Available Final Year Projects for all student streams ending Summer 2024.

Total number of projects available: 110

Project ID 1802878

Supervisor: Dr E.C. Kerrigan Room: 1108C Email: e.kerrigan@imperial.ac.uk

Streams: 1C1S1V

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

Description
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.

Project ID 1802898

Supervisor: Dr A. Spiers Room: 1014 Email: a.spiers@imperial.ac.uk

Streams: 1V

Title
Reinforcement learning of robotic in-hand-manipulation

Description
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.

Project ID 1802904

Supervisor: Dr T. Constandinou Room: 901 Email: t.constandinou@imperial.ac.uk

Streams: 1A1C1S1Q1V

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

Description
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.

Project ID 1802905

Supervisor: Dr T. Constandinou Room: 901 Email: t.constandinou@imperial.ac.uk

Streams: 1A1C1S1Q1V

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

Description
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.

Project ID 1802910

Supervisor: Dr T. Constandinou Room: 901 Email: t.constandinou@imperial.ac.uk

Streams: 1A1C1S1Q1V

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

Description
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.

Project ID 1802911

Supervisor: Dr T. Constandinou Room: 901 Email: t.constandinou@imperial.ac.uk

Streams: 1A1C1S1Q1V

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

Description
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.

Project ID 1802953

Supervisor: Dr O. Sydoruk Room: 703 Email: o.sydoruk@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Embedded system for near-field communication

Description
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.

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.

Project ID 1802955

Supervisor: Dr O. Sydoruk Room: 703 Email: o.sydoruk@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
RF frontend for near-field communication

Description
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.

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.

Project ID 1802963

Supervisor: Dr Sen Wang Room: 1009 Email: sen.wang@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Mapping Imperial College in a Day

Description
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)

Project ID 1802964

Supervisor: Dr Sen Wang Room: 1009 Email: sen.wang@imperial.ac.uk

Streams: 1V

Title
Neural LiDAR 3D Reconstruction

Description
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

Project ID 1802966

Supervisor: Dr Sen Wang Room: 1009 Email: sen.wang@imperial.ac.uk

Streams: 1V

Title
Near-field image reconstruction using Millimeter-wave SAR

Description
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/).

Project ID 1802969

Supervisor: Prof P. Georgiou Room: 902 Email: pantelakis.georgiou@imperial.ac.uk

Streams: 1S1V

Title
Advancing rapid diagnostics for infectious diseases using AI classifiers

Description
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.

Project ID 1802979

Supervisor: Dr C. Bouganis Room: 904 Email: christos-savvas.bouganis@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title

Mapping CNNs to FPGAs - Semantic segmentation

Description
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)

Project ID 1802983

Supervisor: Dr C. Bouganis Room: 904 Email: christos-savvas.bouganis@imperial.ac.uk

Streams: 1A1C1S1Q1V

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

Description
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.

Project ID 1802998

Supervisor: Prof P.L. Dragotti Room: 802 Email: p.dragotti@imperial.ac.uk

Streams: 1S1V

Title
Invertible Neural Networks and diffusion models

Description
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".

Project ID 1802999

Supervisor: Dr F. Teng Room: 1113 Email: f.teng@imperial.ac.uk

Streams: 1A1C1S1Q1V

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

Description
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 .

Project ID 1803006

Supervisor: Prof W.T. Pike Room: 604 Email: w.t.pike@imperial.ac.uk

Streams: 1A1C1S1Q1V

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

Description
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

Project ID 1803035

Supervisor: Dr C. Qin Room: 1009 Email: c.qin15@imperial.ac.uk

Streams: 1S1V

Title
Explainable machine learning for lung cancer nodule classification

Description
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.

