magnetic Resonance Imaging (fMRI) of the brain typically requires a long scanning during which head movements could significantly deteriorate imaging quality [1]. Various optimisation- and deep-learning-based methods have been proposed to reconstruct 3D motion-free brain volumes from motion-corrupted 2D slices. In this project, we would like to investigate Implicit Neural Representation (INR) methods, such as NeSVoR[2], which encode data as a continuous function parameterised by an MLP instead of a discretised grid to handle inter-slice motions with arbitrary spatial resolutions. We would also explore how the generative capacity of recently popular Diffusion Models could be introduced to provide implicit functions with prior knowledge of the domain of imaging, as demonstrated in IDM[3], leading to higher reconstruction fidelity.

Requirement: Proficiency in Python and Pytorch/Tensorflow is essential. Knowledgeable in deep learning and computer vision. Experience in processing medical images is desired.

The project is research oriented. Candidates with strong research interest are encouraged to apply. The project difficulty level is difficult.

References

[1] Zaitsev, Maxim, et al. "Prospective motion correction in functional MRI." Neuroimage 154 (2017): 33-42.

[2] Xu, Junshen, et al. "NeSVoR: Implicit Neural Representation for Slice-to-Volume Reconstruction in MRI." IEEE Transactions on Medical Imaging (2023).

[3] Gao, Sicheng, et al. "Implicit diffusion models for continuous super-resolution." Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition. 2023.

1803343 **Qin,C.**

Machine Learning in Quality Control for Diffusion Tensor Cardiac MRI

Offered to: AML CSP

From: **ISN**

Diffusion tensor cardiac magnetic resonance (DT-CMR) [1] is an emerging technique that provides information on myocardial microstructure. Diffusion imaging yields low SNR images, and it is common to compensate with long acquisitions spanning multiple breath-holds, which inevitably makes it also susceptible to motion artefacts. Cardiac or respiratory motion can both lead to the acquired images to be corrupted, and they are typically needed to be excluded in DT-CMR pre-processing steps before downstream analysis tasks. Conventionally, discarding these images is done visually by an experienced user, but it is laborious and time-consuming. In the project, we aim to develop a machine learning method such as [2] that can automatically detect corrupted frames with more reliability and reproducibility.

Requirement: Proficiency in Python and Pytorch/Tensorflow is essential. Knowledgeable in deep learning and computer vision. Experience in processing medical images is desired.

The project is research oriented. Candidates with strong research interest are encouraged to apply. The project difficulty level is difficult.

[1] Ferreira, Pedro F., et al. "Automating in vivo cardiac diffusion tensor postprocessing with deep learning–based segmentation." Magnetic resonance in medicine 84.5 (2020): 2801-2814.
[2] Wang, Shuo, et al. "Deep generative model-based quality control for cardiac MRI segmentation." Medical Image Computing and Computer Assisted Intervention–MICCAI 2020: 23rd International Conference, Lima, Peru, October 4–8, 2020, Proceedings, Part IV 23. Springer International Publishing, 2020.

PID	Supervisor	Description

1803344 **Qin,C.**

Integrating Deep Learning and Radiomics for Medical Image Analysis

Deep learning (DL)-based algorithms have achieved considerable success in plenty of medical imaging tasks [1]. However, some works have shown that DL-based approaches do not really outperform radiomics[2]-based approaches in risk stratification. These features, extracted from medical images such as PET and MRI, can capture tumor and tissue characteristics such as heterogeneity and shape. Furthermore, they have been demonstrated to correlate with a wide range of diseases, e.g., cardiovascular adverse events [3,4]. To fill the research gap, this project aims to develop a novel approach that incorporates radiomics features into deep learning, thereby unlocking the full potential for optimizing model performance. The developed method could be potentially applied to diverse clinical tasks, such as cardiac scar analysis and nodule detection.

Offered to: AML CSP

Requirement: Proficiency in Python and Pytorch/Tensorflow is essential. Knowledgeable in deep learning and computer vision. Experience in processing medical images is desired.

From: ISN

The project is research oriented. Candidates with strong research interest are encouraged to apply. The project difficulty level is difficult.

[1] Wang, R., Lei, T., Cui, R., Zhang, B., Meng, H., & Nandi, A. K. (2022). Medical image segmentation using deep learning: A survey. IET Image Processing, 16(5), 1243-1267.
[2] Mayerhoefer, M. E., Materka, A., Langs, G., Häggström, I., Szczypiński, P., Gibbs, P., & Cook, G. (2020). Introduction to radiomics. Journal of Nuclear Medicine, 61(4), 488-495.
[3] Wang, J., Bravo, L., Zhang, J., Liu, W., Wan, K., Sun, J., ... & Chen, Y. (2021). Radiomics analysis derived from LGE-MRI predict sudden cardiac death in participants with hypertrophic cardiomyopathy. Frontiers in cardiovascular medicine, 8, 766287.
[4] Zhao, Z., & Yang, G. (2021). Unsupervised contrastive learning of radiomics and deep features for label-efficient tumor classification. In Medical Image Computing and Computer Assisted Intervention–MICCAI 2021: 24th International Conference, Strasbourg, France, September 27–October 1, 2021, Proceedings, Part II 24 (pp. 252-261). Springer International Publishing.

1802910 **Rapeaux,A. (with Constandinou,T.)**

Evaluation of compression algorithms for neural data on an FPGA-NVM system

Problem: As implantable neural interfaces (BMIs) scale their data acquisition capabilities, the power budget for transmitting ever larger amounts of information wirelessly out of the cranium to different storage media for analysis and interpretation is becoming increasingly difficult as battery capacities do not scale in the same way and users require lossless transmission of data. It is therefore essential to reduce power consumption. One strategy is to reduce the amount of data transmitted by first compressing it using a number of lossless compression algorithms. A tradeoff appears between increased power consumption from computing to run the compression algorithm, and power saved from not having to transmit as much data wirelessly. This project aims to characterize this tradeoff using real-world data and hardware platforms to develop a figure of merit capturing compression performance versus power consumption for algorithms implemented on resource-constrained FPGAs (field-programmable gate arrays) connected to NVM (non-volatile memory) storage such as simple flash memories, which combine high storage density and the ability to retain information when turned off, saving power.

Offered to: Control ADIC
AML FPN CSP

The student will use an existing experimental platform consisting of an igloo nano FPGA connected to a 2GB flash memory device to implement different compression algorithms and characterise them in terms of performance (e.g speed, memory requirements, but above all power). The student will also attempt to develop a single figure of merit that captures compression performance versus power consumption, to enable researchers to comparatively evaluate technology combinations for neural signal compression minimising for power consumption. If scope and time permits within the project it will be possible to investigate the use of different FPGAs and memories following the existing scheme, alongside different compression approaches including lossy compression, with the goal of further minimising power consumption.

From: CAS

Essential skills include VHDL/Verilog, experience with signal processing such as filtering and compression (knowledge of general data compression principles highly recommended), electrical measurements in low-noise environments (DC power analyzers, oscilloscopes, logic analyzers).

This project will be co-supervised by Dr Adrien Rapeaux.

PID	Supervisor	Description

1802911 **Rapeaux,A. (with Constandinou,T.)**

Development of an embedded system for instrumentation control and data capture in ex-vivo heart muscle tissue baths.

Offered to: Control ADIC AML FPN CSP

From: CAS

Problem: heart muscle tissue baths are a powerful means to characterise heart muscle and its response to changes in environmental conditions and injury, as well as being a testbed for pharmaceutical or surgical research. An experimental platform has been developed which uses a collection of loosely connected instruments to stimulate the heart muscle sample and record the pull strength using a load cell. The setup allows the replication of the heart's natural loading cycle, however it is difficult and expensive to replicate, and the operation is currently complex and error-prone. Automating control of the instruments and data acquisition is an essential step towards scaling this platform for parallel experiments.

The student will work both at the South Kensington and Hammersmith campuses of Imperial College in partnership with Dr Cesare Terraciano and their EEE supervisor to develop an embedded system for ex-vivo instrumentation control and data acquisition. An existing system can be used as the starting point. The student needs to have experience in PCB design, embedded system design and programming, with knowledge of embedded C essential. Knowledge of heart muscle models such as Windkessel and heart physiology in general are highly encouraged as they will help the student understand the platform's use context.

This project will be co-supervised by Dr Adrien Rapeaux.

1803332 **Rapeaux,A. (with Constandinou,T.)**

Development of a smart under-mattress mat for sleep monitoring

Offered to: Control ADIC AML FPN CSP

From: CAS

Sleep quality directly effects health and is as a crucial determinant of quality of life. Disruptions in sleep patterns serve as a risk factor for various health-related issues. Polysomnography (PSG) has long been considered the gold standard for sleep assessment. However, the inherent limitations of PSG, primarily its intrusive nature and the need for a controlled environment, have spurred a growing interest in more user-friendly alternatives.

The project aims to design an under-mattress pressure sensor system, which is engineered to unobtrusively capture critical biometric data necessary for sleep analysis without the discomfort of attached sensors. The final system should be able to accurately monitor bed occupancy, respiratory and heartbeat, and movements in real-time.

As the project progresses, there is the potential to expand the scope to include more comprehensive sleep monitoring capabilities. This would involve the integration of algorithms development to process the data collected by the sensor array, extracting meaningful insights into the user's sleep health. This involves the detection of sleep stages, identification of potential sleep disorders, and overall sleep quality assessment.

This project is in collaboration with the Sleep Research Centre at the University of Surrey.

The system's design requires expertise in PCB design, as well as in software tools such as MATLAB or Python. Additionally, a background in microcontroller design and signal processing will be preferred. The ideal candidates for this project will be students with a passion for innovating at the intersection of technology and healthcare.

The outcome of this study has the potential to deploy in participants' homes. A successful project conclusion will contribute to our ongoing research -- with the possibility of publication.

