Annual report 2022

Excellence in AI research and innovation

Australian Institute for Machine Learning

THE UNIVERSITY
of ADELAIDE

make history.

Contents

Excellence in AI research and innovation

Our vision

To be global leaders in machine learning research, and high-impact research translation.

Our mission

Research excellence in machine learning (ML), artificial intelligence (AI) and computer vision (CV).

AIML in 2022

Building high-tech AI solutions for local and global businesses

24
SME partner projects in 2022

100+
Events, visits, tours, presentations and workshops

600
School student visitors

Global #1
European Space Agency Satellite POSE Estimation Challenge 2022
(lightbox category)

Global #1 & #2
Learn-to-Race Autonomous Racing Virtual Challenge

Welcome

From the Deputy Vice-Chancellor (Research) and the Pro Vice-Chancellor (Research Excellence)

The University of Adelaide's Australian Institute for Machine Learning (AIML) is an exemplar of the instrumental role that universities play in driving innovation and growth across a range of sectors; creating new jobs and helping build new industries in the process.

Created as a partnership between the University and the Government of South Australia just five years ago, AIML has grown quickly to become one of the largest machine learning research groups in Australia and one of the best in the world for computer vision.

As you will read in this report, AIML is driving AI-led growth in South Australia with impact reaching internationally across a variety of industry areas.

2022 heralded a pivotal moment in the public perception of artificial intelligence; the release of AI language software *ChatGPT* in November has taken the world by storm. AI is now enabling students and researchers from all areas of academia to access synthesised knowledge and forge new pathways of discovery. The University of Adelaide is at the very forefront of some of these digital frontiers.

We hope you enjoy reading AIML's 2022 annual report.

Professor Anton Middelberg
Deputy Vice-Chancellor and Vice-President (Research)

Professor Laura Parry
Pro Vice-Chancellor (Research Excellence)

Director's overview

The University of Adelaide's Australian Institute for Machine Learning (AIML) plays a vital role in driving high-tech innovation and delivering economic growth in South Australia and beyond.

With AIML now in its fifth year, the University of Adelaide has firmly established itself as an international leader in artificial intelligence and machine learning.

Locally based, globally connected

2022 marked the first full year of open onsite activity since South Australia lifted COVID-19 restrictions in late 2021. Despite some continued remote work practices, our institute has enjoyed a welcomed return to in-person collaboration, networking and engagement across the University's North Terrace campus and throughout the growing Lot Fourteen innovation district.

Lot Fourteen is now home to more than 1,500 people working across 150 businesses. This is expected to reach 6,000 by the end of 2028. As the district's anchor tenant, AIML's AI talent pool is increasingly a reason for high-tech business and industry to establish operations here in South Australia. In February, CommBank announced its plans to establish a technology hub at Lot Fourteen to expand its high-tech capability, with 150 staff expected to be hired in the next five years.

In March, US defence not-for-profit MITRE Corporation established its first international locations outside the United States in Canberra and Lot Fourteen, and in December announced a collaboration with the University that will see our AI research capability help support greater regional security for Australia and its global allies.

Our leaders and high achievers

Throughout 2022 AIML members have continued to excel in their AI research and translation endeavours across a variety of fields.

In August, Associate Professor Qi Wu was one of five University of Adelaide researchers to receive a 2022 South Australian Young Tall Poppy Award, recognising his work in *commonsense visual question answering* (VQA) that leverages advanced techniques in computer vision, natural language processing, and knowledge representation.

This year AIML researcher Dr Ehsan Abbasnejad commenced his Future Making Fellowship supporting his research towards developing flexible and cost-effective machine learning tools to strengthen Australia's economy.

In October we welcomed Dr Antonios Perperidis as AI Lead for the Women's and Children's Health Network. Dr Perperidis works closely with hospital staff to identify key areas where AI can be applied to improve paediatric healthcare outcomes.

Our PhD and master degree students continue to excel in their achievements. In August PhD candidate Sofia McLeod received an *EOS Space Systems Research Award* for her work researching event camera-based computer vision systems for spacecraft navigation.

