EDINBURGH CENTRE FOR

ROBOTICS

Innovation Ready

Annual Review 2019/2020

EPSRC Centre for Doctoral Training in Robotics and Autonomous Systems

HERIOT WATT UNIVERSITY

THE UNIVERSITY of EDINBURGH

UKRI Engineering and Physical Sciences Research Council

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All images reproduced in this Annual Review pre-date January 2020

The Centre in Numbers 2014 -2020

Figures correct as at September 2020

2 Centres for Doctoral Training

7 Cohorts

84 Students

5 Alumni

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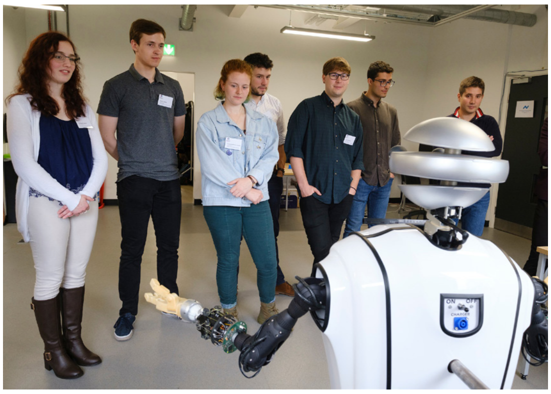

82 Conference Publications

27 Journal Publications

20 Workshop Papers

51 Industry partners

12 Industry projects

Foreword

Welcome to our 2019/20 Annual Review featuring key aspects and activities of students and staff in our EPSRC Centre for Doctoral Training in Robotics and Autonomous Systems.

Our sixth year marked the start of our second CDT programme under the directorship of Professor Helen Hastie and Professor Michael Mistry. Despite the shorter than usual recruitment timeframe, we were pleased to welcome 14 high-calibre students to the first year of the new programme. We successfully negotiated industry funding for two projects for this cohort, bringing our total number of industry projects to 12 across the two CDTs.

Sadly, Covid-19 restrictions have curtailed many of the activities that students and academics would normally have undertaken throughout the academic year. Since March 2020, Centre students and staff have been working from home, with students being supported in their research activities through regular online meetings with their supervisors, and cross-cohort online coffee mornings providing the opportunity to raise issues with Centre Directors and the Admin team.

Despite the significant reduction in activities, we are pleased to be able to report a number of positive outcomes.

During this year, we have celebrated with five of our students, who have successfully defended their thesis and who have subsequently gone on to secure exciting positions in the robotics sector.

Congratulations are also due to Centre academics Michael Mistry, Subramanian Ramamoorthy, Thusha Rajendran, Ekaterina Komendantskaya and Timothy Hospedales who have all been promoted to the position of Professor, and to Dr Adam Stokes who has been awarded the University of Edinburgh Principal's Innovation award for his work on soft robotics.

Our cohort building activities were greatly expanded this year with the introduction of an outward bound weekend for our new cohort of students at the University of Edinburgh's Firbush Centre in the Scottish Highlands. The Scottish weather worked its magic for once and the weekend was deemed a great success, and is now a firm fixture in our academic calendar, although sadly our planned weekend for November 2020 has had to be put on hold for the time being.

Two of our students have undertaken research visits to robotics labs at universities in the USA and four students have undertaken internships. These opportunities not only provide students with the experience of carrying out research in other organisations, but they also encourage the development of a skillset that will be beneficial when students return to their PhD studies.

Although building work for the new National Robotarium has been slightly delayed due to Covid-19, with the anticipated opening date being revised to early 2022, progress is still being made with the launch of the National Robotarium website and the purchase of a TALOS robot, which will be situated at the Bayes Centre at the University of Edinburgh, allowing for research into multi-contact loco-manipulation.

We have continued to welcome a number of high profile speakers to the Centre including Marc Raibert from Boston Dynamics, Margaret Mitchell from Google AI, Professor Mihaela Dinsoreanu from the Technical University of Cluj-Napoca , Professor Ana Paiva, University of Lisbon, Tamim Asfour, Karlsruhe Institute of Technology (KIT), and Dr Kim Hambuchen from NASA.

Keynote speakers at our fifth Annual Conference included Professor Luca Iocchi from Università di Roma "La Sapienza", Italy, who spoke about Cognitive Social Robots, and Dr Michael Gienger from Honda Research Institute Europe who discussed Concepts for Intuitive Human-Robot Interaction.

Academics from the Centre have been well placed to address some of the challenges raised by Covid-19, with Dr Mauro Dragone leading on an Ambient Assisted Living Collaboration project, which will initially support key priority groups in the UK whose conditions have been compounded by the social isolation measures necessitated by the pandemic.

The 2020/21 academic year is now underway with 12 students in our new cohort. Students and staff will continue to be impacted by Covid-19 restrictions but we expect the year to be busy with lots of positive developments. We will continue to post updates on Twitter @EDINrobotics and you can also find our latest newsletters at https://www.edinburgh-robotics.org/newsletters

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About us

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

It captures the expertise of 68 principle investigators of international standing from 12 cross-disciplinary research groups and institutes 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, an £8m capital equipment facility, the £16m ORCA Hub and the £26m National ROBOTARIUM.

The Centre includes affiliated students engaged in related EU, EPSRC and UK-MoD research programmes, and local EPSRC/UKRI CDTs in Data Science, Applied Photonics, Natural Language Processing, Biomedical Artificial Intelligence and Pervasive Parallelism, as well as the NERC/EPSRC CDT in Next Generation Unmanned System Science.

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 such 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.

The External Advisory Board

The External Advisory Board reports to the Steering Group and comprises representatives from the Industry Members engaged with the Centre, plus two international academics and the Centre Management team. It will meet 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 principle 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 underrepresented 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
University of Edinburgh

Centre Impact

In the 7 years since the Edinburgh Centre for Robotics commenced operations in 2013, over £120m of core investment has been secured from the Research Councils, Industry and the Universities. This has established the buildings, equipment, staff, postdocs and students of a research and innovation Centre of international standing, providing an enhanced platform for additional project work in EU, EPSRC and MoD funded projects for 20 active academics, 20 postdocs and over 100 PhD students.

Beyond the scientific impact through high quality international publications, it uniquely operates a spiral approach to innovation with its industrial partners in programmes such as ORCA Hub (https://orcahub.org/). Industrial partners develop use cases and requirements for novel technologies in their planned products and services. From these, capability demonstrations are identified for applied researchers to attempt through a series of short term sprints. As these develop, so the industrial requirements evolve also, to converge on a final set of demonstrations with commercial relevance. Where the market conditions are right, this can then release resources for product development through industrial or venture investment.

Using this approach, the Centre's technologies and skills have created and supported successful international businesses including SeeByte, Coda-Octopus, Hydrason and Ice Robotics, alongside licensing for example with Touch Bionics. Recently Centre staff have supported the creation and growth of spin-out Alana and start-ups Robotical (through the Royal Academy of Engineering Enterprise Fellowship scheme) and Consequential Robotics with the international designer Sebastian Conran and the University of Sheffield. Our latest business Adabotics has recently spun out from the Centre seeded by our innovation fund, and is already winning awards in the Far East.

Our businesses have developed autonomous drones now commercially carrying out inspection of critical infrastructure, especially offshore in deep water. New forms of dolphin-inspired acoustic sensing are externally inspecting inside pipelines and tubular structures. New designs of prosthetic hands have benefited from advanced control system design using machine learning. From our work, affordable fully programmable, customisable walking robots are revolutionising how robotics, AI and STEM subjects are taught in schools and universities. New generations of companion and assistive robots are changing the way we support an ageing and isolated population. Shared-autonomy developments are reducing costs and dependency on manpower in drilling as oil prices fluctuate, and for order fulfilment in distribution warehouses and manufacturing.

During the coronavirus pandemic, teams have utilised Digital Twin technology to develop and test prototypes from their homes before progressing to testing in the real world. This makes it much faster to re-purpose smart machines for new applications or customers. Achieving this increases resilience to large economic shocks, and creates new market opportunities. Smart machines can play an essential role improving our resilience in the low-touch economy of our post-Covid world. They can assist humanity by disinfecting hospitals, moving and organising goods in warehouses, maintaining offshore energy infrastructures, supporting surgical procedures, food preparation and even serving in restaurants and coffee bars. The centre is currently identifying and working on such initiatives to assist society and aid economic recovery in this challenging time.

The success of this research translation methodology has been recognised and resourced by the new National ROBOTARIUM institute scheduled to open early in 2022. It will bring a purpose built 5,000sqm buildings with living labs as the pivot for translation from research to products, co-located with international companies, startups and an incubator/accelerator.

At the Centre, we continue to forge new relationships with international academia and industry. Kawada Robotics are partnering with Edinburgh Centre for Robotics and the City Deal investment to provide cutting edge robot hardware (bimanual Nextage humanoids) for a first of kind hands-on teaching and demonstration capabilities for some of our core ECR courses, when social distancing measures ease. We are also involved with the newly announced moonshot programme in Japan, as partners in delivering research into adaptive human robot collaborations that evolve and adapt at massive temporal scales.

The Centre is closely linked with the Alan Turing Institute through Programme Directorship of the RAI programme within the UK national centre for Data Science and AI. We engage at the highest levels of Government in both the UK and Scotland, with a ministerial appointment as co-chair of the Robotic Growth Partnership and through participation in the UK AI Council and staff in the AI Strategy Working group for Scottish Government. These engagements allow the Centre to continue to develop and support the evolution of the UK as an international innovative economic force and a place where businesses and people come to develop their skills and technology.

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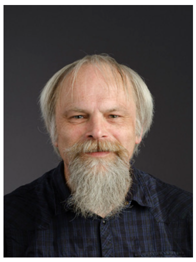

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EPSRC Centre for Doctoral Training
Robotics and Autonomous Systems

TRAINING
EDINBURGH CENTRE FOR ROBOTICS

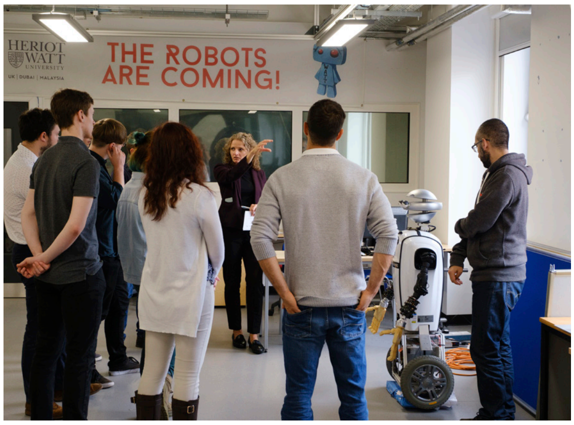
Robots that can learn, adapt and make decisions will revolutionise our economy and society over the next 20 years. They will work for us, beside us, assist us and interact with us. It is estimated that by 2025 such advanced robotic and autonomous systems (RAS) could have a worldwide economic impact of $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 £8m capital equipment facility and the £26m National ROBOTARIUM.
- 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 compete in international robot competitions (RoboCup Search and Rescue, SAUC-E Autonomous Underwater Vehicle Challenge Europe), European Robotics League, Amazon Alexa Challenge.
- Opportunity for competitive selection for funding from Cambridge IGNITE and MIT Sloan School of Management Entrepreneurship Programmes.

Academic Supervisors

We are indebted to the academic supervisors of all cohorts, who are fundamental to the success and direction of the research undertaken in the Centre.

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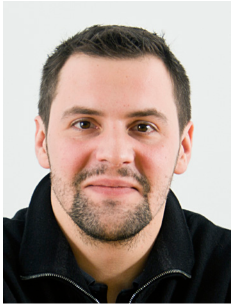

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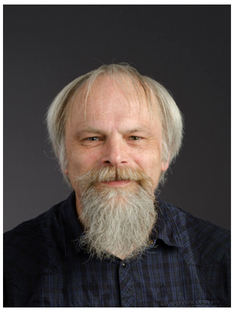

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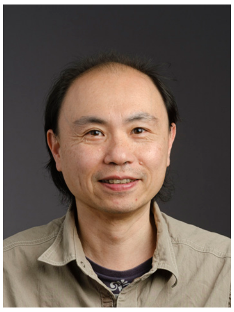

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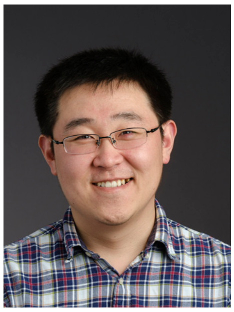

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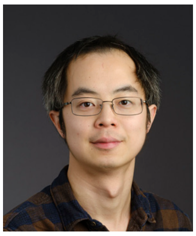
Detection and Tracking of Subsea Pipelines from an AUV



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Low level controller schemes for swarms and simple agents

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Learning constrained motions, and manipulation with contacts

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Multimodal Representation Learning: a Developmental Approach

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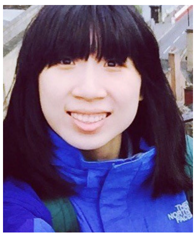

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User Simulator for Social Dialogue Generation

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Towards Robust Robotic Grasp Affordances

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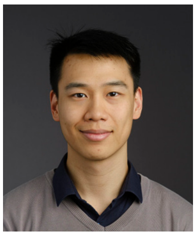
Deep Learning models for Interactive Grounded Language Learning



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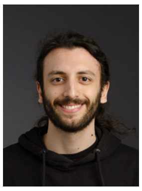
Control and Learning of Versatile Legged Mobility on Complex Terrain

Our students - 2018 cohort



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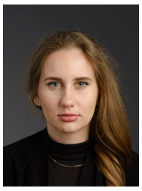
Deep Multi-agent Reinforcement Learning



Miruna Clinciu
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Explainable Artificial Intelligence (XAI)

Traiko Dinev
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Learning and Motor Control

Evripidis Gkanias
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Memory acquisition and retrieval in the insect brain

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Object-Level Semantic Mapping, Localisation and Navigation in Complex Challenging Environments

Borja Marin
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Computer Vision based damage assessment in civil structures

Mateusz Ochal
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Few-Shot Learning for Underwater Optical and Sonar Images

Georgios Papoudakis
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Unsupervised and Reinforcement Learning in Multi-Agent Systems

Jhielson Pimental
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Towards more biological plausible models applied to Robot Control Systems using Spiking Neural Network

Karin Sevegnani
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Quality Estimation for Natural Language Generation

Gary Smith
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Probabilistic logic programming for intent recognition

Ronnie Smith
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Adaptation of Multi-Agent Systems in Ambient Assisted Living

Artūras Straižys
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Force feedback in manipulation of deformable objects

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Multi-Modal Interaction and Manipulation

Nathan Western
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Computer Vision and Automation for Industrial Application

Our students - 2019 cohort

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Constrained Machine Learning for Interpretability and Robustness

Alexandre Colle
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The Role of Aesthetics in Social Robotic Design

Elliot Fosong
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Safe and Efficient Exploratory Probing in Multi-Agent Systems

Daniel Layeghi
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Behaviour discovery by combining learning-based control and trajectory optimisation

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Holistic Video Understanding Integrating Vision and Language

Emily Rolley-Parnell
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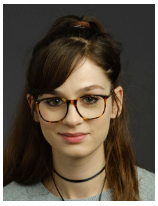
Robotic Control Inspired by the Object Manipulation Performed by Harvester Ants



Robin Trute
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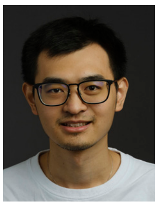
Visual Cues Of Soft Tissue Behaviour In Robotic Surgery



Wei Yu
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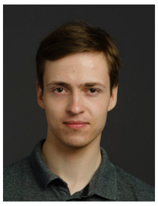
A novel lifelong learning method applied to real-life settings

Andreas Christou
andreas.christou@ed.ac.uk
Enhancing Robot Assisted Gait Rehabilitation (RAGT) with Functional Electrical Stimulation (FES) and Bio-Feedback



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Foundations for Inference in Probabilistic Relational Models

Konstantinos Gavriilidis
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Explainable Autonomy in the Maritime Domain

Emilyann Nault
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Social Robots and Sensory Feedback for Age-Related Cognitive Decline Rehabilitation

Pierre Nicolay
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Lifelong Learning for Vision based AUV Control

Ioannis Skottis
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Design & Control of Fluidic Machines

Liam Wellacott
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A Neurorobotics and Spiking Neural Networks Approach to Cognitive Faculties of Reasoning and Planning

Carlos Zapico
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Adaptive Interaction Control for Underwater Manipulation

Our students - 2020 cohort

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Supervisor: Dr F Giorgio-Serchi

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Supervisor: Dr Michael Herrmann

Simon Wanstall
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Supervisor: Dr Morteza Amjadi

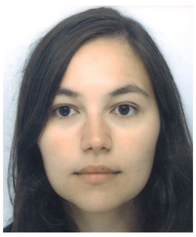
Our Alumni

Dr Andrew Brock (2015 cohort)
Supervisor: Dr Theo Lim
Andrew successfully defended his thesis entitled "Machine Analysis of Engineering Drawings" in February 2020.
Andrew now works at DeepMind in London.

Dr Ross McKenzie (2015 cohort)
Supervisor: Dr Adam Stokes
Ross successfully defended his thesis titled " Modular Robotics for Sorting" in November 2019.
Ross is currently working on localisation and mapping at Dynium Robot, a farming robot start-up.

Dr Wolfgang Merkt (2014 cohort)
Supervisor: Professor Sethu Vijayakumar
Wolfgang successfully defended his thesis titled " Experience-driven Optimal Motion Synthesis in Complex and Shared" in December 2019.
Wolfgang now works at the Oxford Robotics Institute as a post-doctoral researcher.

Dr Christian Rauch (2015 cohort)
Supervisor: Professor Sethu Vijayakumar
Christian successfully defended his thesis entitled "Visual Articulated Tracking in Cluttered Environments" in March 2020.
Christian has joined the Statistical Machine Learning and Motor Control (SLMC) research group at University of Edinburgh.



Dr Raluca Scona (2014 cohort)
Supervisor: Professor Yvan Petillot
Raluca successfully defended her thesis entitled "Robust Dense Visual SLAM Using Sensor Fusion and Motion Segmentation" in February 2020.
Raluca has joined the Dyson Robotics Lab lead by Professor Andrew Davison at Imperial College London as a Dyson Fellow.

Our Affiliated students

Alissa Potekhina
Amanda Cercas Curry
Amani Mansur
Bence Magyar
Benjamin Gautier
Can Pu
Carson Vogt
Chanyu Yang
Chenyang Zhao
Chris Mower
Christos Maniatis
Darius Roman
Francisco Javier Chiyah Garcia
Georgios Savva
Hanz Cuevas Velasquez
Ingo Keller
Ioannis Papaioannou
Ioannis Pisokas
Jack Geary
Jaiyi Wang
Jizbel Abel Johnson
Keyhan Kouhkiloui Babarahmati
Kirsty Duncan
Kyle Walker
Lucas Kirschbaum
Marcel Sheeny
Mariela De Lucas Alvarez
Marija Jegorova
Martin Ross
Matt Pugh
Matthew O'Hara
Max Marlon Randolph Baird
Miltiadis Katsakioris
Muaiyd Al Zandi
Nanbo Li
Nik Tsiogkas
Oguzhan Cebe
Puneet Chhabra
Ross Dickie
Saptarshi Mukherjee
Scott MacLeod
Shubham Agarwal
Todor Davchev
Yordan Hristov
Yurdusev Yakup Akan
Ziyang Hong

Research Themes

RESEARCH
EDINBURGH CENTRE FOR ROBOTICS

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 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.

Our Research Laboratories

Autonomous Agents Research Group

The Autonomous Agents Research Group is a research unit within the School of Informatics, University of Edinburgh. Research in the group is centred on the development of artificial intelligence and machine learning technologies toward the realisation of intelligent agents (such as software agents and robots) which can act autonomously to solve tasks in complex environments. The group has a strong focus on problems of coordination and cooperation in multi-agent systems, in which multiple autonomous agents interact in a shared environment. Current research focuses on inference and planning in multi-agent systems and algorithms for multi-agent deep reinforcement learning. The group is also active in the development of agent technology applications, including in the areas of autonomous driving, warehouse logistics, and cyber security.
https://agents.inf.ed.ac.uk

Bioinspired Robotics Laboratory

Bioinspired robotics draws on solutions found in nature for robotics problems, such as efficient locomotion control, effective navigation over short and long distances, and adaptive learning to flexible and noisy environments. In this lab we focus on understanding how insects, with their tiny brains, can support a range of capacities that easily outclass state-of-the-art robots. The lab carries out behavioural studies, in the lab and in the field, but principally develops computational models of the underlying neural mechanisms, which are tested on robot hardware. Recent projects include a neural model of odometry in the bee brain, tested on a flying robot platform; and an exploration of the learning capacities of maggots, which led to development of a novel learning algorithm that has proved effective on several benchmark robotics tasks.

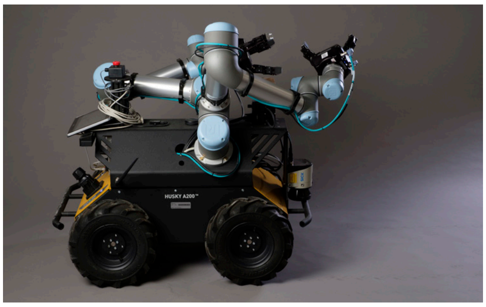
CyberBuild Research Laboratory

The construction sector, which represents between 5 and 10% of the GDP of modern economies, is undergoing a digital revolution that will transform the way we build and maintain our buildings and infrastructure. The CyberBuild Lab, based in the School of Engineering of the University of Edinburgh, supports this transformation by researching and developing technologies in the areas of scene understanding for environment modelling and monitoring, digital twinning, human-robot interaction and more. Examples of on-going research includes: 3D asset modelling from point clouds and images (including using AI), automated dimensional quality control, human-robot interaction using AR. Our work is primarily conducted in multi-disciplinary settings and in collaboration with industry partners.
https://cyberbuild.eng.ed.ac.uk/

Our Research Laboratories

Field Robotics Laboratories

Our research at Robotarium West focuses on enabling mobile robots and autonomous systems to understand real-world complex environments and achieve persistent autonomy in them. Research areas include robotic vision, simultaneous localisation and mapping (SLAM), autonomous navigation, 3D mapping and reconstruction, robot learning, computer vision and machine (deep) learning. The Lab has a Clearpath Husky mobile robot, a highly advanced and adaptable mobile robotics platform which is equipped with a variety of state-of-the-art sensors and manipulators (dual UR5 arms, LIDAR, Inertial Measurement Unit, stereo camera), to fulfil field missions even across challenging terrains. Our work on aerial swarm robots for autonomy and efficiency also addresses robot coordination tasks in critical activities. The industrial applications of our research range from smart transport and delivery systems to outdoor inspection and emergency response challenges.



http://www.macs.hw.ac.uk/RoboticsLab/

Our lab at Robotarium East houses field robots designed to work in extreme and hazardous environments. It includes construction of mock-ups for the offshore and built environment infrastructure asset inspection sector based around the Total Argos Challenge mock up with ANYmal quadruped robot for sensor deployment. The lab is also equipped with fuselage co-assembly and manipulation mock up using a mobile Husky robot with multi arm manipulators for the airline assembly and maintenance, offshore asset inspection, and manufacturing sectors. The space also houses the Valkyrie humanoid robot (collaboration with NASA JSC) with additional mock-ups being constructed to replicate uneven terrain loco-manipulation tasks on the Mars mission. The locomanipulation platform is a modular scaffolding structure conceived to simulate industrial real-life environment in the robotic field-laboratory, which includes ramps and stairs that can be reconfigured to simulate a multitude of scenarios. This will be expanded with a high precision KUKA IIWA dual arm system including integrated force sensing for precise manipulation and safe human robot collaboration. The setup will incorporate real-time Sigma.7 haptic devices with high fidelity for users to sense interaction forces and teleoperate better the torque controlled robots. Together with the VR/AR display and computing units, this will also provide intuitive and versatile controls to the robot during multi-contact and multi-modal operations in extreme and/or hazardous settings. All of this will be supported by a Vicon motion tracking system using 24 cameras along with a variable speed dual x-y-z heavy duty gantry system for support of dynamic locomotion on uneven terrain.

http://web.inf.ed.ac.uk/slmc/

Our Research Laboratories

Gait Laboratory

This laboratory houses the Motek split treadmill with a force plate setup to carry out human lower limb prosthesis motion tests and Exoskeleton support experiments. Data capture is supported through a 12 camera Vicon tracking system along with wireless EMG and Xsens inertial tracking systems. Experiments here are run in collaboration with the NHS Astley Ainslie Hospital and the NHS Newcastle Gait labs, expanding our existing collaboration with local partners.

Human-Robot Interaction (HRI) Laboratory

The Human Robot Interaction (HRI) Laboratory is located within the Robotarium West – a collaboration partnership with the University of Edinburgh. Research in this lab focuses on developing intelligent interactive systems which can collaborate effectively and adaptively with humans, by combining a variety of interaction modalities, such as speech, graphics, gesture, vision, augmented reality and Natural Language. Our systems combine statistical and symbolic information processing, and we are developing data-driven machine learning approaches to build robust agents which can adapt autonomously in uncertain and dynamic interactions. These techniques are applied in a variety of domains, such as conversational assistants (e.g. Alexa, Siri etc), conversational search, emergency response, technology enhanced learning, healthcare with a special interest on robot assisted rehabilitation in the home environment.

Facilities in the HRI lab and also in the Robotic Assistive Living lab allows us to take the evaluation in terms of performance of our models and algorithms from simulations to trials with real users with uninterrupted observation. This lab also has a variety of state-of-the-art robots, which were custom built for research (such as an iCub, Tiago and a Flash MKII) and commercially available social robots (such as Peppers, Naos, and MiROs). Having a wide miscellany of robots with different abilities and capabilities allows us to conduct research ranging from: Interactive Object Learning (IOL) in the area of Teachable Robots, to Robot-assisted Social Skill Training for Adults with ASD, and rehabilitation coaching of stroke survivors in the home environment.

For more information visit our website: https://www.macs.hw.ac.uk/hrigroup/

Our Research Labs

Independent Living Laboratory

The Centre avails of a 'Living-Lab" test-bed at Robotarium West, a fully sensorised 60m^2 home-like environment where our roboticists and computer scientists work alongside usability and health experts, psychologists, and people with assisted living needs, to co-design and test innovative solutions for healthy ageing and independent living. The research focus is on the combination of Robotics, AI and connected data systems, to assist humans and triage issues and also to facilitate communication and connectivity as part of personalised and connected social care practices. The laboratory participates in international initiatives promoting the certification and systematic evaluation and comparison of assistive service robots and user-centred, open innovation ecosystems for the integration of R&D results into real life communities and settings.
https://ralt.hw.ac.uk/

Our facility at Robotarium East houses living labs related to a hospital operating theatre mock up along with a reconfigurable setup for the following three scenarios: 1) surgical theatre assistance, 2) domestic home support, and 3) a factory co-assembly and support scenario. The three tasks can be switched by repositioning the 'equipment' in the work context while leaving the robots permanently fixed. PR2, Baxter and Kuka mobile robots will be used to study human robot collaborations in a hospital/care home setting, with the aim of delivering projects in the assisted living domain. The entire space will be sensorised with high density commodity cameras and activity log tracking systems. This setup will facilitate cutting edge machine learning research and big data approaches with the aim of developing new technology for assistive healthcare and smart cities.

Interaction Laboratory

Our research focusses on conversational AI, Natural Language Processing, and machine learning. We are developing intelligent interactive systems which can collaborate effectively and adaptively with humans, by combining a variety of interaction modalities, such as speech, graphics, gesture, vision, augmented reality and Natural Language. Our systems combine statistical and symbolic information processing, and we are developing data-driven machine learning approaches to build robust agents which can adapt autonomously in uncertain and dynamic interactions. These techniques are applied in a variety of domains, such as conversational assistants (e.g. Alexa, Siri etc), conversational search, emergency response, technology enhanced learning, healthcare informatics, and human-robot interaction (HRI).
We evaluate the performance of our models and algorithms both in simulation and in trials with real users. The Interaction Lab was one of only three teams to reach the finals of the Amazon Alexa Challenge, both in 2017 and 2018. We lead the human-machine interaction work on the EPSRC ORCA Hub for interacting with robots and autonomous systems in remote, hazardous environments.
Our projects include the H2020 MuMMER project, which focuses on interactive human-robot navigation around large indoor spaces such as shopping malls, and the H2020 SPRING project on social robotics for elderly care. Both of these projects also entertain and inform users via our Alexa challenge system.
We are also pushing the boundaries in Natural Language Generation, including open-domain response generation in conversational systems, multimodal grounding, and task-based data-to-text generation, where our team organised the highly subscribed E2E NLG Challenge. Projects in this area include 2 EPSRC funded projects on bias and security, industry collaborations with Adobe, Facebook and Google, as well as a senior research fellowship awarded by the Royal Society.
http://www.macs.hw.ac.uk/interactionlab/

Our Research Labs

Machine learning and symbolic systems Lab

The lab carries out research in artificial intelligence, by unifying ideas from machine learning and symbolic systems (logics, programs and plans), with a recent emphasis on explainability and ethics. We are motivated by the need to augment learning and perception with high-level structured, commonsensical knowledge, to enable systems to learn faster and more accurate models of the world. We are interested in developing computational frameworks that are able to explain their decisions, modular, re-usable, and robust to variations in problem description. A non-exhaustive list of topics include: ethics and explainability in AI (e.g. fairness, moral reasoning, post-hoc explainability), unifying deep learning and probabilistic learning methods, probabilistic programming, automated planning, high-level programming, reinforcement learning, cognitive robotics, multi-agent systems and epistemic planning.
https://vaishakbelle.com/lab/

Ocean Systems Laboratory

This is a multidisciplinary science and engineering research centre that innovates, applies and teaches world class advances in autonomous systems, sensor modelling/processing, and underwater acoustic system theory/design for offshore, marine science, renewable energy and security applications.