This project will be co-supervised by Dr Adrien Rapeaux and Maowen Yin.

PID	Supervisor	Description
1803213	**Sanei,S. (with Vlaski,S.)** **Reformulating XDAWN algorithm for EEG Hyperscanning (multi-subject EEG analysis) for brain computer interfacing** **Offered to: CSP** **From:**	In this project the joint electroencephalogram (EEG) recordings from multiple subjects will be analysed using a conventional single-subject BCI method reformulated to cater for multiple-subject recordings. Common spatial patterns and xDAWN algorithms as popular methods in BCI will be of interest in developing this project. These methods are based on subspace analysis rooted in principal component analysis.
1803214	**Sanei,S. (with Mandic,D.P.)** **Generation of Surrogate data using generative adversarial networks** **Offered to: CSP** **From:**	Surrogate data are very important and useful in places where there are insufficient data available for learning, classification, and recognition. Different methods have been already used for this purpose. In recent years the focus has been on deep learning approaches. In this project, we will investigate the use of tensors for data augmentation (surrogate data generation). Tensors are extension of matrices into multi-dimensional space where various data diversity can be accommodated. The results will be applied to generate new surrogates from a set of gait data to enhance their classification quality. The outcome can also be used for generation of biomedical single- and multi-channel data such as ECG or EEG.
1803215	**Sanei,S. (with Vlaski,S.)** **Adaptive sensor localisation by cooperative diffusion adaptation** **Offered to: CSP** **From:**	The objective here is how to localise (or position) a number of movable sensors to best detect and localise a target. The target is considered to be an RF (radio frequency) source and therefore, the received signal is subject to multipath propagation. This may be done by cooperative beamforming through (diffusion) adaptive filtering. You may consider several drones swarming around a complex urban area (potentially including obstacles such as building, trees, and cars) and want to best identify an RF source (e.g. as a security risk). The sensors (drones) can share the information to best localise themselves for receiving the maximum accumulative RF source power for source identification.

PID	Supervisor	Description
1803216	**Sanei,S. (with Constantinides,A.G.)**	Using the available multichannel electromyogram (EMG) datasets, we should be able to model different hand/body movement/posture using a causal model (such as multivariate autoregressive model) to estimate the connectivity between different EMG sensors and how it evolves for each movement.
Modelling hand movement from multichannel electromyograms (EMGs)		Given the information about the hand/body position can also help in developing an adaptive cooperative model (or graph) which exploits the connectivity measures, as its combination weights, for mapping EMG to the hand/body movement.
	Offered to: CSP	
	From:	
1803217	**Sanei,S. (with Constantinides,A.G.)**	A heart murmur is a sound produced due to turbulent blood flow within the heart. Heart murmurs are sounds — such as whooshing or swishing — made by rapid, choppy (turbulent) blood flow through the heart. The sounds can be heard with a stethoscope. murmurs are often superimposed on the normal heart sound. The objective here is to use a subspace based method such as singular spectrum analysis followed by a classifier to detect and classify these sounds into systolic, diastolic, and continuous murmurs.
Heart Murmur Extraction from Heart Sound Using Constrained Singular Spectrum Analysis for Murmur Classification		
	Offered to: Control ADIC AML FPN CSP	
	From:	
1803154	**Scarciotti,G.**	This project is offered and mentored by MathWorks. The technical description of the project is here https://github.com/mathworks/MATLAB-Simulink-Challenge-Project-Hub/tree/main/projects/Multi-UAV%20Path%20Planning%20for%20Urban%20Air%20Mobility
[EXTERNAL] MathWorks project 1: Multi-UAV Path Planning for Urban Air Mobility		IMPORTANT: - This project follows special rules set by MathWorks. These rules will be clarified during the Q&A held by MathWorks during the project selection window. - MathWorks will provide technical help on using MATLAB and Simulink for the project via:
	Offered to: Control	a. the discussion forum online with MathWorks experts available to ask questions and clarify doubts. b. a total of 1 hour/per month for 1:1 meeting (in person or virtual) with the students to discuss progress and eventual technical issues. It is important that you understand that if you select this project, you agree to this amount of support. If you believe that this amount of support is not enough for you, do not select the project.
	From: CAP	- Dr Scarciotti is serving as a link with MathWorks but will not be offering technical support on the project, which is managed by MathWorks. However, Dr Scarciotti will be the marker of the report and presentation, taking input from MathWorks. - Successful projects may receive rewards from MathWorks.

PID	Supervisor	Description
1803155	**Scarciotti,G.** **[EXTERNAL] MathWorks project 2: Energy Management for a 2-Motor BEV using Model-Predictive Control** **Offered to: Control** **From: CAP**	This project is offered and mentored by MathWorks. The technical description of the project is here https://github.com/mathworks/MATLAB-Simulink-Challenge-Project-Hub/tree/main/projects/Energy%20Management%20for%20a%202-Motor%20BEV%20using%20Model-Predictive%20Control IMPORTANT: - This project follows special rules set by MathWorks. These rules will be clarified during the Q&A held by MathWorks during the project selection window. - MathWorks will provide technical help on using MATLAB and Simulink for the project via: a. the discussion forum online with MathWorks experts available to ask questions and clarify doubts. b. a total of 1 hour/per month for 1:1 meeting (in person or virtual) with the students to discuss progress and eventual technical issues. It is important that you understand that if you select this project, you agree to this amount of support. If you believe that this amount of support is not enough for you, do not select the project. - Dr Scarciotti is serving as a link with MathWorks but will not be offering technical support on the project, which is managed by MathWorks. However, Dr Scarciotti will be the marker of the report and presentation, taking input from MathWorks. - Successful projects may receive rewards from MathWorks.
1803156	**Scarciotti,G.** **[EXTERNAL] MathWorks project 3: Warehouse Robotics Simulation** **Offered to: Control** **From: CAP**	This project is offered and mentored by MathWorks. The technical description of the project is here https://github.com/mathworks/MATLAB-Simulink-Challenge-Project-Hub/tree/main/projects/Warehouse%20Robotics%20Simulation IMPORTANT: - This project follows special rules set by MathWorks. These rules will be clarified during the Q&A held by MathWorks during the project selection window. - MathWorks will provide technical help on using MATLAB and Simulink for the project via: a. the discussion forum online with MathWorks experts available to ask questions and clarify doubts. b. a total of 1 hour/per month for 1:1 meeting (in person or virtual) with the students to discuss progress and eventual technical issues. It is important that you understand that if you select this project, you agree to this amount of support. If you believe that this amount of support is not enough for you, do not select the project. - Dr Scarciotti is serving as a link with MathWorks but will not be offering technical support on the project, which is managed by MathWorks. However, Dr Scarciotti will be the marker of the report and presentation, taking input from MathWorks. - Successful projects may receive rewards from MathWorks.

PID	Supervisor	Description

1803235   **Scarciotti,G. (with Shakib,M.F)**

Moment-matching for recurrent-equilibrium networks

Offered to: Control

From: **CAP**

In the recent years, high-complexity neural networks have been increasingly applied to the modelling and control of dynamical systems. However, due to their high complexity, the learning of such neural networks is a time-consuming and inefficient task.

A particular class of neural networks is the class of recurrent-equilibrium networks (RENs). This class has several advantages over other neural network architectures, e.g., it is trivial to encode stability and robustness properties in RENs and RENs have an interpretation of a so-called Lur'e-system for which many analysis and design tools already exist.

In this project, we aim to develop a moment-matching theory to directly parameterise a family of RENs that capture steady-state data generated by an unknown system. We then search within this family for the REN that optimally captures transient data in addition to steady-state data.

This approach allows a faster learning process for two reasons. First, since all models already capture steady-state data, the learning process starts close to an optimal model. Second, the family of models is parameterised by only a small number of parameters. This small set of parameters can be efficiently learned using gradient-descent optimization, which requires only a few gradient computations in each iteration step compared to a fully-parameterised REN.

The resulting REN can then be used for prediction, observer design, and controller design.

This project is led by Dr Shakib in collaboration with Dr Scarciotti

Programming skills: Either Python (PyTorch), Julia, or Matlab.

References:
Revay, Max, Ruigang Wang, and Ian R. Manchester. "Recurrent equilibrium networks: Flexible dynamic models with guaranteed stability and robustness." IEEE Transactions on Automatic Control (2023).

1803236   **Scarciotti,G.**

Is a nonlinearity measure a good complexity measure?

Offered to: Control

From: **CAP**

A "nonlinearity measure" is a concept introduced to assess how nonlinear a system is. The idea is to compare the system under assessment with the best linear approximant under the worst input. The project proposes to investigate whether a nonlinearity measure is a good "complexity measure". A complexity measure should assess how computationally complex a nonlinearity is. For instance, the dynamical system $\dot x = -x^{1/7}$ takes an average simulation time equivalent to a linear system of order n=3000, while $\dot x = -\tanh(20x)$ takes an average simulation time equivalent to a linear system of order n=20. Both systems have a similar behaviour and approximate the sign function ($\dot x = -\text{sign}(x)$), but their simulation time is wildly different. The project will try to formalise a method to assess the complexity of a nonlinearity.

This is a research-type project adapt to a student who enjoys maths.

