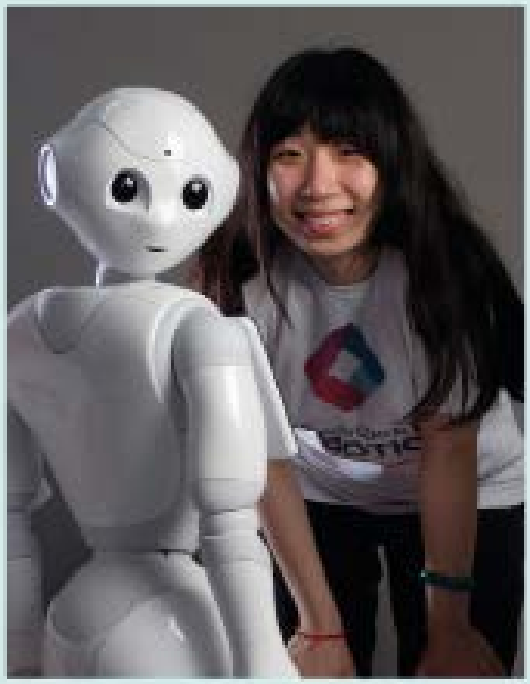
EDINBURGH CENTRE FOR
ROBOTICS

Innovation Ready



Annual Review
2021/2022

EPSRC Centre for Doctoral Training in Robotics and Autonomous Systems

HERIOT WATT UNIVERSITY

THE UNIVERSITY of EDINBURGH

UKRI Engineering and Physical Sciences Research Council

Contents

The Centre in Numbers 2014 -2022

- 2 Centres for Doctoral Training
- 9 Cohorts
- 75 Students
- 35 Alumni
- 74 Academics
- 136 Conference Publications
- 41 Journal Publications
- 40 Workshop Papers
- 53 Industry Partners
- 14 Industry Projects

Figures correct as of 30th September 2022

Foreword

Professor Helen Hastie Director, Heriot-Watt University
Professor Michael Mistry Director, University of Edinburgh

Welcome to our 2021/22 Annual Review featuring the latest news and developments from students and staff in our EPSRC Centre for Doctoral Training in Robotics and Autonomous Systems (CDT-RAS). We are now coming to the end of the third year of our second CDT programme, which has been a challenging time for students and staff due to ongoing Covid-19 restrictions. As restrictions started to lift and life started to return to some normality, we have been enjoying seeing the students more and more face-to-face. We were delighted to welcome 15 enthusiastic students to the programme in September 2021. With teaching finally returning to in person, we were happy to offer the Autonomous Systems Research course and other training in person. This included a fantastic writing week in Barony Castle and our annual retreat to Firbush also went ahead, with outdoor activities mixed in with learning about responsible research and innovation.

We are immensely proud of our students. Despite the recent challenges, we continue to have students graduate from our first CDT programme and progress to full employment in industry and academia. Students have continued to submit and have papers accepted for high profile conferences, which they are now starting to attend in person. This included a number of students winning conference awards, such as the KROS Interdisciplinary Research Conference Award in Social Human-Robot Interaction at the RO-MAN conference in Naples, Italy. Furthermore, a number of students secured prestigious internships with Amazon, Google, Touchlab, SeeByte and Schlumberger, which will allow them to develop and hone their research skills in a working environment. Activities also included taking part in international competitions such as the XPRIZE in California and the Amazon Simbot Challenge, where the Heriot-Watt Student Team has reached the stage in the competition where their entry, named EMMA, will soon be tested live across the USA.

Students in year two of the programme spent Semester 2 working together on their group projects, which resulted in three prototypes; one dialogue system for entry to the Alexa Prize SimBot Challenge and two soft robotic systems that were entered into The International Conference on Soft Robotics competition in April 2022, hosted by the University of Edinburgh. Furthermore, our entrepreneurial students continue to make good use of the Centre's Innovation Fund to allow them to build hardware and/or software prototypes that could lead to a commercial idea.

In recognition of outstanding work to recruit and support gender diverse students, we were very pleased to receive the 2021 Minerva Informatics Equality Award. This prestigious award recognises excellence in the encouragement to enrol, and retention of, female students in Computer Science and Informatics programmes. Claire Ordoyno travelled to Madrid to receive the award.

We were excited to open the National Robotarium building in September 2022 and welcomed the new CEO Stewart Miller. The National Robotarium team has been growing over the last year and now includes the COO, Impact Engineers, Business Development, Outreach and Project management staff. The National Robotarium is a joint initiative between our two universities supported by funding through the DDI programme of the Edinburgh and South East Scotland City Region Deal. It provides an innovative way of supporting research on key robotics issues and a mechanism for enhancing the delivery of impact across a variety of application areas. Along with the Bayes Centre, we now have extensive world-class facilities and innovation spaces, where industry can be involved in scoping and developing the research challenges that will deliver the robots of the future. Also, now our robots finally have a proper home, including MARTIN and MARTINA, our spot robots who were named in a school competition this year and also our ARI robots, who are now ensconced in the HRI labs and the new living lab, named LARA. Don't forget to keep up to date with the latest news via the National Robotarium newsletters.

Our sixth Annual Conference was held online again in September 2021. Our prestigious speakers included Dr Amit Pandey, Professor Lydia Kavraki, Andra Keay and Dr Sabine Hauert. Although this was a fantastic event, we are very much looking forward to seeing everyone in person at the CDT conference in 2022 and finally enjoy an evening meal together.

We look forward to the next two years, which will be the final years of recruitment for the current CDT. With the National Robotarium and related activities including exciting new collaborations, it will likely be an eventful year. On a final note, we would very much like to thank our funders at Heriot-Watt University, the University of Edinburgh, EPSRC, UKRI and our industry sponsors, who have made all of this possible.

About us

The Edinburgh Centre for Robotics (ECR) is a £120m plus joint venture between Heriot-Watt University and the University of Edinburgh, supported by EPSRC, Industry and the Universities.

It captures the expertise of over 70 principal investigators of international standing from across the School of Engineering and Physical Sciences and the Department of Computer Science at Heriot-Watt University, and the Schools of Informatics and Engineering at the University of Edinburgh.

The Centre includes two consecutive EPSRC Centres for Doctoral Training (CDT) in Robotics and Autonomous Systems which train innovation–ready postgraduates, a £9m capital equipment facility, the £19m ORCA Hub and the £26m National Robotarium.

The Centre includes affiliated students engaged in related EU, EPSRC and UKMoD research programmes, and collaborates with other CDTS across the UK.

The strategic aim of the Centre is to supply the urgent need for skilled, industry and market aware researchers in Robotics and Autonomous Systems. Interactions between robots, autonomous systems, their environments and people present some of the most sophisticated scientific challenges we must solve to realise productive and useful assistive or remote systems in our homes, workplaces and industries.

EDINBURGH CENTRE FOR ROBOTICS
Innovation Ready

The Edinburgh Centre for Robotics is training a new generation of researchers to take a key role in solving such problems. These innovation-ready PhD students are being prepared to enter, lead and create the UK's innovation pipeline in this area for jobs and growth.

The Centre focuses on autonomous robot interaction with environments, people, systems and each other. We also research and develop work on Interaction Enablers, applying fundamental theoretical methods to real-world problems, using real robots to solve vital commercial and societal needs.

Research is conducted using state of the art humanoid and field robotic platforms, in interactive spaces with fabrication facilities for soft embodiments, embedded microsensors and dedicated computing. Centre partners include companies in the energy, assisted living, transport, defence, medical and space sectors.

Management Structure

The Executive

The Executive is chaired by the Directors and is responsible for day-to-day operations of the Centre. Membership of the Executive is made up from the leadership teams from each University, Centre Administrators and student representatives. The Executive is responsible for student recruitment, progress and pastoral matters, public outreach, administering budgets, supervisor selection, organisation of annual conference and guest lectures, #Cauldron training programme, and commercialisation processes. It is also the first arbiter in the conflict resolution process with partners and students.

The Steering Group

The Steering Group consists of the Directors, senior academics from the Postgraduate Studies Committees at Heriot-Watt University and the University of Edinburgh, as well as a representative from industry (the Chair), EPSRC and from the RAS CDT student body. The remit of the Steering Group is to monitor the progress of the Centre, IP and licensing arrangements and relations with industry members, and to review and propose strategy and policy. The Steering Group will also act as final arbiter in the conflict resolution process for students and partners.for students and partners.

The External Advisory Board

External Advisory Board reports to the Steering Group and comprises representatives from the Industry Members engaged with the Centre, plus international academics and the Centre Management team. It meets at least annually to monitor the work of ECR, provide strategic advice, support development of new business relationships and promote best practice. Members of the External Advisory Board serve in a non-executive capacity.

The Academic Board

An Academic Board involving all active supervisors and both Universities' representatives will also report to the Steering Group. Meeting annually, and chaired by the Directors, it will monitor the academic quality and delivery of both the taught courses and the research projects and will deal with formal student progression.

Equality, Diversity and Inclusion (ED&I) Statement

The CDT in Robotics and Autonomous Systems is committed to facilitating a shift in the culture and diversity of the robotics research community through pro-active practices to support equality, diversity and inclusion at all levels.

A principal aim is to promote wider gender diversity in the field of RAS. More generally, the CDT will ensure all students and staff are respected and valued for their unique perspectives and contributions, and that no-one is treated differently or less favourably on the basis of age, disability, gender reassignment, marriage and civil partnership, pregnancy and maternity, race, religion or belief, gender or sexual orientation.

Positive actions we are taking include:
Student recruitment - The CDT actively encourages applications from groups who are under-represented in the Centre. We have clear guidelines for student recruitment and all academic staff are encouraged to participate in the recruitment process through interview panels or at the regular consensus meetings when student appointments are made. We ensure diversity on our interview panels to make the selection process fair and transparent for all candidates. We will continue to monitor our marketing materials and website to ensure that we include female students and those from diverse backgrounds. Our future recruitment strategy includes visits to universities by female staff, including the centre director, and female-only student open days.

Training - We are creating a culture of awareness at the Centre to increase diversity by providing Unconscious Bias Training for academics and professional support staff, and a mandatory on-line Diversity in the Workplace training course for all students in the first year of their PhD.
Speakers at our Annual Conference and Gateway training seminars from academia and industry will be selected to reflect our commitment to diversity.

Support - We will promote increased student satisfaction by creating an inclusive, supportive learning environment. We will address the issue of potential isolation that frequently arises from low representation in small cohorts by supporting cross-cohort activities, cross-CDT events and links to the wider PhD student communities within the institutions, which have sufficient mass to overcome this issue.

Inclusion will be enhanced by providing female-only events (e.g. hackathons) and support groups, such as Women in Robotics Edinburgh (WiRE). The personalised Technical Learning Portfolio approach for CDT2 students is specifically designed to provide students with a flexible working pattern, thus maximising retention for students with personal circumstances e.g. for carers or those with health-related issues.
We recognise that ED&I is a matter for all staff and students within the Centre but to ensure that we are able to provide the required level of support, Professor Barbara Webb is primarily responsible for ED&I and Dr Michael Herrmann will provide pastoral care.

The CDT is a partnership between Heriot-Watt University and the University of Edinburgh and is fully aligned with the ED&I policies of these institutions which can be found at the below links.

Heriot-Watt University https://www.hw.ac.uk/uk/services/equality-diversity.htm
University of Edinburgh https://www.ed.ac.uk/equality-diversity

Equality, Diversity and Inclusion Activities

The Centre Executive has been working hard during the last academic year to ensure that we actively address ED&I matters at all stages of the student life cycle.

