

RICARDO CANNIZZARO

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OBJECTIVE

3rd year causal Bayesian ML & robotics PhD Student @ Oxford Robotics Institute | Aerial autonomy Defence Research Scientist @ Australia Defence Science & Technology | 8+ years of building software & hardware systems that perceive, understand and make decisions autonomously in complex real-world applications | Passionate about STEM education, outreach and diversity. Seeking PhD internship roles in causal AI/ML.

Research Interests: Probabilistic generative causal modelling, Bayesian causal inference, probabilistic planning under uncertainty, causal explanations, autonomy assurance, explainable AI, robot knowledge representation and reasoning.

EDUCATION

DPhil (PhD) Engineering Science, Oxford Robotics Institute, University of Oxford *Expected 2024*

I am researching probabilistic generative causal models to encode robot formal knowledge representation and world uncertainty, built from domain expertise and learned from data. I am investigating the use of causal Bayesian inference for prediction, planning and decision-making, and causal explanations for robots operating in challenging complex, uncertain, and partially-observable real-world environments. I am exploring the benefits of applying these models and inference methods to achieve the autonomy assurance for robots undertaking tasks in manipulation, assistive robotics, and mine survey applications Supervised by Dr Lars Kunze within the Cognitive Robotics Group.

Key Achievements

- Gave an invited talk on my research on causality for confounded POMDP planning problems for robotics at the [Causality for Robotics](#) workshop at the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) 2023 in Detroit, USA. Awarded a USD \$250 travel grant by the IEEE Robot Learning Technical Committee. Presented two workshop paper presentations and three posters during the interactive poster session.
- Proposed and developed *CAR-DESPOT*, a novel structural causal model (SCM) based online POMDP robot planner that delivers better task-level planning and policy execution performance by addressing issues of confounding in the robot decision making process, using causal modelling and causal Bayesian inference to eliminate confounding errors. Proposed a method to learn offline the parameterisation of the causal system transition model, used for planning, from ground truth model data. Successfully validated the methods on a toy problem with an unobserved confounder: demonstrated the learned causal model is highly accurate, and the proposed planning method is more robust to confounding and produces overall higher performing policies than the baseline method. Published the research in a IROS 2023 conference paper ([arXiv paper](#), [conference listing](#)).
- Received a USD \$305 conference fee refund award via the IEEE Robotics and Automation Society (RAS) member support program for IROS 2023 conference contributions
- Awarded £340 St Edmund Hall Postgraduate College Grant for IROS 2023 conference attendance
- Awarded £350 St Edmund Hall Postgraduate College Grant for Academic Activities for attendance at the [Causal Learning and Reasoning \(CLear\) conference 2023](#) in Tübingen, Germany
- Made scientific, technical and project management contributions to the [Assuring the Safety of UAVs for Mine Inspection \(ASUMI\) collaborative research project](#), as part of the [Assuring Autonomy International Programme](#), a £12m initiative funded by Lloyd's Register Foundation and the University of York
 - Proposed a novel framework for probabilistic causal discovery, causal Bayesian inference & post-hoc counterfactual explanations for autonomous drones in mine surveying tasks and published an IROS 2023 Causality for Robotics [workshop paper](#)