In Autonomous Systems, we have developed novel planning, obstacle avoidance, world modelling, operator dialog and visual servoing methods for Autonomous Underwater Vehicles and integrated them within open system architectures.
In Sensor modelling and analysis, novel navigation algorithms have been developed sharing information from multiple sensors. Model-based detection and classification algorithms have been successfully developed and trialled seeking mine like objects, seabed trawling impact and marine mammals in acoustic and video data. Our method has always been to have a three point approach to research problems by linking theoretical analysis, software simulations and experimental validation. Our tank facilities and vehicles enable us to validate the theory and simulation findings in real experiments.
http://www.oceansystemslab-heriotwatt.com

Our Research Labs

RAS Rapid Manufacturing and Design Studio

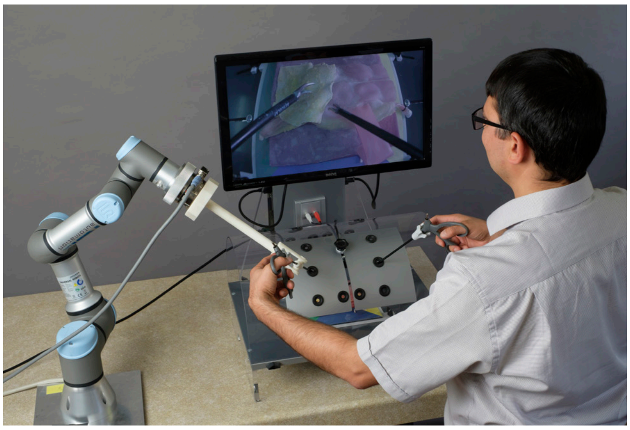
This facility (RMDS) encourages innovation and creation facilitated by digital and collaborative manufacturing tools. The Maker approach brings concepts and scientific principles to physical realisation facilitated by VR/AR, haptics, optical tracking, 3D scanning, 3D printing and laser cutting equipment. Besides research in digital manufacturing, concurrent engineering, collaborative design and review systems, we also research its associated human factors. RMDS has researched and implemented interactive systems using brain control, cyber-physical systems and body-area networks. RMDS is currently involved in an EU H2020 project to design and develop highly interactive mixed reality training environments. Supported by a bespoke multimodal data capture and synchronisation framework RMDS can offer innovative, versatile and comprehensive solutions in the area of knowledge/security/asset management, operational training and assessment, including functional art.
https://www.hw.ac.uk/uk/schools/engineering-physical-sciences/institutes/mechanical-process-energy-engineering/rapid-manufacturing-design-studio-rmds-.htm

Robotic Micromanipulation and Microassembly Laboratory

The Robotic Micromanipulation and Microassembly Laboratory (RMML) develops techniques and solutions for fabrication and manufacturing of microdevices, microsensors, microsystems and microrobots. The capabilities are based on two decades of research in microsystem technology, especially methods and processes of microscale bonding and joining for interconnection, integration and packaging of sensors and microsystems. The current activities include the development of microgrippers which have been used to demonstrate assembly of 3D microstructures with an industrial partner. In an EPSRC funded project, we are developing microassembly methods for high temperature sensors and electronics capable of operation beyond 300°C. The research and knowledge have been transferred to postgraduate teaching in the EU funded Erasmus Mundus Joint Master Degree (EMJMD) Programme in Smart Systems Integration (https://ssi-master.eu/)

Skill Assistance Laboratory

The research activities in this Lab include physical human-robot interaction, assistive robotics, skill assistance, mechatronics design, medical robotics, walking robots, and machine learning. Specifically, our research has been focussed on identifying what "skill" is in manipulation tasks, such as manual-welding in industry and laparoscopy in medicine, through analysing data of novice versus professional subjects in four different modalities: trajectories of tool movement, robotised measurement of mechanical hand impedance, EMG recording of arm muscle activities, and near-infra-red spectroscopy recording of cortical brain activity. These data are analysed to find out the patterns of muscle activity that relate to the level of human skill. Brain activity monitoring provides a path-way to identify the skill level of subjects through criteria that cannot be consciously manipulated by the trainees. This might prove to be useful as a basis for making objective assessments and ultimately for providing individualised assistance in a variety of human-robot cooperative tasks.



https://researchportal.hw.ac.uk/en/persons/mustafa-suphi-erden

Our Research Labs

Smart Systems Laboratory

Our global society is placing increasing demands on its critical infrastructure, systems that deliver vital services such as energy, transportation, telecommunications, food and water, the built environment and healthcare. The systems within these sectors are increasingly complex and interdependent, interacting on a global scale. This complexity is required for efficient operation, but also makes systems more susceptible to cascading failure under stress.
The Smart Systems Group (SSG) believes we must transform data into actionable information and utilise this insight to create innovative, data informed, Smart Systems that can assess, adapt and respond to dynamic conditions. Our multidisciplinary team with expertise in data analysis, artificial intelligence, prognostics, manufacturing, energy systems and sensing technologies, are focused on the design, manufacture and characterisation of transformative Smart Systems. Continuity of service from critical infrastructure and technology as a service trends are fuelling global demand for Smart Systems across all sectors of industry and services to society. We work with a global network of academic and industrial partners to deliver the flexibility, resilience and sustainability, our global infrastructure requires.
https://smartsystems.hw.ac.uk

Soft Systems Group

The Soft Systems Group is part of the Institute for Integrated Micro and Nano Systems in The School of Engineering at The University of Edinburgh. The group uses a wide range of bioinspired engineering approaches to tackle the most challenging issues faced by society.
The research group has an ever growing range of interests including: bioinspired engineering, sensors, robotics, microfluidics, micro/nano fabrication, wearable technology, diagnostics, bioelectronics, and metamaterials. https://softsystemsgroup.com/

Strategic Futures Laboratory

Our research focuses on the use of AI tools to provide strategic overviews of large repositories of unstructured documents in order to aid high-level, evidence-based, decision making. We use advanced machine learning and visualisation approaches to provide intuitive, hierarchical maps of large to vast document sets. Statistical data and easy drill-down are also provided for deep exploration, quantitative analysis and automated decision making. Examples of use include providing strategic level comparison of national UK, US and EU research portfolios (circa 200,000 projects), comparing strengths and complementarities of eight sister organisations, and analysing trends in free of financial transactions.
http://strategicfutures.org

Virtual Reality Laboratory

High fidelity capture of human motion for work in collaboration with computer graphics and animation companies is carried out in this space which will host a range of cutting edge 3D real-time motion sensing and tracking capabilities. A 20+12 camera Vicon system is installed in addition to a more specialised motion capturing system with advanced software for tracking multiple subjects at the same time as well as hand gesture tracking. The lab also includes a high-framerate 3dMD3D body scanner and facial motion tracking system, and Oculus Rift AR/VR displays. This facility will focus on state of the art animation, graphics, and augmented reality with applications to robotics, construction, remote inspection, entertainment, and simulation and training for both research and the industry.

Student Research Outputs - Conference Publications

Wenbin Hu, **Iordanis Chatzinikolaidis, Kai Yuan,** Zhibin Li
Comparison Study of Nonlinear Optimization of Step Durations and Foot Placement for Dynamic Walking. Proceedings of IEEE International Conference on Robotics and Automation (ICRA), 2018, DOI 10.1109/ICRA.2018.8461101

Qingbiao Li, **Iordanis Chatzinikolaidis**, Yiming Yang, Sethu Vijayakumar, Zhibin Li
Robust Foot Placement Control for Dynamic Walking using Online Parameter Estimation, Proceedings of IEEE-RAS International Conference on Humanoid Robots, 2017, DOI 10.1109/HUMANOIDS.2017.8239552

A. Vanzo, **J. L. Part,** Y. Yu, D. Nardi and O. Lemon
Incrementally Learning Semantic Attributes through Dialogue Interaction, to appear in Proceedings of the 17th International Conference on Autonomous Agents and Multiagent Systems (AAMAS), Stockholm, Sweden, July 2018

J. L. Part and O. Lemon
Incremental Online Learning of Objects for Robots Operating in Real Environments, in Proceedings of the 7th Joint IEEE International Conference on Development and Learning and on Epigenetic Robotics (ICDL-EPIROB), Lisbon, Portugal, September 2017

J. L. Part and O. Lemon
Teaching Robots through Situated Interactive Dialogue and Visual Demonstrations, in Proceedings of the 26th International Joint Conference on Artificial Intelligence (IJCAI), Melbourne, Australia, August 2017

Artjoms Šinkarovs, Sven-Bodo Scholz, Robert Stewart, and **Hans-Nikolai Vießmann**
Recursive Array Comprehensions in a Call-by-Value Language. In IFL 2017: 29th Symposium on the Implementation and Application of Functional Programming Languages, August 30-September 1, 2017, Bristol, United Kingdom.

Henderson, Graham, **Daniel Gordon,** and Sethu Vijayakumar
Identifying invariant gait metrics for exoskeleton assistance. In Proceedings of IEEE Robio 2017, IEEE International Conference on Robotics and Biomimetics

Raluca Scona, Simona Nobili, Yvan R. Petillot, Maurice Fallon
Direct Visual SLAM Fusing Proprioception for a Humanoid Robot
In Proceedings of International Conference on Intelligent Robots and Systems (IROS) 2017
DOI: 10.1109/IROS.2017.8205943

Raluca Scona, Mariano Jaimez, Yvan R. Petillot, Maurice Fallon, Daniel Cremers
StaticFusion: Background Reconstruction for Dense RGB-D SLAM in Dynamic Environments
In Proceedings of International Conference on Robotics and Automation (ICRA) 2018
DOI: 10.1109/ICRA.2018.8460681

Wolfgang Merkt, Yiming Yang, **Theodoros Stouraitis, Christopher Mower**, Maurice Fallon, Sethu Vijayakumar
Robust Shared Autonomy for Mobile Manipulation with Continuous Scene Monitoring. Proc. 13th IEEE Conference on Automation Science and Engineering, Xian, China (2017)

Yiming Yang, Vladimir Ivan, **Wolfgang Merkt** and Sethu Vijayakumar
Scaling Sampling–based Motion Planning to Humanoid Robots. Proc. IEEE International Conf. on Robotics and Biomimetics (ROBIO 2016), Qingdao, China (2016).

Wolfgang Merkt, Vladimir Ivan, and Sethu Vijayakumar
Leveraging Precomputation with Problem Encoding for Warm-Starting Trajectory Optimization in Complex Environments. Proc. IEEE International Conf. on Intelligent Robots (IROS 2018), Madrid, Spain (2018)

Student Research Outputs - Conference Publications

Kai Yuan, Zhibin Li
A Unified Model Predictive Control Framework for Gait Planning and Feedback Control of Legged Locomotion. Proceedings 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)

Gordon, D. F. N., Matsubara, T., Noda, T., Morimoto, J., and Vijayakumar, S.
Bayesian Optimisation of Exoskeleton Design Parameters. Biomedical Robotics (BIOROB), 2018 IEEE International Conference on. IEEE, 2018.

Christian Rauch, Timothy Hospedales, Jamie Shotton, Maurice Fallon
Visual Articulated Tracking in the Presence of Occlusions, 2018 IEEE International Conference on Robotics and Automation (ICRA), Brisbane, Australia, 2018, pp. 643-650.
doi: 10.1109/ICRA.2018.8462873

È. Pairet, J. D. Hernández, M. Lahijanian, and M. Carreras
"Uncertainty-based Online Mapping and Motion Planning for Marine Robotics Guidance," in IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2018.

M. Campbell, I. Schlangen, E. Delande, and D. Clark
Image Registration Using Single Cluster PHD Methods, in Advanced Maui Optical and Space Surveillance Technologies Conference, 2017.

K. S. Lohan, **E. Sheppard,** G. E. Little, G. Rajendran
Distinguishing children with ASD using pupil diameter metrics. 6th Joint IEEE International Conference on Development and Learning and on Epigenetic Robotics 2016

Tugal, H., **Gautier, B.**, Kircicek, M. & Erden, M. S.
Hand-Impedance Measurement During Laparoscopic Training Coupled with Robotic Manipulators
28 Jun 2018 (Accepted/In press) Proceedings of the 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2018). IEEE

C. Yang, **K. Yuan, W. Merkt**, T. Komura, S. Vijayakumar, and Z. Li,
"Deep Reinforcement Learning of Locomotion Skills for the Humanoid Valkyrie" , IEEE International Conference on Humanoid Robots (Humanoids), 2018

Yiming Yang, **Wolfgang Merkt,** Vladimir Ivan, Sethu Vijayakumar
Planning in Time-Configuration Space for Efficient Pick-and-Place in Non-Static Environments with Temporal Constraints, Accepted to IEEE-RAS International Conference on Humanoid Robots, 2018.

Henrique Ferrolho, Wolfgang Merkt, Yiming Yang, Vladimir Ivan, Sethu Vijayakumar
Whole-Body End-Pose Planning for Legged Robots on Inclined Support Surfaces in Complex Environments, Accepted to IEEE-RAS International Conference on Humanoid Robots, 2018.

Y. Hristov, A. Lascarides, S. Ramamoorthy
Interpretable Latent Spaces for Learning from Demonstration, Conference on Robot Learning (CoRL), 2018.

Erden, M. S. & **Chun, H-T.**
Muscle Activity Patterns Change with Skill Acquisition for Minimally Invasive Surgery: A Pilot Study
31 May 2018 (Accepted/In press) Proceedings of the 7th IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechatronics (BioRob 2018).

João Moura, Mustafa Suphi Erden
Formulation of a control and path planning approach for a cab front cleaning robot . In Procedia CIRP, 5th International Conference on Through-life Engineering Services (TESConf), 2017, DOI: 10.1016/j.procir.2016.09.024.

Student Research Outputs - Conference Publications

Leopoldo Armesto, **João Moura,** Vladimir Ivan, Antonio Salas, and Sethu Vijayakumar
Learning constrained generalizable policies by demonstration. In Robotics: Science and Systems XIII (RSS), 2017, DOI: 10.15607/RSS.2017.XIII.036.

T. López-Guevara, N.K. Taylor, M.U. Gutmann, S. Ramamoorthy, K. Subr
Adaptable pouring: Teaching robots not to spill using fast but approximate fluid simulation, Conference on Robot Learning (CoRL), 2017.

S. Penkov, A. Bordallo, S. Ramamoorthy
Physical symbol grounding and instance learning through demonstration and eye tracking, IEEE International Conference on Robotics and Automation, 2017.

Frost, Gordon, David M. Lane, **Nikolaos Tsiogkas,** Daniele Spaccini, Chiara Petrioli, Maarja Kruusmaa, Victoria Preston, and Taavi Salumäe
MANgO: federated world Model using an underwater Acoustic NetwOrk. In OCEANS 2017-Aberdeen, pp. 1-6. IEEE, 2017.

Tsiogkas, Nikolaos, Valerio De Carolis, and David M. Lane
Towards an online heuristic method for energy-constrained underwater sensing mission planning. In Intelligent Robots and Systems (IROS), 2017 IEEE/RSJ International Conference on, pp. 6801-6808. IEEE, 2017.

Mocialov, B., Vargas, P. A., & Couceiro, M. S.
Towards the evolution of indirect communication for social robots. In Computational Intelligence (SSCI), 2016 IEEE Symposium Series on (pp. 1-8). IEEE.

HC Lin, **J Smith,** KK Babarahmati, N Dehio, M Mistry
A Projected Inverse Dynamics Approach for Multi-arm Cartesian Impedance Control - ICRA 2018

N Dehio, **J Smith,** D Leroy, G Xin, HC Lin, JJ Steil, M Mistry
Modeling & Control of Multi-Arm and Multi-Leg Robots: Compensating for Object Dynamics during Grasping - ICRA 2018

G Xin, HC Lin, **J Smith, O Cebe,** M Mistry
A Model-based Hierarchical Controller for Legged Systems subject to External Disturbances - ICRA 2018

A Brock, T Lim, JM Ritchie, N Weston
SMASH: One-Shot Model Architecture Search through HyperNetworks." ICLR 2018

A Brock, T Lim, JM Ritchie, N Weston
Neural Photo Editing with Introspective Adversarial Networks." ICLR 2017

Ardón P, S. Ramamoorthy, K.S. Lohan
Object affordances by inferring on the surroundings, In Proc. IEEE Workshop on Advance Robotics and its Social Impact, 2018.

Brock, A., Lim, T., Ritchie, J. M. & Weston, N.
ConvNet-Based Optical Recognition for Engineering Drawings. ASME IDETC/CIE 2017

Brock, A., Lim, T., Ritchie, J. M. & Weston, N.
Context-Aware Content Generation for Virtual Environments. ASME IDETC/CIE 2016

È. Pairet, P. Ardón, F. Broz, M. Mistry, and Y. Petillot.
"Learning and Generalisation of Primitives Skills Towards Robust Dual-arm Manipulation," in AAAI Fall Symposium Series, Reasoning and Learning in Real-World Systems for Long-Term Autonomy (AAAI-FSS), 2018.

M. Burke, **Y. Hristov,** S. Ramamoorthy
Hybrid system identification using switching density networks, Conference on Robot Learning (CoRL), 2019.

Student Research Outputs - Conference Publications

P. Ardón, È. Pairet, S. Ramamoorthy, and K. S. Lohan.
"Towards Robust Grasps, Using the Environment Semantics for Robotic Object Affordances," in AAAI Fall Symposium Series, Reasoning and Learning in Real-World Systems for Long-Term Autonomy (AAAI-FSS), 2018.

J. L. Part and O. Lemon
Towards a Robot Architecture for Situated Lifelong Object Learning, to appear in Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Macau, China, November 2019

J. H. Ng, R. Petrick
Incremental Learning of Action Models in Model-based Reinforcement Learning, International Joint Conferences on Artificial Intelligence (2019).

D. Angelov, Y. Hristov, S. Ramamoorthy
Using causal analysis to learn specifications from task demonstrations, In Proc. International Conference on Autonomous Agents and Multiagent Systems (AAMAS), 2019.

D. Angelov, Y. Hristov, S. Ramamoorthy
DynoPlan: Combining Motion Planning and Deep Neural Network based Controllers for Safe HRL, In Proc. The Multi-disciplinary Conference on Reinforcement Learning and Decision Making (RLDM), 2019.

È. Pairet, P. Ardón, M. Mistry, and Y. Petillot
Learning and Composing Primitive Skills for Dual-arm Manipulation, in Annual Conference Towards Autonomous Robotic Systems (TAROS19). Advanced Robotics at Queen Mary (ARQ) best paper award.

P. Ardón, È. Pairet, R. Petrick, S. Ramamoorthy, and K. S. Lohan
Reasoning on Grasp-Action Affordances, in Annual Conference Towards Autonomous Robotic Systems (TAROS19). Best paper award finalist.

È. Pairet, P. Ardón, X. Liu, J. Lopes, H. Hastie, and K. S. Lohan
"A Digital Twin for Human-Robot Interaction", in ACM/IEEE International Conference on Human-Robot Interaction (HRI), 2019.

Carreno, Y., Petrick, R.P. and Petillot, Y.
Multi-Agent Strategy for Marine Applications via Temporal Planning. In 2019 IEEE Second International Conference on Artificial Intelligence and Knowledge Engineering (AIKE) (pp. 243-250). IEEE. June 2019.

Carreno, Y., Petrick, R.P. and Petillot, Y.
Towards Long-Term Autonomy Based on Temporal Planning. In Annual Conference Towards Autonomous Robotic Systems (pp. 143-154). Springer, Cham. July 2019.

Daniel E. Clark, **Mark Campbell**
Joint Multi-Target Tracking and Parameter Estimation with the Second-Order Factorial Cumulant Filter. 2019 22nd International Conference on Information Fusion (FUSION). Ottawa, Canada.

Ben Krause, **Emmanuel Kahembwe**, Iain Murray, and Steve Renals
Dynamic Evaluation of Neural Sequence Models. Proceedings of the 35th International Conference on Machine Learning, PMLR 80:2766-2775, 2018.

João Moura, Vladimir Ivan, Mustafa Suphi Erden, and Sethu Vijayakumar
Equivalence of the Projected Forward Dynamics and the Dynamically Consistent Inverse Solution. Robotics: Science and Systems XV (RSS), 2019, DOI: 10.15607/RSS.2019.XV.036. [Best Paper Award Finalist]

Y. Hristov, D. Angelov, A. Lascarides, M. Burke, S. Ramamoorthy
Disentangled Relational Representations for Explaining and Learning from Demonstration, Conference on Robot Learning (CoRL), 2019.

Student Research Outputs - Conference Publications

Wolfgang Merkt, Vladimir Ivan and Sethu Vijayakumar
Continuous-Time Collision Avoidance for Trajectory Optimisation in Dynamic Environments, Proc. IEEE Intl. Conf. on Intelligent Robots and Systems (IROS 2019), Macau, China (2019).

Chris Mower, Wolfgang Merkt, Aled Davies and Sethu Vijayakumar
Comparing Alternate Modes of Teleoperation for Constrained Tasks, Proc. 15th IEEE Intl. Conf. on Automation Science and Engineering (CASE 2019), Vancouver, BC, Canada (2019).

Wolfgang Merkt, Vladimir Ivan, Yiming Yang and Sethu Vijayakumar
Towards Shared Autonomy Applications using Whole-body COntrol Formulations of Locomanipulation, Proc. 15th IEEE Intl. Conf. on Automation Science and Engineering (CASE 2019), Vancouver, BC, Canada (2019).

H.-N. Vießmann, A. Šinkarovs, and S.-B. Scholz
Extended Memory Reuse: An Optimisation for Reducing Memory Allocations. In Proceedings of the 30th Symposium on Implementation and Application of Functional Languages (IFL 2018), Lowell, MA, USA, September 2018.

A. Šinkarovs, R. Bernecky, **H.-N. Vießmann**, and S.-B. Scholz
A Rosetta Stone for Array Languages. In Proceedings of the 5th ACM SIGPLAN International Workshop on Libraries, Languages, and Compilers for Array Programming (ARRAY 2018). New York, NY, USA, June 2018.

A. Šinkarovs, S.-B. Scholz, R. Stewart, and **H.-N. Vießmann**
Recursive Array Comprehensions in a Call-by-Value Language. In Proceedings of the 29th Symposium on the Implementation and Application of Functional Programming Languages (IFL 2017). New York, NY, USA, September 2017. https://doi.org/10.1145/3205368.3205373

James Garforth, Barbara Webb
Visual Appearance Analysis of Forest Scenes for Monocular SLAM. Proceedings of IEEE International Conference on Robotics and Automation (ICRA), 2019, DOI:10.1109/ICRA.2019.8793771

M. Burke, **S.V. Penkov,** S. Ramamoorthy
From explanation to synthesis: Compositional program induction for learning from demonstration, Robotics: Science and Systems (R:SS), 2019.

S.V. Penkov, S. Ramamoorthy
Learning programmatically structured representations with perceptor gradients, In Proc. International Conference on Learning Representations (ICLR), 2019.

E. Nault, L. Baillie, and F. Broz
"Auditory and haptic feedback in a socially assistive robot memory game," in Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction, 2020, pp. 369–371.

R. Smith, Y. Ding, G. Goussetis, and M. Dragone
A COTS (UHF) RFID Floor for Device-Free Ambient Assisted Living Monitoring. In Proceedings of the 11th International Symposium on Ambient Intelligence (ISAmI), 2020.

Ardón, P.; Pairet, È.; Y. Petillot; Petrick, R.; Ramamoorthy, S.; and Lohan, K. S.
"Self-Assessment of Grasp Affordance Transfer". IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). October 2020.

D. Robb, M. Ahmad, C. Tiseo, S. Aracri, A. C. McConnell, V. Page, C. Dondrup, F. Garcia, H. Nguyen, **È. Pairet, P. Ardón**, T. Semwal, H. Taylor, L. Wilson, D. Lane, H. Hastie, and K. Lohan
"Robots in the Danger Zone: Exploring Public Perception through Engagement", in ACM/IEEE International Conference on Human-Robot Interaction (HRI), 2020.

Student Research Outputs - Conference Publications

W. Hu, **I. Chatzinikolaidis, K. Yuan**, and Z. Li
"Comparison Study of Nonlinear Optimization of Step Durations and Foot Placement for Dynamic Walking" , IEEE International Conference on Robotics and Automation (ICRA), 2018

Y. Carreno, È. Pairet, Y. Petillot, and R. Petrick
"A Decentralised Strategy for Heterogeneous AUV Missions via Goal Distribution and Temporal Planning", in International Conference on Automated Planning and Scheduling (ICAPS), 2020.

Y. Carreno, È. Pairet, Y. Petillot, and R. Petrick
"Task Allocation Strategy for Heterogeneous Robot Teams in Offshore Missions", in International Conference on Autonomous Agents and Multiagent Systems (AAMAS), 2020.

Henrique Ferrolho, Wolfgang Merkt, Vladimir Ivan, Wouter Wolfslag, Sethu Vijayakumar
"Optimizing Dynamic Trajectories for Robustness to Disturbances Using Polytopic Projections", in IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Las Vegas, USA, 2020.

Z. Sun, **K. Yuan,** W. Hu, C. Yang, and Z. Li
"Learning Pre-Grasp Manipulation for Objects in Un-graspable Poses", IEEE International Conference on Robotics and Automation (ICRA), 2020

C. McGreavy, K. Yuan, D. Gordon, K. Tan, W. Wolfslag, S. Vijayakumar, and Z. Li
"Unified Push Recovery Fundamentals: Inspiration from Human Study", IEEE International Conference on Robotics and Automation (ICRA), 2020

K. Yuan and Z. Li
"An Improved Formulation for Model Predictive Control of Legged Robots for Gait Planning and Feedback Control", IEEE-RAS International Conference on Intelligent Robots and Systems (IROS), 2018

Paulius Dilkas, Vaishak Belle
Generating Random Logic Programs Using Constraint Programming. Proceedings of the 26th International Conference on Principles and Practice of Constraint Programming (CP), 2020

Z Hong, Y Petillot, S Wang
"RadarSLAM: Radar based Large-Scale SLAM in All Weathers" In Proceedings of International Conference on Intelligent Robots and Systems (IROS) 2020

Yaniel Carreno, Yvan Petillot, and Ronald P. A. Petrick
Towards Robust Mission Execution via Temporal and Contingent Planning. In Proceedings of the 21st Towards Autonomous Robotic Systems (TAROS) Conference, 2020.

Caetano Ranieri, Renan Moioli, Roseli Romero, Mariana Araújo, Maxwell Santana, **Jhielson Pimentel** and Patrícia Vargas
Unveiling Parkinson's Disease Features from a Primate Model with Deep Neural Networks. Proceedings of IEEE World Congress on Computational Intelligence (WCCI)/International Joint Conference on Neural Networks (IJCNN), 2020.

Wouter Wolfslag, **Christopher McGreavy,** Guiyang Xin, Carlo Tiseo, Sethu Vijayakumar, Zhibin Li
Optimisation of Body-ground Contact for Augmenting Whole-Body Loco-manipulation of Quadruped Robots IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2020

Hugo Sardinha, Mauro Dragone, Patricia A. Vargas
Combining Lévy Walks and Flocking for Cooperative Surveillance using Aerial Swarms
(To appear in) Proceedings of the 17th European Conference on Multi-Agent Systems (EUMAS 2020)

Student Research Outputs - Conference Publications

Hugo Sardinha, Mauro Dragone, Patricia A. Vargas
Towards an Adaptive Lévy Walk using Artificial Endocrine Systems
(To appear in) Proceedings of the 12th International Conference on Adaptive and Self-Adaptive Systems and Applications (ADAPTIVE 2020)

Alessandro Suglia, Ioannis Konstas, Andrea Vanzo, Emanuele Bastianelli, Desmond Elliott, Stella Frank and Oliver Lemon
"CompGuessWhat?!: a Multi-task Evaluation Framework for Grounded Language Learning". In: Proceedings of the 58th Annual Meeting of the Association for Computational Linguistics. 2020

Alessandro Suglia, Antonio Vergari, Ioannis Konstas, Yonatan Bisk, Emanuele Bastianelli, Andrea Vanzo and Oliver Lemon
"Imagining Grounded Conceptual Representations from Perceptual Information in Situated Guessing Games".(To appear) Proceedings of the 28th International Conference on Computational Linguistics (COLING). 2020

Olivia Foulds, **Alessandro Suglia**, Leif Azzopardi, Martin Halvey. "Predicting perceptual speed from search behaviour." Proceedings of the 43rd International ACM SIGIR Conference on Research and Development in Information Retrieval. 2020.

Student Research Outputs - Journal Publications

Leopoldo Armesto, **João Moura,** Vladimir Ivan, Mustafa Suphi Erden, Antonio Salas, and Sethu Vijayakumar
Constraint-aware Learning of Policies by Demonstration. In International Journal of Robotics Research (IJRR), 2018 DOI: 10.1177/0278364918784354

João Moura, William McColl, Gerard Taykaldiranian, Tetsuo Tomiyama, Mustafa Suphi Erden
Automation of Train Cab Front Cleaning with a Robot Manipulator. In IEEE Robotics and Automation Letters, 2018, DOI: 10.1109/LRA.2018.2849591. (selected for presentation at the 14th IEEE International Conference on Automation Science and Engineering - CASE)

Gordon D.F.N, Henderson G and Vijayakumar S
Effectively Quantifying the Performance of Lower-Limb Exoskeletons Over a Range of Walking Conditions. Front. Robot. AI 5:61 doi 10.3389/frobt.2018.00061

Yiming Yang, **Wolfgang Merkt,** Vladimir Ivan, Zhibin Li, and Sethu Vijayakumar
HDRM: A Resolution Complete Dynamic Roadmap for Real-Time Motion Planning in Complex Scenes. IEEE Robotics and Automation Letters, 2018, In Press. DOI: 10.1109/LRA.2017.2773669

Yiming Yang, **Wolfgang Merkt, Henrique Ferrolho**, Vladimir Ivan, and Sethu Vijayakumar
Efficient Humanoid Motion Planning on Uneven Terrain Using Paired Forward-Inverse Dynamic Reachability Maps. IEEE Robotics and Automation Letters, 2017, In Press. DOI: 10.1109/LRA.2017.2727538

Krasoulis, A., **Kyranou, I.,** Erden, M. S., Nazarpour, K., & Vijayakumar, S.
Improved prosthetic hand control with concurrent use of myoelectric and inertial measurements. Journal of neuroengineering and rehabilitation, 14(1), 71.

Tsiogkas, Nikolaos, and David M. Lane
An Evolutionary Algorithm for Online, Resource-Constrained, Multivehicle Sensing Mission Planning. IEEE Robotics and Automation Letters 3, no. 2 (2018): 1199-1206.

Kyranou, I., Vijayakumar, S. & Erden, M. S
Causes of Performance Degradation in Electromyographic Pattern Recognition in Upper Limb Prostheses. 27 Aug 2018 (Accepted/In press) In: Frontiers in Neurorobotics.

Ardón P., Dragone, M. & Erden, M. S
Reaching and Grasping of Objects by Humanoid Robots through Visual Servoing. 6 Jun 2018 Haptics: Science, Technology, and Applications. Springer, p. 353-365 13 p. (Lecture Notes in Computer Science; vol. 10894)

M. Burke, **Y. Hristov,** S. Ramamoorthy, Hybrid system identification using switching density networks, Conference on Robot Learning (CoRL), 2019.

M. Burke, **S.V. Penkov**, S. Ramamoorthy
From explanation to synthesis: Compositional program induction for learning from demonstration, Robotics: Science and Systems (R:SS), 2019.

E. Sheppard, K. S. Lohan, G.E. Little, G. Rajendran
Towards improved child robot interaction by understanding eye movements,IEEE TCDS Special Issue A sense of interaction in humans and robots: from visual perception to social cognition 2018

E. Sheppard, K. S. Lohan, G.E. Little, G. Rajendran
Towards improved child robot interaction by understanding eye movements,IEEE TCDS Special Issue A sense of interaction in humans and robots: from visual perception to social cognition 2018

Mahon, S.T.; Roberts, J.O.; Sayed, M.E.; **Chun, D.** H.-T.; Aracri, S.; **McKenzie, R.M.**; Nemitz, M.P.; Stokes, A.A.
Capability by Stacking: The Current Design Heuristic for Soft Robots. Biomimetics 2018, 3, 16.

