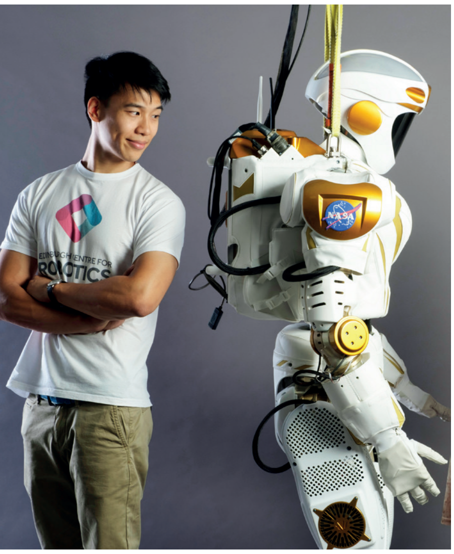
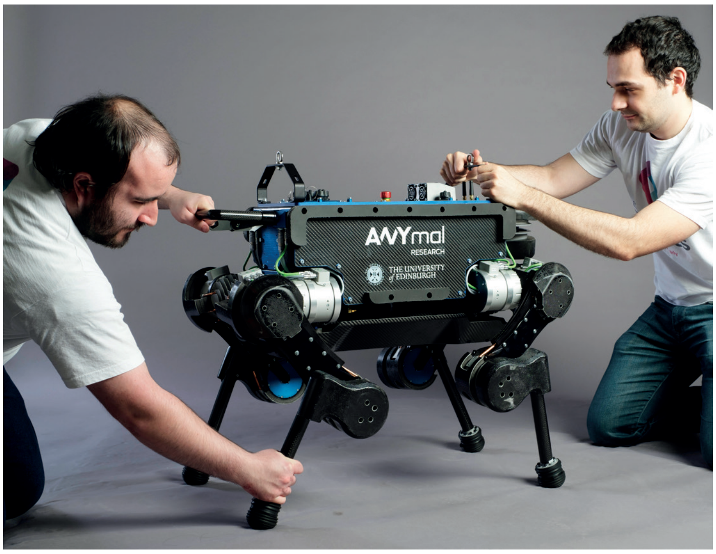
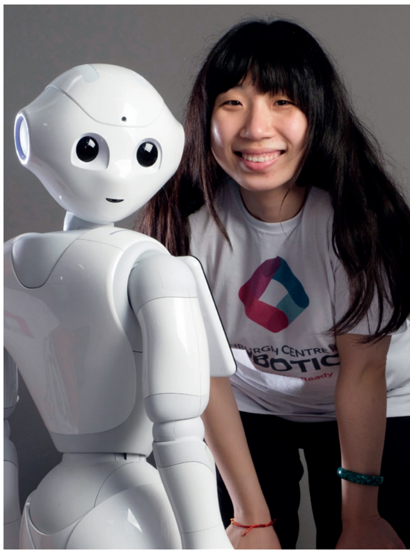
EDINBURGH CENTRE FOR

ROBOTICS

Innovation Ready







Annual Review 2017/2018

EPSRC Centre for Doctoral Training in Robotics and Autonomous Systems

HERIOT WATT UNIVERSITY

THE UNIVERSITY of EDINBURGH

EPSRC
Engineering and Physical Sciences Research Council

@EDINRobotics

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To view our Annual Review online, please visit:
www.edinburgh-robotics.org/reports
This publication can also be made available in alternative formats on request.

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The Centre in Numbers

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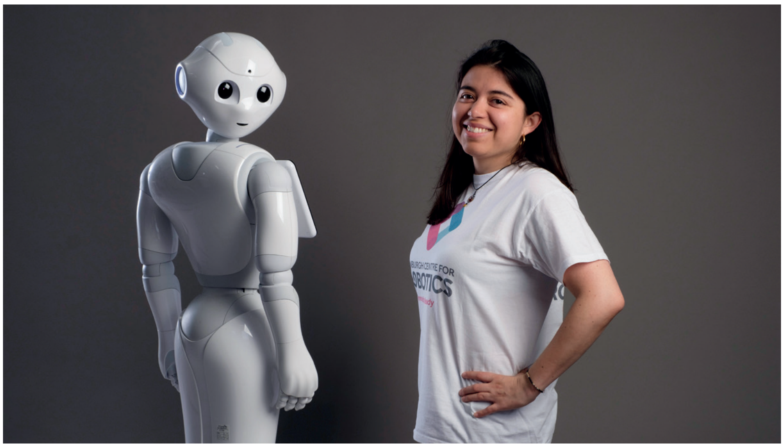
TRAINING
EDINBURGH CENTRE FOR ROBOTICS

5 cohorts of students

65 students

50 academics



RESEARCH
EDINBURGH CENTRE FOR ROBOTICS

45 Conference Proceedings

11 Journal Publications

13 Workshop Papers

"The program's structure strikes a nice balance between taught and research courses, giving you the opportunity to gain relevant knowledge and quickly identify potential topics for the PhD phase of the program. Having access to unique state-of-the-art robotics hardware and processing power allows for working on a plethora of exciting and important research questions."
Martin, PhD student, 2016 cohort

Foreword

Welcome to our 2017/18 Annual Review. Our fourth year of operation as an EPSRC Centre for Doctoral Training in Robotics and Autonomous Systems has been exceptionally busy, with a number of key activities and developments continuing to increase our profile as one of the leading centres for RAS research in the UK.

At the start of the final year of the current RAS CDT, we are pleased to report that we have 65 PhD students engaged in the 4-year PhD. Ten of our industrial supporters are providing full financial support for eleven studentships, augmenting those of EPSRC.

Work on the Bayes Centre at the University of Edinburgh is now complete and academics and students are making full use of the new bespoke facilities at ROBOTARIUM East for ANYmal and Valkyrie. Further developments include Living Labs where research can be undertaken in environments replicating an operating theatre, domestic life and a manufacturing facility. The Independent Living Laboratory at ROBOTARIUM West was certified as a suitable venue for hosting the European Robotics League Service Robot Challenge earlier this year, one of only two laboratories in the UK to receive this certification. The lab subsequently hosted a successful competition with participants from Germany, Spain and the UK and has been invited to host the next challenge at the end of 2018.

The Centre has celebrated success on a number of fronts. Key achievements include the Edinburgh City Deal which will provide funding of £27m for the National ROBOTARIUM, and the £36m ORCA Hub, a programme aimed at addressing the offshore energy industry's vision for a completely autonomous offshore energy field.

Students from the Centre are participating in the Amazon Alexa Challenge and again are the only UK team to reach the final, following in the footsteps of the successful 2017 team. Funding has been made available to two teams of students to further innovation from research underway in the Centre. One of the teams has leveraged this initial funding through competition prize money to complete a full prototype that has been successfully used in research work. Female students are addressing the gender imbalance in STEM subjects by setting up Women in Robotics Edinburgh (WiRE), an initiative to provide a forum where females working in Robotics and related subjects can meet to share experiences and knowledge.

Congratulations are due to Centre academics Lynne Baillie (School of Mathematical and Computer Sciences) and David Flynn (School of Engineering and Physical Sciences) on their appointments to Professor, and to Dr Subramanian Ramamoorthy on his appointment as Fellow at the Alan Turing Institute. Finally accolades are still being received for the highly successful 2017 Year of Robotics marketing campaign, with recognition from the Herald Higher Education Awards and Heist.

We have continued to welcome a number of high profile speakers to the Centre. Wendell Wallach (Yale) and Professor Sebastian Conran delivered thought provoking keynotes at our third annual conference. Wendell Wallach discussed how we can keep robotics and AI from slipping beyond our control; Professor Conran talked about his career in design and how he is now applying his skills to design within the robotics sector.

Students participated in a full-day workshop on Morals and the Machine considering matters such as "Could a robot be a person?"; "Dehyping robots" and "A ten point plan towards banning lethal autonomous weapons". The workshop was led by Professor Tony Prescott, Wendell Wallach and Dr Sabine Hauert and included lively group discussions on a range of current societal concerns related to robots.

A number of high profile visits have been made to the Centre including Sam Gyimah, Theresa May and Nicola Sturgeon. Academics have also visited Australia, China, Japan and the USA to deliver keynotes, promote the research activities of the Centre and to explore potential collaboration opportunities.

We hope the above overview provides a flavour of Centre activities over the past year. We are looking forward to a busy 2018/19 which will see further progress in the development of the National ROBOTARIUM at Heriot-Watt University. We also expect our first cohort of students to graduate and progress to making a significant contribution to industry and academia, and we look forward to hearing about their future successes. We will be posting about our latest developments on Twitter @EDINrobotics; you can also subscribe to our quarterly newsletter by visiting our website www.edinburgh-robotics.org.

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Edinburgh Centre for Robotics
Director
University of Edinburgh

About us

The Edinburgh Centre for Robotics (ECR) is a £100m joint venture between Heriot-Watt University and the University of Edinburgh, supported by EPSRC, Industry and the Universities.

It captures the expertise of 50 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 an EPSRC Centre for Doctoral Training (CDT) in Robotics and Autonomous Systems which trains innovation–ready postgraduates, the ROBOTARIUM, a £8m national capital equipment facility and the £35m ORCA Hub.

The Centre includes affiliated students engaged in related EU, EPSRC and UK-MoD research programmes, and local EPSRC CDTs in Embedded Intelligence, Data Science, Applied Photonics 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.

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 aim to apply 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 oil and gas, 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.

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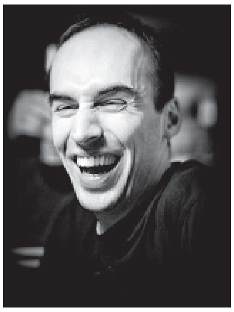

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EPSRC Centre for Doctoral Training

Robotics and Autonomous Systems

TRAINING
EDINBURGH CENTRE FOR ROBOTICS

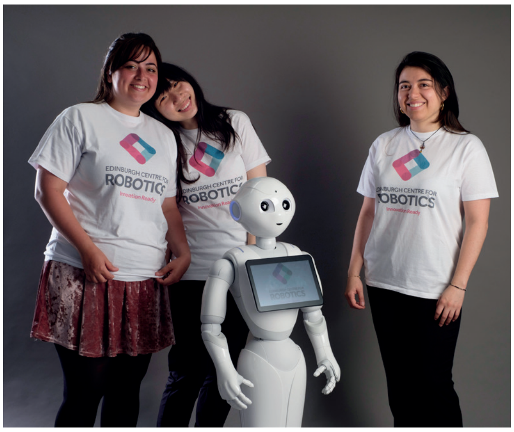
Robots that can learn, adapt and take decisions will revolutionise our economy and society over the next 20 years. They will work for us, beside us, assist us and interact with us. It is estimated that by 2025 such advanced robotic and autonomous systems (RAS) could have a worldwide economic impact of $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.

"Since starting the PhD phase of the CDT I have been able to take advantage of so many opportunities such as the Centre's Innovation Fund, RoboCup, Summer School and launching our women's network. These have all helped me grow so much as a researcher and have given me more confidence in my abilities as an engineer."

Siobhan - PhD student, 2016 cohort



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 studentships covering tuition fees and maintenance at prevailing EPSRC rates.
- Access to our world class infrastructure, enhanced through our £8m ROBOTARIUM facility.
- Students benefit from supervision by academic experts from both institutions and graduate with a joint PhD from the University of Edinburgh and Heriot-Watt University.
- Excellent training opportunities, including masters level courses in year one, supplemented by training in commercial awareness, social challenges and innovation.
- Innovation funding available to support development of early commercialisation prototypes.
- Opportunity for competitive selection for funding from Cambridge IGNITE and MIT Sloan School of Management Entrepreneurship Programmes.
- Opportunities to compete in international robot competitions (RoboCup Search and Rescue, SAUC-E Autonomous Underwater Vehicle Challenge Europe), European Robotics League

“My first year in the CDT has been a wonderful experience and an exciting journey. This cohort provides me with the opportunity to explore other topics that I didn’t learn in previous academic years. During the first year we increased our knowledge by choosing classes that support our research in a wide range of taught courses. I feel very proud to be part of this family, this CDT is the best place for my professional development. The Edinburgh Centre for Robotics provides the best environment, equipment and academics to help us innovate for the benefit of society. "

Yaniel - PhD student, 2017 cohort

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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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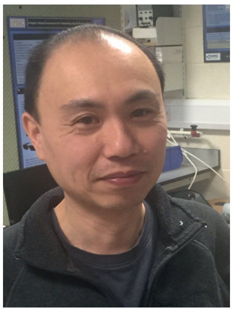

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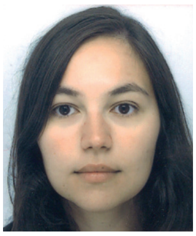
A Framework for Knowledge Acquisition and Grounding through Situated Interactive Dialogue and Visual Demonstrations



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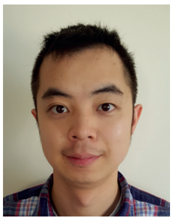

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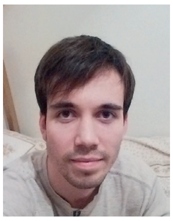

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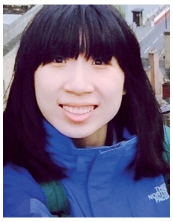

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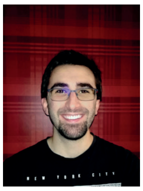

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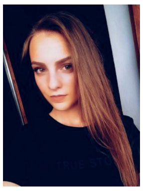

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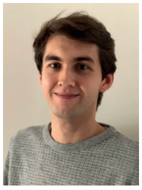

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Research Themes

RESEARCH
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.

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.

	UNDERPINNING THEORY					
INTERACTION THEMES	Modelling & Estimation	Logic & Semantic Representation	Search & Optimisation	Learning & Adaptation	Bio-inspired Methods	Cognitive Modelling
1 **Environment Interactions:** Control, Actuation, Sensing, Planning, World Modelling	x	x	x	x	x	
2 **Multi-Robot Interactions**: Collaborative Decision Making, Swarming	x		x	x	x	
3 **People Interactions**: Affective Computing, Smart Spaces	x	x	x	x		x
4 **Self Interactions**: Condition Monitoring, Health Management, Prognostics. Persistent Autonomy	x	x	x	x		x
5 **Enablers**: Architectures and Embodiments, Validation & Verification	x	x	x	x	x	

Our Research Laboratories

Autonomous Agents Research Group

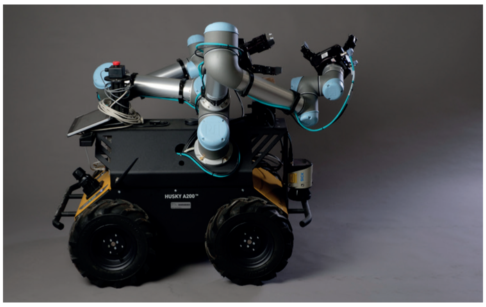
The Autonomous Agents Research Group is a research unit within the Centre for Intelligent Systems and their Applications. Research in the group is centred on the development of artificial intelligence and machine learning technologies toward the realisation of intelligent agents (such as software agents and robots) that can act autonomously to solve problems in complex dynamic 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 algorithms for multi-agent reinforcement learning and methods for inference and planning in dynamic multi-agent systems. The group also has experience in the development of autonomous agents applications, including in the areas of autonomous vehicles and cyber security.
http://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.

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, and 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, as well as 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. 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. This setup will also incorporate a real-time teleoperation system for using the torque controlled robots, a haptic HRI device, VR/AR display, and computing units to 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.

Gait Laboratory

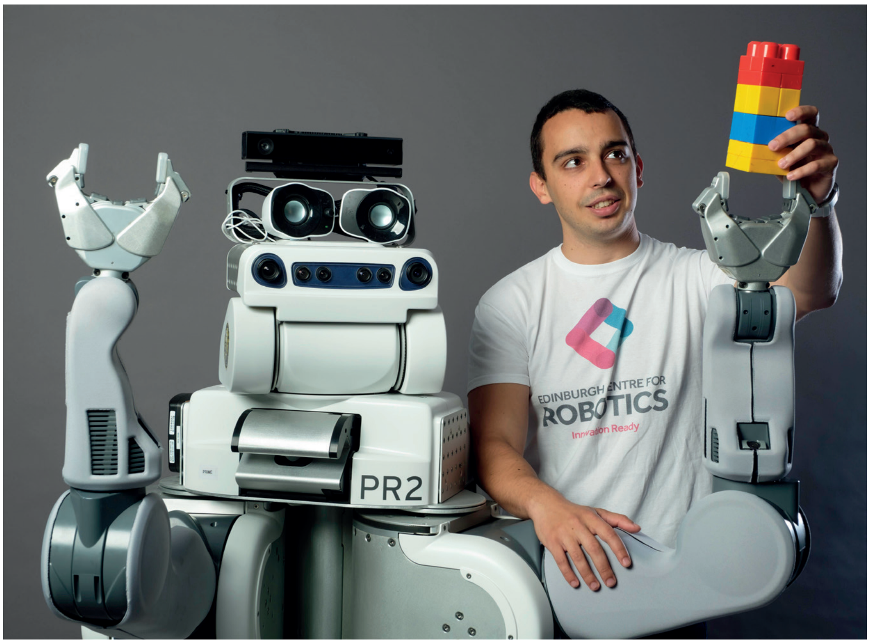
This laboratory houses the Motek split treadmill with a force plate setup to carry out human lower limb prosthesis motion tests and Exoskeleton support experiments. Data capture is supported through a 12 camera Vicon tracking system along with wireless EMG and Xsens inertial tracking systems. Experiments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

Our Research Labs (cont)

Independent Living Laboratory

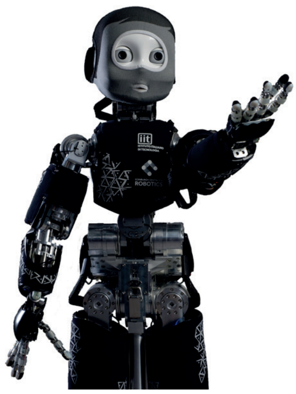
The Centre avails of a 'Living-Lab" test-bed at Robotarium West, a fully sensorised 60m^2 home-like environment where our roboticists and computer scientists work alongside usability and health experts, psychologists, and people with assisted living needs, to co-design and test innovative solutions for 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://researchportal.hw.ac.uk/en/persons/mauro-dragone

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 addresses some of the central problems in computer science and AI by developing intelligent interactive systems which can collaborate effectively and adaptively with humans, and combining a variety of interaction modalities, such as speech, graphics, gesture, vision and Natural Language. Our methods 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 interfaces, mobile search, wearable technology, technology enhanced learning, healthcare informatics, and human-robot interaction, including interacting with (remote) autonomous vehicles and sensors. 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 Amazon Alexa Challenge 2017 and we have been selected for the Amazon Alexa Challenge 2018, where we are currently the leading team.



Projects include the H2020 MuMMER project which focuses on interactive human-robot navigation around large indoor spaces such as shopping malls and airports. This also entertains and informs customers via our Alexa challenge system.
http://www.macs.hw.ac.uk/hrigroup/

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.


©ORCA Hub

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 (cont)

RAS Rapid Manufacturing and Design Studio

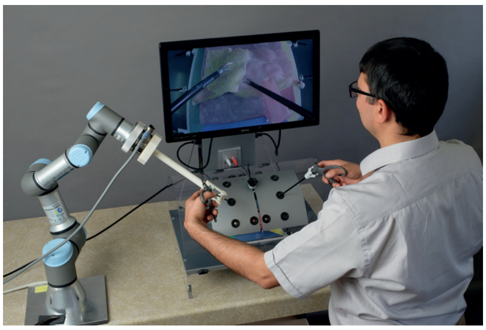
This facility (RMDS) encourages innovation and creation facilitated by digital and collaborative manufacturing tools. The Maker approach brings concepts and scientific principles to physical realisation facilitated by VR/AR, haptics, optical tracking, 3D scanning, 3D printing and laser cutting equipment. 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/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 (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

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.
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.

