Matthew Budd

PhD Student in Robotics at the University of Oxford

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Research Interests

Sequential decision-making under uncertainty, with a focus on metareasoning (enabling autonomous systems to reason about their own reasoning capabilities and constraints), model-based reinforcement learning including Bayesian methods, communication-aware decision-making, and deployment on robotic platforms.

Education

DPhil in Robotics and Machine Learning 2020 – 2024
University of Oxford *Oxford*

- Supervised by Prof. Nick Hawes and Dr. Bruno Lacerda (Goal-Oriented Long-Lived Systems lab, Oxford Robotics Institute).
- DPhil Research Studentship supported by an Amazon Web Services Lighthouse Scholarship.

Master of Engineering in Engineering Science 2016 – June 2020
Pembroke College, University of Oxford *Oxford*

- First class (average 81%, 87% for Master's project). Placed 5th in a cohort of ~160 students.
- MEng research project: *Safe Planning for Markov Decision Processes with Unknown State Features*. Proposed and analysed a novel MDP safe exploration algorithm, which outperformed the state of the art and generalised the class of model that could be safely explored. Later extended during PhD research. Available: `matthewbudd.com/static/doc/M_Budd_Thesis.pdf`
- Awards: recipient of the Head of Department's Prize for Excellent Performance (2020), the Paul Martins - BP Scholarship in Engineering (2019), Gibbs Prize - Practical (2017), college Scholarships (2017, 2018, 2019), and an Institute of Engineering and Technology Diamond Jubilee Scholarship.

Research Experience

Robotics researcher October 2023 – February 2024
Ericsson Research, Stockholm, Cyber-Physical Systems Group. *Stockholm, Sweden*

- Research internship at ER working on communication-aware robotic systems, particularly UAVs.
- Carried out in-depth literature review into 4G/5G cellular systems for UAVs.
- Developed models and algorithms for ensuring robust communication at UAV altitudes and velocities. Improved significantly on then-current state-of-the-art.
- Carried out short-term co-supervision of two KTH master's students, as 5G/UAV domain expert. Their work focused on integrating robotic systems with cellular communication technologies.

PhD field research / robotic trial experience 2021 –
Working with a number of robot platforms to carry out experiments in the real world.

- Field trial for HUDSON project (below) – 4 weeks total deploying underwater robots and running experiment regimes at Loch Ness in Scotland, in adverse conditions and fighting hardware issues.
- 3-day safe exploration evaluation in underground bunker setting using a Boston Dynamics Spot. Responsible for experiment planning and monitoring/debugging system components on-the-fly.
- Demonstrated with the Spot robot at UK Atomic Energy Establishment "RACE" robotics test facility in Culham, as part of the Robotics and AI in Nuclear programme grant.

Research assistant July – October 2020
Autonomous planning - HUDSON project, `orcahub.org/engagement/partnership-fund/hudson`

- Main researcher on the Oxford team, I was responsible for the research, design and implementation of a novel autonomous underwater vehicle (AUV) planning framework.
- First system to enable retrieval of data from underwater sensor networks under high uncertainty.
- Took a lead role in coordinating work packages between teams of researchers at several institutions.

RoboCup @Home League 2019 – 2022
Team ORIon: `ori.ox.ac.uk/student-teams/team-orion/` *Sydney, Australia*

- **Manipulation sub-team leader and acting team leader** for 2022 RoboCup (Thailand) [`link`].
  - Overhauled manipulation & simulation system, assigned work packages to the 3-person sub-team.
  - Improved team-wide processes and managed the whole team as acting leader at the competition.
  - Researched and implemented robot manipulation behaviours for the Toyota HSR platform.
- 2019 (Sydney): design/implementation of manipulation behaviours, network/hardware debugging.

MEng 3rd-year group design project, 3-person team October 2018 – May 2019
"A New Beam-Profile Monitor for the Large Hadron Collider at CERN"

- Research and design development for a proposed cutting-edge proton beam imaging instrument.
- Optimised the design of high-speed gas jet apparatus with a GPU-accelerated simulation regime.
- Final technical presentation to Cern LHC Beam Instrumentation Group in Geneva.