G. I. Parisi, R. Kemker, **J. L. Part,** C. Kanan and S. Wermter
Continual Lifelong Learning with Neural Networks: A Review, in Neural Networks, 2019

Student Research Outputs - Journal Publications

M. Asenov, M. Rutkauskas, D.T. Reid, K. Subr, S. Ramamoorthy
Active localization of gas leaks using fluid simulation, IEEE Robotics and Automation Letters, Vol 4(2): 1776 - 1783, 2019. Presented at the IEEE International Conference on Robotics and Automation, 2019.

M. Rutkauskas, **M. Asenov,** S. Ramamoorthy, D.T. Reid
Autonomous multi-species environmental gas sensing using drone-based Fourier-transform infrared spectroscopy, Optics Express, Vol. 27, Issue 7, pp. 9578-9587, 2019.

È. Pairet, P. Ardón, M. Mistry, and Y. Petillot
Learning Generalisable Coupling Terms for Obstacle Avoidance via Low-dimensional Geometric Descriptors, in IEEE Robotics and Automation Letters (RA-L), 2019.

P. Ardón, È. Pairet, R. Petrick, S. Ramamoorthy, and K. S. Lohan
Learning Grasp Affordance Reasoning through Semantic Relations, in IEEE Robotics and Automation Letters (RA-L), 2019.

K. Yuan, I. Chatzinikolaidis, and Z. Li
Bayesian Optimisation for Whole-Body Control of High Degrees of Freedom Robots through Reduction of Dimensionality, Robotics and Automation Letters (RA-L), 2019

E. Triantafyllidis, C. Mcgreavy, J. Gu and Z. Li
"Study of Multimodal Interfaces and the Improvements on Teleoperation," in IEEE Access, vol. 8, pp. 78213-78227, 2020, DOI: 10.1109/ACCESS.2020.2990080.

K. Yuan, C. McGreavy, C. Yang, W. Wolfslag, and Z. Li
"Decoding Motor Skills of AI and Human Policies: A Study on Humanoid and Human Balance Control", IEEE Robotics and Automation Magazine (RAM), 2020

R. Wen, **K. Yuan**, Q. Wang, S. Heng, and Z. Li
"Force-guided High-precision Grasping Control of Fragile and Deformable Objects using sEMG-based Force Prediction", IEEE Robotics and Automation Letters (RA-L), 2020

C. Yang, **K. Yuan,** S. Heng, T. Komura, and Z. Li
"Learning natural locomotion behaviors for humanoid robots using human bias", IEEE Robotics and Automation Letters (RA-L), 2020

I. Chatzinikolaidis, Y. You, and Z. Li
"Contact-Implicit Trajectory Optimization Using an Analytically Solvable Contact Model for Locomotion on Variable Ground", IEEE Robotics and Automation Letters, 2020, DOI: 10.1109/LRA.2020.3010754

D. Angelov, S. Ramamoorthy
Learning from Demonstration of Trajectory Preferences through Causal Modeling and Inference, In Proc. Robotics: Science and Systems Workshop on Causal Imitation in Robotics (RSS18-CIR), 2018.

T. López-Guevara, R. Pucci, N.K. Taylor, M.U. Gutmann, S. Ramamoorthy, K. Subr
To Stir or Not to Stir: Online Estimation of Liquid Properties for Pouring Actions , In Proc. Robotics: Science and Systems Workshop on Learning and Inference in Robotics: Integrating Structure, Priors and Models (RSS18-LAIR), 2018.

Student Research Outputs - Workshop Papers

S. Penkov, S. Ramamoorthy
Using program induction to interpret transition system dynamics,, In Proc. ICML Workshop on Human Interpretability in Machine Learning (ICML-WHI), 2017.

T. Davchev, T. Korres, S. Fotiadis, N. Antonopoulos, S. Ramamoorthy
An empirical evaluation of adversarial robustness under transfer learning, In Proc. ICML Workshop on Understanding and Improving Generalization in Deep Learning, 2019.

Yordan Hristov, Svetlin Penkov, Alex Lascarides, Subramanian Ramamoorthy
Grounding Symbols in Multi-Modal Instructions, Language Grounding for Robotics Workshop, Annual Meeting of the Association for Computational Linguistics (ACL), 2017.

I.Papaioannou, A. Cercas Curry, J. L. Part, I. Shalyminov, **X. Xu**, Y. Yu, O. Dušek, V. Rieser, and O. Lemon
An Ensemble Model with Ranking for Social Dialogue, in Workshop on Conversational AI at the Conference on Neural Information Processing Systems (NIPS), Long Beach, CA, USA, December 2017.

M. Campbell and D. Clark
Time-Lapse Estimation for Optical Telescope Sequences, in Geolocation and Navigation in Space and Time, 2018.

E.Sheppard, K. S. Lohan, G.E. Little , L. Bonnar , S. Kelly and G. Rajendran
Understanding the difference in pupil dilation between children with and without ASD during a joint attention memory task, 3rd Workshop on Child-Robot Interaction at Human-Robot Interaction 2017

Carreno, Y., Petrick, R.P. and Petillot, Y.
Multi-Vehicle Temporal Planning for Underwater Applications. In ICAPS 2019 Workshop on Planning and Robotics (PlanRob). July 2019.

A Brock, T Lim, JM Ritchie, N Weston
Generative and Discriminative Voxel Modeling with Convolutional Neural Networks. Selected for Oral presentation at 3D Deep Learning Workshop, NIPS 2016

A Brock, T Lim, JM Ritchie, N Weston
FreezeOut: Accelerate Training by Progressively Freezing Layers. Optimization workshop, NIPS 2017

Mocialov, B., Turner, G., Lohan K., Hastie H.
Towards Continuous Sign Language Recognition with Deep Learning. In Proceedings of the Workshop on the Creating Meaning With Robot Assistants: The Gap Left by Smart Devices, 2017.

Mocialov, B., Hastie, Helen., Turner, Graham
Transfer Learning for British Sign Language Modelling (Accepted at the COLING conference, the Fifth Workshop on NLP for Similar Languages, Varieties and Dialects, 2018)

Ben Krause, **Emmanuel Kahembwe**, Iain Murray, and Steve Renals
Exploiting repetitions in music with dynamic evaluation. Proceedings of the ICML Machine Learning for Music Discovery Workshop (ML4MD), Extended Abstract, Long Beach, 2019

Artjoms Šinkarovs, Robert Bernecky, **Hans-Nikolai Vießmann,** and Sven-Bodo Scholz
2018. A Rosetta Stone for array languages. In Proceedings of the 5th ACM SIGPLAN International Workshop on Libraries, Languages, and Compilers for Array Programming/(ARRAY 2018). ACM, New York, NY, USA, 1-10. DOI: https://doi.org/10.1145/3219753.3219754

J. L. Part and O. Lemon
Incremental On-Line Learning of Object Classes using a Combination of Self-Organizing Incremental Neural Networks and Deep Convolutional Neural Networks, in Workshop on Bio-inspired Social Robot Learning in Home Scenarios at the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Daejeon, Korea, October 2016.

J. H. Ng, R. Petrick
"Incremental Learning of Action Models for Planning", Workshop on Knowledge Engineering for Planning and Scheduling (KEPS) (2019)

Student Research Outputs - Workshop Papers

P. McKenna, F. Broz, I. Keller, **J. L. Part,** G. Rajendran and R. Aylett
Towards Robot-Assisted Social Skills Training for Adults with ASC, in Workshop on the Challenges of Working on Social Robots that Collaborate with People at the ACM Conference on Human Factors in Computing Systems (CHI), Glasgow, UK, May 2019

Carreno, Y., Petrick, R.P. and Petillot, Y.
Multi-Vehicle Temporal Planning for Underwater Applications. In ICAPS 2019 Workshop on Planning and Robotics (PlanRob). July 2019

Colle, A., & Gaudl, S. E. (2020)
Non-Zoomorphic Robots : The Role of Aesthetics in Social Robotic Design. HRI '20 Companion, 23–26.

R. Smith
Adaptivity as a Service (AaaS): Enabling Deep Personalisation for a Heterogeneous Ambient Assisted Living Landscape. In Proceedings of the Workshop on Behavioural Patterns and Interaction Modelling for Personalized Human-Robot Interaction at the ACM/IEEE International Conference on Human-Robot Interaction, 2020.

Pierre Le Bras, **Yaniel Carreno,** Alan Lindsay, Ronald Petrick and Mike Chantler
2020. Plan-Curves: Visualizing Multi-Agent Temporal Plans. In Proceedings of ICAPS Workshop in Knowledge Engineering for Planning and Scheduling (KEPS).

Student Research Outputs - Book Chapters

Paola Ardon, Mauro Dragone, Mustafa Suphi Erden
Reaching and Grasping Behaviours by Humanoid Robots Through Visual Servoing
Haptics: Science, Technology and Applications.
Chapter to appear in Springer International Publishing AG, part of Springer Nature (2018).

Vladimir Ivan, Yiming Yang, **Wolfgang Merkt,** Michael P. Camilleri, Sethu Vijayakumar
EXOTica: An Extensible Optimization Toolset for Prototyping and Benchmarking Motion Planning and Control, In: Koubaa A. (eds) Robot Operating System (ROS). Studies in Computational Intelligence, Springer, vol. 778, pp. 211-240 [DOI]

K. Lohan, M. Ahmad, C. Dondrup, **P. Ardón, È. Pairet,** and A. Vinciarelli.
"Adapting Movements and Behaviour to Favour Communication in Human-Robot Interaction", in Modelling Human Motion: from Human Perception to Robot Design. Springer. In press.

Student Research Outputs - Other Publications

I. Papaioannou, A. Cercas Curry, J. L. Part, I. Shalyminov, **X. Xu**, Y. Yu, O. Dušek, V. Rieser and O. Lemon
Alana: Social Dialogue using an Ensemble Model and a Ranker trained on User Feedback, in Proceedings of the 1st Alexa Prize, Las Vegas, NV, USA, November 2017.

Ben Krause, Marco Damonte, Mihai Dobre, Daniel Duma, Joachim Fainberg, Federico Fancellu, **Emmanuel Kahembwe**, Jianpeng Cheng, Bonnie Webber
Edina: Building an Open Domain Socialbot with Self-dialogues. Proceedings of the 1st Alexa Prize, Las Vegas, NV, USA, November 2017.

Theodoros Stouraitis, Iordanis Chatzinikolaidis, Michael Gienger, Sethu Vijayakumar
Dyadic collaborative Manipulation through Hybrid Trajectory Optimization, Conference on Robot Learning (CoRL), 2018. (Best System Paper Award Finalist - Oral presentation 8% acceptance rate)

"Alana v2: Entertaining and informative open-domain social dialogue using ontologies and entity linking.".
Alana team, Heriot-Watt University. Amazon Alexa Prize Proceedings (2018).

Selected projects from across the Centre 2019/2020

Selected projects from across the Centre 2019/2020

Research Area: Robotic Navigation

Online Mapping and Motion Planning under Uncertainty for Autonomous Safe Navigation in Unknown Environments

PhD candidate: Èric Pairet
Supervisor: Professor Yvan Petillot
Collaborators: Dr. Juan David Hernández (Rice University, USA), Dr. Marc Carreras (Univesity of Girona, Spain), Dr. Morteza Lahijanian (University of Colorado Boulder, USA)

Objectives

Autonomous robots have been increasingly employed to assist humans notably in hazardous or inaccessible environments in recent years. Examples include rescue missions in disaster response scenarios, in-water ship hull and wind turbine quality assessment inspections, underwater archaeology, and deep underwater and space exploration, among many others. A fundamental requirement for a robot engaged in any of these applications is to be adept at navigating autonomously through highly unstructured and hostile environments. However, this is not a trivial task due to limited or complete lack of prior knowledge about the environment in which the robot has to operate. This implies that the robot has to base its decision making on on-board sensors despite their limited accuracy. In addition, the robot itself might suffer from poor localisation, as well as restricted and uncertain manoeuvrability. Therefore, even though challenging, it is essential to jointly consider all these motion and sensory constraints as well as their associated uncertainties, when planning for navigation actions. This problem becomes particularly more challenging in safety-critical missions where the safety of the robot must be ensured at all times. Our goal is to endow a robot with the required online mapping and motion planning capabilities to safely navigate in unexplored environments.

Approach

Our strategy consists of an iterative mapping-planning scheme capable of continuously modifying the vehicle's motion plan towards a desired goal according to the incremental environmental awareness (see Fig 1). The vehicle's surroundings are incrementally encoded as an uncertainty-aware map. Then, over this representation, the framework plans feasible trajectories (according to the system's kinodynamic constraints) which provide probabilistic safety guarantees by taking into account the uncertainty on the system's localisation and motion, as well as the uncertainty on the environment awareness. Online computation constraints are met with novel advancements on multi-layered planning and an efficient evaluation of uncertainties. All in all, the framework provides at any time motion plans that are guaranteed to be feasible and safe in face of localisation, mapping and motion uncertainties.

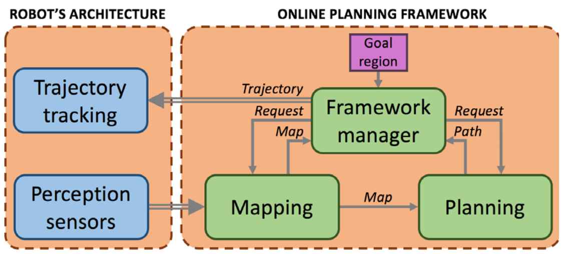


Fig 1: Framework for online mapping and motion planning under kinematic and uncertainty constraints.

Online Mapping and Motion Planning under Uncertainty for Autonomous Safe Navigation in Unknown Environments - Èric Pairet

Results

We first evaluate the novel components of the framework that enable for online motion planning under uncertainty. Extensive benchmark results remark that our approach significantly outperforms by multiple orders of magnitude previous methodologies in terms of probabilistic accuracy and computation time. We also evaluate the framework as a whole, deploying it on an unmanned aerial vehicle (UAV) to navigate through the challenging DARPA Subterranean Challenge 2019 environment (see Fig 2), and on an autonomous underwater vehicle (AUV) to navigate through a real-world breakwater structure (see Fig 3). The experimental results demonstrate the suitability of the proposed method to address the challenge of probabilistically-safe autonomous navigation in unknown environments while being suitable for systems with limited on-board computational power.

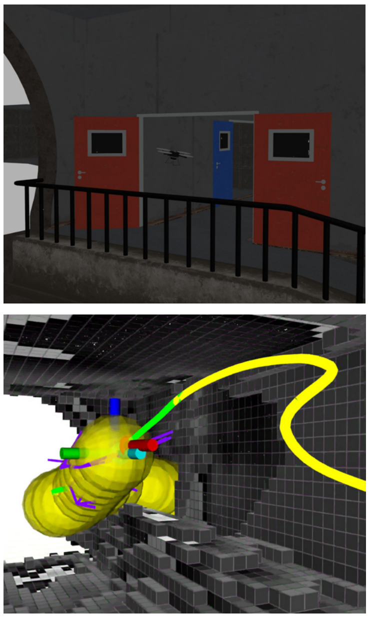


Fig 2: UAV navigating in the DARPA Subterranean Challenge 2019
Video: https://youtu.be/I5X_QFKDpel

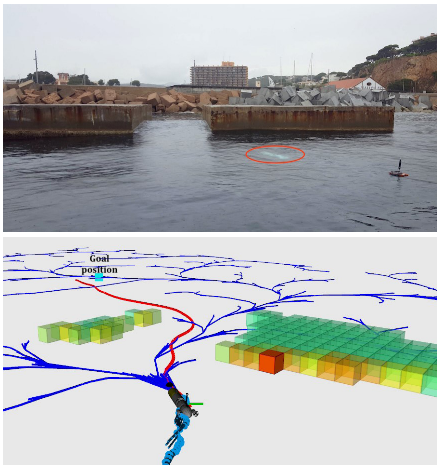


Fig 3: AUV navigating in a real breakwater structure
Video: https://youtu.be/dTejsNqNC00

Impact

Previous methods in the literature uniquely focus on particular challenges of robot navigation, thus not providing a full strategy. To the best of the authors' knowledge, our work is the first generic end-to-end architecture capable of jointly dealing online with kinodynamic and probabilistic constraints in unknown environments for safe robotic navigation. Notably, the framework is not restricted to the presented experimental evaluation nor a specific platform; any mobile robot, either terrestrial, maritime or aerial system can benefit from this work.

Future Work

The modularity of the proposed framework allows for multiple extensions and variations. A possible extension is leveraging the multi-resolution encoding of the uncertainty-aware maps to check the compliance of the safety guarantee at different resolutions. Formulating this process as a multi-resolution kernel checking could speed up computations even further. Also, the conducted experimentation pointed out that automatically adjusting the replanning period might be beneficial, as well as studying more intelligent synergies within the multi-layered planning scheme.

Publications

È. Pairet, J. D. Hernández, M. Carreras, Y. Petillot, and M. Lahijanian. "Online Mapping and Motion Planning under Uncertainty for Safe Navigation in Unknown Environments", in the International Journal of Robotics Research (IJRR), 2020. Under review. Video: https://youtu.be/I5X_QFKDpel

È. Pairet, J. D. Hernández, M. Lahijanian, and M. Carreras. "Uncertainty-based Online Mapping and Motion Planning for Marine Robotics Guidance," in IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS). October 2018. Video: https://youtu.be/dTejsNqNC00

Research Area: Human-Computer Interaction

Study of Audio-Visuo-Haptic Multimodal Interfaces and the Improvements on Human Performance in Teleoperation

PhD candidate: Eleftherios Triantafyllidis
Supervisor: Dr Zhibin Li
Contributors: Christopher McGreavy, Jiacheng Gu

Fig 1: Human operators with various interfaces and stimuli complete manipulation tasks of varying complexity.

Introduction

Research in multi-modal interfaces aims to provide solutions to embodiment and increase overall immersion. However, an extensive comparison of an audio-visual-haptic multi-modal interface for manipulating tasks of varying complexity is yet missing. Hence, we explore this very idea, a thorough investigation of the effectiveness of all combinations of auditory, visual and haptic modalities interface and its 8 modalities, reflected upon object manipulation with varying task complexity. We evaluated our system by conducting a study, incorporating both subjective measurements, assessing cognitive workload and system usability, as well as objective measurements, by incorporating time and spatial accuracy-based metrics.

Approach

To accommodate hand manipulation, we integrated a set of necessary software plugins to stimulate the different modalities. The Leap Motion SDK and Arduino SDK were integrated into the primary simulation engine Unity3D facilitating all the necessary built-in physics properties. We designed the multi-modal interface by first incorporating a generic display monitor and a commercial virtual reality head-mounted display (VRHMD) to serve as monocular and stereoscopic visual feedback respectively. For auditory stimulation, we used a generic audio headset by stimulating both direct and warning sounds.

The main contributions of our work include the following:

1. To the best of our knowledge, this is the first exhaustive comparison of its kind between all combinations of visual, auditory and haptic interfaces for tasks of varying difficulty;
2. A low-cost hardware and software approach in designing an effective vibrotactile glove;
3. A unique and reproducible interface which allows various combinations of sensory feedback for performing various tasks under different settings;
4. Virtual reality environment with high-fidelity physics simulation (friction, collision, contact forces) to closely resemble real-world interaction.

Study of Audio-Visuo-Haptic Multimodal Interfaces and the Improvements on Human Performance in Teleoperation - Eleftherios Triantafyllidis

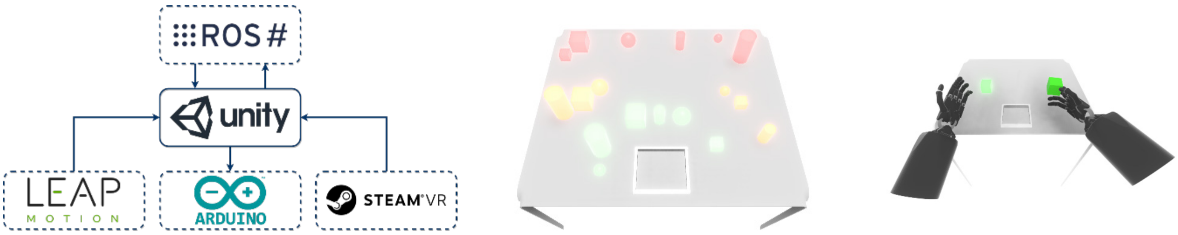


Fig 2: The simulation environment with all software plugins (left), the manipulation tasks of varying difficulty in the simulation environment (middle) and an operator manipulating a cube during a task in the experiment (right).

Results

Our results showed that transitioning from monocular to stereoscopic vision contributed to a task performance increase of about 40% overall measurements, likely attributed to enhanced depth perception over a monocular display. Moreover, haptic feedback accounted to another 10% task performance increase, over all measurements, while auditory made a rough contribution of 5% limited to spatial accuracy. Figure 3 visually depicts the aforementioned.

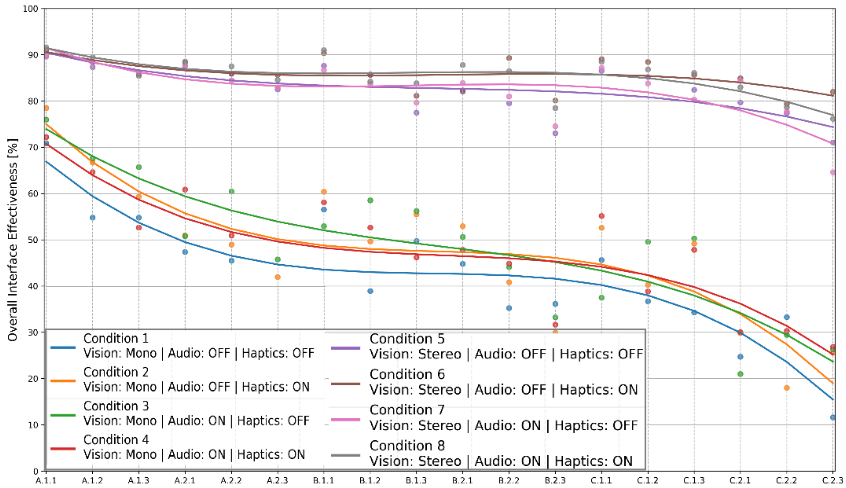


Fig 3: The figure illustrates the polynomial regression (fourth-degree) as well as scatter plot with the data points, of all conditions across all tasks reflected on all metrics incorporated in our work, including subjective and objective measurements. Task complexity increases from left to right. Measurements include subjective, i.e. Workload Demand and Usability, and objective, Placement & Completion Time, Target Error, Position & Rotation Accuracy.

Impact and Future Work

In our work, we explored a first of its kind, exhaustive comparison of visual, auditory and haptic modalities and their influence towards task performance of varying complexity. One could argue that implementing a variety of metrics including spatial and time-based metrics would be sufficient. However, an important limitation arises in such situations; inter-study comparability. With the absence of a standardized human performance metric, inter-study comparisons are almost impossible, thus severely limiting reproducibility of the provided data and drawing conclusions from it. Consequently, we are working on proposing a 3D extension of Fitts's law, which still is to date a gap in existing work; and hoping to increase comparability, reproducibility as well as generalization of our method towards the entirety of the 3D manipulation domain to fully explain human performance in a higher-dimensional model.

Publication

E. Triantafyllidis, C. Mcgreavy, J. Gu and Z. Li, "Study of Multimodal Interfaces and the Improvements on Teleoperation," in IEEE Access, vol. 8, pp. 78213-78227, 2020, doi: 10.1109/ACCESS.2020.2990080. Online: https://ieeexplore.ieee.org/document/9076603

Research Area: Robust Loco-Manipulation

Optimising Dynamic Trajectories for Robustness to Disturbances Using Polytopic Projections

PhD candidate: Henrique Ferrolho
Supervisor: Professor Sethu Vijayakumar
Contributors: Wolfgang Merkt, Vladimir Ivan, Wouter Wolfslag

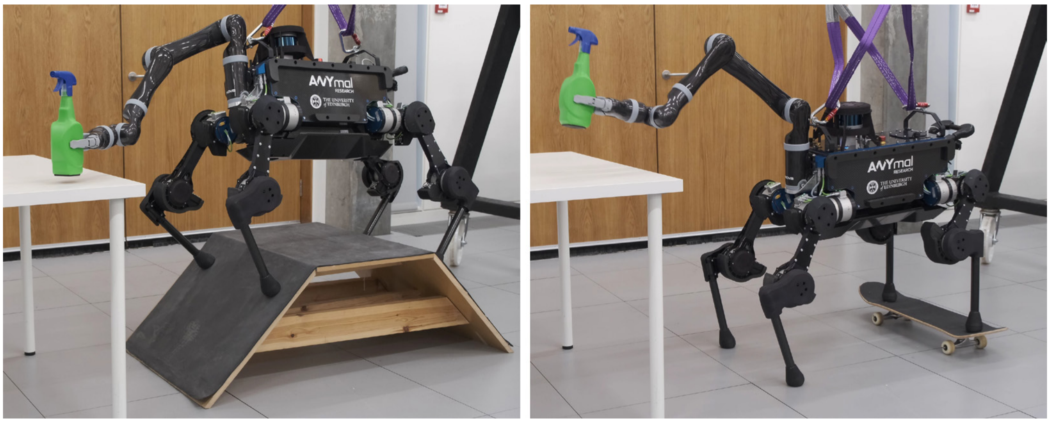


Fig 1: A loco-manipulation system performing a pick-and-place task in challenging environments. The robot shown in the pictures is our ANYmal quadruped, which we equipped with a Kinova arm.

Introduction
Fixed-base manipulators usually have a limited workspace, but attaching a robot arm to a floating-base system (such as the quadruped shown in Fig. 1) allows to virtually extend the reachability limits of the system as a whole. The resulting platform has increased capabilities and more degrees of freedom, but now we must also ensure the robot stands robust against external forces and uncertain contact properties.

Objectives
Our goal is to account for worst-case disturbances applied to the end-effector of the robot, and plan locally-optimal trajectories for maximum robustness against those perturbations.

Approach
Humans adapt different configurations for different tasks: e.g., we lean against a heavy door if we have to push it open, and we lean away from it if we have to pull it open. The amount of force we can apply in a certain direction depends on the geometrical configuration of our bodies. The same is true for the kinematic structure of a robot, and we can take this into account when choosing the most suitable position for each joint of the robot. In order to maximise robustness against disturbances, we choose the joint configuration that increases the magnitude of the forces the robot can execute with its end-effector in any given direction.

Optimising Dynamic Trajectories for Robustness to Disturbances Using Polytopic Projections - Henrique Ferrolho

The main contributions of our work are:
1. Definition of robustness as a distance function to actuation and friction-cone boundaries;
2. Integration of that robustness metric in a dynamic trajectory optimisation framework;
3. Problem-structure exploitation to transcribe an (otherwise intractable) NLP problem;
4. Evaluation against a traditional energy-based objective across different scenarios;
5. Validation of trajectories in full-physics simulation and real-world experiments.

Results

The trajectories optimised with our method demonstrated greater robustness in all the scenarios we tested (see Fig. 2). Notably, we created an extreme scenario where the robot had to perform a "handstand", i.e., support its own weight on two legs while using the other two for balancing. In that scenario, it was especially important to press downwards against the floor and upwards against the ceiling to maintain stability. The energy-minimization approach was unable to capture this caveat, and guided the solver to a trajectory less robust than the initialisation. On the other hand, our metric was able to improve the initialisation. A video of the real-world experiments is available at youtu.be/vDesP7IpThw .

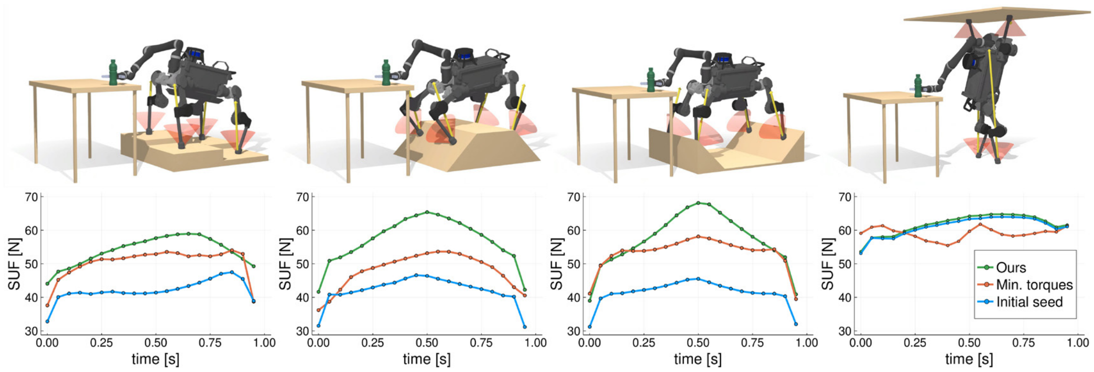


Fig 2: We evaluated a pick-and-place task over slabs at different heights and inclined supports. The plots under each scene show the smallest unrejectable force (in newtons) for each approach.

Impact

In previous work [1], the set of feasible actuations and contact forces was only computed once (for the initial state) and used as an approximation for optimising the centre-of-mass path of the motion. With our work, it is now possible to not only optimise the full state of the robot with whole-body dynamics but also do it for every discretised point of the trajectory.

Future Work

This work focuses on robustness to disturbances from any given direction, but some tasks require robustness in specific directions. We are now working towards a formulation for cases where prior knowledge about the environment can be used to our advantage.

References

[1] R. Orsolino, M. Focchi et al. , "Application of Wrench-Based Feasibility Analysis to the Online Trajectory Optimization of Legged Robots", IEEE RA-L , 2018.

Publications

H. Ferrolho, W. Merkt, V. Ivan, W. Wolfslag, S. Vijayakumar, "Optimizing Dynamic Trajectories for Robustness to Disturbances Using Polytopic Projections", in IEEE/RSJ IROS , 2020. Online: bit.ly/ferrolho2020optimizing

Research Area: Biorobotics

Using a quadcopter to model the visual navigation behaviours of flying insects

PhD candidate: Jan Stankiewicz
Supervisors: Professor Barbara Webb, Professor Yvan Petillot

Background

Some species of solitary wasp dig small burrows in the ground for their nests. An important part of their lifecycle is to explore the environment around this nest and to transport resources back to it so that they can feed their young. Biologists have demonstrated that these wasps are able to locate their nest sites using primarily visual information. This is a particularly impressive ability given that wasp eyes have 1/60th the acuity of our own. We have previously demonstrated that a path integration circuit enables wasps to navigate within 15m of their nest following a foraging excursion of up to 1km. In this work we set out to demonstrate how they might bridge the gap between the path integration circuit and visual contact with their nests.

