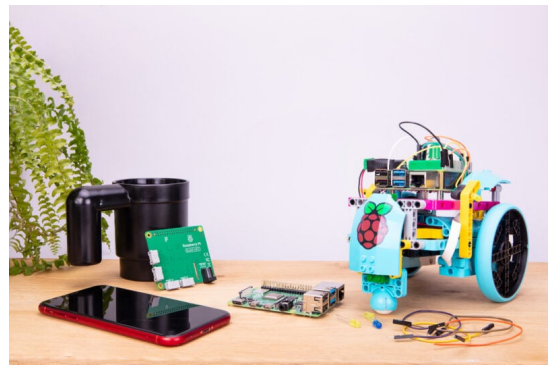


# 1 Behavioural Interactions in Simulated and Physical Robots

One of the goals of Artificial Life research, and that of Computational Intelligence, is to simulate natural phenomena to understand the complex world we live in. Both physical and natural agents (be that simulated or physical robots, or natural beings such as humans) are subject to interference from the unintended consequences of the actions of others that exist within the environment, dynamicity arising from changing or variable environments, or a mixture of both - making learning how to achieve goals a complicated process for both artificial and natural agents. Simulations by nature tend to simplify the complexity of these natural phenomena to understand the core interactions that take place in the physical world, where principled simplification can be used to simulate behaviour in simple simulations, that can help understand and predict behaviour in both complex simulations [1] and physical robots [2]. The two elements of the project complement one another, as simulation allows time- and cost-efficient exploration of new ideas, whereas real-world robots require time to configure but have a richer range of behaviours and interactions to observe. The activities outlined in this project are therefore designed to explore these complex interactions that arise in environments where agents coexist, with the aim of understanding how complex phenomena may simulated to reflect that of reality.

The primary aim for this project is to investigate how a collective of physical robots may be simulated to understand the dynamics that arise when multiple robots exist in a shared environment, and investigate whether this simulation can be used to predict robot behaviour in the physical world. The project will explore physical phenomena using LEGO Spike Prime kits that can be integrated with Raspberry Pis, cameras, and display modules, that can be configured according to the requirements of the experiments and research interests of the student. Since the LEGO robots are configurable, meaning that the robots may be heterogeneous in their physical appearance and capabilities, this project has flexibility to be tailored to explore phenomena such as the emergence of roles, cooperation and/or competition in resource-constrained environments. The project activities and outcomes will therefore depend on the student's research interests, such as exploring agent cooperation through gamification, self-organising or swarming behaviours that could give rise to identifying agents that are damaged and adapting behaviour accordingly, or the emergence of roles in an agent society. Designing a suitable simulation environment, potentially with ROS, would be the first objective for this project; for example, previous work in the advisory team investigated how simulated agents evolve to achieve goals independently in a gamified environment inspired by the Snowdrift Game (i.e. a two-person social dilemma with a cost for cooperation, but consequences for defection) [3]. After analysing the behaviours arising in simulation and defining hypotheses for how these results may translate to the real world, the experimentation would be repeated by configuring the physical LEGO robots to navigate the problem and observing the behaviours that arise. These observations from simulation and reality would gain insight into how behaviour may be predicted, and facilitate understanding of the complex phenomena that artificial agents face when they exist in a dynamic environment.



**Figure 1:** LEGO Spike Prime robot with Raspberry Pi (<https://www.raspberrypi.com/news/raspberry-pi-build-hat-lego-education/>)

## References

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- [3] C. M. Barnes, A. Ekárt, and P. R. Lewis, "Social action in socially situated agents," in *Proc. of the IEEE 13th International Conference on Self-Adaptive and Self-Organizing Systems*, 2019, pp. 97–106. DOI: 10.1109/SASO.2019.00021.

## 2 Advisory Team

### 2.1 Dr Chloe M. Barnes

Dr Chloe M. Barnes is a Lecturer in the Department of Applied AI and Robotics at Aston University, UK since 2022, after receiving her BSc in Computer Science and PhD from the same institution in 2017 and 2021 respectively. Her research interests are focused on observing and understanding how individuals behave when they are affected by unintended interactions and social dynamics when they share an environment, where her research is inspired by theory from neuroscience, biology, psychology and sociology to mitigate those interactions. Her research thus lies in the fields of Computational Intelligence, Artificial Life, and Evolutionary Agent-Based Systems. Dr Barnes has been a member of the Organising Committee for both the Artificial Life (ALIFE) and IEEE Autonomic Computing and Self-Organising Systems (ACSOS) conferences, has been a member of the Programme Committee for the ALIFE conference, the UK Workshop on Computational Intelligence, and the Workshop on Self-Improving Systems Integration, and is also the Steering Committee Secretary for the ACSOS conference. She is a member of both the Aston Centre for AI Research and Application (ACAIRA) and the Artificial Life and Intelligent Collectives Engineering research group at Aston.