- Leading the creation of a collaboration between the University of Oxford and University of York to investigate the use of temporal logics and formal probabilistic model checking methods to bridge high-level abstract functional, safety, social, legal, and ethical constraints of autonomous systems with symbolic probabilistic causal model representations of robot-world systems and causal Bayesian inference for prediction, planning, and counterfactual explanations — in aid of codifying the assurance of autonomous AI and robot systems.
- Lead a scientific trial to perform 3D scanning and mapping of a mine tunnel segment at the Boulby underground Lab in the [ICL Bulby Mine](#), using a bespoke LIDAR-camera-IMU SLAM software and hardware system from the ORI Dynamic Robot Systems group. Successfully generated a fully registered point cloud 3D SLAM map covering over 200m of tunnel length. Undertaking work to generate a colourised point cloud, colourised mesh representation, and a high-fidelity Gazebo simulation world to be used to test and validate autonomous drone behaviours in simulation.
- Co-organised a 6-month extended hackathon. Organised project timeline, competition description, team planning documents and presentations. Developed PX4 flight control unit and Robot Operating System (ROS) based aerial autonomy software, delivered an autonomy framework, and validated the framework in a physics-based Gazebo robot simulation mock-mine environment.
- Supported CRG research, discussion, and outreach activities at the [IEEE International Conference on Robotics & Automation](#) (ICRA) 2023 in London, UK
 - Assisted with coordination of the [Multidisciplinary Approaches to Co-Creating Trustworthy Autonomous Systems workshop](#), on the topic of factors contributing to the trustworthiness of autonomous systems including: robustness and resilience in dynamic and uncertain environments; building trust in their functionality, explainability, accountability, and understandability with a diverse set of users; governance and regulation of their design and operation; and alignment with human values and ethics. Recorded workshop discussion minutes, coordinated breakout groups, and performed social media coverage.
 - Delivered a series of Cognitive Robotics Group lab research overview presentations and autonomous vehicle explanation demonstrations to international visitors at the Oxford Robotics Institute as part of official [ICRA 2023 lab tours](#)
- Led and grew [Team ORIon](#), the ORI's official student robotics competition and outreach team
 - Performed the Team Lead role for Team ORIon during the 2021/22 academic year
 - Led a team of 11 PhD, masters, and undergraduate students to develop complex autonomous behaviours to enable the Toyota Human Support Robot to assist people by with every-day tasks around the home including fetching household objects, putting away the groceries, and acting as a robot party host
 - Grew the team from 4 to 11 active members in 12 months and led a team refresh following a COVID-hiatus
 - Led the coordination of the 11-person team participation in the [RoboCup@Home](#) 2022 international robotics competition Domestic Standard Platform League in Bangkok, Thailand — one of the largest annual robotics competitions — with 14 different leagues and teams from across the world
 - Raised £33k in total funding from the Oxford Engineering Science department, Oxford colleges, industry sponsors, and private donors to permit competition attendance of all critical team personnel
 - Awarded a £350 St Edmund Hall Postgraduate College Grant for participation at RoboCup@Home 2023
 - Coordinated technical and software development of autonomous behaviours by the sub-teams
 - Organised team recruitment activities, software and hardware training sessions, and social activities
 - Coordinated public science outreach and robot demonstrations at University of Oxford events
 - Continuing to support the team since August 2022 by consulting the leadership team on organisational and technical matters and advocating for departmental support
- Co-supervised four 4th year Oxford Engineering Science undergraduate student research projects (4YPs)

- Co-supervised four 4YPs on: causal discovery and causal Bayesian planning and counterfactual explanation methods for robot manipulation tasks; human-robot natural language explanation systems for human support robots; and causal discovery and causal Bayesian planning and counterfactual explanation methods for autonomous drones undertaking survey tasks in mine environments
- Wrote project proposals and project task outlines; interviewed and selected candidates; created on-boarding materials and delivered educational tutorials; provided guidance on research project management, research methods, and robotics and causal ML academic subject matter expertise; and provided software development and robot hardware and simulation support (Python, ROS, Gazebo)
- Undertook teaching assistant role for University of Oxford 3rd year Information Engineering Systems course
 - Scheduled, organised, and led tutorials for three classes throughout the 2021/22 academic year on topics of image processing, digital signal processing, estimation, and inference
 - Marked and provided detailed feedback on submitted student tutorial solutions and tailored tutorial content to focus on gaps in understandings to maximise student educational benefit from the tutorials
 - Received consistent student evaluations reporting very high quality of subject knowledge, teaching, organisation, feedback, and positive atmosphere fostered in class
- Undertaking University of Oxford Scientific Entrepreneurship Course
- Undertaking University of Oxford Language Centre Italian Fast-Track Course Parts 1-2

Bachelor of Engineering (Robotics & Mechatronics)(Hons), Swinburne University, Australia *2013 - 2016*
 First Class Honours - GPA 4.0/4.0. Highest achieving graduate (course Dux). Industry-based learning year with DST Group. Industry-sponsored 4YP on remote particle-filter-based chemical source localisation with a ground robot.