Staff closely involved in advertising for recruitment attended a workshop led by Equate Scotland on inclusive recruitment practices. After the workshop, the language used in our main application sites was revised to be more welcoming and encouraging to a range of applicants. The next phase will include providing guidance to academics responsible for writing research project descriptions including good practice examples.

We were aware that there was potential for unconscious bias in our recruitment process and we have addressed this by requiring all academics involved to undertake unconscious bias training and ensuring that we have a female academic on interview panels for female students. A core interview panel, standardised interview questions and a clear written record of the interview proceedings ensure consistency in our recruitment practices.

Students are asked to complete online Diversity in the Workplace training when they start the CDT programme and it is proposed that we organise a student workshop to explore EDI issues in robotics as soon as possible. The CDT also collaborates with CDTs from the School of Informatics at the University of Edinburgh to survey students on how well the ED&I policies work and we act on feedback provided.

The CDT-RAS Female Mentorship Programme was created in February 2021 to empower and inspire female students and to help combat feelings of isolation. It supports the student-led WiRE (Women in Robotics Edinburgh) group, and was set up in response to the WiRE Group identifying a need for advice and guidance. The Mentorship Programme connects CDT-RAS female students to inspirational women in the field of robotics and AI through seminars and mentorship sessions, complemented by networking opportunities. This programme is currently being trialled with our female students and we intend to make this available to all students in the CDT in the future.

Going forward, we will be highlighting the successful trajectories of our diverse graduates as inspiration for future applicants to the programme.

Equality Award win for EPSRC Centre for Doctoral Training in Robotics and Autonomous Systems

In recognition of outstanding work to recruit and support gender diverse students, the EPSRC Centre for Doctoral Training (CDT) in Robotics and Autonomous Systems has won the 2021 Minerva Informatics Equality Award.

The prestigious award recognises excellence in the encouragement to enrol, and retention of, female students in Computer Science and Informatics programmes.

Open to faculties and research labs in universities across Europe, the accolade is awarded to an initiative that demonstrates exceptional results in supporting the careers of women in informatics research and education.

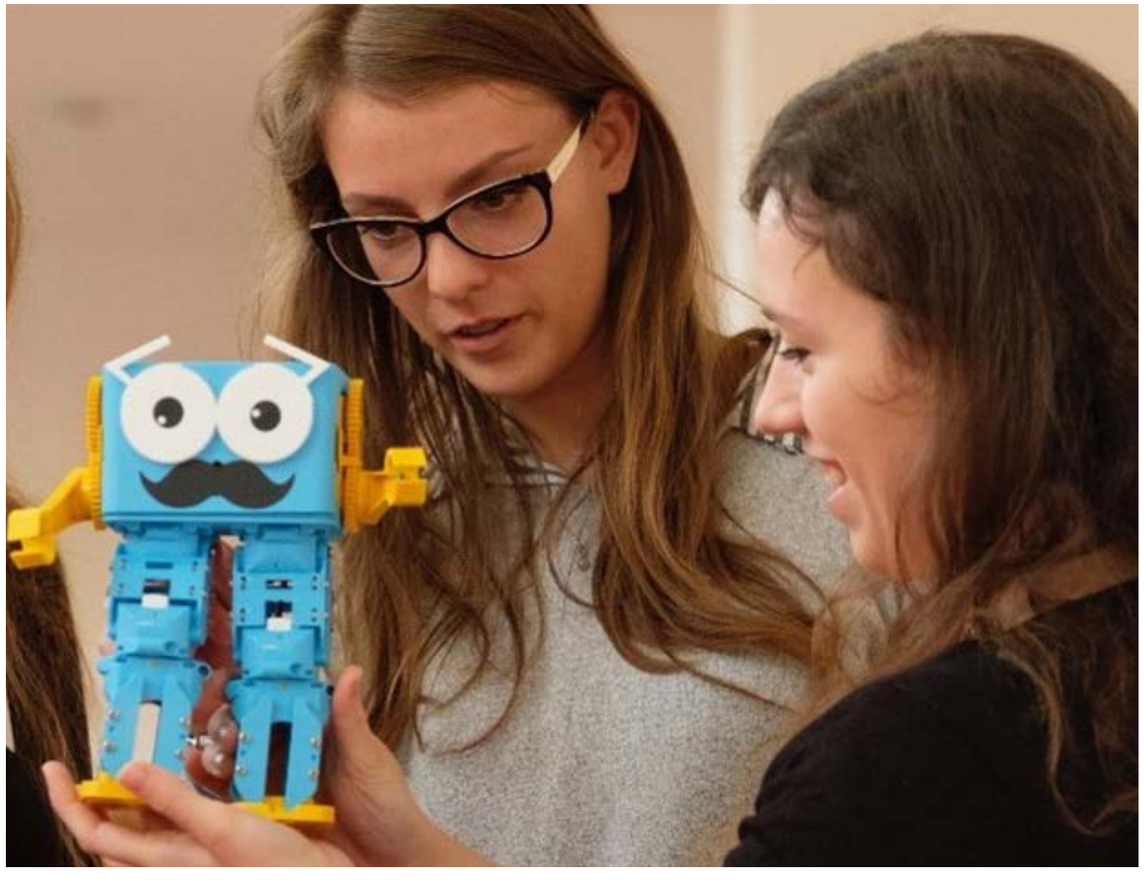
The award was presented at a ceremony on 26 October during the 17th European Computer Science Summit (ECSS 2021). The Minerva committee emphasised that the standard of entries this year was very high, but that the range of support offered by the CDT and its proven impact were what set the Centre apart.

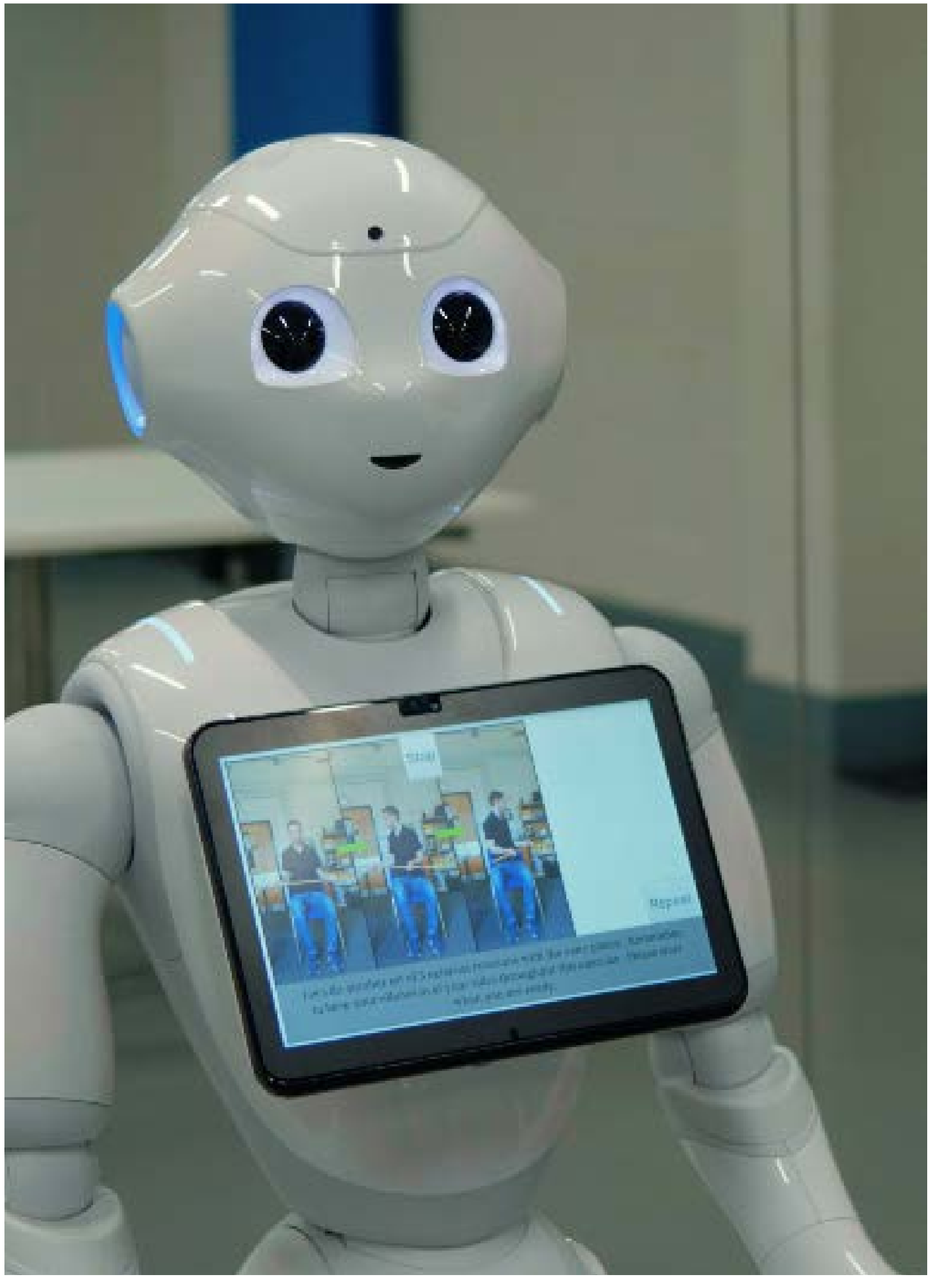
Professor Helen Hastie, Director of the EPSRC Centre for Doctoral Training in Robotics and Autonomous Systems, and co-academic lead of the National Robotarium based at Heriot-Watt University, said: "We are extremely honoured to receive this prestigious award in recognition of our ongoing commitment to supporting equality, diversity and inclusion at the Centre. We have collaborated closely across all areas of the CDT to recruit and retain gender diverse students, with our numbers increasing strongly year on year since 2017.
“Female and gender non-binary students made up 33% of the 2020 cohort with 100% retention of these students from the 2019 and 2020 cohorts. We are enormously proud of the success of all our students and are committed to growing and building on our existing initiatives to create a welcoming, inclusive environment and to further widen the pool of diverse and talented individuals choosing robotics as a career."
Claire Ordoyno, Business Development Executive at the CDT travelled to Madrid to receive the prize and present the scope and impact of the CDT’s actions. She said: “Our student body has many inspiring examples of inclusivity rooted at its core including a Female Mentorship Programme and the student-led WiRE (Women in Robotics Edinburgh) group, which the Mentorship Programme supports. It was created by female CDT students to address feelings of isolation and now has members outside of the CDT which is a wonderful example of its wider impact.”

Professor Barbara Webb, equality and diversity lead at the CDT, said: “It has been crucial to our approach that we combine a wide range of diversity initiatives to embed inclusion at the centre of our culture.
For example, in recruitment we start by including visits to universities by inspiring female academics. We then ensure gender inclusive language is used throughout our application process, and arrange for wide representation on interview panels to make the selection process fair and transparent.
We require our academic and support staff to take Unconscious Bias Training and our students have a mandatory Diversity in the Workplace course in their first year.”

The Minerva Award is sponsored by Google and carries a prize of 5,000 Euros to further work on promoting gender equality, creativity and entrepreneurial processes. These are an essential component of the CDT programme.

The centre is leading the UK's efforts to realise the potential of robotics by producing a new generation of highly skilled researchers, trained to take a central role through technical ability coupled with industry, market and social awareness. The centre is funded by the Engineering and Physical Sciences Research Council (EPSRC), which supports postgraduate training in engineering and the physical sciences.