### 2.2 Dr James Borg

Dr Borg is Lecturer in Computer Science in the Department of Applied AI and Robotics at Aston University, UK. He received his PhD in Evolutionary Systems from Keele University, UK, and has a BSc Artificial Intelligence and Computer Science, and MSc Advanced Computer Science from the University of Birmingham, UK. Dr Borg's research interests include Artificial Life, Evolutionary Systems, Social Learning, Cultural Evolution, Open-Ended Evolution, Adaptive Systems, and Social-technical Systems. Dr Borg is a member of EPSRC Peer Review College, has reviewed for a number of international journals including (but not limited to) Artificial Life, Adaptive Behaviour, ACM Transactions on Autonomous & Adaptive Systems, and Journal of Computational Social Sciences. He is a programme committee member for both the Artificial Life (ALife) and Genetic and Evolutionary Computation (GECCO) conferences and has been a guest editor for the Cognitive Systems Research Journal. Dr Borg is currently a member of the Association of Computer Machinery (ACM), British Computer Society (BCS), and International Society for Artificial Life (ISAL). He is also a member of Aston Centre for AI Research and Application (ACAIRA) management committee, and the programme director for Aston University's BSc Artificial Intelligence and Robotics programme.

### 2.3 Prof. Anikó Ekárt

Anikó Ekárt is professor of Artificial Intelligence at Aston University. Following her PhD at the Eötvös Loránd University, Hungary, she worked at the University of Birmingham as lecturer and at the Institute for Computer Science and Control, Budapest Hungary as senior research fellow. She has started as a lecturer at Aston University in 2006 and has taken various roles since, including Programme Director for MSc programmes in Artificial Intelligence, Associate Dean Postgraduate Taught Programmes and more recently Director of Research Degree Programmes in the College of Engineering and Physical Sciences. She is the director of the recently launched Aston Centre for Artificial Intelligence Research and Application (ACAIRA). Her research interests are centred around artificial intelligence methods and their application, with a focus on evolutionary algorithms and genetic programming. Following genetic programming performance improving methods, she has successfully contributed to applications of AI techniques to health, engineering, transport, and art. She enjoys interdisciplinary collaborations and has a large network of co-authors. In 2022 she was the winner of the Evo\* Award for Outstanding Contribution to Evolutionary Computation in Europe.

## 3 Research Group Information

### 3.1 Aston Centre for Artificial Intelligence Research and Application (ACAIRA)

Dr Barnes, Dr Borg, and Prof Ekárt are part of the Aston Centre for Artificial Intelligence Research and Application launched in February 2024 under the direction of Prof Ekárt. The centre gathers 27 academic staff members joining forces from various departments within the School of Computer Science and Digital Technologies, and their PhD students, who are typically joined by approximately 200 MSc students working on their dissertations May-to-January every year. The team co-creates AI solutions with stakeholders and uses AI to promote fairness and equity, guided by the 17 UN Sustainable Development Goals. The main aim of ACAIRA is to generate impactful societal benefits through: (1) principled and tailored AI solutions to modern-day social, health and environmental challenges via close collaboration with SMEs, local authorities, and governmental organisations; and (2) educating the next generation of AI leaders. The research carried out by the team includes:

- Theoretical foundations of AI and ML, their advantages, and limitations.
- Explainability and interpretability of results obtained by AI and ML, especially in critical applications.
- Using AI as a catalyst for a fairer society. The key areas of interest are health, justice, education, transport, and energy.
- Investigating sustainable AI solutions.