Project ID 1803049

Supervisor: Dr S. Vlaski Room: 810 Email: s.vlaski@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Data Mining for Single-Cell RNA Sequencing in Liver Disease

Description
== 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

Project ID 1803065

Supervisor: Dr Aaron Zhao Room: 903 Email: a.zhao@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Mixed-precision Quantisation for Graph Neural Network Acceleration

Description
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

Project ID 1803077

Supervisor: Dr W. Dai Room: 811 Email: wei.dai1@imperial.ac.uk

Streams: 1C1S1V

Title
Array 4D Sensing: Testbed and Demos for New Capabilities

Description
Array 4D Sensing: Testbed and Demos for New Capabilities

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

We consider a scenario with the new capability to not only estimate the location and motion of objects in an environment, 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 Dimensiona Data Processing

Meeting Time: To be announced

Students who are genuinely interested, please submit a CV in our meeting

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Project ID 1803079

Supervisor: Dr W. Dai Room: 811 Email: wei.dai1@imperial.ac.uk

Streams: 1C1S1V

Title
Interpretable Learning via Proximal Optimization

Description
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:
14 Nov (Tuesday) 12:00-13:00 Room 503
15 Nov (Wednesday) 12:00-12:45 Room 503

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

Project ID 1803080

Supervisor: Dr W. Dai Room: 811 Email: wei.dai1@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Automatic Segmentation for Ovarian Cancer via Deep Learning

Description
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
14 Nov (Tuesday) 12:00-13:00 Room 503
15 Nov (Wednesday) 12:00-12:45 Room 503

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

Project ID 1803081

Supervisor: Dr W. Dai Room: 811 Email: wei.dai1@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Deep Reinforcement Learning for Breast Cancer Personalized Treatments

Description
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:
14 Nov (Tuesday) 12:00-13:00 Room 503
15 Nov (Wednesday) 12:00-12:45 Room 503

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

Project ID 1803091

Supervisor: Prof S. Lucyszyn Room: 602 Email: s.lucyszyn@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Extremely Low Frequency (ELF) Communications with Machine Learning

Description
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!

Project ID 1803097

Supervisor: Dr J.A. Barria Room: 1012 Email: j.barria@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Data Stream evolution analysis using Multiresolution Wavelet Transform

Description
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 streem 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.

Project ID 1803100

Supervisor: Dr J.A. Barria Room: 1012 Email: j.barria@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Time series anomaly detection using contrastive learning

Description
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.

Project ID 1803103

Supervisor: Dr J.A. Barria Room: 1012 Email: j.barria@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Early warning algorithms using Wavelet probabilistic Neural Networks

Description
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.

Project ID 1803107

Supervisor: Dr J.A. Barria Room: 1012 Email: j.barria@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Traffic anomaly analysis and congestion precursor detection

Description
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)

Project ID 1803109

Supervisor: Dr S.M. Moosavi Dezfooli Room: 1003 Email: seyed.moosavi@imperial.ac.uk

Streams: 1V

Title
What do LLMs know about sequence prediction?

Description
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.

Project ID 1803110

Supervisor: Dr S.M. Moosavi Dezfooli Room: 1003 Email: seyed.moosavi@imperial.ac.uk

Streams: 1V

Title
Robustness to distribution shift

Description
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.

Project ID 1803113

Supervisor: Dr S.M. Moosavi Dezfooli Room: 1003 Email: seyed.moosavi@imperial.ac.uk

Streams: 1V

Title
How (Un)robust deep networks can be?

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

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?

Project ID 1803114

Supervisor: Dr S.M. Moosavi Dezfooli Room: 1003 Email: seyed.moosavi@imperial.ac.uk

Streams: 1V

Title
Understanding the geometry of visual transformers

Description
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.

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.

Project ID 1803150

Supervisor: Dr Sen Wang Room: 1009 Email: sen.wang@imperial.ac.uk

Streams: 1V

Title
Underwater Object Detection and Segmentation

Description
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.

Project ID 1803151

Supervisor: Dr Sen Wang Room: 1009 Email: sen.wang@imperial.ac.uk

Streams: 1V

Title
Sonar Nerual 3D Reconstruction

Description
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

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Project ID 1803174

Supervisor: Dr C. Bouganis Room: 904 Email: christos-savvas.bouganis@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Revisiting the Exit-Policy of Dynamic Deep Learning Models

Description
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.