Academic excellence

AIML researchers and students have continued to push forward the boundaries of fundamental machine learning research, publishing more than 100 papers in peer-reviewed journals and conference proceedings throughout the year.

Most notably, AIML members presented 23 papers at the 2022 IEEE Conference on Computer Vision and Pattern Recognition (CVPR) in New Orleans. Held annually in North America since 1985, CVPR is ranked by Google Scholar at number four among all academic journals (by h5-index), beaten only by long-established science journals Nature, The New England Journal of Medicine, and Science.

CVPR's rising prominence in broader academia speaks to the importance and value of computer vision research in fuelling innovation, not just in AI and tech fields, but across industry and business more broadly.

Engaging with the community

As Australia's first site dedicated to machine learning research, AIML plays a leading role in building AI literacy across industry, government and the broader Australian community.

In April, the institute worked with the Australian Strategic Policy Institute (ASPI) to publish *Artificial intelligence: your questions answered*, a short collection of papers offering a timely introduction to the world of AI and the opportunities and risks the technology presents to Australia.

> ## "Innovation in AI is accelerating, creating opportunities to grow the economy, solve challenging problems, accelerate discovery and enhance national security."
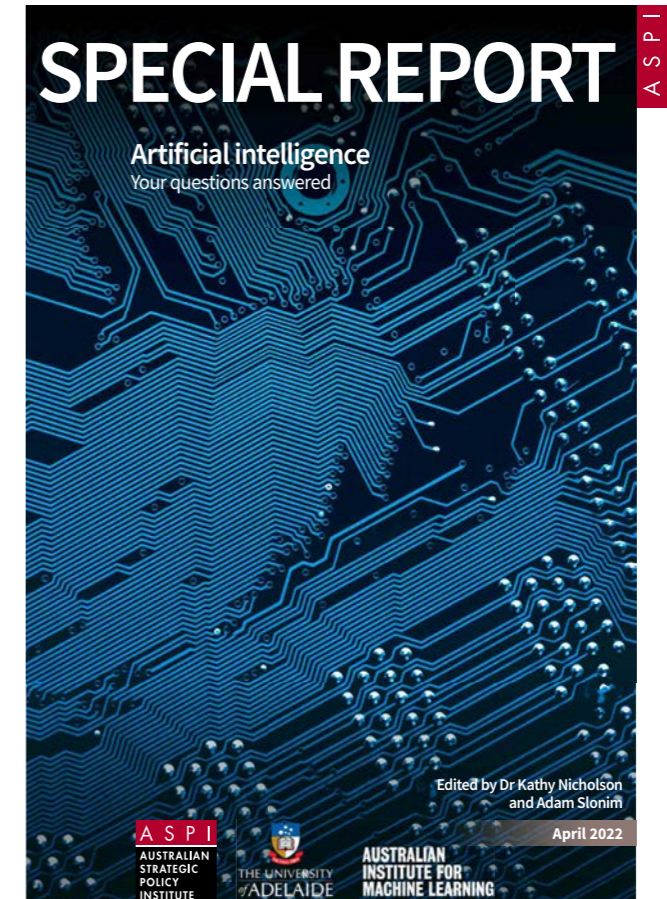>
> **Professor Tanya Monro AC,** Australia's Chief Defence Scientist

Alongside the University's AI experts, the report's authors included Australia's Chief Defence Scientist, Professor Tanya Monro; former Senator for South Australia, Rex Patrick; Chief Scientist for South Australia, Professor Caroline McMillen; ASPI Director of Defence, Strategy & National Security, Michael Shoebridge; and Science & Technology Australia CEO, Misha Schubert.

In late August, around 100 invited guests joined us for the *AIML Research Showcase* at Adelaide Oval which gave a glimpse of some of the cutting-edge technology being developed at the University. Guests enjoyed research explainers from AIML members, poster presentations, and a panel discussion about South Australia's high-tech future with Minister for Industry, Innovation and Science the Hon. Dr Susan Close MP.