Reference:
https://www.sciencedirect.com/science/article/pii/S1474667017468406

PID	Supervisor	Description
1803237	**Scarciotti,G.** **Model order reduction of time-delay systems using a swapped interconnection** **Offered to: Control** **From:** **CAP**	Given a large-order system and some specific properties of interest of this system, the problem of model reduction consists in the determination of a reduced-order model that, under some particular operating conditions, possesses these selected properties. The problem is of fundamental importance in the modern control and systems field because the majority of the theory and methods developed in this field rely on the availability of an accurate but simple model. This project focuses on model order reduction of time-delay systems. In particular, the aim project of the project is to develop a swapped-interconnection method for this class of systems. This is a research-type project adapt to a student who enjoys maths. Reference: https://imperiallondon-my.sharepoint.com/:b:/g/personal/gs3610_ic_ac_uk/EfxzKKcgfd5CkboJEZRlkTsB6K2jJdgUS8iF7WZEcTbojg?e=TFc1ms
1803362	**Scarciotti,G. (with Vlaski,S.)** **SDE theory for understanding stochastic gradient algorithms** **Offered to: Control ADIC AML FPN CSP** **From:** **CAP**	== Overview - The deterministic gradient descent algorithm converges to local minima. Using the theory of stochastic differential equations (SDEs) it is possible to show that adding a noise term to the algorithm causes it to converge to global minima. Recently, this mathematical approach has gathered increasing attention in the context of variations of the stochastic descent method for distributed optimisation and machine learning. The project will look into understanding how the theory of SDE is applied to show these insights, reproduce some of the results in the literature, and possibly look at how to use this theory to demonstrate the convergence properties of more recent algorithms. This project is supervised by S. Vlaski and G. Scarciotti. S. Vlaski will advise on the optimisation aspect while G. Scarciotti will advise on the SDE aspect. G. Scarciotti can provide the students with recordings of a course on SDE which he taught a few years ago. == Requirements - A strong mathematical background and interest is required. - Students will benefit from knowledge in optimisation. == References - https://proceedings.mlr.press/v202/monzio-compagnoni23a/monzio-compagnoni23a.pdf - https://arxiv.org/pdf/1709.07085.pdf
1803377	**Scarciotti,G.** **Hybrid Energy Forecasting and Trading Competition** **Offered to: Control AML FPN** **From:** **CAP**	Forecasting production from wind and solar power plants, and making effective decisions under forecast uncertainty, are essential capabilities in low-carbon energy systems. This project is based on the IEEE PES Hybrid Energy Forecasting and Trading Competition https://ieee-dataport.org/competitions/hybrid-energy-forecasting-and-trading-competition#files The FYP will use the data and tools provided for the competition to study the forecasting and trading problems. While the FYP is disjoint from the competition, the student is invited to partecipate in the competition.

PID	Supervisor	Description
1803235	**Shakib,M.F (with Scarciotti,G.)**	In the recent years, high-complexity neural networks have been increasingly applied to the modelling and control of dynamical systems. However, due to their high complexity, the learning of such neural networks is a time-consuming and inefficient task.

Moment-matching for recurrent-equilibrium networks

Offered to: Control

From: CAP

A particular class of neural networks is the class of recurrent-equilibrium networks (RENs). This class has several advantages over other neural network architectures, e.g., it is trivial to encode stability and robustness properties in RENs and RENs have an interpretation of a so-called Lur'e-system for which many analysis and design tools already exist.

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The resulting REN can then be used for prediction, observer design, and controller design.

This project is led by Dr Shakib in collaboration with Dr Scarciotti

Programming skills: Either Python (PyTorch), Julia, or Matlab.

References:
Revay, Max, Ruigang Wang, and Ian R. Manchester. "Recurrent equilibrium networks: Flexible dynamic models with guaranteed stability and robustness." IEEE Transactions on Automatic Control (2023).

PID	Supervisor	Description
1803317	**Shi,M. (with Yeatman,E.M.)**	Effective monitoring and recognition of eating behaviours are critical for nutrition research. Traditional methods, such as self-reporting food diary, suffer from significant accuracy limitations and provide inadequate insight into these behaviours. This study aims to establish an effective and robust wearable monitor for the recognition and classification of eating behaviours, using appropriate machine learning algorithms and wearable inertial measurement units. The potential student should demonstrate a strong interest in wearable devices and machine learning for time series data processing. Strong programming skill and a deep understanding of machine learning algorithms are expected. A solid background in embedded systems is preferred. This study will be a part of a comprehensive research project focusing on wearable devices for nutrition monitoring, offering students the opportunity to collaborate within a multidisciplinary team. In addition to guidance from the EEE supervisors, students will also receive direction of Dr M Cai from the Faculty of Medicine, who specialises in nutrition research. Depending on their contributions, students may have the chance to co-author research publications in the relevant field.

Machine Learning and Wearable Devices for Eating Behaviour Monitoring

Offered to: Control AML CSP

From: OSD

PID	Supervisor	Description

1803230 **Silva Deacto,G.**

Stability analysis of switched nonlinear systems under constrained time-dependent switching rules

Offered to: Control

From:

Switched systems are composed of a finite number of subsystems and a rule (or function) to orchestrate the switching among them. This rule plays an important role for the overall system stability. Indeed, whenever it is suitably designed, it can ensure global asymptotic stability, even if all subsystems are unstable. On the other hand, an unsuitable switching rule may lead the system to instability even if all subsystems are stable. In this project, our goal is to study stability of switched nonlinear systems under time-dependent switching rules. More specifically, we are mainly interested in treating the following problem:

* Persistent dwell time - Obtain stability conditions for systems subject to switching rules characterised by having an infinite number of disjoint time intervals of length no smaller than tauP, on which the switching rule must be constant, interspersed by intervals of time with length no greater than tauS, where it is arbitrary.

Before tackling the main problem, a study of the recent literature concerning persistent dwell time and minimum dwell time is considered for the sake of comparison. The applicants need to be able to develop programs in Matlab and to have a solid background on analysis and control of dynamic systems.

1802898 **Spiers,A.**

Reinforcement learning of robotic in-hand-manipulation

Offered to: AML

From: ISN

In-hand-manipulation (IHM) is the process of moving objects within the grasp of the hand, without first putting them down and picking them up again. Building specialised robot hands, designing control schemes, and running physical experiments to test new IHM hardware ideas and algorithmic approaches is expensive and time-consuming.

In this project you will first use the robot simulation software Gazebo to create a virtual environment where conceptual 2 to 4 finger designs based on the D-PALI robot gripper (developed at Imperial). Once this test bed is complete, reinforcement learning will be used to automatically develop control schemes that coordinate finger movement to achieve desired object motions (e.g. translations and rotations in 2D and 3D). The capability and efficiency of moving given objects with the different grippers will allow us to determine which designs are most promising. If time allows, you can test the control algorithms on real robotic hardware.

1803176 **Spiers,A.**

DJ Scratch Classification for Musical Training

Offered to: AML

From: ISN

We have collaborated with a professional turntablist DJ to develop a machine learning-based platform that will be trained to recognise the manipulations of a digital DJ controller when used to create scratches (percussive sounds traditionally made using a vinyl turntable). So far we have made some fundamental progress in this area.

The software platform may be used for DJ training, by automatically analysing and annotating the pre-recorded scratch routines of professional DJs for offline study by novices, or by comparing a novice DJ's scratches to those of a teacher.

This unusual project will suit an individual with a passion for music and/or musical performance. The student will be working closely with professional musicians and will need to learn some of these musical techniques themselves, so please only apply if you are enthusiastic about these topics.

PID	Supervisor	Description
1803275	**Spiers,A. (with Pitt,J.V.)** **A self-organising multi-robot system (SObotics)** **Offered to: AML** **From: ISN**	Robotic arms are used extensively in industry for the manipulation of objects and tools. In multi-robot systems these arms collaborate to perform tasks that are outside the scope of the individual (e.g. carrying a heavy object or moving an object beyond the reach of one arm). In this project you will work with three or more desktop robot arms (model: ROBOTIS Manipulator-X) in the framework of self-organising multi-agent systems, using the robots to complete a physical manipulation task while trying to minimise a cost function. An example task (which is subject to modification) could be placing an object (only accessible to robot A) in a container (only accessible to robot B) and passing that container from a start position (accessible to robots A and B) to an end destination (only accessible to robot C). This is to be completed in the framework of minimising time taken, with the goal of creating an efficient object/container production line.
1803277	**Spiers,A. (with Mikolajczyk,K.M.)** **Towards Tactile Sensor Agnostic Feature Extraction with a Robotic Arm** **Offered to: AML** **From: ISN**	In the field of computer vision, the majority of algorithms do not need a particular type of camera and will work comparably between a smartphone camera or the webcam of a laptop. Conversely, approaches to tactile sensing vary greatly by the type of sensor being used, as the sensors themselves vary in terms of transducer type (e.g. capacitive / optical) and resolution. This project aims to create a method of comparatively analysing the data between various tactile sensors using machine learning approaches to extract common features. A variety of tactile sensors (DIGIT, Contactile, Xela) will be mounted on a UR5 robotic arm for repeatable data collection. This project builds on work from last year, which dealt with controlling the robotic arm and reading data from some of the sensors using a ROS (Robotic Operating System) framework.
1803376	**Spiers,A.** **DJ Scratch Classification for Musical Training** **Offered to: AML** **From: ISN**	We are collaborating with a professional turntablist DJ to develop a machine learning-based platform that can recognise the manipulations of a digital DJ controller when used to create scratches (percussive sounds traditionally made using a vinyl turntable). The software platform may be used for DJ training, by automatically analysing and annotating the pre-recorded scratch routines of professional DJs for offline study by novices, or by comparing a novice DJ's scratches to those of a teacher. This unusual project will suit an individual with a passion for music and/or musical performance. The student will be working closely with professional musicians and will need to learn some of these musical techniques themselves, so please only apply if you are enthusiastic about these topics. This project was successfully run last year and this year will improve upon that student's work and existing dataset.

