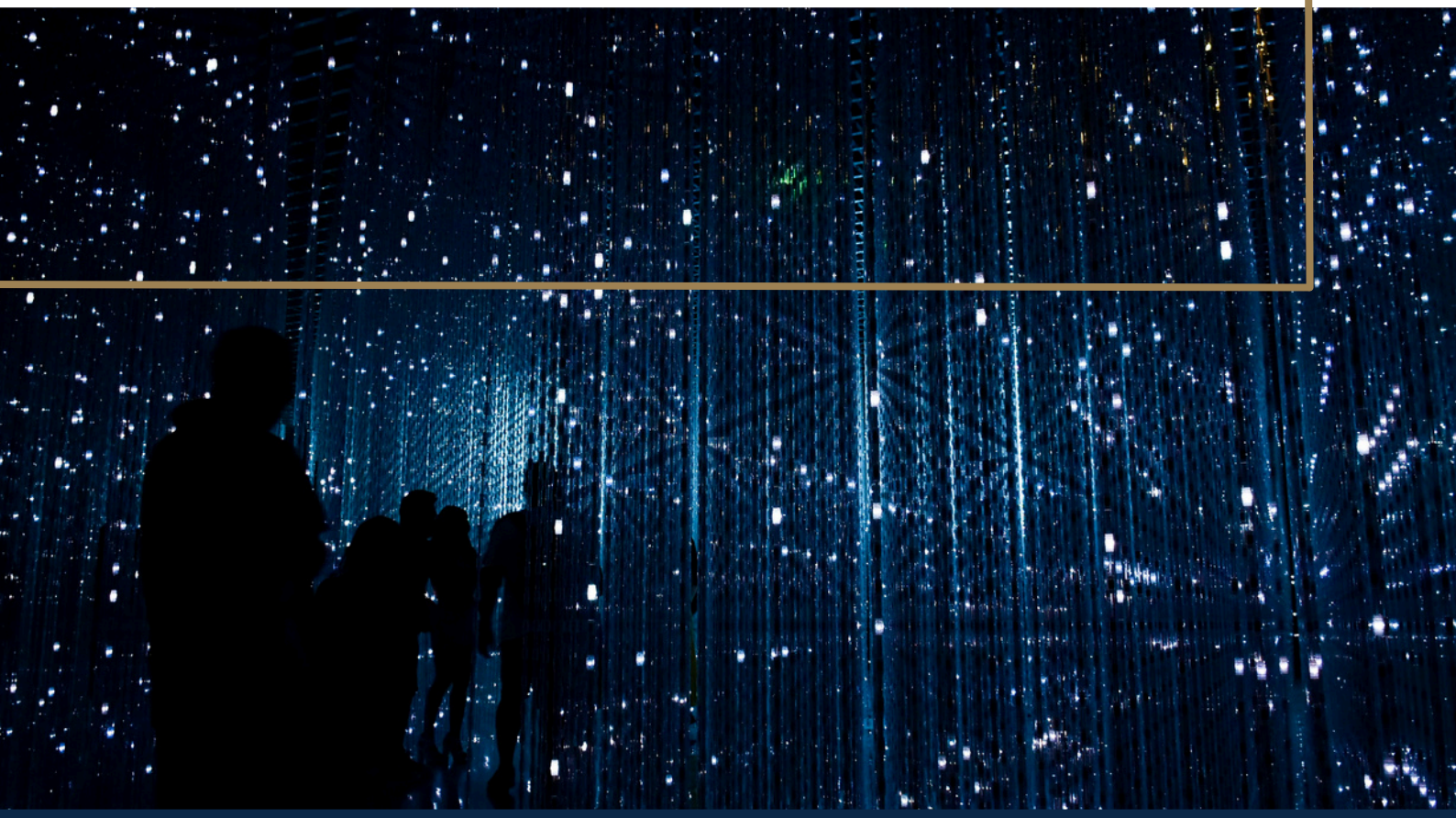
UNIVERSITY OF LIVERPOOL

UKRI Engineering and Physical Sciences Research Council

2025

SIGNAL PROCESSING GROUP



AN INNOVATIVE DATA SCIENCE, AI AND MACHINE LEARNING RESEARCH CENTRE.

