UNIVERSITY OF Southampton

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THINK DIFFERENTLY

UKRI MINDS CENTRE FOR DOCTORAL TRAINING
NEWSLETTER

UK Research and Innovation

WELCOME FROM THE DIRECTOR

A very warm welcome to this first newsletter from the UKRI MINDS Centre for Doctoral Training. We aim to use this newsletter to give you a better understanding of our research training programme, to highlight some of the exceptional work being undertaken by our PhD students, and to outline how you can become involved as sponsor, collaborator, supervisor, or future student.

The MINDS CDT is one of 16 centres of excellence for research training in Artificial Intelligence funded by UK Research and Innovation, the University of Southampton, and a wide range of industry partners. We are unique as a CDT in our focus on research that lies at the interface between algorithmic AI techniques and hardware to enable AI. This area is critically important for future smart infrastructure and industries where AI will add value to performance and productivity. Our research is centred around four themes:

- → Nanoelectronic Technologies for AI – we are investigating novel hardware technologies to enable AI techniques to operate at a fraction of the power required in current devices
- → Embedded AI – we are investigating techniques to embed AI and machine-learning models in low power devices and to manage their security
- → Task-Optimised Devices and Systems – we are exploring how to optimise the interface between tasks performed in hardware and those in software
- → Agent-Based Adaptive Systems – we are developing novel techniques to decentralise AI such that infrastructures and systems can operate at scale, optimise performance, and work with people effectively

A big thank you to all our partners for their support across the CDT: ARM, Audio Analytic, AWE, Barton Peveril 6th Form College, DSTL, Huawei, IBM, Intel, InfoSec Global, IP Group, Nvidia, NXP Semiconductors, Roke Manor Research Ltd., Royal Bank of Canada, SailAI, Senseye, Shell, Tata Consultancy Services and Thales.

Our students are supported by supervisory teams drawn from across traditional disciplinary boundaries. We use responsible research and innovation practices throughout the programme. In this way we anticipate and reflect on the potential impacts of research projects, working with a range of stakeholders to inform future developments. Read on to find out more about this unique research training centre and the students at the heart of our programme.

Tim Norman
UKRI MINDS CDT Director

Find out more:
mindscdt.southampton.ac.uk

MEET THE TEAM

Prof Tim Norman

Having read engineering, Tim moved disciplines to computer science graduating with a PhD in AI from UCL in 1997. He joined ECS in 2016 because of its strong collaborative and interdisciplinary research culture. His expertise lies in multi-agent systems, safe AI, human-AI teaming and reasoning under uncertainty. He is Director of the MINDS CDT, working with colleagues to deliver on our vision, building the CDT community and helping develop exceptional young researchers.

Prof Themis Prodromakis

Themis is an internationally recognised leader in emerging memory technologies and AI hardware. He is Director of the Centre for Electronics Frontiers at Southampton and guides a large interdisciplinary group of engineers. As Co-Director of MINDS CDT, Themis contributes to shaping strategy, impact acceleration and providing experience in nanoelectronic technologies for AI.

Dr Christine Evers

Christine is a Lecturer in Computer Science. Within the MINDS CDT, Christine is the Cohort & Training Programme Lead and Theme Lead for Embedded Artificial Intelligence (EAI). Her research – focusing on Bayesian inference for machine listening, with a particular interest in robot audition and human-robot interaction – is located at the intersection of robotics, machine learning, acoustics, and statistical signal processing.

Dr Reena Pau

Reena is ECS Outreach Director, mentoring students to deliver outreach activities in schools and colleges, and building their skills to inspire the next generation of AI experts while also becoming more confident in science communication. Reena works with the CDT to ensure creation and delivery of the right messages to support diversity and equality in all aspects of CDT work.

Prof Rob Maunder

Rob is a Professor in the Next Generation Wireless research group at the University of Southampton. He is also the founder and CTO of AccelerComm. Rob leads the Task Optimised Devices and Systems theme in the MINDS CDT and is also the Impact Co-ordinator.

Dr Alex Serb

Alex is an electronics researcher specialising in hardware for artificial intelligence using emerging memory technologies. His work covers the entire spectrum from algorithms to physical microchip implementations. Examples include artificial neural networks, symbolic processors and bio-interfacing circuitry. He is Theme Lead for Nanoelectronic Technologies for AI (NTAI).