PID	Supervisor	Description
1803316	**Spyrou,E. (with Stratigakos,A.)** **Learning-based methods to speed up the Unit Commitment problem** Offered to: FPN From: CAP	The clearing window of electricity markets is becoming increasingly smaller, partially in response to the uncertainty and variability introduced by stochastic renewable generation. In turn, this challenges the traditional workflows of system operators (SOs). For instance, SOs like MISO must solve multiple Unit Commitment (UC) problems, which is a mixed-integer problem that determines the generators on/off status, per day under stringent time constraints . Data-driven methods, e.g., machine learning and statistical methods, can complement traditional, off-the-shelf optimization solvers and provide considerable reductions in the computation time required to solve UC problems. This project will aim to quantify the benefits of using data-driven methods to speed up the solution of the UC problem. The problem will consist of three key parts: (1) literature review on methods to speed up the UC problem and data collection, (2) development of an optimization model for the UC problem and evaluation of different methods to speed up its solution (e.g., constraint screening, warm-start solutions), (3) analysis and reporting of the results.
1803318	**Spyrou,E.** **Modeling demand flexibility in future power systems** Offered to: FPN From: CAP	Demand flexibility or active demand participation is anticipated to play an essential role in future power systems. The academic literature and practice suggests at least two paradigms for incenting demand flexibility. One paradigm compensates demand flexibility in advance and charges non-performance penalties. Another paradigm compensates demand flexibility through monetary incentives for performance. This project aims to model different schemes for demand flexibility and summarize their strengths and weaknesses based on qualitative analysis and quantitative analysis of model results.
1803319	**Spyrou,E.** **Power System Operations under Extreme Conditions** Offered to: FPN From: CAP	In recent years, the number of extreme events has increased. During extreme events, power system components have higher probability of failure. In some cases, electricity must be curtailed. Historically, rolling power outages have been practiced. While rolling power outages treat customers equally, they are not necessarily equitable. This project will review current practices for operations under extreme conditions (emergencies), model them, and summarize their strengths and weaknesses through qualitative analysis and quantitative analysis of the model results.

PID	Supervisor	Description

1803320 **Spyrou,E.**

Modeling approaches for long duration storage

Offered to: Control ADIC
AML FPN CSP

From: CAP

This project aims to compare different modeling approaches for long duration storage in power systems operations model. Some approaches incorporate targets for state of energy at the end of the horizon, others include strike prices for charging/discharging. This project aims to review proposed approaches, contrast them to understand their strengths and weaknesses, and potentially propose methodological enhancements to improve their performance.

1803368 **Stathaki,P.T.**

Automated Crop Detection from Aerial Images Using Machine Learning

Offered to: Control ADIC
AML FPN CSP

From: CSP

The proposed MSc project aims to develop an automated system for crop detection from aerial images using machine learning techniques. Aerial imagery has become increasingly vital in agriculture for monitoring crop health and identifying potential issues such as disease outbreaks and pest infestations. This project will involve the creation of a comprehensive dataset of annotated aerial images encompassing various crop types. By implementing machine learning models, including deep learning algorithms, we will develop a robust system capable of accurately detecting and classifying crops in these images. The project's ultimate goal is to provide a user-friendly interface that allows farmers and agricultural professionals to upload their own aerial images and receive precise crop detection results, contributing to more efficient and sustainable crop management practices.

1803369 **Stathaki,P.T.**

Tiny Object Detection using Deep Learning

Offered to: Control ADIC
AML FPN CSP

From: CSP

This MSc project proposal focuses on the development of deep learning-based solutions for the detection of tiny objects, a critical challenge with far-reaching applications. The project's primary objectives involve customizing deep learning architectures, curating a diverse dataset, and conducting thorough evaluations to ensure accurate and efficient tiny object detection. The successful completion of this project promises to advance the capabilities of computer vision systems in various domains, from healthcare to surveillance and robotics, by providing reliable methods for detecting and analyzing small-scale objects. Ultimately, this research aims to contribute to the enhancement of technology and its practical applications in addressing real-world problems associated with tiny object detection.

PID	Supervisor	Description

1803370   **Stathaki,P.T.**

Target Detection using Deep Learning with Limited Training Data

This proposal focuses on target detection using deep learning, with a particular emphasis on the daunting task of achieving high-performance results with limited training data. The project aims to leverage state-of-the-art deep learning architectures, along with innovative strategies such as transfer learning and data augmentation, to overcome the challenges posed by data scarcity. By exploring these techniques, the project seeks to provide solutions that enable accurate target detection even in scenarios where acquiring a substantial amount of labeled data is impractical. The ultimate goal is to contribute to the development of more efficient and resource-friendly deep learning models for target detection, with applications in a wide range of domains, including surveillance, security, and autonomous systems.

Offered to: Control ADIC AML FPN CSP

From: **CSP**

1803375   **Stathaki,P.T.**

Semantic Segmentation of Land from Aerial Imagery

This MSc project aims to develop an efficient and accurate semantic segmentation model for classifying land cover categories in high-resolution aerial imagery. Leveraging deep learning techniques, we will create a comprehensive dataset with pixel-wise ground truth annotations, investigate state-of-the-art architectures, and develop a user-friendly software tool for automated land cover segmentation. The project's outcomes will find practical applications in fields like urban planning, environmental monitoring, and land use management, contributing to informed decision-making and resource allocation.

Offered to: Control ADIC AML FPN CSP

From: **CSP**

1803316   **Stratigakos,A. (with Spyrou,E.)**

Learning-based methods to speed up the Unit Commitment problem

The clearing window of electricity markets is becoming increasingly smaller, partially in response to the uncertainty and variability introduced by stochastic renewable generation. In turn, this challenges the traditional workflows of system operators (SOs). For instance, SOs like MISO must solve multiple Unit Commitment (UC) problems, which is a mixed-integer problem that determines the generators on/off status, per day under stringent time constraints . Data-driven methods, e.g., machine learning and statistical methods, can complement traditional, off-the-shelf optimization solvers and provide considerable reductions in the computation time required to solve UC problems. This project will aim to quantify the benefits of using data-driven methods to speed up the solution of the UC problem. The problem will consist of three key parts: (1) literature review on methods to speed up the UC problem and data collection, (2) development of an optimization model for the UC problem and evaluation of different methods to speed up its solution (e.g., constraint screening, warm-start solutions), (3) analysis and reporting of the results.

Offered to: FPN

From: **CAP**

PID	Supervisor	Description
1802953	**Sydoruk,O.**	Near-field communication (NFC) is used for short-range data transfer. Common applications are access control and contactless payments. Several manufacturers offer NFC ICs that perform operations according to standard protocols.

Embedded system for near-field communication

Offered to: Control ADIC AML FPN CSP

From: OSD

However, new applications for NFC have recently started to emerge, for example, distributed communication with mobile transponders and sensing. The latter aims to create sensors that are both powered and communicated with wirelessly and so require no battery. As a result, such sensors can operate, without need for maintenance, in harsh or difficult to reach environments.

The existing standard electronics and ICs often cannot cater for the emerging applications. Bespoke solutions are needed. This project will aim to develop an embedded system for NFC that realised a standard vicinity protocol, but also allows for bespoke control of signal transmission and reception. Specifically, the project will concentrate on microcontroller programming, hardware control, signal processing, and interface between digital and analogue hardware.

The project will suit a student with interest and experience in microcontroller programming. Interest in RF analogue electronics is desirable; however, prior experience in the area is not necessary.

| 1802955 | **Sydoruk,O.** | Near-field communication (NFC) is used for short-range data transfer. Common applications are access control and contactless payments. Many manufacturers offer NFC readers that communicate with NFC transponders according to standard protocols. |

RF frontend for near-field communication

Offered to: Control ADIC AML FPN CSP

From: OSD

However, new applications for NFC have recently started to emerge, for example, distributed communication with mobile transponders and sensing. The latter aims to create sensors that are both powered and communicated with wirelessly and so require no battery. As a result, such sensors can operate, without need for maintenance, in harsh or difficult to reach environments.

These novel applications pose an increased demand on performance of RF analogue electronics used in readers. For example, there may be a need to communicate over larger distances, to handle higher power, and to decrease signal loss.

This project will explore RF frontends with improved performance. The project will contain two parts, and the student may choose to do only the first or both parts. The first part is the design of RF devices, such as couplers, filters, receivers, and modulators. The second part is assembly of these devices into a complete RF frontend for NFC, which will then be tested on real transponders.

| 1802958 | **Sydoruk,O.** | THIS project will explore the possibility of using magnetically-coupled LC resonators for detecting mechanical displacements. It could be theoretical, experimental or both. |

Magneto-inductive Displacement Detector

Offered to: ADIC CSP

From: OSD

It would suit a student with interest in electromagnetic devices, theory, and simulations. It is related to the module Sensors

PID	Supervisor	Description

1803290   **Sydoruk,O.**

RFID antennas for centrifuges

Offered to: Control ADIC
           AML FPN CSP

From: **OSD**

RFID technology enables battery-less sensor operation. As a result, RFID sensors can be made small and positioned unobtrusively on critical infrastructure. The aim of this project is to develop an RFID read-out system for sensors positioned on rotating machines, such as centrifuges.

The project can be simulation-based on design-and-build, depending on the student's preferences. It will suit a student with interest in RF electronics and EM hardware.

1802868   **Syms,R.R.A.**

Wireless energy theft

Offered to: FPN

From: **OSD**

The aim of this project is to consider the modern phenomenon of electrical energy theft, described as 'non-technical loss' in wired distribution systems. In the UK, energy theft is not common but is nonetheless covered in Section 13 of the 1968 Theft Act. Energy theft is rife in third world countries, where non-paying consumers simply connect additional wires to the system. For many years, it has been accepted but its scale has now risen so far that it is an active subject of research, and attempts are being made to detect and counter it by smart metering systems. Energy theft is likely to be more prevalent in wireless distribution systems since the necessary links are inherently less visible. The aim of this project will be to answer the following questions. Can wireless energy theft be modelled? What are the symptoms, and what can be done to counter it? What are the best strategies of energy provider, recipient, and thief?