In November we also launched *AI in Industry*—our new public networking event series aimed at demonstrating the value of applied AI—with MyVenue CEO Tim Stollznow demonstrating the value of his company's partnership with AIML, and the benefits of implementing AI in his business more broadly. The Adelaide-based startup is now selling its hospitality point-of-sales software to sporting and concert venue clients across the United States.

Throughout the year the AIML building has been a hive of activity, hosting more than 100 events, VIP visits, tours, seminars, presentations, workshops and networking opportunities. We've been especially proactive in nurturing Australia's future AI talent; we held nine school tours throughout the year, with AIML student ambassadors giving AI information sessions to almost 600 primary and secondary students.

2023 and beyond

This last year saw significant development in the public interest in machine learning technology, particularly with generative AI products such as ChatGPT, DALL-E 2, and Midjourney. There's fierce global competition—but also collaboration—to publish new AI research and develop new AI capability. I'm sure this upward trend will continue in the near future.

I greatly appreciate the enthusiastic and continued support of the Government of South Australia, particularly the Department of the Premier and Cabinet; the Department for Industry, Innovation and Science; and the Department for Trade and Investment; as well as our government agency project partners.

I also acknowledge the valuable support and collaboration with our federal stakeholders, the Australian Government Department of Education; the Department of Industry, Science and Resources; and CSIRO data61.

I thank our advisory board members, academic leaders, early and mid-career researchers committee, and all our hard-working members for their valuable contribution to machine learning science and innovation.

Lastly, I thank the University of Adelaide for its continued and growing support of AIML's mission of research excellence in machine learning, artificial intelligence, and computer vision.

SPECIAL REPORT ASPI

Artificial intelligence
Your questions answered

Edited by Dr Kathy Nicholson and Adam Slonim
April 2022

Professor Simon Lucey

Director, Australian Institute for Machine Learning (AIML)

Diversity, gender equity, and inclusion

73%
of AIML members come from a non-English speaking background

50%
of AIML members are aged 25 to 34

23%
of AIML members are women

Diversity and inclusion in STEM are essential for the future of our tech industry.

At AIML, we understand that having researchers and students from a diverse range of backgrounds and genders improves research outcomes and produces higher quality conclusions. A lack of diversity can produce narrow and biased outcomes that may not be reflective of the wider population.

While STEM research and industry have traditionally been male-dominated, the tide is gradually changing, and our community is actively becoming more diverse and inclusive.

We strive to actively include more women, and gender and ethnic diversity in our AIML community because we recognise the value it brings to our research collaborators, industry clients and partners, and the broader community as a whole.

Ada Lovelace group

Named after the pioneering English mathematician and writer, this group hosts a bi-monthly discussion group for women and non-binary AIML members to discuss career progression and celebrate female participation in machine learning research and innovation.

Centre for Augmented Reasoning

The Centre for Augmented Reasoning (CAR) has a particular focus on increasing female participation. To boost gender representation, CAR is seeking at least 25% of PhD scholarships be awarded to women. A female only recruitment campaign is helping to achieve this.

Events and sponsorship

We are working with community groups to promote diversity in science, mathematics and technology. This has included sponsorship of the annual *Women in AI (WAI) Awards*, South Australia's *HerTechPath*, and co-hosting events such as a panel discussion about women working in engineering with the University of Adelaide's *Women in STEM Society (WISTEMS)*.

Dr Kathy Nicholson

Operations Manager, Australian Institute for Machine Learning (AIML)

AIML research fellows

Dr Ehsan Abbasnejad

Future Making Fellow 2022-2025

Dr Ehsan Abbasnejad is a senior lecturer at the University and a team leader in the Centre for Augmented Reasoning (CAR). He obtained his PhD from the Australian National University in 2015 and was a graduate researcher in machine learning at National ICT Australia (now CSIRO Data61).

Prior to joining the University of Adelaide in 2016, Dr Abbasnejad worked for Microsoft Research, Xerox Research and NEC Labs America. While at AIML he has led multiple machine learning projects in agriculture, defence and health. His research interests include responsible machine learning and out-of-distribution generalisation with applications to various vision and language tasks.