Dr Bahar Rastegari

Bahar is based in the Agents, Interaction, and Complexity (AIC) research group; she joined ECS in 2018, having lived in four cities and three continents before arriving in Southampton. Her research interests include computational social choice and algorithmic mechanism design. She is Recruitment Coordinator for MINDS CDT, as well as Theme Leader for Agent-Based Adaptive Systems.

Dr Dimitra Georgiadou

Dimitra leads the Organic and Flexible Nanoelectronics Research Theme in the Centre for Electronics Frontiers and is Deputy Impact Champion for the CDT. Her research focuses on using solution-processed materials to develop flexible electronic devices for application in smart imaging, computer vision and the Internet of Things.

Ms Emma Miles

Emma is the MINDS CDT Programme Manager. She manages the delivery of business-critical services in line with the CDT's strategic objectives and priorities. Emma has over a decade of experience in student and academic administration, having worked at the University of Southampton since 2010.

OUR RESEARCH TRAINING PROGRAMME

The MINDS CDT offers a four-year integrated PhD (iPhD) programme, consisting of a one-year taught component, followed by three years of research. During the first two semesters, students are enrolled in a selection of taught modules. They select four optional modules from across the MSc programmes within the School of Electronics and Computer Science (ECS). These are tailored to the background and intended research project of each individual student. Optional modules are complemented by four core modules that provide students with a thorough understanding of the key challenges in research at the intersection of AI and Electronics, while ensuring responsible innovation and impact, and providing the technical skills for interdisciplinary teamwork.

During the taught component of the iPhD programme, we connect students with potential supervisors and industry partners to develop their own research projects and establish supervisory teams. The first year is concluded by a 'feasibility study' of the proposed research during the summer months with their PhD supervisors.

Throughout the first year as well as the research phase of the iPhD programme, students benefit from a wide range of activities to ensure cohort cohesion, promote cross-disciplinary collaboration, and facilitate engagement with stakeholders and the public. The annual 'innovation camp' is led by our students, integrating activities such as hackathons, entrepreneurship training from SetSquared and outreach development with a good dose of social activities. To further support ideas for commercialisation teams can pitch for awards of £10k to enable them to access the impact services offered by Future Worlds.

Our students benefit from wider research networks including the UKRI Trustworthy Autonomous Systems (TAS) Hub (tas.ac.uk), which is a collaboration of researchers and industry partners working on world-leading best practices for trustworthy and trusted 'socially beneficial' autonomous systems. The TAS Doctoral Training Network offers a range of opportunities to get involved with TAS research projects and to network with students from across the UK.

PROJECT TITLES

Cohort 1

Jack Dymond
Achieving progressive intelligence for low power systems

Thomas Kelly
Decentralised AI for situational awareness

Sulaiman Sadiq
Efficient DNNs for inference at the edge

Christopher Subia-Waud
Relative movement quantisation for lossless network compression

Hsuan-Yang Wang
Binaural machine listening in the cocktail party scenario

Jack Williamson
AI-assisted predistortion for wireless communications

Cohort 2

Callum Aitchison
Secure computing systems based on stochasticity of RRAM

Jonathan Barnes-Nunn
Nature-inspired communication in multi-agent reinforcement learning

Ahmet Cirakoglu
Hardware accelerators for space applications

Matthew Durrant
Reducing carbon emissions in shipping: Tax incentives, optimisation and prediction

Madeleine Dwyer
Machine learning for on-chip detection of security attacks

Harry Horler
Machine learning aided adaptive hierarchical modulation based cooperative non-orthogonal multiple access

Charles Hutchins
Game theory and multi-agent systems to detect and respond to cyber intrusions in IoT environments

Ilias Kazantzidis
Safe reinforcement learning

Olaf Lipinski
Emergent communication in multi-agent systems

Alexander Lowe
Hardware for symbolic processing AI

Matthew Pugh
Tribological fault prediction using digital twin techniques

Caterina Sbandati
Hardware accelerators for neuromorphic sensing

Kian Spencer
Graph neural networks for robotic sensing

Elliot Stein
Convolutional neural networks for auditory attention in robots

Mark Towers
A neuro-symbolic approach to explainable reinforcement learning

Alexander-Hanyu Wang
AI hardware accelerators

Jing Zhou
Machine learning & control for active robot audition

HARDWARE ACCELERATORS FOR NEUROMORPHIC SENSING

Caterina Sbandati

Supervisory Team:
Professor Themis Prodromakis, Dr Alexander Serb, Professor Koushik Maharatna