Publications

1. Stephens, A., **Budd, M.** *(joint first authorship)*, Staniaszek, M., Casseau, B., Duckworth, P., Fallon, M., Hawes, N.& Lacerda, B. (2024, August). Planning Under Uncertainty for Safe Robot Exploration using Gaussian Process Prediction. *Autonomous Robots*.
2. **Budd, M.**, Lacerda, B., & Hawes, N. (2024, February). Stop! Planner Time: Metareasoning for Probabilistic Planning Using Learned Performance Profiles. *AAAI Conference on Artificial Intelligence*.
3. **Budd, M.**, Duckworth, P., Hawes, N., & Lacerda, B. (2023, March). Bayesian reinforcement learning for single-episode missions in partially unknown environments. *6th Annual Conference on Robot Learning (CoRL)*.
4. **Budd, M.**, Salavasidis, G., Kamarudzaman, I., Harris, C. A., Phillips, A. B., Hawes, N., Duckworth, P., & Lacerda, B. (2022, October). Probabilistic Planning for AUV Data Harvesting from Smart Underwater Sensor Networks. *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*.
5. **Budd, M.**, Duckworth, P., Hawes, N., & Lacerda, B. (2021, August). Mission Planning in Unknown Environments as Bayesian Reinforcement Learning. *IJCAI'21 Workshop on Robust and Reliable Autonomy in the Wild (R2AW)*.
6. **Budd, M.**, Lacerda, B., Duckworth, P., West, A., Lennox, B., & Hawes, N. (2020, October). Markov Decision Processes with Unknown State Feature Values for Safe Exploration using Gaussian Processes. *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*.

Teaching

Teaching Assistant / Programme Designer March 2022
AIMS Centre for Doctoral Training Robotics Course

- Improved the documentation, design and administration of a 4-day course which teaches mobile robotics to ~ 12 doctoral students. Taught on the course alongside one other teaching assistant.

General Robotics Research Training 2021-2022
ORI Robocup @Home League, team training

- Teaching assistance for two short courses introducing new graduate and undergraduate team members to ROS, software development best practices and Team ORIon's software stack.

Technical Skills

Research

- Confident with Python, NumPy, C++, ROS, Git, LaTeX, deep RL frameworks (OpenAI Gym, Stable Baselines 3).
- Working knowledge of ML DevOps (Weights & Biases), PyTorch, MATLAB, Simulink, containerisation (Docker), GPU-accelerated (CUDA) programming, cluster and cloud computing (AWS, Slurm).
- Experiment design, robotic trial skills.

Systems Engineering

- Linux, web development, mechanical & electrical CAD and prototyping, embedded (microcontroller, FPGA) systems, real-time OSs (FreeRTOS), databases (SQL), communications (5G NR, IPv4/v6, IEEE 802.15), industrial computer vision systems, basic-level SysAdmin & cryptography,
- Robotic research platforms: Boston Dynamics Spot, Clearpath Jackal, ecoSUB, Toyota Human Service Robot (HSR).

Industrial Experience

Technology Scholar at Cambridge Consultants Ltd. July – September 2019
Summer internship placement in a software and electronics group *Cambridge*

- **Software engineer** on a medical inhaler test rig project.
  - Design, development and testing of embedded software (embedded C++ and a FreeRTOS-based framework) and the front-end user interface (JavaScript and Python with a Tornado webserver).
  - Responsible for modelling elastic light scattering from microscopic vapour particles. Designed and ran a CELES (`github.com/disordered-photonics/celes`) simulation regime with CUDA.

Control Engineering Intern at Archangel Lightworks June – August 2018
Summer internship placement in a satellite optical communications start-up Harwell, Oxfordshire

- **Pointing, Acquisition and Tracking (PAT) Prototype Development** for Free-Space Optical Comms.
  - Completed a literature review and requirements identification/justification for the PAT system.
  - Produced a project plan, cost analysis and interface definitions between systems.
  - Carried out integration of multiple hardware and software components (a custom FPGA-based controller, actuators, IMU/GPS, and imaging devices) to prototype a high-speed PAT system.

Micro-Intern at Ensoft Ltd. December 2017
Week-long internship, adding functionality to the Ensoft intranet *Harpenden*

- **Python web-app development with Django**, for the front- and back-end of the site.
  - Added new functionality to automatically handle desk allocation changes by updating large IP phone configuration files and mailing lists, and front-end interface design work for these features.

Technology Scholar at Cambridge Consultants Ltd. September 2015 – July 2016, Summer 2017
Gap-year placement and summer internship in a software and electronics group *Cambridge*

- **Embedded Low-Power Communications Engineer** and Linux Kernel Software Developer.
  - Network architecture research and design for full-fledged IPv6 communications on IoT devices.
  - Designed and implemented: Linux kernel-space software in C including kernel modules and adding functionality to the kernel network stack, user-space software in C and Python, embedded software in C for Cortex-M microcontrollers. Cross-compiled custom designed Embedded Linux distributions with Yocto and OpenEmbedded.
- **Electronics and Low-Level Software Lead** on an internal cross-disciplinary robotics project.
  - Successfully delivered and presented a prototype robot arm system to be demonstrated at a company-wide meeting, overcoming significant time/budget constraints.
  - Took a lead role in the engineering design process, from requirements specification onwards.
  - `cambridgeconsultants.com/insights/robots-from-golden-fairy-to-iron-serf`