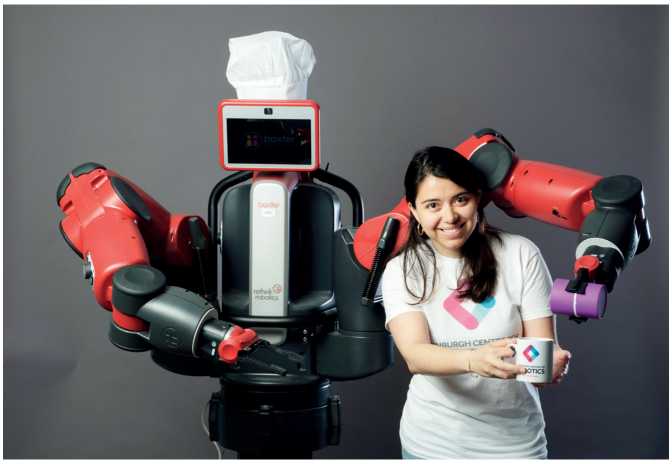
Smart Systems Laboratory

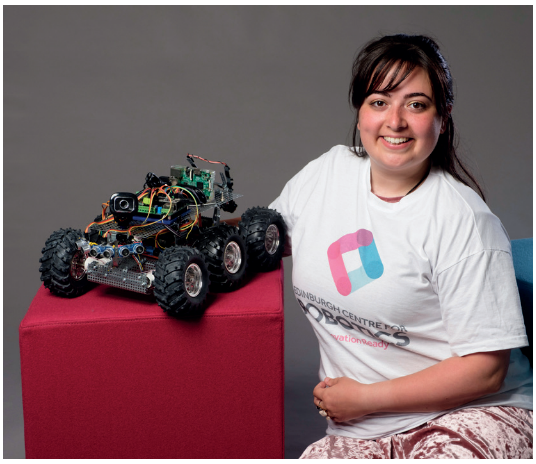
Our global society is placing increasing demands on its critical infrastructure, systems that deliver vital services such as energy, transportation, telecommunications, food and water, the built environment and healthcare. The systems within these sectors are increasingly complex and interdependent, 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

Selected projects from across the Centre 2017/18





Research Area: Human Robot Interaction

Interpretable Latent Spaces for Learning from Demonstration

Supervisors: Dr Subramanian Ramamoorthy, Professor Alex Lascarides
PhD candidate: Yordan Hristov

Objectives

Effective human-robot interaction, such as in robot learning from human demonstration, requires the learning agent to be able to ground abstract concepts (such as those used in instructions) in a corresponding high-dimensional sensory input stream from the world. Models such as deep neural networks, with the high capacity entailed by large parameter spaces, can be used to compress high-dimensional sensory data down to lower dimensional representations. These low-dimensional representations facilitate symbol grounding, but may not guarantee that the representation would be human-interpretable. We propose a method which utilises the grouping of user-defined symbols and their corresponding sensory observations in order to align the learnt compressed latent representation with the semantic notions contained in the abstract labels. We demonstrate this through experiments with both simulated and real-world object data, showing how such alignment can be achieved in a process of physical symbol grounding.

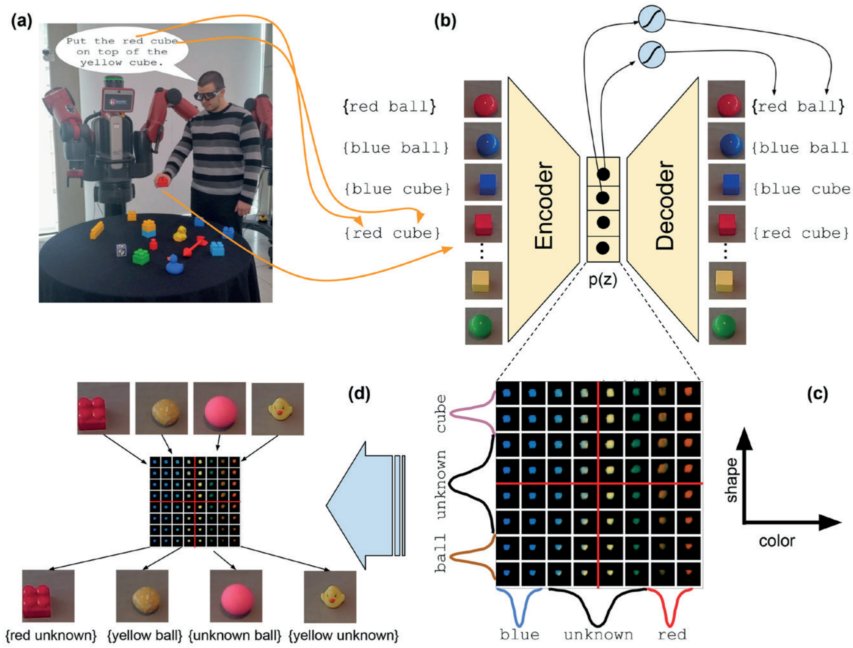


Figure 1: Overview of the framework. The expert demonstrates the task at hand while uttering symbols which are grounded according to the expert's pattern of attention within the environment. The conceptual grouping of the symbols - e.g. which symbols are a color and which a shape - is given. **(a)** The gathered dataset is used to train a variational autoencoder with a set of auxiliary classification losses - one per conceptual group. Each classifier takes information from a single latent dimension. **(b)** The training procedure guarantees that the semantic meaning of each group will be encoded in a separate latent dimension with linearly separable classes **(c)** Using the per-class estimated 1D Normal distributions, together with in-between distributions for unknown labels, we can perform 1-NN classification.**(d)**

Approach and Results

Our main contribution consists of a framework (sketched in figure 1) which allows for independent user-defined factors of variation, manifested in a high-dimensional space, to be projected to a lower-dimensional latent space while preserving the factors' orthogonality. The latter is guaranteed by aligning each of the basis vectors that span the latent space with a single factor. Each factor is specified as a set of weak labels over the high-dimensional space and thus for the same data the framework can learn different representations, given different sets of symbols.

We test the proposed technique both on a synthetic dataset, with controlled factors of variation and on a dataset of real-world objects captured from a set of human demonstrations for the task of sorting objects in a table-top setup according to the user's preference. The real-world data was captured through video capture along with natural language and eye-tracking data [2], following the GLIDE framework [3] described in earlier reports.

Impact

This work is well aligned with several on-going projects, including COGLE (under the DARPA XAI programme) and the ORCA HUB. The framework being developed here contributes to the kind of intelligent human-robot interaction envisioned in these projects.

Future Work

These results are part of a programme of work at the centre of which is physical symbol grounding. We are currently exploring methods that would enable faster task-oriented reinforcement learning by a robot in the presence of a human teacher. The goal of the agent would be to learn goal-directed motor control policies. The human expert could verbally guide the interaction of the agent with the environment, rendering the overall process significantly more sample efficient and safe while exploring. A key prerequisite for the achievement of these two goals is the ability of the agent to ground the utterances/symbols of the expert both in its observations of the surrounding world and in the actions it performs.

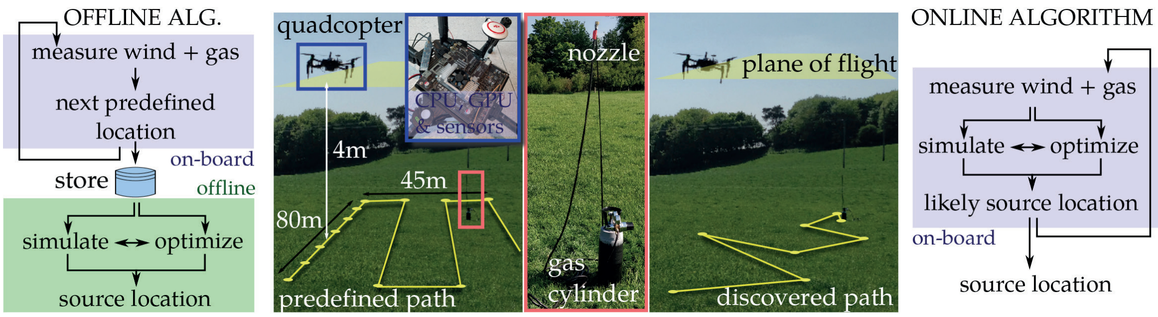
Publications

[1] Y. Hristov. A. Lascarides, S. Ramamoorthy, Interpretable Latent Spaces for Learning from Demonstration, In Proc. Conference on Robot Learning (CoRL), 2018.
[2] Y. Hristov, S.V. Penkov, A. Lascarides, S. Ramamoorthy, Grounding symbols in multi-modal instructions, Language Grounding for Robotics Workshop, Annual Meeting of the Association for Computational Linguistics (ACL), 2017.
[3] S.V. Penkov, A. Bordallo, S. Ramamoorthy, Physical symbol grounding and instance learning through demonstration and eye tracking, IEEE International Conference on Robotics and Automation, 2017.

Research Area: Active Sensing

Active Localization of Gas Leaks using Fluid Simulation

Supervisors: Dr Subramanian Ramamoorthy, Dr Kartic Subr
PhD candidate: Martin Asenov



Objectives

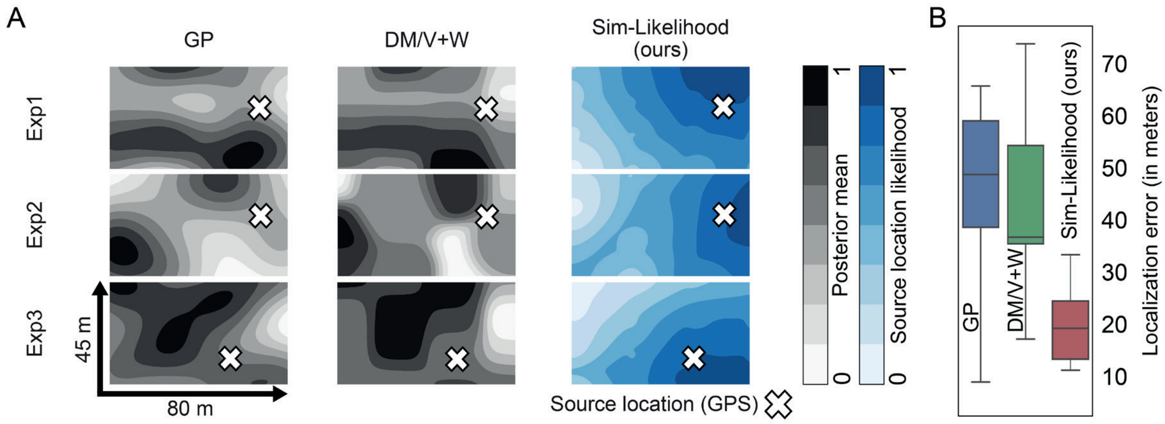
Sensors are routinely mounted on robots to acquire sparse measurements of spatio-temporal fields. Locating features within these fields and reconstructing (mapping) of the dense fields can be challenging in many situations, such as while locating the source of a gas leak. In such cases, a model of the underlying complex dynamics can be exploited to discover pathways within the field. We use a fluid simulator as a model to infer the location of gas leaks. We perform localization via minimization of the discrepancy between observed measurements and gas concentrations predicted by the simulator. Our method accounts for dynamically varying parameters such as wind and its effects on the distribution of gas. We develop algorithms for offline inference as well as for online path discovery via active sensing. We demonstrate the efficiency, accuracy and versatility of our algorithm using real experiments conducted in outdoor environments. We deploy an unmanned air vehicle (UAV) mounted with a CO2 sensor to automatically seek out a gas cylinder emitting CO2 via a nozzle. We evaluate the accuracy of our algorithm by measuring the error in the inferred location of the nozzle.

Approach

We propose the use of a fluid simulation as the model of the underlying phenomenon. We pose the problem of estimating the location of an environmental feature (e.g. source) as that of optimizing the fit between a fluid simulation model and the point-wise measurements of the resulting scalar field. This is a process of calibrating the simulation model, which we show can be done online as measurements arrive (indeed, in a way that can be implemented on resource constrained hardware within a standard commercial grade UAV) and used to drive search processes based on information-gain criteria.

Results

We evaluate our algorithm by implementing it on a UAV equipped with sensors to detect CO_2. Our algorithm is able to cope with dynamically varying wind, and efficiently localizes the source of leaks even if the UAV is not started on the path of the gas. By capturing these dynamics, our proposed approach achieved lower localization error (< 20m) than GP (50m) and DM/V+W (40m). Likewise, our approach achieved better performance than with standard bayesian optimization approaches to compute the minimum (35m). Moreover, our algorithm is fast (up to 20× faster than BO) and can be implemented within a commercial off-the-shelf on-board computer which is customarily used with UAVs such as the DJI M100.



Impact

This work, which is funded by the Defence Science and Technology Laboratories, is aimed at usage in hazardous field environments. An example of an application where this could find use is the UK government's Chemical, Biological, Radiological and Nuclear Defence response teams. The work reported here was completed through a CDE Phase 1 and Phase 2 projects.

Future Work

We are investigating the concept of using flexibly parameterized dynamics simulators directly as models in model-based planning, including the domain of "intuitive physics" within the context of performing useful robotics tasks (e.g. manipulation of soft objects). We explore how we can calibrate real-world scenes with sophisticated physics simulators in order to perform fast inference and motion planning.

Research Area: Humanoid Robotics

Whole-Body End-Pose Planning for Legged Robots on Inclined Support Surfaces in Complex Environments

Supervisor: Professor Sethu Vijayakumar
Research Associates: Dr. Yiming Yang, Dr. Vladimir Ivan
PhD candidates: Henrique Ferrolho, Wolfgang Merkt

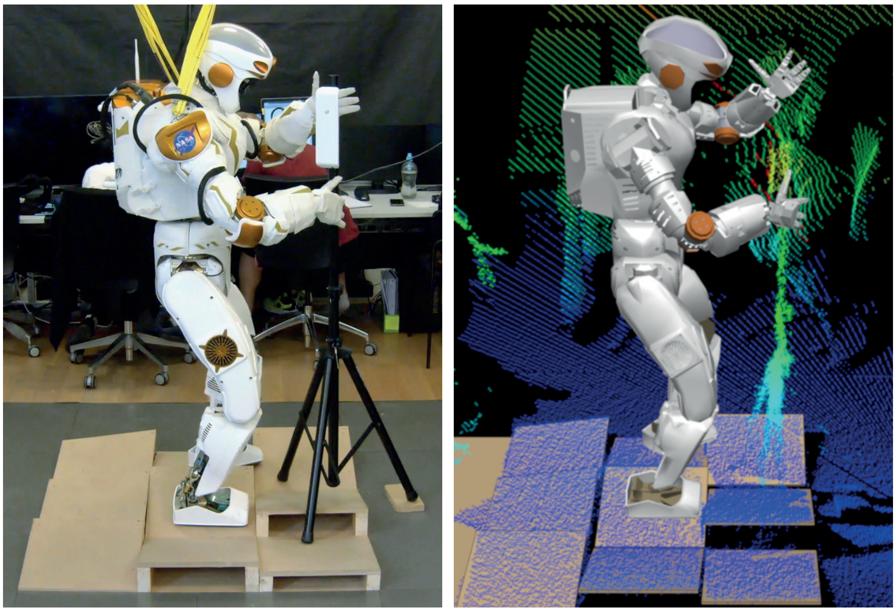


Figure 1
Bimanual manipulation task where the robot has to reach for an antenna on an environment of inclined support regions.

Left: photo of the robot in a pre-grasp stance.

Right: lidar sensor data, fitted terrain model, and a whole-body pre-grasp configuration.

Objectives

Finding valid whole-body pre-grasp configurations for high-degree-of-freedom (DoF) legged robots in free space and on flat terrains is relatively straightforward. However, the problem becomes extremely challenging when obstacle avoidance is taken into account, and when balancing on more complex terrains, such as inclined supports or steps. Our goal is to enable automatic planning of robust balanced whole-body reaching configurations which manipulation and locomotion planners can reliably use as input for desired targets.

Approach

Decomposing the kinematic structure of the robot allows the use of paired forward-inverse dynamic reachability maps to increase coverage of the configuration space by leveraging combinatorics. In turn, it enables fast end-pose planning on flat terrains at different heights. In order to attain our goal of further supporting fragmented terrains with varying inclinations, this work includes the following additional contributions:
1. Integration of support region contact property information into both pre-computation and on-line planning stages, including whole-body static equilibrium robustness;
2. Proposal of a more informed and meaningful rejection-sampling strategy for the lower-body dataset of legged platforms.

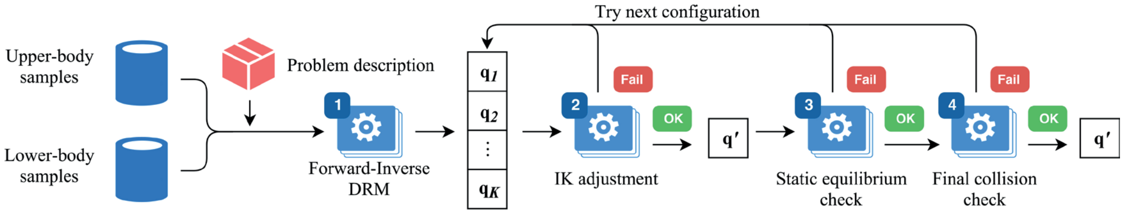


Figure 2 Overview of the proposed planning pipeline. The numbered blocks with a gear represent the key *stages* along the pipeline.

Result

Our method enables automatic adaptation to environment constraints and planning of collision-free statically-balanced stance locations and whole-body configurations for legged platforms over terrains of arbitrary inclination. Benchmark results show that our approach significantly outperforms previous methodologies in terms of planning success rate and planning duration ; moreover, it is able to do so while requiring datasets with fewer samples which leads to less memory consumption. Finally, analysis of the number of rejected candidates per planning request until a feasible solution is found showed that our proposal is an order of magnitude more efficient than previous approaches.

Impact

This work allows us to automatically plan pre-grasp whole-body configurations for legged robots when, traditionally, such configurations were either provided by a human operator or based on inverse kinematics (IK) without collision avoidance. Relieving operators from intervening in this process is an important leap towards more robust robot autonomy. Furthermore, our method results in greater exploration of the redundancy of high-DoF platforms and leverages repositionability, making it more suitable for complex environments.

Future Work

Analysis of the different failure stages during our extensive benchmarks shows that the main bottleneck is due to adjusted samples no longer meeting static equilibrium criteria. A possible step towards addressing this issue is to explicitly include the robustness measure in the formulation of the IK optimization problem (Stage 2). However, finding a differentiable proxy metric is non-trivial and an interesting avenue for future work.

References

A. Del Prete, S. Tonneau, and N. Mansard, Fast algorithms to test robust static equilibrium for legged robots, in IEEE ICRA , 2016.

Publications

Y. Yang, W. Merkt, H. Ferrolho, V. Ivan, and S. Vijayakumar, Efficient humanoid motion planning on uneven terrain using paired forward-inverse dynamic reachability maps, IEEE Robotics and Automation Letters (RA-L) , 2017

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, IEEE International Conference on Humanoid Robots , 2018. Submission under review. Video: https://youtu.be/tt6oYKuPI_A

Research Area: Humanoid Robotics

An Improved Formulation for Model Predictive Control of Legged Robots for Gait Planning and Feedback Control

Supervisor: Dr Zhibin Li
PhD candidate: Kai Yuan

Objectives

Predictive control methods for walking commonly use low dimensional models, such as a Linear Inverted Pendulum Model (LIPM), for simplifying the complex dynamics of legged robots. This work identifies the physical limitations of the modelling methods that do not account for external disturbances, and then analyzes the issues of numerical stability of Model Predictive Control (MPC) using different models with variable receding horizons. We propose a new modelling formulation that can be used for both gait planning and feedback control in an MPC scheme. The advantages are the improved numerical stability for long prediction horizons and the robustness against various disturbances. Benchmarks were rigorously studied to compare the proposed MPC scheme with the existing ones in terms of numerical stability and disturbance rejection. The effectiveness of the controller is demonstrated in both MATLAB and Gazebo simulations.

Approach

We propose an MPC framework that particularly distinguishes the external perturbation in our formulation making it real-world applicable, and also has dual-uses for Motion Planning and Feedback Control. Our formulation is able to generate a stable COM motion given Center of Pressure (COP) or Capture Point references while satisfying the ZMP constraints. Our contributions are summarized as follows:

- Analysis of numerical and physical issues in existing MPC frameworks;
- A proposed formulation that solves the numerical and physical problems analyzed above;
- Integration of the proposed MPC with whole-body control for real-world application
- Benchmarking of the proposed MPC framework against existing ones.