The main criticalities of implantable prosthetic systems lie in the excessive data-rates, strained power budgets and stringent biocompatibility requirements imposed on their microelectrode biointerfaces. Moreover, the current paradigm of "record and immediately send the data off-patient", is not conducive to the development of smart, fast, secure and functionally independent bioimplants. Thus, the bioprostheses of the future require the development of more energy-efficient computation paradigms capable of handling neural data in situ. Recent developments in emerging nanoelectronic technologies have made such designs possible for the first time.

Our project aims to exploit the intrinsic analogue programmability of emerging, nanoscale memory-resistive devices, also known as "memristors" to perform ultra-low power spike-sorting on-chip and then feed this data to artificial neural networks using the very same devices as ultra-compact artificial synapses. This is underpinned by the ability of memristors to act as both computation and storage elements: Memristors undergo non-volatile resistive state transitions as a function of the integral of the input voltage, thus behaving as thresholded input integrators. This leads to a whole array of possible functions such as memristors acting as: (a) spike detectors or simpler "wake up circuits" letting the system know when interesting neural activity is occurring and starting up high-precision, but expensive circuitry; (b) neural activity encoders and template matchers, where the input activity feature of interest is the weighted integral; and (c) artificial synapses performing fast, in-memory computation whilst remaining capable of implementing plasticity rules and remaining non-volatile throughout.

The aim of this PhD project is to develop and demonstrate an ultra-low power sensing-processing module that receives spiking inputs sourced by both electrophysiological inputs and neuromorphic sensors (for example: silicon retinas, e-nose, etc.) and can process and refine them down to a very information-rich, but low bandwidth signal. This is expected to require a small-scale neural network. This work is a key stepping-stone towards the smart, chronically implanted bioimplants of the future which will provide countless patients around the world with restorative functionality against a host of diseases, traumatic lesions or even genetic defects.

EFFICIENT DNNS FOR INFERENCE AT THE EDGE

Sulaiman Sadiq

UoS Supervisors:
Professor Geoff Merrett, Professor Jonathon Hare

ARM Supervisors:
Dr Partha Maji, Simon Craske

With approximately 13.8 billion connected devices, we are currently living in a world surrounded by Deep Learning AI models. These models power a range of applications on low-power edge devices such as smart wearables and appliances. Typically, these devices have extremely low processing capabilities making it difficult to execute AI models locally, with collected data often sent to the cloud for processing. This restricts the use cases of AI due to associated reasons of security, privacy and latency. On the other hand, manual design of efficient Deep Neural Networks (DNNs) for on-device execution is an involved and time-consuming process which requires expert human knowledge to improve efficiency across different metrics such as latency, energy consumption and network size. In our work, carried out in collaboration with ARM Research and the International Centre for Spatial Computational Learning, we have been working on developing algorithms to automate the design of DNNs that deliver optimal performance on constrained edge devices.

We developed DEff-ARTS, a differentiable efficient architecture search algorithm for automatically deriving network architectures for image classification on resource-constrained edge devices. By framing the search as a multi-objective optimisation problem, we simultaneously minimised the classification loss and the computational complexity of performing inference on the target device. Our formulation allowed for easy trading-off between the sub-objectives depending on user requirements.

Experimental results on image classification showed that DEff-ARTS was able to derive highly competitive network architectures with up to 7x reduction in required compute cycles and 2x smaller model sizes compared to other contemporary approaches. Currently, we are working on Dynamic DNNs where a run-time configurable super-network contains multiple efficient sub-networks of varying complexity that can be switched between as required. With multiple models we can further reduce memory usage to enable concurrent running of larger models or multiple workloads.

DECENTRALISED AI FOR SITUATIONAL AWARENESS

Tom Kelly

Supervisory Team:
Professor Sarvapali (Gopal) Ramchurn, Dr Danesh Tarapore and Dr Klaus-Peter Zauner

DSTL Supervisor:
Dr Oli Lanning

Robotic swarms are complex systems made up of a large number – sometimes hundreds or thousands – of relatively simple robots. Drawing on local communication between individual members of the swarm to spread information about their state and the environment, the swarms make decisions and accomplish tasks such as exploration and mapping. But these communications can be hindered by a variety of factors; for example in a contested environment, adversaries may be jamming communication within an area and the swarm may wish to avoid communication in certain areas to avoid the chance of being detected. When communications break down between members of a swarm, it can become difficult to maintain accurate and up-to-date information about the state of the swarm and the environment in which it is operating.