About the Signal Processing Group

Led by professors Simon Maskell and Jason Ralph, the Signal Processing Group is home to 87 academic, research and professional service staff who specialise in creating and delivering advanced data science and machine learning solutions by blending fast, efficient numerical algorithms with the power of parallel computing.

We have significant research strengths in **Bayesian computational methodology, decision support, autonomy, tracking, image and radar processing, quantum sensing, acoustic analytics, and simulation**. Our expertise spans a diverse set of application domains across the **health, manufacturing and defence and security sectors**.

We pride ourselves on anticipating the needs of our partners and evolving state-of-the-art technologies.

Our Portfolio

Our multi-million-pound research and development portfolio continues to grow. Complementing this, we host **two doctoral training centres** that not only support the delivery of cutting-edge research but also cultivate the **next generation of leaders ensuring a lasting impact for years to come**.

Who we are

TRAINING

2 doctoral training centres

- Centre for Doctoral Training in Distributed Algorithms
- Energy Transfer Technologies Doctoral Training Hub

PHD STUDENTS

- 52 students trained in the Distributed Algorithms CDT
- 7 aligned PhD students
- Currently 1 Hub PhD student based at the University of Liverpool in SPG, total of 12 across the UK in 2 cohorts

POSTDOCS & DATA SCIENTISTS

- 4 data scientists
- 19 postdoctoral research associates

ACADEMICS

6 academic staff members

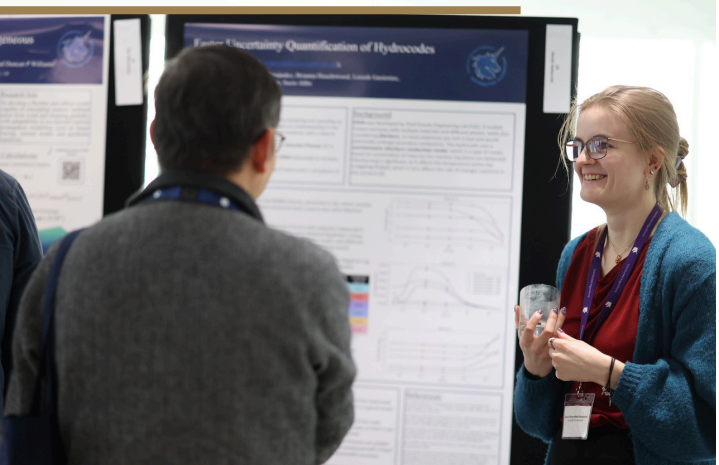
- Professor Simon Maskell
- Professor Jason Ralph
- Dr Angel Garcia-Fernandez
- Dr Lee Devlin
- Dr Murat Uney
- Dr Alessandro Varsi

PROFESSIONAL SERVICES

- 5 members of professional service staff including a programme manager, 2 centre managers, and 2 project officers

PARTNERSHIPS

- Over 30 external partners from industry and government



Energy Transfer Technologies Doctoral Training Hub

The Hub was designed by Professor Jason Ralph in 2023 and aims to train 60 PhD students across 5 cohorts to **develop generation-after-next technologies for applications in defence and security**. Spread across the UK, from Southampton to Glasgow, the Hub hosts students at several universities. All our projects have an external industry or governmental partner, aiming to bridge the gap between academia and the wider community, providing our students with research challenges and an **expert collaborative training environment**.

We are continually growing our network of academic and external partners to foster a collaborative community **dedicated to identifying the technologies required for innovative energy transfer systems**. Through this effort, we aim to identify and develop the essential foundations necessary for the successful advancement and implementation of these technologies, providing a robust framework for impactful PhD research.

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Centre for Doctoral Training in Distributed Algorithms

The CDT was designed by Professor Simon Maskell in 2019 with the aim of training 5 cohorts of 60 PhD students to have the skills and experience that enables them to be **leaders in Distributed Algorithms**. Students, academics and external partners work together to **generate novel data science and future computing solutions to questions once considered impossible**.