Project ID 1803199

Supervisor: Prof B. Clerckx Room: 816 Email: b.clerckx@imperial.ac.uk

Streams: 1S1V

Title
Computer Vision and Sensing-Aided 6G Wireless Communications

Description
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.

Project ID 1803205

Supervisor: Prof B. Clerckx Room: 816 Email: b.clerckx@imperial.ac.uk

Streams: 1S1V

Title
Machine Learning to Optimize 6G Wireless Communications

Description
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.

Project ID 1803217

Supervisor: Dr S. Sanei Room: unknown Email: s.sanei@imperial.ac.uk

Streams: 1A1C1S1Q1V

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

Description
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.

Project ID 1803234

Supervisor: Dr Sen Wang Room: 1009 Email: sen.wang@imperial.ac.uk

Streams: 1V

Title
Vision-Enabled Underwater Robots for Autonomous Operations

Description
This project aims to advance various essential components in the development of an autonomous underwater robot using the BlueROV2 platform (). 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) ().

Project ID 1803240

Supervisor: Prof P.L. Dragotti Room: 802 Email: p.dragotti@imperial.ac.uk

Streams: 1A1S1V

Title
Implicit Neural Representation for signal reconstruction

Description
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.

Project ID 1803241

Supervisor: Dr T. Clarke Room: 615 Email: t.clarke@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
A Novel Digital Simulation Algorithm for Issie

Description
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/

Project ID 1803243

Supervisor: Dr C. Ling Room: 815 Email: c.ling@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
AI image generation based on improved diffusion models

Description
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.

Project ID 1803244

Supervisor: Dr C. Ling Room: 815 Email: c.ling@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Post-quantum signatures with applications to blockchains

Description
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)

Project ID 1803245

Supervisor: Dr C. Ling Room: 815 Email: c.ling@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Post-Quantum Key Exchange over the Internet

Description
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)

Project ID 1803246

Supervisor: Dr C. Ling Room: 815 Email: c.ling@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title

Coding Theory for Post-Quantum Cryptography

Description
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)

Project ID 1803256

Supervisor: Prof G. Li Room: unknown Email: geoffrey.li@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
MSc Project: Bayesian Optimisation in UAV Management and Path Planning

Description
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.

Project ID 1803257

Supervisor: Prof G. Li Room: unknown Email: geoffrey.li@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Elastic Resource Allocation with Deep Reinforcement Learning

Description
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.

Project ID 1803258

Supervisor: Prof G. Li Room: unknown Email: geoffrey.li@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Neuromorphic Semantic Communication for Future Wireless Systems

Description
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.

Project ID 1803259

Supervisor: Prof G. Li Room: unknown Email: geoffrey.li@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Deep learning-enabled ISAC System Design

Description
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.

Project ID 1803260

Supervisor: Dr C. Bouganis Room: 904 Email: christos-savvas.bouganis@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Build a UAV interfaced with an embedded system

Description
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.

Project ID 1803273

Supervisor: Dr D. Gunduz Room: 1016 Email: d.gunduz@imperial.ac.uk

Streams: 1V

Title
Neural Network based Secure Image/Video Transmission

Description
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.

Project ID 1803275

Supervisor: Dr A. Spiers Room: 1014 Email: a.spiers@imperial.ac.uk

Streams: 1V

Title
A self-organising multi-robot system

Description
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.

Project ID 1803277

Supervisor: Dr A. Spiers Room: 1014 Email: a.spiers@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Towards Tactile Sensor Agnostic Feature Extraction with a Robotic Arm

Description
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.

Project ID 1803282

Supervisor: Dr Kiziroglou Room: unknown Email: mkizirog@imperial.ac.uk

Streams: 1A1C1V

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

Description
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.