1802879   **Syms,R.R.A.**

Dual frequency magneto-inductive systems

Offered to: ADIC

From: **OSD**

Magneto-inductive waveguides are linear arrangements of magnetically coupled L-C resonators, which allow propagation at radio frequency over a narrow spectral range. MI waveguides have applications in near-field communications, wireless power transfer and sensing of magnetic resonance imaging (MRI) signals. The aim of this project is to investigate the design of magneto-inductive systems capable of operating at two widely different frequencies (for example, as signals from two different nuclei in MRI), together with multiplexers capable of injecting and extracting the signals. Suitable designs will then be prototyped on PCBs and characterised using network analysers. The project would suit someone interested in RF systems design and measurement.

1803222   **Syms,R.R.A.**

Fast polyphase code discovery

Offered to: CSP

From: **OSD**

Polyphase codes are commonly used in radar. Each bit in the code is encoded with a phase shift, so the codes are PSK type and transmitted at constant power. Detection is carried out by correlation, and the autocorrelation function ideally consists of a large central spike with low sidelobes. Polyphase codes sets are used in applications such as multiple input multiple output (MIMO) radar and code-division multiple access (CDMA) communications, where several distinguishable signals are required. Sets should satisfy the additional constraint of low cross-correlation. Unfortunately, the problem of identifying suitable codes scales very poorly. For example, if B phases are allowed, and there are M bits, the autocorrelations of B^M different codes must be checked. To find code pairs, the cross-correlations of $(B^M)^2/2$ pairs must be considered. Worse still, the codes are affected by Doppler shifts in radar applications. The aim of this project is to examine strategies for code identification that do not involve an exhaustive search, such as simulated annealing. The project would suit someone with an interest in number theory and Matlab programming.

PID	Supervisor	Description
1803223	**Syms,R.R.A.** **Signalling with Polyphase Codes** **Offered to: ADIC CSP** **From:** **OSD**	Polyphase codes are commonly used for coded signalling, especially in noisy channels. Each bit in the code is encoded with a phase shift, so the codes are PSK type and transmitted at constant power. Detection is carried out by correlation, and the autocorrelation function ideally consists of a large central spike with low sidelobes. The aim of this project is to design and build a signal generator capable of encoding a bitstream with two different PSK codes in the HF band and a two-channel correlation detection system capable of regenerating the output as ones and zeros. Accompanying simulations can be carried out in Matlab. The project would suit someone with an interest in communications hardware design.
1803224	**Syms,R.R.A.** **Signalling with Golay Codes** **Offered to: ADIC CSP** **From:** **OSD**	Ideal orthogonality (delta-function autocorrelations and zero cross-correlations) cannot be achieved using any unipolar codes, since the cancellation needed to reach zero cannot arise. To overcome this limitation, an ingenious solution was proposed by Golay. Instead of transmitting single codes, pairs of unipolar codes are sent, and their correlations are then subtracted. The result can be perfect orthogonality. Golay codes are widely used for signalling in attenuating media (for example, ultrasound waves in pipes). The aim of this project is to design and build a signal generator capable of encoding a bitstream with Golay codes in the HF band and a two-channel correlation detection system capable of regenerating the output as ones and zeros. Accompanying simulations can be carried out in Matlab. The project would suit someone with an interest in communications hardware design.
1803251	**Syms,R.R.A.** **MEMS filter design** **Offered to: ADIC** **From:** **OSD**	Filters based on passive components such as resistors, capacitors and inductors are inherently limited by losses at high frequency, especially in inductors. Very high performance can be achieved at hundreds of MHz using electrostatically driven microelectromechanical systems (MEMS), because of the very low gas and material damping achievable using vacuum-packaged single crystal silicon. The aim of this project is to investigate the design and performance optimization of arrays of higher-order MEMS bandpass filters suitable for use as intermediate frequency (IF) filters, multiplexers and demultiplexers. The work will be carried out with Matlab simulations based on lumped-element and distributed models. The project would suit someone interested in filter theory and dynamics, with an ability to program.

PID	Supervisor	Description

1802999 **Teng,F.**

Techno-economic Feasibility of Base Stations Energy Consumption Flexibility and Backup Battery to Provide Services in Electricity Markets

Offered to: Control ADIC AML FPN CSP

From: **CAP**

The energy crisis leads to significant challenges in the communication industry due to soaring electricity prices and potential electricity shortages. However, this also brings in opportunities for the industry to fundamentally shift its role and interactions with electricity systems. With the long-term goal of decarbonization, the penetration of renewable energy has been rising worldwide, which brings enormous fluctuation to electricity systems. More flexible resources are required and extremely valuable to facilitate the decarbonization agenda.

The cellular base stations (BSs) are flexible in energy consumption and equipped with backup batteries for reliability. While guaranteeing reliability, the equipped backup batteries have spare capacity to provide services to the power grid. Realizing the BS dispatch potential towards electricity system operation may simultaneously benefit both mobile operators and power systems. In particular, mobile operators can reduce their electricity bills by shifting the electricity purchase to a low-price period and earn extra payments from the electricity markets by providing ancillary services. This

project investigates the feasibility of integrating backup batteries of BSs into electricity systems in terms of technology readiness, business model creation, and market opportunities .

1803003 **Teng,F.**

Estimation on Synthetic Inertia Contribution from Wind Farm

Offered to: Control FPN

From: **CAP**

Background:
In order to achieve zero carbon operation of the power system by 2025 to reduce the total greenhouse gas emission, the Great Britain (GB) system operator is integrating large-scale wind power in the generation mix. With the conventional power plants being replaced by wind turbines, significant challenges are anticipated in terms of system operation and stability. One such challenge is driven by the reduction of system inertia, since wind turbines are interfaced to the grid through power electronic converters that decouple the rotational Kinetic Energy (KE) from the system.

In this context, SI provision based on the stored KE from WTs has been proposed in the literature to facilitate the frequency regulation subsequent to system disturbances. However, from the perspective of the system operators, it is of essential importance to estimate the total available SI in the system during the scheduling process. In details, the following factors may need to be considered: wind speed distribution and variation, WT modelling, wake effect…

Goal:
This project aims to develop a mathematical/analytical model to estimate the amount of SI in the system or single wind farm to inform the optimal system scheduling.

1803004 **Teng,F.**

Data-driven approaches to transient voltage stability assessment

Offered to: FPN

From: **CAP**

The declining system inertia driven by the increasing penetration of RES imposes significant challenges on the system operation. This project will develop mathematical constraints to maintain system stability, which can be incorporated into power system optimisation problems. Due to the complex dependence and nonlinearity of system dynamics, we will investigate the feasibility of data-driven approaches to formulate the constraints in a combat manner so that the complexity and accuracy can be balanced. The student will need to have experience in using python for ML application s and familiar with power system optimisation.

PID	Supervisor	Description

1803066   Teng,F.

Wireless Communication-enabled Hardware-In-the-Loop Demonstration of Distributed Resilient Control for Cyber-Physical Power Systems

Offered to: FPN

From: CAP

To bolster the transition in energy supply and embrace digitisation, renewable energy resources, which are typically distributed, can be adeptly managed and controlled using cutting-edge distributed control techniques and Information and Communication Technologies (ICT). In such a context, tools like wireless communication and edge computation demonstrate their prowess in effectively managing extensive distributed energy resources. Given this, there's an urgent and timely need to pinpoint the theoretical challenges associated with the creation of such an ICT-driven distributed resilient control framework and to assess the associated hardware performance.

Leveraging the principle of the hardware-in-the-loop control system and the real-time power system simulator OPAL-RT, this project endeavors to address both theoretical and pragmatic obstacles tied to wireless communication-facilitated distributed control and estimation in power systems. This includes the identification and modeling of potential contingencies, with a spotlight on cybersecurity and privacy concerns in wireless-integrated power system operations. The research aims to shed light on the advantages and opportunities presented by advanced ICT, particularly with the integration of wireless networks like 5G, in the proficient management of renewable energy assets. Moreover, it aims to establish a validation platform for power system control techniques. Such efforts are pivotal for a cost-efficient shift towards a future-proof, intelligent, and carbon-neutral power system.

1803379   Toumazou,C.

An intelligent AI based shopping system for Skincare based on UV and DNA

**Offered to: Control ADIC
          FPN CSP**

From: CAS

NantBeam is a wearable health device which can enhance the user's health and wellbeing by offering only personalised food product recommendations. The device is equipped with an integrated camera and barcode scanner that enables the user to scan product barcodes while shopping, with a colour coded indicator system presenting product recommendations based on the user's deoxyribonucleic acid ('DNA') profile. A new capability is to integrate a skincare detection that would detect UVA, UVB, and ambient light exposure. This project will develop algorithms and firmware for the UV light sensing and skincare product recommendations enabling people to shop for skincare products based on UV and DNA.

1803380   Toumazou,C.

Shopping with your Biology

**Offered to: Control ADIC
          FPN CSP**

From: CAS

Type2 diabetes is on the dramatic increase with more than a third of the population will some level of prediabetes. The aim of the project is to design a low power wearable continuous monitoring system for HbA1c Glucose monitoring and integration to a wearable technology for smarter shopping. The project will involve hardware and software design and AI to intelligently adjust food product choices based upon blood glucose levels. A small user trial will be designed to demonstrate the health benefits of the technology.

PID	Supervisor	Description

1803381 **Toumazou,C.**

Smart Payment for healthy food products and integration of the microbiome

Offered to: **Control ADIC FPN CSP**

From: **CAS**

NantBeam can provide the personalized shopping experience based on your dna results, however the system is not integrated with the supermarket checkout system. This project will focus on designing an integrated checkout system on the wearable to enable personalised shopping through a payment cloud based on your own genetic traits. The project will be mainly a digital MCU interface to the wearable and and a local Machine learning algorithm. The project will also consider the the intrinsic correlation between breath analysis of the microbiome and DNA through a wearable technology and breath sensors.