At its peak, the CDT hosted 52 students, but where are the first 2 cohorts now?

GRADUATES

- Cohorts 1 and 2 have begun to submit their theses and graduate
- 11 students have submitted their theses
- 7 submissions are pending
- 4 PhDs have been awarded

CAREERS

- 7 students have gone on to an academic career (3 within the Signal Processing Group)
- 1 is employed in industry
- 3 leavers' destinations are currently undecided

All students strive to deliver the CDT vision: **to work at the intersection of academia and industry to develop and deliver novel solutions through the use of data-driven optimisation and high-performance computing**. These relationships have been, and continue to be, mutually beneficial, with over 30 external partners investing in the CDT, many investing in more than one PhD.

Success stories

Simon Maskell is awarded the Royal Academy of Engineering and Dstl Research Chair in Information Fusion

Funded by Dstl.

-Through this new Chair, Professor Maskell will focus on developing generation-after-next algorithms with applications in real-world intelligence, security and defence situations.

Read more.

Spinouts and Industry Success:

Voyant Innovations

-Delivers autonomous tracking and data fusion solutions for sea, land, air and space, designed by Simon Maskell and senior postdoc, Lyudmil Vladimirov.

Intellegri

-Offers risk management solutions for the insurance industry, designed by Simon Maskell and senior data scientist, Alex Philips.

SenseAI Innovations

-A suite of AI technologies which dramatically changes how image sensing is used. CDT graduate, Jack Wells, is a lead developer.

The PhD journey
by Liam Mai

Life as a PhD student in the Signal Processing Group

My PhD journey has introduced me to industry and what opportunities are available to me in a digestible and structured way. Although the PhD journey is filled with challenges that I am learning to overcome, it is **more of a marathon than a sprint**, and I am steadily **developing the technical and soft skills that will be invaluable for my future**.

Working with my industry partner:
My PhD project, entitled 'Robust Video Tracking in Difficult Environments', focuses on developing automated tracking systems for airborne objects under challenging conditions, such as poor lighting and complex backgrounds. The industry partnership with Thales has allowed me to gain deeper insights into the broader applications of algorithms and my research, through our monthly meetings. The outcomes of this research will be impactful, with potential applications across several industries such as security, healthcare, sports analytics, disaster management, and environmental monitoring.

Networking:
Earlier this year, I attended a conference and took part in the Early Careers Challenge (ECC), which provided a unique opportunity to engage in system design - a rarity in academia. Through the ECC, I gained an insight into how industry approaches problem-solving, and it was an opportunity to collaborate and network with young professionals in industry. The challenge deepened my understanding of concepts such as literature review, work breakdown structure, stakeholder engagement, and PIPE (Process, Information, People, and Equipment) analysis.

I have attended several Hub events hosted by the University of Southampton, QinetiQ, and Imperial College London; I met my fellow students spanning several universities, had a low-pressure introduction to networking, and a chance to develop public speaking skills and confidence.

WHERE WE'RE MAKING A DIFFERENCE

The Signal Processing Group, which hosts the Centre for Doctoral Training in Distributed Algorithms and the Energy Transfer Technologies Doctoral Training Hub, is working collaboratively with its partners to generate novel solutions to challenges that were once considered impossible.

On the following pages, and in their own words, some of our postdoctoral researchers and PhD students explain the work they're doing, what problem it solves, and why it's important. The Signal Processing Group conducts a wide breadth of cross-disciplinary research, including tackling challenges in health, defence, space, and even pets!

A series of case studies

TRACKING SPACE SATELLITES

Ben Oakes is working to build a plugin and algorithms that will, in the long run, help the UK track and contribute to the safety of space satellites. With a background in astrodynamics, Ben works alongside industry partner Dstl on this project.

Keywords: Space, Astro, Stone Soup, Python, State Estimation

What I'm doing:
I have been working on a project called 'Stone Soup for Astro'. Stone Soup is an open-source Python framework for tracking and state estimation maintained by Dstl, and supported by a wide community of open-source code contributors. Whilst there are many models and scenarios for air, ground, and maritime applications, there is currently a limited capability for space-based problems. Space is quickly becoming an exciting and much needed research area with the increasing number of satellites being launched into orbit.