Dr Jack Valmadre

Future Making Fellow 2022-2025

Dr Jack Valmadre is a researcher working in computer vision and deep learning. He obtained his PhD in 2016 at the Queensland University of Technology before taking a postdoctoral research position at the University of Oxford (2015-2018). Dr Valmadre later worked as an applied research scientist with Google AI in France, before joining the University of Adelaide as a Future Making Fellow in early 2022.

Dr Valmadre's machine learning research interests include object detection and tracking, class taxonomies, zero- and few-shot learning, theory of deep learning, music generation, weak supervision, and open-world vision.

Dr Antonios Perperidis

Women's and Children's Health Network Translation Fellow 2022-2027

Dr Antonios Perperidis is an AIML research fellow and AI Lead for the Women's and Children's Health Network, exploring how AI can be applied to clinical practice. He obtained his PhD in image analysis methods for cardiac sonography at the University of Edinburgh in 2011

and has been developing translational healthcare solutions both in academic and commercial environments ever since.

Prior to joining the University of Adelaide in October 2022, he worked as a research engineer for Canon Medical Research Europe in Edinburgh. Dr Perperidis's research interests cover machine learning and image analysis for biomedical applications with experience in all phases of the healthcare-AI development life cycle, from early-stage concept and system design to algorithm development and software integration.

Associate Professor Qi Wu

ARC DECRA Fellow 2019-2022

Professor Qi Wu is AIML's Director of Vision and Language Methods and a principal researcher with the University's Centre for Augmented Reasoning. He obtained his PhD in visual object classification and detection from the University of Bath in 2015 before joining the University of Adelaide as a postdoctoral researcher with AIML's predecessor, the Australian Centre for Visual Technologies.

In 2022 Professor Wu received a South Australian Young Tall Poppy Science Award in recognition of his globally recognised work developing algorithms for common-sense visual-question-answering (VQA). Professor Wu's research interests include cross-depictive style object modelling, object detection and vision-to-language problems, with a particular focus on VQA and vision-and-language navigation.

'Line-busting' AI for faster snacks at the big game

For Dr Milad Dakka, the life of a machine learning engineer working at AIML is not too dissimilar to that of British super-spy James Bond.

"Your typical day as an engineer with the engineering team is a little bit like a nerdy 007 movie, where somebody comes to you and says 'you've got a mission,'" Dr Dakka says.

"A company will have a particular problem and then you need to find a solution to it, and so we go through the whole process."

That was how the collaboration between Dakka and Adelaide start-up company MyVenue kicked off.

MyVenue, based in the neighbouring TechCentral building at Lot Fourteen, had rolled out a point-of-sale (POS) system for food and drink sales to stadiums and arenas.

The technology is being used in world-famous venues like Wrigley Field in Chicago and Hard Rock Stadium in Miami, which is home to the NFL's Dolphins and the Miami F1 Grand Prix.

The software is hosted in the cloud, reports data in real-time, and works offline. This allows cashiers to accept payments even if the internet drops out in the venue.

MyVenue's chief executive Tim Stollznow approached AIML with his own super-spy mission a few years after the rollout of their POS software.

He wanted to see how years worth of data could be used to help forecast stock and labour requirements at venues to streamline operational costs.

"We wanted to know venue data was digestible, if it could be fed into a machine, was predictable, and if a pattern could be found… or if it was just random hogwash," Stollznow says.

That's where Dr Dakka and his team came into their own, he says.

"It turns out that some of the modern tools available to us were just perfect," Dr Dakka says.

"More importantly than predicting the future, they enabled us to predict uncertainty."

Dakka says once they could control their AI model for uncertainty, his team began seeing predictability in customer sales behaviour.

The team sorted the data into 10-minute intervals, using the past three hours to predict the next two.

"We were seeing the model correctly predicting a rise in sales as the game starts, and sort of the ebbs and flows of the game in a useful way, in an actionable way that can be turned around and acted upon by operators at the venue.

"That was exciting and that's only phase one of the project's success and now we're already starting to talk about where to go from here."

Stollznow says the algorithm will allow stadiums to fairly accurately predict how much stock will be required for their venue's events.

"That reduces wastage, improves cash flow, and hopefully prevents venues from running out of stock," he says.