This problem is highlighted when humans are actively involved in a situation where they may be acting as operators, supervisors or team-mates of the swarm. Here it is vital that the swarm can effectively distil and disseminate to the human the vast amounts of information that it is collecting, in order to provide situational awareness. This project aims to develop techniques that can aid a swarm system's ability to maintain and improve a human's situational awareness, even in environments where communications may be limited. These approaches will focus on maintaining information of the current and projected future states of the swarm and the environment as well as the communication landscape for the swarm. Swarm systems will use these approaches to make collective decisions about the swarm itself and the environment in which it is operating, as well as providing human team-mates with reliable and up-to-date projections of the swarm.

AI-ASSISTED PREDISTORTION FOR WIRELESS COMMUNICATIONS

Jack Williamson

Supervisory Team:
Professor Rob Maunder, Professor Michael Ng, Professor Tim Norman

With the growing use of mobile communications, there is a greater requirement for efficiency to control the operating costs of networks. One area which can benefit from an increase in efficiency is the power amplifier. This component of a transmitter increases the power-level of the signal to increase the distance that the signal can travel. However, there is an issue with the performance of current amplifier designs – they are a compromise between three design criteria: efficiency, linearity, and cost. This creates a situation where in order to design an amplifier that is very linear, it is generally costly to produce and inefficient to run. Digital predistortion (DPD) provides a solution to this problem by allowing the amplifier to have nonlinearity in its response, while modifying instead the input signal in a way that accounts for the flaws in the amplifier's behaviour, so that the predistorter combined with the amplifier appears to be linear.

The aim of my project is to use artificial intelligence to provide a solution for DPD in wireless communication systems, as this offers the potential for higher levels of performance while also reducing the complexity compared to traditional methods. These traditional methods relied either upon fitting a function to the properties of the amplifier, which can quickly become mathematically complex, or using a look-up table of values to correct for amplifier distortion, which can require a large amount of memory to perform effectively. Machine learning, and specifically recurrent neural networks, can provide a new way of addressing this problem with amplifiers, as they can not only learn a nonlinear function, but also learn long-term patterns in data, which can be used to address issues with hysteresis in amplifiers.

In the later stages of the project, the goal is to develop a bespoke hardware-based solution for DPD, firstly using programmable logic (FPGA), and potentially an ASIC solution. This will give the best possible performance of the predistorter in terms of latency and efficiency.

WORK WITH US!

Industry partners on the UKRI MINDS CDT can take advantage of a wide range of active opportunities, while bringing their own unique perspective to benefit our students and future research collaborations. We welcome support and involvement from partners for our enhanced training activities and for our outreach events; opportunities are also available for co-funding studentships, with great benefits for students, supervisors, and partners. To find out more and discuss any of these opportunities further, please contact mindscdt@soton.ac.uk