Project ID 1803286

Supervisor: Prof S. Lucyszyn Room: 602 Email: s.lucyszyn@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Ultra-sensitive microwave receiver

Description
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.

Project ID 1803287

Supervisor: Prof S. Lucyszyn Room: 602 Email: s.lucyszyn@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Noise radar simulation

Description
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.

Project ID 1803288

Supervisor: Dr Aaron Zhao Room: 903 Email: a.zhao@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Hardware Acceleration of Swin-Transformers

Description
More detail available at https://jianyicheng-research.notion.site/Hardware-Acceleration-of-Swin-Transformers-4b0deca075924e42bc1365e3577729c8

Background

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.

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.

Project ID 1803289

Supervisor: Dr T. Constandinou Room: 901 Email: t.constandinou@imperial.ac.uk

Streams: 1A1C1S1Q1V

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

Description
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

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Project ID 1803290

Supervisor: Dr O. Sydoruk Room: 703 Email: o.sydoruk@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
RFID antennas for centrifuges

Description
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.

Project ID 1803293

Supervisor: Dr A. Bhandari Room: 802 Email: a.bhandari@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Audio Source Separation from Modulo Samples

Description
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

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Project ID 1803294

Supervisor: Dr A. Bhandari Room: 802 Email: a.bhandari@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Inverse Problems with Folding Non-linearities.

Description
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.

Project ID 1803295

Supervisor: Dr A. Bhandari Room: 802 Email: a.bhandari@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Hardware Testbed for Unlimited Sampling Architecture

Description
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.

Project ID 1803296

Supervisor: Dr A. Bhandari Room: 802 Email: a.bhandari@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
High Dynamic Range Thermal Imaging and Reconstruction

Description
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.

Project ID 1803297

Supervisor: Dr A. Bhandari Room: 802 Email: a.bhandari@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Photoplethysmogram Modelling and Recovery via Unlimited Sampling

Description
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.

Project ID 1803298

Supervisor: Dr A. Bhandari Room: 802 Email: a.bhandari@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
High Dynamic Range Lightfield Imaging in Fourier Domain

Description
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.

Project ID 1803299

Supervisor: Dr A. Bhandari Room: 802 Email: a.bhandari@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Acoustic and Audio Logging using a New Digital Sensing Principle

Description
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.

Project ID 1803300

Supervisor: Dr A. Bhandari Room: 802 Email: a.bhandari@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title

Image Feature Extraction in Computer Vision with Folded Images

Description
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.

Project ID 1803301

Supervisor: Dr A. Bhandari Room: 802 Email: a.bhandari@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Coded Exposure Time-of-Flight 3D Imaging

Description
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.

Project ID 1803302

Supervisor: Dr Y. Gu Room: 1105 Email: yunjie.gu@imperial.ac.uk

Streams: 1Q1V

Title
Rapid control prototyping for stability study of renewable inverters

Description
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

Project ID 1803309

Supervisor: Dr A. Junyent-Ferre Room: 1103 Email: adria.junyent-ferre@imperial.ac.uk

Streams: 1A1C1S1Q1V

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

Description
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.

Project ID 1803310

Supervisor: Dr T. Constandinou Room: 901 Email: t.constandinou@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Unobtrusive sleep apnea diagnosis using ultra-wideband radar technology

Description

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.

Project ID 1803311

Supervisor: Dr A. Abu Ebayyeh Room: unknown Email: a.abu-ebayyeh@imperial.ac.uk

Streams: 1V

Title
Machine Learning for Industrial Applications

Description
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/

Project ID 1803312

Supervisor: Dr D.F.M. Goodman Room: 1001 Email: d.goodman@imperial.ac.uk

Streams: 1V

Title
Learning to vote when it matters

Description
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/

Project ID 1803313

Supervisor: Dr D.F.M. Goodman Room: 1001 Email: d.goodman@imperial.ac.uk

Streams: 1V

Title
Theseus-bot

Description
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.