Result

Our study showed that the proposed formulation was able to reject larger disturbances than the previous LIP formulations. Furthermore, in combination with a whole-body controller, the proposed MPC framework was able to blindly traverse unknown inclined terrain of up to 5° and 10° for pitch and roll inclination respectively.

Impact

Our work proposed a formulation for Model-Predictive Control based on the Linear Inverted Pendulum, which has an improved performance over previous formulations and is suitable for both gait planning and feedback control of legged locomotion. It resolves two previously unattended problems: (1) numerical stability in the case of long prediction horizons, making the proposed method more suitable for gait planning; (2) enhanced disturbance rejection attributed to the incorporation of COP as a new state variable, and therefore correctly including the COP in the feedback loop.

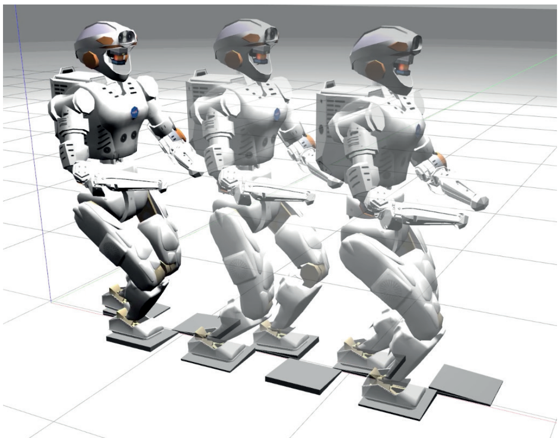


Figure 1: Valkyrie traversing uneven terrain

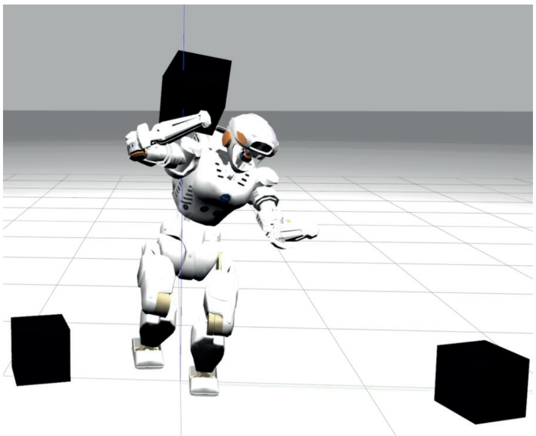


Figure 2: Valkyrie withstanding 3kg box disturbances

Future Work

Our future work involves development of multi-contact algorithms for more complex and dynamic gait motions over more challenging terrain. Furthermore, learning methods will be leveraged to autonomously explore these motions while our proposed formulation stabilizes and implement these motions on Valkyrie. Lastly, the developed gait motions will be implemented on the real robot.

Publication

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

Research Area: Myoelectric Prosthesis Control

Causes of Performance Degradation in non-invasive Electromyographic Pattern Recognition in Upper Limb Prostheses

Supervisor: Dr Mustafa Suphi Erden, Professor Sethu Vijayakumar
PhD candidate: Iris Kyranou

Objective

Over the last years the design of prosthetic devices has evolved incorporating electrically actuated components in conjunction with the classic mechanical design. Modern prosthetic hands consist of five individually actuated digits and use myoelectric techniques for their control. Novel control methods become necessary that allow taking full advantage of the functionalities of the new devices.

Image courtesy of Össur

Surface Electromyography (EMG)-based pattern recognition methods have been investigated over the past years as a means of controlling upper limb prostheses. Despite the very good reported performance of myoelectric controlled prosthetic hands in lab conditions, real-time performance in everyday life conditions is not as robust and reliable, explaining the limited clinical use of pattern recognition control. The main reason behind the instability of myoelectric pattern recognition control is that EMG signals are non-stationary in real-life environments and present a lot of variability over time and across subjects, hence affecting the system's performance.

In this paper an extensive literature review is performed to present the causes of the drift of EMG signals, ways of detecting them, and possible techniques to counteract for their effects in the application of upper limb prostheses.

EMG drift causes

The most common causes of the variability of the EMG signal include physiological reasons, such as muscle fatigue, muscle atrophy or hypertrophy, electrode conductivity (perspiration, humidity); user variations due to adaptation or learning; and physical reasons, such as electrode shift, soft tissue fluid fluctuations, contraction intensity changes between trials, additional weight and arm posture change. In our study we performed a literature review that identifies the five most common reasons of the EMG signal variability, namely, muscle fatigue, electrode shifts, arm posture, learning/adaptation of user, and inter-subject variability.

- Fatigue: describes a temporary decrease in one's physical capacity of performing motions.
- Electrode Shift: refers to the displacement of electrodes from their original position, caused by donning/doffing or repositioning of the prosthetic socket over time in one day or from day to day.
- Arm posture: Different hand postures might result to the same muscles working differently with more or less effort, even if the hand performs the same grasp.
- Learning/adaptation of the user: As the users get more familiar with the environmental and task requirements, the way they perform the task changes, resulting in different EMG recordings.
- Inter-Subject Variability: Even though the underlying anatomy between different users is the same, differences in anthropometric variables, like body mass and forearm circumference, or variations in the execution of the motions, due to individual preferences, result in different EMG signals generation.

Results

The following table presents the possible approaches that are suggested in literature for each EMG drift cause. Most of the suggested solutions involve recording extra information from different levels of disturbance or investigating the most suitable feature sets that counteract for the effects of the disturbance. Other solutions include a more sophisticated electrode configuration, additional sensory modalities, skills generalization and domain adaptation.

Cause	*Approaches*					
	data abundance	feature selection	electrode configuration	additional sensors	transferable skills	adaptation
Fatigue	+	+				
Electrode shift	+	+	+			
Arm posture	+	+		+		
Learning					+	
Inter-subject variability	+	+				+

Future Work

A new path in research is the application of domain adaptation techniques, such as transfer learning, for the mitigation of the aforementioned causes of signal drift. Domain adaptation is based on the assumption that data under the presence of EMG drifts would be different than the training data, but also they would originate from the same distribution. When this is true, information gathered before the signal drift can be utilized to reduce the amount of time and data that are needed to adapt to the shifted signal. The majority of research on adaptive techniques shows that it can be beneficial in the case of EMG concept drift.

Recent advancements in deep learning research have provided great results in machine learning applications, especially in the fields of computer vision and speech recognition. This motivates the investigation of the suitability of deep learning methods for pattern recognition applications that use electromyographic data. One interesting characteristic of deep convolutional networks is that the network can act like a feature extractor if it is deep enough, thus when it is used in a myoelectric pattern recognition application it removes the need to specify suitable features for the application. Moreover, due to the nature of the training in a neural network, the process of transfer learning is very straightforward. Our future work is going to focus on investigating the behaviour of deep networks on myoelectric pattern recognition applications, that are subject to non-stationary EMG signal.

Impact

Kyranou, I., Vijayakumar, S. & Erden, M. S., "Causes of Performance Degradation in Electromyographic Pattern Recognition in Upper Limb Prostheses", Frontiers in Neurorobotics , 27 Aug 2018 (Accepted/In press), doi: 10.3389/fnbot.2018.00058.

Research Area: Humanoid Robotics / Human Inspired Robotics

Human Inspired Push Recovery for Humanoid Robotics

Supervisor: Dr Zhibin Li
PhD candidate: Christopher McGreavy

Objective

Controllers which allow legged robots to balance are difficult to design. As most of the robot's weight sits above the legs, they have a tendency to fall, especially when they receive unexpected contact from the environment. Humans on the other hand have a similar morphology, but are much better at keeping their balance when they trip or are pushed. Since humans can perform better than humanoid robots, can we increase robot performance by using human control as a guide? Our objective in this project was to uncover the control strategies humans use to recover from pushes and use them to make legged robots better at push recovery.

Approach

To see which controller is being used in humans when they recover from pushes we first needed some human data. To get the data we needed to push some humans! To apply pushes to participants, we used a medical grade treadmill to move them forwards then stop suddenly. Stopping the treadmill suddenly brings the feet to a halt, but means the rest of the body continues to move forward, just like if someone was pushing the person.

Reflective markers placed on the bodies of participants were tracked by infrared cameras. Using this equipment we were able to record the movement of participants as they recovered from the push.

The placement of the markers allowed us to calculate the centre of mass for each person over the course of a movement. The centre of mass is a vital component in balance; if it is not located above your feet, you fall over, so we used these measurements to figure out how people control their centre of mass when they are pushed to bring it back to rest over the centre of the foot. We can then investigate to see which mathematical models fit the control used by humans.

Figure 1: Time sequence of one experiment trial. (a) Participant in the start position facing forwards; (b) to the centre of the treadmill, where the belt stops and they begin to fall; (c) The subject takes a step to recover from the fall.

Result

When looking at the methods used by humans to bring the centre of mass back to a position where they can balance, we see something similar to a simple proportional differential (PD) controller which is used regularly in robotics. Such a simple controller was unexpected, as more complex controllers are used by robots to achieve inferior results. We also see that the parameters used for the controller increases with the force of the push. These parameters changed in stages over the course of recovery, starting quite minimally but ramping up if the push was too strong. We can use these findings to determine how robots should react when pushed.

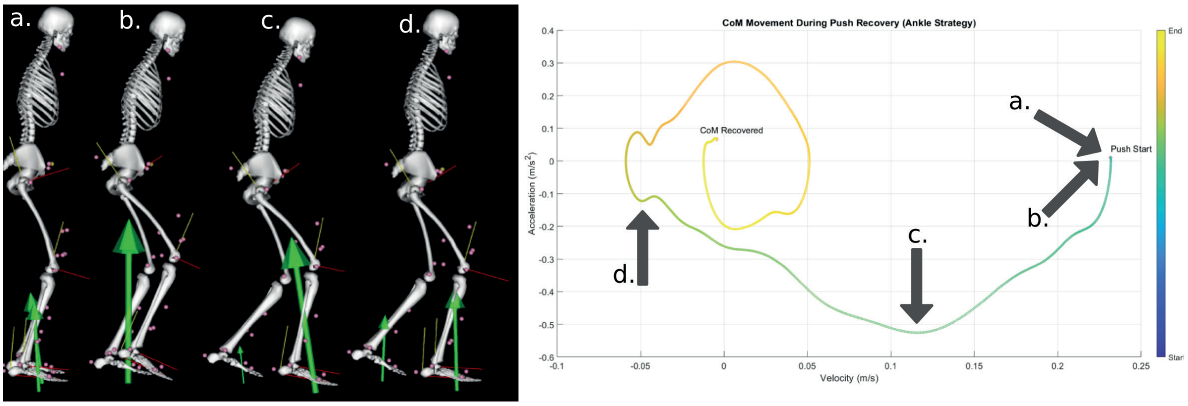


Figure 2: Left: analysis view of a recovery with ground reaction forces (Green Arrows).
Right: Acceleration of the centre of mass. Note the distinct spiral pattern. (a) push starts; (b) foot is lifted (c) foot lands and pushes the centre of mass back (d) balance is recovered using both feet

Impact

Analysing humans whilst performing a simple set of behaviours provided a new way of approaching a problem in robotics with quite a mature set of solutions. It showed how we can apply the controllers we already possess in more effective ways to potentially achieve improved performance. More generally, this shows that we can learn a lot about humanoid control in simple behaviours which opens the door to learning a great deal more about how to solve issues in much more complex, dynamic movements.

Future Work

Next, we plan to apply the things we have learned directly into humanoid robotics. Improving the way in which we use controllers can lead to better robot performance during push recovery. Longer term, the goal is to use human inspired techniques to help humanoid robots to perform robust agile and dynamic motion.

Research Area: Human-Robot Interaction

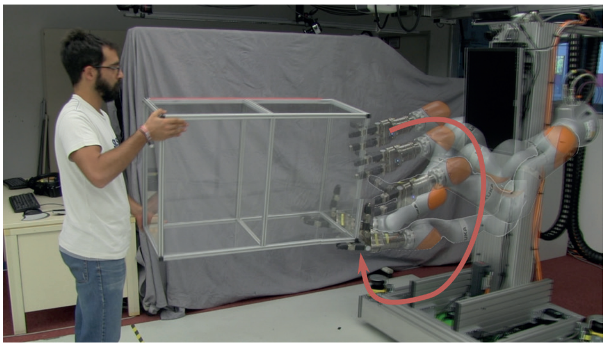
Dyadic collaborative Manipulation through Hybrid Trajectory Optimization

Supervisors: Professor Sethu Vijayakumar, Dr Michael Gienger
PhD candidates: Theodoros Stouraitis, Iordanis Chatzinikolaidis

Objectives

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 alternations and considerable uncertainty, to the extent that robots fail to successfully complete the collaborative tasks in hand. On the other hand humans collaborate naturally, as we are adept at co-manipulation due to extensive prior experience. In this project, we venture to enhance our understanding of the mechanisms of joint action, towards developing robot partners that co-exist with humans and can act collaboratively in pairs, as human dyads do. Towards achieving this goal, this particular piece of work is focused, on how can a robot policy be partner informed and flexible towards complying with the requirements of DcM scenarios.

Current state of the art approaches have demonstrated robot policies that consider the partner's actions, however the achieved flexibility is limited as the grasp-holds utilized by the robot are always fixed. On the contrary human dyads exploit the redundancy in the contact space, in order to realize the optimal solution. Thus, the focal point of this work aims on how can a robot policy generate hybrid motion plans that exploit simultaneously both the contact and the force space towards finding the optimal solution. We also propose a formalism to generate partner informed robot policies in the context of trajectory optimization methods and optimal control methods in general.



Approach

First, we refer to Dyadic co-Manipulation (DcM) as a set of two individuals jointly manipulating an object, as shown in the figure above. The two individuals partner together to form a distributed system, towards augmenting their manipulation abilities. We utilize the trajectory optimization framework to generate flexible hybrid optimal robot policies according to the following observations; i) motions through contact have phases (modes) and the contact set remains invariant within each phase. The required a-priori knowledge is a rough known model of the partner's policy, a model of the object and the number of contact changes to be performed by the robotic agent. With this information, our method computes dynamically consistent and optimal solutions for the i) trajectory of the object, ii) robot agent forces, iii) robot agent contact locations and iv) respective timings of these actions, as shown at the animation in Fig.1. The proposed formulation transcribes the above described trajectory optimization problem to a non-linear program that can be efficiently solved using out of the box gradient based solvers. The concept is demonstrated both in simulation as well as with in real world with a dyad of a human and a robot.

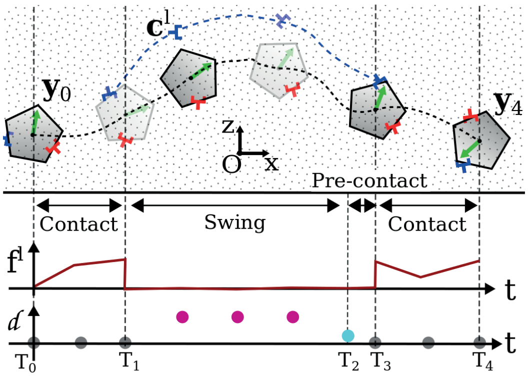


Figure 1: Hybrid motion plan with one grasp-hold change. The grey dotted area illustrates the physical space (x,z,θ), while the force applied by the left (blue) end-effector is $\mathbf{f}^l$. The knots of the trajectory are shown in the bottom graph along with the contact distance of the left end-effector to the object's surface.

Results

The feasibility of the generated hybrid plans in terms of dynamic consistency is important in dynamic manipulation tasks. Thus, we compare the object's trajectory generated by the proposed optimization method and the trajectory generated by a Simulink-based dynamic simulation after feed-forward streaming the planned forces into it. These hybrid plans are realizable and one such hybrid plan is shown in Fig.2. The experiment with a 32 DoFs robot demonstrates that the solutions have a large potential to be employed in real co-manipulation scenarios. Regarding the motion of the robot, as the algorithm provides the end-effector poses, standard IK are utilized to compute the full configuration of the robot.

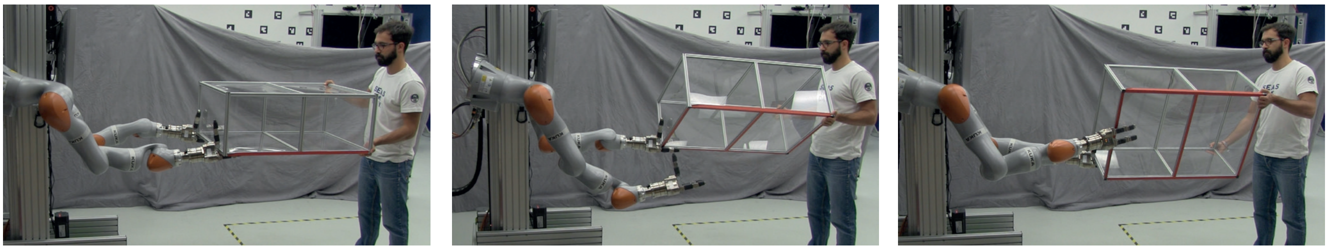


Figure 2: DcM scenario with a human partner and a robot during change of contacts.

Impact

Endowing robotic agents with collaborative capabilities is of crucial importance towards the development of robotic partners. Such robots can be industrial partners or home care robots and all share a common attribute; the need to manipulate their environment in physical and mental collaboration with humans. Thus, enhancing robots with joined planning manipulation capabilities such the ones demonstrated in this work is crucial. Further, this work aims towards a better understanding of the mechanisms of joint action by human dyads.

Future Work

Future work will focus on elaborate models for the human policy, and a more tight integration of feedback to realize a robust behaviour in interaction between the robot, the object and the human partner.

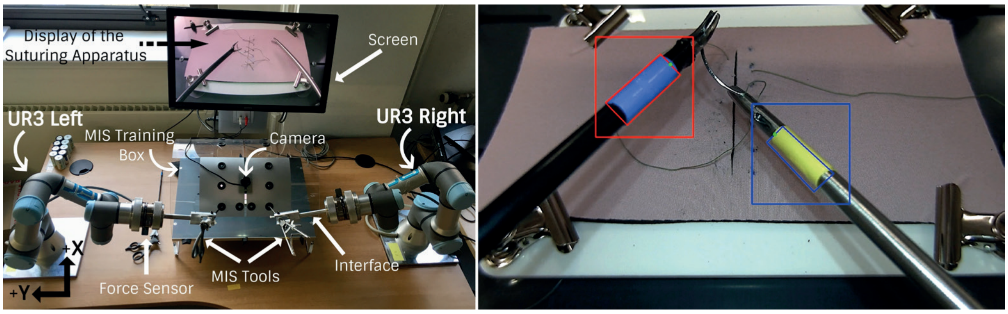
Publications

Theodoros Stouraitis, Iordanis Chatzinikolaidis, Michael Gienger, Sethu Vijayakumar.
Dyadic collaborative Manipulation through Hybrid Trajectory Optimization, Conference on Robot Learning (CoRL), 2018. (to appear)

Research Area: Medical Robotics

Laparoscopy instruments tracking for single view camera and skill assessment

Supervisor: Dr Mustafa Suphi Erden
PhD candidate: Benjamin Gautier



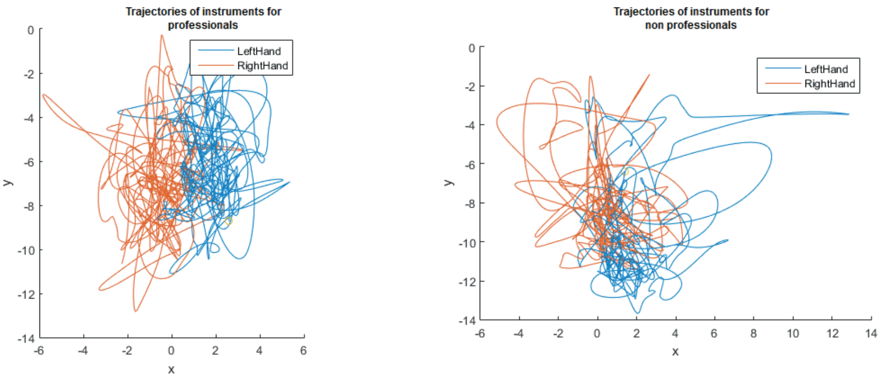
Main Objectives
The objective of this study is to develop a training software allowing to reduce the time spent on training for laparoscopic surgery. The software should take as input the video cues of the laparoscopy instrument movements in a training box and should extract the instrument trajectories. The software should compare the extracted trajectories to a database of trajectories of professionals and novice performers using a classification algorithm in order to estimate the level of the skill and identify the movement techniques used by the performer. Ultimately two UR3 robotic arms will be used in a co-manipulation mode to help the trainees to improve their movements. The robot movements will make use of the knowledge of expert tool movements. This case study presents the video processing algorithm to track the laparoscopy instrument trajectories and the initial results comparing the performance of professional laparoscopy surgeons versus novice subjects.