By Kurtis Eichler

Up to the challenge

International AI challenges allow AIML engineers and students to compete against some of the world's brightest minds, and test the limits of their mathematics and programming skills in a range of fields, often with outstanding results.

AIML members collaborate to solve tricky simulated problems in a video game-like environment, such as virtual motorsport races or satellite rendezvous missions.

The challenges provide applied scenarios for students to rank their performance in an international arena, and give them the opportunity to showcase the quality of their work to prospective clients and future employers.

Podium finish in global AI race

Global #1 & #2

An AIML team scored double pole positions in a global virtual motor racing event that saw hundreds of AI researchers and engineers around the world compete to build high performance virtual race cars.

The University of Adelaide research students and AIML engineers used their spare time to compete in the *Learn-to-Race Autonomous Racing Virtual Challenge,* beating more than 400 international competitors to secure first and second place finishes in their categories.

Postgraduate students Matthew Howe, Adrian Orenstein and James Bockman worked with machine learning engineers Lachlan Mares, Stefan Podgorski and Sam Bahrami for the challenge.

Teams created virtual agents that autonomously navigated a computer-generated racetrack using the vehicle's speed information and images from a driver's perspective to guide them.

To achieve this, participants built something called a *reinforcement learning agent*—a type of machine learning that rewards the agent's correct behaviour, and punishes any undesired behaviour. Effective reinforcement learning agents are able to perceive and interpret their environment (in this case, the race track) from input data, and learn through a process of trial and error.

The racetracks were computer-generated, but modelled on real-world locations, such as the Thruxton Circuit in the UK or the Las Vegas Motor Speedway.

The *Learn-to-Race Challenge* is organised and hosted by data science competition platform AICrowd; and sponsored by Carnegie Mellon University, Arrival, and Amazon Web Services.
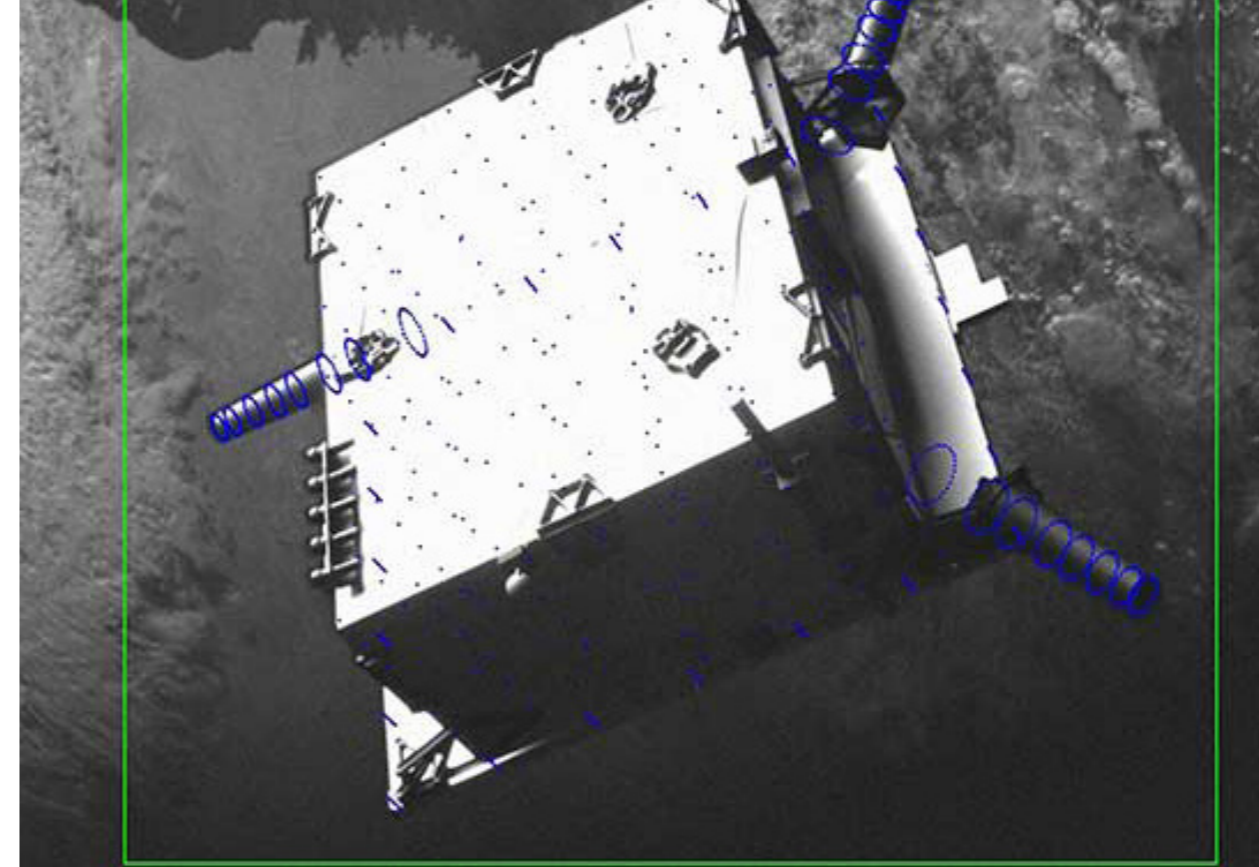
Leading the way in space AI