Why it's important:
We rely on satellites for many parts of our day-to-day lives; they are used for GPS, communication, and internet as well as many other areas. Currently, although there are some implementations of different astrodynamic models, and separate tracking algorithms, there is no easily accessible and open-source framework that implements these algorithms together to allow for easier research.

The impact of this project:
The development of this plugin will allow people with an interest in tracking space-based objects to use and produce new models and algorithms, which will eventually help the UK contribute to the safety and security of the space domain.

Read more

OPPORTUNISTIC COMPUTING FOR REAL-WORLD PROBLEMS

Matthew Carter is leveraging idle PCs, mobile devices and more, to tackle large-scale computational tasks, with a view to applying this to real-world problems including monitoring the evolution of pandemics, and helping with the search to find MH370. Matthew works with industry partner IBM.

Keywords: Bayesian Inference, Opportunistic Computing, Distributed Computing, Healthcare Analytics

What I'm doing:
Opportunistic computing leverages idle resources like workstations, GPUs, and even mobile devices to tackle large-scale computational tasks. By tapping into these underutilized resources, opportunistic computing offers an accessible and cost-effective, and potentially energy-efficient alternative to traditional high-performance computing solutions. At their peak, opportunistic frameworks have enough compute power to rival some of the biggest HPC infrastructures.

I have developed an opportunistic SMC sampler that capitalises on the spare compute at the University of Liverpool. So far, this opportunistic SMC sampler has been applied to several example problems in epidemiology and proteomics with plans to apply the framework to pertinent real-world problems soon.

The impact of this project:
I plan to apply the framework to a wide set of real-world problems including monitoring the evolution of pandemics, utilising proteomics to understand Alzheimer's Disease, and aiding in the search of MH370.

Read more

USING MACHINE LEARNING TO HELP DESIGN THE NEXT-GENERATION OF AIRCRAFT

Mehdi Anhichem uses machine learning to fuse aerodynamic data, which is essential to every stage of the aircraft design process. In particular, machine learning can help the aviation sector to create planes that meet strict performance standards whilst also aligning with the need to reduce the environmental impact of air travel. Mehdi works alongside industry partner Aircraft Research Association on this project.

Keywords: Aerodynamic, machine learning, data fusion, uncertainty quantification

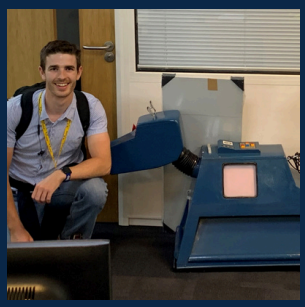
What I'm doing:
The research I am conducting uses machine learning to propose data-driven solutions for the aircraft design process. Machine learning offers powerful tools to approximate the relationship between inputs and output, in my case, between flight conditions and design objective. My focus is on the fusion of data from experimental and numerical methods.

My supervisors and I recently published a journal paper on data fusion of aerodynamic data. In the context of aircraft design, aerodynamic data are essential for every stage of the design process. They inform decisions about wing and fuselage shapes, engine placement, control surface design, and overall aircraft configuration. Accurate aerodynamic data are foundational to designing aircraft that meet performance, efficiency, safety, and regulatory requirements.

The impact of this project:
This work aims to offer fresh approaches for aircraft manufacturers. By getting the best out of the produced data, these new tools will help them create planes that meet strict performance standards while also aligning with the aviation industry's ambitious sustainability goals. By embracing these innovations, aircraft manufacturers can play a crucial role in reducing the environmental impact of air travel.

Read more

MINING VETERINARY TEXT USING LARGE LANGUAGE MODELS TO FIND TRENDS IN DOGS' DISEASES



Adam Williams uses Large Language Models to extract disease signals from large amounts of veterinary free text. Detecting these signals allows for better outbreak monitoring in dogs, examination of trends associated with diseases, and for better information to inform policy on how vets can better communicate to owners on caring for their dogs. Adam works with Dogs Trust.

