Plant Biology meets Computer Vision

Interdisciplinary research project reimagines plant phenotyping

Last month, Canadian biopharmaceutical company Medicago R&D Inc., the APPF and the Centre for Entrepreneurial Agri-Technology (CEAT) at ANU successfully completed the first phase of a five-year research collaboration to monitor the growth and performance of plants used in the production of Virus-Like Particles (VLPs). The second phase of the collaboration will support $1.5M of research to enable Medicago to optimise proprietary plant-based technology that is used to produce vaccines and protein-based therapeutics.

Medicago uses a plant species indigenous to Australia – *Nicotiana benthamiana* – to produce VLPs. VLPs mimic the structure of viruses and can induce an immune response without causing an infection. When purified, VLPs could be used as vaccines to combat influenza, COVID-19 and other viral infections. Medicago's recombinant technology is rapid, versatile, and scalable. It is ideal for rapidly producing vaccines that match new strains of viruses, such as in the case of seasonal influenza and emerging strains of COVID-19.

The research seeks to gain further insight into the factors that regulate VLP production within individual plants. Central to that work has been the development of a way to non-invasively examine plants using advanced infrastructure and imaging technology. Subsequently, machine-learning approaches – like that used in facial recognition – are used to continuously map the canopies of plants.

The data, tools and models developed in the project will help Medicago rapidly and non-invasively assess factors influencing VLP production at scale.

Executive Vice President of Innovation, Development & Medical Affairs at Medicago – Prof. Marc-Andre D'Aoust – has expressed his satisfaction at the completion of Phase I.

"The outputs received from Phase I are reflective of the quality of the work done and demonstrate achievement of the milestones. It is a pleasure collaborating with ANU teams and seeing this project deliver according to plan toward the spectral features-based process control system that we envision. I look forward to witnessing the magic continue to operate in Phase II." – Prof. Marc-André D'Aoust, EVP, Medicago.

Members of the project steering team at Medicago echo the sentiments of their leader.

"It is great to see the synergy between the various departments at ANU and the APPF. The project team is focused towards doing whatever it takes to meet the goals of the program without compromising the quality of the work and we appreciate this spirit of collaboration." - Dr. Pooja Saxena, Manager – Research Partnerships, Medicago.

The APPF's Plant Phenomics Group at ANU – including Dr Tim Brown, Dr Richard Poiré and Dr Frederike Stock – has provided access and expertise in state-of-the-art research infrastructure, such as hyperspectral and 3D-scanning, and sophisticated controlled environment growth chambers. In addition, the team contributes knowledge and expertise in plant production, experimental design, phenomics, and data collection.

"It is exciting to be able to provide our unique phenotyping capabilities to support a cross-domain collaborative project. This brings together expertise to develop new capabilities in support of an

industry partner, while also expanding local research capacity. Medicago has been an excellent partner to work with and we are looking forward to continuing this research in Phase II of the project. - Dr Tim Brown, Director APPF, ANU Node.”

The research team from CECS, consisting of Professor Hongdong Li and Dr Liang Zheng and research fellows, are developing advanced computer vision and machine learning techniques to support *in vivo* 3D plant modelling and non-invasive phenomics analysis for the *Nicotiana benthamiana* data collected by the APPF team.

“Existing 3D Computer Vision algorithms, while working well for modelling the 3D shapes of man-made objects such as a house or a car, often fall short in modelling complex natural biological shapes such as tree branches or plant stems and leaves. This cross-college interdisciplinary project provides a unique opportunity for computer scientists to be working closely with plant biologists in addressing the above scientific challenge. Together, they will jointly develop cutting-edge artificial intelligence technology and novel plant phenotyping methods, pushing the frontiers of both fields forward." - Professor Hongdong Li, College of Engineering and Computer Science, ANU.

Initiated and supported by the Centre for Entrepreneurial Agri-Technology (CEAT) and the Office of Business Engagement and Commercialisation (BEC) at ANU, the project is led by researchers from the APPF, ANU Research School of Biology (RSB), ANU College of Engineering and Computer Science (CECS) and ANU Biological Data Science Institute.

CEAT – led by Dr Owen Atkin and supported by Meredith Thomas and Mandy Nguyen – and BEC (Dr Lauren Du Fall) are proud to have supported the collaboration since its inception.

"It has been a pleasure to be involved in a project that harnesses the knowledge, expertise and infrastructure of the ANU to help increase vaccine production – particularly in the context of the COVID-19 pandemic,” said Professor Atkin, Director of CEAT.

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CEAT was founded by the ANU, CSIRO, and the ACT Government in 2018, and became an ANU Innovation Institute in 2020. CEAT’s mission is to bring together experts from a range of academic disciplines to collaborate with producers, industry, and end-users to co-design innovative, interdisciplinary solutions to challenges facing the agriculture sector.

The APPF is a NCRIS enabled facility, and this project reflects the aim of NCRIS to support high-quality research that will drive greater innovation and address key national and global challenges. APPF’s distributed network of complementary nodes includes the Plant Phenomics Group at ANU, CSIRO’s High-Resolution Plant Phenomics Centre and The Plant Accelerator at the University of Adelaide.

The ANU CECS is a world leader in research and education of many technology-based disciplines, including artificial intelligence, machine learning and computer vision, robotics, computational science and data analytics, control and systems engineering, and quantum cybernetics.

Medicago is a biopharmaceutical company headquartered in Quebec City with production sites in Quebec, Canada and Durham, North Carolina, USA. Medicago’s mission is to improve global health outcomes by leveraging innovative plant-based technologies for rapid responses to emerging global health challenges.