### 3.2 Collaborations

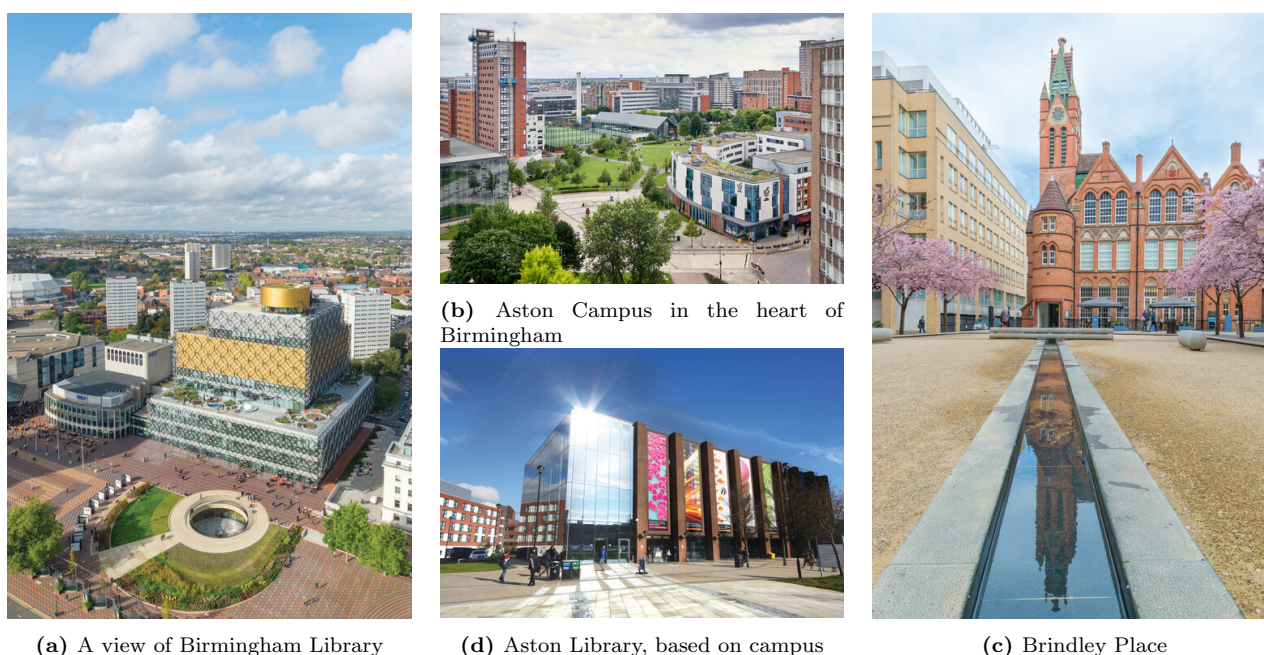
Most of our research is cross-disciplinary. We collaborate with researchers from across Aston University and external organisations alike, e.g., 3. Brain, Agilysis, Arcus, Asos, Blackline, CapGemini, Cognition, Gymshark, SmartApprentices, Thames Laboratories, Google, the Joint Research Centre of the European Commission, Los Alamos National Lab, and universities worldwide, including Aristotle University, Greece, UiT Norway, UF Alfenas, Brazil, Ontario Tech University, Canada, University of Sciences and Technology, Islamabad, Pakistan, Georgia Institute of Technology, USA, University of Texas, Medical Branch, USA, Université Mohammed VI Polytechnique, Morocco, Symbiosis Institute of Technology, Pune, India.

## 4 Aston University and Birmingham

Aston University has been a university since 1966 and was founded in 1895, with a diverse student community of 18,000 students from over 120 countries. Aston campus is located in the heart of Birmingham - England's second-largest city - with on-campus facilities such as sports centres, a swimming pool, gym, library (Figure 2d), cafés and pubs. On-campus accommodation is available to students, as well as a number of alternative options within walking distance to the university. Aston was also named both “*University of the Year*” and “*Outstanding Entrepreneurial University*” in 2020 by the Guardian and Times Higher Education respectively.

The advisory team are in the Department of Applied AI and Robotics, which is located in the School of Computer Science and Digital Technologies, in the College of Engineering and Physical Sciences. The advisory team are also members of the Aston Centre for Artificial Intelligence Research and Application, with Prof. Ekárt being the director, and Dr Borg being a member of the management team (<https://www.aston.ac.uk/research/eps/acaira>). Undertaking this project would allow the student to network with colleagues from the department and school, as well as the opportunity to work with other students in the Graduate School, due to the interdisciplinary nature of the college and school structure of the university.

Aside from Aston's green campus (Figure 2b), Birmingham is a beautiful city, with more miles of canals than Venice that can be explored. It is well connected to major UK cities such as London, Edinburgh and Manchester, with good links to the motorway and rail network; it is also in close proximity to Birmingham Airport (a 10 minute train ride from the city centre, where Birmingham New Street train station is a 15 minute walk from Aston campus) - making the city a major transport hub for the country. The city also boasts the largest regional public library in Europe (Figure 2a), located a 25 minute walk from campus into the city centre. The city centre is a 5-10 minute walk from campus, with a range of shops, cinemas, restaurants, bars, theatres, markets, and train stations. Birmingham is also renowned for its arts, history, culture, and street food scene, with places to visit such as Birmingham Museum and Art Gallery (15-20 minute walk), Thinktank Science Museum (10 minute walk), Ikon Gallery (Figure 2c, 30 minute walk), Digbeth Dining Club (various locations), and its long history of markets in the city (<https://visitbirmingham.com/things-to-see-and-do/attractions/culture-and-heritage/>).



**Figure 2:** Aston University campus and the surrounding city of Birmingham