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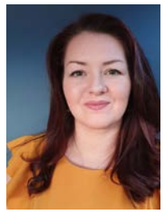

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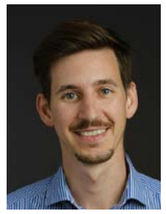

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EPSRC Centre for Doctoral Training Robotics and Autonomous Systems

Robots that can learn, adapt and make decisions will revolutionise our economy and society over the next 20 years. They will work for us, beside us, assist us and interact with us. It is estimated that by 2025 such advanced robotic and autonomous systems (RAS) could have a worldwide economic impact of $1.7 trillion to $4.5 trillion annually, with an emerging market value of €15.5 billion.

The Edinburgh Centre for Robotics is advancing the UK's industrial potential in this revolution by producing a new generation of highly skilled researchers, trained to take a leading role. They are technically skilled, industry and market aware, and prepared to create and lead the UK's innovation pipeline for jobs and growth.

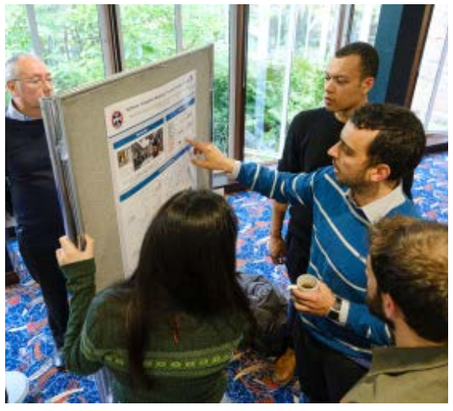
Our Doctoral students are part of a multi-disciplinary enterprise, requiring sound knowledge of physics (kinematics, dynamics), engineering (control, signal processing, mechanical design), computer science (algorithms for perception, planning, decision making and intelligent behaviour, software engineering), as well as allied areas ranging from biology and biomechanics to cognitive psychology. Our students specialise in one of these areas, gaining a deep understanding of technical aspect and theoretical foundations. They also receive broad training across these fields so as to meaningfully engage with a wide cross section of the robotics community.

Achieving impact with robotics also requires non-technical skills, for example an understanding of technology translation, creativity and entrepreneurial processes. These are an essential component of the CDT programme, captured in the #Cauldron training programme.

We offer around 15 studentships per year. Funding comes from EPSRC, Industrial Partners, Heriot-Watt University and the University of Edinburgh.

Key Benefits EPSRC Centre for Doctoral Training Robotics and Autonomous Systems

- Fully funded 4-year studentships covering tuition fees and maintenance at prevailing EPSRC rates and project related costs.
- Access to our world class infrastructure, enhanced through our £26m capital equipment facility, the National ROBOTARIUM and the BAYES Centre.
- Students benefit from supervision by academic experts from both institutions and graduate with a joint PhD from Heriot-Watt University and the University of Edinburgh.
- Excellent training opportunities, including some masters level courses in year one, supplemented by the #Cauldron programme, which includes training in commercial awareness, social challenges and innovation.
- Innovation funding available to support development of early commercialisation prototypes.
- Opportunities for international placements in prestigious labs with industry or international partners.
- Opportunities to work on group project, and compete in international robot competitions (e.g. RoboCup Search and Rescue, SAUC-E Autonomous Underwater Vehicle Challenge Europe), European Robotics League, Amazon Simbot Challenge.
- Opportunity for competitive selection for funding from Cambridge IGNITE and MIT Sloan School of Management Entrepreneurship Programmes.



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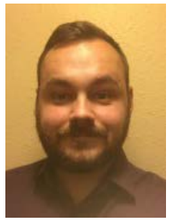

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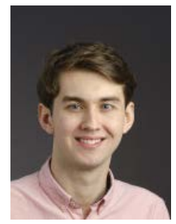

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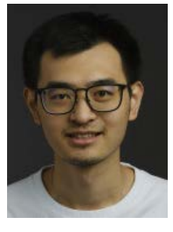

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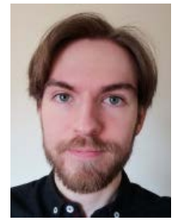

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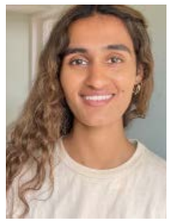

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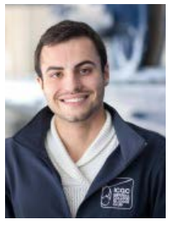

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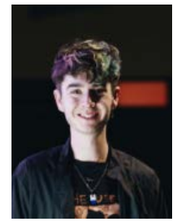

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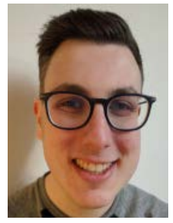

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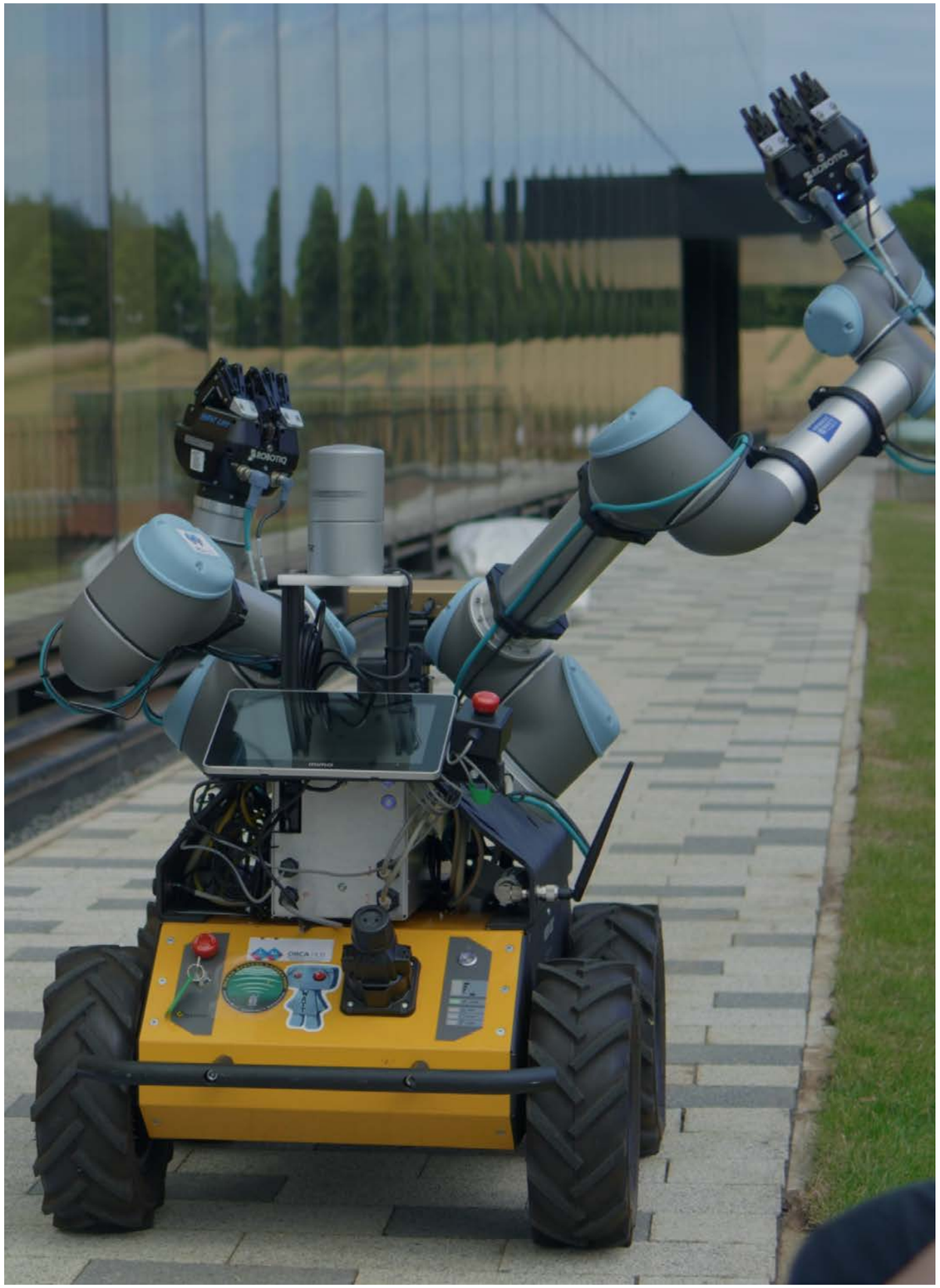

Research Themes

Research in the Centre is underpinned by established bodies of theoretical work. We apply fundamental theoretical methods to real-world problems on real robots to solve pressing commercial and societal needs.

The central theme running throughout our research at the Centre for Doctoral Training is Safe Interaction, which is broken down into the following four themes:

1. **Physical Interactions** deals with the interaction between the robot and the environment and includes studies in control, actuation, compliance, sensing, mapping, planning, embodiments, swarms.

2. **People Interactions** deals with interactions between robots and humans in a variety of settings and applications, and includes studies in human-robot interaction, affective robotics, smart spaces, human-robot teaming, collaborative decision-making, cobots, multimodal interfaces.

3. **Self-Interactions** deals with introspection for condition monitoring, prognosis, explainable AI, certification, verification, safety, security, multi-agent interactions.

4. **Interaction Enablers** deals with core technologies for Robotics and Autonomous Systems and includes studies in vision, embedded and parallel computing, novel and soft fabrication methods, optimisation, (transparent) machine learning, deep reinforcement learning and other AI techniques inc. natural language processing (NLP).

RESEARCH
EDINBURGH CENTRE FOR ROBOTICS

Research and innovation in the Centre focuses on new ways to make robots interact: with the **environments** around them, seeing, mapping, touching, grasping, manipulating, balancing; with **people**, understanding mood or emotion, using different sensory pathways including sight, touch, speech, gesture while predicting intentions and sharing plans; with **each other,** working collaboratively to achieve a task or capability; and with **themselves**, monitoring their self-health and performance.

We study the sensing, world modelling, planning and control architectures that can make these robots **persistently autonomous**, operating in unknown environments for extended periods adapting their plans in response to events to complete tasks. We also investigate **shared autonomy** where people and robots operate in highly synergistic ways to complete tasks.

We study nature to develop **bio-inspired** systems that sense and process data using the methods that have evolved in biological organisms. Finally, we also think about **ethical issues**, the decisions robots should and shouldn't be allowed to make, and the **regulatory** environments they work in.

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Basile, Pierpaolo, **Alessandro Suglia**, Claudio Greco, Giovanni Semeraro.
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Selected case studies 2021/2022

Learning robotic cutting from demonstration: Non-holonomic DMPs using the Udwadia-Kalaba method

PhD candidate: Artūras Straižys
Supervisors: Professor Subramanian Ramamoorthy, Dr Suphi Erden, Dr Michael Burke

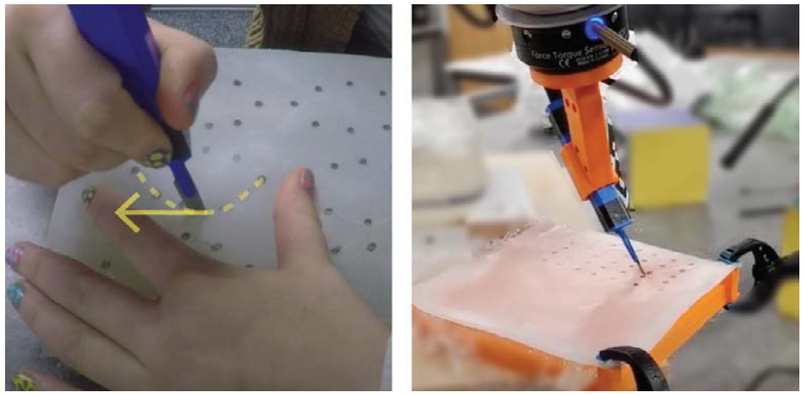

Figure 1: Cutting tasks feature non-holonomic constraints that must be considered in automation: a pure lateral movement of the blade is undesired, as it causes unnecessary stress to the material and risks tearing, an unwanted mode of fracture propagation.