Global #1 & #3

Autonomous technology is increasingly being used for space satellite operations, which is the basis for the *Satellite Pose Estimation Challenge*—a global AI competition organised by the European Space Agency and Stanford University's Space Rendezvous Laboratory

AI systems are crucial for uncrewed spacecraft as they can determine the location of other satellites, spacecraft, and space debris.

In the competition, teams had to develop AI software that could estimate the pose (position and orientation) of an orbiting satellite using just a single image.

A microwave-shaped satellite called Tango, launched by the Swedish Space Corporation in 2010, was the subject of the challenge.

The team *TangoUnchained*—a collaboration between AIML's Sentient Satellites Lab and European space startup Blackswan Space —competed against 35 other groups to place first and third in the competition's two categories, repeating the University's previous success placing first in 2019.

Teams were given a dataset of labelled computer-generated images which they could use to train their AI models, which were then tested and benchmarked against a real photograph of a scale model produced by Stanford University's Space Rendezvous Laboratory (SLAB).

Machine learning researchers refer to this process as solving a *domain gap* problem, which trains AI on labelled data from one source (domain) and deploying it on unlabelled data (target).

AIML PhD student Mohsi Jawaid said that AI-based computer vision systems provide a compelling sensing and perception solution for autonomous space missions.

"And it's not just satellites, it could be any space bodies, space junk, asteroids. You want to get accurate vision of it so you can approach it safely."

SmartSat CRC Professorial Chair of Sentient Satellites Professor Tat-Jun Chin said that competition in AI for space technology is growing rapidly.

"The latest competition was much tighter, no doubt due to the growth in interest in space and AI over the last few years," Professor Chin said.

By Kurtis Eichler and Eddie Major

AI fast-track for development of water saving plants

Understanding how plants control their rate of gas exchange and water loss through leaf pores is a fundamental part of plant biology. However, studying the tiny doughnut-shaped openings—known as stomata—through microscope images, can be time-consuming for scientists.

Known to science since 1889, stomatal pores are vital to ecosystems as they act as gateways allowing carbon dioxide to enter a plant and oxygen and water to exit.

Using a type of AI called *deep computer vision,* the Australian Institute for Machine Learning worked with researchers from the University of Adelaide's Waite Research Institute to develop AI-powered software tools which make analysing the dynamics of stomata less labour-intensive.

StomaAI was developed by AIML machine learning PhD candidate James Bockman and Dr Na Sai during her plant physiology PhD.

Measuring the aperture of plant stomata allows researchers to get a clearer picture of how they function and respond to their environment. It's a common task for biologists studying plant signalling pathways and stress perception.

StomaAI allows scientists to accurately determine the number of open and closed stomatal pores and their density on the plant leaf; as well as take precise measurements of a pore's area, length, and aperture from microscope images.