Materials and Methods
The training kit we work with is composed of the following elements: a 1920 x 1080px fish eye camera, a training box and two laparoscopy instruments used to handle and move a suturing needle. A group of ten PhD students (5 males and 5 females) of Heriot-Watt University were recruited to train for five weeks for experimental laparoscopy suturing. The subjects had no prior knowledge on surgery or laparoscopy. A set of videos of the performance of the subjects were recorded during the weeks 4, 5 and at the end of the practice, giving us a set of three videos for each novice subject tracing their improvement from the first time they successfully performed a suture to the end of the practice. Another set of video data were recorded in Dundee Institute of Healthcare Simulation in University of Dundee, where seven professional surgeons with hundreds of hours experience in laparoscopy practice followed the same process as our subjects. A group of four trainee surgeons for laparoscopy were also recorded. In order to process the collected videos, using a Hue Value Saturation thresholding on a flattened image, the instruments are detected with a canny edge detector, a Hough line detection and a Convex

Hull to handle partial hiding. Then using a Kalman filter and specific properties of the training setup the tips of the instruments are successfully tracked. The depth is identified by using the triangle similarity model on a modified shape of the object, which uses the perimeter of the object. In order to recover the correct perimeter for a given position we reshaped the detected polygon based on the real object width/length ratio.

Results

Form the tracking we extract trajectories of two distinctive sets: The Cartesian coordinates of the tip of the instruments (X,Y,Z) and the elementary motions of an instrument (α,β,y). The figure below shows sample trajectories of the tip of the tools for a professional surgeon (left hand side) versus a novice subject.



Comparison points\Groupe	HeriotWatt subjects	HospitalMean
Time (in seconds)	794,1	506,64
Total path length (meter) left	2,98985	3,2155312
Total path length (meter) right	3,65735	3,5876878
Average speed (mm/second)	0,66795	1,2024
Avgrage acceleration (mm/second^2)	0,0274	0,235019118
Motion smoothness (mm/second^3)	0,0274	0,1369
Working area (cm^2)	2,8502	3,54718

Using these trajectories, we computed a set of features that are used in the state-of-the-art assessment papers for Laparoscopy skill assessment. These means of these computed features are given in the Table above. These values pointed out that those state-of-the art quantitative features did not succeed to perfectly discriminate across the professional versus novice subjects, although a visual inspection of the trajectories easily reveals distinctive features between these groups in terms of orderliness and space separation between right-hand and left-hand tools (see the figure above). This result motivates us to search for other discriminative features based on tool movement patterns.

Future Work

We are currently working on two different methods of comparisons that should give better results. The first one consists of comparing the smoothness of a motion by working in the Fourier space to separate the hand-tremor components from the main trajectory. The second method we are investigating consists of extracting discriminative components of the patterns of movements from the trajectories by the means of a linear discriminant analysis or machine learning based pattern recognition. For example, using the images above, we can see that professionals will always have their left instrument staying on the left and the right one on the right.

Research Area: Medical Robotics

Hand Exoskeleton to Assess and Treat Hand Spasticity

Supervisor: Dr Mustafa Suphi Erden
PhD candidate: William McColl

Objective

This project aimed to build and test a hand exoskeleton that can help assess and treat hand spasticity. Assessments that are currently done are subjective which highlights the need for a device that can quantify the results and make a consistent evaluation. Current rehabilitative training can be expensive and time-consuming, an exoskeleton could help reduce these issues studies also show that patients are more likely to stick to exercises if unconventional methods are used rather than the routine treatment exercises. For spasticity assessment and treatment, ideally an exoskeleton that could move the three finger joints separately is needed, however for proof of concept we aimed at a one DOF exoskeleton for a single finger.

Approach

A review of the current techniques to assess and treat spasticity was done to identify the requirements needed. Opinions from medical experts were also used to understand the specification required of the exoskeleton hand. Initially, only the forefinger would be assessed to determine whether the concept was feasible. The final prototype was controlled using a single linear actuator that could move each joint simultaneously; a GUI was developed to monitor the hand and to visualise the sensor readings; this helps with training as the patient needs to stay with the personalized force thresholds in order not to trigger a false limit.

Results

Figure 1 shows the final design of the exoskeleton; the joint centres coincide with the user's finger joints which makes the exoskeleton sturdier than an over finger design. The joints move simultaneously using links that push each adjacent joint. Resistive force sensors were added above and below the finger to determine when the patient has reached their maximum or minimum range of movement. Figure 3 shows a sample force and servo motor position profile for a maximum velocity finger movement assessment. The exoskeleton was modelled in a musculoskeletal modelling called OpenSim, Figure 2, where motion captured data could be used as an input to analyse the muscles and joints during the movement. Multiple mock assessment tests were done at three different velocities, maximum, minimum and gravity assisted. Training sequences were analysed for varying levels of spasticity severity.

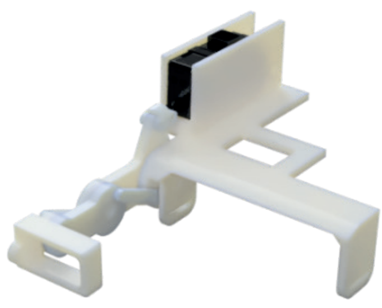


Figure 1

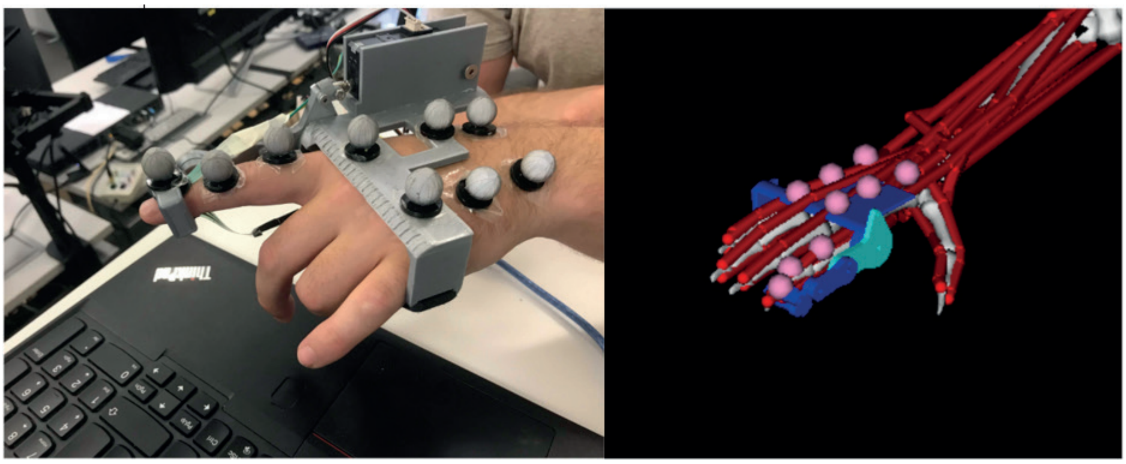


Figure 2

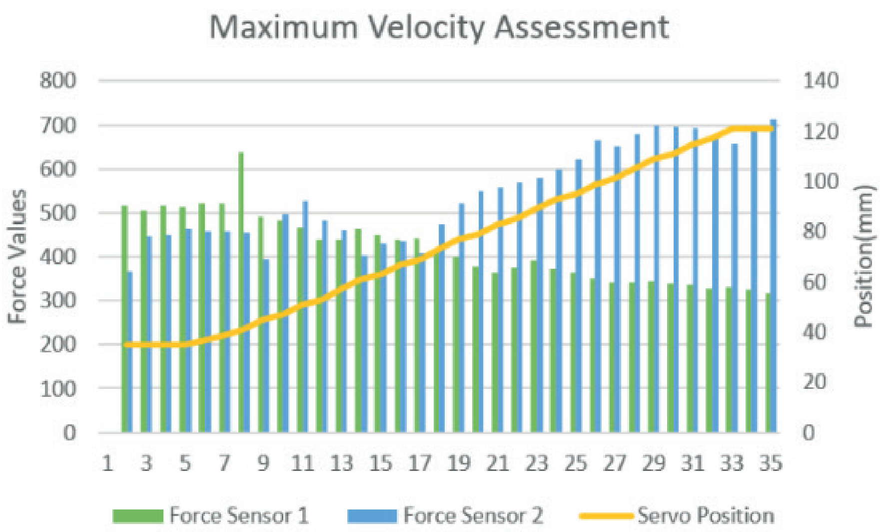


Figure 3

Future Work

The final design of such system requires testing with real spasticity patients. The final prototype necessitates a more detailed and more robust control according to the different modalities of assessment and therapy practices. The final design should also be made with sturdier material. Using these actual results, a final and practical spasticity assessment can be made in line of the currently used assessment criterion, the Tardieu scale. With sufficient data from patient records machine learning can be used to improve the assessment algorithm. A final design with actuation at each joint would enhance the functionality of the exoskeleton.

Research Area: Robotic Learning by Demonstration

Constraint Consistent Data Segmentation

Supervisors: Dr Mustafa Suphi Erden, Professor Sethu Vijayakumar
Research Associate: Dr Vladimir Ivan
PhD candidate: João Moura

Objective

This case study focuses on segmentation of different types of data collected during the demonstration phase for robot learning. In such demonstrations different types of data corresponding to the different environmental constraints or different forms of movement are usually collated one after the other as a single data stream, as this provides practical easiness during the experiments and physical demonstration activity. However, at the stage of processing the data for robot learning, these different types or parts of data should be segmented. Usually this is performed manually, which might be quite tedious and time consuming. In this case study we develop a method to aid the segmentation of such different parts of a single data stream.
For instance, for the wiping motion with the Kuka robotic arm in Fig. 1, we collected a full dataset with samples containing the robot joint positions (configuration) and joint velocities. Fig. 2 shows the corresponding end-effector Cartesian positions. The data collection process involved positioning a table with a given orientation, demonstrating a circular wiping motion and repeating this for a few times using the same motion but different table orientations.

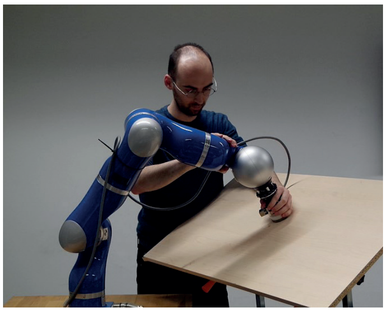


Figure 1: Demonstration of a circular wiping trajectory on a flat surface. The demonstrations were repeated for multiple orientations.

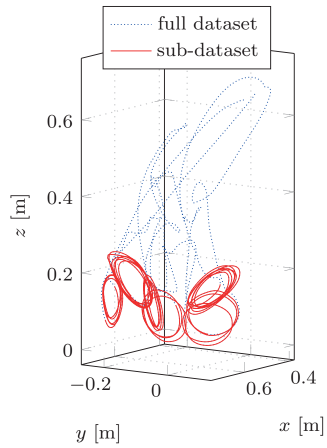


Figure 2: End-effector Cartesian position for a full unseparated dataset (blue), recorded for different constraints in the form of flat surface inclinations. Overlapping are the manually separated sub-datasets (red)

These demonstration data were used in our constraint-aware learning method for learning the underlying motion (the circular motion in this experiment), despite the demonstrations being performed under different constraints. Our learning algorithm requires that we provide a set of sub datasets, each for a different constraint. However, in the data collection process all the data was collected at once and, therefore, we introduced an intermediate step of separating the full dataset into the individual ones. This manual separation in our study was achieved by visually inspecting the data and selecting the initial and final indices of the data points for each sub-dataset. However, for larger full datasets with high dimensional data points, this task becomes challenging, time consuming, and prone to errors. Therefore, we need to create a tool to either completely automate the dataset separation process or at least to aid the manual one.

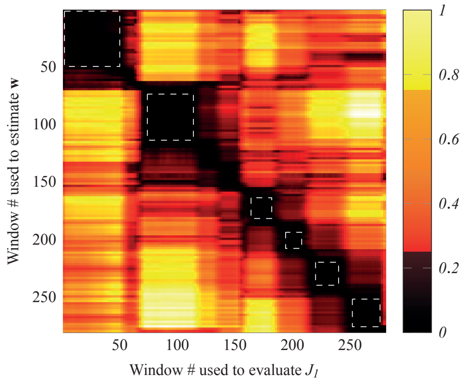


Figure 3: Normalized constraint error cost computed for different windows of the full dataset using the constraint parameters estimated for different windows of the full dataset.

Approach and Results

The constraint-aware learning method developed estimates the constraint and subsequently uses the estimation of the constraint to obtain the underlying motion. The estimation of the constraint consists in finding a set of parameters (w) that minimize a given cost function (J1). Therefore, we could potentially use this same cost function to segment the sub-datasets.

One approach is to select a set of consecutive data points that represent a window within the full dataset. We then compute the parameters for that window. We shift the window across the dataset by some increment smaller than the size of the window, creating a new window. If the parameters estimated in this new window produce a small value for the cost function, then this suggests that the data covered by these two windows is subject to the same constraint. By repeating this process for the full dataset, we then obtain a matrix such as the one shown in Fig. 3. This matrix corresponds to the data shown in Fig. 2, and the white boxes correspond the ground true manual separation. Fig 3. shows that the regions for which the cost is small correspond to the different sub datasets and, therefore, this metric can be used to aid finding the separation data point indices.

Future Work

This metric can be further combined with other application specific metrics. Data points where the robot is static may be removed using pre-processing if necessary. Alternatively, a tactile sensor could be used to detect when the end tool is in contact with the surface, etc.

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

Research Area: Field Deployment

Structure building on and manipulation of randomly tumbling objects in zero-gravity with self-reconfigurable robots

Supervisors: Professor Nick Taylor, Dr Patricia A Vargas
PhD candidate: Thibault Lacourtablaise

Objective

The construction or deployment of structures on an object in a zero-gravity environment is challenging in the sense that they induce a destabilisation of the object's rotational dynamics. Where traditional method of attitude stabilisation use expense or exchange of energy, our main objective is to take a different approach and use the changes of mass distribution as a mean to mitigate disturbances, and help to partially or fully control the attitude and rotational dynamics of randomly tumbling objects.

Approach

We approached the problem by gaining a deeper understanding of the physical effects of dynamic changes of mass distribution of simple objects such as cylinders or ellipsoids in order to define optimal "routes" along which a mass moving on the surface of this object would cause the least disturbances to its rotational dynamics. These "routes" provide trackable paths for a robot or structure to envelop a tumbling object in a fluid-like fashion.

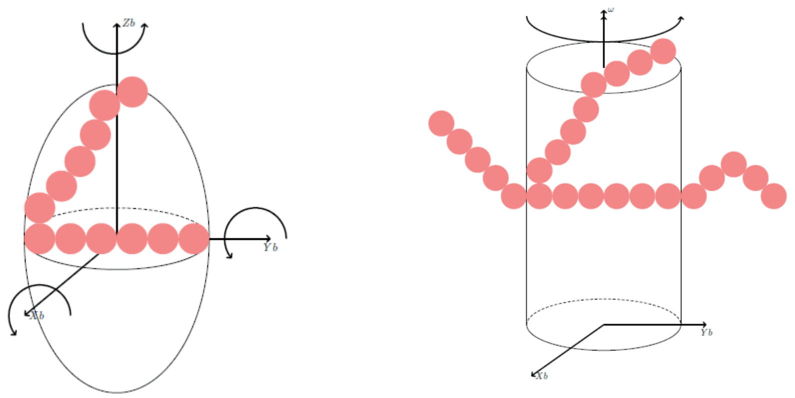


Figure 1: On the left the modular robot envelops the ellipsoid while minimising disturbances and on the right it develops appendages and actuator arms on the cylinder. Both objects are in stable spin ideally.

We are now designing and testing a Finite-State-Machine based decentralised deployment and reconfiguration algorithm for a modular self-reconfigurable robot with identical modules in order to fulfil our objectives. Depending on their place in the structure each module will either be anchored to the object or travelling on top of the other modules to reach its final anchoring place. This final anchoring place is located at the tip of a string of previously anchored modules along an optimal "route". Once reached the module anchors at this place while maintaining the optimal direction of the optimal "route" other modules should follow. In its final state the robot should envelop the object evenly.

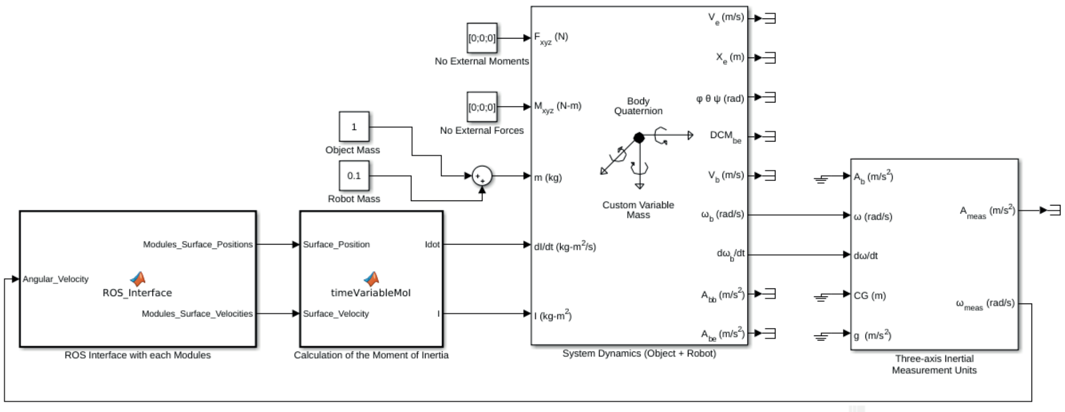


Figure 2: Diagram of the system (object + robot) and its interface with ROS where each module's controller is programmed.

Results

We have been able to derive a set of surface curves along which a mass can travel at an appropriate velocity while the spin rate of the object is maintained to an acceptable level. The nutation induced by the moving mass can be mitigated by choosing the starting point of the envelopment process.

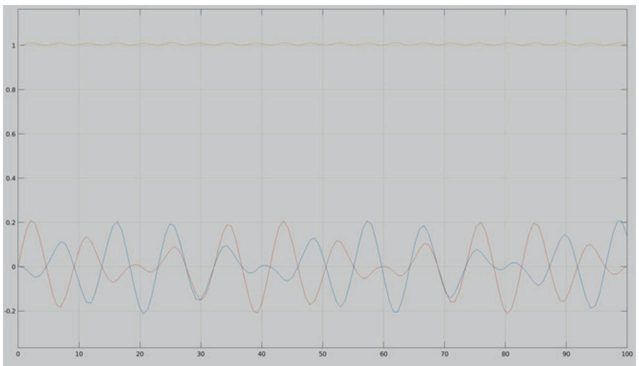


Figure 3: Angular velocities evolution of an ellipsoid (in rad/s) during the motion of a mass on its surface. The spin rate at the top is relatively constant while the other angular velocities are indicative of nutation

Impact

The deployment of autonomous structures on objects or their manipulation in zero-gravity is mainly of interest for applications in outer space such as the mitigation and disposal of space debris, the servicing and maintenance of spacecraft and space mining.

Future Work

We are currently investigating a method to actively damp nutation. It is intended to use appendages grown from sets of modules as actuators. This method could be thought of as a stabilization using moving arms and will require adaptability and learning.
We are also investigating the possibility of deployment on objects with uneven surfaces and mass distributions.