What I'm doing:
Every day, thousands of people will take their beloved pets to the vets. The reason for these visits could include anything from a routine check-up to diagnosis of a serious health condition. In all cases, the details of the visit (what was wrong, medications prescribed and other notes) will be recorded by the presiding vet in a veterinary clinical note, an electronic record of the visit. The challenge of my PhD is to discover how to best analyse extract trends in disease and treatment from these records, with a particular focus on diseases affecting dogs. I will be doing this on a dataset of 11 million vet records (6 million of which are specific to dogs) collected by the Small Animal Veterinary Surveillance Network (SAVSNET).

To extract information from veterinary records at scale, I will be using Large Language Models (LLMs). LLMs are artificial intelligence models, trained on large amounts of data to model how language is used and hence perform functions such as text generation and text classification amongst others.

The impact of this project:
By improving the ability to extract disease signals from large quantities of free text, it will allow for better outbreak monitoring in dogs and by extension allow for us to specifically examine trends associated with diseases (e.g. are certain breeds more susceptible, are certain medications over-prescribed). This information can then be used by Dogs Trust to inform policy on communicating to owners on how best to care for their dogs.

Read more

USING STATE-OF-THE-ART AI TECHNOLOGIES TO

HELP ENHANCE THE QUALITY OF LIFE FOR WOMEN EXPERIENCING MENOPAUSAL SYMPTOMS

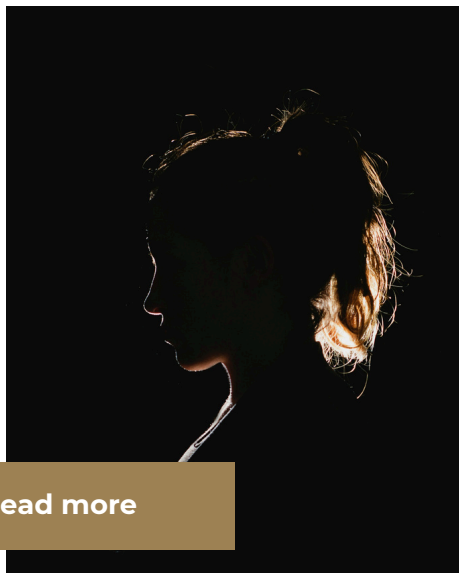
Wenping Jiang is developing artificial intelligence applications in women's healthcare, especially to enhance individualised treatment plans. The potential impact of this project is to enhance the quality of life and productivity of women experiencing perimenopausal and menopausal symptoms, and to streamline diagnostics. Wenping works with industry partner Newson Health.

What I'm doing:
The overarching aim of this PhD project is to develop advanced machine learning (ML) and deep reinforcement learning (RL) methods to improve the interpretation of clinical data, personalise treatment outcomes, and enhance overall healthcare efficiency. Specifically, the project seeks to leverage the extensive clinical data provided by Newson Health to gain novel insights into menopause diagnosis and treatment, and advance individualised healthcare by exploring state-of-the-art AI technologies.

The impact of this project:
The impact of this project is multifaceted, with significant societal, economic, and clinical implications. From a societal perspective, the project's success could substantially improve healthcare outcomes for millions of women worldwide.

By developing AI tools that provide personalised and targeted treatment options, the project has the potential to enhance the quality of life and productivity of women experiencing perimenopausal and menopausal symptoms, and contribute to public health by reducing the risks of severe conditions associated with menopause.

Advancements in menopause research through AI can reduce healthcare costs by streamlining diagnostics and personalising treatment plans. Meanwhile, effective management of menopausal symptoms may help post-menopausal women remain in work, whether full-time or part-time, significantly boosting the economy.



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DEVELOPING AI SYSTEMS THAT LEVERAGE TECHNIQUES USED BY ANIMALS TO NAVIGATE

Teodor Avram-Ciochirca is carrying out exciting cross-disciplinary research between physics, biology, computer science, maths and electrical engineering. This project uses AI techniques to understand how animals use biologically available signals and cues to navigate, such as polarized light, and the application of the findings could help enhance the accuracy and reliability of navigation systems, increase the autonomy of vehicles, and improve operation security. Teodor works alongside industry partner Raytheon on this project.