Project ID 1803314

Supervisor: Dr D.F.M. Goodman Room: 1001 Email: d.goodman@imperial.ac.uk

Streams: 1V

Title
Neural reuse and modularity in resource constrained task families

Description
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

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Project ID 1803315

Supervisor: Dr D.F.M. Goodman Room: 1001 Email: d.goodman@imperial.ac.uk

Streams: 1V

Title
Brain equivalent of momentum learning rules

Description
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/fvzzwHKlMzk
- 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

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Project ID 1803317

Supervisor: Prof E.M. Yeatman Room: 609 Email: e.yeatman@imperial.ac.uk

Streams: 1C1S1V

Title
Machine Learning and Wearable Devices for Eating Behaviour Monitoring

Description
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.

Project ID 1803320

Supervisor: Dr E. Spyrou Room: 1102 Email: evangelia.spyrou@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Modeling approaches for long duration storage

Description
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.

Project ID 1803321

Supervisor: Dr C. Papavassiliou Room: 915 Email: c.papavas@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Amplifiers using Memristors

Description
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.

Project ID 1803322

Supervisor: Dr C. Papavassiliou Room: 915 Email: c.papavas@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title

Simulated annealing using True Random Number generators

Description
Our group has developed a True Random Number Generator which uses a memristor as a random seed.
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.

Project ID 1803327

Supervisor: Prof Y.K. Demiris Room: 1014 Email: y.demiris@imperial.ac.uk

Streams: 1V

Title
Social Navigation for an Intelligent Robot Wheelchair

Description
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

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Project ID 1803328

Supervisor: Dr T. Constandinou Room: 901 Email: t.constandinou@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Implantable "smartvessel" for monitoring and prevention of thrombosis

Description
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.

Project ID 1803329

Supervisor: Prof Y.K. Demiris Room: 1014 Email: y.demiris@imperial.ac.uk

Streams: 1V

Title
Robot affordances determination using Large Language Models

Description

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.

Project ID 1803330

Supervisor: Dr S. Parbhoo Room: 1017 Email: s.parbhoo@imperial.ac.uk

Streams: 1V

Title
Causally-informed Data Augmentation for OOD generalization

Description
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.

Project ID 1803331

Supervisor: Dr S. Parbhoo Room: 1017 Email: s.parbhoo@imperial.ac.uk

Streams: 1V

Title
Counterfactually Augmented Off Policy Evaluation

Description
Counterfactually Augmented OPE

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

Project ID 1803332

Supervisor: Dr T. Constandinou Room: 901 Email: t.constandinou@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Development of a smart under-mattress mat for sleep monitoring

Description
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.

Project ID 1803333

Supervisor: Dr S. Parbhoo Room: 1017 Email: s.parbhoo@imperial.ac.uk

Streams: 1V

Title
Shaping Rewards for Counterfactually Augmented Off Policy Evaluation

Description
Shaping Rewards for Counterfactually Augmented Off Policy Evaluation

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

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Project ID 1803334

Supervisor: Dr S. Parbhoo Room: 1017 Email: s.parbhoo@imperial.ac.uk

Streams: 1V

Title
Monte Carlo Tree Search for Experimental Design

Description
Monte Carlo Tree Search for Experimental Design

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).

Project ID 1803335

Supervisor: Dr S. Parbhoo Room: 1017 Email: s.parbhoo@imperial.ac.uk

Streams: 1V

Title
Can we use LLMs to generate reasonable counterfactuals?

Description
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.

Project ID 1803336

Supervisor: Dr S. Parbhoo Room: 1017 Email: s.parbhoo@imperial.ac.uk

Streams: 1V

Title
Understanding and Extrapolating from Latent Spaces

Description
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)

Project ID 1803339

Supervisor: Dr C. Qin Room: 1009 Email: c.qin15@imperial.ac.uk

Streams: 1S1V

Title
Implicit Function Learning on fMRI Motion Correction

Description
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.

Project ID 1803341

Supervisor: Prof W.T. Pike Room: 604 Email: w.t.pike@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Unveiling the interior of Mars using signal analysis

Description
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.