1802935 **Ul Nazir,F. (with Pal,B.C.)**

Forecasting MW from DG in the UK from weather data

Offered to: **FPN**

From: **CAP**

In a particular day in August, 2016 National Grid (NG) experienced lowest demand in their system. This is due to generation from PV in the system that is at distribution level. NG does not have any record of this generation because it is not connected to their system. However, there are plenty of local weather information stations across different areas of UK where temperature, sun index all are measured. The challenge is how such information can be translated to available MW when the installed capacity of PV farm is known. The objective is to estimate the MW from solar to grid for most cost effective reserve planning. The project will explore various estimation/prediction tools used in industry for that purpose. Make a comparison and contrast their performance. A good first class project requires new method to explore.

PID	Supervisor	Description

1803049   **Vlaski,S.**

Data Mining for Single-Cell RNA Sequencing in Liver Disease

Offered to: Control ADIC AML FPN CSP

From: **CSP**

== Overview

Single-cell RNA sequencing is a novel technique for the extraction of genetic data from cells. It's emergence has opened the doors for understanding biological processes at a much more granular level than previously, allowing for the analysis of the genetic makeup of individual cells, rather than the entire organism. This has led to a flurry of interest in the medical community, leading to the generation of massive amounts of data in various disease contexts. The overarching objective of single-cell RNA sequencing is the identification of disease markers, prediction and diagnosis, understanding of the underlying disease mechanism, and ultimately the development of therapeutics.

Despite its potential, data resulting from RNA sequencing poses significant challenges for data analysis. Data takes the form of a gene expression matrix, where tens of thousands of gene expressions are measured for tens of thousands of single cells. This project will perform an investigative analysis of available datasets for single-cell RNA expression in the context of liver disease, with the aim of identifying markers of liver disease at the cellular level. The analysis will make use of state-of-the-art techniques for large-dimensional data mining and analysis including dimensionality reduction, visualisation, variable selection, as well as prediction using regression/classification techniques. Prospective students should be keen to dive into the relevant biomedical data sets and publications in addition to surveying appropriate literature from statistics, signal processing and machine learning.

== Requirements
- Proficiency with statistical and machine learning techniques for large-dimensional data processing (dimensionality reduction, variable selection, visualisation, sparsity, regression/classification)
- Experience in data analysis with Python and/or R

== References
- https://arxiv.org/pdf/2110.06048.pdf
- https://www.cell.com/immunity/pdfExtended/S1074-7613(20)30357-5
- https://www.livercellatlas.org

1803213   **Vlaski,S. (with Sanei,S.)**

Reformulating XDAWN algorithm for EEG Hyperscanning (multi-subject EEG analysis) for brain computer interfacing

Offered to: CSP

From: **CSP**

In this project the joint electroencephalogram (EEG) recordings from multiple subjects will be analysed using a conventional single-subject BCI method reformulated to cater for multiple-subject recordings. Common spatial patterns and xDAWN algorithms as popular methods in BCI will be of interest in developing this project. These methods are based on subspace analysis rooted in principal component analysis.

PID	Supervisor	Description

1803215 **Vlaski,S. (with Sanei,S.)**

Adaptive sensor localisation by cooperative diffusion adaptation

Offered to: CSP

From: CSP

The objective here is how to localise (or position) a number of movable sensors to best detect and localise a target. The target is considered to be an RF (radio frequency) source and therefore, the received signal is subject to multipath propagation. This may be done by cooperative beamforming through (diffusion) adaptive filtering. You may consider several drones swarming around a complex urban area (potentially including obstacles such as building, trees, and cars) and want to best identify an RF source (e.g. as a security risk). The sensors (drones) can share the information to best localise themselves for receiving the maximum accumulative RF source power for source identification.

1803362 **Vlaski,S. (with Scarciotti,G.)**

SDE theory for understanding stochastic gradient algorithms

Offered to: Control ADIC AML FPN CSP

From: CSP

== Overview
- The deterministic gradient descent algorithm converges to local minima. Using the theory of stochastic differential equations (SDEs) it is possible to show that adding a noise term to the algorithm causes it to converge to global minima. Recently, this mathematical approach has gathered increasing attention in the context of variations of the stochastic descent method for distributed optimisation and machine learning.

The project will look into understanding how the theory of SDE is applied to show these insights, reproduce some of the results in the literature, and possibly look at how to use this theory to demonstrate the convergence properties of more recent algorithms.

This project is supervised by S. Vlaski and G. Scarciotti. S. Vlaski will advise on the optimisation aspect while G. Scarciotti will advise on the SDE aspect. G. Scarciotti can provide the students with recordings of a course on SDE which he taught a few years ago.

== Requirements
- A strong mathematical background and interest is required.
- Students will benefit from knowledge in optimisation.

== References
- https://proceedings.mlr.press/v202/monzio-compagnoni23a/monzio-compagnoni23a.pdf
- https://arxiv.org/pdf/1709.07085.pdf

PID	Supervisor	Description

1803363 **Vlaski,S.**

Primal-Dual Techniques for Distributed Multitask Learning

Offered to: Control ADIC AML FPN CSP

From: CSP

== Overview
Distributed learning techniques allow a collection of intelligent agents to cooperatively solve optimisation and learning problems while relying on limited interactions and ensuring privacy, communication efficiency and robustness.

Most strategies are designed for so called "singletask" problems, where agents solve a single, common problem and agree on a single, common model. Such techniques are appropriate in homogenous environments, but fail when agents are heterogeneous, and instead wish to learn distinct but related models. To this end, recent works have developed techniques for distributed learning under subspace constraints, where local models are distinct, but lie on a lower dimensional subspace. While effective in the presence of noise, the resulting algorithms exhibit a small but significant bias. This project will develop novel algorithms based on primal-dual algorithms which remove this bias and are expected to yield superior performance in the low-noise regime.

== Requirements
- Proficiency with optimization and machine learning
- Experience in implementing learning algorithms in python and relevant libraries

== References
- https://ieeexplore.ieee.org/abstract/document/9084370
- https://arxiv.org/abs/2210.13767

1803364 **Vlaski,S.**

Combination Policies for Decentralized Deep Learning

Offered to: Control ADIC AML FPN CSP

From: CSP

Background

The aim of decentralized learning is to solve machine learning and optimization problems across a collection of intelligent agents without the need for a central coordinator. Decentralized systems are sometimes dictated by the underlying architecture, but also have many advantages in terms of communication efficiency, robustness to node and link failure, and privacy. One critical component of a decentralized algorithm is its "combination policy", which guides individual agents on how they should interact with their peers. Many types of combination policies exist in the literature, most of which are linear. Linear combination policies are very tractable, but have drawbacks when attempting to learn highly non-linear structures (such as neural networks).

Scope

This project will investigate combination policies for decentralized learning with an emphasis on learning non-linear functions, such as neural networks. Existing combination policies will be surveyed and evaluated on their ability to guide the learning of nonlinear mappings, and new combination policies will be proposed.

Prerequisites

Coding ability in Python/Matlab, desire to learn ML packages such as Pytorch. Some background and/or interest in machine learning, adaptive filtering and/or optimization is a plus.

References
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https://arxiv.org/pdf/2003.14366
https://arxiv.org/abs/2102.04828
https://ieeexplore.ieee.org/abstract/document/9414449

PID	Supervisor	Description

1802963   **Wang,Sen**

Mapping Imperial College in a Day

Offered to: AML

From: **ISN**

This project will develop a 3D LiDAR-Visual-Inertial mapping system which can build 3D maps of environments efficiently and accurately. The system can be handheld or mounted on a mobile robot for autonomous 3D mapping. The final system will be tested and demonstrated at Imperial College, building its 3D accurate map in a few hours.

It is essential to have strong skills in programming (C++ or Python) and, ideally, experience in using Linux/Unix and Robot Operating System (ROS) (https://www.ros.org/).

Some related publications:
K Zhang, Z Hong, S Xu, S Wang. CURL: Continuous, Ultra-compact Representation for LiDAR. Robotics: Science and Systems (RSS), 2022 (https://arxiv.org/abs/2205.06059)
Lin, Jiarong, and Fu Zhang. "R ^{3} LIVE++: A Robust, Real-time, Radiance reconstruction package with a tightly-coupled LiDAR-Inertial-Visual state Estimator." arXiv preprint arXiv:2209.03666 (2022). (https://arxiv.org/abs/2209.03666)

1802964   **Wang,Sen**

Neural LiDAR 3D Reconstruction

Offered to: AML

From: **ISN**

Neural Radiance Fields (NeRF) [1, 2], a deep learning based 3D volumetric scene representation, has been extraordinarily successful and impactful since it was published two years ago. However, most of the existing NeRF works focus on vision systems for room-size environments.

This project will study and develop NeRF based high-fidelity, dense 3D reconstruction for large-scale environments (e.g., an Imperial building or a street) using solid-state LiDAR sensors which provide dense range and intensity measurements.

[1] Code, videos, results: https://www.matthewtancik.com/nerf
[2] Paper: https://arxiv.org/abs/2003.08934

1802966   **Wang,Sen**

Near-field image reconstruction using Millimeter-wave SAR

Offered to: AML

From: **ISN**

This project will develop a radar sensing based robot localisation and navigation system for autonomous vehicles/robots. A Texas Instruments mmWave radar sensor will be mounted on a mobile robot for experiments. The project will demonstrate the benefits of the system for all-weather operation.

It is essential to have strong skills in programming (C++ or Python) and, ideally, experience in using Linux/Unix and Robot Operating System (ROS) (https://www.ros.org/).

