A^{2}I^2 - Capability Statement

We add value to society by leveraging recent advances in artificial intelligence. Our focus areas are (i) decision support systems, (ii) robustness of complex systems, (iii) simulations and digital twins, and (iv) knowledge systems. Our domain expertise spans defence, health, education, advanced manufacturing, and finance.

We have a multi-disciplinary team that undertakes fundamental research to discover knowledge, translate research advances into concept demonstrators and near production ready solutions that can be piloted within the actual context of use. Our engagement models and project delivery models are tuned to the needs of our project sponsors.

The team consists of **innovators**, **researchers**, **software engineers**, **data scientists**, **project managers**, and **analysts** with a diverse and deep skill set. We leverage the breadth and depth of Deakin's leading research capability and collaborate with leading Australian and international research organisations when needed.

Capabilities

We have demonstrable capability in,

- Leveraging recent advances in computer vision, natural language processing, signal processing and optimisation methods and applying them in a variety of different domains.
- Analysing messy and incomplete/noisy data to build models that improve/inform decision making (*Data science*)
- Creating distributed data and computation systems (IoT, Container orchestration)
- Developing mobile/web/wearable/pervasive computing solutions (apps) using industry standards (*Software Engineering*)
- Engineering complex, secure & scalable software systems (*Robust and Fault Tolerant*)
- Creating virtual reality and augmented reality solutions (*Immersive Experiences*)
- Developing full featured digital twins and simulation environments; processing logs of simulation environments to derive high-order knowledge (*Simulation systems*)
- Delivering solutions that are human centred (*UX and HCI*)
- Applying evidence-based engineering and project management practices (*Evidence driven*)
- Auditing and due diligence of technology and software projects that use AI methods (*Investigation and Auditing for Robustness when using AI*)
- Inventing new algorithms and techniques in our fundamental research spanning optimisation, computer vision, natural language processing and advancing novel data processing and computational architectures to support developing the next generation of artificial intelligence.

Our recent work

Accelerated materials design - Materials design is a costly and time-consuming process as there is often an extremely large design space and minor changes in chemistry or processing parameters can result in significant changes to the functional properties of the product. Our suite of Bayesian optimisation algorithms have been successfully used to both identify new material compositions and optimise their processing. These optimisation algorithms have been tailored to specific partner requirements, e.g., improved mechanical properties, more flexible composition limits, shorter heat treatments, etc., and have been applied across diverse material systems, including aluminium alloys, high entropy alloys, steels, polymer fibres, and coatings, and manufacturing techniques, including additive manufacturing, casting, and polymer extrusion.

Intelligent Autonomous Analyst - We are creating an infrastructure and decision support systems for the Australian Defence Force to help them create and run complex analysis, simulation, and reasoning systems. This technology integrates our research in robust distributed system engineering and decision making with narrative construction to help the defence force adjust and inform strategy.

Algorithmic assurance - Most machine learning algorithms are inherently black-box. Thus, it is important to verify an AI algorithm behaves as per its design specifications e.g. in terms of robustness to different conditions, safety against adversarial attacks, fairness/bias etc. We have pioneered this research area, which we call Algorithmic Assurance. By using Bayesian techniques for optimisation and level set estimation we give practitioners the most insight into their algorithm's behaviour for the least commitment of time. We have applied this methodology to assure AI and ML models in diverse domains: computer vision (object classification neural network models), scientific domains (neural network models approximating simulators) etc.

Risk prediction systems: Although many risk factors have been researched, in practice they are often not explicitly documented or easily measurable. Combining varied risk factors to generate a single risk score is a challenge. We construct risk prediction systems to address this challenge. Individualized suicide risk prediction, preterm risk prediction, cancer mortality prediction, consolidating both obvious and subtle evidence scattered around multiple databases are some examples.

Improve Decisions made by Subject Matter Experts - We created systems for subject matter experts (Doctors, sports coaches, C2 commanders, first-responders) to allow them to undertake complex analysis on data with minimal training in statistics, and machine learning techniques. Our solutions built on top of our expertise in data analytics and domain-specific modelling. Our collaboration spans sports, mental health, army training, search-and-rescue and improving situational awareness in command-and-control systems (C2).

Reducing Recovery Time of Trauma Patients - Leveraging on a long collaboration with National Trauma Research Institute we are improving the treatment that trauma patients get from the time they are picked up by the ambulance all the way through to when they are discharged. The decision support technology is in use at Alfred Hospital, and across various other sites in the world. We are currently working on improve the ambulance experience and post-trauma recovery.

Supporting Youth Wellbeing – We developed a scalable system that supports mental health and wellbeing using a digital phenotype and recent advances in artificial intelligence. Our system monitors both passive and active data at a population level as well as individual level to target more focused interventions reducing the need for training mental health professionals.