Introduction

Dynamic Movement Primitives (DMPs) are a popular method for encoding, generating, and adapting complex end-effector trajectories. However, the reactive nature of DMPs restricts their use in tasks with non-holonomic constraints, such as cutting (Fig. 1). The non-holonomic systems are path-dependent; hence, motion adaptation requires global trajectory re-planning to reach the goal state. We extend the Cartesian space DMPs with a coupling term that enforces a set of holonomic and non-holonomic equality constraints at run-time.

Method

We apply the Udwadia-Kalaba (UK) theory to derive an analytical expression for the constraint coupling term. We demonstrate the usefulness of the proposed method in learning robotic cutting skills from demonstration. To this end, we encode the demonstrated pose trajectory with two uncoupled DMPs for position and orientation movement components. We extend the position DMP with an analytically derived constraint coupling term and we optimize the unconstrained orientation DMP such that the constraint coupling term is minimized.

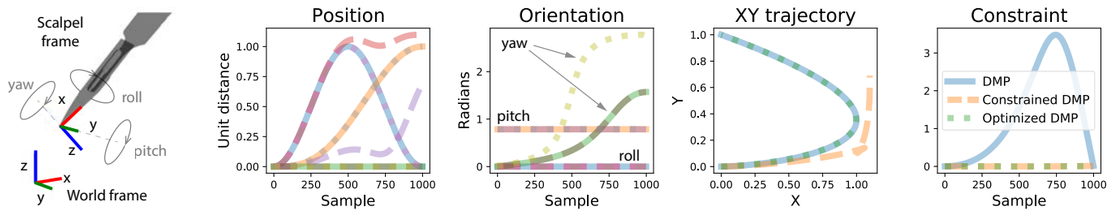

Figure 2: (Left) Scalpel frame. (Other) Regular DMP (solid lines) imitates the demonstrated cutting trajectory that closely follows the desired curved contour on the XY plane but violates the constraint. The constrained DMP constrained (dashed lines) satisfies the constraint but deviates from the demonstrated position trajectory. The optimized DMPs closely follow the desired pose trajectory and satisfy the constraint.

Results

Fig. 2 illustrated the numerical example of the proposed approach. Here, we assume that desired cutting contour lies on the XY plane. The demonstration successfully traces the contour but violates the constraint (Fig. 3A).

As expected, the constrained position DMP deviates from the desired contour (Fig. 3B). The proposed optimization of DMPs with respect to UK-based coupling term shows successful trajectory tracking without constraint violation (Fig. 3C).

Fig. 4A shows the demonstrations of elliptical tissue excision (Fig. 1, left). The constraint curves indicate the systematic violation of the non-holonomic constraint. Fig. 4B shows the proposed non-holonomic DMPs with optimized orientation, which match the demonstrated position trajectories and satisfy the constraint throughout the entire task execution.

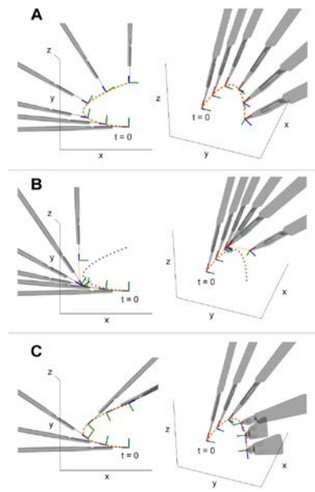

Figure 3 (A) Demonstration violates the non-holonomic constraint. (B) The rollout of constrained DMP. (C) The rollout of optimized DMP. Note, that the optimized DMP closely follows the desired path on the XY plane (marked by a dotted line) and satisfied the non-holonomic constraint.

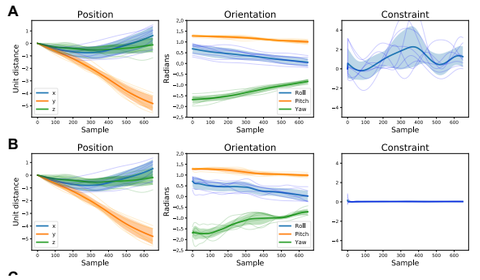

Figure 4 (A) Demonstrated blade trajectories in the elliptical excision task. (B) Optimized non-holonomic DMPs. (C) Adjustments to orientation trajectories of the blade.

Impact

We proposed a novel method to constrain DMPs via an additional coupling term derived from the elegant Udwadia-Kalaba theory. This approach allows the incorporation of a broad range of equality constraints and their combination, such as holonomic, nonholonomic, scleronomic, rheonomic, catastatic and acatastatic, among others. This contribution opens many opportunities for the application of DMPs in tasks under non-holonomic constraints, such as scalpel cutting or catheter steering.

Influence of Animal-like Affective Non-verbal Behaviour on Children's Perceptions of a Zoomorphic Robot

PhD candidate: Isobel Voysey
Supervisors: Dr Michael Herrmann, Prof. Lynne Baillie, Prof. Joanne Williams

Introduction

Charities like the Scottish Society for Prevention of Cruelty to Animals (Scottish SPCA) have a mission to improve animal welfare for the good of animals, the people who interact with them, and society more broadly. One way that they do this is through education programmes in schools, which aim to teach children about animals' welfare needs and mental abilities and to reduce acceptance of cruelty to animals. The Scottish SPCA does not take live animals into schools for multiple reasons, from concerns about stressing the animals to concerns about potential bites, scratches, or allergies. This means that they currently use stuffed toys and videos to get children to think about interactions with animals. However, a previous study conducted in partnership with the Scottish SPCA showed that simple mechanical rabbits produced better educational outcomes than stuffed toy ones [1]. Therefore, my PhD project is working in conjunction with the Scottish SPCA to develop a robot to try to make their programmes more engaging and effective at teaching children about animal sentience, encouraging appropriate behaviour, and changing attitudes to cruelty.

Objectives

The research questions for this study were formulated with the aims of animal welfare education programmes in mind to assess whether a zoomorphic robot could potentially be used in that context. They were as follows:

1. What mental abilities do children ascribe to a zoomorphic robot?
2. What is the impact of animal-like affective non-verbal behaviour on ascribed mental abilities and social attributes?
3. What are children's attitudes to cruelty towards a zoomorphic robot? What reasoning do they give for their beliefs?

Approach

We conducted an experiment investigating children's perceptions of a zoomorphic robot, MiRo, which was carried out with 49 participants aged between 7 and 10 years old at a local primary school.

The children were split into two groups: one which interacted with a version that expressed animal-like affective non-verbal (emotive) behaviour through the ears, eyes, and tail and one which interacted with a version without emotive behaviour. Participants each had an individual interaction with MiRo which comprised three sense familiarisation tasks – to show them the robot could see them, hear them, and feel them – and a three-minute freeform interaction.

Figure 1: Experimental setup showing child interacting with MiRo

We measured several measures before and after the interaction so we could compare changes in beliefs. The dependent variables were perceived mental abilities (in emotion, perception, cognition intention, and self-awareness), social attributes, and attitude to cruelty.

Results

Children who interacted with the emotive robot increased in their beliefs about its emotional ($p=0.04$, $r=0.49$), perceptual ($p=0.03$, $r=0.51$), and cognitive ($p=0.03$, $r=0.55$) abilities. Children who interacted with the non-emotive version had no significant change in their perceptions of its abilities.

Both groups of children were very unaccepting of cruelty towards robotic animals, especially so for intentional cruelty, and acceptance of cruelty was negatively correlated with perceived zoomorphism, animacy, and likeability. However, there was a divide in the reasoning children gave about why intentional cruelty was unacceptable. We conducted a post-hoc analysis on the reasoning children gave using the constant comparative method [2]. This divided the responses into two distinct themes of reasoning:

1. It damages someone's property (N=27)
2. It's a being with moral standing (N=14)

We ran further tests to see if there were any other differences between the groups and there was no demographic difference, but children who had used language that suggested a view of the robot as a being with moral standing had rated it as significantly more animate ($p=0.03$, $r=0.34$), and had ascribed higher abilities in perception ($p=0.02$, $r=0.36$), emotion ($p=0.04$, $r=0.31$), and intention ($p=0.009$, $r=0.41$).

Future Work

The next steps of this project are to conduct participatory design workshops with educators from the Scottish SPCA and schoolchildren to develop a robotic system for animal welfare education, both the physical robot and the interaction paradigm. Our study has highlighted the importance of animacy for views on moral standing, so we will particularly be looking for features identified by animal welfare educators and children that could give the robot a sense of animacy.

Publications

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Figure 2: Word cloud representing frequency of words used by children in their reasoning about why it is unacceptable to kick a robotic animal

EMMA: Embodied MultiModal Agent for Language-guided Action Execution in 3D Simulated Environments

PhD candidates: Bhathiya Hemanthage, Malvina Nikandrou, Georgios Pantazopoulos
Supervisors: Dr Alessandro Suglia, Amit Parekh

Introduction

Robots that perform tasks in human spaces can benefit from natural language interactions that facilitate human-robot collaboration. The Amazon Alexa Prize SimBot Challenge is an ongoing university competition that aims to propel research efforts on embodied agents that learn to execute tasks from instructions. In particular, the challenge introduces a gamified simulated environment that abstracts low-level control in order to focus on contextual language understanding, visual grounding, and reasoning. The outcome of the challenge is determined based on the ratings of Alexa users (in the United States) reflecting their experience guiding the teams' agents in completing different missions.

We develop Embodied MultiModal Agent (EMMA) , a language-enabled embodied agent capable of executing actions conditioned on dialogue interactions. Existing agents in similar environments treat action prediction as a classification task, whereas EMMA is a unified, autoregressive text generation model that accepts visual (observations) and textual (dialogue) tokens as input, and produces natural language text and executable actions. Combined with multitask pretraining, this approach allows knowledge transfer between domains, leading to an embodied agent able to generate grounded actions.

Approach

We conducted an experiment investigating children's perceptions of a zoomorphic robot, MiRo, which was carried out with 49 participants aged between 7 and 10 years old at a local primary school.
EMMA 's components are shown in Figure 1: Perception, Ambiguity Detector, Policy, and

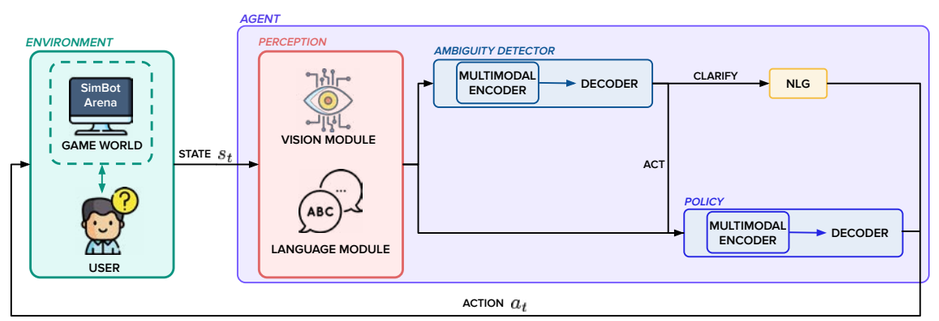

Figure 1: High-level architecture of EMMA. The Perception component processes new visual and language input at each timestep. Both streams are then passed to the Ambiguity Detector and Policy. The resulting action at is either a physical action or text generated from the NLG component.