Research Area: Reinforcement Learning

Learning to predict bouncing balls

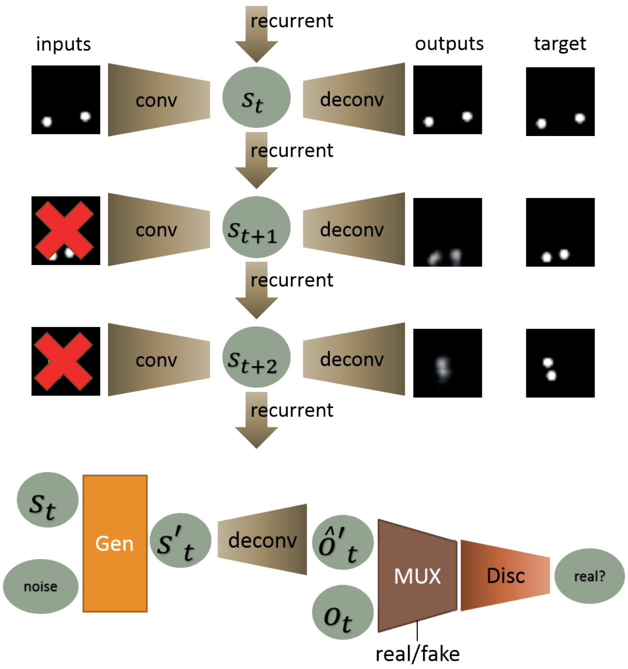
Supervisors: Professor Nick Taylor, Dr Subramanian Ramamoorthy
PhD candidate: Marian Andrecki

Objective

Reinforcement learning has seen great successes in recent years. Most notably: beating human champions at competitive games such as Go (board game) and Dota2 (reputable e-sport). However, the advances are slow to propagate to agents embedded in the real world - e.g. robots. Reinforcement learning requires thousands of hours of gameplay in order to perform at human level. Training time is currently the most salient obstacle for non-simulated systems. It has been argued that pure reinforcement learning is data inefficient because the reward signal - the only feedback used - is sparse and contains little information. Our approach is to extract more information from agent's experiences by training a predictive model. Such a model can additionally be used for state estimation, future prediction, planning and safe exploration. In this work, we investigate learning to predict stochastic motion of bouncing balls.

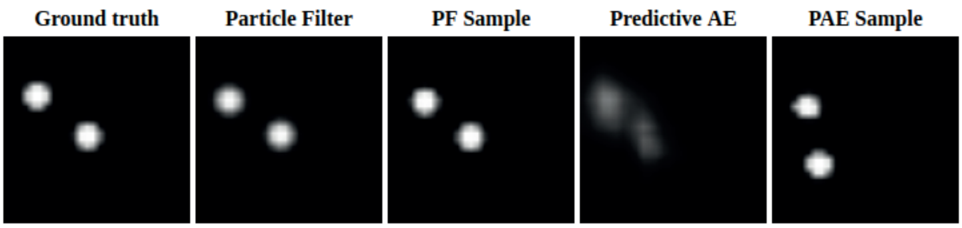
Approach

We extend a neural architecture previously used to learn dynamics of Atari games. The updates allow us to generate predictions for a larger class of non-deterministic environments. The architecture relies on a combination of convolutional-deconvolutional layers (for image representation) and recurrent links (to capture temporal aspect of dynamics). The input is a video with a number of frames removed. Then the network is optimised to reconstruct the video fully. As the training progresses, higher proportion of input is hidden. Ultimately, network generates the average of plausible reconstructions (and futures).
Additionally, we develop a method based on Generative Adversarial Networks, that allows us to sample from the distribution of possible environment states (presented in the second diagram).



Result

We compare predictions generated with those offered by a model-based method - a particle filter. This is a very strong baseline, as it is provided with an accurate environment model, while our method learns the model from data. We found that the scheme enables learning of forward models that generate predictions close to those output by a particle filter. As was expected, our approach is less certain about its predictions, but is never overconfident. The more complex the dynamics of the environment (e.g. higher number of bouncing balls), the larger the difference in confidence of the two methods. The uncertainty can be observed as the higher blurring in the images. Using adversarial networks we extract sharp samples from possible environment states.



Impact

Ability to learn predictive models directly from videos enables new research paths for agents that start with minimal knowledge about their environments. Expected gains include improved data-efficiency, ability to plan and curiosity-driven exploration.

Future Work

The ongoing research, which builds on ideas presented here, deploys this approach in a stochastic, partially observable game environment. The work involves quantifying gain in performance of a reinforcement learning agent when imbued with the predictive ability. The particular game used as a testbed is Pommerman - developed for an AI competition which will be finalised during NIPS 2018.

Research Area: Underwater Robotics

Subsea Pipeline Detection in Multibeam Echosounder for AUV Applications

Supervisors: Dr Sen Wang, Professor David Lane
PhD candidate: Vibhav Bharti
Industrial Sponsor: Kawasaki Heavy Industries

Objective

Autonomous Underwater Vehicles (AUVs) have become very popular for long-range underwater survey missions as they are generally easier, faster and cheaper to operate than cable controlled Remotely Operated Vehicles (ROVs). A well-established commercial application of this is the inspection of subsea cables and pipelines, where an AUV is required to follow a target pipe over long ranges. Most AUV based approaches employ a Multibeam Echosounder (MBE) along with other sensors to follow pipe. The key challenge is to track the pipes robustly even when it is difficult to detect them accurately due to partial burial and occlusion. This work presents a novel algorithm for robust pipeline detection and tracking at close range using only a Multibeam Echosounder (MBE). Based on the detections, the tracking algorithm filters out false detections by fusing with previous detections.

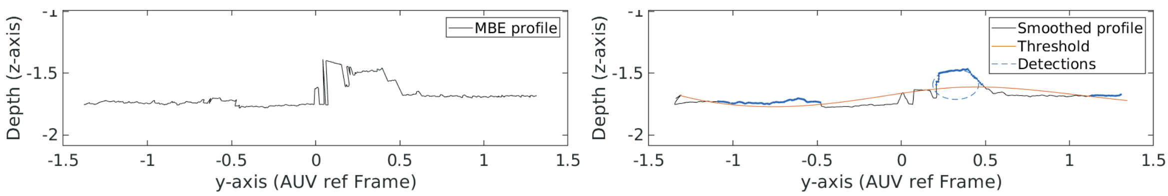


Fig 1: Raw MBE Profile from Blueview echosounder (left), result from detection algorithm (right)

Approach

A subsea pipeline is an object having distinct properties different from nature. For its detection using MBE, the shape parameter (or radius) can be used. However, direct detection of exposed pipes in MBE data is challenging due to measurement noises (as seen in figure above). Literature on pipeline tracking using a MBE is scarce due to its commercial/proprietary nature. AUTOTRACKER project is one the major projects employing a MBE for pipeline tracking on real scenarios. Their algorithm relies on Metropolis-Hastings monte carlo method and fits pipeline model parameters to MBE data to compute a likelihood. Other similar approach describes a fuzzy logic based methodology for pipe detection in MBE, where likelihood of each data point is computed to be belonging to pipe in accordance to its height with respect to its adjacent data points.

A comprehensive way to detect pipeline is to fit ellipse model to all sequential combinations of MBE data points and computing likelihood of each. However, this is computationally expensive. Therefore, we propose to only use subsets from MBE profile that are possible candidates to be a pipe and referred as initial guesses. A set of points that may belong to pipe is generated by using adaptive thresholding, which is achieved by using polynomial curve fitting method on the data points. Specifically, if the degree of polynomial fit is kept low enough, then the fitting algorithm favours the seabed profile over objects that stand out from seabed (such as exposed pipes). The set of candidate points from previous step are used for non-linear least square algorithm that fits the points to a model of an ellipse. An elliptical model is chosen since the MBE will produce elliptical profiles when the orientation of target pipe is not parallel to AUVs heading orientation. Since there will be multiple detections, an elimination criterion rejects unrealistic possibilities. Elimination rules are based on properties such as burial depth and length of major axis. Current tracking method is based on simple alpha-filter (simplified alpha-beta filter). Overall tracking algorithm is modified to accommodate for false detections.

Results

The proposed system has been tested in both real experiments and ROS simulation. Since it is difficult to obtain ground truth of underwater pipes, the simulation is used to evaluate the pipe detection and tracking accuracy. Figure below shows the root-mean-square error (RMSE) of the tracking results, which are mostly less than 0.1m for pipe of .25m radius. The real experiment is conducted with MBE mounted on a surface vehicle in a dock, and the system setup is shown in bottom figures. As can be seen, the proposed algorithm can detect pipes robustly.

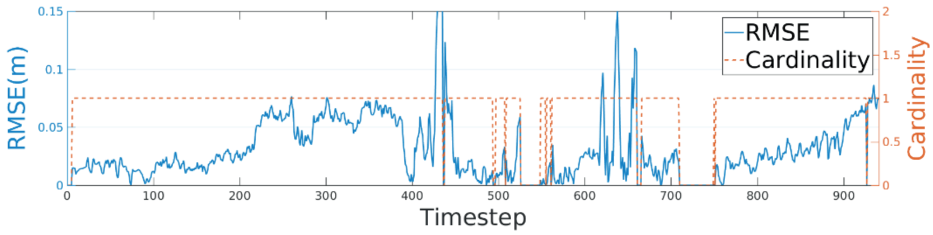


Fig 2: RMSE error detection, cardinality is 0 when pipeline is buried

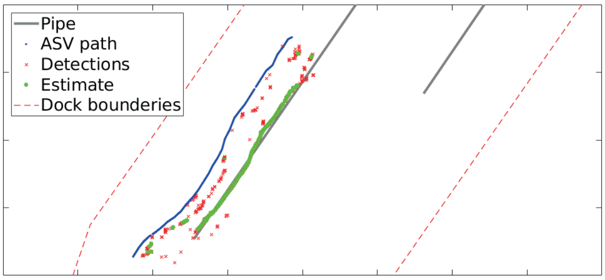


Fig 3: Detection & tracking result on real data

Fig 4: Blyth dock setup

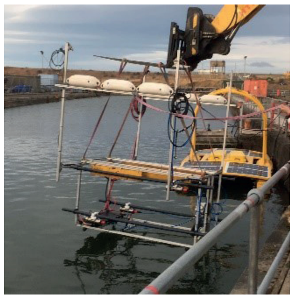


Fig 5: Sensor setup

Conclusions

A simple novel algorithm is developed capable to be used as standalone for detection and tracking. In future this method will be used with other sensors such as magnetometer and camera to improve the tracking capability. This will enable the AUV to resurface less and may also reduce the need to relocate the pipeline which is usually done after resurfacing by performing lawnmower motion around legacy data. Thus increasing efficiency and reducing the overall operational costs.

Publications

V. Bharti, D. Lane and S. Wang, "A method for tracking subsea pipelines in multibeam echosounder", under review at IEEE OES Autonomous Underwater Vehicle Symposium, 2018.

Research Area: Soft Robots

Energy based control of soft robotic systems

Supervisors: Professor Nick Taylor, Dr Adam Stokes
PhD candidate: Derek Chun

Objective

Soft robots are machines that convert energy from one form into another. The current trend of soft robotic systems are actuators focused on achieving deformation, which typically overlook the energy transduction through the whole system and the energy interaction with the external environment to perform a task. The energy may not be converted into useful work done, which affects the performance of the machine.

The objective is to define an energy-based framework to develop soft robotic systems which is based on bond-graph theory and port-Hamiltonian approach. In this case study, a soft assistive device is shown in Figure 1 [1]. The framework is applied to gain insights into soft robotic systems.

Figure 1: A soft assistive device [1]

Approach

Bond graph theory is a method to describe energy transduction through different physical domains through generalised effort and flow variables. There are three modelling elements; capacitive energy storage (C), inductive energy storage (I) and dissipative element (R). The behaviours are based on the electrical analogy of capacitors, inductors and resistors respectively. Figure 2 shows a power bond carrying energy from element A to B. The word bond-graph in the top of Figure 3, describes the energy transduction through the major subsystem. The bottom of Figure 3 is the bond-graph representation of the devices. The power supply is represented by an effort (voltage) source, Se. The electrical to hydraulic domain transformation is represented by a transformation gyrator, GY, where the voltage relates to the speed of the compressor and subsequent flow rate of the fluid. The soft actuator then modulates the energy transformation, TF, from a pressure in the hydraulic domain to a force in the mechanical domain. It is a function of the material properties and geometry of the soft actuator. The person interacts with the soft-actuator via a force. The energy transduction through the system is serial as denoted by the 1-junction. 0-junctions represent parallel energy paths which are not applicable in this example. Bond graph theory can readily represent complex multidomain soft robotic systems.

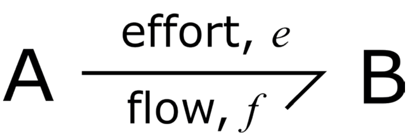


Figure 2: A power "bond" denotes energy flow from element A to B

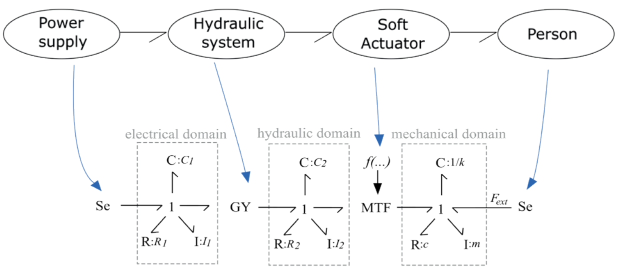


Figure 3: (Top) word bond-graph and (Bottom) bond-graph representation of a soft assistive device

The next part of the framework uses the port-Hamiltonian approach to represent the control model of the soft robotic system as illustrated in Figure 4. The modelling approach is port-based which builds on the multi-domain bond-graph approach of composing complex systems with power-preserving interconnections. The Hamiltonian corresponds to the total energy of the system. The bond graph representation is rearranged into the Dirac structure in Figure 4, which represents a mathematical reformulation and energy conservation of the system.

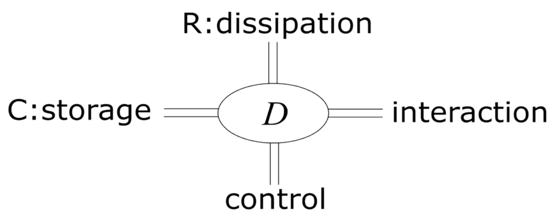


Figure 4: A port-Hamiltonian system

The system is modelled as energy storing and energy dissipating components, connected via ports to power conserving transmissions and conversions in different physical domains. The system can be controlled by interconnecting it to "energy shaping" and/or "damping injection" components, and by adding energy routing controllers. The temporary energy storage I and C elements models the dynamics of the system. The external energy interaction from the environment and control actions can be derived mathematically.
More information about bond-graph theory and the port-Hamiltonian approach can be found in [2].

Status

The next step is to apply a port-Hamiltonian approach to a distributed parameter system and investigate the energy interaction with the environment using a physical soft robot.
This is an approach that can characterise different elements within the soft robotic systems and move them from an iterative experimental approach to an engineering paradigm where each element can be well characterised. Complex task-orientated useful soft robotic systems can then be created [3].

Conclusion

Soft robotic systems can be applied in a wide range of applications; wearable robotics, exoskeletons, prosthetics, soft grippers, assistive robotics, underwater robotics, hazardous environments, and surgical robotics. Current soft robotic systems have limitations in many aspects, such as basic open loop control, efficiency and power. The energy transduction through the entire system must be well characterized and understood to improve these aspects. A structured engineering framework is required to move away from the iterative experimental approach and develop task orientated useful systems in the future.

References

[1] Polygerinos, P., Wang, Z., Galloway, K.C., Wood, R.J. and Walsh, C.J., 2015. Soft robotic glove for combined assistance and at-home rehabilitation. Robotics and Autonomous Systems, 73, pp.135-143.
[2] Duindam, V., Macchelli, A., Stramigioli, S. and Bruyninckx, H. eds., 2009. Modeling and control of complex physical systems: the port-Hamiltonian approach. Springer Science.
[3] Ross, D., Nemitz, M.P. and Stokes, A.A., 2016. Controlling and simulating soft robotic systems: insights from a thermodynamic perspective. Soft Robotics, 3(4), pp.170-176

Research Area: Swarm Robotics

Bringing Stigmergy into the Real World

Supervisors: Dr Mauro Dragone, Dr Patricia A Vargas
PhD candidate: Siobhan Duncan

Objective

Our goal is to enable the coordination of robots within large-scale swarm robotics systems by taking inspiration from a biological phenomenon known as stigmergy. Stigmergy is a key factor in the coordination of natural swarm systems as it enables the emergence of global intelligence through the interactions agents have with stimuli found in the environment. Agents leave traces of their actions within a medium, such as the environment, which then increase the probability to prompt new actions when sensed by other agents.

Stigmergy has been proven to be a key component of swarm systems, but has to date mostly been confined to simulation-based or table-top experiments. Emerging technologies, such as IoT and Cloud computing, could be instrumental in taking swarm systems from the laboratory into the real world.

Approach

Contrary to past efforts, which have tried to mimic biological mechanisms and found those hard to realize in hardware implementation, we are focusing on a bio-inspired approach leveraging emerging technologies, such as the Internet of Things (IoT) and Cloud Computing to realize a novel medium to explore stigmergy-based swarm coordination.

In the first stage all work has been implemented in simulation, which is further outlined in the Results section; in the second stage, experiments using IoT, Cloud and 5G technologies will be carried out; and finally in the third stage some assumptions will be relaxed, such as connectivity, communications between robots, etc.

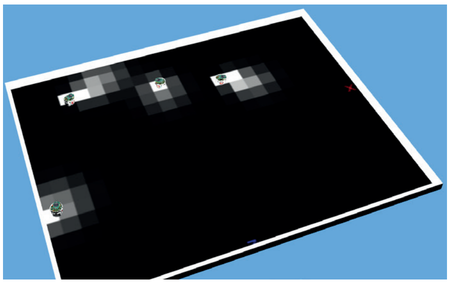


Figure 1

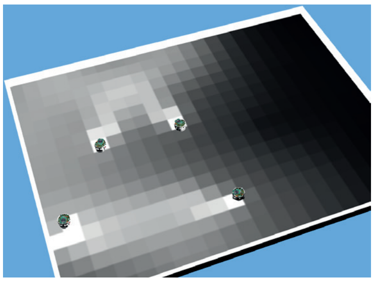


Figure 2

Result

So far all work has been implemented in simulation using both the Webots simulator and a ROS/ Gazebo setup. Both of these setups allow for rapid prototyping with multi-agent systems.

In Webots a controller based on Levy flight, a type of random search modeled on hungry animals, has been implemented for the e-puck robot. These robots can then be simulated in an arena, discretised into cells. These cells are represented as a matrix of integers between 0-255, allowing the map to be maintained using traditional image processing techniques and libraries.

The e-pucks leave pheromone traces in this shared map which over time diffuse and evaporate. As seen in Figures 1 and 2. These pheromones can be used to understand which areas of the arena have been searched, and how recently, in order to coax agents into un-searched areas of the environment without the need for central planning.

Although this is still a tabletop setup, the stigmergy cells are an abstraction which can later be ported to other technologies, such as grids in a shared map, range of an IoT device with memory to share, visual or communications scope of a drone in an overhead network, etc...

For the RoboCup 2018 Rescue League Virtual Robot competition two ROS packages were developed which implemented a shared stigmergy map using a similar principle and a local pheromone controller which runs on each robot and interprets the information from the stigmergy map. This involved much more complex environments, such as that shown in Image 3, and using a mixture of ground and aerial robots. The packages proved effective in encouraging robots into unexplored areas in an unknown and cluttered environment without the need for a planner.