Bachelor of Science (Mechatronic Systems), University of Melbourne, Melbourne, Australia *2010 - 2012*
 Awarded the Kwong Lee Dow scholarship for demonstrating excellence in leadership and academia

PROJECTS

Causal Reasoning & Explanations for Robot Manipulation. Leading a 8-person collaborative research project investigating the use of probabilistic causal generative models and Bayesian causal inference, for prediction, action-selection, and counterfactual explanations for mobile robots undertaking manipulation tasks in home-care and domestic assistance applications, to increase robustness of robot task execution and increase AI/robot trust and explainability with human end-users. Developed a causal world model encoding robot-world-task relationships using the PyBullet physics-based simulator, the robot decision-making process, and noise and uncertainties in robot sensing and manipulation actions. Developed Bayesian prediction and probabilistic optimal action-selection methods for the robot block stacking task as an exemplar application. Integrated the reasoning methods into a ROS-based autonomy framework targeting the Toyota Human Support Robot hardware, including an Aruco marker based 3D perception system and ROS MoveIt motion-planner and manipulation system ([IROS Causality for Robotics Workshop paper](#)). Demonstrated block tower prediction and next-best action selection for autonomous robot block tower construction using robot hardware, and in the Gazebo physics-based robot simulator. Extending the project to formulate the robot-world-task model as a SCM and develop post-hoc counterfactual explanation methods to explain robot behaviour and tasks outcomes in terms of robot perceptions, decisions, and actions. These methods will be used to create a human-robot natural language explanation system for human support robots, and will be integrated with the [Ethical Black Box](#) data recording system and [human-robot dialogue system](#) developed under the [RoboTIPS](#) UK Research and Innovation EPSRC Established Career Fellowship awarded to Dr Marina Jarotka (Project Ref: [EP/S005099/1](#)).

Decentralised MCTS for Robot Intelligence, Surveillance, and Reconnaissance Missions. simultaneous exploration and exploitation based on mutual information and present a general solution for scout-task coordination using decentralised Monte Carlo tree search (D-MCTS). We evaluate the performance of our algorithms in a multi-drone surveillance scenario Collaborated with UTS academic partners to increase task performance in heterogeneous multi-robot systems using dec-MCTS. Advised on UAS software and hardware design and field deployments; ran

field trials (incl. role of safety pilot); and co-authored scientific papers. Published a conference and workshop paper at ICRA 2021 on heterogeneous multi-robot teams for multi-drone surveillance applications. Won the [Best Paper Award](#) at the ICRA 2021 [Robot Swarms in the Real World Workshop](#)

Scaleable Multi-Robot Exploration & Return in Apriori Unknown Environments. Developed C++/ROS based decentralised multi-agent robot control software and performed robot autonomy software and aircraft companion computer hardware integration, to deliver DST Group project outcomes for the [Trusted Autonomous Systems Defence-Led Cooperative Research Centre](#). Led simulation- and hardware-in-the-loop (SITL, HITL) validation and lab-based autonomous flight validation activities.

Autonomous Drone Navigation & Mapping in Mixed GNSS-Available Urban Environments. Developed custom ArduCopter multi-rotor flight controller firmware and C++/ROS autonomy software to enable resilient drone navigation, localisation, and mapping in mixed GNSS-available urban environments, to deliver against DST Group commitments to the [Trusted Scalable Search with Expendable Drones project](#) within the [Trusted Autonomous Systems Defence-Led Cooperative Research Centre](#). Implemented adaptive use of SLAM and GNSS pose estimates (e.g., from GPS measurements) for hybrid localisation and stable automated localisation transitions. Performed validation through simulation and robot hardware indoor/outdoor flight trials.

Team ORion Task-Level Planning Sub-Team Lead (2021/22). Coordinated the design and development of high-level autonomous robot behaviours to accomplish complex domestic tasks by drawing on capabilities provided by the other sub-teams (e.g., perception, manipulation, human-robot interaction) for the RoboCup@Home 2022 competition and various team outreach activities.