Natural Language Generation (NLG). Each new instruction is processed by the Ambiguity Detector. In the case of ambiguity, the model outputs both the type of clarification (e.g. the location of an object) as well as the object to be disambiguated. The NLG uses this output to generate an appropriate clarification in a template-based manner. After receiving the dialogue history and the current observation of the environment, the Policy module generates the next actions until the stop action is predicted.

EMMA is a Transformer encoder-decoder model that benefits from multitask vision-and-language pretraining in order to jointly predict actions and object references. The pretraining tasks are selected to distill in the model both global and fine-grained image understanding skills. EMMA is then finetuned on the downstream tasks of ambiguity detection and action prediction using the SimBot challenge data. The action space includes seven low-level navigation actions (such as 'Move Forward', 'Rotate Left') as well as twelve interaction types (such as 'Pick up', 'Toggle'). A correct interaction ,action requires predicting the correct action and a pixel-wise object mask. The data include both human and synthetic instructions. Human instructions are additionally annotated with clarification questions and answers when necessary.

Results

We evaluate the ability of the Policy model to predict the correct next action given the instructions and ground-truth action history. For ambiguous instructions, the dialogue history includes the instruction followed by a clarification question and answer. We first compare the performance of the Policy model against a baseline trained from scratch on the SimBot data. Our results validate the benefits of our pretraining procedure, especially for predicting the correct objects. Figure 2 shows an example of model predictions. In addition, we examine the model's sensitivity to clarification questions. We observe that when including the clarification question and user response, the model is able to predict the correct action more often.

	Unambiguous Instructions		Ambiguous Instructions	
Method	Exact Match	Object Accuracy	Exact Match	Object Accuracy
EMMA	**93.76**	**92.32**	**90.68**	**85.24**
- clarifications	**93.76**	**92.32**	85.44	82.59
- pretraining	72.91	44.09	64.30	44.50

Table 1: Results for next action prediction. We report the Exact Match which checks if both the predicted action and object are correct, as well as the standalone Object Accuracy.

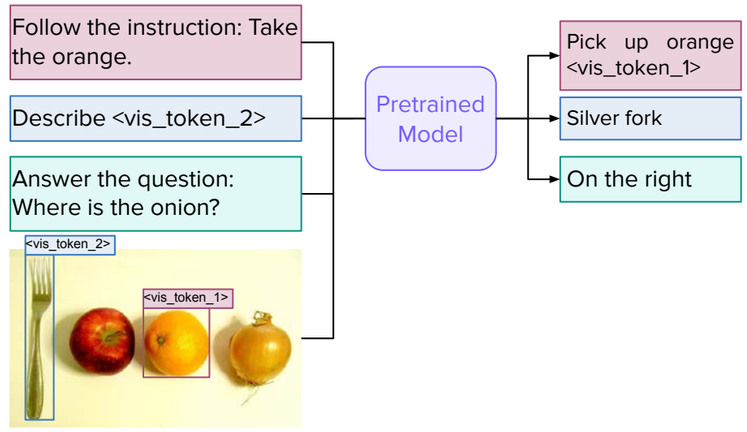

Figure 2: Example of model predictions for different tasks after finetuning for action prediction. These examples showcase the use of a) natural language prompts to specify the task, b) visual tokens to reference detected objects.

Impact

As agents become capable of performing a large variety of tasks, natural language will play an essential role in safe and trusted human-robot interactions. Mainly, language can act as a flexible and interpretable way of communicating goals. In addition, instructions and clarifications can help agents in completing more tasks by providing additional guidance when necessary.

Future Work

For the next steps of the competition, we plan to expand the interaction capabilities of our model in order to provide richer feedback in cases of low confidence or failed attempted actions. The can help the agent finish the task successfully, especially when instructions require a longer sequence of actions. More broadly, we are interested in exploring the ability of our model to transfer task knowledge between real and simulated environments. Thanks to these generalisation skills, we will transfer EMMA to a robot executing tasks in the real world.

Publications

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Robust Vehicle Perception in Adverse Weather: Variational Simultaneous Stereo Matching and Defogging in Low Visibility

PhD candidate: Ted Ding
Supervisors: Dr Sen Wang, Professor Andrew Wallace

Introduction

Given a stereo pair of daytime foggy images (Fig. 1 left), we seek to estimate a dense disparity map (Fig. 1 top right) and to restore a fog-free image (Fig. 1 bottom right) simultaneously. Such tasks remain extremely challenging in low visibility (e.g. not greater than 40 meters), partially preventing modern autonomous vehicles from operating safely. Existing stereo matching algorithms are predominantly developed under the assumption of clear scenes. Meanwhile, the vast majority of the literature on defogging addresses single images. There is very little work that tackles these two tasks simultaneously, even though they are deeply linked by scene depth, which can be inferred from the disparity of stereo matching and scattering of the fog model respectively. We expect that both results can be improved by better exploiting this underlying connection, and therefore propose a novel simultaneous stereo matching and defogging algorithm based on variational continuous optimisation.

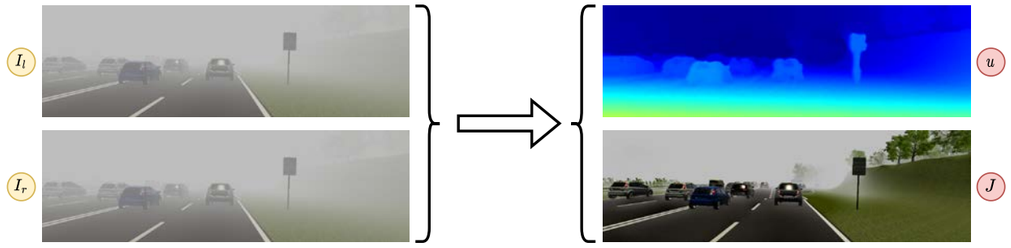


Figure 1: Simultaneous stereo matching and defogging

Method

Our system, depicted in Fig. 2, effectively fuses depth cues from disparity and scattering to achieve accurate depth estimation as the first step. Then the depth information is used to help restore a defogged image by leveraging a photo-inconsistency check. Our approach is based on variational methods that are easy to make parallel for acceleration. Moreover, it does not require training data containing foggy images with corresponding clear image and ground truth dense depth data. The acquisition of such data in real outdoor scenes is time consuming at best and not always possible.

Results

We evaluate our methods extensively on both synthetic data (VKITTI2 [1]) and real data (PAD [2]). Results show the proposed algorithm outperforms comparative methods in all metrics on depth estimation, and produces visually more appealing defogged images, especially in extremely low visibilities. A qualitative result on VKITTI2 is shown in Fig. 1. Quantitative and qualitative results with (partial) comparing methods on PAD are shown in Tab. 1 and Fig. 3 respectively.

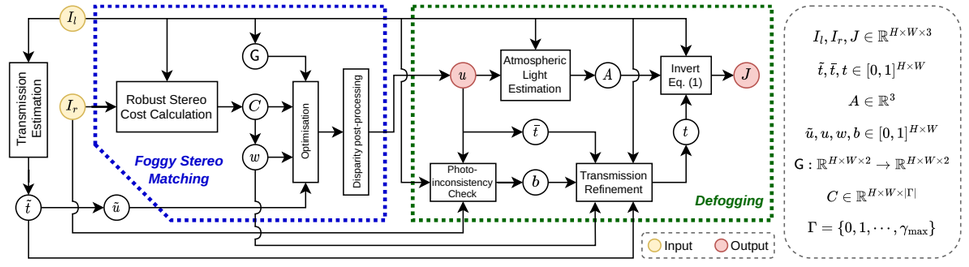


Figure 2: The proposed two-stage system consists of a Foggy Stereo Matching module and a Defogging module. The former estimates a dense normalised disparity map u from a rectified stereo pair of foggy images I{l,r}, then the latter performs defogging and restores a fog-free image J. Within the Foggy Stereo Matching module we design an anisotropic weighting scheme to allow for non-uniform penalty parameters which are seamlessly incorporated in the disparity optimisation process, and propose a customised regularisation term which effectively injects disparity cues from scattering by encouraging gradient alignment.

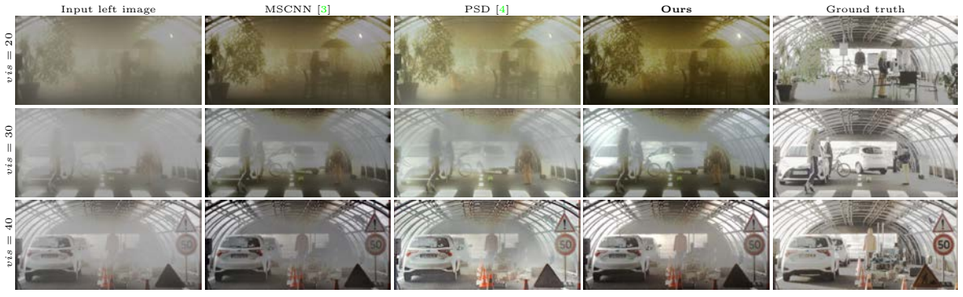
Method	SSIM	PSNR
MSCNN [3]	0.519	12.023
PSD [4]	**0.588**	**16.676**
4KDehazing [5]	0.510	10.419
Ours	0.519	13.433

(a) Defogging

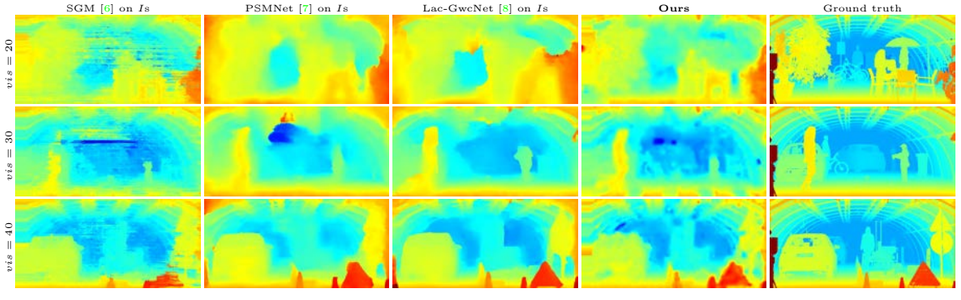
Method	D1-all	RMSE	MAE	SILog	Sq Rel	Abs Rel	$\delta < 1.25$	$\delta < 1.25^2$	$\delta < 1.25^3$
SGM [6]	42.515	3.832	2.518	21.377	0.786	14.191	78.496	92.250	98.464
PSMNet [7]	49.913	4.700	3.115	21.950	1.029	15.519	71.102	87.698	96.764
Lac-GwcNet [8]	38.637	4.266	2.671	22.084	0.921	13.563	76.881	89.227	95.653
Ours	**37.647**	**3.550**	**2.282**	**19.078**	**0.651**	**12.352**	**80.435**	**93.959**	**98.871**

(b) Stereo matching

Table 1: Quantitative results on PAD. Ours performs the best/second best in all metrics.



(a) Defogging results. Our method is better at removing fog from distant objects and preserving fine details.



(b) Disparity results. Our method preserves fine structures to a greater extent in extremely low visibilities.

Impact

This work fits into the research topic of robust vehicle perception in adverse weather. Dense and accurate depth estimation is essential for advanced driver-assistance systems. Combined with a corresponding high-fidelity intensity image, depth information can benefit high-level computer vision tasks such as object detection and semantic segmentation. Further, clear intensity images aid object recognition and help human drivers plan and act safely. We make our code publicly available at https://github.com/tedyiningding/VSSMD

Future work

For future work we consider: a) using motion information embedded in consecutive frames and incorporating more matching constraints to improve depth estimation results; b) adopting a more sophisticated fog model (e.g. blurring and fog inhomogeneity) to better recover intensity images.