While some computer programs have attempted to semi-automate this process in the past, no such technology has allowed researchers to get results seconds after microscopy images are taken.

"The real beauty of this tool is that it takes so little time to get these measurements," Dr Sai says.

"Usually, people take about 100 stomata apertures at a minimum, and that can take four hours to do, whereas we can get thousands of stomata and measure finer and finer effects in a fraction of the time using this tool."

Machine learning PhD candidate James Bockman says the researchers wanted to test whether their software could mimic the work of experts.

"Not only could we say it was really good at doing the computer vision task, but we were also saying it was as good as humans at doing the measuring task, which gives us assurance that it's a drop-in replacement for a human doing it," Bockman says.

StomaAI is a joint research outcome developed through interdisciplinary collaboration between the ARC Center of Excellence for Plant Energy Biology and the Australian Institute for Machine Learning. The software is available online: sai.aiml.team

By Kurtis Eichler

Centre for Augmented Reasoning

Artificial intelligence is transforming the way we learn, the way we make decisions, and the way we solve problems. The University of Adelaide is helping to build the expertise Australia needs in order to thrive in the coming AI-enabled global economy.

Formally established in 2021, the University of Adelaide's Centre for Augmented Reasoning (CAR) is a $20 million investment by the Australian Government Department of Education in growing Australia's AI capability.

Headquartered within AIML, and building on its existing research strengths, the centre is helping to create the next generation of AI experts and solidifying the University as a key strategic research institution for machine learning in Australia.

What is augmented reasoning?

Augmented reasoning is a new and emerging field of AI that combines the ability of computers to recognise patterns through traditional machine learning, with the ability to reason and learn from prior information and human interaction. This allows computers to better understand people and their needs through more natural interaction.

Augmented reasoning can give AI the ability to address some of the frustrations and problems that we all experience with current technology, and help make computers and other technology more user-friendly, efficient, and intelligent.

Investing in skilled people

Building Australia's AI capability means growing the skilled talent pool that can increase the impact of machine learning research in Australia, and help drive the application of AI throughout Australia's industries.

Advanced reasoning research grants

By early 2024 the centre will host 28 postdoctoral research fellows in an ambitious fundamental research program aimed at growing Australia's domestic capability in natural language processing, computer vision, deep learning, and machine reasoning

2 2021   **7** 2022   **28** 2023-24

**Postdoctoral research fellows**
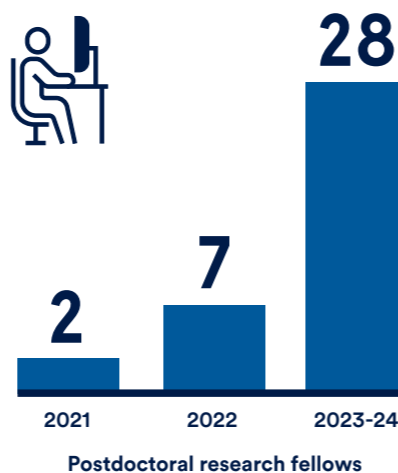
PhD scholarships

The centre is supporting postgraduate research in machine learning with 3-year PhD scholarships, with strategies and resources dedicated to improving gender diversity in the field.

2 2022   **10** 2023-24   2021

PhD student scholars
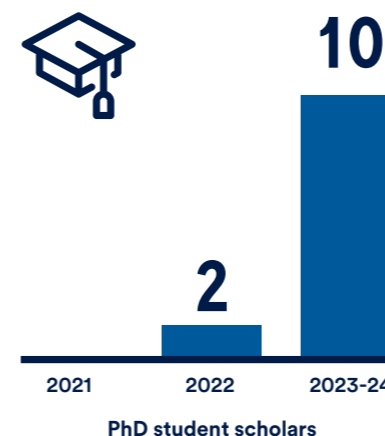
High performance researcher support

The centre is committed to attracting some of the world's leading AI research minds, with funding to retain high performance researchers and support for Discovery Early Career Researcher Award, Future Fellow and Laureate Fellow applications.