Implemented complex behaviours as finite-state machines, using the ROS SMACH state machine package, robust to robot failure modes (eg manipulation failure) and sources of environmental uncertainty (eg object placement). Conducted verification and testing in Gazebo simulation and on robot hardware. Performed verification to ensure compliance of the autonomous behaviours developed for the RoboCup 2022 competition to rulebook task specifications.

SKILLS

AI/CS Skills	Probabilistic Bayesian Causal Modelling (CBNs, SCMs), Estimation & Inference (statistical & generative methods); Stochastic Variational Inference Parameter Estimation; POMDP Planning (MCTS, Dynamic Programming); Search & Shortest-Path Algorithms; Image & Signal Processing, Finite State Machines, Graph Theory, SLAM
Software Skills	C++/Python Object-Oriented Programming; Pyro Probabilistic Programming Language; PyTorch; pgmpy; ROS; Bash; MATLAB; Linux Networking; Linux/Windows/Mac OS; Collaborative Software Development (Git, GitHub/GitLab)
Robotics Skills	Embedded Robot Systems Design, Deployment & Field Trial Experimentation; Simulation & Verification; UAS Design; Flight Controller Firmware Development; Sensor Signal Processing; Electronics, Sensor & Actuator Integration; Control
Soft Skills	A 15+ year demonstrated record of leadership and teamwork skills, including: planning, organising, communicating and managing resources; motivation and conflict resolution; and stakeholder liaison. Undertook many leadership positions at work, university, and volunteering. Project management skills: organised several large-scale events with 50-100+ attendees (ball event, camps, outreach events), adept with project management tools.

WORK EXPERIENCE

Robotics Specialist (Defence Research Scientist) (S&T 3/4 Above)	Sep 2020 - Present (Study Leave)
Defence Science and Technology Group (DSTG)	Melbourne, Australia

- Performed R&D of trusted aerial autonomous systems for the Australian Defence Force and provided trusted advice

- Published a conference and workshop paper at ICRA 2021 on heterogeneous multi-robot teams for multi-drone surveillance applications. Won the [Best Paper Award](#) at the ICRA 2021 *Robot Swarms in the Real World Workshop*.
- Recipient of the DST Group PhD Study Support Programme (DPSSP) Award - Full Time International Mode, to undertake doctoral research at the University of Oxford on robust causal inference for the assurance of robot autonomy. Awarded 3-years PhD stipend funding. Received in-principle support for an additional 1-year funding extension.
- Undertook deputy manager role for the Fishermans Bend Flight Laboratory, performed lab training and inductions, maintained critical scientific infrastructure, and ensured health and safety compliance

Robotics Specialist (Defence Research Scientist) (S&T 3/4 Below)

Jan 2017 - Aug 2020

Defence Science and Technology Group (DSTG)

Melbourne, Australia

- Performed R&D of trusted aerial autonomous systems for the Australian Defence Force and provided trusted advice
- Published papers at top-tier international and Australian conferences (e.g., ICRA, Australasian Conference on Robotics and Autonomous Systems) on topics including robot swarming and teaming, characterisation of UAS sensor failure modes in particle-dense environments, and SLAM
- Led an experimental validation of a novel particle-filter-based 2D SLAM algorithm (6-person team). Generated a new dataset containing data from 7 scanning and solid-state LIDARs on a hexacopter, collected independently during automated laboratory flights. Evaluated the novel SLAM algorithm on two sensors from the dataset and analysed error propagation, compared performance with GMapping, published results in a paper.
- Supported 5+ key strategic robotics and autonomy research agreements with local and international partners across academia, industry and government/Defence. Performed UAS technology demonstrations at 4 international Defence joint trials in Australia, US, Canada, and Singapore.

Defence Research Scientist Cadet

Jul 2015 - Dec 2016

Defence Science and Technology Group (DSTG)

Melbourne, Australia

- Contributed to aerial autonomous systems R&D outcomes for the Australian Defence Force.
- Empirically validated a novel chemical source localisation with a bespoke sensor and ground robot using hardware design, C++/ROS/MATLAB software, and signal processing skills.