Approach

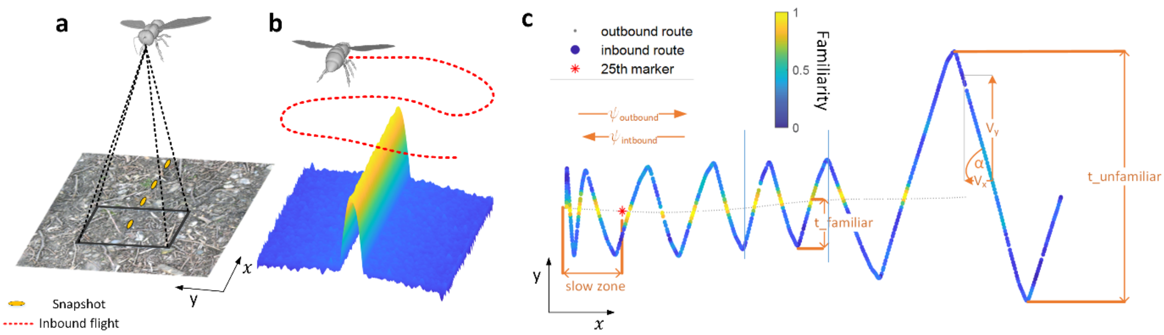


Fig 1: a) Learning – on an outbound route the agent periodically captures snapshots of the ground in a contiguous chain. b) Homing – on an inbound route, the agent detects and follows the "ridge of familiarity" formed by the chain of outbound views. The agent can follow this ridge by oscillating transversely over it. c) complete route – The agent can follow the entire route using a simple bang-bang control paradigm with the sign of a transverse component of motion flipped an arbitrary duration (t_familiar) after the ridge of familiarity is detected.

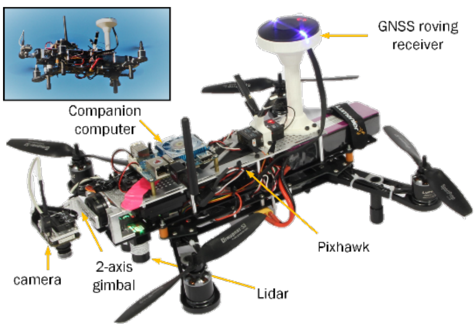


Fig 2: Quadcopter biorobot annotated with key hardware. Inset shows the aircraft in flight

We were inspired by the "visual route following" approach that has been implicated in the desert ant's navigational toolkit. The literature shows that if an agent periodically stores view "snapshots" along a route, it can subsequently use this information to follow the same path in future. While porting this approach to a 3D task-space leads to a problem of greater dimensionality, we found that an aerial perspective has the benefit of a downward view which provides salient information for the task of localisation in the XY plane. We also found that the sinuous flight paths of flying insects form an ideal basis for the line following procedure outlined in Fig. 1.

We developed a quadcopter (see Fig. 2) to deploy this concept so that we could test our behavioural model in the real world. We began by collecting a dataset that comprised of a straight outbound path of downward facing images and a corresponding inbound route which

Using a quadcopter to model the visual navigation behaviours of flying insects - Jan Stankiewicz

zigzagged over the outbound route. Each image was geo-tagged with a differential GPS sensor reading. This enabled us to trial candidate view matching pipelines offline and optimise against four criteria: 1) views must be anatomically plausible (i.e. of the same resolution of the wasp); 2) all inbound/outbound route crossover points should be detected; 3) there should be no false positive detections; 4) views should have as wide a catchment area as possible. We compared six different approaches and found that a complex wavelet transform provided a comparison space that detected view overlaps with 100% accuracy and had the widest catchment area of any arrangement. Given the specification of a reliable view matching pipeline, a route following procedure could be specified (see Fig. 1c) and its performance evaluated in different environmental conditions.

Results

Using the best pre-processing approach, our biorobot can robustly navigate along previously traversed routes. We found this procedure to be 100% effective across a variety of different real and simulated environments (Fig. 3). Failure modes are introduced when the ground height of the inbound route has a difference of greater than 10% of the outbound route. Simulated worlds that make use of texture tiling can also be problematic (due to aliasing), indicating that our procedure is particularly suited to the chaotic nature of natural environments. We show that this approach is amenable to very low visual acuities (6°/pixel) and that the camera angle can be pitched up to 60° without any loss in performance. We also show that the approach can be used to follow curved paths.

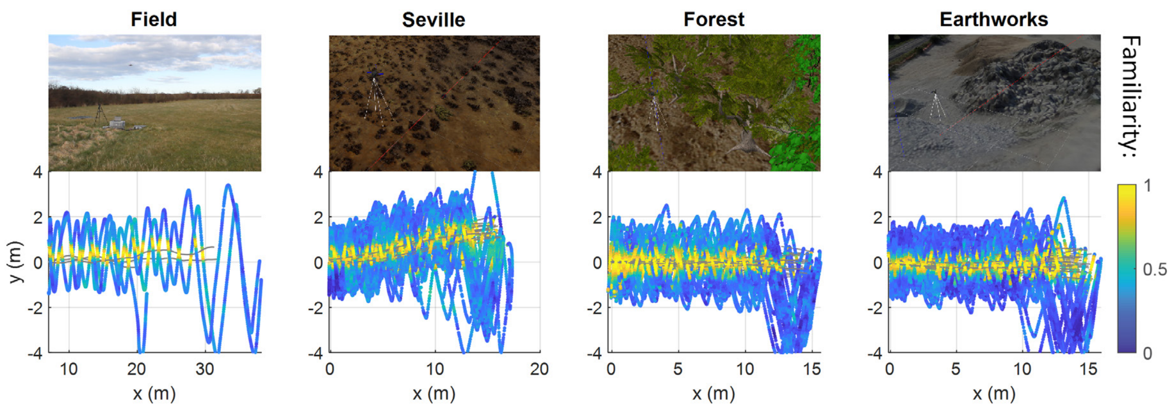


Fig 3: Examples of trials performed in different test environments. Top row: images of sample test environments. Bottom row: scatterplot of trajectories of several trials performed in the above environment.

Impact

A significant barrier to the wider deployment of autonomous micro aerial vehicles is the lack of lightweight navigation systems that can operate in GPS-denied environments. The approach outlined herein has a low computational overhead compared to state-of-the-art SLAM systems and it could be applied directly to situations requiring point-to-point navigation. Essentially, we have created a line-following procedure, where the track can be procedurally generated on-the-fly. We have also developed a new hypothesis that outlines how ground nesting wasps may locate their nests.

Future work

In future we would like to use a computer vision system to record the 3D trajectories of wasps returning to their nests. This will enable us to test our route-following hypothesis in addition to further quantifying the precision with which these animals navigate. We would also like to interrogate the failure modes of the approach by testing it across longer routes or by investing the impact of changing the lighting conditions.

Research Area: Learning by Demonstration

Learning Generalisable Coupling Terms for Obstacle Avoidance via Low-Dimensional Geometric Descriptors

PhD candidates: Èric Pairet, Paola Ardón
Supervisors: Professor Yvan Petillot, Professor Michael Mistry

Objective

Robot learning by demonstration endows a robot with the ability to learn a skill and employ it in different contexts. One of the primary approaches to learning skills are dynamic movement primitives (DMPs). This approach offers a robotic agent exceptional generalisation capabilities to novel skill contexts. DMPs, however, lack the essential ability to generalise a learnt skill in the presence of obstacles. For instance, the on-going pick-and-place policy of a robotic system sorting and storing items in a home environment might be interrupted by the sudden appearance of an obstacle in the middle of the DMP planned action. In this scenario, the robot must be able to modulate its behaviour online to succeed in its task while providing some safety guarantees. Our goal is to extend the capabilities of any robotic system controlled through DMP-encoded policies to safely modulate its behaviour in the presence of unexpected obstacles.

Approach

Our approach to the challenge stated above is the hybrid DMP-learning-based framework schematised in Figure 1. Such a framework wraps the deployment of a DMP with a multi-layered perception-decision-action analysis for obstacle avoidance. First, the relevant features of the environment, namely obstacles relative location and geometry, are extracted from stereo-vision and encoded as unified system-obstacle descriptors in a low-dimensional geometric space. The purpose of this scene representation is to enable the inference of suitable regulation actions of the robot behaviour according to the environment and the underlying task. We employ a regressor chain of neural networks to learn to regulate the DMPs-encoded policy through theoretical methods that we call coupling terms. Besides the novelty of each component of the framework, this work's main contribution is the efficient unification of perception, decision, and action levels via low-dimensional geometric descriptors of the environment that allow modifying the robot behaviour on-the-fly.

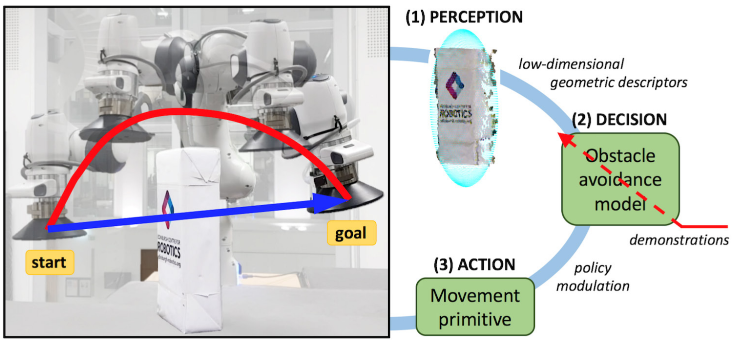


Fig 1: Proposed hierarchical framework for learning and producing generalisable obstacle avoidance behaviours. Example of a pre-planned start-go-goal (blue) and modulated policy (red).

Results

Our method extends the capabilities of DMP-encoded policies to safely adapt its behaviour in the presence of unexpected obstacles. Extensive benchmark results remark the robustness and generalisation capabilities of the proposed approach regardless of the obstacle avoidance scenario. Moreover, these results imply that our approach significantly outperforms previous

Learning Generalisable Coupling Terms for Obstacle Avoidance via Low-Dimensional Geometric Descriptors - Èric Pairet, Paola Ardón

methodologies while requiring fewer training data. Finally, we deploy our approach in challenging real-world environments, such as the one depicted in Figure 2. This experimental evaluation demonstrates the suitability of our approach for robotic systems in real-world environments, as it generalises obstacle avoidance behaviours to novel scenarios, even when those involve multiple obstacles, or are uniquely described by partial visual-depth observations.

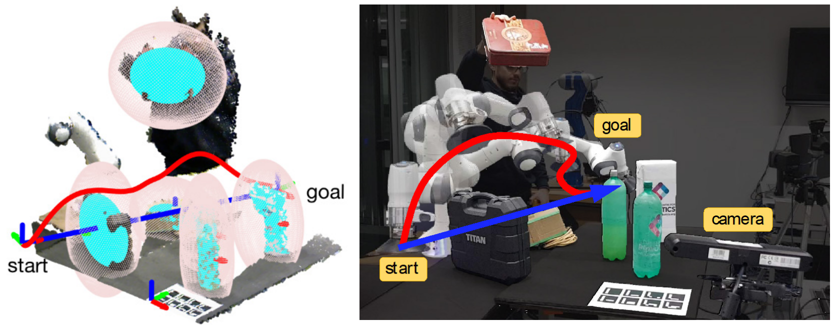


Fig 2: Panda arm engaged in a start-to-goal policy (blue trajectories) while modulating its behaviour (red trajectories).
Left: Environment perception with unified low-dimensional encoding of the system's and obstacle's geometry (rose ellipsoids).
Right: Proposed hierarchical framework dealing with multiple novel obstacles in a cluttered environment.
Video: https://youtu.be/lym5cCbjl3k

Impact
Dynamic movement primitives (DMP) are widely adopted in many robotic systems. These models, however, not always account for a safe, modular strategy to avoid collisions. The proposed framework is not restricted to the presented experimental evaluation nor platform. Therefore, any robotic system following a DMP-encoded policy can benefit from this work to safely modulate its behaviour in the presence of unexpected obstacles. Furthermore, our method is easily extendable to account for link collisions by finding the closest geometric section on the robot to the obstacle, and then modulating the kinematic null-space movement with the proposed approach.

Future Work
An interesting avenue for future work is to modulate the system's orientation policy to overcome an obstacle, which, for instance, might have a significant impact on manipulators carrying large bulks. Another interesting extension of this work is learning route selection priorities in cluttered environments, so systems can autonomously reason about the most convenient direction to avoid an obstacle.

Publications
È. Pairet, P. Ardón, M. Mistry, and Y. Petillot. "Learning Generalisable Coupling Terms for Obstacle Avoidance via Low-dimensional Geometric Descriptors," in IEEE Robotics and Automation Letters (RA-L), 2019. Video: https://youtu.be/lym5cCbjl3k

È. Pairet, P. Ardón, M. Mistry, and Y. Petillot. "Learning and Composing Primitive Skills for Dual-arm Manipulation", in Conference Towards Autonomous Robotic Systems (TAROS), 2019. (Best Advanced Robotics Paper Award)

Research Area: Perception, Autonomous Vehicles

DeepBEV: A Conditional Adversarial Network for Bird's Eye View Generation

PhD candidate: Helmi Fraser
Supervisor: Dr Sen Wang

Objective

Obtaining a meaningful, interpretable yet compact representation of the immediate surroundings of an autonomous vehicle is paramount for effective operation as well as safety. Many solutions to this problem involve the use of multiple cameras or other range finding sensors, which can increase the cost and complexity of systems. This work proposes a solution to this by representing semantically important objects from a top-down, ego-centric "bird's eye" view generated from a single image taken by a monocular camera. Crucially, we formulate this problem as an adversarial learning task: tasking a generator model to produce bird's eye view representations which are plausible enough to be mistaken as a ground truth sample.

Approach

Our proposed system parses a single driver's view image of the road into a so called "bird's eye" view, representing nearby semantically important objects, such as other vehicles. This is achieved by a conditional Wasserstein Generative Adversarial Network with gradient penalty trained on publicly available datasets.

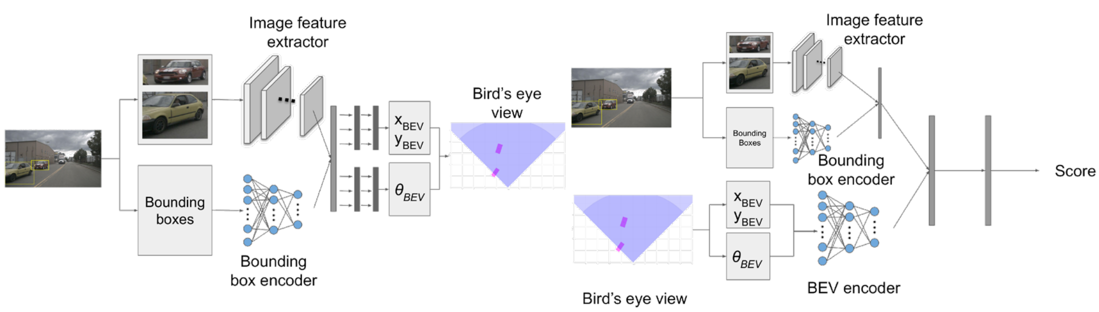


Fig 1: Generator (left) and critic (right) system diagram

Our model is composed of two sub-networks: a generator network and a critic network.

The generator network is tasked with producing bird's eye view representations from an image, while the critic network is designed to assign a "realness" score to this representation, distinguishing a generated bird's eye view representation from its ground truth counterpart. This score then forms an error signal for model training. Effectively, the generator attempts to fool the critic into thinking that its output is a more truthful representation of the scene than the ground truth.

DeepBEV: A Conditional Adversarial Network for Bird's Eye View Generation - Helmi Fraser

Results

Evaluation was performed on several publicly available datasets such as the nuScenes dataset and Virtual KITTI 2, measuring the similarity of predictions versus the ground truth.

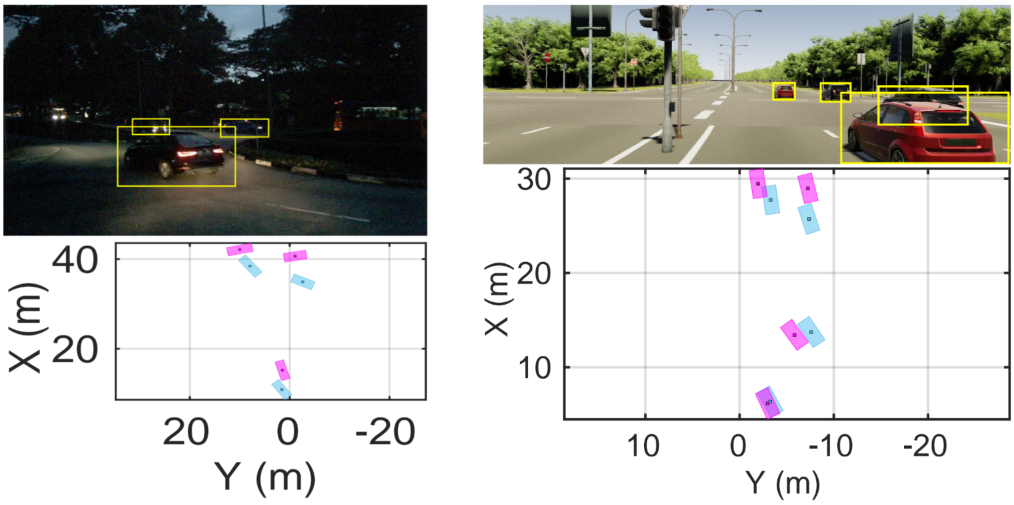


Fig 2: Samples from the evaluation set. Left is from nuScenes, right is from Virtual KITTI 2. Blue denotes ground truth object pose, magenta denotes model prediction.

Impact

We show that a model trained in this way generalises better between datasets – real world and synthetic – compared to baseline, strictly supervised models as well as being lightweight and real time capable. In addition, our approach is inexpensive, only requiring data from a single monocular camera during inference and does not require more complex sensors such as LiDAR or radar.

Future Work

Future work involves improving the accuracy and robustness further to be suitable for deployment on an autonomous vehicle, as well as investigating the applicability of using the trained critic network as an error estimator for produced bird's eye view representations.

Research Area: Motion Planning

Contact-Implicit Trajectory Optimization Using an Analytically Solvable Contact Model for Locomotion on Variable Ground

PhD candidate: Iordanis Chatzinikolaidis
Supervisors: Dr Zhibin Li, Professor Sethu Vijayakumar

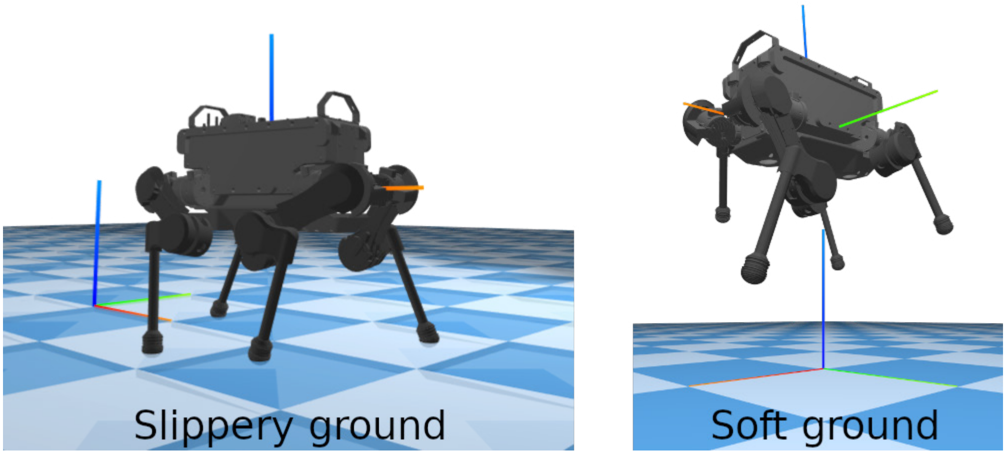


Fig1: Dynamic motions computed by the proposed framework: trotting on slippery ground (left); jumping on soft ground (right).

Introduction

Trajectory optimization (TO) frameworks for legged systems usually requires specification of several quantities (e.g. contact locations, step timings, body or limb motions), while the environment is assumed rigid. Here we present an approach that can automatically compute low-level motion plans from high-level objectives, while at the same time being able to accommodate a variety of environments such as hard, slippery, and soft (Fig 1).

Objectives

Our goal is to formalise a principled framework that can allow dynamic motion generation for legged robots by requiring minimum user input, while being able to accommodate a variety of situations and environments.

Approach

Our approach can be summarised as follows: The user specifies the desired task via suitable cost functions. For example, it might be desirable for the robot to reach a particular place in the environment, pass from via points, or to move in a specific direction while keeping a constant body speed, while simultaneously minimising the actuation effort. Furthermore, the user provides as input a model of the environment and its properties. These properties are encoded by the intuitive selection of two parameters. One parameter specifies the softness or hardness of the terrain, while the other parameter specifies how slippery it is. Based on this information only, the optimiser computes a suitable motion plan. This plan includes the motion of all joints together with the actuation profiles, locations where the limbs should contact the environment, at which time instant contacts should take place, etc.

Contact-Implicit Trajectory Optimization Using an Analytically Solvable Contact Model for Locomotion on Variable Ground - Iordanis Chatzinikolaidis

The contributions of our work are the following:
1. An analytically solvable contact model suitable for direct contact-implicit TO, which can be utilized in formulations without complementarity constraints while satisfying unilaterality and friction cone constraints.
2. The proposed contact model is generic and can be used to compute motion plans on hard, soft, and slippery surfaces in a unified manner.
3. A TO framework that integrates the new contact model for generating contact-implicit motion plans for a high degree of freedom robot, demonstrating the advantages of the proposed method with extensive comparisons performed against the rigid contact model and a TO formulation with complementarity constraints.

Results

We perform a series of tests and comparisons to demonstrate the properties of our framework along with its advantages and disadvantages. More specific, we include the following results:

1. Comparison against the standard rigid contact model. The aim here is to show the generalisation capabilities of our contact model and the intuitive parameter selection property.
2. Comparison against a state of the art contact-implicit TO framework. The goal of this comparison is to quantitative demonstrate the improvements of our method and how the lack of complementarity constraints by the contact model can improve the performance.
3. Motion adaptions for a quadruped when the properties of the environment change. Two cases are studied: (i) A comparison for a trotting gait on a hard versus a slippery ground. (ii) A comparison when performing a jump on a hard and on a soft terrain. Snapshots for the computed jump on soft ground are shown in Fig 2.

A video of our results is available at youtu.be/eLx1DebDHmY.

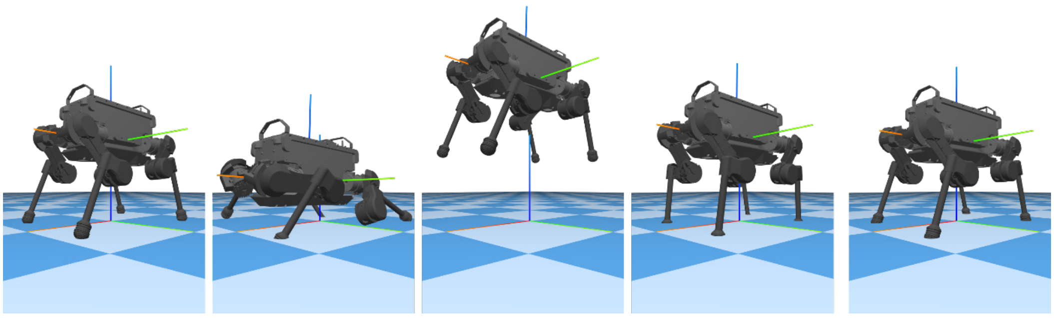


Fig 2: Optimised jumping motion on soft ground, where the feet penetrate the ground surface.

Impact

With respect to previous work, our framework is easier to setup (requires small adaptation of the standard rigid body dynamics equations), faster to solve (due to the lack of challenging complementarity constraints), and can be applied to a larger number of setting (supports the specification of environmental properties rather than assume that they are only rigid).

Future Work

The main limitation of our current work is that it is not real-time capable yet. We are working towards improving the computational performance of our framework by leveraging the structure inherent in the problem.

Publications

I. Chatzinikolaidis, Y. You, Z. Li, "Contact-Implicit Trajectory Optimization Using an Analytically Solvable Contact Model for Locomotion on Variable Ground", IEEE Robot. Autom. Lett., 2020, DOI: 10.1109/LRA.2020.3010754.

Research Area: Simultaneous Localisation and Mapping (SLAM)

Radar based Large-Scale SLAM in All Weathers

PhD candidate: Ziyang Hong
Supervisor: Dr Sen Wang

Objective

Simultaneous Localization and Mapping (SLAM) has been extensively investigated with numerous sensor modalities, e.g., sonar, camera and LiDAR, in the last decades. However, for outdoor large-scale SLAM, ensuring its robust operation is still very challenging especially in adverse weather conditions. To achieve 24/7 autonomous navigation in large-scale outdoor environments, a robust SLAM system must be able to operate in extreme weather conditions. However, this is still an open research problem. Recently, the emerging Frequency-Modulated Continuous Wave (FMCW) radar sensors which can work in various weathers have been increasingly adopted for self-diving cars and autonomous robots. This project aims to investigate whether these radars can be used for robust SLAM in large-scale environments in extreme weather conditions, such as heavy snowfall.

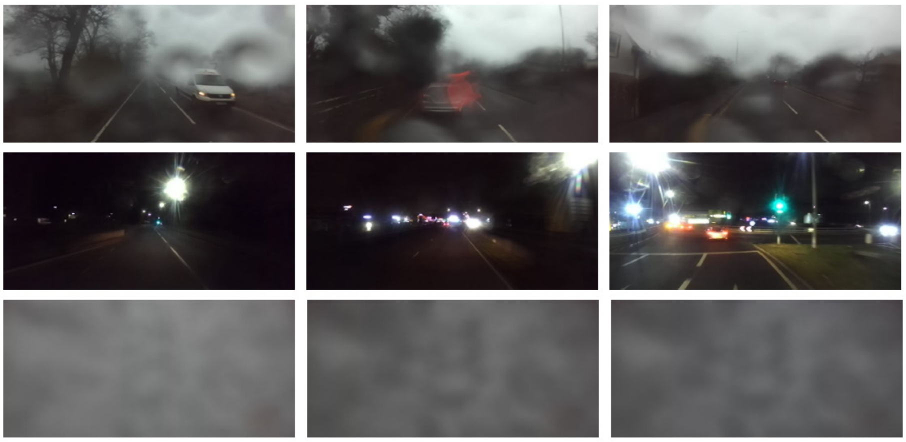


Fig 1: Images Collected in Fog/Rain (top), Night (middle) and Snow (bottom). Images quality significantly degrades in these conditions, making it extremely challenging for vision based algorithms. Note for the snow sequence at bottom, the camera is completely occluded by the heavy snowfall.

Approach

Given a sequence of radar scans, our proposed system termed RadarSLAM aims to estimate radar (robot) poses and a global consistent map using graph SLAM. To this end, the proposed RadarSLAM system is designed to have four main subsystem: pose tracking, local mapping, loop closure detection and pose graph optimization.

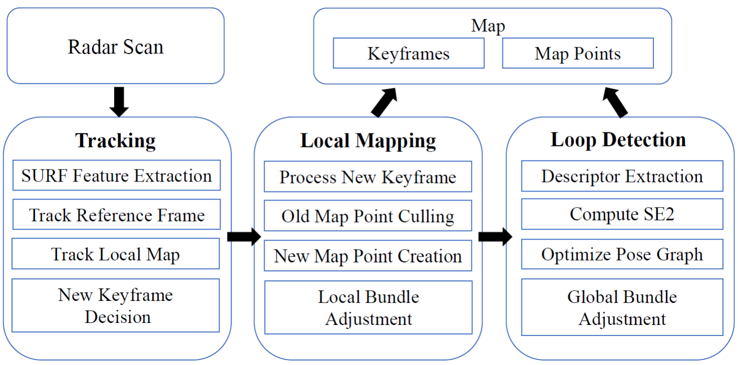


Fig 2: System diagram

Radar based Large-Scale SLAM in All Weathers - Ziyang Hong

Results
We tested our proposed system on both publicly available radar localization benchmark [1] and self-collected data. The self-collected data includes multiple adverse weather sequences with fog and snow. We show that Among all the three sensor modalities, only the radar system is able to operate and localize reliably in all the weather conditions.

Fig 3: Snow Sequence.
Top: Radar images captured in snow. Note the front half of the radar data is lost due to thick snow covered on the radar.
Bottom Left: Photo of the heavy snowfall during data collection.
Bottom Right: Significant amount of snow cover on the camera, LiDAR and radar.

Fig 4: Estimated trajectories and map points overlaid on Google satellite Images. Blue: trajectory, black: map point. Zoomed in views are highlighted in red boxes. The data sequences from left to right are: Oxford Radar Dataset[1], Snow and Night time. Uur method is able to build consistent maps across different weathers and condistions where Lidar and vision sensors might fail.

Future Work
The future work will investigate the fusion of Inertial Measurement Unit with radar for better accuracy. Also we will be looking into the reusability of the map produced by our SLAM system and perform long-term localization task on it.

Impact
This work has shown the superiority and reliability of our proposed RadarSLAM system with FMCW radar to enhance the capability of automotive vehicle navigating in large scale and extreme environment.

References
[1] The Oxford Radar RobotCar Dataset: A Radar Extension to the Oxford RobotCar Dataset
Dan Barnes, Matthew Gadd, Paul Murcutt, Paul Newman and Ingmar Posner

Publications
Z Hong, Y Petillot, S Wang
RadarSLAM: Radar based Large-Scale SLAM in All Weathers
In Proceedings of International Conference on Intelligent Robots and Systems (IROS) 2020
Accepted to appear

Research Area: Robust Humanoid Locomotion

Unified Push Recovery Fundamentals: Inspiration from Human Study

PhD candidate: Christopher McGreavy
Supervisors: Dr Zhibin Li, Professor Sethu Vijayakumar
Contributors: Kai Yuan, Daniel Gordon, Kang Tan, Wouter Wolfslag

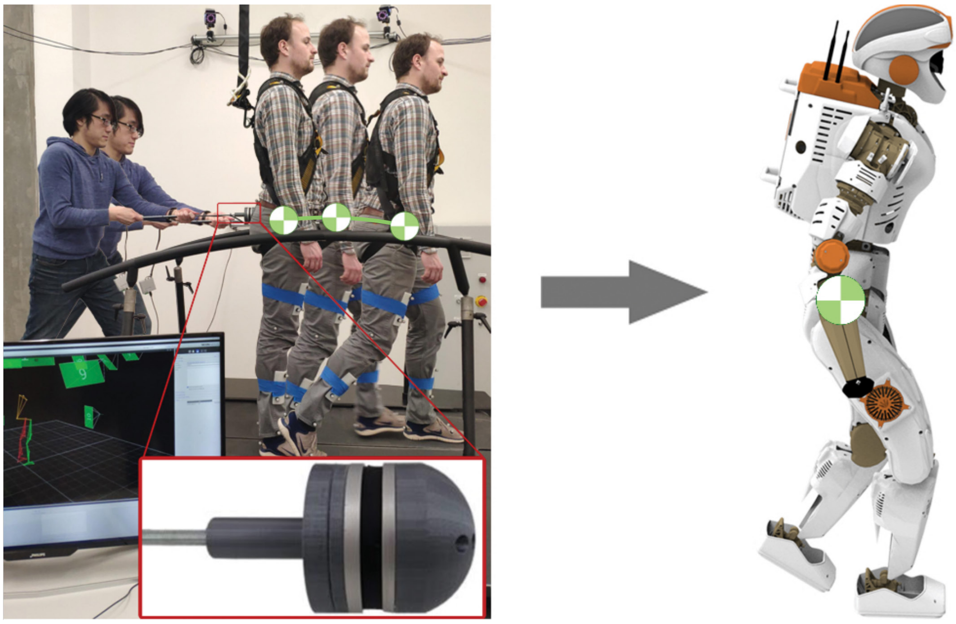


Fig 1: Data is collected from human subjects when they are pushed. This data is then used to build a push recovery model for humanoid robots

Introduction

Humans are agile and can adapt quickly if they are disturbed while moving. Robots are improving, but don't have the same level of agility just yet. To bring robots closer to humans, we can try to learn how humans react to being pushed while standing and use this to help improve robot recovery control (fig 1).