2 2022   **8** 2023-24

High performance researchers
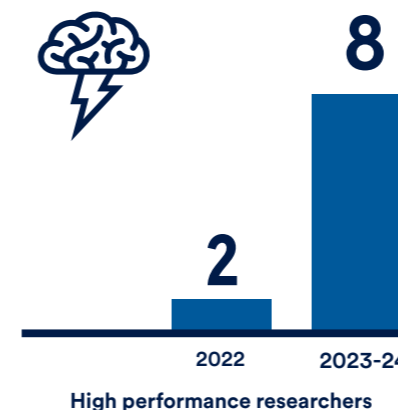
Engaging with the community

Through the centre, the University of Adelaide is taking a leading role in improving AI literacy in Australia and increasing the visibility of Australia's AI capabilities on the international stage.

Through its community engagement program, CAR is building connections with a growing cohort of stakeholders across industry, government, academia, and the broader public. In 2022 this activity has included media articles and TV interviews, public events, and industry workshops.

Top AIML publications 2022

Throughout 2022, AIML members authored more than 100 papers in leading international journals and conference proceedings, contributing notable advances in fundamental machine learning research.

AIML's research leaders have nominated the following short selection of papers as being the most impactful in their respective fields.

Names in bold are AIML members.

Anh-Dzung Doan, Michele Sasdelli, David Suter, **Tat-Jun Chin.** A Hybrid Quantum-Classical Algorithm for Robust Fitting: *IEEE Conference on Computer Vision and Pattern Recognition (CVPR) 2022*

Amin Parvaneh, Ehsan Abbasnejad, Damien Teney, Reza Haffari, **Anton van den Hengel, Javen Qinfeng Shi.** Active Learning by Feature Mixing: *IEEE International Conference on Computer Vision and Pattern Recognition (CVPR) 2022*

Bowen Zhang, Zhi Tian, Quan Tang, Xiangxiang Chu, Xiaolin Wei, Chunhua Shen, **Yifan Liu.** SegViT: Semantic Segmentation with Plain Vision Transformers: *Conference on Neural Information Processing Systems (NeurIPS) 2022*

Bohan Zhuang, Chunhua Shen, Mingkui Tan, Peng Chen, **Lingqiao Liu, Ian Reid.** Structured Binary Neural Networks for Image Recognition: *International Journal of Computer Vision 130 (9), 2081-2102 (IJCV)*

Jack Valmadre. Hierarchical classification at multiple operating points: *Conference on Neural Information Processing Systems (NeurIPS) 2022*

Sameera Ramasinghe, Simon Lucey. Beyond Periodicity. Towards a Unifying Framework for Activations in Coordinate-MLPs: *European Conference on Computer Vision (ECCV) 2022*

Violetta Shevchenko, Ehsan Abbasnejad, Anthony Dick, Anton den Hengel, Damien Teney. EBMs vs. CL: Exploring Self-Supervised Visual Pretraining for Visual Question Answering: *arXiv:2206.14355*

Xiaoxuan Liu, Ben Glocker, Melissa McCradden, Marzyeh Ghassemi, Alastair Denniston, **Lauren Oakden-Rayner**. The Medical Algorithmic Audit. *The Lancet Digital Health, 4(5), 2022*

Yangyang Shu, Baosheng Yu, **Hai-Ming Xu, Lingqiao Liu**. Improving Fine-grained Visual Recognition in Low Data Regimes via Self-boosting Attention Mechanism: *European Conference on Computer Vision (ECCV) 2022*

Yanyuan Qiao, Yuankai Qi, Yicong Hong, Zheng Yu, Peng Wang, **Qi Wu.** HOP: History-and-Order Aware Pre-training for Vision-and-Language Navigation. *IEEE Conference on Computer Vision and Pattern Recognition (CVPR) 2022*

Zhibin Liao, Kewen Liao, Haifeng Shen, Marouska F Van Boxel, Jasper Prijs, Ruurd L Jaarsma, Job N Doornberg, **Anton Van den Hengel, Johan W Verjans.** CNN Attention Guidance for Improved Orthopedics Radiographic Fracture Classification: *IEEE Journal of Biomedical and Health Informatics, 26(7), 3139-3150*