Context Aware and Adaptive Timetabling - We are currently working with an industry partner to develop timetabling systems that are adaptive to change and better aware of the context in schools.

Improving Mental Health - We work closely with various partners (notably Black Dog Institute) and other organisations to develop systems that can continuously collect data and provide personalised interventions to improve mental health.

Securing Australia Against Cyber Attacks - We are working on a cutting-edge method to detect and stop spam and phishing attacks that cripple Australian corporate networks. We are working closely with Mailguard (one of Australia's leading cyber security organisations) to improve their cyber-security software solutions.

Digital Enhanced Living for Aged Care - Building on the promise of IoT, Data science, and cheap computers, we are developing a technology platform that allows people to gain better insights into their health and enable them to *remain independent* within their homes. Our work aims to transform aged care and enhance day-to-day living. (Collaboration with Uniting Age Well

Building Resilient Cities and Organisations - We developed innovative methods to measure, detect and predict traffic congestion (Partnered with GCS Agile for Brisbane City Council)

Improving Education - We are leveraging virtual reality technology as well as recent advances in learner-oriented learning management systems (LMS). Of note is a system we developed to increase the empathy towards people living with dementia (EDIE). This is achieved through the development of innovative education methods that better communicate the symptoms associated with dementia and the side effects of aging. We are also applying recent advances in data science to better understand how users interact with technology to improve the overall educational material (ESA Suggestion Engine). This research has broader application in traditional education as well as corporate training.

EDIE - A VR experience that aims to build empathy by living in the shoes of a person with dementia. This has already influenced Australian health policy, and is in use globally (Singapore, Canada, EU). [Collaboration with Dementia Australia]

seeUV – Educates kids about the dangers of UV. The SeeUV app offers an augmented reality filter to create a virtual representation of ultraviolet radiation, and also enables users to capture a selfie to simulate what damaged skin looks like. (Collaboration with Cancer Council)

Virtual Forest – An immersive experience that offers an intervention to calm people in aged care environments. The interactive elements of the program are designed to give back some control to people living with dementia – it is their forest, and they can experiment with it and enjoy it. [Collaboration with Dementia Australia]

RePAIR - An immersive and engaging experience that encourage patients to follow a physiotherapy plan with an intention of reducing post-operative recovery time due to better compliance and remote expert support. [Collaboration with National Trauma Research Institute]

Nurse LMS – A system that uses constructive alignment methodology to improve the learning and education of nurses that are remote.

Fundamental Research Themes

Bayesian Optimisation
- Developing fast, scalable Bayesian optimisation frameworks;
- Developing collaborative human-machine frameworks for discovery and invention.

Robustness, Assurance and SE4AI
- Developing techniques to provide assurance that algorithms conform to user expectations;
- Addressing data poisoning vulnerabilities to make AI safe to use;
- Improving the robustness of AI systems against noise and uncertainty through probabilistic and Bayesian methods.

Deep Learning & Beyond
- Advancing deep learning methodologies for effective and efficient end-to-end learning with minimal human supervision;
- Inventing new self-supervised learning algorithms that need limited labels and are aware of their own limitations;
- Advancing the frontiers of reinforcement learning to build safe, self-motivated social agents equipped with memory, theory of mind and advanced perception capabilities;
- Advancing the perception capability of AI systems through new computer vision algorithms to understand and communicate with human;
- Developing new capability in AI that learns to reason about the world in space and time.

Translational Research Focus Areas
- Accelerating the process of scientific discovery by applying Bayesian optimisation, multi-arm bandits, active learning techniques and generative models;
- Leveraging advances in machine learning to analyse electronic medical records, signals from wearable and monitoring devices, provide objective and quantitative diagnosis and prognosis, recommend treatments, assist rolling out of care packages, and improve delivery efficiency;
- Leveraging recent advances in deep learning and data science to speed up scientific computation in organic chemistry, structural biology and materials science;
- Using patterns in social media signals obtained from unobtrusive data sources to extract socially meaningful indices;
- Developing methods that tailor disease diagnosis and treatment to specific individuals;
- Creating virtual reality and augmented reality solutions;
- Providing solutions to improve cybersecurity through automated anomaly detection in computer networks, cyberspace and social media;
- Analysing messy and incomplete/noisy data to build models that improve/inform decision making (*Data science*).

Technical Engineering Skills
- Applying evidence-based engineering and project management practices to engineer scalable AI systems;
- Creating distributed data and computation system;
- Developing mobile/web/wearable/pervasive computing solutions (apps) using industry standards;
- Engineering complex, secure & scalable software systems;
- Delivering solutions that are human centred;
- Auditing and due diligence of technology and software projects that use AI methods.