PID	Supervisor	Description
1802983	**Wang,Sen (with Bouganis,C.)** **Accelerating Visual Simultaneous Localisation and Mapping (SLAM) System using FPGA** **Offered to: Control ADIC AML FPN CSP** **From: ISN**	Visual Simultaneous Localisation and Mapping (SLAM) is a critical technology for autonomous robotics, enabling robots to navigate their environment in real-time. However, the computational demands of visual SLAM algorithms often limit their deployment on resource-constrained robotic platforms, e.g., aerial and underwater robots. This project aims to accelerate a Visual SLAM system using Field-Programmable Gate Arrays (FPGAs) to enable more efficient and cost-effective robotic navigation and mapping solutions. The project will involve design and implement FPGA hardware architectures for accelerating a chosen Visual SLAM algorithm while maintaining its accurate localisation and mapping performance. A state-of-the-art visual SLAM system (programmed in C++) will be provided along with some test dataset collected from an on-board stereo camera. A physical robot platform can also be provided for testing if interested. The project will focus on the hardware design aspect and more specifically on the design of an accelerator unit that will be placed in the FPGA and accelerate the computationally heavy parts of the algorithm. An initial faithful implementation of the system will be considered, and time allowed, numerical approximations will be explored to further accelerate the overall system considering the impact on the accuracy. The project offers an opportunity for students who would like to delve into the intersection of hardware acceleration, robotics, and computer vision. Good knowledge of C++ and RTL is required.
1803150	**Wang,Sen** **Underwater Object Detection and Segmentation** **Offered to: AML** **From: ISN**	This project will focus on object detection and segmentation for underwater environments that have a limited amount of existing training data by nature. Underwater scenarios also suffer from limited visibility, challenging illumination and excess noises for optical images. The project can explore either 1) a photorealistic underwater simulator (e.g., HoloOcean) and sim-to-real transfer or 2) few-shot learning directly on real-world data. Some underwater datasets collected by our lab can be provided for this project. There are also some underwater data available from the internet.
1803151	**Wang,Sen** **Sonar Nerual 3D Reconstruction** **Offered to: AML** **From: ISN**	Underwater 3D reconstruction of objects using an imaging sonar is a challenging and open task with no existing solution. Some recent work has been exploring the use of neural reconstruction, e.g., NeRF, for forward-looking sonar [1]. This project will investigate how to perform imaging sonar based 3D reconstruction using neural implicit representation. Sonar datasets and underwater robot locations can be provided to enable the focus on neural reconstruction. Python or C++ programming is essential. Reference: [1] Neural Implicit Surface Reconstruction using Imaging Sonar <https://arxiv.org/pdf/2209.08221>

PID	Supervisor	Description

1803234 **Wang,Sen**

Vision-Enabled Underwater Robots for Autonomous Operations

Offered to: AML

From: ISN

This project aims to advance various essential components in the development of an autonomous underwater robot using the BlueROV2 platform (<https://bluerobotics.com/store/rov/bluerov2/>). The project will include tasks such as configuring the hardware of the BlueROV2 robot and setting up a Raspberry Pi 4 embedded board with the Robot Operating System (ROS). Additionally, the project may entail the design of a waterproof housing for a stereo camera, which will subsequently be integrated with the BlueROV2 robot. Following these hardware aspects, the project will focus on the development of algorithms related to underwater robot control (Model Predictive Control - MPC), path planning, localisation, 3D mapping, autonomous navigation, object recognition, and/or image segmentation, depending on your specific interests and objectives.

It is essential to have good skills in hardware design and integration, and some experience in programming (C++ or Python) and, ideally, Robot Operating System (ROS) (<https://www.ros.org/>).

1802982 **Wickerson,J.**

Random testing of place-and-route tools

Offered to: ADIC

From: CAS

FPGAs are becoming ever more popular, and are being used in an increasing variety of domains, including safety-critical applications. It is vital that hardware designs are being implemented correctly on FPGAs, but it is hard to be sure about this, because there is a complicated and rather opaque sequence of steps taken to transform a Verilog design into a netlist and then to place-and-route it into a bitstream to send to the FPGA.

This project asks: are place-and-route tools correct?

It will involve generating random RTL designs, giving them to place-and-route tools, then using an existing reverse-engineering tool to convert the generated bitstream back into RTL, and finally checking that the two RTL designs are equivalent. (If not, there is a bug somewhere!)

The project would be well suited to a student with strong programming skills and good competence with FPGA synthesis tools.

1803337 **Wickerson,J.**

Fuzzing C++ STL containers

Offered to: ADIC

From: CAS

Tools like Csmith have had remarkable success at finding bugs in compilers, simply by generating random (but valid) C/C++ programs and seeing if they are compiled correctly.

This project is about extending Csmith (or writing a new tool) to generate random C++ programs that make use of STL containers (such as vectors, queues, and linked lists). Then we can feed these programs into tools that purport to handle STL containers (such as Synopsys Coverity), and see if they handle them correctly.

This project is suitable for a student who enjoys programming, ideally has some experience with C++, and enjoys the thrill of trying to find bugs in things!

PID	Supervisor	Description

1803338   **Wickerson,J.**

Finding bugs in RTL equivalence checkers

    Offered to: ADIC

    From: **CAS**

A "formal equivalence checker" (FEC) is a tool that takes two hardware designs in RTL, and determines whether they are behaviourally equivalent -- for all possible inputs, and for an unlimited number of clock cycles. Such tools are very valuable to hardware designers.

We'd like to test whether the current crop of commercial FECs (such as Siemens FormalPro, Cadence Conformal, and Synopsys Formality) are actually reliable. So, this project will involve generating random hardware designs (possibly building on an existing tool called Verismith) and feeding them to a FEC-under-test, to see if it always gives the correct answer.

This project is suitable for a student who enjoys programming, and would relish the thrill of trying to find bugs in things!

1803340   **Wickerson,J.**

How reliable are high-level equivalence checkers?

    Offered to: ADIC

    From: **CAS**

A "high-level equivalence checker" (HLEC) is a tool that takes a software program (e.g. in C/C++) and a hardware design (e.g. in Verilog), and determines whether they are behaviourally equivalent -- for all possible inputs, and for an unlimited number of clock cycles. Such tools are very valuable to hardware designers.

We'd like to test whether the current crop of commercial HLECs (such as Siemens Questa SLEC, Cadence C2RTL, and Synopsys VC Formal) are actually reliable. So, this project will involve generating random software programs (possibly building on an existing tool called Csmith), compiling them to hardware using a high-level synthesis tool, and then feeding both to an HLEC-under-test, to see if it always gives the correct answer.

This project is suitable for a student who enjoys programming, and would relish the thrill of trying to find bugs in things!

1802904 **Williams,I. (with Constandinou,T.)**

Developing a wireless intracranial neuromonitoring device for drug-resistant epilepsy: impact of global vs. local referencing

Offered to: Control ADIC
AML FPN CSP

From: **CAS**

Epilepsy affects around 600,000 people in the UK, with roughly a third unable to control their seizures with medication and subsequently being diagnosed with Drug-Resistant Epilepsy (DRE). This condition results in increased life challenges leading to lower social outcomes and patients suffering disproportionately from traumatic injuries and psychiatric diseases.

Surgery could help many, typically by removing parts of the brain that are involved in initiating seizures. However, in order to identify these parts of the brain and assess whether they can be safely removed, it is often necessary to perform invasive brain activity recordings. This is currently achieved by inserting electrodes into the brain through tiny holes in the skull and connecting them to wires that run through the skull and skin to equipment that records brain signals. Unfortunately, this process has two major downsides:
- The patient has an open wound through to their brain for the monitoring period. The associated risks limit the monitoring period to around 3 weeks and limit the amount of data gathered (or not observing any seizures) which can prevent surgery.
- The patients are tethered to a hospital bed. This can be deeply distressing for patients, (who may be constrained even from trips to the bathroom) and is sometimes not tolerable (e.g. for small children).

A team at Imperial is developing electronics for a new implantable device that will be tiny, and wireless, aiming to massively improve the patient experience, whilst also improving the diagnostic yield of this type of monitoring. The team plan for this to be tested in a first-in-human pilot study in 2025.

This MSc thesis project will specifically assess the impact of global versus local referencing in intracranial SEEG electrode recordings by analysing previous recording data that have been annotated by epilepsy experts. This will be a multi-disciplinary project working with medical professionals, our engineering team, and industry partners. The bulk of the technical work will involve signal analysis/processing methods using tools such as Matlab, and Python. A successful project conclusion will contribute to our ongoing research -- with the possibility of publication.

This project will be co-supervised by Dr Ian Williams.

1803280 **Wright,S.W. (with Kiziroglou,M.)**

3D-Shaped Magnetic Transducers

Offered to: Control ADIC

From: **OSD**

Supervisors: Steven Wright, Michail Kiziroglou, Eric Yeatman
One of the main energy transduction methods for sensing, actuating and powering application is through magnetic fields. Typical mechanisms include magnetic induction, i.e. the induction of a voltage on a conductive loop or coil by the time variation of magnetic flux passing, and the Hall effect. The effectiveness of such devices depends on the available magnetic flux, which for small devices is limited, because it is proportional to the device area. A promising new method for improving magnetic functionalities in small devices is to channel the flux through soft magnetic materials shaped in funnelling geometries [1]. In this project, 3D-shaped magnetic transduces will be developed for use in energy harvesting, high-sensitivity sensing and actuating applications. Custom designs, developed by the student may be fabricated by an external industrial partner as well as by in-house 3D printing of polymer-based magnetic materials. The fabricated shapes will be integrated into functional prototype energy harvesters, sensors or magnetic actuators. The devices will be tested using custom evaluation setups developed for specific aircraft and infrastructure sensing applications, available in the department facilities. It is possible that the work will lead to a scientific publication.

[1] M. E. Kiziroglou, S. W. Wright, and E. M. Yeatman, "Power Supply based on Inductive Harvesting from Structural Currents," IEEE Internet of Things Journal, vol. 9, no. 10, pp. 7166 - 7177, 2021.