	Costs	Benefits
Invited Speakers We organise invited speakers for MIND6001 & MIND6002 (October-December) to speak on topics varying from pitching ideas to senior executives to research challenges in electronics and AI. Our seminar series provides regular slots for industry speakers.	Preparation and delivery time	Students gain valuable insights from industry Partner benefits from early engagement with our students
Industry Challenge Projects MIND6003 runs from February to May during which teams of students work together to solve a problem set by an industry partner Teams produce a proof-of-concept demonstration, conduct an impact assessment, produce a flyer and a 3min video; see our YouTube playlist: https://bit.ly/352MNyd	Weekly meetings with the team of students and academic supervisor	Students gain experience working with industry partners Partner gains new insights to a research challenge
Outreach MINDS CDT students are expected to engage in outreach activities each year, and we aim to collaborate and share this opportunity with industry partners	Staff time to prepare and deliver outreach	Students engage with outreach Partner contributes to corporate responsibility agenda
Internships Students spend three months during the research phase of their PhD (years 2-4) to work with the partner, which may include translating their research to industry problems	Salary and expenses paid by the partner	Student gains industry experience Partner gains access to student expertise
STARS Short-Term collaborAtive Research activitieS (STARS) are 1-2 week engagements with industry partners to work together exploiting opportunities to take research to higher TRLs	Intensive period working collaboratively on a problem	Student gains industry experience Partner gains access to student expertise
Co-Funded iPhD Studentships The partner sponsors a student by funding 50% of the total cost of a studentship through the CDT, helps to shape the research agenda in collaboration with academic supervisors The student will typically go on an internship with the co-sponsor for 3 months during their PhD, but at no additional cost	Approx. £12.5K per year for 4 years and engagement in research supervision	Student gains substantial industry research experience Partner helps guide the research and gains substantial access to student expertise
International Student Sponsorship The partner sponsors an exceptional international student: → From a low- or middle-income country (OECD); or → Who will increase the diversity of students supported through the CDT Partner is involved in interviews for the studentship, and as with Co-Funded iPhD Studentships, they help shape the research agenda and typically host the student on an internship	Approx. £20K per year for 4 years and engagement in research supervision	Student gains opportunity to study in the UK and substantial industry research experience Partner helps guide the research and gains substantial access to student expertise

Find out more:
mindscdt.southampton.ac.uk

Outreach

While the last year has been challenging, the MINDS students and outreach team have remained busy!

Events included a very successful one-hour presentation by Jack, Tom, and Yang on 'Artificial Intelligence and Combatting Violent Crime' (MIND6003), to a virtual audience of 60. They were joined also by two classes of A-level students, an old persons' home and members of the public. Alfred (79) said: 'As an ex-police officer I was amazed at how artificial intelligence can be applied to policing. This has the potential to save lives. I thought artificial intelligence was something from the movies' Alison, a 6th form student studying A-levels in Maths, Physics and Computing, commented: 'In college we mainly look at theory rather than application. It was great to see how what we learn in lessons can be put into practice with further study. I actually had no idea that AI could be used in this way.'

More recently we worked with Thales to run two sessions for Richard Taunton's 6th Form College. Madeleine, Caterina and Ben Pritchard (Thales) talked about their work on methods to monitor the performance of Artificial Intelligence and Machine Learning to ensure the safety of autonomous systems.

All our students study the design, delivery and evaluation of outreach activities and contribute, with the support of our outreach expert Dr Reena Pau, to this important part of our research philosophy. When restrictions ease, we hope to support more in-person events where practical demos and face-to-face talks can begin again, providing impact beyond the online sessions.

We are grateful to our outreach partner, Barton Peveril 6th Form College, for providing a great sounding board for our activities and for their enthusiastic support.

Responsible Research and Innovation

While Artificial Intelligence can be applied to the significant benefit of society and the economy, it can also be misused. MINDS CDT students are conducting research at the leading edge of AI, and it is important that this research is responsible and has a positive impact on the world. From the very beginning our students develop their expertise in anticipating impacts of research, reflecting on potential impacts on society, engaging with diverse stakeholders, and acting on what they've learned. They then apply these techniques throughout their PhD programme. We use the AREA (Anticipate, Reflect, Engage and Act) framework from Orbit-RRI (www.orbit-rri.org), which underpins the PAS 440 (Responsible Innovation Guide) from the British Standards Institution.

Outreach is one of the ways in which we engage with diverse stakeholders, but we also work with Public Policy Southampton, the Alan Turing Institute, and our network of industry partners, aiming to understand potential impacts on policy, society, and the economy.

Events

We are holding a virtual get-together for all our students, academic supervisors and industry and government partners on 8 September 2021 14:00-17:00. This will be a great opportunity to learn more about our students' research, and to develop new research project ideas for members of the team joining us in October. If you are interested in engaging with the CDT as a potential industry partner or as an academic supervisor, please contact us via mindscdt@soton.ac.uk for an invitation.

In partnership with the UKRI Centre for Doctoral Training in Safe and Trusted AI (King's College and Imperial College London) we are holding an event on Ada Lovelace Day (12 October 2021) to celebrate our women scientists and students and their research.

October sees the launch of our monthly seminar series for the new academic year. We look forward to talks from leading academics across the world who are conducting research relevant to our four themes, as well as from industry researchers, and others addressing important aspects of equality, diversity and inclusion in AI. Look out for more exciting announcements on mindscdt.ai

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