What I'm doing:
Contemporary navigation techniques are incredibly accurate but highly dependent on global navigation satellite systems (GNSS). Although, GNSS is globally recognized, daily used, and thoroughly integrated in the quotidian life, it sometimes might not be available or have a weak signal. Alternative navigation such as inertial navigation systems, also known as INS, are a reliable short-term solution, but accuracy degrades rapidly over time raising new challenges.
My work is focused on developing artificial intelligence systems, which leverage techniques used by animals to navigate. It is a cross-disciplinary research between physics, biology, computer science, mathematics and electrical engineering. The aim is to mitigate, or completely remove, the error accumulation.

The impact of this project:
If such an artificial intelligence system could be completed and used, the difference it would make would be of intense magnitudes. For example, considering current world events, navigating war zones to save hostages would be much safer and easier. Such a system would enhance the accuracy and reliability of alternative navigation systems, increase the autonomy of vehicles, enhance operation security and much more which will put my partner, Raytheon in a competitive advantage in the market.

Read more

UNLOCKING DATA DRIVEN SOLUTIONS TO TACKLE REAL WORLD PROBLEMS

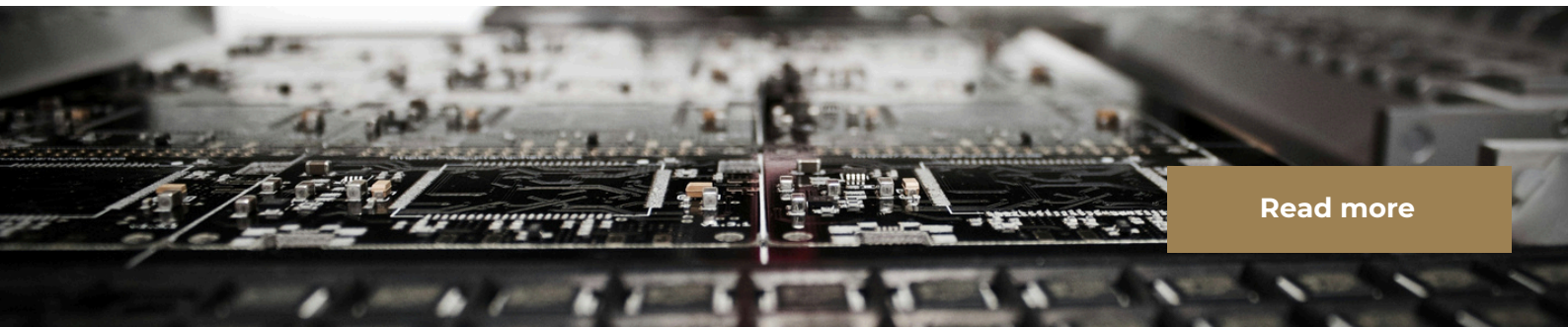
PREDICTING FAILURES WITHIN PRECISION MANUFACTURING

George Jones is motivated by seeing how data science can be utilised to tackle complex, multi-domain, real-world problems. Together with 2 colleagues, George set up Emerging Data Technologies Ltd and focussed in on deploying machine learning methods to predict dimensional and geometrical quality failures within precision manufacturing. The work the company does enhances the precision manufacturing sector, aims to reduce quality errors by 75%, thereby saving scrappage, labour and energy costs. The technology has been backed twice by Innovate UK.

What I'm doing:
Seeing how data science can be utilised to tackle complex, multi-domain, real-world problems is honestly what gets me up in the morning. The impact these data driven solutions can provide is second to none, and being able to unlock that for others is something I genuinely love doing.

Through experience and literature review, 2 colleagues and I set up Emerging Data Technologies Ltd and discovered that the majority of all dimensional and geometrical quality failures within precision manufacturing can be attributed to a defined set of risk factors. We thought it was not unreasonable to deploy machine learning methods to predict these risk factors ahead of time, allowing machine operators to act before the part being created, turns to (expensive!) scrap.