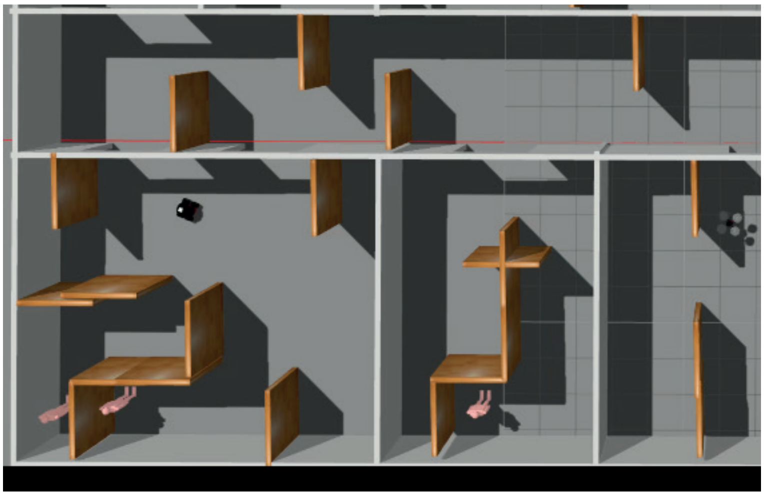


Figure 3

Impact

Swarm robotics has the potential to revolutionize the robotics world, as swarm systems can tackle a wide range of applications more effectively and efficiently than any single robot. However, stigmergy is a key factor in the coordination of swarm systems as it enables the emergence of global intelligence through the interactions agents have with stimuli found in the environment, rather than through a central planner. Enabling stigmergy in large-scale industrial systems would help towards making field swarm robotics a reality.

Future Work

We are currently carrying out further experimentation in simulation to enhance the Levy flight algorithm with stigmergy, in parallel experiments using real robotic systems are currently being organized and will be carried out soon. The Edinburgh Centre for Robotics has a living lab with an RFID floor and IoT gateway which will be used as an stigmergy medium, as well as a fleet of drones with GPS+4G connectivity which can be used for field testing experiments with cloud computing.

Research Area: Swarm Robotics
Merging Swarm Intelligence and Probabilistic Motion techniques in Search and Rescue missions

Supervisor: Dr Patricia A Vargas, Dr Mauro Dragone
PhD candidate: Hugo Sardinha

Objective
The aim of this work is to increase the flexibility and effectiveness of an aerial swarm system for area coverage and search missions.
Designing efficient coordination strategies in multi-UAV systems is of paramount importance in a variety of tasks such wildfire detection, Search & Rescue scenarios or pollution monitoring. Particularly where points of interest are sparse (e.g. victims) and do not have a known distribution, it is crucial that such strategies maximize the likelihood of these points being discovered. To tackle this issue, the current work proposes a hybrid strategy between the traditional concepts used in the coordination of artificial swarms, known as flocking, and a stochastic component to enable the swarm with the capability of avoiding long-term local searches.

Approach
It has been noted by mathematicians that a formal model can be derived that explains the motion of many natural systems in search for food/prey. It has been recorded that these collectives follow a run-and-tumble motion. This behaviour alternates with some probability between two distinct phases: the tumble, which refers to a seemingly random local search, much like the random walk known in many engineering applications; and the run, which refers to a long straightforward motion, allowing the agent to explore a more distant section of the domain. This process is known in the literature as Lévy Walk.
This concept has the potential to bring great improvements to the search task in disaster scenarios, precisely because of its inherent random behaviour. Due to the probability of long walks happening in between local searches, the probability of an agent traversing a wider area and finding victims is increased. When merged with with the traditional flocking algorithm, this approach will enable a member of the swarm, at any given time, to generate an apparent random trajectory. As the flocking algorithm is based on local interactions, it is envisioned that the swarm will gain flexibility by, for instance, being able to split and rejoin at later stage.

This initial prototype of the proposed approach was tested in MATLAB as a proof-of-concept. Figure 1 shows 16 frames of a generated motion. As it is shown, during this experiment, due to its inherent randomness the Lévy walk allows a member of the swarm to change its velocity differently than what would be predictable by flocking. However, due to the local nature of interactions these changes propagate through its neighbourhood resulting in splitting maneuver. The red circles at Δt = 40s show the swarm splitting into two different groups, whereas the black circles at Δt = 20s and Δt = 110s highlight respectively the swarm before splitting and after rejoining. Additionally Figure 2 shows, qualitatively, the evolution of the total area covered over time.

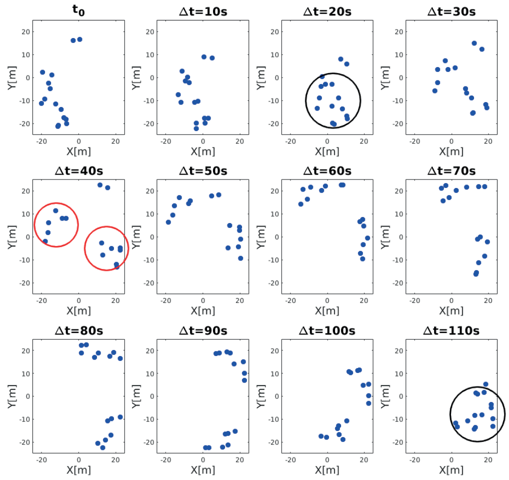


Fig 1: Example of swarm being able to split and rejoin

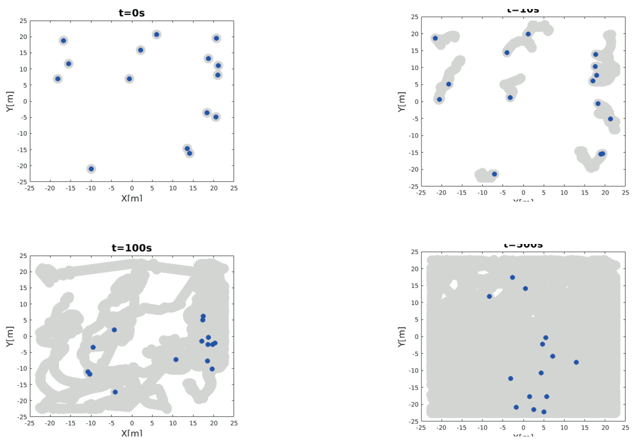


Fig 2: Evolution of the total area covered in 500s

Future Work

Future work will focus both on quantitative metrics of this behaviour as well as its benchmark with alternative strategies. Furthermore, this will be implemented in ROS leveraging the Ardupilot/ROS framework already developed by the author. Figure 3 shows the erlecotper UAV that will be used in the real experiments.

Fig 3: Erlecopter UAV Image ©Erlerobotics

Impact

Work is under way to identify the most suitable comparisons to be made and publish our proposed approach. Furthermore, it is expected that this work will also shed additional light on the behaviour of distributed systems, by contributing with a more complex description of flocking behaviours found in Nature.

References

[1] H. Sardinha, M. Dragone, and P.A. Vargas. Closing the Gap in Swarm Robotics Simulations using an Ardupilot/Gazebo Plugin. 2018 (Under revision).

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.

Learning to grasp movable objects based on tactile information

Honda Research Institute Europe

Intelligent systems will shape our future in a variety of forms, ranging from accident-free mobility to cognitive robotics and from smart process management to the efficient use of resources. Intelligence is necessary to handle complexity in products and in processes. The goal of this industrially sponsored project is to research concepts and methods for tactile-based exploring and grasping of movable objects.

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.

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

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

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

Robotic Inspection and Manipulation for Fusion Remote Maintenance
UK Atomic Energy Authority
This PhD project aims to develop new technologies to support operators of RH robotics systems in nuclear facilities. Current RH systems, though reliable and capable, suffer from limitations in visualisation and capabilities of dealing with confined workspaces. The vast majority of tasks are carried out through strict human-in-the-loop operation. Future nuclear remote maintenance systems will require more advanced visualisation capabilities and automation of basic RH/inspection tasks in order to cut down on maintenance time and increase plant price-performance. This research will complement already-existing RACE research into AR and remote handling task automation for these future applications.

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 alternations and considerable uncertainty, to the extent that robots fail to successfully complete the collaborative tasks in hand. This project aims at developing the required theory to overcome these limitations and demonstrate collaborative human-robot manipulation scenarios. In Dyadic co-Manipulation (DcM) scenarios, a robot collaborates with a human as naturally as a dyad of humans would do. In the future, the direct societal impact of this research will be found in daily scenarios where robots will assist humans to manipulate objects of interest.

"I am sponsored by BAE Systems Surface Ships Ltd at the Edinburgh Centre for Robotics. The collaboration between these prestigious organisations is providing me with a unique opportunity to apply my research to real applications in the underwater domain and is a great platform for exchanging experience and knowledge."
Yaniel - PhD Student, 2017 cohort

"My PhD is focussing on novel theoretical models that enable innovative solutions for real world problems. My funding body and collaborator, Honda Research Institute Europe, supports my scientific quest and helps me ground my research in actual problems, while the Edinburgh Centre for Robotics, where fundamental research has been taking place for many decades, provides me with the environment, knowledge and facilities. Both organisations are very important for a great PhD journey."
Theodoros - PhD Student, 2016 cohort

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.

To ensure that the UK is best placed to maximise this opportunity, the Edinburgh Centre for Robotics offers an innovative 4-year PhD programme which aims to equip graduates with the technical skills and industry awareness required to create an innovation pipeline from academic research to global markets.

Although the Centre is principally funded by EPSRC, we aim to augment this each year with a number of industry funded places. This additional funding maximises the number of students who can participate in our cutting-edge programme and in turn provides industry with a wider talent pool of innovation-ready graduates.

How to engage with the Centre

Any company with a research activity in the UK 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 before beginning the research phase at one of the partner universities.

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.

Key features and benefits of engaging with Edinburgh Centre for Robotics

- Access to world leading academic expertise to provide industrial R&D solutions
- Access to world class infrastructure through the recent £8m EPSRC capital grant ROBOTARIUM
- Developing graduates into industry leaders of tomorrow through excellent training opportunities, supplemented by training in commercial awareness, social challenges and innovation
- Industry informed training and seminars
- Industry advisory panel providing direction to the Centre's research activity

If you are interested in submitting a proposal for a new research project, please contact:

Professor David Lane d.m.lane@hw.ac.uk
Professor Sethu Vijayakumar sethu.vijayakumar@ed.ac.uk

Highlights 2017-18

ORCA HUB
Offshore Robotics for Certification of Assets

Centre wins £36M - the largest ISCF programme in Scotland to date

Edinburgh Centre for Robotics, in collaboration with Imperial College London and the Universities of Oxford and Liverpool, has been successful in its bid for funding from the UK government's £84M Industry Strategic Challenge Fund. The resulting £36M grant, which was announced towards the end of 2017, is a major win of relevance for Edinburgh Centre for Robotics allowing it to establish the ORCA Hub, a multi-disciplinary consortium which brings together internationally leading experts and over 30 industry partners, to undertake research into Robotics and AI in extreme environments.

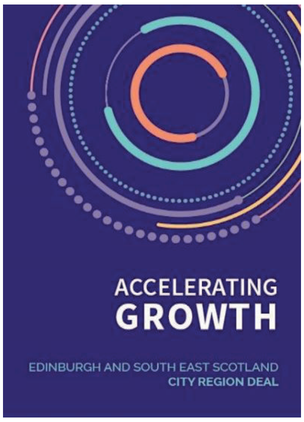
The Hub's primary goal is to use robotic systems and AI to revolutionise Asset Integrity Management for the offshore energy sector. This will be achieved through the provision of game-changing, remote solutions which can be readily integrated with existing and future assets and sensors, and that can operate and interact safely in autonomous or semi-autonomous modes in complex and cluttered environments.

Using spiral innovation development around industrial use cases and business models the Hub will develop robotics solutions enabling accurate mapping of, navigation around and interaction with offshore assets that support the deployment of sensor networks for asset monitoring. The first demonstrations to industry representatives, focussing on subsea and aerial activities, were carried out at the Underwater Centre in Fort William in July 2018.

For more information about ORCA Hub please visit: www.orcahub.org

Science Minister Visits Edinburgh Centre for Robotics

Science Minister, Sam Gyimah, visited the Edinburgh Centre for Robotics at the University of Edinburgh on 3rd August where he met with Scottish Deputy First Minister, John Swinney MSP, to discuss the economic opportunities for the UK and Scotland in Robotics and Artificial Intelligence (AI) which are being developed as part of the £100m National ROBOTARIUM.
Mr Gyimah joined Directors, Professor David Lane and Professor Sethu Vijayakumar, for a tour of the Edinburgh Centre for Robotics facilities at the University of Edinburgh. There he met ANYmal, and NASA's ground-breaking humanoid robot, known as Valkyrie.
Mr Gyimah's visit was followed up on 8th August by a visit from Prime Minister Theresa May and Scottish First Minister Nicola Sturgeon to formally sign the Edinburgh and South East Scotland City Region Deal.



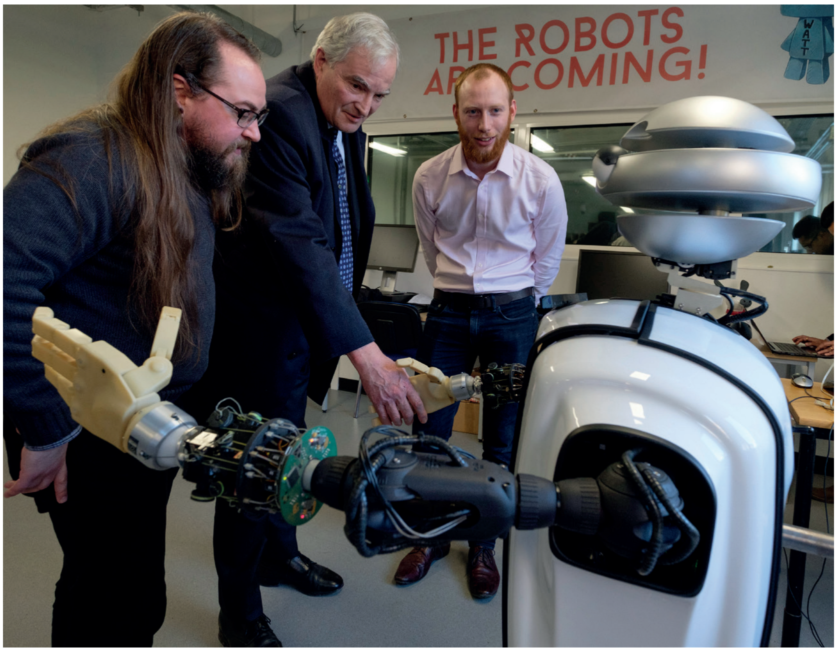
The Deal includes a £27m capital investment for the Centre for Robotics creating a brand new National ROBOTARIUM comprising a 4000sqm new building at Heriot-Watt University and an extension of facilities in the Bayes Centre, University of Edinburgh.
The investment will create a major international research facility for TRADE - Talent, Research, Adoption, Development and Entrepreneurship in Robotics, Autonomous Systems and Artificial Intelligence. Central to the facilities will be a collection of indoor and outdoor safe and realistic operating environments representative of the sectors where these systems eventually operate. These Living Laboratories have different physical scales to pivot research into commercial products and services. Examples include robotic mobility and intervention applications in healthcare, hazardous environments, transport, warehousing, agriculture and manufacturing. Companies of all sizes worldwide are being encouraged to locate and work in the National ROBOTARIUM spaces to enhance technology transfer and impact. The building programme is expected to complete by 2020.

Highlights 2017-18 (cont)

Lord Henley visits Edinburgh Centre for Robotics

Lord Henley, Parliamentary Under Secretary of State at the Department for Business, Energy and Industrial Strategy, visited Heriot-Watt University in February and toured the Ocean Systems and Human Robot Interaction laboratories to hear more about the innovative research being carried out at the Edinburgh Centre for Robotics.

During the event the Minister met with academics and was given a demonstration of some of the Centre's underwater robots that will play a key role in the ORCA Hub which will develop robotics and AI technologies for use in extreme and unpredictable environments. Lord Henley also viewed the Human Robot Interaction Lab where he met the iCub robot, Nikita, as well as the Flash and Husky robots.



Dr Frank Broz, Lord Henley and Dr Peter McKenna with robot, Alyx,

"Heriot-Watt University is a great example of an organisation investing in the future of the UK and I was incredibly impressed by the robotics and artificial intelligence they have created. The University's ground-breaking studies reflect the government's Industrial Strategy ambitions to develop the high-skilled, high-value jobs of the future."

Lord Henley, Department for Business, Energy and Industrial Strategy

International contest reveals assisted living robots of the future

Following the success of the first European Robotics League local tournament of the Service Robots (ERL-SR) competition in January 2018, the Edinburgh Centre for Robotics will host its second ERL-SR local tournament, from the 3rd to 7th December 2018.

As in the first round, the second local tournament will take place at Heriot-Watt University's custom-built assisted living testbed. The laboratory is a 60 square meter, fully sensorised smart robotic space designed to facilitate user-driven design and testing of innovative ICT Robotic solutions for healthy ageing and assisted living.

Funded by the European Union's Horizon 2020 Programme for research, the ERL brings a common framework for two indoor robotics competitions, ERL Industrial Robots and ERL Service Robots and one outdoor robotics competition, ERL Emergency Robots. The three competitions are designed to target three clear objectives: the European societal challenge of an aging population, the strengthening of the European robotics industry and the use of autonomous systems for emergency response.

The first ERL-SR local tournament in Edinburgh was refereed by postdoctoral researchers and undergraduate students from Heriot-Watt University. Teams from the UK, Germany and Spain competed in different Task Benchmarks (TBM) and Functionality Benchmarks (FBM). These benchmarks are designed to evaluate how robots can help an elderly person with their day-to-day activities. Robots are required to generate a map of their environment, detect random changes in the location of furniture and other items, interact effectively with humans and demonstrate different behaviours when dealing with known and unknown people, and help them with general tasks throughout the day.

Robotics competitions such as the ERL offer a unique opportunity to break down real-world challenges into a competition format, similar to the UEFA Champions League in football, which is exciting for robotics scientists, the robotics industry and the general public alike. Crucially, they provide a systematic way to compare and evaluate the performance of different systems, and thus ultimately foster the development of effective service robots.

More information, including press releases and videos from the first tournament can be found online at https://sites.google.com/site/erlsrhwu2018/

Please contact Dr. Mauro Dragone (m.dragone@hw.ac.uk) if you would like to be involved, for instance, by contributing to the organisation, acting as referee, or participating in the first ECR team to compete in the event in December.

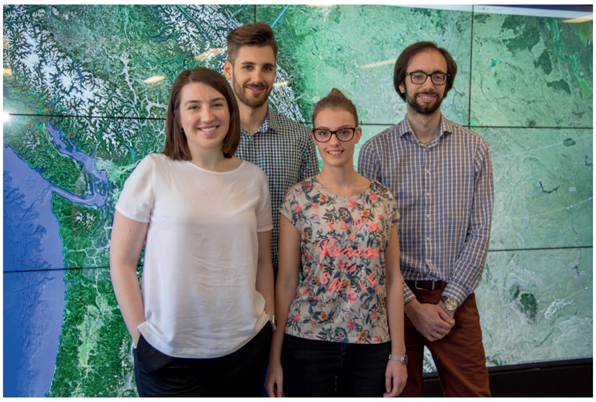
Highlights 2017-18 (cont)

Heriot-Watt Team are Amazon Prize finalists for a second year!
For the second year running, a team from Heriot-Watt University has reached the final of the international Amazon Alexa Prize and is once again the UK's only representative in the high-profile competition.

The Amazon Alexa Prize is a global university competition that is dedicated to the advancement of conversational artificial intelligence and is named after the Alexa voice command system that powers the Amazon Echo. It challenges teams to develop a software capable of understanding and responding to humans in a socially intelligent manner, over many different topics of conversation such as news, music, movies, and celebrities.

Team Alana, comprising of seven PhD students and four faculty advisors, will travel to Las Vegas in November where they will compete against the Czech Technical University and the University of California Davis for the coveted title. The Edinburgh-based team recently navigated its way through the semi-final stage after impressing Amazon's US customers with its advanced artificial intelligence software that can understand and respond to human conversation.

At stake in this year's competition is a $500,000 prize for the team selected for creating the best socialbot. Additionally, a $1m research grant will be awarded to the winning team's university if their socialbot achieves the grand challenge of conversing coherently and engagingly with humans for 20 minutes with a 4.0 or higher rating.