Objectives

Our goal is to record human motion while they recover from being pushed then distill their motions into a model which can generate motions for legged robots to recover from pushes.

Approach

Human subjects were pushed from the back with a force sensor. The force sensor measured the push itself and the reaction of the human was recorded using an optical motion capture system which records the movements of the subject's limbs. With this data we digitally reconstructed the motions to analyse how humans reacted to different types of push. In total, 60 pushes were performed on 4 subjects, which allowed us to: identify sequences of high level motions, mimic human motion at the centre of mass, translate this motion into a model which can be used by humanoid robots.

Unified Push Recovery Fundamentals: Inspiration from Human Study - Christopher McGreavy

The main contributions of our work are:

1. Experimental design extracting useful physical quantities to identify recovery strategies in humans
2. Classification criteria of human push recovery strategies
3. Evidence of minimum jerk regularisation as core strategy during push recovery.
4. Control design of a minimum jerk controller that resembles human CoM behaviour
5. Application of extracted core principles to robotics controller with better performance

Results

The centre of mass is important when designing motions for robots, so we focused on modelling the centre of mass in humans. When doing this, we found that human motion could be mimicked by using a Minimum Jerk model, which is common in human motion research. We also found that humans tend to cycle through movements when they are recovering from pushes and only take a step when they really need to (figure 2). Based on these findings, we were able to create a model using the Minimum Jerk model to help create human-like recovery motions for humanoid robots. We were then able to improve this model to best fit the strengths of robots.

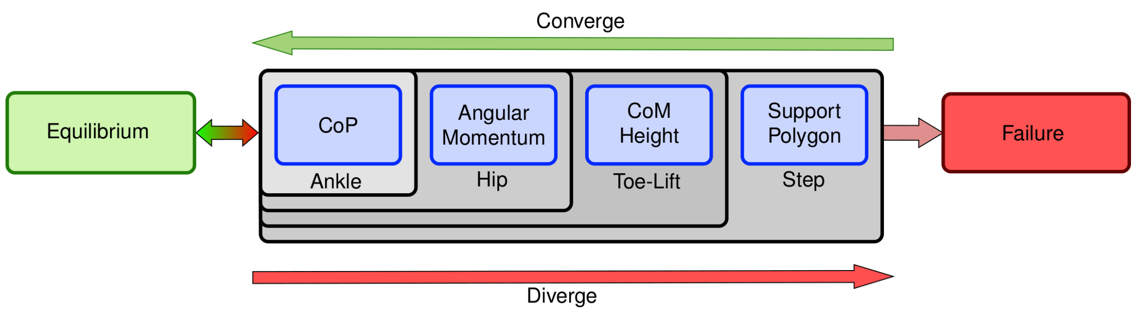


Fig 2: Humans gradually make use of different motions depending at different points during the push and in response to different push magnitudes.

Impact

Using Minimum Jerk model which we developed by analysing human motion, we can now generate motions for the robot which can be used to recover from pushes in a more simplified manner than was previously possible, allowing robots to recover more quickly from a wide range of pushes and produce motions which are closer to those seen in humans.

Future Work

The next stage for this work is to investigate where the robot is realistically able to place its foot when taking a step to maximise the amount of space that the robot has to recover.

Publications

C. McGreavy, K. Yuan, D. Gordon, K. Tan, WJ. Wolfslag, S. Vijayakumar, Z. Li, "Unified Push Recovery Fundamentals: Inspiration from Human Study" in Proc. 2020 IEEE Int. Conf. Robotics and Automation (ICRA)
Online: bit.ly/mcgreavy2020unifying

Research Area: Robotic Grasp Affordances

Self-Assessment of Grasp Affordance Transfer

PhD candidates: Paola Ardón, Èric Pairet
Supervisors: Dr Katrin Lohan, Professor Subramanian Ramamoorthy, Professor Yvan Petillot, Dr Ron Petrick

Objective

Our goal is to endow an artificial agent to self-assess the performance of an affordance task.

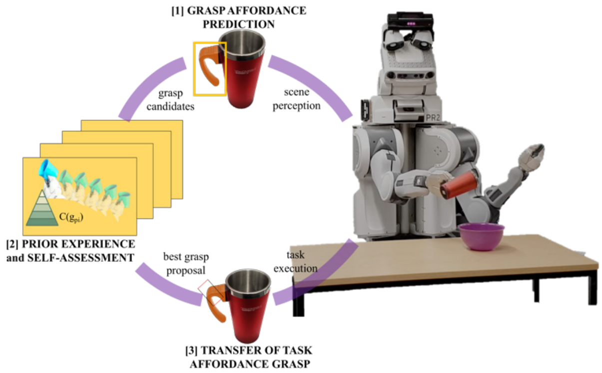


Fig 1: PR2 self-assessing a pouring affordance task. The system first predicts the object's grasp affordances. Then, based on prior affordance task experiences and a heuristic confidence metric, it self-assesses the new object's grasp configuration that is most likely to succeed at pouring.

Introduction

Reasoning about object grasp affordances allows an autonomous agent to estimate the most suitable grasp to execute a task. While current approaches for estimating grasp affordances are effective, their prediction is driven by hypotheses on visual features rather than an indicator of a proposal's suitability for an affordance task. Consequently, these works cannot guarantee any level of performance or successful task completion. Contrary, we present a pipeline for self-assessment of grasp affordance transfer (SAGAT) based on prior experiences. Evaluation shows that our method exhibits a significant performance improvement on different tasks up to 11.7% against current state-of-the-art methods.

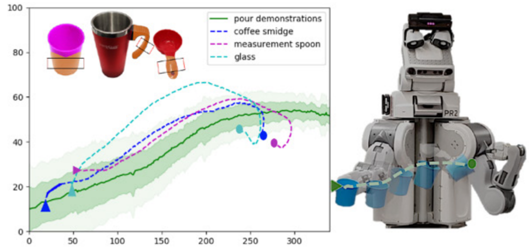
Approach

The proposed approach, depicted in Fig. 1, starts by extracting multiple grasp configuration candidates from a given grasp affordance region. The outcome of executing a task from the different grasp candidates is estimated via forward simulation. These estimates are employed to evaluate and rank the relation of task performance and grasp configuration candidates via a heuristic confidence function. Namely, we base our heuristic on the Kullback-Leibler divergence entropy measure. The resulting ranking is stored in a library of task affordances. The library serves as a basis for one-shot transfer to identify grasp affordance configurations similar to those previously experienced, with the insight that similar regions lead to similar deployments of the task. We evaluate the method's efficacy on addressing novel task affordance problems by training on one single object and testing on multiple new ones.

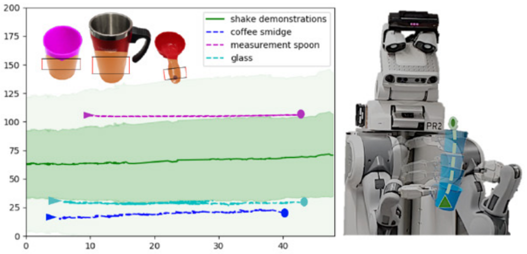
Results

Our primary contribution is to self-assess an affordance task. We use a total of 7, synthetic and real, objects for testing. Fig. 2 depicts the mean and variance (green scale) of the prior experiences in the library for the tasks pour, shake and handover. Each task was performed with three real objects with notably different features. As observed, our strategy is invariant to the initial and final states of the task. This is reflected in the obtained task affordance effect, which falls inside the variance of the demonstrations. We use the policies in the learnt library of task

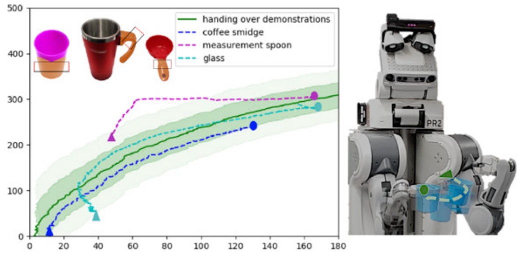
Self-Assessment of Grasp Affordance Transfer - Paola Ardón, Èric Pairet



(a) Pour task affordance



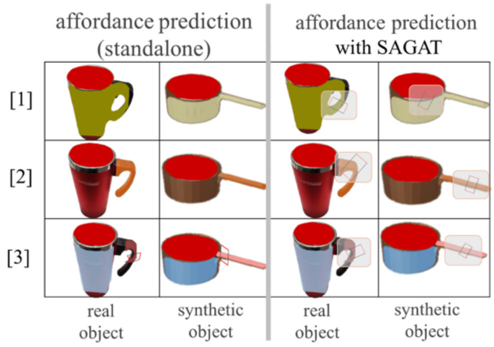
(b) Shake task affordance



(c) Handover task affordance

Fig 2: Task affordance performance when deployed on novel objects (colour-coded lines) in comparison with the multiple successful demonstrations (green scale distribution).

affordances to replicate the pour, shake and handover tasks on each object, for each grasp affordance, and for each method when used as stand-alone and combined with SAGAT. We run a total of 126 tasks deployments on the robotic platform. As observed in the table of Fig. 3, by using our approach, the deployability success is enhanced for all the tasks by 11.7% compared to using state-of-the-art methods out of the box.



	[1]	[1]+SAGAT	[2]	[2]+SAGAT	[3]	[3]+SAGAT
Pour	70%	**82%**	72%	**83%**	73%	**85%**
Shake	84%	**87%**	85%	**87%**	86%	**88%**
Handover	80%	**85%**	81%	**86%**	82%	**86%**

Fig 3: Comparison of success rates on task affordance deployment when using state-of-the-art grasp affordance extractors as stand-alone and with our method. The images show examples for the task of pouring.

Impact

Our approach can be used on state-of-the-art methods for grasp affordance detection to enhance the deployment reliability of a task.

Future Work

Future work includes to implement task planning layer that connects actions with grasp affordances to perform and self-assess multiple tasks.

Publications

P. Ardón, È. Pairet, R. Petrick, S. Ramamoorthy, K. Lohan, "Self-assessment of grasp affordance transfer", In Proc. IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2020. Website: http://bit.ly/grasp_affordance_reasoning

References

[1] T.-T. Do, A. Nguyen, and I. Reid, "Affordancenet: An end-to-end deep learning approach for object affordance detection," in International Conference on Robotics and Automation (ICRA), 2018.
[2] P. Ardón, È. Pairet, R. P. Petrick, S. Ramamoorthy, and K. S. Lohan, "Learning grasp affordance reasoning through semantic relations," IEEE Robotics and Automation Letters, vol. 4, no. 4, pp. 4571–4578, 2019.
[3] F.-J. Chu, R. Xu, and P. A. Vela, "Learning affordance segmentation for real-world robotic manipulation via synthetic images," IEEE Robotics and Automation Letters, vol. 4, no. 2, pp. 1140–1147, 2019.

Research Area: Machine Learning for Industrial Application

Waste Detection in Passenger Trains with Convolutional Neural Networks

PhD candidate: Nathan Western
Supervisor: Dr Mustafa Suphi Erden

Objective

Train cleaning is an essential part of fleet maintenance undertaken by every rail operator in the UK, maintaining a pleasant environment and making train travel hygienic and safe. The Rail Safety and Standards Board (RSSB) commissioned this research to develop an automated system for cleaning train carriages, including the hard to reach under-seat area. Train operators in the UK spent $4.4 billion on maintenance in the 2017-2018 period. Automating even part of the carriage cleaning procedure could create significant savings. The current carriage cleaning procedure involves human workers who perform a visual inspection and pick up any waste items present. Not only does this process involve some risk of disease or illness via the handling of biological waste (even wearing personal protective equipment) but the repeated bending down can cause lower back problems. The current project aims at detection and identification of typical waste in passenger trains as an imperative part of an automated train cleaning robotic system.

Selecting appropriate training data for training neural networks is an important part of the process of creating machine learning tools for application in industry. We undertook this work to provide a systematic investigation into the effect of image perspective (or view) on convolutional neural network (CNN) accuracy when classifying waste objects on trains. Specifically, this research identifies the increase in accuracy afforded by training using images that represent the perspective of the tool utilising the CNN for classification. This is compared to accuracy when training with a larger dataset (a collection of training data), which is has traditionally been given greater importance when discussing training CNN models. The development of a specialised tool to capture images of waste in hard to reach areas in train carriages was also completed to support this research.

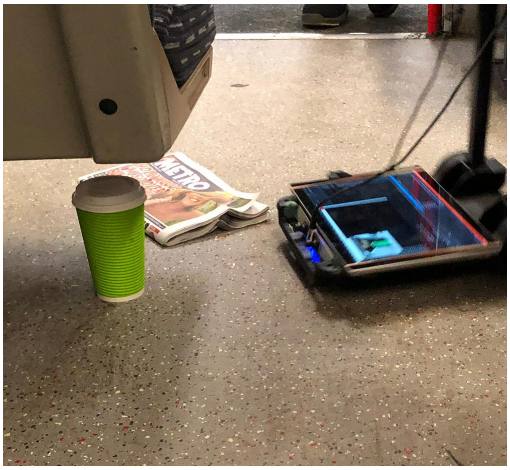


Fig 1: Collecting images of waste in train carriages

In addition to an investigation of these training methods, we also provide a comparison of three popular mobile CNN models that are often used in industry applications. Our work compares MobileNetV2, ShuffleNet and SqueezeNet CNN architectures and their precision, recall, accuracy and classification speed when classifying images of waste items found on trains. We conducted this work with a view to implementing the best performing CNN in an automated cleaning system for train carriages, but the conclusions drawn are designed to be applicable to other applications.

We successfully identified that training with images with an application-appropriate view results in increased classification accuracy when training ShuffleNet and SqueezeNet models. MobileNetV2 achieved best performance when trained with a larger dataset of waste images. Our method achieved the best results when applied to the ShuffleNet lightweight CNN, correctly classifying waste items with an accuracy of 88.61%.

Waste Detection in Passenger Trains with Convolutional Neural Networks - Nathan Western

Approach

To determine the most appropriate CNN training method to classify poorly lit images of waste items on trains, this research first collected a large dataset of images of waste items taken in a studio environment. This dataset contained images of waste in three light conditions, with three different backgrounds, and in varying poses, to represent as many features of these waste items as possible. This dataset contains 11,600 unique images, which were processed to create 58,300 total training images.

Fig 2: An example of the types of images contained in the Studio dataset

A smaller dataset of images of waste on trains was also collected. These contained only images of waste found on trains, in situ, arriving at a busy London station. In order to facilitate image collection on trains, we have designed and implemented a rig that can easily navigate train carriages and take images at floor level, including the hard to reach under-seat area. This dataset contains 2,361unique images, which were processed to create 11,805 total training images.

Fig 3: The rig developed for collecting images of waste in train carriages.

Results

Our research showed that view should be considered when training CNN models, and can have a greater impact on accuracy than dataset size. SqueezeNet achieved a classification accuracy of 55.38% when trained on the larger dataset of images compared to an accuracy of 67.71% when trained on the smaller dataset with a more appropraite view. The results were similar for ShuffleNet, which classified images with 62.57% accuracy when trained with the large dataset. This was increased to an 88.61% accuracy when using the smaller dataset of application specific images. MobileNetV2 did not benefit from this, achieving 61.12% accuracy when trained with a larger dataset of images, and 54.34% accuracy when trained on the smaller dataset. Despite being the most computationally expensive mobile CNN, the ShuffleNet model trained with the application sympathetic dataset was selected for further development in this project, as it achieved the highest accuracy in testing.

Future Development

The CNN models trained in this project will be used in the development of an automated cleaning system for train carriages, with a focus on cleaning the hard to reach under seat area. These models will be used to identify the presence of waste items in a video feed, and further developed to provide the location of waste.

Impact

This research is supported by the Rail Safety and Standards Board.

Research Area: Trajectory Optimization

Multi-mode Trajectory Optimization for Impact-aware Manipulation

PhD candidates: Theodoros Stouraitis, João Moura
Supervisors: Dr Michael Gienger (Honda RI), Professor Sethu Vijayakumar
Research Associate: Dr Lei Yan

Objective

Robotic manipulation involving transition from free motion to contact is a challenging problem in robotics due to, among other factors, (i) the hybrid nature of the problem and (ii) the uncertainty introduced by the contact dynamics. While there are some trajectory optimization (TO) methods addressing the hybrid nature of the problem and a quite comprehensive research literature on compliant controllers for contact transitions, those are often addressed separately, resulting in a gap between the planning and the execution of tasks that involve contact transitions. Such gap typically leads, in practice, to high impact forces or, as an alternative, the need of significantly slowing down the execution of such robotic motions.

As a typical example scenario, consider an agent that attempts to stop an object in motion, as shown in Fig. 1 and 2, where the robot needs to simultaneously modulate and synchronise both motion and compliance with the object itself in order to gracefully halt its motion.

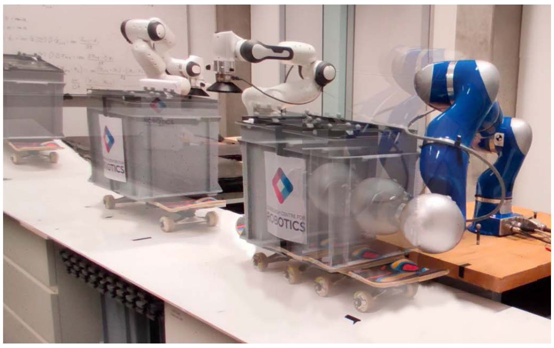


Fig 1: Experimental setup where the robot halts an object with a mass of 20kg moving at a speed of 0.88m/s

In this work, we address this problem at the level of "impact-aware" trajectory optimization. We ask ourselves, "How could we plan hybrid motions, such that they are easily executable by out-of-the-box controllers?", which we can re-frame as a problem of planning such that the robot maintains consistent contact during and after impact - even for tasks with moving objects.

Approach

Our approach consists of a novel impact-aware multi-mode Trajectory Optimization method that encodes both hybrid dynamics and hybrid control in a single formulation. This enables planning smooth transitions from free motion to contact at speed.

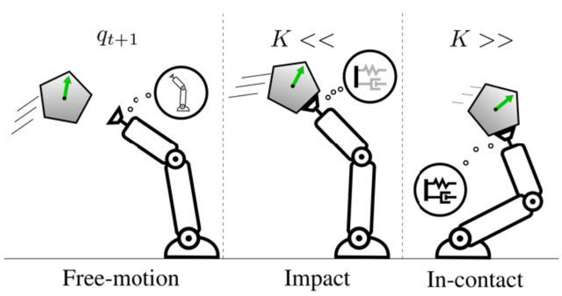


Fig 2: Pictorial Description of the multi-modeTO for the task of halting a moving object.

The core insight is based on the duality between the impact model used and the capabilities of compliance controllers available in the latest collaborative robots. By modulating the robot's endeffector compliance, we can emulate a number of different types of collisions ranging from elastic to in-elastic and deduce the optimal force transmission model given the system's limitations, e.g. workspace limits.

Multi-mode Trajectory Optimization for Impact-aware Manipulation - Theodoros Stouraitis, João Moura

The contributions of our work are:

- A parametric programming technique to encode both hybrid dynamics and hybrid control in a single multi-mode trajectory optimization formulation.
- A generic impact model formulation based on a second-order critically damped system to generate smooth contact forces and simultaneously optimize the stiffness.
- A multi-mode trajectory optimization framework that can deal with both multi-contact motion planning and contact force generation for impact-aware manipulation.

Results

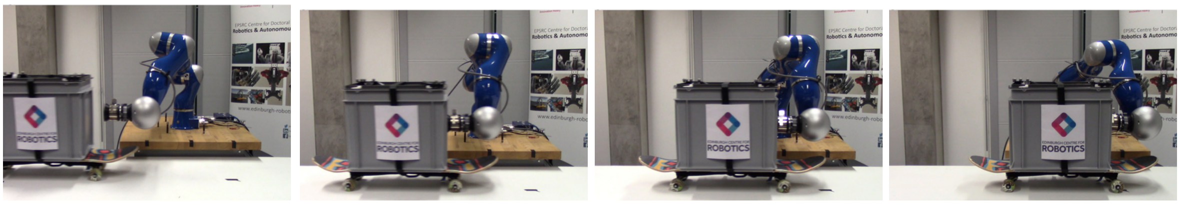


Fig 3: Keyframes of the experiment where the robot halts a moving object with a speed of 0.66 m/s,

We validate our approach in a real setting with the KUKA LWR arm and the Vicon motion capture system, where the latter is used to measure the position of the object in real time. Fig. 3 shows the experimental setup. The object is 20 kg and its initial position on a slope accelerates it to an initial velocity. Once the object arrives in a predefined position range, we estimate its velocity and acceleration on-the-fly.
As a baseline, we use the LWR arm's compliance controller with a very soft configuration, resulting in a maximum impact force of 199.47 N (see Fig. 4), which is 10 times larger than the one obtained using our proposed impact-aware method, shown in Fig. 5 for object speeds of approximately 0.66 m/s and 0.88 m/s.

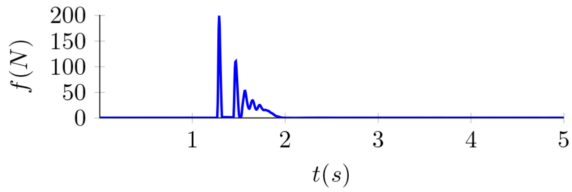


Fig 4: Experimental result of impact between the object and the end-effector during halting an object with speed of 0.66m/s, using standard compliance control

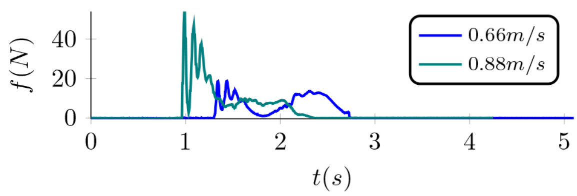


Fig 5: Experimental result of contact force during halting motion, using impact-aware TO

Future Work

Future aspirations include extending the framework to a bimanual setup, towards manipulating flying and tumbling objects. To realize this aspiration, we will explore extending the proposed framework to a fully closed loop MPC implementation.

Publications

Theodoros Stouraitis, Lei Yan, João Moura, Michael Gienger and Sethu Vijayakumar. Multi-mode Trajectory Optimization for Impact-aware Manipulation. To appear in IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2020.

Research Area: Bio-Inspired Robotics

Behavioural Analysis of Harvester Ants for the Design of a Sequential Robotic Grasping Method

PhD candidate: Emily Rolley-Parnell
Supervisors: Professor Barbara Webb, Dr Adam Stokes

Objective

The objective of this work is to reduce the computation required for grasping methods for manipulating objects that are complex or cannot be modeled, e.g. collapsed buildings for rubble removal. This will be achieved by making a sequential grasp point synthesis method that is inspired by ants through using the sensors and manipulation tools available to ants.
Bio-inspired robotics is a branch of robotics that uses the neural, material, behavioural, and control features found in living beings and uses them to inspire improvements in the world of robotics. There are many examples of grasping in the natural world, however, the context we are looking at is grasping objects that are complex, and have varying size. Harvester ants eat a combination of seeds, fruits and other insects, all of which they carry back to the nest to consume. From this wide variety of foods it is clear that they manipulate objects of different shape, size and texture, most of which have never been encountered before. The ant mouth parts (mandibles) and an actuated two finger robotic gripper work in very similar ways when considering the motion of actuation. Ants are an example of a biological system that are small with 100,000 to 250,000 neurons but are capable of carrying out sequential grasps with the aim of picking up an object, food or material, that has usually never been encountered before. If this were to be compared to RAM as found in computers, the closest comparison between living beings and computers may be between a neuron and a "bit" of information, a binary value. The current control methods used for grasping unfamiliar objects use many gigabytes of RAM which may be described as an over-engineered solution to a grasping problem that is solved by ants.

Approach

To design a grasping control algorithm that is bio-inspired, we require a better understanding of the biological system, i.e. ants. Therefore the method is to:

- Establish what behaviours are repeated when ants are sensing food – through pose tracking and analysis.
- Understand the effect of the ant mandible characteristics on an ant's ability to manipulate irregularly shaped objects.
    - » If the mandible shape improves the success of manipulation, design a robotic gripper that incorporates the physical and sensory features found on the mandibles.
- Define sensor analogues that are currently available in the world of robotics that perform a similar function to the sensors used by ants.
- Establish a grasping control method that uses the sensor analogues and the information gathered from the research on mandibles that uses sequential grasping.

Results

The first stage of this work is in motion, where the aim is to analyse ant activity while they are interacting with food. After having carried out preliminary experiments using a high speed RGB camera, it is clear that the most useful data is high speed, 3D video data in a high resolution to be able to clearly discern the pose and activity of the ants. Deep Lab Cut [1] was used on the preliminary video data to extract the ant pose, and BORIS [2] (Behavioral Observation Research Interactive Software) was used to label the different behavioural features observed in the video data. An example of the activities observed can be found in Figure 1, where the object being

Behavioural Analysis of Harvester Ants for the Design of a Sequential Robotic Grasping Method - Emily Rolley-Parnell

interacted with is a crumb of biscuit. These softwares will be applied to the 3D, high resolution, high speed video collected in the next stage of experiments.

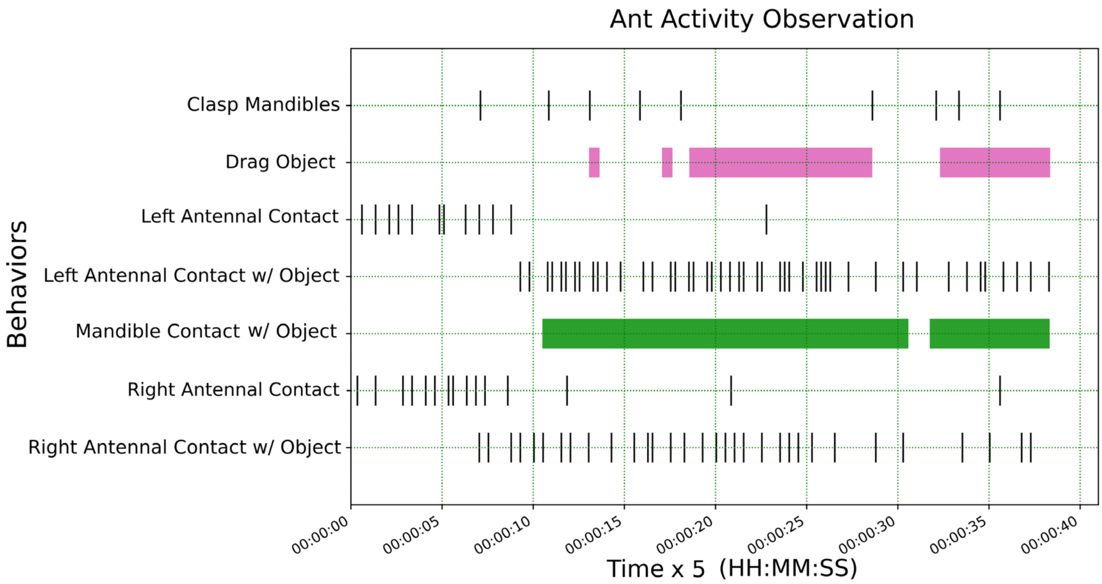


Fig 1: An example graph as temporally labelled using BORIS software on a video of an ant interacting with a piece of food.

Impact
This work is the first stage of a project that aims to reduce grasp synthesis methods down to the base components by allowing re-grasping and therefore reducing the computational power and complexity of sensors required for grasping. By reducing the computational power required for these algorithms, they may be more accessible and cheaper to implement.

Future work
The work described here is the first stage in making a robotic grasping method that uses the sensory mechanism and sequential grasping inspired by ants. The next stage is to carry out more detailed experiments that observe ant behaviour using high speed stereo vision to record controlled manipulation experiments.

References
[1] Mathis, A., Mamidanna, P., Cury, K. M., Abe, T., Murthy, V. N., Mathis, M. W., & Bethge, M. (2018). DeepLabCut: markerless pose estimation of user-defined body parts with deep learning. Nature Neuroscience, 21(9), 1281–1289. https://doi.org/10.1038/s41593-018-0209-y

[2] Friard, O. and Gamba, M. (2016), BORIS: a free, versatile open-source event-logging software for video/audio coding and live observations. Methods Ecol Evol, 7: 1325-1330. doi:10.1111/2041-210X.12584

Research Area: System Identification

Online Simultaneous Semi-Parametric Dynamics Model Learning

PhD candidate: Joshua Smith
Supervisor: Professor Michael Mistry

Objective

The usage of robotic systems in numerous applications has been growing, backed by a variety of research directions and hardware developments. Typically all these applications boil down to having a robot perform a task or to move around a space. In the past this has been achieved through kinematic control through either velocity or position signals. More recently there has been a stronger focus for dynamics control of these applications which allow control of forces during these applications. Force control can be necessary/desired for the task and/or for the safety of users and the environment around the robot.

To be able to use dynamics control on a robot platform we require knowledge of how the state of the robot translates to the forces experienced on the joints. Typically this can be achieved via three categories of methods: Parametric, Non-Parametric and Semi-Parametric. Parametric models are based on physics, modeling known physical effects. Non-Parametric models are based on pure machine learning, treating the problem as a map from the input parameters to the output parameters. Semi-Parametric models are a combination of both physics and machine learning, using both previous models.

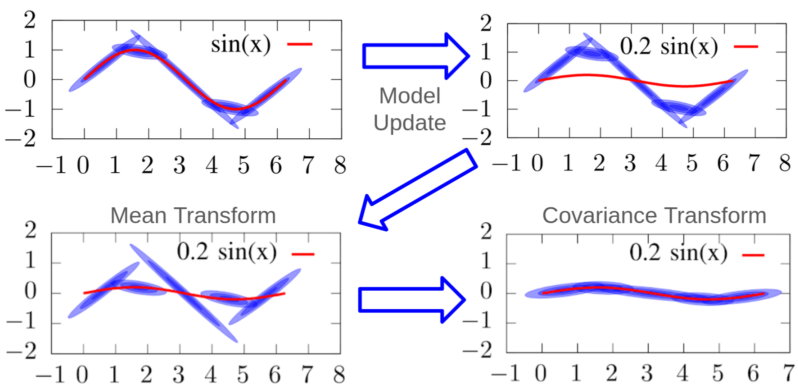


Fig 1: Sine example of the consistency transform. Upper left: Original model; Upper right: Updated Model based on parametric change of 0.8 sin (x); Lower Left: Model after GMM means are transformed; Lower Right: Model after GMM covariances are transformed.

Approach

Specifically in this work we focus on an implementation of a semi-parametric model that can be trained online. The online training presents a non-stationary problem when training the sub-models together which we solve through the use of a consistency transform which corrects the inconsistency between the two models without additional learning. This consistency transform is demonstrated in figure 1 using a sine wave example using a Gaussian Mixture Model. The semi-parametric model implemented uses a Gaussian Mixture Model as the non-parametric model. The parametric component uses a composite adaptive controller to train the parametric model and produce the control torques.