Project ID 1803342

Supervisor: Prof W.T. Pike Room: 604 Email: w.t.pike@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Denoising the seismic record of Mars

Description
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.

Project ID 1803343

Supervisor: Dr C. Qin Room: 1009 Email: c.qin15@imperial.ac.uk

Streams: 1S1V

Title
Machine Learning in Quality Control for Diffusion Tensor Cardiac MRI

Description
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.

Project ID 1803344

Supervisor: Dr C. Qin Room: 1009 Email: c.qin15@imperial.ac.uk

Streams: 1S1V

Title
Integrating Deep Learning and Radiomics for Medical Image Analysis

Description
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.

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] 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.

Project ID 1803347

Supervisor: Prof A. Manikas Room: 801 Email: a.manikas@imperial.ac.uk

Streams: 1A1C1S1Q1V

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

Description
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.

Project ID 1803348

Supervisor: Prof A. Manikas Room: 801 Email: a.manikas@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Cognitive MIMO Radar

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

Project ID 1803349

Supervisor: Prof A. Manikas Room: 801 Email: a.manikas@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Experimental MIMO radar for localisation and tracking of multi-UAVs

Description
see Professor Manikas

Project ID 1803350

Supervisor: Dr T. Constandinou Room: 901 Email: t.constandinou@imperial.ac.uk

Streams: 1A1C1S1Q1V

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

Description
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.

Project ID 1803358

Supervisor: Prof J.V. Pitt Room: 1013 Email: j.pitt@imperial.ac.uk

Streams: 1V

Title
Stability, Scalability and Sustainability of Social Influence

Description
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.

Project ID 1803359

Supervisor: Prof J.V. Pitt Room: 1013 Email: j.pitt@imperial.ac.uk

Streams: 1V

Title
Cooperative Reinforcement Learning

Description
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 ow 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. As well as implementing the ML algorithms that allow the system to learn from (to begin with) no data and incremental data, the deeper question is in the convergence, or otherwise, or interacting and cooperating human and computational intelligence: does the used end up ignoring or always deferring to the system's recommendations? does the system learn faster than the human? does the user learn anything about cooperative survival, and/or a diverse population having to cooperate to

achieve collective collective goals? Is the human-AI system itself stable or unstable? To what extent does the user under- or over-trust the system's recommendations?

The project is 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.

Project ID 1803360

Supervisor: Prof J.V. Pitt Room: 1013 Email: j.pitt@imperial.ac.uk

Streams: 1V

Title
Machine Learning Plug-ins for PlatformOcean Application(s)

Description
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.

Project ID 1803361

Supervisor: Prof J.V. Pitt Room: 1013 Email: j.pitt@imperial.ac.uk

Streams: 1V

Title
Self-Organised Social Arrangements for Mega-Bike

Description
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.

Project ID 1803362

Supervisor: Dr S. Vlaski Room: 810 Email: s.vlaski@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
SDE theory for understanding stochastic gradient algorithms

Description
== 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

Project ID 1803363

Supervisor: Dr S. Vlaski Room: 810 Email: s.vlaski@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Primal-Dual Techniques for Distributed Multitask Learning

Description
== 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

Project ID 1803364

Supervisor: Dr S. Vlaski Room: 810 Email: s.vlaski@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Combination Policies for Decentralized Deep Learning

Description
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

Project ID 1803365

Supervisor: Dr C. Bouganis Room: 904 Email: christos-savvas.bouganis@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
What' s that sound

Description
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.

Project ID 1803366

Supervisor: Prof M. O'Malley Room: 1114 Email: m.omalley@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Planning for extreme weather events on power system distribution grids

Description
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.

Project ID 1803367

Supervisor: Prof M. O'Malley Room: 1114 Email: m.omalley@imperial.ac.uk

Streams: 1A1C1S1Q1V

Title
Data-driven Nodal Inertia Estimation

Description
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.