Publication

Y. Ding, A.M. Wallace, and S. Wang. “Variational Simultaneous Stereo Matching and Defogging in Low Visibility,”
in BMVC, 2022.

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Figure 3: Qualitative results on PAD

Engaging with the Centre

Robots will revolutionise the world’s economy and society over the next twenty years, working for us, beside us and interacting with us.

The UK Engineering and Physical Sciences Research Council (EPSRC) has invested nearly £500m in new Centres for Doctoral Training (CDTs) to develop industrially relevant, cutting-edge technologies and the research leaders of the future.

The Edinburgh Centre for Robotics, a £120M joint venture between Heriot-Watt University and the University of Edinburgh, has been running an EPSRC CDT in Robotics and Autonomous Systems since 2014, training around 70 highly-skilled graduates. As a result of a successful follow-on bid, we received an additional eight years of funding, allowing us to train a further five cohorts of between 10-15 innovation-ready PhD students annually from September 2019.

In order to maximise the number of students who can benefit from this programme, we invite proposals for new research projects from companies with a research activity in the UK.

The theme of the CDT RAS 2.0 is **Safe Interaction**, which includes the following topics:

Physical Interactions:

Control, actuation, compliance, sensing, mapping, planning, embodiments, swarming

People Interactions:

Human-robot interaction, affective robotics, smart spaces, teaming, collaborative decision-making, cobots, multimodal interfaces

Self-Interactions:

Condition monitoring, prognosis, explainable AI, certification, verification, safety, security

Interaction Enablers:

Vision, embedded and parallel computing, novel fabrication methods, machine learning algorithms and other AI techniques including NLP

How to engage with the Centre
A company can choose to support a relevant PhD research project in a university laboratory, in return gaining early access to results, the potential to exclusively license foreground IP and the right to host the student at their site for 3 months of the project. Companies generally provide financial support for stipend, UK/EU fees and project costs.

Entry to the programme is in September, with students completing two semesters of taught courses whilst starting to explore their PhD research direction.

Project proposals from companies are accepted throughout the year but are particularly encouraged by the end of March to allow recruitment to the programme in the new academic year.

In addition to funding a studentship, companies can also provide support by:
- Providing access to equipment/software at their premises
- Co-supervision of students and projects
- Student placements and internships
- Contribution to MSc taught programmes
- Support for student robot competitions

If you are interested in engaging with the Centre, please contact:
Professor Helen Hastie h.hastie@hw.ac.uk
Professor Michael Mistry michael.mistry@ed.ac.uk

Industrial studentships

Statistical Methods for AUV Underwater Pipeline Tracking in Multi Sensor Data
Kawasaki Heavy Industries, Kobe, Japan
Pipeline tracking is a challenging task for Autonomous Underwater Vehicles because sections of the pipe may be deliberately buried and not visible from the surface. This project investigates multi-sensor solutions to tracking pipelines in and out of burial from an AUV flying low over the pipe using multi-sensor data, to be selected from sub bottom sonar, wideband biosonar, magnetometer, laser and video. The PhD work focuses on statistical methods for tracking, starting with the Probability Hypothesis Density filter.

Cooperative Control of Drilling Equipment
Schlumberger, UK
As automation of drilling processes is developed, operation will be split between completely automated tasks and tasks that are carried out by humans. The project looks at how teams comprising human and robotic actors can collaborate to achieve complex and uncertain tasks in drilling operations.

Interactive Robotic Inspection Strategies Using Unstructured Data
Renishaw, UK
Document based 2D technical drawings rather than a digital 3D model are still the main format in a production-inspection workflow. This research is focused on using unstructured data such as the symbolic representations of geometric dimensioning and tolerance (GD&T) as input to conduct a teach-execute regime for coordinate measuring robots.

Shared Autonomy for Kinesthetic Tools
Costain, UK
Many repetitive industrial tasks require significant cognitive load which results in operator fatigue and in turn can become dangerous. The development of robotic sensing technology and compliant feedback technology will allow semi-autonomous robotics systems to improve this type of workflow. This project aims to explore methods in which a robotic system with shared autonomy can contribute to the operation of a Kinesthetic tool (such as a piece of machinery) and in doing so reduce the cognitive load and fatigue of the human operator.

Towards Full Autonomy: Deep Learning Enhanced Scene Understanding for Underwater Robots
SeeByte Limited
This project will investigate state-of-the-art driven machine learning techniques, e.g. Convolutional and Recurrent Neural Networks, as well as Deep Reinforcement Learning techniques, extending these novel approaches to be applicable to the underwater robotics domain.

Bridge Inspection - Inspection of Brickwork and Masonry Assets
RSSB, UK
This project aims to inspect the brickwork and masonry assets of railway bridges, particularly the intrados of arches where access is limited. The project will use drones to collect images autonomously under the arches and then analyse the images to automatically detect the defects in the structure.

Intention-aware Motion Planning
Thales, UK
The goal of this industrially sponsored project is to research and extend previous techniques to give a new approach to categorising motion and inferring possible future system states to support robust maritime autonomy decision making processes.

Long Term Autonomy for Multi Agent Systems in the Maritime Domain
BAE Systems
The main aim of this project is to develop algorithms that can devise, execute and monitor plans suitable for long-term missions of marine 'systems of systems' where overall goals are well defined but their effective implementation is dependent on external parameters that cannot be pre-determined.

Intention Aware Human-Robot Collaborative Manipulation of Large Objects
Honda Research Institute Europe
Until the past few years, robots were typically temporally or spatially separated from human co-workers to ensure humans' safety. In the case of today's cobots that's not the case anymore. However, the unpredictability and the variability of humans' actions generate scenarios with frequent plan alterations and considerable uncertainty, to the extent that robots fail to successfully complete the collaborative tasks in hand. This project aims to develop the required theory to overcome these limitations and demonstrate collaborative human-robot manipulation scenarios.

Explainable AI and Autonomy for the Maritime Domain
SeeByte Limited & SRPe
The principal goal for this project is to enable effective text-based interaction between an operator and an AUV to unlock situation awareness in the underwater domain and explain behaviours. This will be achieved by investigating Data2Text methods to derive verbal explanations from a mix of structured and unstructured data, including a world model and its dynamic environment, status from the vehicle, as well as a representation of the autonomy model logic.

Mobile Inspection Units on the Train
RSSB, UK
This project aims to develop robotized inspection units that can navigate and manipulate in the confined workspaces, typical of in-between and under the seats of a train cab. The typical application for an on-train mobile robot platform is inspection of the compartments for cleaning and hazard identification purposes. The platform is also intended to have manipulation capability to perform some cleaning tasks.

Lifelong Learning for Vision based AUV Control
Rovco & SRPe
Precise robot control for underwater inspection is of paramount importance to generate high quality survey data. This is a challenging problem as the environment these robots operate in is dynamic, uncertain and very difficult to model a priori. Moreover, the robot configuration changes from mission to mission and tuning the controllers for each configuration is time consuming. The main objective of this project is to design adaptive low-level controllers for autonomous underwater vehicles using sensor feedback and machine learning frameworks. The algorithms will take input from real time sensors and actuators and adapt in real time to changes in vehicle performances (change of payload, actuator fatigue, tether drag) and environmental conditions (waves, currents, wind). Ideally, they should be portable across multiple robots.

Miscommunication and Repair in Visual Conversational AI
Alana AI Ltd
This project will investigate and develop visually grounded NLP models that allow grounded representations to be systematically edited, repaired or recomputed, paving the way for VAI systems that are able to both understand user repairs as well as engage in repair when needed. The said models will be evaluated against appropriate 'visual repair' datasets collected as part of the project. The resulting VAI systems will be developed using the existing Alana framework and evaluated with Alana's partially sighted users.

Verification Library for Trustworthy Software
Imandra
Imandra are an AI startup developing a cloud-scale automated reasoning system to bring rigour and governance to algorithms across sectors. The aim of the project is to make designing, implementing and deploying trustworthy software easier by building a comprehensive NN verification library in Imandra for verification of Neural networks and autonomous systems.

Achievements

Heidelberg Laureate Forum 2022

Samuel Garcin attended the 9th Heidelberg Laureate Forum as a Young Researcher in September.

About the HLF:
"From September 18 to 23, some of the brightest minds in mathematics and computer science came together for unrestrained, interdisciplinary exchange. This compelling event had plenty of activity awaiting the participants, e.g. laureate lectures, panel discussions, plus various interactive program elements. This year's Hot Topic centered on a subject of great interdisciplinary and public interest: "Deep Learning – Applications and Implications." During the weeklong conference, young researchers and other participants had the opportunity to connect with scientific pioneers and learned how the laureates made it to the top of their fields." From the HLF website

About the HLF Laureates:
Each year the recipients of the most prestigious awards in mathematics and computer science, the Abel Prize, ACM A.M. Turing Award, ACM Prize in Computing, Fields Medal, IMU Abacus Medal and Nevanlinna Prize are invited to participate in the Forum." From the HLF website.

About the Young Researchers:
The opportunity to join the annual Heidelberg Laureate Forum is provided exclusively to outstanding young scientists in mathematics and computer science (or closely related fields) at the Undergraduate/Pre-Master, Graduate PhD and Postdoc levels.
Extensive interaction with the laureates of mathematics and computer science is possible because their participation is not only limited to giving lectures, instead it continues throughout all aspects of the program. Ample time is provided to discuss with these scientific pioneers during breaks, meals and social events.
At the Heidelberg Laureate Forum, the brightest minds in mathematics and computer science interweave, find inspiration and push forward. Samuel Garcin attended CIFAR Deep Learning + Reinforcement Learning (DLDR) Summer School in July.

Each year, the CIFAR Deep Learning + Reinforcement Learning (DLRL) Summer School brings together graduate students, post-docs and professionals to cover the foundational research, new developments, and real-world applications of deep learning and reinforcement learning. The school is hosted by CIFAR in partnership with Canada's three national AI institutes: **Amii** in Edmonton, **Mila** in Montreal and the **Vector Institute** in Toronto." **From the DLDR website**

Emanuele De Pellegrin
Emanuele worked as a Unity VR developer with TouchLab Limited competing for the ANA Avatar XPRIZE. He developed the main user interface for the VR teleoperation training simulation environment.

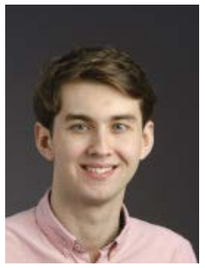
CDT RAS Innovation fund

Paul Baisamy was awarded £13,000 from the CDT RAS Innovation fund for the development of a cardiac assist device. The objective of the Innovation Fund is to assist with the preparation of prototype hardware and/or software that could lead to a commercial idea. It is awarded on a competitive basis with shortlisted applicants invited to present their idea to a panel of researchers and business advisers.

Summary of the proposal: Heart failure occurs when a patient's heart can no longer provide a sufficient cardiac output to satisfy the metabolic needs of the organism. To assist the heart in its function of pumping blood, Left Ventricular Assist Devices (LVADs) can be implanted in the patient's chest. LVADs restore a sufficient amount of blood flow to suppress heart failure symptoms in these critically ill patients.

Currently, LVADs on the market are only able to produce a continuous flow as opposed to the pulsatile flow of the human heart. This leads to various complications for the patients. We propose the development of an implantable LVAD whose main feature will be its ability to produce a pulsatile flow similar to that of a healthy heart with a very high level of energy efficiency. Such a device would be unique as a pulsatile implantable LVAD able to adapt to the patient's cardiac frequency and with portable batteries has never ever been engineered so far. Our approach, closer to the real functioning of a human heart compared to the pumps currently available on the market, will guarantee a very low level of complications after the implantation and will ensure a high life expectancy for patients.