LEADERSHIP

- Served on the executive committee of the Young Scientists of Australia Melbourne Chapter Inc. for 9 years, in roles including President (2013-2016), Immediate Past President (2016-2019), Social Coordinator (2009-2012). Serving as President for 3 terms, I directed the 12-person executive committee to realise the organisation's goal of promoting science to the youth of Australia by delivering science outreach and social events for our 200+ membership base (ages 15-25). Under my leadership, the organisation annually delivered 12 social events and provided 40+ staff members across five 3-day STEM outreach programs for secondary school students. I further expanded the member services and outreach activities, directing the creation of 7 new initiatives.

PUBLICATIONS

- CAR-DESPOT: Causally-Informed Online POMDP Planning for Robots in Confounded Environments. Ricardo Cannizzaro, Lars Kunze. IEEE/RSJ IROS 2023. [\[Paper\]](#)
- Towards a Causal Probabilistic Framework for Prediction, Action-Selection & Explanations for Robot Block-Stacking Tasks, Ricardo Cannizzaro*, Jonathan Routley*, Lars Kunze. IEEE/RSJ IROS 2023 Workshop on Causality for Robotics. [\[Paper\]](#)

- Towards Probabilistic Causal Discovery, Inference & Explanations for Autonomous Drones in Mine Surveying Tasks. Ricardo Cannizzaro*, Rhys Howard*, Paulina Lewinska, Lars Kunze. IEEE/RSJ IROS 2023 Workshop on Causality for Robotics. [\[Paper\]](#)
- An Upper Confidence Bound for Simultaneous Exploration and Exploitation in Heterogeneous Multi-Robot Systems. Ki Myung Brian Lee, Felix Kong, Ricardo Cannizzaro, Jennifer L Palmer, David Johnson, Chanyeol Yoo, Robert Fitch. IEEE ICRA 2021. [\[Paper\]](#)
- Decentralised Intelligence, Surveillance, and Reconnaissance in Unknown Environments with Heterogeneous Multi-Robot Systems. Ki Myung Brian Lee, Felix H Kong, Ricardo Cannizzaro, Jennifer L Palmer, David Johnson, Chanyeol Yoo, Robert Fitch. IEEE ICRA 2021 Workshop on Robot Swarms in the Real World: From Design to Deployment. [\[Paper\]](#)
- ColMap: A Memory-Efficient Occupancy Grid Mapping Framework. Alex Fisher, Ricardo Cannizzaro, Madeleine Cochrane, Chatura Nagahawatte, Jennifer L Palmer. Robotics and Autonomous Systems 2021. [\[Paper\]](#)
- Evaluation of LIDAR and X-Band Radar Sensors in a Particle-Dense Environment. Ricardo Cannizzaro, Meaghan G Smith, Alexander W Blain, Thomas Baum, Kelvin Nicholson, Jennifer L Palmer. AIAC18: 18th Australian International Aerospace Congress (2019): HUMS-11th Defence Science and Technology (DST) International Conference on Health and Usage Monitoring (HUMS 2019): ISSFD-27th International Symposium on Space Flight Dynamics (ISSFD) 2019. [\[Paper\]](#)
- Experimental Validation of a Random-Finite-Set-Based SLAM Algorithm for Micro UAS. Ricardo Cannizzaro, Madeleine Cochrane, Lance Fang, Jennifer L Palmer. Australasian Conference on Robotics and Automation (ACRA) 2019. [\[Paper\]](#)
- Data Ferrying with Swarming UAS in Tactical Defence Networks. Robert Hunjet, Bradley Fraser, Thomas Stevens, Laura Hodges, Karina Mayen, Jan Carlo Barca, Madeleine Cochrane, Ricardo Cannizzaro, Jennifer L Palmer. IEEE ICRA 2018. [\[Paper\]](#)
- Source Localisation with a Bernoulli Particle-Filter-Based Bearings-Only Tracking Algorithm. Jennifer L Palmer, Ricardo Cannizzaro, Branko Ristic, Thomas Cheah, Chatura Nagahawatte, John Gilbert, Sanjeev Arulampalam. Australasian Conference on Robotics and Automation (ACRA) 2015. [\[Paper\]](#)