Kuka LWR 4 Manipulator

Online Simultaneous Semi-Parametric Dynamics Model Learning - Joshua Smith

Results

To analyse the performance of the semi-parametric model, we compare to just the parametric model alone on a simulated kuka-lwr-4. We use the second joint as it handles the most forces in terms of the subsequent links and gravity, and use the tracking error and feedback torques as the comparison metric. Both these metrics show the prediction performance of the model as the tracking errors should tend towards zero and the feedback torques should be minimized the more accurate the feedforward torque prediction.
As we can see from figure 2, the GMM semi-parametric model improves the perfomance decreasing the tracking errors and the feedback torques better than the parametric model alone.

Impact

The development of these online semi-parametric models allow for more accurate dynamics control. The increase in accuracy can improve the performance of existing controllers reducing the effects of errors caused by model inaccuracy. Also the generation of forces on the environment or in a human-robot collaborative task are more reliable and controllable which is key for safety.

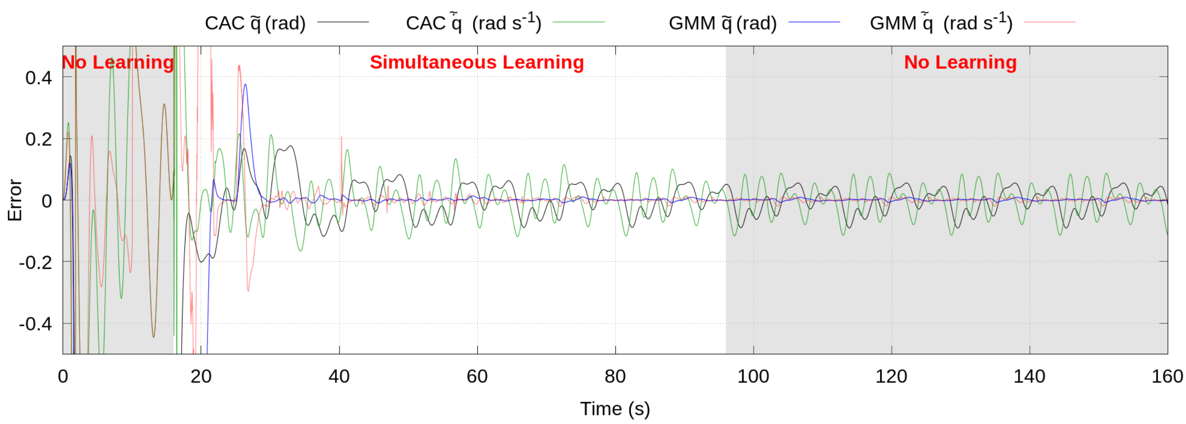


Fig 2: Position and velocity errors of joint 1, during an execution of the Composite Adaptive Control only (CAC) and the Gaussiam Mixture Model (GMM). The learning is performed between 16 to 96 seconds. Before 16 seconds the robot is only controlled by the feedback gains.

Future Work

We plan on extending this consistency framework to other models such as neural networks to demonstrate the flexibility of the concept. We also aim to explore the stability of such methods to see if stability can be mathematically proven.

Publications

J. Smith and M. Mistry, "Online Simultaneous Semi-Parametric Dynamics Model Learning," in IEEE Robotics and Automation Letters, vol. 5, no. 2, pp. 2039-2046, April 2020, doi: 10.1109/LRA.2020.2970987.

Research Area: Computer Vision based damage assessment

Masonry crack detection with Faster R-CNN

PhD candidate: Borja Marin
Supervisor: Dr Mustafa Suphi Erden

Objective

There are multiple reasons to the deterioration of masonry structures such as time, environmental conditions, change in load patterns and frequency or the quality of the materials used among others. It is due to the uncertainty when measuring these variables that regular inspections are necessary to ensure a good working condition of the structure. However, depending on the size of the structure, the resources needed for such inspections might carry very high costs. According to [1], Network Rail has a £7 million rolling program in Scotland for railway bridge improvements, including drainage work, deck replacements, steel strengthening and painting for 11 structures. This gives an idea of the cost that these structures carry and how important it is to have cost-effective inspections. In order to reduce the cost of the inspections and repairs, this study targets towards developing an inspection system with drones that is portable and easy to deploy without putting the employees at risk. This would allow inspectors making predictions of possible structural and hence, assigning maintenance works without climbing up and manually inspecting the structure. In this study, we developed the machine learning with convolutional neural networks for crack detection to be used in the complete application.

Approach

In this study we use deep learning to tackle defect identification in masonry structures using RGB images [2]. This allows us to have a small system that can be embedded on a drone for fast operation. Besides, we adopt Faster R-CNN architecture [3] to perform defect detection. However, due to the random nature of cracks, generating a set of reference bounding-boxes to train the deep learning algorithm is challenging. This results in partial detections of cracks. As a solution to this, we propose a detection scheme, called Progressive Detection, that can completely recover the full size of a defect by splitting the original image into sub-images. This methodology increases the detection resolution by a factor of n, where n is the number of sub-images generated.

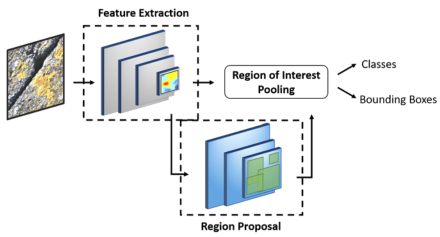


Fig 1: General architecture of Faster R-CNN object detector

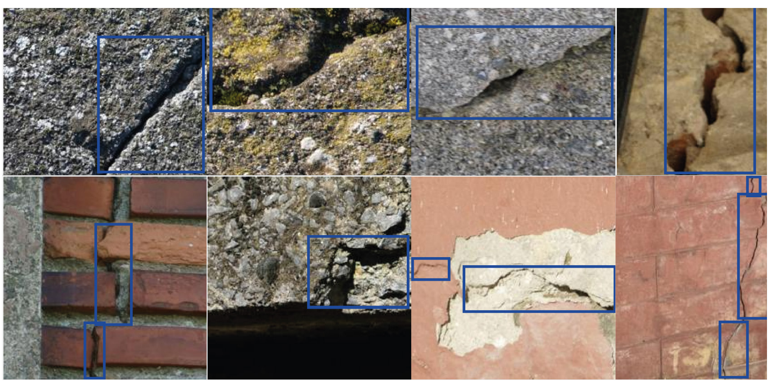


Fig 2: Examples of damages and their corresponding bounding boxes from the Crack detection dataset.

Masonry crack detection with Faster R-CNN - Borja Marin

Furthermore, we have generated an annotated crack dataset with 3000 images from various masonry structures with different surface textures and lighting conditions.
We also compare the performance of three networks (Resnet50, Mobilenetv2 and ZF512 [3]) in terms of run-time, detection precision, classification accuracy and network complexity in order to find the most suitable architecture to embed on a drone.

Results

The data collected during the benchmarking of the networks indicate the following:

1. Our progressive detection framework successfully recovers cracks with four sub-images for any network, generating more optimised bounding-boxes that contain the defect almost completely. The performance in this scenario increases 15% for Mobilenetv2.

2. Being a much smaller network, Mobilenetv2 benefits from a lower training time for its peak performance, achieving similar results to Resnet50, both in detection and classification, and outperforming ZF512 by a great margin. This makes it the perfect fit for a drone deep learning based crack detection platform.

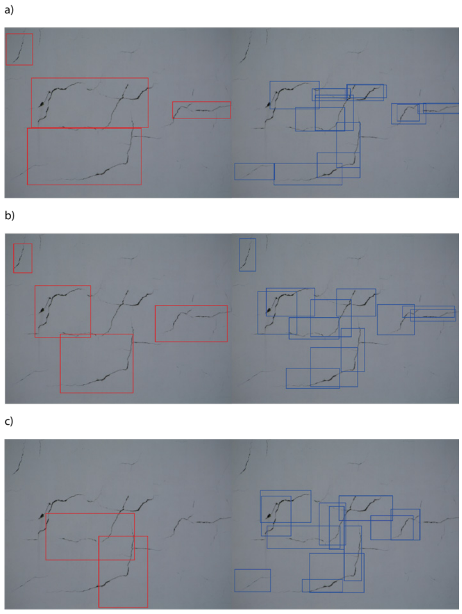


Fig 3: Original (left) and progressive detection (right) examples in low light condition with Resnet50 (a), Mobilenetv2 (b) and ZF512 (c)

Impact

With this work, we aim to provide a defect detection system that can be embedded onto a drone, significantly reducing the costs of structure inspections and risks for employees, as well as provide real time structural health data. This could potentially improve how visual inspections are carried out and help experts better plan or determine areas that need immediate action.

Future Work

These results are part of a research programme that aims to inspect the brickwork and masonry assets of railway bridges, specifically areas with limited access. We will develop an autonomous flying UAV capable of inspecting an arched structure with the implementation of a wall-following path planning algorithm, using ultrasonic sensors, combined with a deep learning detection framework. Thus, on our future work we will elaborate robust control and path planning routines for drones.

References

[1] - Network Rail. Infrastructure insights: bridges. [Online]. Available: https://www.networkrail.co.uk/infrastructure-insights-bridges/
[2] - . J. Cha, W. Choi, and O. Büyüköztürk, "Deep learning-based crack damage detection using convolutional neural networks, "Computer-Aided Civil and Infrastructure Engineering, vol. 32, no. 5, pp. 361–378, 2017.
[3] - S. Ren, K. He, R. B. Girshick, and J. Sun, "Faster R-CNN: towardsreal-time object detection with region proposal networks,"CoRR, vol.abs/1506.01497. [Online]. Available: http://arxiv.org/abs/1506.01497

Research Area: Robotic Grasp Affordances

Learning Grasp Affordance Reasoning through Semantic Relations

PhD candidates: Paola Ardón, Èric Pairet
Supervisors: Dr Katrin Lohan, Professor Subramanian Ramamoorthy, Dr Ron Petrick

Objective

To improve the robot's understanding of an upcoming task, our goal is to detect and extract multiple grasp affordances on known and novel objects via visual input.

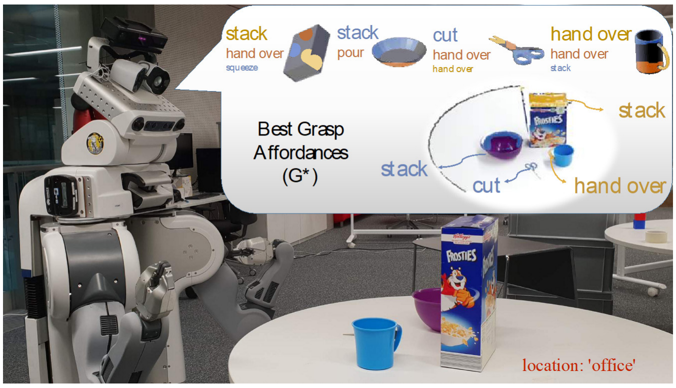


Fig 1: PR2 reasoning about grasp affordances of objects on a table top office scenario. The affordances are colour coded with the corresponding grasping region on the objects. On the top three affordance labels, the larger the size, the more suitable that affordance is in the perceived context.

Introduction

Reasoning about object affordances allows an autonomous agent to perform generalised manipulation tasks among object instances. While current approaches to grasp affordance estimation are effective, they are limited to a single hypothesis. Contrary, we detect and extract multiple grasp affordances on an object. Our approach is based on the objects semantics, which yields benefits in terms of generalisation for grasp affordance prediction on novel objects. An example of our approach is shown in Fig.1.

Approach

The contribution of our approach is threefold. First, we present an approach for multi-target prediction of grasp affordances on an object using Markov Logic Network (MLN) theory to build a knowledge base (KB) graph representation. Our method is able to reason about the most probable grasp affordance, among a set, by inferring the context semantics relation using Gibbs sampling. Second, to test the prediction on the grasping task, we map the obtained grasp affordances to the three-dimensional (3-D) data of the object. The system learns the object shape context and related prototypical grasping patches to create hypotheses of grasp locations. Finally, we collect and make available a new dataset for visual grasp affordance prediction that promotes more robust and heterogeneous robotic grasping methods. The dataset contains different attributes from 30 different object classes. Each instance is related not only to the semantic descriptions, but also to the physical features describing visual attributes, locations, and different grasping regions for a variety of actions.

Results

Our primary contribution is to associate a set of grasp affordances with an object. Fig. 2 portrays possible grasp affordances for objects in different shape contexts across. The affordances are sorted by the normalised weights between -1 to +1 per grasping region, where the higher the weight, the more likely that affordance is to be successful when grasping the object using the colour coded grasping region. From the results we can observe that the knowledge base reflects socially acceptable variations of grasp affordance relations. Fig.3 shows the comparison of our approach with state-of-the-art methods. We use 16 novel object classes and try the

Learning Grasp Affordance Reasoning through Semantic Relations - Paola Ardón, Èric Pairet

affordance detection and grasping task 25 times per object class for a total of 400 evaluations. The results are shown in the table. Given that we use the object semantics; we observe that our approach outperforms the detection of grasp affordances on novel objects.

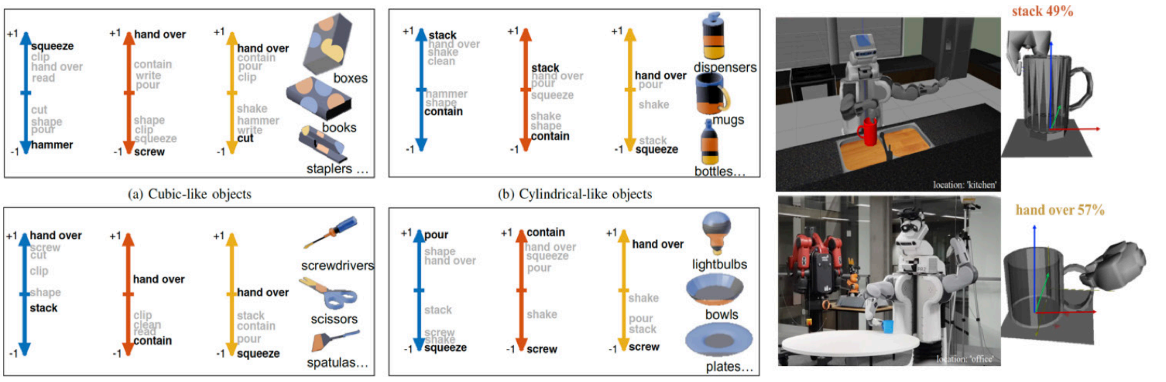


Fig 2: ((a)-(d)) Visualisation of the normalised learned grasp affordance likelihood subject to objects' shape context and grasp regions (colour coded arrows with corresponding regions on the objects). The more positive the weight, the more likely that region offers a feasible grasp for the indicated affordance. We include the likelihoods close to the extremes. (e) Shows examples of PR2 grasping an object in different simulated (kitchen) and real-world (office) scenarios while checking the variations on the detected grasp affordances

Objects shape	Detection (%)		d_h		On the robot (%)	
	[2]	ours	[3]	ours	detection/grasp	avg
Cubic	82.7	88.5	0.05	0.01	90.3 / 100	95.2
Cylindrical	79.6	87.4	0.01	0.03	87.1 / 96.1	91.6
Irregular	77.8	88.6	0.09	0.12	87.9 / 77.3	82.6
Spherical	83.2	90.5	0.02	0.03	91.6 / 100	95.8

Fig 3: Comparison of our method with state-of-the-art alternatives. On the table, the grasp is considered successful if: (i) the gripper approaches the grasp affordance region of the object below a Hausdorff distance threshold (dh < 0.2), and (ii) if the object is successfully grasped.

Impact
In contrast to state-of-the-art techniques, instead of hand-defining the grasp affordance labels on the objects, we collected data from participants to obtain the relation of object attributes, locations and grasp affordance labels. Therefore, our approach not only learns grasp affordances but also characterises socially acceptable grasp behaviours.

Future Work
Future work includes the prediction of action probabilities to be executed by associating objects in the scene, to evaluate our method with different manipulators, and the assessment of end-state comfort-effect for grasping in human-robot collaboration tasks.

Publications
P. Ardón, È. Pairet, R. P. Petrick, S. Ramamoorthy, and K. S. Lohan, "Learning grasp affordance reasoning through semantic relations," IEEE Robotics and Automation Letters, vol. 4, no. 4, pp. 4571–4578, 2019. Website: http://bit.ly/grasp_affordance_reasoning

References

[2]T.-T. Do, A. Nguyen, and I. Reid, "Affordancenet: An end-to-end deep learning approach for object affordance detection," in International Conference on Robotics and Automation (ICRA), 2018.

[3] I. Lenz, H. Lee, and A. Saxena, "Deep learning for detecting robotic grasps," International Journal of Robotics Research, vol. 34, no. 4-5, pp. 705–724, 2015.

Research Area: Sensor Fusion

A low complexity algorithm for jointly estimating many targets and meta-level tracking

PhD candidate: Mark Campbell
Supervisors: Dr Daniel Clark, Dr Yoann Altmann, Professor Yvan Petillot

Objective

In the multiple target tracking domain, there has been a shift towards estimating higher-level, or meta-level, information alongside the standard multi-state estimation. This meta-level information can include sensor-level information such as detection statistics, compensation for movement uncertainty or sensor localisation. Having the capability to estimate this information not only improves the accuracy of the multi-state estimation but also allows more robust sensor fusion to take place. If this meta-level parameter affects the multi-target state in a global manner, where the parameter is common to each target, it can be viewed as a group interaction between the targets. This group interaction can then be modelled and exploited using point processes to allow integration into existing Bayesian multi-target tracking paradigms. The Single Cluster (SC) filter aims to jointly estimate the multi-target state along with the meta-level parameter in such a manner. This contribution proposed in this work is two-fold: the use of the Linear-Complexity Cumulant (LCC) filter and the use of a log-domain particle filter within the SC framework. The aim of both of these contributions is to improve the robustness of the SC filter whilst reducing the computational complexity.

Approach

This work presents a low computational complexity solution to the problem of joint multi-target tracking and parameter estimation. Here, an improved implementation of the Single Cluster (SC) filter was proposed. It utilizes the Linear-Complexity Cumulant (LCC) filter and a log-domain particle filter, to provide a more robust and computationally efficient solution. The LCC filter is a low computational complexity filter, which propagates the second-order factorial cumulants in the same order of time as the popular Probability Hypothesis Density (PHD) filter. It has been shown to be more robust than the PHD filter due to its replacement of the Poisson assumptions in the PHD filter with Panjer assumptions. The log domain particle filter implementation to estimate the sensor parameters solves the issue of numeric stability that plagued the previous SC implementations. This instability was due to the fact that likelihood functions of unlikely particles tended to zero leading to severe particle degeneracy. Previous implementations used complex Sequential Monte Carlo (SMC) resampling methods such as progressive correction to overcome this issue at the expense of greatly increased execution time.

Results

Two different scenarios were generated in order the test the algorithm, where the meta-level parameter that is being estimated is the sensor's spatial drift overtime. Scenario A is a small-scale scenario with a low probability of detection and high clutter rate and Scenario B has a large number of calibration targets.

A low complexity algorithm for jointly estimating many targets and meta-level tracking - Mark Campbell

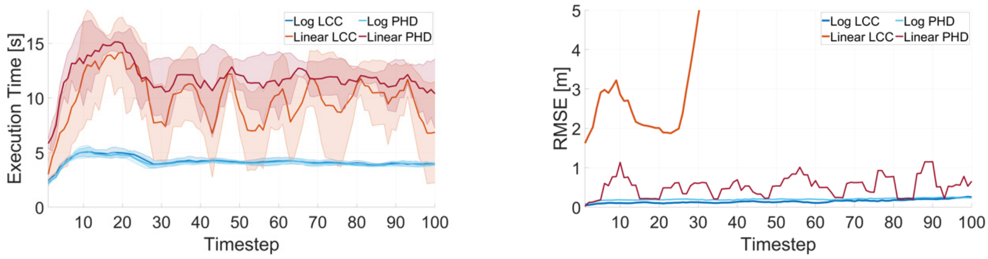


Fig 1: Results for scenario A. Left: Execution Time. Right: Root Mean Square Error (RMSE) of the sensor position estimates

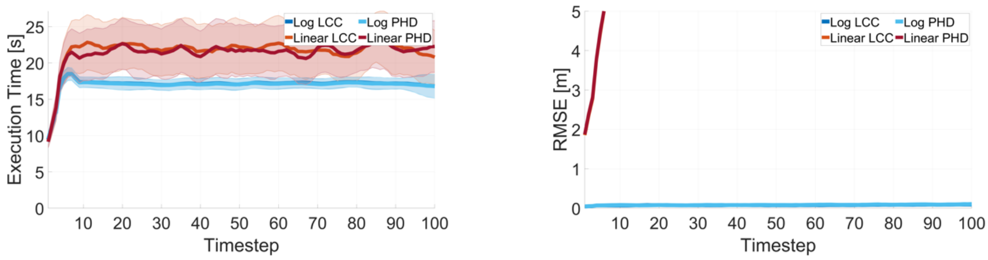


Fig 2: Results for scenario B. Left: Execution Time. Right: RMSE of the sensor position estimates

The results (Fig 1) start to display the benefit of the Log-Domain Single Cluster (L-SC) filter. Not only is it faster than the linear SC filter (Fig 1, Left) but it is significantly more accurate in sensor state estimation. The results for Scenario B (Fig 2) clearly demonstrate L-SC filter's advantages over the linear SC filter. Yet again, the L-SC filter is more computationally efficient (Fig 2, Left). Fig 2, Right shows that both multi-object filters in the linear SC implementation are unable to handle this larger-scale scenario, as they both immediately fail.

Impact

Our work here aims to provide scalable and efficient algorithms for multi-target tracking and sensor fusion across a wide range of applications areas such as: Simultaneous Localisation and Mapping (SLAM), sensor calibration, estimating sensor drift in microscopes , Space Situational Awareness (SSA), triangulating multiple targets and calibrating cameras and fusing heterogeneous sensors for maritime surveillance. Two journal papers have been submitted detailing the L-SC filter [1] and the optimized tracking filter [2].

Future Work

For future work, we will apply the algorithms to real data obtained from a variety of sensor sources. We will also aim to implement the algorithms in the open-source Stone Soup framework managed by Defence Science and Technology Laboratory (Dstl) to increase the impact of the work.

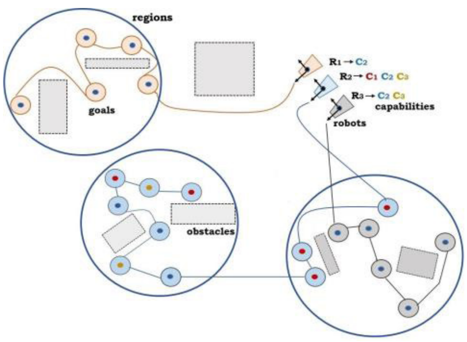
References

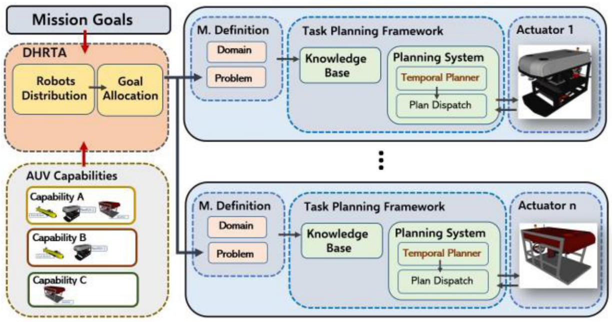
[1] M. Campbell and D. Clark. "A low complexity algorithm for jointly estimating many targets and meta-level tracking"". In: IEEE Transactions on Aerospace and Electronic Systems. (2020).
[2] D. Clark and M. Campbell. "A Gaussian mixture intensity filter for largescale multi-target tracking". In: IEEE Transactions on Signal Processing. (2020).

Research Area: Self Interactions

A Decentralised Strategy for Heterogeneous AUV Missions via Goal Distribution and Temporal Planning

PhD candidate: Yaniel Carreno
Supervisors: Dr Ron Petrick, Professor Yvan Petillot





Objective

Autonomous Underwater Vehicles (AUVs) present a flexible platform for addressing many types of challenging problems in the marine environment, including seabed inspection, maintenance of offshore underwater structures, and vehicle detection for defence. While such applications have previously been explored in limited contexts, long-term deployments in such settings often require a level of autonomy that is not currently available in deployed systems. We proposed a novel strategy called Decentralised Heterogeneous Robot Task Allocator (DHRTA) that attempts to improve the quality of multi-robot plans by optimising goal allocation. This work builds on previous approaches that use temporal planning for AUVs, such as the PANDORA project, EUROPtus, and the centralised Multi-Role Goal Assignment (MRGA) approach carried out as part of the ORCA Hub project.

Approach

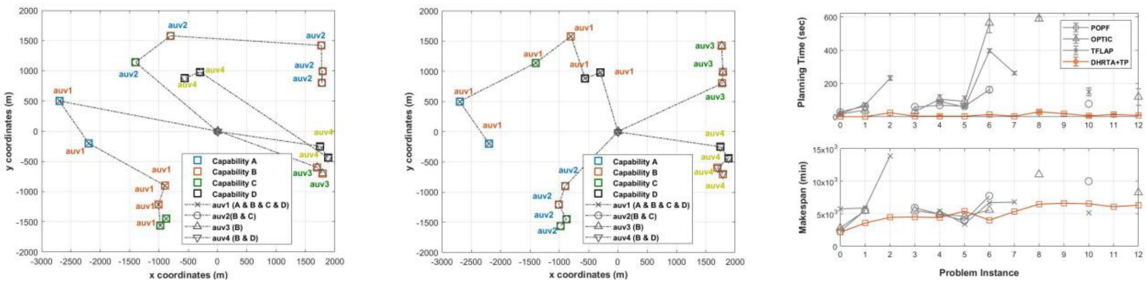
We address the task allocation problem in the context of a set of heterogeneous robots executing highly constrained missions. Relevant state-of-the-art temporal planners support the generation of multi-agent plans by combining forward search and partial-order construction. These frameworks apply ordering constraints among the actions during the plan search which primarily attempts to improve the plan's makespan while handling soft constraints and preferences. However, the plan's makespan optimisation does not guarantee good task allocation, particularly for missions with capability and resource constraints. We present the DHRTA approach which attempts to improve the task allocation performance of temporal planners (TP). The objective function of the DHRTA algorithm consists of two cost functions: (i) the number of solvable tasks for a robot, which refines the goal set that can be executed for each robot based on a capability analysis, and (ii) the linear combination of distance between the points of interest (POI) and the makespan of the tasks.

Result

We evaluate the DHRTA algorithm in two simulated experiments. In the first experiment, we analyse the performance of goal distribution on a particular problem using OPTIC and DHRTA+TP (DHRTA combined with temporal planning). We use OPTIC as the temporal planner in our DHRTA+TP strategy, since it has demonstrated promising performance in many domains.

A Decentralised Strategy for Heterogeneous AUV Missions via Goal Distribution and Temporal Planning - Yaniel Carreno

The second experiment examines the efficiency of the approach by analysing plan quality. We compare the performance of DHRTA+TP, with the results of three benchmark planners: TFLAP, POPF and OPTIC. We evaluate the approach on fleets of five heterogeneous AUVs supervising up to 10 regions. Overall, we found that DHRTA+TP optimises goal distribution (see B) for the same number of robots respect to OPTIC (see A) due to the additional factors it considers: goal capability requirements, robot capabilities, task makespan and goal locations. The task allocation generated by DHRTA also results in quality improvements to the planned action schedules. We found DHRTA+TP generates solutions for all problems in less than 5 mins of planning with better makespan results compared with benchmark planners (see C). DHRTA+TP also produces the shortest plan generation time over all problems.



(A) (B) (C)

Impact

Problems such as long-term seabed inspection, systematic maintenance of offshore underwater structures, and underwater vehicle detection for defence applications require a level of autonomy that AI planners provide. The tasks allocation methods improve the performance of planning solutions and it is crucial to reduce the consumption of resources during the mission.

Future Work

We are investigating several exciting directions such as online task reallocation, plan deviation analysis and plan repair to increase the performance of the system during the execution of real missions in extreme environments.

Publications

- Yaniel Carreno, Èric Pairet, Yvan Petillot, and Ronald P. A. Petrick. 2020. A Decentralised Strategy for Heterogeneous AUV Missions via Goal Distribution and Temporal Planning. In Proceedings of ICAPS.
- Carreno, Y.; Pairet, È.; Petillot, Y.; and Petrick, R. P. A. 2020. Task Allocation Strategy for Heterogeneous Robot Teams in Offshore Missions. In Proceedings of the International Conference on Autonomous Agents and Multiagent Systems (AAMAS).
- Yaniel Carreno, Yvan Petillot, and Ronald P. A. Petrick. Towards Robust Mission Execution via Temporal and Contingent Planning. Conference: In Proceedings of the 21st Towards Autonomous Robotic Systems (TAROS), 2020.
- Pierre Le Bras, Yaniel Carreno, Alan Lindsay, Ronald Petrick and Mike Chantler. 2020. Plan-Curves: Visualizing Multi-Agent Temporal Plans. In Proceedings of ICAPS Workshop in Knowledge Engineering for Planning and Scheduling (KEPS).

Research Area: Human Robot Interaction

Socially Assistive Robots and Sensory Feedback for Age-Related Cognitive Decline Rehabilitation

PhD candidate: Emilyann Nault
Supervisors: Professor Lynne Baillie, Dr Frank Broz

Objective

As the elderly population continues to increase, so does the need for physical and mental care [6]. For those with age-related cognitive decline (ARCD), cognitive rehabilitation is a common non-pharmacological treatment [2]. However, logistical and personal factors and a high demand on limited staff, can impede access and adherence to this therapy [2]. Even for healthy older adults, engaging in cognitive training can improve and prolong cognitive function [7], thus potentially postponing and limiting the need for care down the line. Therefore, both those with an ARCD diagnosis and healthy older adults could benefit from a system that can maximise engagement with cognitive exercises.