PID	Supervisor	Description
1803281	**Wright,S.W. (with Kiziroglou,M.)** **Efficiency and Aging of Piezoelectric/Magnetic Energy Harvesting MEMS.** **Offered to: Control ADIC** **From: OSD**	Supervisors: Steven Wright, Michail Kiziroglou, Eric Yeatman A major challenge in the development of Internet of Things (IoT) services is powering the distributed microsystems that are used for local sensing and actuation, as required for example in aircraft structural health monitoring. A technology that is underway for addressing this challenge is energy harvesting, i.e. the collection of local environmental energy for local use. In this project, in collaboration with Fraunhofer-ISIT, a hybrid piezoelectric and magnetic energy harvesting transducer concept will be investigated for collecting energy from power lines. The devices are based on a pioneering method for magnetic materials integration in MEMS devices [1] and are already available, provided by Fraunhofer ISIT for tests. The tests will be performed on an existing evaluation setup for inductive power line harvesting transducers. They will focus on evaluating the maximum possible power output, evaluating aging effects of the piezoelectric devices as well as on investigating new methods for device life-extension. Example of wear-reduction methods to be investigated include electrical and mechanical pre-biasing. This study is of broader interest as it addresses the key aspect of aging in piezoelectric transducers. [1] M. T. Bodduluri et al., "Fully Integrated High-Performance MEMS Energy Harvester for Mechanical and Contactless Magnetic Excitation in Resonance and at Low Frequencies," Micromachines, vol. 13, no. 6, p. 863, 2022.
1803355	**Yang,G. (with Parisini,T.)** **Cyber-attacks Detection Using Networks of Sensors** **Offered to: Control** **From: CAP**	This a research-oriented project deals with designing a distributed estimation scheme by which detecting cyber-attacks on large scale systems in which a networks of sensors is available. Several kind of cyber-attack have to be considered including replay attacks and covert attacks. The algorithms will have to be validated in Matlab/Simulink.
1803357	**Yang,G. (with Parisini,T.)** **Distributed State and Parameter Estimation for Large Scale Systems** **Offered to: Control** **From: CAP**	Large scale systems are crucial to daily life but susceptible to faults and attacks. Therefore, it is essential to monitor the system state using provided measurements. According to the communication graph, the measurements (nodes) are distributed over the entire system, and information is exchanged among all the nodes. This project aims to propose a distributed state and parameter estimation scheme to achieve state omniscience. Moreover, the student is encouraged to explore the feasibility of the proposed design, and its robustness against disturbance or fault (e.g. input noise, output noise, and communication link failure). A numerical model (preferably based on some application scenarios) is desired to be built to evaluate the performance of the proposed design.

PID	Supervisor	Description

1803282   **Yeatman,E.M. (with Kiziroglou,M.)**

Controlled Actuation of Micro-Robots by On-Board Visual Feedback.

    Offered to: Control ADIC AML

    From: **OSD**

Supervisors: Eric Yeatman, Michail Kiziroglou
One of the most exciting technologies emerging in recent years is the combination of rapid prototyping techniques such as 3D printing with microscale actuators and advanced control algorithms to develop precision microrobots. Applications include micro-surgery tools, tethered and un-tethered diagnosis instruments, implants and precision drug delivery and other biomedical devices. A MEMS-actuated, origami-inspired, 3D printed and flexure based delta robot has recently been developed [1]. Various functional features are currently being investigated including mechanical driving of endoscopy probes, micro-lenses and medical scanners and on-board visual feedback by the integration of a camera and micro-location tag systems. A use case of special interest is probe-based confocal laser endomicroscopy (pCLE), which is very promising for supporting informed decisions on removing cancerous tissue during surgery. In the proposed project, updated versions of this robot will be fabricated by 3D printing, and precise motion control will be investigated by applying visual feedback algorithms. The project involves a unique combination of state-of-art hardware prototyping activities and visual motion feedback software implementation.

[1] X. Chen, M. E. Kiziroglou, and E. M. Yeatman, "Linear displacement and force characterisation of a 3D-printed flexure-based delta actuator," Smart Materials and Structures, vol. 31, no. 10, p. 104001, 2022/09/05 2022.

1803317   **Yeatman,E.M. (with Shi,M.)**

Machine Learning and Wearable Devices for Eating Behaviour Monitoring

    Offered to: Control AML CSP

    From: **OSD**

Effective monitoring and recognition of eating behaviours are critical for nutrition research. Traditional methods, such as self-reporting food diary, suffer from significant accuracy limitations and provide inadequate insight into these behaviours. This study aims to establish an effective and robust wearable monitor for the recognition and classification of eating behaviours, using appropriate machine learning algorithms and wearable inertial measurement units. The potential student should demonstrate a strong interest in wearable devices and machine learning for time series data processing. Strong programming skill and a deep understanding of machine learning algorithms are expected. A solid background in embedded systems is preferred. This study will be a part of a comprehensive research project focusing on wearable devices for nutrition monitoring, offering students the opportunity to collaborate within a multidisciplinary team. In addition to guidance from the EEE supervisors, students will also receive direction of Dr M Cai from the Faculty of Medicine, who specialises in nutrition research. Depending on their contributions, students may have the chance to co-author research publications in the relevant field.

PID	Supervisor	Description

1803065   **Zhao,Aaron**

Mixed-precision Quantisation for Graph Neural Network Acceleration

    Offered to: Control ADIC
                AML FPN CSP

    From: **CAS**

In recent times, Graph Neural Networks (GNNs) have attracted great attention due to their classification performance on non-Euclidean data. FPGA acceleration proves particularly beneficial for GNNs given their irregular memory access patterns, resulting from the sparse structure of graphs. These unique compute requirements have been addressed by several FPGA and ASIC accelerators, such as HyGCN and GenGNN.

Additionally, quantisation has been widely explored as a method for reducing model complexity and computational latency in neural networks. Networks can benefit from low-precision numerical representations through Quantization-Aware Training (QAT), which aims to minimize accuracy loss in quantised models. Degree-Quant, proposed by Tailor et al., was one of the first suggested approaches in applying QAT to GNNs. After demonstrating high-degree nodes are the predominant source of quantisation error, the authors address this issue by stochastically applying a protection mask at each layer following the Bernoulli distribution. High-degree nodes are computed in a low-precision formats, significantly improving quantised model accuracies.

AGILE (Accelerated Graph Inference Logic Engine) is an FPGA accelerator enabling real-time GNN inference for large graphs, introduced during an FYP project last year (see [GitHub](https://github.com/pgimenes/agile)). One of its main contributions was a multi-precision node dataflow inspired by DegreeQuant. The accelerator extends the DegreeQuant paradigm, by enabling GNN inference at an arbitrary number of numerical representations, with arbitrary bit widths. As the first GNN accelerator with hardware support for multi-precision computation, significant improvements were observed in throughput and device resource usage. However, it is still an open challenge to support training software for multi-precision inference and demonstrate the accuracy benefits at the software level.

This project involves:

- Support the multi-precision GNN paradigm in software by writing PyTorch training code.
- Experiment with several multi-precision quantisation set-ups, optimising for inference latency and accuracy across a range of models and datasets.

Potential extension tasks:

- Integrate training software into MASE, the Circuits and Systems (CAS) group's in-house tool chain for ML exploration.
- Contribute to the design and verification of AGILE to fully support the proposed quantisation set-ups.

Proposed reading

Graph Neural Networks

- A Gentle Introduction to Graph Neural Networks https://distill.pub/2021/gnn-intro
- Semi-Supervised Classification with Graph Convolutional Networks https://arxiv.org/abs/1609.02907v4
- Graph Attention Networks https://arxiv.org/abs/1710.10903v3

Quantisation and DegreeQuant

- A White Paper on Neural Network Quantization https://arxiv.org/abs/2106.08295v1.
- Degree-Quant: Quantization-Aware Training for Graph Neural Networks https://arxiv.org/abs/2008.05000v3

Hardware Accelerators

- HyGCN: A GCN Accelerator with Hybrid Architecture. https://arxiv.org/abs/2001.02514v1
- GenGNN: A Generic FPGA Framework for Graph Neural Network Acceleration https://arxiv.org/abs/2201.08475v1
- AGILE: Accelerated Graph Inference Logic Engine

PID	Supervisor	Description
1803288	**Zhao,Aaron**	More detail available at https://jianyicheng-research.notion.site/Hardware-Acceleration-of-Swin-Transformers-4b0deca075924e42bc1365e3577729c8

Hardware Acceleration of Swin-Transformers

Background

Offered to: Control ADIC AML FPN CSP

Given the increasing volume and quality of genomics data, extracting new insights requires interpretable machine-learning models. Genomic Interpreter was proposed as a novel architecture for genomic assay prediction. This model outperforms the state-of-the-art models for genomic assay prediction tasks.

From: CAS

Inference of such models can be both memory and compute-intensive due to the vast number of parameters they encompass. To compute these Swin transformers with high performance and energy efficiency, there has been a trend of mapping these models onto hardware accelerators. Among various accelerator designs, dataflow architecture has shown promising performance due to its deep pipeline and its scalability in data parallelism.

Project Objectives

Prior work has exploited efficient sparse computation for Convolutional Neural Networks. This project aims to extend the framework to support 1D-Swin transformers.

1. Design and implement an memory rolling layer in hardware with parameterizable sizes
2. Implementing a 1D-swin transformer for dataflow hardware acceleration
3. Evaluate the hardware results and compare with the state-of-the-art accelerators

Potential Extensions (leading to publication)

1. Explore quantization in hardware and achieve high performance

Skill requirements

The project would best suit a student who:

1. knows to program in Verilog/SystemVerilog and Python
2. has an interest in cutting-edge digital electronics research.
3. Students who know to program in PyTorch are preferred.