The impact of this project:
The cost savings do not only come from directly reducing scrappage caused by manufacturing errors. Reduction in corrective costs, both in terms of labour and energy, can also be realised from the reduction in rework. Aside from the obvious reduction in machining power consumption, resources within the manufacturers' operations are also freed up, increasing throughput and overall efficacy of the business.



Read more

USING AI TO INCREASE THE EFFICIENCY OF THE MENTAL HEALTH SYSTEM

Yifan Zhou's project 'AI-based virtual environment for risk tracking in mental health' aims to see how feasible it is to integrate resources towards using AI as a tool to aid the diagnosis of mental health conditions, helping to increase the efficiency of the mental health system.

What I'm doing:
Electronic Health Records (EHRs) are a rich but underused source of health information that provide an opportunity for predictive modelling; thereby providing valuable insights for better patient management and care. The project aims to discover the feasibility of integrating the resources in the city of Liverpool towards using AI as a tool to aid the diagnosis of mental health conditions, and to assess the feasibility of applying machine learning techniques to manage caseload priorities and to intervene so that the risk of crises can be mitigated in the field of mental health.

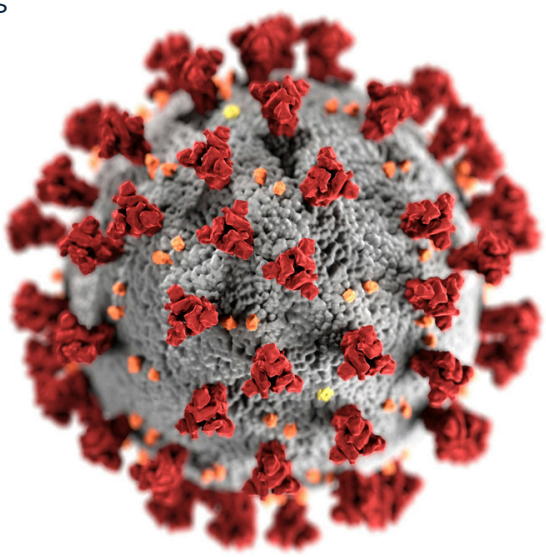
The impact of this project:
With approximately one in six people in the UK living with mental health issues, at a cost of £70 - £100 billion to the economy, this research is very relevant. Using AI will increase the efficiency of the mental health system, particularly where large data sets are concerned. The output of this work has helped to illustrate a way to integrate the resources in Liverpool to tackle a mental health issue. Also, the project proves the possibility of predicting depression and mental health crisis in the near future, using AI.

USING DATA SCIENCE TO TACKLE THE COVID-19 PANDEMIC

Conor Rosato undertook a six-month secondment at the UK Health Security Agency (UKHSA) as a data scientist during the COVID-19 pandemic. Working as part of a collaborative effort to integrate advanced epidemiological models into national-level decision-making, the University of Liverpool's model was uniquely suited to infer syndromic trends, complementing statistical models from other institutions.

What I'm doing:
During my six-month secondment at the UKHSA I was involved in adapting a COVID-19 syndromic surveillance model, developed at the University of Liverpool during my PhD, to run on the UKHSA's high-performance computing infrastructure. This work contributed to producing consensus estimates for key public health metrics, including the R number, predicted hospital admissions, and deaths. The secondment underscored the importance of interdisciplinary collaboration and the rapid application of academic research in a public health crisis, helping to bridge the gap between research innovation and practical policymaking.

The impact of this project:
This work was crucial in generating consensus estimates by combining outputs from multiple models. The consensus estimates, which incorporated diverse methodologies, provided a more reliable basis for decision-making than any single model could offer. These metrics were used by public health officials to evaluate the trajectory of the pandemic and implement appropriate measures, such as lockdowns and vaccination strategies. Additionally, our weekly presentations were instrumental in keeping policymakers, healthcare leaders, and scientific advisors updated on the latest trends, facilitating swift and informed responses to the evolving situation.



I now aim to explore ways to enhance real-time syndromic surveillance, ensuring preparedness for future public health emergencies.

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FIND OUT MORE

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