Approach

Based on the motivational benefits of Socially Assistive Robots (SARs) [3] and the accuracy benefits of sensory feedback [4,5], we designed a memory game that utilises the tactile sensors on the SAR Pepper (Figure 1a). Three sensory feedback conditions were employed and assessed with each participant: auditory, haptic, and auditory & haptic. Auditory feedback was delivered via a beep through Pepper's speakers and the vibrotactile feedback was delivered through a wearable device worn on the wrist (Figure 1b). The feasibility of the system was assessed with nine young adults (M=25.5 years old).

a) b)

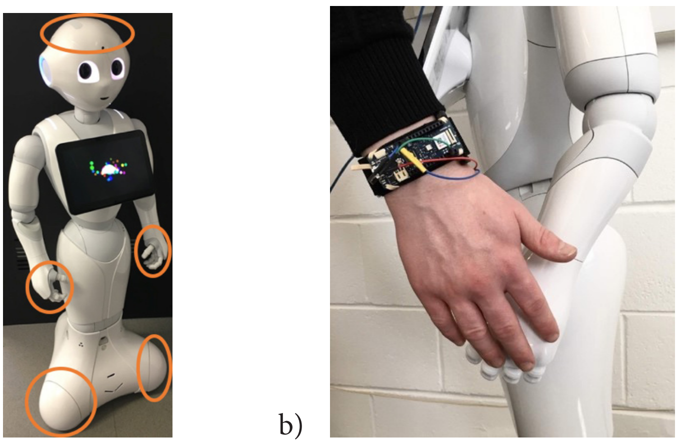


Fig 1: Robotic Memory Game with Sensory Feedback
a) SAR Pepper – The tactile sensors used in the game are highlighted in orange
b) Haptic wearable device – The device was created from an Arduino and a vibrating motor

Results

We did not find a difference in game accuracy across the sensory feedback conditions (p=0.99). The scores from the NASA Task Load Index did not result in high workload across all conditions, and it suggests that participants felt that they performed best in the auditory condition (Fig 2). The scores from the system usability scale (SUS) supported this, whereas participants most preferred the auditory condition (83.3) over haptic (78.1) and auditory and haptic (74.7). These results were contrary to our hypothesis, but we attribute this to the lack of strength of the vibrotactile feedback due to hardware constraints, as confirmed by the majority of our participants. Interestingly, we found that female participants were more sensitive to the haptic feedback compared to the male participants. Similar results have also been found in regard to thermal stimuli [1].

Socially Assistive Robots and Sensory Feedback for Age-Related Cognitive Decline Rehabilitation - Emilyann Nault

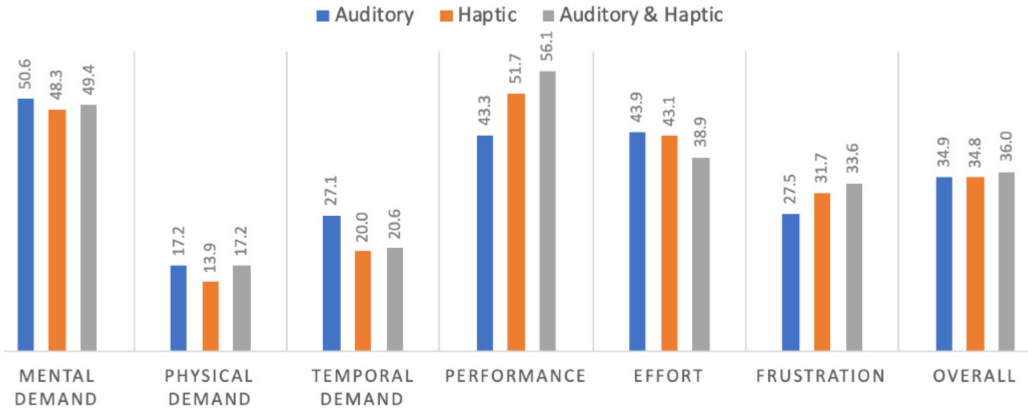


Fig 2: Raw NASA TLX Results

Future Work

The next step for this work is to assess the system with older adults. We have made improvements such as increasing the strength of the haptic feedback. This project has been delayed due to COVID-19 but will hopefully be able to be carried out in the coming months. We are also in the process of conducting virtual interviews with health professionals to gain an understanding of the current rehabilitation practices and motivation strategies used by therapists, as well as how these practices may be transferred to a robotic rehabilitation system.

Impact

This feasibility study was the first step in gauging how a robot-facilitated cognitive task that incorporates sensory feedback would be received. This work will inform the development of a robotic cognitive rehabilitation system for older adults with ARCD with the aim of combating the factors that prevent access and adherence to cognitive rehabilitation.

References

[1] M. Akazue, M. Halvey, L. Baillie, & S. Brewster, "The effect of thermal stimuli on the emotional perception of images," In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems. 2016, pp. 4401-4412.
[2] A. L. Faria and S. B. i. Badia, "Development and evaluation of a web-based cognitive task generator for personalized cognitive training: a proof of concept study with stroke patients," in Proceedings of the 3rd 2015 Workshop on ICTs for improving Patients Rehabilitation Research Techniques, 2015, pp. 1–4.
[3] J. Fasola and M. J. Matarić. "Robot exercise instructor: A socially assistive robot system to monitor and encourage physical exercise for the elderly." In Proceedings - IEEE Int. Work. Robot Hum. Interact. Commun., 2010, pp. 416–421.
[4] S. Finney and C. Palmer. "Auditory feedback and memory for music performance: Sound evidence for an encoding effect," Memory & Cognition, 2003, 31(1), pp. 51–64.
[5] S. Kuznetsov, A. K. Dey, and S. E. Hudson. "The Effectiveness of Haptic Cues as an Assistive Technology for Human Memory," Proceedings of the 6th International Conference on Foundations of Digital Games - FDG 11, 2009.
[6] A. Tapus, C. Tapus, and M. J. Mataric, "The use of socially assistive robots in the design of intelligent cognitive therapies for people with dementia," in 2009 IEEE international conference on rehabilitation robotics. IEEE, 2009, pp. 924–929.
[7] S. L. Willis, S. L. Tennstedt, M. Marsiske, K. Ball, J. Elias, K. M. Koepke, J. N. Morris, G. W. Rebok, F. W. Unverzagt, A. M. Stoddard, and E. Wright, "Long-term effects of cognitive training on everyday functional outcomes in older adults," Jama, vol. 296, no. 23, pp. 2805–2814, 2006.

Publications

E. Nault, L. Baillie, and F. Broz, "Auditory and haptic feedback in a socially assistive robot memory game," in Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction, 2020, pp. 369–371.

New Research Programmes

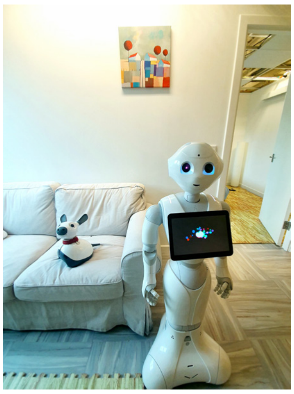
METRICS

METRICS (Metrological Evaluation and Testing of Robots in International CompetitionS) organises challenge-led and industry-relevant competitions in the four Priority Areas (PAs) identified by ICT-09-2019-2020: Healthcare, Infrastructure Inspection and Maintenance (I&M), Agri-Food, and Agile Production.

Within METRICS, Heriot-Watt will engage with stakeholders in co-design activities to contribute to identifying tests and performance for the competitions. It will offer its robotic assisted living test-bed (RALT) for teams to test their equipment in advance of the official Healthcare competition, and collect and curate data to support cascade evaluation campaigns.

The robots are evaluated on functionalities such as object detection, activity recognition, object handover, task-oriented grasping and speech understanding, which are required to complete tasks such as assessing the activity state of a person, delivery items such as medicines to a person and preparing and transporting a drink. The field campaigns will be conducted at certified test-beds with physical robots, whereas the cascade campaigns will be conducted online, where performance is evaluated on datasets collected during the field campaigns.

http://care.hw.ac.uk/projects/METRICS.html



OpenAAL

The Open Ambient Assisted Living (OpenAAL) project targets the fast co-creation of scalable and affordable solutions to support the care of vulnerable people whose urgent need has been exemplified by the COVID-19 pandemic. The project, running from July 2020 to April 2021, is funded by EPSRC under the Impact Acceleration Accounts schema. These are strategic awards provided to institutions to support knowledge exchange (KE) and impact from their funded research. The project will use digital twin, Internet of Things (IoT) and Cloud technologies to provide a platform where researchers, industry and care providers alongside end users of assisted living services can co-create technology, where time and distance is no longer a barrier – any time, any place access. The project will initially support key priority groups in the UK whose conditions have been compounded by the social isolation measures necessitated by the COVID-19 pandemic. These include those with multi-morbidity conditions, disabilities, and those in acute stages of mental ill health.

Explainable Reasoning, Learning and Ad-Hoc Multi-Agent Collaboration

Dr Stefano Albrecht has been awarded USD1M from the Office of Naval Research (ONR) with partners at the University of Texas in Austin, and University of Birmingham.

This 3-year project will address key underlying knowledge representation and reasoning, learning, and multi-agent collaboration challenges by developing algorithms and architectures for explainable reasoning and learning; communication in ad hoc teamwork; and open ad hoc teamwork.

New Research Programmes

Fact-Accurate Text Summarisation

Automatic Text Summarisation is one of the core tasks of Artificial Intelligence: given one or more documents the task is to generate a summary that best describes them. The key elements of any summarisation system focus on 'what to say', i.e., which content to keep, and 'how to say it', i.e., compressing the content into the resulting text.

However, it is also one of the most challenging applications of Artificial Intelligence and deploying it in the wild can result in generating fake news, hence potentially damaging irreversibly the trust of humans in modern AI. This research, funded by the Royal Society and led by Dr Ioannis Konstas, proposes a novel system that aims to capture the important facts contained in the input document, making sure they are mentioned with fidelity at the output summary, and can explain (e.g., by showing visually) the connections between the facts in the document(s) and summary.

Building a summarisation system specifically for news articles that possesses all these properties can play a crucial role in building the trust between the user and the machine. It can have a great impact on society if deployed on existing smart assistants such as Amazon Alexa or Google Home, potentially reaching out to millions of people.

A multiscale digital twin-driven smart manufacturing system for high value-added product: Smart Assembly System Smart Assembly System

Dr Xianwen Kong, Dr Mustafa Suphi Erden and Dr Patricia A Vargas , all academics from Heriot-Watt University, have been awarded a £513K EPSRC grant as a part of a £2.8M EPSRC project entitled "A multiscale digital twin-driven smart manufacturing system for high value-added product" (EP/T024844/1, 2020-2024) led by Prof X Luo from the University of Strathclyde. This project is to research and develop the underlying science and technology for the creation of a new generation smart digital twin-driven manufacturing system that can actively self-optimise for customised next-generation high performance 3D products with enhanced productivity and sustainability. The HWU team led by Dr Kong will focus on the development of a smart assembly system for the smart manufacture system starting from the assembly system for micro-3D products developed in a recently completed EPSRC project (EP/K018345/1).

Trustworthy control synthesis

Professor Subramanian Ramamoorthy, an academic from University of Edinburgh, has been awarded a grant from the UK National Physical Laboratory. Prof Ramamoorthy's project on "Trustworthy control synthesis" builds on recent work on Safe AI, and addresses how he can develop methods to ensure safety in machine-learning enabled robot control systems. The grant is in the form of a Metrology Fellowship, providing £164K.

New Research Programmes

AISEC: AI Secure and Explainable by Construction

This project, led by Professor Ekaterina Komendantskaya in collaboration with Professor Verena Rieser, will create and deploy a novel framework for documenting, implementing and developing policies for complex deep learning systems by using types as a unifying language to embed security and safety contracts directly into programs that implement AI. The project will produce a development tool AISEC with infrastructure (user interface, verifier, compiler) to cater for different domain experts: from lawyers working with security experts to verification experts and
system engineers designing complex AI systems. AISEC will be built, tested and used in collaboration with industrial partners in two key AI application areas: autonomous vehicles and natural language interfaces.

AISEC has a significant international span, with 12 partners from Academia and Industry in Europe (France, Germany, Israel, the Netherlands, Norway) and the US. Industrial partners are: Imandra, FiveAI, Horiba Mira, Hugging Face, Amazon, the Norwegian Defense Research Agency, Nec Europe, Symphonic. Academic partners come from the universities of St Andrews, Boston, Leiden and the Hebrew University.

Designing Conversational Assistants to Reduce Gender Bias

This project, led by Professor Verena Rieser, will address gender stereotypes in technology, and will combine ML, NLP, psychology and education to fight these stereotypes. The project will run until May 2023 in partnership with the BBC, Equate Scotland, Google and The Scottish Parliament.

The Robotcafe

Funded by an EPSRC Innovation Acceleration grant, we are building a RobotCafe, which we are hoping will eventually be installed in the National Robotarium. The project is led by Professor Helen Hastie and Dr Jose Lopes and involves the latest in social robotics: the Furhat Robot.
The Robot will interact with customers and take their beverage orders. Importantly, this will be a platform for researchers at ECR to test and evaluate new and novel techniques for social interaction with real users and thus provide a method for demonstrating impact. As we will have returning customers, we can also explore the development of human-robot trust over time and this will have long-term effects in terms of increased adoption and acceptance of robots in our everyday lives. Finally, we anticipate that this will be a memorable experience for visitors to the National Robotarium and contribute to the positive dissemination of the important human-robot interaction work at Heriot-Watt University and the Edinburgh Centre of Robotics, and potentially lead to exciting technology transfer opportunities.

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 work flow. 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.

Industrial studentships

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 than 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 work spaces 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.

Industrial Partners

ABB
BAKER HUGHES a GE company
Balfour Beatty
BAE SYSTEMS INSPIRED WORK

bp
CHITENDAI
codeplay
CONSTRUCTION SCOTLAND INNOVATION CENTRE

COSTAIN
THE DATA LAB value from data
DIGITAL HEALTH & CARE INSTITUTE
DI4D PERFORMANCE CAPTURE

dyson
FIVE AI
HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA
HITACHI

HRI
HYDRASON solutions
industrial systems and control
L3HARRIS | ASV

Kawasaki Powering your potential
KINOVA ROBOTICS
KUKA
LEONARDO

MACTAGGART SCOTT Innovators since 1898
MARZA ANIMATION PLANET
NII 大学共同利用機関法人 情報・システム研究機構 国立情報学研究所 National Institute of Informatics
OC Robotics

Industrial Partners

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 recently 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

Highlights 2019-20

Team Building Weekend

Thirty students from the Centre spent a fun few days in November at the University of Edinburgh's Firbush Outdoor Centre on Loch Tay for a weekend of team-building and outdoor activities. The group, accompanied by Professor Helen Hastie and Dr Adam Stokes, left Edinburgh by coach on the Friday evening, arriving at Firbush in time for supper and "Doomsday Prediction", the first of the weekend's Responsible Research and Innovation themed educational activities.

Students were asked to form small groups and to choose a topic from a list that included robot teachers, face recognition, and cyborgs, and then to discuss how this technology could be used to the detriment of society. On the Saturday evening, students had five minutes to share their imagined dark future with a group presentation of their ideas on how and why the technology might be misused. This was followed on Sunday morning with a reversal of "Doomsday Prediction" when students discussed the steps that need to be taken to prevent misuse of their selected technology. Prizes were awarded for the best team building group and the best RRI project.

Students also had the opportunity to make use of the fantastic facilities at Firbush and after an early breakfast on the Saturday morning, many participated in activities including walking, cycling, mountain biking, rowing, canoeing and kayaking. The focus during the Saturday afternoon session was team building and the Firbush instructors guided the students through four different team building exercises. After the final educational activity on the Sunday morning, students were free once more to enjoy the outdoors and many of them opted to enjoy the clear but cold weather by rowing and kayaking down Loch Tay to the village pub.
The students arrived back in Edinburgh on the Sunday evening, having enjoyed the weekend's activities and strengthened friendships with members of their own and other cohorts.

Highlights 2019-20

Dr Adam Stokes wins University of Edinburgh Principal's Innovation Award

Centre Deputy Director, Dr Adam Stokes from the School of Engineering at the University of Edinburgh, has won a Principal's Innovation Award.

This is the first year of this award scheme, which invited applications from researchers across the University of Edinburgh, for "high risk, blue sky projects", which could be seen as potentially transformational for the economy and pivotal in the development of a whole new sector or technology.

After a highly competitive selection process, Dr Stokes was awarded £10k and a package of research support from the University for his proposal entitled "Soft systems for hard problems ". Dr Stokes and the Soft Systems Group will use the £10k prize money to facilitate workshops with key industrial and academic partners to translate the learning from their award-winning research into the development of new types of "Fluidic Robotics", and to write research proposals focusing on high-impact, disruptive innovations.

According to Dr Stokes, robotics solutions have only become more urgent and relevant due to the Covid-19 pandemic. "The pandemic has highlighted the need for many more aspects of our lives to be underpinned by systems that are resilient, persistent, decentralised, and sustainable", he explained.

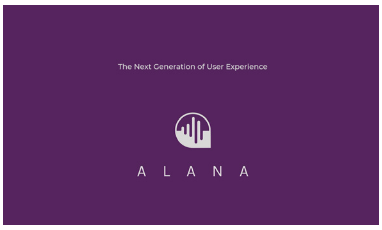
"The extreme environments in which robots usually operate include industries such as nuclear, mining, space and offshore. The global pandemic has brought public buildings and spaces, e.g. hospitals, schools, parks, into the "extreme" category: environments which are dangerous and where physical tasks can be best carried out by robots."

Commenting on the award, Dr Stokes said "This award recognises the robotics research that my group and I are doing here in The School of Engineering and the Edinburgh Centre for Robotics. We are exploring novel ways to build and control machines that are designed for safe-interaction or which provide capability in challenging environments. I look forward to the next phase of our research programme as we explore how to use basic applied research to solve important problems."

Soft Systems Group
Bioinspired Engineering

Heriot-Watt University spin-out company formed

Alana, a spin-out company from Heriot-Watt University, is developing artificial intelligence

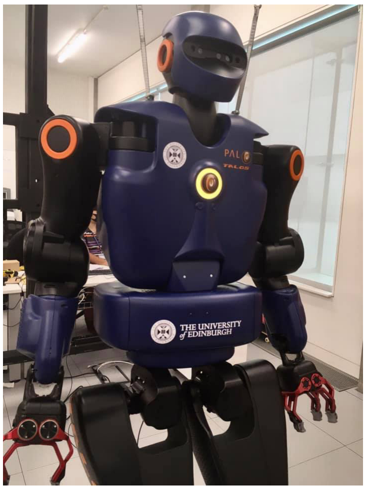


(AI) software that can understand and respond to human conversation.
The founding team of Prof. Verena Rieser, Prof. Oliver Lemon, Dr Ioannis Konstas and Dr Arash Eshgi are already seeing significant demand across a range of sectors for the technology which previously was successful in bringing a team to the finals of the Amazon Alexa Prize in two consecutive years.

Prof. Verena Rieser, Director of the Natural Language Processing lab at Heriot-Watt says: "**Alana is different from the voice-activated assistants on the market today, such as Alexa and Siri, as the software enables long, extended conversations in machine learning research with well established solutions for customer facing interfaces**".

Highlights 2019-20

TALOS, the Humanoid Robot, arrives at University of Edinburgh



TALOS is the latest arrival in the robotics lab in the University of Edinburgh's Bayes Centre.

Standing at 1.75m tall, the humanoid robot has inverse dynamics controllers, torque based motion command capabilities and an extremely generous range of motion compared to other humanoid platforms. The team in the Centre for Robotics Research lab will use TALOS to conduct research on multi-contact loco-manipulation. The lab, where TALOS is housed, is already equipped with multiple complementary platforms, a 2-axis large area hoist, and some mock-up navigation circuits with slopes and steps on which the team intends to push the capabilities of TALOS, and co-develop further improvements in collaboration with PAL.

Professor Sethu Vijayakumar, Director of the EPSRC CDT in Robotics and Autonomous Systems, advised that TALOS would help the research team to validate some of the recent algorithmic advances in hierarchical long horizon motion planning, novel MPC techniques for hybrid problems such as foot step selection, contact optimisation and multi-objective trajectory optimisation as well as some sensory integration strategies for state estimation and localisation. He added that they are keen to develop Shared or Punctuated Autonomy paradigms on the platform, where a user can provide high level, immersive target goals/feedback to the robot without direct line of sight and the robot can achieve significant robust autonomy in achieving a desired task.

Professor Vijayakumar went on to explain that the team has already upgraded the IMU sensors on the torso of the robot which will hopefully enable them to improve state estimation and drift compensation during long horizon loco-manipulation but also enable them to tackle more dynamic movements.

Highlights 2019-20

Turing Lecture: Building Dynamic Robotics with Marc Raibert of Boston Dynamics
Over 630 attendees logged in to watch the full interview between Marc Raibert, Founder and Chairman of Boston Dynamics and Professor Sethu Vijayakumar, and to interactively take part in the live online polls and Q&A session.

Boston Dynamics are leaders in some of the world's most advanced robots including Spot, Atlas and Handle. The company specialises in robots which can reach inaccessible areas and are able to move more quickly to get the work done faster.

Marc Raibert started the conversation by explaining athletic intelligence (how we use our bodies to walk, balance) and cognitive intelligence (planning for events). Boston Dynamics are interested in the interaction between these two capabilities as good athletic intelligence combined with cognitive intelligence is essential for a fully functioning hardware system.

Marc then touched on the Covid-19 pandemic, describing how Spot was recently trialled at a Boston hospital to measure patient heart rate, body temperature, oxygenation and respiration. The robot was fitted with a screen to allow medical staff to interact with the patient from a safe distance.

Marc provided an insight into future plans at Boston Dynamics which include a lightweight version of Spot fitted with an arm to grasp and remove any items from the ground that the robot's camera identifies as hazardous. Further research is being carried out into athletic intelligence to allow the robot to perform the set task even when the situation is not precisely what was planned.

The discussion was followed by a lively Q&A session with questions being asked about the optimal robot size, the dream application for Spot, and ethical concerns.

Attendees then participated in an interactive poll where they were asked their views on robots taking vitals in a hospital (60% of those polled were comfortable with this), and in which areas they expect robots to have most impact in the next 5 years (37% polled health and medical assistance).

Highlights 2019-20

Annual CDT Conference

Our annual conference which took place on Tuesday 8th October at South Hall, on the Pollock Halls campus at the University of Edinburgh, was attended by over 100 students, academics and industry partners.

The Directors of Phase II of the CDT programme, Professor Helen Hastie and Dr Michael Mistry, welcomed delegates to the conference and introduced the 2019 cohort. Professors David Lane and Sethu Vijayakumar provided a review of the 2018/19 academic year highlighting student successes, new research programmes, outreach activities and the development of the National ROBOTARIUM.

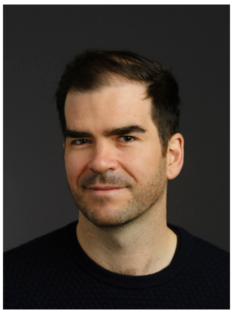
Keynote speakers included Professor Luca Iocchi from Università di Roma "La Sapienza", Italy, who spoke about Cognitive Social Robots, and Dr Michael Gienger from Honda Research Institute Europe who discussed Concepts for Intuitive Human-Robot Interaction. Student presentations took place throughout the day in five topic-based groups: Sensing, Planning, Control, Human Robot Interaction and Machine Learning for RAS. Delegates were given the opportunity to view and discuss the students' work during the poster session and to visit the ROBOTARIUM facility at the University of Edinburgh.

The Conference Dinner took place at the Playfair Library where the winners of the best presentation and poster (Siobhan Duncan, 2016 cohort) and best case study (Martin Asenov, 2016 cohort) were announced.

Prof Thusha Rajendran gave a light hearted After-Dinner talk about identity, what it means to be a psychologist/computer scientist/roboticist and how you can use the stereotypes about you to your advantage.

Achievements

MAAH video and Converge Challenge Success for Student



Alexandre Colle, a year 2 PhD student in the CDT, with a background in design, has collaborated with others to develop MAAH, a robot designed to bring comfort and companionship to users, while blending in with the home environment. Now, in collaboration with Swen Gaudl, Research Fellow from Falmouth University and Reiner Rockel, PhD Researcher from Agrotextiles, Alexandre has created a HRI2020 video of MAAH.

The video, which can be viewed here, describes the process of development of the first prototype of the MAAH, explaining the main idea behind its conception and the major steps required to reach a functional device. Alexandre advised that MAAH represents a provocation for the robotic community and is an attempt at offering a different view of a social robot.

Alexandre's MAAH robot design has also led to him being named as a finalist in the Heriot-Watt cohort of the Converge Challenge 2020 in the Creative Challenge section.

Centre Academic wins prestigious A.T. Yang Memorial Award in Theoretical Kinematics

Dr Xianwen Kong attended the 2020 ASME (America Society of Mechanical Engineers) International Design Engineering Technical Conferences & Computers and Information in Engineering Conference during 17-19 August 2020. His paper entitled "Variable Degree-of-freedom Spatial Mechanisms Composed of Four Circular Translation Joints" was selected as the winner of the prestigious A.T. Yang Memorial Award in Theoretical Kinematics at the 44th Mechanisms and Robotics Conference of this conference.

Professor Verena Rieser was recently included in RE-WORK's top 5 Women in AI in the UK

Achievements

Best Paper Runner-Up Award

Prof Subramanian Ramamoorthy and members of his group, including Dr Michael Burke, Yordan Hristov and CDT student Daniel Angelov, had a productive visit to the third edition of the international Conference on Robot Learning (CoRL 2019), held in Osaka, Japan.

Their paper on "Disentangled Relational Representations for Explaining and Learning from Demonstration" won the Best Paper Runner-up Award.

This paper presents a new model for grounding spatial relations, enabling robots to understand natural language instructions that come closer to the way we describe tasks to each other.

They also presented a second paper, on "Hybrid system identification using switching density networks".

Dr Laura Sevilla-Lara wins 2019 Google Faculty Research Award

Dr Laura Sevilla from the School of Informatics at the University of Edinburgh has been awarded a Google Faculty Research Award. The aim of this Google programme is to support the world-class technical research in Computer Science, Engineering and related fields that is performed at academic institutions around the world, giving Google researchers the opportunity to partner with faculty who are carrying out impactful research.
Google received 900 proposals from over 330 universities spread across 50 countries which were vetted by more than 1000 expert reviewers. Proposals were assessed based on merit, innovation, connection to Google's products/services and alignment with their overall research philosophy. Dr Sevilla's proposal was one of 150 selected by Google to receive funding.

Students win Enterprise Initiative Grant

Edinburgh Innovations has awarded one of their Enterprise Initiative Grants for the development of the RoboBrico service robot, a project started by CARE Group members Alexandre Colle, Ronnie Smith, and Scott MacLeod in their spare time. The robot looks to fill a gap in the health and social care assistive technology market, by providing an affordable and highly customisable platform catered to customer needs through co-design. The robot will also be used by Alexandre Colle in the coming year in control studies exploring the role of customisation and modularity in Human-Robot Interaction (HRI).

Professor Sethu Vijayakumar elected fellow of the ELLIS network

Centre Director, Prof Sethu Vijayakumar, has recently been elected as a Fellow of the European Lab for Learning and Intelligent Systems (ELLIS). He will be involved with the programme "Ellis Robot Learning: Closing the Reality Gap!" that focuses on questions relating to reducing the reality gap in robotics.
The ELLIS Fellowship Programmes bring together academics at regular meetings throughout Europe to promote the free exchange of ideas and to help create a European community of top AI researchers to retain and attract talent.

Achievements

Sensory Feedback in a Socially Assistive Robot (SAR) Memory Game

RAS CDT student Emilyann Nault, Professor Lynne Baillie, and Dr Frank Broz investigated the utility of a cognitive task that employs auditory and haptic feedback being facilitated by the SAR Pepper in the context of age-related cognitive decline.

The haptic wearable device was developed with the assistance of Dr Theodoros Georgiou, and the rest of the system was implemented by Ms Nault.

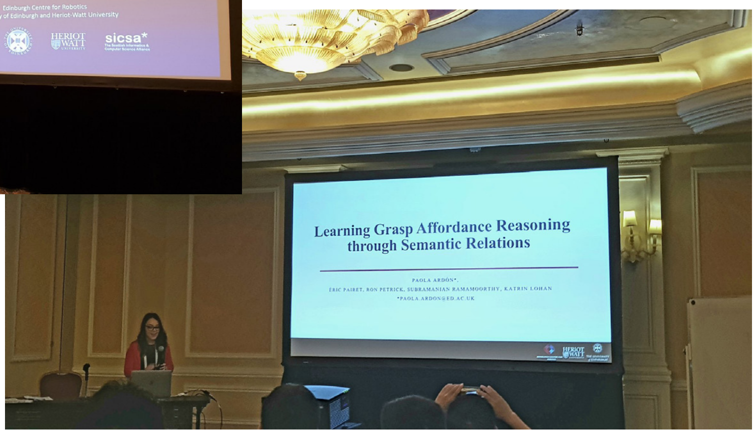
A late-breaking report was published in the 2020 ACM/IEEE International Conference on HRI discussing the feasibility study with young adults conducted in Heriot-Watt University's HRI Lab (doi: https://dl.acm.org/doi/pdf/10.1145/3371382.3378375).

The poster presentation of this work has been uploaded to the ACM SIGCHI YouTube channel (https://www.youtube.com/watch?v=SCCBFwLPr9Y&list=PLqhXYFYmZ-VepURI_B1-Qi0A9aF7FAS3y&index=34), and the poster received an honourable mention at the first virtual BCS Women Lovelace Colloquium in April of 2020.

Conference Papers

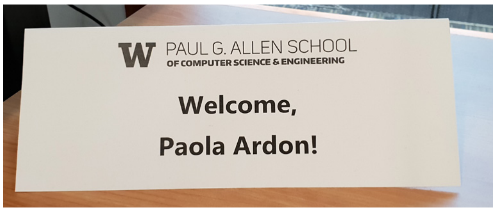
Dr Adam Stokes, an academic from University of Edinburgh, has had a paper accepted at the RoboSoft 2020 Virtual Conference.
The paper titled "Soft Non-Volatile Memory for Non-Electronic Information Storage in Soft Robots" was authored alongside Asst. Prof. Markus Nemitz (Worcester Polytechnic Institute, USA); Asst. Prof. Dan Preston (Rice University); and Dr Christoffer Abrahamsson, Lukas Wille and Prof. George Whitesides (all from Harvard University).
The full text of the paper is available here.

CDT students Paola Ardón Ramírez and Èric Pairet Artau (both 2017 cohort) had papers selected for the International Conference on Intelligent Robots and Systems which took place in Macau, China from 3rd to 8th November. Paola presented on 'Learning Grasp Affordance Reasoning through Semantic Relations" and Èric discussed "Learning Generalisable Coupling Terms for Obstacle Avoidance via Low-dimensional Geometric Descriptors"



Student Activities

Academic visit to University of Washington, Seattle



Final year CDT student Paola Ardon's research is focussed on robots collaborating on household tasks for which she uses the concept of grasp affordances, i.e. knowing how to appropriately grasp objects given a task.

From the outset, it was intended that the project would begin on a theoretical basis but would grow hierarchically to a framework that people could actually use, with the added benefit of enabling Paola's research to evaluate how 'intelligently' the robot is helping with the household chores.

Towards the end of Paola's second year, she agreed to collaborate with Assistant Professor Maya Cakmak on a joint project that involved creating a method to assist humans with grasping objects. The project would have a specific focus on people with mobility impairments and the main objective would be to facilitate the handover of the object depending on the receiver's task.

Paola arrived at the Human Centred Robotics (HCR) lab at University of Washington in Seattle for a four month academic visit in December 2019. This lab is well known for its collaborations with Microsoft Research, NVIDIA, Amazon and Google, so this was a great opportunity for Paola.

During her time there, the research group followed a timeline to achieve the set goals for the academic visit. Paola learned a lot from collaborating with other members of the HCR lab and identified some good ideas for her own research project in the CDT. In addition to getting the chance to collaborate on a parallel line of work involving grasping for limb repositioning when going through therapy, Paola was also able to visit the NVIDIA robotics lab, take a tour of their installations and be briefed on their research activities.