L to R: Amanda Curry, Alessandro Suglia, Karin Sevegnani, Dr Ioannis Konstas

"To once again reach the final of the Amazon Alexa Prize is a wonderful achievement and highlights the extraordinary talent we have in human voice recognition here at Heriot-Watt University. This is a competition that attracts entrants from across the world and Team Alana's progress in such a prestigious event enforces the University's international reputation as a leader in robotics and artificial intelligence."
Professor Richard A. Williams, Principal and Vice-Chancellor of Heriot-Watt University

"I'm really proud of the team and what we have achieved so far. The Amazon Alexa Prize pushes our capabilities but ultimately highlights the global talent pool we have at our disposal at Heriot-Watt. To reach the final for the second year running is a truly magnificent achievement, particularly as we were competing against some outstanding universities in the semi-final stages. We will now work hard in preparation for the final in Las Vegas. Hopefully, we can use our experience from last year to spur us on and return with the Prize."
Amanda Curry, Alana Team Leader

amazon alexa

@alanathebot
#AlexaPrize

Parliamentary receptions mark end of highly successful Year of Robotics

Academics and students from the Centre, along with guests from industry, attended a reception hosted by Gordon MacDonald, MSP for Edinburgh Pentlands, at the Scottish Parliament on Wednesday 8th November to celebrate Heriot-Watt's 'Year of Robotics'. Professor Oliver Lemon, Director of the Interaction Lab at Heriot-Watt University, outlined how the Centre's research is contributing towards the UK's drive to realise its industrial potential in the rapidly evolving robotic sector. He also shared the University's success in the Amazon Alexa Challenge.

Principal Professor Richard Williams, MSP Shirley-Anne Somerville and Professor Oliver Lemon

Principal Professor Richard Williams acknowledged the success of the 'Year of Robotics' initiative, which included hosting the European Robotics Forum in March which attracted 800 delegates, and numerous outreach activities that inspired more than 1,400 school children, 3,000 members of the public and 150 industry partners through face-to-face sessions with our robots and researchers. The Principal highlighted the Edinburgh and South East Scotland City Deal which includes funding for the UK National ROBOTARIUM, and shared the news of the £36m ORCA project to develop robots for offshore energy that was announced just that day.

A reception was also held on 21st November at the Palace of Westminster to showcase the Centre's work to MPs. Academics and students attended to talk about our research activities and to demo some of the robots that the Centre is currently working with.

These dynamic, hands on and interactive events gave the Centre an opportunity to engage with MPs and MSPs to increase awareness and understanding of the potential for robotics in Scotland.

CDT student Siobhan Duncan talks robotics with Baroness Neville-Jones at the Westminster reception

Dr Katrin Lohan with Pepper, the robot at the Westminster reception

Highlights 2017-18 (cont)

UK Robotics Week
21st - 29th June 2018

The Centre was again active during UK Robotics week and the following activities give a snapshot of some of the events in which we participated.

Workshop on Complex Cyber Physical Systems 2018

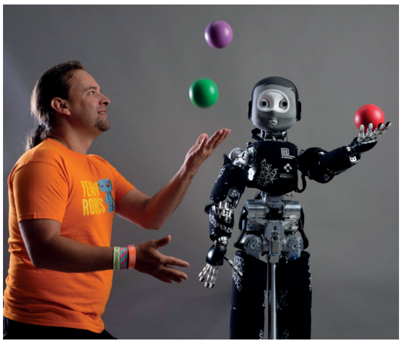
Dr Katrin Lohan organised this workshop during UK Robotics Week to discuss novel quantitative and qualitative methodologies to systematically quantify the predictive ability of cyber physical systems in the interface with humans, with a particular focus on the human factor in cyber physical systems, bridging from social signals to IoT systems.

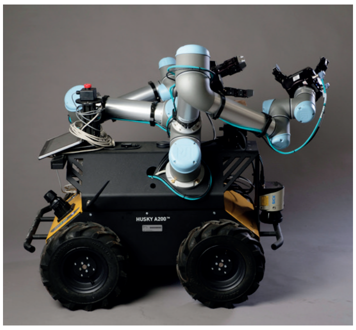
Speakers at the workshop included Professor Alessandro Vinciarelli (University of Glasgow), Associate Professor Dr Serge Thill (University of Plymouth), John Perry (Denchi Power), and Dr Suphi Erden and Dr Mauro Dragone, both from Heriot-Watt University.

The workshop attracted 30 participants and included academics, current and prospective students.

Human Robot Interaction Laboratory

The HRI lab did some demos of its robots for school pupils who were on work experience placements. Affiliated student, Ingo Keller, showed the pupils some of the research work involving the iCub and the Flash robot.





Liverpool International Business Festival, 21st June 2018

ORCA Hub Members participated in the 2018 Liverpool International Business Festival during UK Robotics week. Prof Mike Fisher (University of Liverpool) presented the Hub members plans for significantly improving safety and efficiency in the offshore energy sector. Attendees had the opportunity to visit the ORCA stand to meet the Heriot-Watt University Husky robot, a rugged unmanned ground vehicle.

Centre Students achieve Entrepreneurial Success

To further innovation from research underway in the Centre, the CDT has some modest resources available to assist with the preparation of prototype hardware and/or software that could lead to a commercial idea. To date, two groups of students have taken advantage of this funding to pay for consumable items or small pieces of essential equipment to develop their prototypes. One of the groups has been very successful in attracting additional funding through participation in a number of competitions.

ECR student Wolfgang Merkt and research assistants Yiming Yang and Vladimir Ivan are developing a high-performance, high-payload, and high-precision mobile manipulation collaborative robot along with an accompanying AI software platform to target applications such as smart manufacturing. The team is supported by Professor Sethu Vijayakumar as Chief Scientific Advisor.

The project draws on over ten years of experience developing, integrating, and deploying state-of-the-art robotic applications in industry and research.

Leveraging the CDT Innovation Funding along with personal funds and competition prize money, the team – under the name Adabotics – completed a full prototype that has been used in research projects and evaluation studies and iterated based on industrial customer requirements and user input.

Adabotics has also been very successful in international business and artificial intelligence competitions including a 2nd Prize at the UK Division Finals of the Shenzhen Innovation & Entrepreneurship International Competition, a 3rd Prize at the Global Finals for Smart Manufacturing of the Shenzhen Innovation & Entrepreneurship International Competition, and the 1st Grand Prize of the Nanjing Global Artificial Intelligence Application Competition.



Yiming Yang and Wolfgang Merkt receiving the 1st Prize in the Nanjing Global Artificial Intelligence Application Competition in Nanjing on September 6, 2018 from Nanjing Mayor and Vice Governor of Jiangsu Province Mr Lan Shaomin at the China Artificial Intelligence Summit.

Images courtesy of China AI Summit.

Achievements

Team Edinbots take part in RoboCup 2018 Rescue Simulation League

A team of students represented the Edinburgh Centre for Robotics at RoboCup 2018 in Montreal, Canada from the 15th to the 22nd of June. RoboCup is a robotics event that brings teams together from around the world to compete in a variety of challenges that the Robotics sector may face both now and in the future.

RoboCup 2018
MONTRÉAL · CANADA

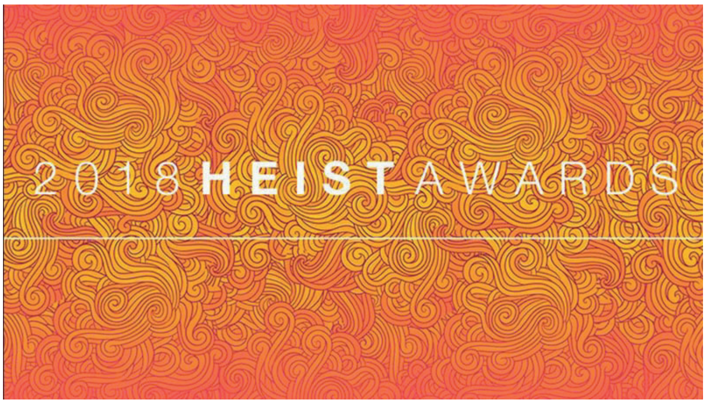
Team Edinbots competed in the Rescue Simulation League, a challenge where a group of robots navigate autonomously through an unknown disaster environment in search of victims. Edinbots competed against a team from Cambridge University in an exhilarating, fast-paced and tight final set of 4 matches, with Cambridge winning by an extremely narrow margin.
Despite this the students felt that participation in this challenge was a great learning experience. Several members of the team are working on PhDs directly related to Swarm Intelligence or on research that spans multi-sensor fusion, image processing and software engineering, so the students' involvement was especially relevant for their studies.

Hugo Sardinha, PhD student in the 2016 cohort and RoboCup participant, commented:
"Competitions such as the RoboCup are an incredible opportunity, allowing students to develop, test and improve their current work, which in turn stimulates competitiveness and creativity. The team is deeply grateful to the Centre for supporting us and making this great experience possible!"

L to R: Vibhav Bharti, Ingo Keller, Hugo Sardinha, Siobhan Duncan

Heriot-Watt and the Edinburgh Centre for Robotics shine at UK awards

For almost three decades, the 'Heist Awards' have been synonymous with excellence and innovation in education marketing and Heriot-Watt University was delighted to be one of only six institutions short-listed in the prestigious 2018 Heist Awards held in Manchester in July 2018. The University received the Gold award in the 'Best Marketing Initiative to Promote Research Excellence' category for its Year of Robotics campaign, held throughout 2017 with a packed calendar of events involving schools, the public, academia, industry collaborators, funders and policy makers.



Accepting the accolade on behalf of Heriot-Watt University and the Year of Robotics team, Martyn Spence, Director of Marketing and Communications, said:

"It is a tremendous honour to be once again recognised with a Heist Award for a campaign that really captured the imagination and delivered on all levels. It was always our intention to reach out to a wide audience across various countries and, I'm proud to say, we worked together to achieve this goal whilst successfully promoting the University's world-class reputation for Robotics, Artificial Intelligence and Human-Robot Interaction. This award is testament to the dedication and team work of a university-wide group of academics and professional staff who demonstrated a real passion for their research and a willingness to work together to reach audiences as diverse as school children and senior government ministers.

Commenting on Heriot-Watt University's achievement, the judging panel remarked:
"Heriot-Watt University have triumphed with this shining example of world-class UK research. This initiative is a master-class in showcasing research and making it relevant to a number of audiences and was an out and out winner with the judges."

This award followed on from success in the Herald Higher Education Award where Heriot-Watt University won 'Campaign of the Year' for Year of Robotics 2017.

Receiving the award on behalf of Heriot-Watt University, Dr Laura Wicks, Public Engagement lead, commented:
"Thanks to all who contributed to this massive effort. It's really great to have this recognition outside the University – we were up against strong competition from other universities in Scotland so it's amazing to win."

Achievements (cont)

Turing Fellow Appointment

Dr Subramanian Ramamoorthy has recently been appointed as a Fellow of the Alan Turing Institute. He is based primarily within the ATI offices in the Bayes Centre in Edinburgh and will help drive the Institute's scientific programme in collaboration with other partners.

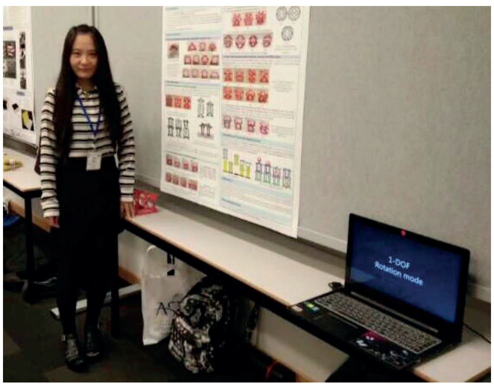
The University of Edinburgh is a founder member of the Alan Turing Institute, the UK's national institute for Data Science and Artificial Intelligence. The Institute's goals are to undertake world-class research in data science and artificial intelligence, apply its research to real-world problems, drive economic impact and societal good, lead the training of a new generation of scientists, and shape the public conversation around data.

Influential Paper Award

Dr Ron Petrick was awarded an Influential Paper Award at the 2018 International Conference on Automated Planning and Scheduling (ICAPS) in Delft, Netherlands, for his paper "A Knowledge-Based Approach to Planning with Incomplete Information", co-authored with Professor Fahiem Bacchus from the University of Toronto. This award recognises papers that have significantly influenced automated planning research and is one of the top honours in the ICAPS community.

Student Success in Robot Design Competition

Jieyu Wang, a third-year affiliated PhD student supervised by Dr Xianwen Kong and Dr Matt Dunnigan, was selected for the final round of the 2018 ASME (America Society of Mechanical Engineers) Student Mechanism and Robot Design Competition. The competition took place at the ASME 2018 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference (IDETC/CIE 2018) in Quebec City, Canada during 26-29 August 2018. Jieyu's project is about the design of deployable mechanisms with multiple-mode constructed using symmetric spatial triads. She was provided with an $800 travel fund from the competition organizer to participate in the competition in Canada. This was the third external travel grant that Jieyu has received for attending international conferences during her PhD study.



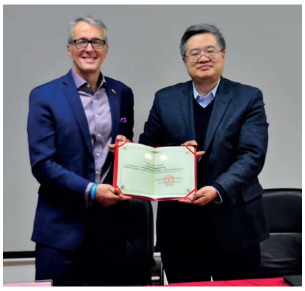
ENEI Keynote and Workshop

Wolfgang Merkt (2014 cohort) delivered a keynote at the Encontro Nacional de Estudantes de Informática (ENEI) at the University of Porto in March 2018. ENEI brings together 500 computer science students from across Portugal and is the premier conference of its kind. Wolfgang gave one of the headline keynotes alongside the inventor of MINIX Prof. Andrew S. Tenenbaum which received wide media coverage including national newspapers and television.
In the afternoon, Henrique Ferrolho (2017 cohort) gave a well-attended hands-on workshop as a practical introduction to robot kinematics.

Keynote and Workshop.
Images courtesy of ENEI

Centre Director - overseas appointments

Professor David Lane was appointed to Honorary Distinguished International Visiting Professor positions in Shenyang and Zheijiang Universities in China.



CDT students secure prestigious internships

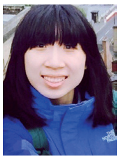
Five of the Centre's students are currently undertaking internships with organisations at the forefront of AI and machine learning technology. These internships are an excellent opportunity for students to gain experience of working in research within a large organisation and we are confident that skills gained will be beneficial when they return to their PhD studies.

Andrew Brock (2015 cohort) Interning at DeepMind, where he is engaged in cutting-edge scientific research involving technologies.

Boris Mocialov (2015 cohort) has been working with Adobe on a system that will predict project development success at early stages through the use of machine learning.

Ross McKenzie (2015 cohort) is working with the Cyber and Information Systems Division in the Defence, Science and Technology Laboratory (DSTL) focusing on aspects of Artificial Intelligence.

Tatiana López-Guevara (2015 cohort) has secured a four-month long internship at Google in Zurich.



Xinnuo Xu (2016 cohort) is on an internship with the Conversational Systems Group in Microsoft Research, Redmond, USA working on task-oriented dialogue evaluation using Generative Adversarial Networks.

Student Activities

Heriot-Watt University Robotics Society - Union of automation and interaction

The Society, which now has over 200 members ranging from undergraduate to postgraduate students, has had another busy year with members working on a range of projects to promote STEM subjects.

One of these projects involves working together with the BBC to introduce micro:bit, a tiny programmable computer, into a local school where there are limited opportunities for working with robots. The aim of this project is twofold; to teach pupils in the early years of secondary school to programme, and to encourage interest in STEM subjects. To become involved in this initiative, undergraduate students from the Society proposed a project which involved designing 3D-printed K9 robots as featured in Dr Who with integrated micro:bits. The Society is currently preparing the robots before they are given to the pupils for assembly, and programming for simple tasks such as following light or sound. The Society aims to provide a unique micro:bit experience to the pupils so they are more likely to see their potential as engineers.

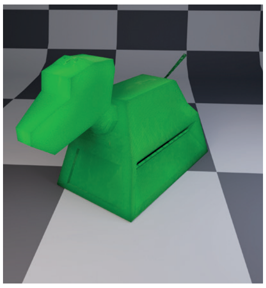
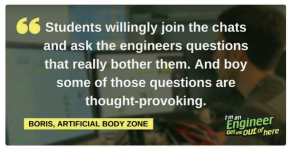


Image courtesy of Jack Rome

Society members, Siobhan Duncan and Boris Mocialov from the CDT, and affiliated student Ingo Keller, were awarded 3rd prize at the Watt Ventures Awards for their pitch for their business idea EduBot – Robotics Education for Kids.
During the 2017 Year of Robotics, it became apparent to the team that there are limited opportunities for children to interact with, test and programme robots in a safe learning environment. Although teachers are eager to incorporate robotics in their lessons, schools do not have the resources or skills to deliver world-class robotics teaching in the classroom, which puts Scottish children at a disadvantage in an ever increasingly automated world.
This led the team to come up with the idea of EduBot, a low cost educational robotics platform which can be leased or sold to schools to deliver learning resources and workshops. Their winning video is available here https://1drv.ms/v/s!Auc-jB-azCtUcqs1Z2j34ZDLQh8

CDT student, Boris Mocialov, participated in the competition "I'm an engineer, get me out of here" in the artificial body zone category. During the competition, students from schools across the UK asked six competing engineers questions about building robotics and prosthetics and then chose their favourite engineer. Boris won the most votes and £500 to invest in future Society activities.


I'm an Engineer Team
@IAEGMOOH
Follow

Winner of the @wellcometrust Artificial Body Zone and PhD student @HeriotWattUni Boris @mocialov says he enjoyed chatting with students about "how amazing and entertaining engineering can be". Read his thank-you message here: artificialj18.imanengineer.org.uk/2018/06/26/tha ... #IAEUK

3:00 PM - 28 Jun 2018

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flickr https://www.flickr.com/groups/hwu-roboticssociety/

E-mail hwuroboticssociety@gmail.com

Student Journal Club

The students of the RAS CDT run a Journal Club which meets every two weeks with two speakers presenting a recent paper in their field. It is now in its second year and the presentations continue to give rise to lively debates, with the latest cohort showing great interest in attending and presenting. Topics have included EMG signals, analysis of control schemes and swarms. The Journal Club has no specific robotic theme, which encourages a broader spectrum of opportunities and challenges for the participants. Since the research work of the RAS CDT students is so diverse, the journal club is able to provide a range of learning possibilities for the attendees, exposing the students to areas of research that they may not have otherwise encountered. Furthermore, it brings together the students from both universities and provides them with the chance to network with each other, either through discussion that arises from the questions presented to the speaker, or during the break over a few slices of pizza.

The journal club also allows the students to practice their presentation skills. The format of the presentation is entirely up to the speaker, which gives them the freedom to try out new presentation styles. What makes the Journal Club presentations challenging, however, is that students are presenting research in a field that may not be familiar to all the attendees. The speakers therefore need to learn how to make a presentation that is not only interesting and highlights the importance of the paper but is also accessible to all those attending. The majority of the attendees have now presented, and those still to do so, mostly the latest cohort, have been enthusiastic about speaking at future meetings, so finding speakers has never been difficult. The journal club gives the students an invaluable experience as it helps with presenting to a challenging audience, and it broadens the students' academic horizons.

Student Activities (cont)

CreatED 2018: 24-hour Hackathon

CreatED 2018 was a 24-hour hardware Hackathon organised by the Heriot-Watt Robotics Society and the Robotics Society at the University of Edinburgh. Around one hundred attendees queued outside the Appleton Tower at the University of Edinburgh waiting to collect their t-shirts and wrist bands. Some had backpacks and sleeping bags with them as they had travelled from afar including from overseas to be a part of this fantastic event.

Representatives from sponsoring companies gave workshops and mentored the participants as they engaged in their various projects. As night fell, two rooms at the Appleton Tower were made available for sleeping. However, many participants preferred to remain at their work stations to focus on improving their projects, many of which had already started to take shape.

Sleepless nights can lead to a very lazy morning, but not for the participants of the CreatED Hackathon. Even before breakfast the ground floor of the Appleton Tower was a hive of activity as participants prepared to present their innovative projects, with small final touches being made before the 'gong' , signifying the end of the Hackathon, sounded. Once all the participants had made their presentations, everyone made their way to one of the lecture theatres for the announcement of the winners and the closing ceremony.