Ronnie Smith won the IET Postgraduate Prize



Ronnie Smith is a PhD student at the Edinburgh Centre for Robotics, as part of the EPSRC Centre for Doctoral Training in Robotics & Autonomous Systems at Heriot-Watt University and the University of Edinburgh. His research focuses on enabling pro-active robotic assistance for people who need support during activities of daily life at home.

Ronnie's research brings together a number of topics to bring humans 'in-the-loop' and give them ownership over their own assistive technology. This includes applying active learning to activity recognition, using a novel conversational interface. This reduces the need for supervised learning and helps to deal with long-term changes in user behaviour or environment. Currently, Ronnie is focusing on using the conversational agent to allow the user to ask the robot for help during activities, in order to intelligently provide pro-active assistance when that activity is detected in the future.

Recognition of his work through the IET Postgraduate Prize will help Ronnie in promoting his work and stimulating engagement with industry stakeholders in the care sector. The prize will also support him in disseminating the results of his work. Ronnie hopes to continue his work on assistive robotics through post-doctoral research.

Fraser Garrow
Fraser attended a SPECIES society evolutionary computing summer school this year in Spain. There were lectures from several leading researchers in the evolutionary computing community. There was also a short challenge project for which Fraser's group delivered the best experimental results. Collaboration continues with the summer school supervisor with the aim of submitting a paper at Evo* 2023.

Internships

Samuel Garcin

Samuel is currently undertaking a 3-month research visit at Mila, Montreal where he is advised by Prof. Prakash Panangaden (McGill) and Dr Pablo Samuel Castro (Google Brain). He is working on developing theoretical guarantees for State Representation Learning methods in Deep Reinforcement Learning.

Mateusz Ochal

Mateusz Ochal interned with SeeByte Ltd, Edinburgh, for 3-months from 1st Oct 2021 to 31st Dec 2021. He worked in the computer vision team and explored ways to apply state-of-the-art Few-Shot Learning (FSL) algorithms to recognise certain types of objects in video data. FSL aims to offer more efficient and reliable training of deep learning models using limited training data, with as few as one sample per class. This is particularly useful in marine settings where it can be expensive or impractical to obtain large quantities of labelled data points. During the internship, Mateusz successfully demoed FSL algorithms to quickly learn and recognise novel targets in marine environments. In the future, the technology could used to aide target monitoring and surveillance applications.

Eleftherios Triantafyllidis

Eleftherios Triantafyllidis interned at Telexistence Inc. Tokyo, Japan working on state-of-the-art robotic planning and vision methods. More specifically, during his internship, he was solely responsible for merging existing company repositories intended for real-world robotic tasks and adapting these for the first time to an accurate physics-based simulator (NVIDIA's ISAAC Sim) allowing the company to validate all their future experiments with significantly fewer resources. Finally, this also allowed for the verification of existing and new planning algorithms to be used on the simulator with endless state transitions and rendering the transferability of learning-based models from the simulator to the real robotic hardware significantly easier due to also focusing on minimising the Sim2Real gap. This led to the successful presentation of his work on behalf of the company in IROS 2022 in Kyoto, Japan in a real-time day-long presentation of the robotic system in the simulator.

Filippos Christianos

Filippos Christianos did his 3-month internship at NVIDIA as a research scientist. Filippos worked with the autonomous vehicles research team where they experimented on a new method for occlusion inference and planning. The new method is promising and is showing improvements over several baselines, possibly paving a way for autonomous vehicles to better handle and reason on occluded objects.

Karin Sevegnani

Karin Sevegnani completed a 6-months remote internship for Amazon (San Francisco, US), from June to December 2021. She focused on designing and developing a recommendation system for the new Amazon Style store that opened in the US during 2022.
In particular, she used contrastive learning to capture user intent from natural language text and improve the recommendation quality of fashion products. The designed model demonstrates a significant improvement in offline recommendation retrieval metrics when tested on a real-world dataset collected from an online retail fashion store, as well as widely used open-source datasets in different e-commerce domains, such as restaurants, movies and TV shows, clothing and shoe reviews.

Konstantinos Gavriilidis

Konstantinos Gavriilidis from the 2019 cohort took an internship at the Edinburgh-based company SeeByte between March 2022 and August 2022. During this internship, he travelled along with SeeByte employees to Boston for the MOOS DAWG'22 Conference. In collaboration with the Marine Autonomy Lab of MIT, they demonstrated their work on Composite Autonomies where multiple autonomies (Neptune and MOOS-IvP) were used for better vehicle control and perception. Additionally, an explanation framework was utilised to provide situational awareness in terms of the causality behind behaviour activations. For the experiment, two vehicles were used: USV Philos and the versatile USV Heron, which in unison discovered obstacles at Charles River and successfully completed their tasks. Overall, it was an exciting opportunity, to test the developed functionality with real vehicles and to undertake relevant work for his industrial PhD funded by SeeByte and SRPe.

Student Activities - Year Two Group Project

All three of the Year 2 Groups did very well and we were impressed with how well they worked together to overcome a number of challenges. Two groups took part in the RoboSoft conference challenge and one in the Amazon Simbot challenge.
The winning group developed a soft gripper for autonomous object manipulation and Fernando Acero, Paul Baisamy, Mhairi Dunion and Georgios Kamaras were awarded an Amazon voucher in recognition of this.
The group projects were as follows –

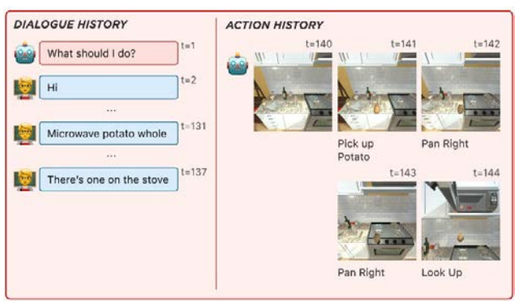
Pretraining for dialogue-based instruction following

Students: Bhathiya Hemanthage, Malvina Nikandrou
Academic Supervisor: Alessandro Suglia

Description

The group participated in the Heriot-Watt team for the Alexa Prize SimBot Challenge, which aims to develop an agent that can execute household tasks in a simulated environment, while taking user instructions and agent responses into account.

The approach was inspired by the success of combining vision and language on tasks that require understanding image semantics, such as Visual Question Answering. However, using object-centric representations along with a long dialogue history is challenging as input lengths of language and vision signals become prohibitively large. Therefore, an efficient attention masking strategy originally introduced for processing long text-only documents was adopted.



The model is trained in three stages: 1) image-text pretraining, 2) video-text pretraining, and 3) task-specific finetuning. Image-text pretraining targets learning aligned visio-linguistic representations, while video-text pretraining targets learning temporal reasoning. The pretrained model is transferable to embodied downstream tasks facilitating both navigational and manipulation actions.

Impact

The multi-task capabilities of the system were presented at SIGDIAL 2022 via a Demo Paper.

Soft Robotic Locomotion

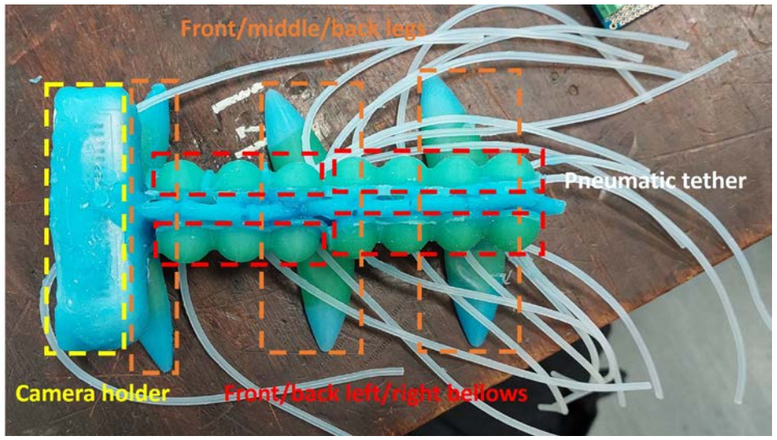
Students: Emanuele De Pellegrin, Ted Ding, Fraser Garrow, Isobel Voysey, Simon Wanstall
Academic Supervisor: Adam Stokes

Description

The group developed a soft robot called WAYNE (``Worms are All You NEed") and attended the RoboSoft Competition 2022 terrestrial race. Inspired by ragworms, WAYNE is designed to have three sets of legs and four sets of bellows as its on-board actuators. It is made from Ecoflex for expanding areas and Dragonskin for less stretchable but still compliant areas. Controlled by solenoid valves, through polyurethane hoses the actuators can be inflated by an air compressor or deflated by a vacuum pump. Legs and bellows are used primarily for translational and directional locomotions respectively. When they are jointly actuated, more complex moves such as wriggling can be achieved. WAYNE also features an on-board camera which is used to sense the presence of obstacles.

Impact

The group showcased their work in Robot Lab Live 2022, which is a robotics live stream event organised by the UK-RAS Network.



Student Activities - Year Two Group Project

Soft gripper for autonomous object manipulation

Students: Acero, George Kamaras, Mhairi Dunion, Paul Baisamy
Academic Supervisor: Adam Stokes

Description

The aim of this project was to design a robotic system capable of manipulating a wide array of irregular shapes and delicate items and able to autonomously perform complex operations such as serving a dram of whisky or picking and placing objects in different target locations. The group designed its system around three key components: a soft gripper mounted on a collaborative robot arm capable of grasping a variety of objects, a software solution enabling the robot to perform the tasks autonomously, and the communication between the software and the gripper. The soft gripper was inspired by iris mechanisms found in camera apertures to be capable of adapting to any object shape. The gripper consists of two layers of silicon rubber blades arranged in a circular shape which are controlled by a motor to synchronously move all blades in a grasping motion. The software solution was based on Robot Operating System (ROS) to communicate with the robot, and MoveIt for motion planning. A depth-perception camera was used to determine the object locations and MoveIt to create motion plans to move the robot into the desired position. Finally, an Arduino controlled the gripper, passing serial and voltage signals from the control software to the Arduino that modified the gripper status (grasp/ungrasp). With this solution, the robot was able to successfully and autonomously detect, grasp and manipulate a variety of objects, ranging from a filled bottle of whisky, a USB stick or an empty can without prior knowledge of the specific objects or their exact positions

Impact

The group took part in the RoboSoft 2022 manipulation competition in Edinburgh where the gripper was tested on a variety of manipulation tasks. During this edition, the competition aimed at challenging the state-of-the-art in soft robotic manipulation to pave the way for the development of safe and reliable soft grippers.

Public Outreach

UK-RAS Robot Lab Live

Population Targeted

Public with interest in robotics

Activities Undertaken

Livestream demonstration of the capabilities of a bioinspired, soft, ragworm robot called WAYNE (Worms are All You NEed). The robot was intended for use in search and rescue operations because its body is made entirely of soft, silicone parts that can squeeze through tight spaces and resist impact damage from falling debris. WAYNE is powered using compressed air, controlled via a series of electronic valves. The stream included teaching about soft robotics, bioinspired design, and the system we created. We then demonstrated that the robot could crawl over sand and swim in water, two tasks that most robots would struggle to accomplish. After the demonstration, a question and answer session allowed viewers to ask anything they wanted about the system and have a team member talk them through it. The stream was a continuation of the CDT group project that involved competing in the Robosoft 2022 locomotion competition. Team members involved were Simon Wanstall, Fraser Garrow, Ted Ding, Isobel Voysey, and Emanuele De Pellegrin.

Intended Benefit

Inform the public about the possibilities of soft robotics and get people excited about robotics as a whole.

Summary of Feedback and/or Publicity

The feedback was entirely positive and the publicity led to an invitation to talk on the Robot Talk podcast.