Paola, front left, during her visit

Paola reports that the lessons learned during her academic visit have allowed her to grow significantly as a researcher. Unfortunately, the COVID-19 outbreak impacted on the final stage of the project when it was intended that humans would have the chance to test the framework and to provide feedback on the robot's performance. This is currently being re-evaluated in line with 'social distancing' rules but Paola is confident that they will be able to evaluate the framework appropriately.

Paola acknowledges that visiting such a prestigious university and having such a great research experience would not have been possible without funding from the SICSA PECE Bursary.

Student Activities

Student Collaboration with Professor Lydia Kavraki

Èric Pairet, 2017 cohort, recently finished a four-month academic placement at Kavraki's lab, Rice University in Houston. During the placement, he actively collaborated with Professor Lydia Kavraki, a leading researcher in the area of computational robotics, artificial intelligence and biomedicine. As Èric's research is in the field of robotics motion planning, establishing such a collaboration was really inspiring for him.

Èric arrived at Rice University in mid-November 2019 and spent the initial period getting to know the installations of the university, the routine in Kavraki's lab and its incredibly interesting research, some of it in collaboration with the National Aeronautics and Space Administration (NASA).

Èric is second from right in second row

Èric worked with Professor Lydia Kavraki on reusing prior experiences in robotic motion planning applications. This work was inspired by human behaviour; i.e. when we want to perform a particular task, we already have an intuition about the motion we should plan for it. Èric developed a planning algorithm entitled experience-driven random trees, that exploits some a-priori information of the task that the robot must accomplish. Initial experimentation was conducted on a Fetch robot, a mobile platform with a robotic arm, on a stock replenishment task. The results indicated that accounting for relevant information in the planning stage allows us to quickly and more reliably obtain well-looking natural plans.

Èric found his placement at Kavraki's lab to be extremely stimulating and productive and he highly recommends that researchers take the opportunity, if available, to visit an external research centre. Èric reports that it was a very enriching experience, which has allowed him to grow as a researcher.

Èric acknowledges that conducting this academic placement would not have been possible without the funding from the SICSA PECE Bursary.

Student Activities

Students Receive Research Culture Grant Award

Siobhan Duncan

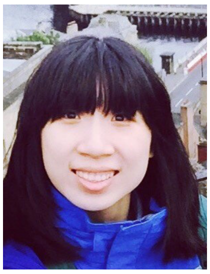
The Research Futures Academy at Heriot-Watt University recently launched the Research Culture Grant to support postgraduate research students and research staff to develop new student-led or post-doc-led initiatives to enhance the research culture at Heriot-Watt University.

CDT students Siobhan Duncan (2016 cohort) and Helmi Fraser (2017 cohort) were successful in securing £2000 of this new funding to hold a small, student-led robotics conference in the Orkney Islands.

Helmi Fraser

The students had planned a two-day programme of talks from speakers from industry and academia for Spring 2020. These talks were intended to run alongside workshops, and a Research Cafe where ideas could be shared and collaboration developed in a relaxed forum. The students also hoped to have time to run some STEM education outreach activities at a local school during their visit, which unfortunately has had to be postponed on account of Covid-19 but we hope it can go ahead in the future.

Xinnuo Xu, 2016 cohort,had a paper accepted at the 58th Annual Meeting of the Association for Computational Linguistics (ACL) which was held virtually from 5th to 10th July 2020. The title of the paper is "Fact-based Content Weighting for Evaluating Abstractive Summarisation".



Hugo Sardinha, 2016 cohort, has had a paper accepted at the 17th European Conference on Multi-Agent Systems (EUMAS) being held from 14th to 15th September 2020. This work presents a hybrid model, merging deterministic co-ordination and stochastic exploration strategies for cooperative coverage missions in aerial swarms.

Ronnie Smith, who is in the 2018 cohort, will be presenting a contribution on the use of passive Radio-Frequency Identification (RFID) for wearable-free human monitoring in Ambient Assisted Living (AAL) environments at the 2020 International Symposium on Ambient Intelligence (ISAMI) which is being held from 7th to 9th October 2020 online. This work is the result of a collaboration between Ronnie's research group, the Cognitive Assistive Robotic Environments (CARE) Group, and colleagues in the Institute of Sensors, Signals and Systems at Heriot-Watt University who specialise in microwave engineering. Their approach is one of the few in its class to be evaluated in a real home environment, taking advantage of the centre's Robotic Assisted Living Testbed (RALT).

Student Activities

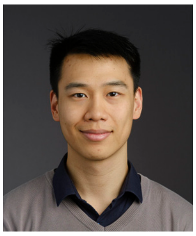
Yaniel Carreno and Eric Pairet Artau, 2017 cohort, have had their joint work presented at the AAMAS (Autonomous Agents and Multi-Agent Systems) International Conference), which was held from 9th to 13th May 2020. AAMAS is the leading scientific conference for research in autonomous agents and multi-agent systems.
Yaniel and Eric presented their work on autonomous agents and their interaction making, with an emphasis on task allocation strategies for heterogeneous robots. This work provides a solution to real-world problems associated with the autonomous maintenance and supervision of structures in the offshore oil and gas industry sector.

Student internships

The following CDT students are currently undertaking prestigious internships which give them experience of carrying out research in a large organisation and help them develop skills that will be beneficial when they return to their PhD studies.

Fazl Barez (2019 cohort)
is currently undertaking a 4-month internship on Spatial Reasoning with the Knowledge Graph Team at a Huawei Research Centre.

William Smith (2016 cohort)
spent 6 months in Denmark working on machine learning and computer vision with Bang and Olufsen.

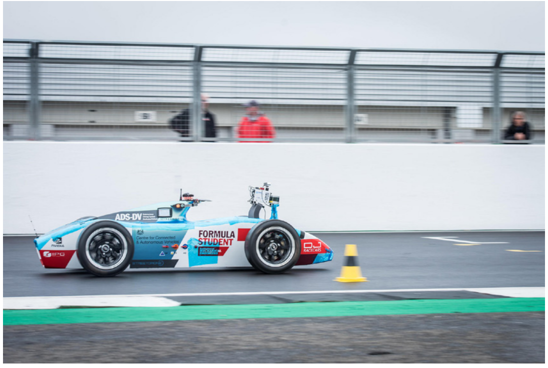


Kai Yuan (2017 cohort)
carried out a 3-month internship with Roland Berger GmbH working on an IT carve-out project for a leading automotive supplier.

Elliot Fosong (2019 cohort)
is currently taking part in a research project to develop a safe, robust, and interpretable planning and prediction method for autonomous vehicles during his 6-month internship with FiveAI.

Student Activities

Student success in Formula Student competitions



Formula Student is an international competition that promotes careers and excellence in engineering by challenging university students to build a single-seat race car.

Every year since 2014 students from various disciplines including engineering, business, and marketing have come together as Edinburgh University Formula Student (EUFS) to design and build a single seat racing car to compete at the Formula Student UK competition at Silverstone.

In October 2017, EUFS expanded to include a brand new project, the AI team. This team aims to design and build a fully electric self-driving race car and to participate in international student competitions as part of Formula Student Driverless.

As an intermediate step to that goal, the team participated in the IMechE's FS-AI competition where they created the software for a self-driving car and applied it to a vehicle provided by the competition organisers. The team has had great success so far, winning all the annual competitions since 2018, with the 2020 competition currently running virtually.

This year the team are retrofitting one of the previous EUFS racing cars with an electric motor, actuators and sensors along with a rugged computer with their autonomous driving software, with plans to become the first Formula Student team in the UK to enter an autonomous racing car to FS UK 2021.

EDINBURGH UNIVERSITY FORMULA STUDENT

Public Outreach

RSE Curious: Designing a Feminist Alexa – An Exercise in Empathic Design

During the month of August the Royal Society of Edinburgh ran Curious, a programme of 25 Tea and Talk events inspired by the coffee house discussions of the Scottish Enlightenment where people would gather to debate issues of the day. The events offered insight from some of the world's leading experts across three key themes of health and wellbeing, innovation and invention, and our planet.

Professor Verena Rieser from Heriot-Watt University was joined by Mark West, author of the UNESCO report "I'd blush if I could", and Fiona Linton-Forrest, a member of the design team working on the persona of the BBC's new bot Beeb.

The workshop looked at the potential societal impact of anthropomorphising Chatbots and Personal Intelligent Assistants, such as Amazon's Alexa or Apple's Siri, with a particular focus on their frequent personification as an obedient female and their inability to respond constructively to abusive language as a way to explore gendered AI. Interested members of the general public were invited to participate in a challenge to design a more inclusive bot by submitting drawings of how they envision Alexa's physical embodiment. The outcomes of this workshop will inform research funded by the UK Research and Innovation council.

Manchester International Festival - Life Hacked

Two Centre Academics participated in the Life Hacked summit at the Manchester International Festival held virtually in July. They joined the artists, scientists and thinkers who being challenged by the big questions of our automated age which include ethical considerations around AI; making the web more democratic; and whether machines can help us to rebuild the planet faster than we are using them to destroy it.

In the Strange Chaos in the Atmosphere session, artist Rafael Lozano-Hemmer discussed his 2019 festival commission "Atmospheric Memory" with Verena Rieser, Professor in Conversational Artificial Intelligence at Heriot-Watt University and Professor Sophie Scott from UCL's Institute of Cognitive Neuroscience.

In the session on Machine Learning and Automation for the People, Professor Subramanian Ramamoorthy from the University of Edinburgh debated "Are new 'intelligent' technologies a chance to create a more equal society, or will human stupidity mean they entrench existing inequalities?" The panel, chaired by Lizzie O'Shea, a human rights lawyer, includedAaron Bastani, founder of Novara Media, data ethicist Abeba Birhane and Professor Dan McQuillan from University of London.

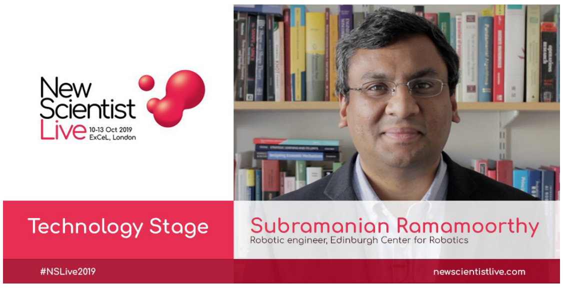
Centre Director speaks at V&A Dundee event

Professor Sethu Vijayakumar spoke in January 2020 at an event at the V&A in Dundee on the subject of Shared Autonomy: The Future of Interactive Robotics.

His keynote explored advances in machine learning, allowing the audience to discover how the next generation of robots will work much more closely with humans, other robots and interact significantly with the environment around it.

Public Outreach

Centre Academic presents at 2019 New Scientist Live



The 2019 New Scientist Live show, which took place at London's ExCeL Centre from 10th - 13th October, attracted la large number of visitors. Talks took place across five stages, running alongside hands-on activities and exhibits. Prof Subramanian Ramamoorthy from the Centre presented on the Technology Stage with a talk which considered how we can trust a robot. Prof Ramamoorthy asked probing questions such as "What makes humans so much better at behaving in a safe and dependable way, What principles can we borrow from neuroscience & cognitive science to make our robots better?"

Natural Language Processing Podcast

Professor Verena Rieser was invited by AllenNLP to talk about her work in Natural Language Processing in a podcast with Ondřej Dušek from the Charles University in Prague.
In the podcast they talk about the complexities of generating natural language when there is some kind of structured meaning representation as input. They also discuss their end-to-end

natural language generation challenge E2E NLG which involved a dataset of task-based dialogue generation focused on the restaurant domain, wth some very innovative data collection techniques.

CogX 2020 Conference

Professor David Lane, Director of Edinburgh Centre for Robotics, led sessions at the Virtual CogX 2020 Conference on Monday, 8th June on the Next Gen Infrastructure and Cloud Services stage. Prof. Lane spoke with Paul Clarke, CTO, Ocado and Sabine Hauert, University of Bristol about "Digital Twins in a Crisis". They later met with Prof. Nefti-Meziani from Salford University and James Kell from Rolls-Royce to discuss how to go about "Unlocking the smart robotics revolution".

Dr Morteza Amjadi gives talk at Durham University

Dr Morteza Amjadi, from the School of Engineering and Physical Sciences at Heriot-Watt University was invited to give a talk at a seminar on Advanced Materials, Electronics & Communications in the Department of Engineering at Durham University.

The title of Dr Amjadi's talk was Functional Nanomaterial Composites for Soft Sensing and Actuation and this was presented to an audience of PhD students, Research Associates, and academic staff including the Dean.

When Physical and Virtual Worlds Collide: Data, Digital Twins and Smart Machines in Offshore Energy

Professor David Lane gave an invited talk to an industrial audience convened by SubseaUK all engaged in the installation, maintenance and decommissioning of offshore energy systems. The future use of smart machines offshore will be intimately linked to the use of digital twin models and to the curation of data for safety, resilience and sustainability of an asset's operation.

Public Outreach

Digital Health and Care Fest

Centre Academics, Dr Mauro Dragone and Dr Christian Dondrup presented at one of the sessions at the 2019 Digital Health and Care Fest on Thursday 21st November.
This event, which took place at the Strathclyde Technology and Innovation Centre in Glasgow, showcased digital innovation in health and social care, and provided delegates with opportunities to learn about digital initiatives in relation to workforce, innovative technologies, data, transformation and service design, and current research. It also encouraged debate with key national digital strategy colleagues from Scottish Government, the NHS, academia, industry and the care and support sector.

Dr Dragone and Dr Dondrup participated in a session titled "Smart Sensing and Robotic Innovation", which introduced the Scottish Research Partnership in Engineering (SRPE) and its role in digital innovation, which is to develop innovative yet sustainable digital and robotic-enabled care solutions that can be effectively integrated with the housing and connected care ecosystem. This is an urgent priority in tackling the social care crisis in the UK. This interactive workshop identified challenges and opportunities in the current innovation landscape, bringing together academia, and care and support providers. The presenters shared their research in smart sensing and robotics for assisted living and connected social care, the current integration of these technologies by housing organisations, and the potential for engagement with the SRPE.

In addition to presenting, the Centre also showcased some robots including regulars Pepper and Miro, and Maah, our new recruit, a social robot promoting sensory experience and comfort via a 3D knitted robe. CDT student, Alexandre Colle, reported that delegates were very curious to learn more about these robots and their potential for healthcare, with attendees reporting that they felt very positive about the role Pepper, Miro and Maah could play in the care and support sector.

CogX 2020 Conference

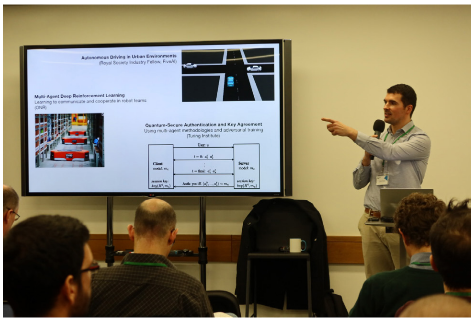
Professor Sethu Vijayakumar, Director of Edinburgh Centre for Robotics, led a panel discussion on Collaborative Robotics and Autonomous Systems on the CognitionX stage at the above conference which took place online in June 2020. Panel members included Ingmar Posner, Oxford Robotics Institute; Sara Bernadini, Royal Holloway University; and Andrew Davison, Imperial College London.

International Plenary Presentation: American Society Of Mechanical Engineers 39th International Conference on Ocean Arctic and Offshore Engineering

In August, Professor David Lane gave an invited plenary presentation to an experienced international audience of marine engineers titled "New Developments in Offshore Robotics For Certification of Assets", describing latest developments in the ORCA Hub involving students from the Centre .

Public Outreach

UK Multi-Agent Systems Symposium



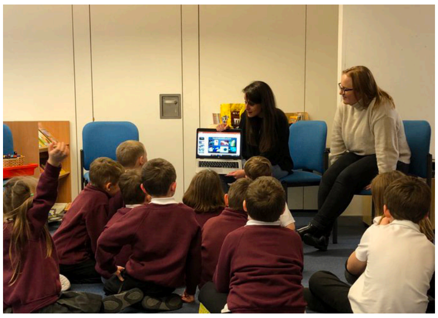
Dr Stefano Albrecht from the School of Informatics at the University of Edinburgh was the lead organiser of the UK Multi-Agent Systems (MAS) Symposium which took place on Monday 24th February at the Alan Turing Institute in London.

The aim of the symposium was to explore the MAS research landscape in the UK by bringing together UK-based research labs at universities and in industry who have a significant focus on MAS research.

The Symposium, which was very well attended, included a presentation from Edward Hughes and Yoram Bachrach from DeepMind on recent multi-agent research at their organisation. Sam Devlin from Microsoft Research spoke about Multi-agent learning and evaluation for open world games, and Subramanian Ramamoorthy, representing FiveAI, discussed "Towards safe-by-design planning for autonomous driving in urban environments".

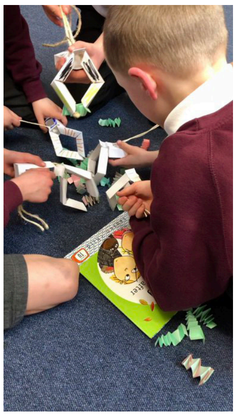
In addition to these presentations, there were also discussion sessions and opportunities for attendees to network. It is intended that this event will allow for the creation of a virtual map of the locations and research foci of UK-based labs which will facilitate future collaborations.

Masterclass in Robotics held at West Linton Primary School



Dr Adam Stokes, Deputy Director of the CDT RAS, along with some of his Post-Doctoral Research Associates, was recently involved in STEM outreach at West Linton Primary School located in the Scottish Borders.

The team delivered a series of weekly interactive classes that focussed on teaching young children about robots, programming and robotic engineering.



The children had the opportunity to engage with small robots and try some basic coding, including gaining experience in programming with Cozmo and Spheros robots. They even built their own soft robot for a competitive 'vegetable harvesting' task.

During one of the workshops the children learned about the Mars Rover and afterwards were able to drive around a TurtleBot to complete various tasks from their own 'mission control'.

The team were grateful for the support provided by the ORCA Hub and RAEng who supplied the robots for this initiative.

Throughout the running of the workshops the team were highly impressed by the children's knowledge and eagerness to learn. It seems that they may have stumbled across a new generation of top engineers!

Collaboration

COLLABORATION
EDINBURGH CENTRE FOR ROBOTICS

Ambient Assisted Living Collaboration

Scientists from Heriot-Watt University are launching what is believed to be the world's first open and remote access living lab to research and create solutions for Ambient Assisted Living (OpenAAL).

The multi-disciplinary lab will target the fast co-creation of scalable and affordable solutions to support the care of vulnerable people whose urgent need has been exemplified by the COVID-19 pandemic.

The project is funded by EPSRC under the Impact Acceleration Accounts scheme and has gained support from NHS Lothian, The Digital Health and Care Institute (DHI), Blackwood Home and Care Group, Consequential Robotics, Alcuris Ltd, Cyberselves and The Data Lab. The Coalition of Care and Support Providers in Scotland (CCPS) will play a key role in connecting the project to members in its supporting organisations. Additional collaborators from the care sector are now being urged to join the project.

Part of the National Robotarium, based at Heriot-Watt University, the OpenAAL lab will use digital twin, Internet of Things (IoT) and Cloud technologies to provide a platform where researchers, industry and care providers, alongside end users of assisted living services, can co-create technology.

The platform, which utilises the facilities from Heriot-Watt's existing living lab - a complete flat with adjoining workshop – will ensure both time and distance are no longer barriers to research and innovation. It is hoped that, as the project expands, researchers from all over the world may use the space to collaborate.

The project will initially support key priority groups in the UK whose conditions have been compounded by the social isolation measures necessitated by the pandemic. These include those with multi-morbidity conditions, disabilities, and those in acute stages of mental ill health.

Heriot-Watt has unique laboratory facilities and world-leading expertise. Its technologies can be used to enable non-intrusive monitoring of behaviour and vital signs, detect patterns and trends in behaviour and individual health statuses.

Dr Mauro Dragone, assistant professor, said: **"Our priority is to ensure the devised solutions are practical and feasible, so they can be quickly implemented in the face of challenging social and economic conditions. There is huge potential to unify efforts and provide better support to the nation's most vulnerable at this time. By combining the University's unique**

laboratories with expertise in the care sector, we have the opportunity to tackle the current challenges head-on, but also establish long-term and cost-effective solutions to the wider challenges faced by individuals with assisted living needs in the home.

"Successful innovation in this field is crucial to alleviate the strain on our health and social care services and enhance the resilience of our communities. By collaborating across sectors and mobilising Scotland's ground-breaking technology, this project has the potential to bridge considerable gaps in communication, break down institutional silos and facilitate wide-scale industry cooperation."

National Service veteran David Weir, 87, is registered blind. Prior to lockdown, he was a regular attendee at charity Scottish War Blinded's West Lothian activity hub, the Linburn Centre.

Mr Weir said: **"The biggest challenge I've faced in recent months has been the lack of social contact. I've always been interested in new technologies and I readily embrace any assistive solutions that are available so I'm keen to see what solutions this new research can come up with. For example, my adapted mobile, provided by the charity, has overcome so many communication struggles.**

"Over the day, I face a series of challenges which I hope this type of research and technology can support and overcome. Measuring the right volume of liquid for medication, for example, would be invaluable as I can't see the liquid or lines on the measuring tubes. At present, I can accept an incoming video call but can't easily place one, even with the benefit of voice activation. Smart home technologies are of particular interest. For example, I have a digital thermostat, but I can't read the digital display and setting the temperature on the cooker and grill is extremely difficult.

"During lockdown, shopping online has become even more important, but all websites are designed differently and navigating them, even with text-to-speech capabilities, is tough. If I touch the wrong area of the website for more information, I can end up lost and I can't navigate back. Having the opportunity to interact with researchers in the course of their work will be really beneficial to end users like me."

The lab is welcoming support from producers, suppliers and service companies of assistive technology, telecare, telehealth, smart home solutions, and other Internet of Things products.

This article was first published on the Heriot-Watt University website on 1st July 2020.

Covid-19 Response – Robotics in Hospitals

In April 2020, the Professors David Lane and Sethu Vijayakumar were approached by the Scottish Government COVID-19 Advisory Group for advice on how robotics could help with the coronavirus epidemic in healthcare facilities. Colleagues across the Centre convened and a series of recommendations were made, particularly with regard to disinfecting healthcare spaces. The conclusions on our readiness also informed the Robotics Growth Partnership RAS2030 strategy approach to improving UK resilience.

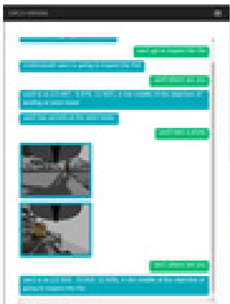
Collaboration

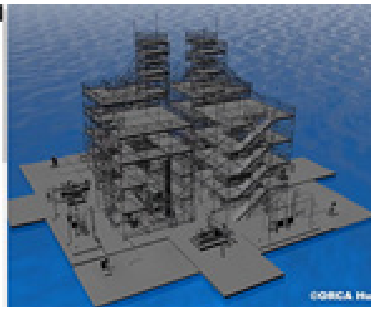
COLLABORATION
EDINBURGH CENTRE FOR ROBOTICS

Speaking the same language

Researchers from the ORCA (Offshore Robotics for the Certification of Assets) Hub, a consortium of five universities led by Heriot-Watt and Edinburgh universities, have unveiled a new method of communication that allows machines and humans to speak the same language and understand each other's actions in real time.

Named MIRIAM (Multimodal Intelligent inteRactIon for Autonomous systeMs), the new method of communication is a significant breakthrough that enables people to work with autonomous robots. It allows users to ask robots questions, understand their actions and receive mission status through a digital twin. MIRIAM uses natural language, allowing users to speak or text queries and receive clear explanations about the robot's behaviour in an intuitive way.





By improving how robots communicate, MIRIAM will help to build the confidence of those who will be using them and thus overcome any adoption barriers in the workplace.

MIRIAM will be used by a new collaborative team that sees Heriot-Watt University, through the ORCA Hub, working and integrating its research with the expertise of Phusion, an engineering software firm and Merkle Aquila, a data science firm. They are the latest additions to global energy partner Total's multimillion-pound research consortium that is working to develop autonomous capabilities with multiple robotic systems for work offshore energy installations. MIRIAM will initially work with a tracked robot that will be deployed at Total's Shetland Gas Plant.

Kris Kydd, Head of Robotics at Total E&P UK said:
"Total believes that robots have a huge amount to offer our industry. We are pioneering their use on oil and gas sites and this collaboration is helping us to make significant progress. This announcement is the first important step towards making the actions of autonomous robots clear and understandable, and this will allow them to gain the confidence of the wider workforce. Robots offer immediate advantages such as increased safety and efficiency. In the long-term, they offer us new ways of working and are limited only by our imagination."

Helen Hastie is a professor of computer science at Heriot-Watt University and an ORCA work package lead. She explains:

"When robots have an autonomous element, it means that they sense the environment and can make certain decisions by themselves. However, there is currently a communication barrier between robots and their human supervisors in relation to the reasoning behind system actions. This is particularly problematic in remote, highly challenging, and hazardous environments such as offshore, which can involve multiple vehicles and platforms.

"This lack of transparency can lead to a reduction in situation awareness and thus user-confidence in the robots, hindering the human-robotic team and resulting in unnecessary aborts or laborious manual manipulation of the robot. It is therefore essential that a supervisor understands what the robot is doing and why.

"MIRIAM's technology is designed to provide invaluable transparency in this process. Our team of researchers have taken a user-centred design approach, which supports Total's forward-thinking efforts to making operations safer offshore. We have also modified MIRIAM to the specifics of Total's robotics programme."

Phusion IM is supporting the project with the implementation of a Master Data Model that will enable the framework for a digital twin of Total's facilities. This will allow the creation of autonomous routines, enabling Total's robot to undertake maintenance checks and feedback results in a consistent manner to the digital twin – creating a single source of information for the operating asset.

MIRIAM will allow humans to communicate with this digital twin, and the data held in it, including the robot, via text or speech. This means supervisors can ask where the robot is going, what it plans to do next and why, and query data it has gathered during its missions.

The project will be used by the original OGRIP (Offshore Ground Robotics Industrial Pilot) robot developed by Total E&P UK, Austrian tech firm Taurob and the Aberdeen-based Oil and Gas Technology Centre (OGTC). OGRIP is designed to support exploration and production operations in increasingly harsh and challenging conditions, including extreme cold, arid climates and isolated locations.

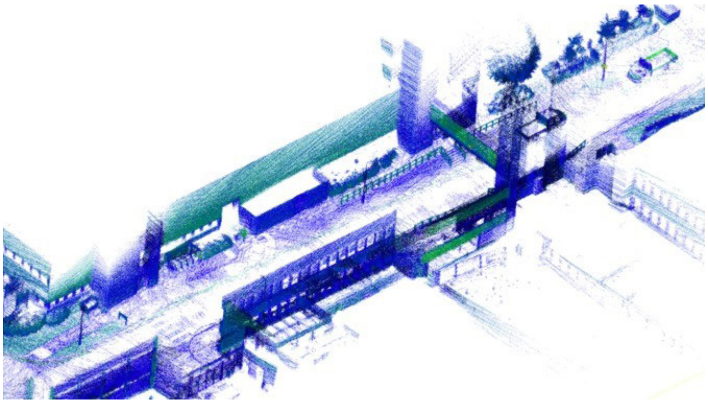
Development of the UK's AI Roadmap

As part of the Govt appointed AI Council, Professor David Lane has worked on development of the UK's AI Roadmap with senior colleagues from across the UK's research and industrial AI landscape. A series of recommendations on skills and initiatives have been made to Government through the Office for AI to maintain the UKs leading international position. During the pandemic the Council gave weekly technical advice to Government and NHSX. Its activities have supported recent signing of a bilateral UK-US AI accord to develop ethical AI guidelines and regulations.

Strategic Engagement

UK Robotics Growth Partnership RAS2030 Strategy

Throughout the 2020 pandemic, the UK Robotics Growth Partnership co-chaired by Professor David Lane has been developing a national strategy for UK Robotics and Autonomous Systems. Sponsored by the Minister for Science, Research and Innovation Amanda Solloway the purpose is to supercharge the UKs economy, sustainability and resilience. Key is development of shared synthetic and physical environments for research, development and education. Standards and a shared digital commons create connected digital twins, or the Twinternet. For early implementation the Centre has lead a consortium of Universities in the ISCF Robotics for a Safer World Challenge to prototype early demonstrations. These have been presented and discussed with stakeholders through a series of weekly Think-Ins co-organised with Tortoise Media, for researchers, industry, policy stakeholders and the general public.



3D Reconstruction from LIDAR

Scotland's AI Strategy

Professor Helen Hastie in her role as SICSA lead for AI, has been consulting on the Scottish Government's AI Strategy. This initiative led by MSP and Cabinet Secretary for Finance, Kate Forbes through The DataLab aims at deriving a strategy that recognises Scotland's strengths whilst considering its size and resources, and deriving how Scotland can emerge as a world leader in the application and deployment of AI by taking a citizen focus – how AI and Data can benefit the citizens of Scotland and the world, whilst also enabling economic growth. The strategy will be developed with benefit to the people of Scotland as the core guiding principle and align to the Scottish Government's National Performance Framework purpose of improving the wellbeing of the people of Scotland and giving opportunities for all to flourish.

Appointment to Chair of The EPSRC Trustworthy Autonomous Systems Strategic Advisory Board

Professor David Lane has been appointed by EPSRC to advise and oversee Governance of this important public investment. During 2020 EPSRC has commenced a major programme of work in Trustworthy Autonomous Systems. Working through a Hub and multiple Nodes, teams across the UK will research fundamental topics in the Governance & Regulation, Responsibility, Security, Trust, Functionality, Resilience, Verifiability of Autonomous Systems. The Strategic Advisory Board supports the EPSRC leadership team and Hub/Node Directors.

National Robotarium

This world-leading research and development facility will translate cutting-edge research into technologies to create disruptive innovation in an expanding global market, delivering sustainable economic benefit to Edinburgh, the UK and beyond.

As global leaders in robotics and autonomous systems, Heriot-Watt University and the University of Edinburgh are delivering Data-Driven Innovation as part of the Edinburgh and South East Scotland City Region Deal.

Opening on our Edinburgh Campus in 2022, the purpose-built centre will have unrivalled facilities, adding to our laboratories in Ocean Systems, Human Robotic Interaction and Assisted Living, to explore collaborative interaction between humans, robots and their environments.

The National Robotarium will leverage existing research and the expertise of UK industry with the significant market opportunity of robotics and autonomous systems.

Building capacity across complementary areas of embedded intelligence and expert systems, the National Robotarium will link to other UK and international research locations to attract further inward investment.

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.
https://www.hw.ac.uk/uk/research/the-national-robotarium.htm

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This publication is available online at:

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Published by:
EPSRC Centre for Doctoral Trainining in
Robotics and Autonomous Systems
Heriot-Watt University
University of Edinburgh

Thank you to all students and staff who contributed to the production of this publication.

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