UK-RAS Robot Talk Podcast

Population Targeted

Public with interest in robotics

Activities Undertaken

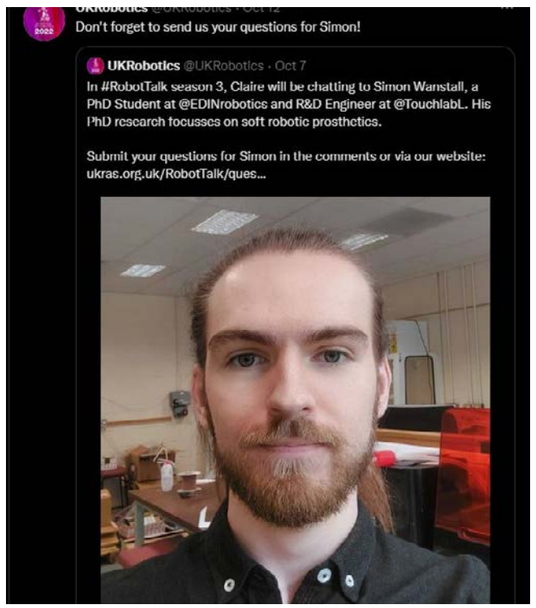
Podcast interview about my research in soft robotic prosthetics, involvement with WAYNE and my placement with Touchlab Ltd

Intended Benefit

Spread awareness about the different areas of robotics and the current state of the art via an easily digestible, podcast format

Summary of Feedback and/or Publicity

Summary of Feedback and/or Publicity: Podcast is yet to air, but initial feedback was that the chat was entertaining for the presenter



ANA Avatar XPRIZE

Key Individuals
Zaki Hussein (CEO), Laura Gracia Gaberol (COO), Vasilis Mitrakos (My Manager and VP of E-Skins)

Location
National Robotarium, Heriot-Watt Campus

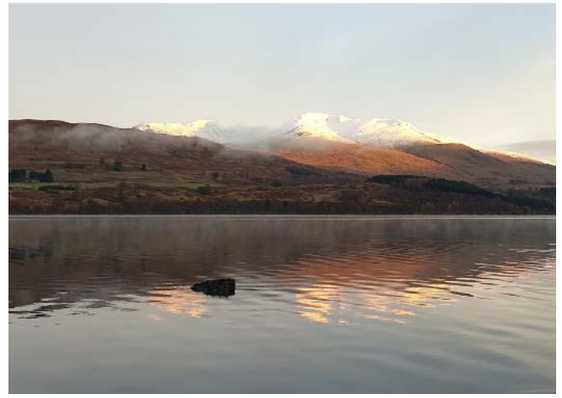
Duration
6 Months

Duration
6 Months

Work Undertaken
Development of multimodal sensors by adding temperature sensing capabilities to current Touchlab e-skins, working as a team member for the ANA Xprize Avatar Finals in Long Beach, California, advising about where soft robotics could integrate with the e-skins, and integrating Touchlab e-skins into advanced pick-and-place systems. current work involves using the mechanical engineering, soft robotics and materials science specialities to help integrate the Touchlab sensors into an avatar robot in an attempt to win the grand prize of 5 million USD. The avatar robot is intended to be piloted by a user who can see and feel everything the robot does and control its actions through VR.

At 5 minutes to midnight on 01/11/22, we got the avatar system working for the first time, as the CEO (Daniel) of our partner company Cyberselves took control of the robot and shook hands with our roboticist, Shayne Shaw. Daniel could see Shayne through the robot's eyes and felt the pressure on the mechanical hand via the Touchlab e-skin transferring the force data through a haptic (HaptX) glove.

Firbush

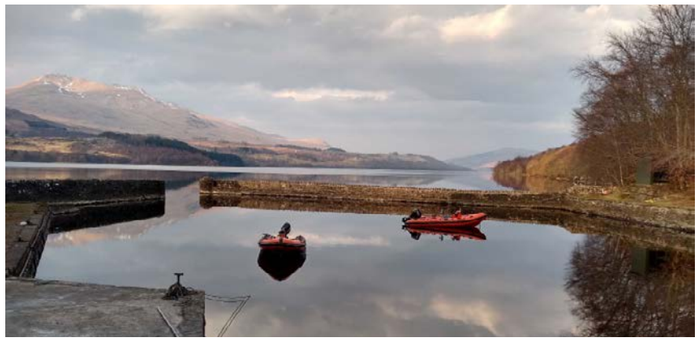


A group of CDT RAS students attended two action packed days at the University of Edinburgh Firbush Outdoor Centre near Killin. After packed lunch on arrival at Firbush, the Firbush staff briefed everyone about the site and the activities. In the afternoon students spilt into two groups. One went kayaking, starting with a trip up the loch, and finishing with kayak games in the harbour. The other group was paddle boarding and went for a trip in the opposite direction, finishing off with some challenges on the paddle boards. After an excellent dinner everyone regrouped in the Sinderson Room for the evening's Responsible Research and Innovation (RRI) activity, splitting into 4 groups to look at doomsday scenarios related to each groups' research activities, and how best to avoid these scenarios. When that was complete, a group game of werewolves and villagers got underway bringing the whole group together.

Students chose to spend the Tuesday morning session canoeing and kayaking, orienteering and cycling. The canoe trip headed to look at the beaver lodge on an island at the head of the loch. The orienteers stretched their activity out to include lunch out on the hillside, while the cyclists explored nearby Killin.

After lunch the students participated in windsurfing, orienteering and cycling. The windsurfing was a great success with all 9 people up and sailing at the same time, although the wind subsequently dropped which made it more challenging to keep sailing. The orienteers had a good walk up the hill behind Firbush and the cyclists once again went round Killin. After an excellent dinner everyone regrouped for the reporting back on the RRI doomsday scenarios which brought up a number of interesting points. When this was complete further games of werewolves and villagers got underway.

After another great breakfast on Wednesday morning everyone returned to Edinburgh. The trip was a great opportunity to encourage cohort building amongst the students, who reported that the Firbush staff were excellent and looked after them very well.

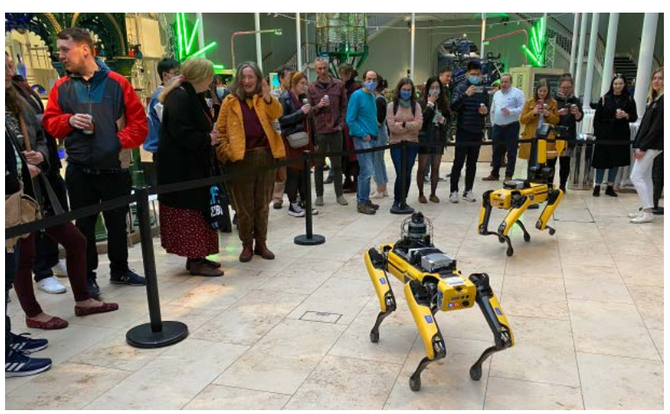


Writing Retreat at Barony Castle

In May 2022, a group of students spent 4 days in Barony Castle Hotel near Peebles in the Scottish Borders. The day would start with a short seminar from a member of staff. These included 'Introduction to Technical Writing' (Prof. Hastie), 'Getting Creative' (Dr. Belle), 'Abstract Workshop' (Dr. Albrecht), 'Paper Writing as Project Management' (Prof. Stokes) and 'Reducing Redundancy' (Dr. Dondrup). For the rest of their time at the castle, the students worked on various writing assignments, such as conference and journal papers and student annual reports. They also took the time to relax and enjoy the facilitates and the beautiful countryside. Students mentioned that they benefited from the focus time in a distraction-free setting, giving them time to hone their writing skills, whilst getting to know their fellow students.

Edinburgh Science Festival

CDT students showcased robotics and AI to families from across Edinburgh and beyond as part of Edinburgh Science Festival 2022. The Datasphere exhibit at the National Museum of Scotland included hands-on demos on surgical robotics, robotic arms, stroke rehabilitation and SPOT, the Boston Dynamic's robot dog. During the daytime exhibits, thousands of local families engaged with the researchers, asking questions and learning about how robotics will be integrated into our lives in the future. An evening event at the museum, 'Data after Dark' allowed further meaningful dialogue with more than 100 adults.



Retirement

The CDT would like to take this opportunity to thank the director of CDT-RAS 1, Professor David Lane, and Anne Murphy, Centre Manager, who retired from the CDT-RAS and Heriot-Watt University in 2022. Both David and Anne were instrumental in the CDT start up, seeing it through a second successful funding bid to ensure the continuation of the programme. Both David and Anne have worked tirelessly to make the Centre a place where students could thrive and creating the strong and innovative research programme that exists today. They will both be missed by students and staff alike, and we would like to take this opportunity to wish them a very long and happy retirement.

Professor David Lane, FRSE, FRGS, FREng, CBE is a leading researcher in Robotics and Autonomous Systems. His illustrious career spans 4 decades at Heriot-Watt University, as an undergraduate student and PhD student in the 80s and later as an academic where he led the Oceans Systems Laboratory and created the Edinburgh Centre for Robotics with Edinburgh University. In the 1990's, he put Heriot-Watt University and the Ocean Systems Laboratory on the map as one of the leading centres in marine robotics in the world. He achieved international recognition for his academic work and led major EU and UK projects. In 2013, he created the Edinburgh Centre for Robotics (ECR) in collaboration with the University of Edinburgh, leading over £140M of investment from the UK government. ECR is now the lead robotics research group in the UK and has achieved international recognition for its work in the EPSRC ORCA HUB project. An £18.5M project that he led until his retirement in 2020.

In May this year, a retirement party was held in David and Anne's honour, which was attended by both students and staff. The event was enjoyed by all who attended and both David and Anne were overwhelmed by the lovely messages and generosity bestowed upon them.

Congratulations

Professors Helen Hastie and Barbara Webb are elected FRSE

In March 2022 our CDT Director, Prof Helen Hastie (HWU), and our Committee Member for Equality and Diversity, Prof Barbara Webb (UoE), were elected Fellows of the Royal Society of Edinburgh. They join a growing body of academics associated with the CDT who have received this honour and we congratulate them both.

THE NATIONAL ROBOTARIUM
PEOPLE CENTRED :: INTELLIGENCE DRIVEN

The National Robotarium is a world-leading centre for Robotics and Artificial Intelligence. Its responsible and collaborative approach creates innovative solutions to global challenges. Its pioneering research moves rapidly from laboratory to market, developing highly skilled visionaries and delivering substantial benefits for society. Its ethos is People centred; Intelligence driven. This world-leading research and development facility translates cutting-edge research into technologies to create disruptive innovation in an expanding global market in robotics and autonomous systems, delivering sustainable economic benefit to the Edinburgh City Region, Scotland, and the UK.

The £22.4m purpose-built centre, opening in 2022, has unrivalled facilities adding to our existing laboratories in Ocean Systems, Human Robotic Interaction and Assisted Living and also includes smart manufacturing. The design of the new building and its world class facilities will encourage the collaborative approach that is at the heart of the National Robotarium's ethos. Facilities include a partner suite: an area dedicated to fostering collaboration between industry partners, academics and government. With a strong focus on entrepreneurship and job creation, the National Robotarium will offer an ecosystem for industry collaboration where humans and robots work in partnership.

The National Robotarium's first CEO has been appointed. Stewart Millar's ambition is to build the National Robotarium into a globally recognised centre of excellence for AI and Robotics, working directly with business to accelerate innovation and drive value from world class research, create talent of the future through a flexible skills programme and support entrepreneurs capable of creating exciting new businesses to fuel our economy.

https://thenationalrobotarium.com/

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