Boris, PhD student - 2016 cohort, and one of the organisers of the Hackathon, commented:

"Hackathons are important for generating ideas and trying out new equipment in a very short time. Although it was a demanding weekend, everyone who took part agreed that they would love to come back again next year."

For more information see: https://createdhack.github.io/

Image courtesy of Boris Mocialov

Women in Robotics, Edinburgh

WiRE - Women in Robotics Edinburgh

WiRE is an ambitious initiative led by the female RAS CDT students to encourage more female undergraduates to follow a career in Robotics through the provision of workshops and keynotes.

The Society has already made an impressive start with Dr Jessica Hamrick, a Research Scientist from DeepMind, accepting an invitation. Dr Hamrick shared not only her experiences as an undergraduate and PhD student, but also presented her work on Meta-Reasoning and Mental Simulation at DeepMind.

WiRE member Siobhan Duncan had successfully organised a Google Hash Code team programming competition and had 30 attendees from companies and universities across the Central Belt signed up to participate. This was to be held in conjunction with a talk from Dr Amanda Prorok from University of Cambridge but unfortunately both events had to be cancelled due to severe weather conditions. It is hoped that both the hackathon and the talk can be rescheduled in the near future.

WiRE members Raluca Scona, Tatiana Lopez and Elizabeth Vargas with Dr Jessica Hamrick (2nd from left)

@womenroboticsed

Public Outreach

Centre Academic speaks at Public Workshop on Current Trends in AI

Dr Ron Petrick was an invited speaker at the Current Trends in Artificial Intelligence public workshop hosted by DTU Compute in Copenhagen, Denmark. The workshop brought together researchers from academia and industry working on different aspects of artificial intelligence, from machine learning to logic-based methods, who were asked to reflect on their own research, and where the field as a whole was heading. A short documentary from the event called "AI: Beyond Fear" was released by the Science & Cocktails Foundation.

Workshop website: http://www2.compute.dtu.dk/~tobo/trends-in-ai2/
Documentary: https://youtu.be/6y5N6DGJqxg

Professor's talk inspires pupils to study STEM subjects

Professor Helen Hastie was invited by Merchiston Castle School to be the guest speaker at their Scholars' Dinner where she spoke about human-robot interaction and the purpose of humans when robots start to take over jobs. Although it is anticipated that occupations that require routine work may soon be replaced by robots, Professor Hastie reassured the pupils that occupations that require problem solving, creativity or flexibility will not be affected in the near future, since a lot of development work still needs to be done in the field of AI. The pupils had a chance to play with some Miro robots and all agreed that Professor Hastie's talk had provided them not only with an insight into the rapidly developing technological world but with inspiration to study STEM subjects.

Dumfries and Galloway Science Festival

RAS CDT students Siobhan Duncan and Boris Mocialov attended the Dumfries and Galloway Science Festival along with Nathan Todd and Klaudia Kleczkowska from the Heriot-Watt Robotics Society.
The event took place on Saturday 21st April at Easterbrook Hall in Dumfries. Students demonstrated some of the small robots that belong to Edinburgh Centre for Robotics and the Robotics Society, showing the audience the inner workings of the robots and explaining how robots can walk and talk, and are aware of surroundings and people. The younger members of the audience were mainly interested in playing with robots, which is undeniably the first step towards acceptance of robots in society.
Attendees were fascinated by the variety of robots available and their applications in industry and in the home, with the event being hailed as a success in educating the public about robots and their impact.

ECR students take part in Robotics & Artificial Intelligence discussion

Centre students Teun Krikke, Joao Moura, Xinnuo Xu and Martin Asenov sat on the Robotics & Artificial Intelligence Panel - EUYSRA. Teun reported that the event attracted a diverse crowd of students from a variety of educational backgrounds including Biology, Engineering, the Arts and Sociology. The students asked a wide range of questions during both the presentations and the panel discussions.

One student asked the panel to discuss Elon Musk, Stephen Hawking and the dangers of AI. This proved to be one of the most interesting discussion topics and also presented the panel with some of the most challenging questions to answer.

Further discussion centred around robotics and where the field of Robotics & Autonomous Systems would be in 20 years with a strong focus on the extent to which robots can mirror human behaviours.

Socially Competent Robot (SoCoRo) team attend Scottish Autism Conference

Ever wondered what it would be like to have a robot boss or robot colleague? This is just one of the topics raised by the Socially Competent Robot (SoCoRo) team at this year's Scottish Autism Conference. The event, hosted by the Edinburgh International Conference Centre (EICC) on 28th March, gave researchers the opportunity to openly discuss the SoCoRo project aims, and gather feedback from a variety of interested parties including parents of autistic children, academics, teachers, and adults with Autism Spectrum Disorder (ASD).

The overall goal of SoCoRo is to design a robot that will deliver behavioural skills training for adults on the spectrum who are seeking employment. Alyx (the robot) will be deployed as a tool to develop the specific vocational and social requirements of clients, based on the job they are pursuing. A user-centred approach to autism therapy is important, given the varied presentation of the condition. For example, some autistic adults may be socially introverted, whereas other are comfortable in conversation.

Dr Peter McKenna summarised the conference as follows:

"In terms of feedback, the audience agreed the user-centred approach gave the project added value. Adults with autism indicated they would happily interact with Alyx once familiar with it, and were enthusiastic at the prospect of a robot-based vocational training day."

Dr. Thusha Rajendran, one of the project's primary investigators, wrapped up the session adding that in order for autism therapy to move forward, research and other domains should embrace the philosophy of neurodiversity. Typically, autism is perceived as a condition, with a focus on the individual and how to change them. Conversely, neurodiversity stresses the importance of individual differences, and that society should consider changing and reshaping the environment to fit people's strengths. Robots could well be the way forward in this domain, as they provide a non-judgemental social interaction partner for social skill practice and rehearsal. Thus, the reality of social robots is quite different to that painted in dystopian sci-fi; robots could help give people the tools for independence, rather than try to strip them of it.

Public Outreach (cont)

IET ENgfest

RAS CDT students Vibhav Bharti, James Horn and Siobhan Duncan exhibited some of the Centre's robots at the IET (Institute of Engineering and Technology) headquarters in London as part of the Festival of Engineering in October 2017.

The students took along some of the Centre's smaller robots including a NAO, some Spheros and Hamilton which they exhibited on a stand which also contained Edinburgh Centre for Robotics promotional material and banners.

The students set the NAO to dance, drawing a large crowd of children and adults, mesmerised by its cool moves to tunes including Thriller, Macarena and Gangnam Style. Siobhan Duncan reported that the NAO is a great tool for engaging people with robotics as it has a wide range of movements, allowing it to dance or mimic movements like push-ups. Its functionality, such as the ability to play sounds effects, allowed the students to combine R2D2 sound effects to go with a Star Wars routine.

The Spheros robots were set up to race each other around the exhibitor's area. This particular demo was a big attraction as children really engage with activities in which they are directly involved and nothing is more hands on than racing a remote controlled robot.

The stand was constantly busy with young people asking questions about the different robots that had been taken to the Festival and also those that are based in the ROBOTARIUM. The Centre students had lots of opportunities to engage with young people to explain the link between STEM subjects and a career in robotics.

ECR represented at Future Combat System Expo 2018

Heriot-Watt University and the Edinburgh Centre for Robotics was represented in the Future Combat Systems Expo 2018, that took place on the 3rd of July and was organized by BAE Systems. This forum was an opportunity for the Centre to present its research and engage with industry to identify the most pressing needs in the area of underwater systems.

Sending your robot to Mars? List of things to pack

Sethu Vijayakumar participated in TEDx Glasgow on Friday 1st June, giving a talk entitled 'Sending your robot to Mars? List of things to pack'.

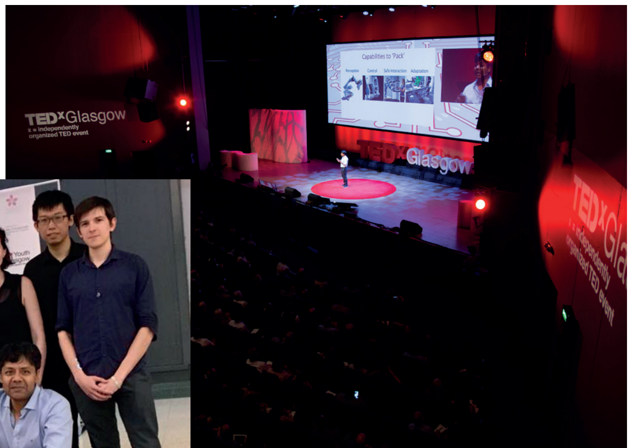
In his talk, Sethu outlined the capabilities that would be required for a successful unmanned robotic pre-deployment mission to Mars, drawing on the Centre's expertise in large-scale learning and control of highly complex robotic platforms which is an excellent fit with NASA's roadmap of the Mars missions. Unmanned robotic pre-deployment would make such missions around 50-60% cheaper, much more sustainable longer term and help validate untested technology in the field without putting human lives in danger.

In addition to talking about the Mars mission, Sethu described how the core technology being developed and deployed in the area of 'shared autonomy' has interesting spillovers in other domains. The Centre is exploring its use in the asset inspection and maintenance of large offshore oil and gas rigs, as well as hard to access infrastructures, such as drainage, high rise buildings and bridges using robotic deployment. Similar technology is helping solve the problem of efficient control of exoskeletons and prosthetic devices in shared control paradigms on human bodies.

Three live robotics demonstrations were also included, with students from the Centre joining Sethu to assist with the robots.

A short interview given by Sethu ahead of the event can be read here: http://www.tedxglasgow.com/2018/05/sethu-vijayakumar-robotics-and-mars/

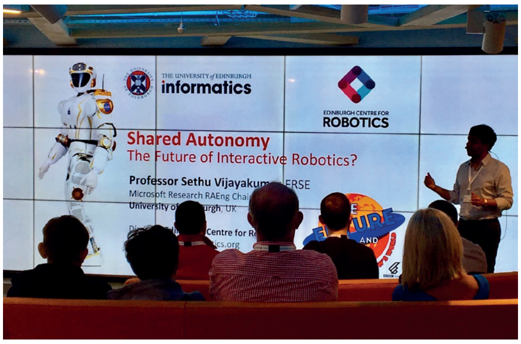
The talk can be viewed online here: https://youtu.be/kj4NZrdGQhs



Public Outreach (cont)

Professor Sethu Vijayakumar speaks at OGTC's Tech20

The Oil and Gas Technology Centre (OGTC) has launched a series of weekly events called 'Tech20'. It is hoped that these social showcases, where speakers present a technology focused topic, will inspire a culture of innovation in the North-East of Scotland.



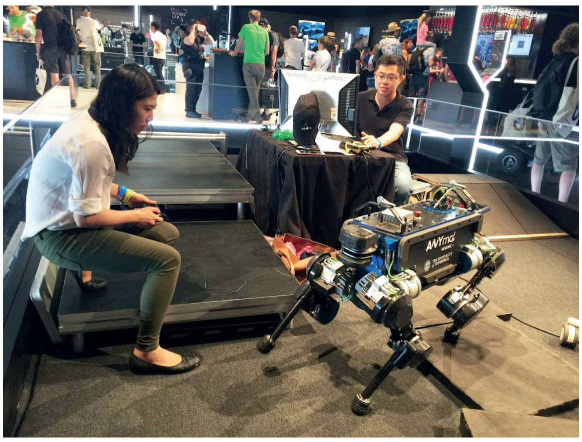
On March 30th Professor Sethu Vijayakumar participated as a keynote speaker at the OGTC in Aberdeen as part of the Tech20 event series. His talk was titled: Shared Autonomy: The Future of Interactive Robotics?

In his talk he discussed compliant actuation and scalable machine learning techniques for real-time learning and adaptation, shared representations and robust multi-modal sensing. He highlighted technologies that are enabling us to reap the benefits of increased autonomy while still feeling securely in control.

ANYmal Attends Goodwood Festival of Speed

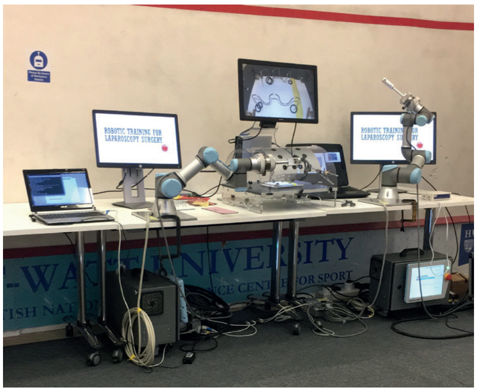
Centre Academic Dr Michael Mistry took the quadruped robot, ANYmal, and a team from the Edinburgh Centre for Robotics to the Goodwood Festival of Speed in mid-July. The ANYmal robot can move and operate autonomously in challenging terrain and is being deployed in the Centre's ORCA Hub 'Planning, Control and Manipulation' stream of work which is led by Dr Mistry.

The team gave demonstrations of ANYmal as part of the Future Lab exhibit throughout the course of the weekend and members of the public had the opportunity to shake hands with a quadruped robot.



Edinburgh International Science Festival

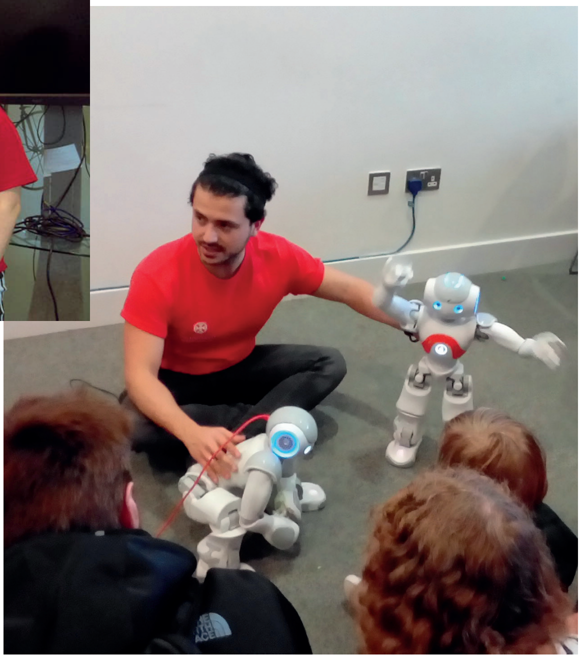
Dr Suphi Erden's research group demonstrated the Robot Assisted Surgical Training Setup at several venues across Edinburgh between 9th to 14th April. The advertising for this event read as follows: "Discover how robot assistants can help you perform keyhole surgery! You'll find demonstrations and explanations to help you find out about what it feels like to be a surgeon. You'll even have the chance to try out the laparoscopy training box, watching how robots can help make moving surgical instruments more accurate and precise."



As described above, the aim of this outreach activity was to demonstrate a co-manipulated robotic system for laparoscopy training and to inform the public about co-manipulated robotic systems as applied in the medical domain for training and assistance purposes. The demonstrations also allowed the public to interact with the system in order to show how a human and a robot can use a medical instrument together.

Students also demonstrated a couple of the robots from the Centre. The NAO interactive demo involved hooking the robot up to a laptop and then allowing children to program basic movements, including waving and sitting down. Pre-programmed demos, which wait for activation through a pat on the head, were set up so that younger children could also participate.

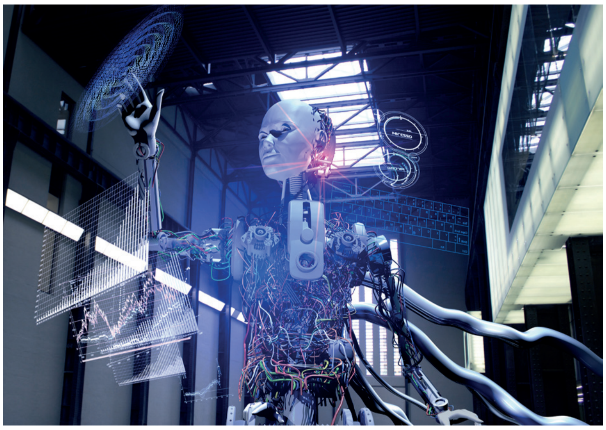
Spheros which were remote controlled through android tablets were set up in a small arena contained by a plastic chain and children took turns using the remote controls to change their colours. They were then tasked with showing the next person in line how to use the App on the tablet.



Collaboration

Research partnership signed with prestigious Chinese robotics laboratory

The Centre signed a Memorandum of Understanding with the prestigious State Key Laboratory of Robotics in Shenyang to work on joint research projects in marine, nano, energy and medical robotics. The agreement was announced during First Minister Nicola Sturgeon's trade mission to China in April 2018.



"We've been speaking in-depth with the State Key Laboratory of Robotics for a number of months, and it's fantastic to see the partnership up and running. This closely forged relationship will only benefit our already highly-successful cutting-edge robotic and artificial intelligence research."
Professor David Lane, Centre Director

"We're delighted to sign this very significant Memorandum of Understanding with the Edinburgh Centre for Robotics. Not only will it establish a collaborative relationship in scientific research, personnel visiting and scholar exchange – it will also bring two countries together in a very highly skilled research industry."
Professor Shuo Li, Deputy Director of The State Key Laboratory of Robotics

Collaboration agreements with overseas universities

The Centre has been very active in building relationships with prestigious overseas universities to facilitate international training for CDT students through placements. The following institutions have indicated that they would be delighted to host CDT RAS students to study topics and applications of common interest for an extended period of several months.

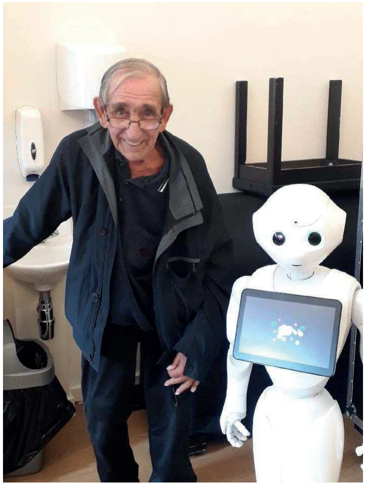
Carnegie Mellon University, USA
Cornell University, USA
Fudan University, China
Harvard University, USA
Istituto Italiano di Tecnologia (IIT) in Italy
Queensland University of Technology
Shenyang Institute of Automation, China
The University of Sydney, Australia
Universitaet Bremen, Germany
University of Maryland, USA

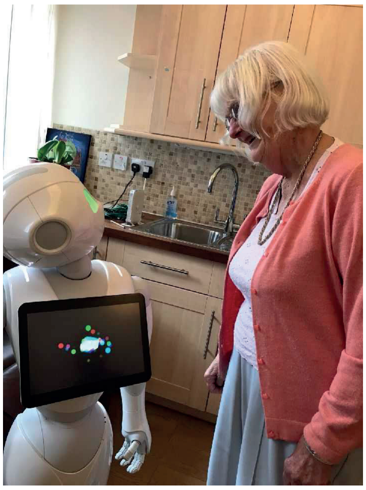
COLLABORATION
EDINBURGH CENTRE FOR ROBOTICS

Pepper plays dominoes with elderly in Edinburgh social club

Every Tuesday, Wednesday and Thursday, the Dean Social Club in the LifeCare Centre in the Stockbridge area of Edinburgh, welcomes its elderly members for half a day packed with social activities including music, tai-chi, dominoes and Scrabble. The mission of the centre is to help Edinburgh's lonely and isolated over-60s by providing companionship that is integrated with local communities.

Pepper the robot joined them recently to play dominoes and was an instant hit.





MSc student Guillaume Gautier and PhD student Scott MacLeod programmed the robot under the supervision of Dr. Mauro Dragone at Heriot-Watt University. This research work is part of the ongoing effort from Heriot-Watt's researchers to work with care organisations such as LifeCare, and people with assisted living needs, to co-design and test innovative solutions for healthy ageing and independent living.

"This specific project will contribute to our understanding of what value robots like Pepper can bring to the social care sector, for example, by helping to promote social inclusion and generally provide better support to persons in need and to the millions of unpaid and paid carers in the UK."

Dr Mauro Dragone, Edinburgh Centre for Robotics

Collaboration (cont)

RSE
The Royal Society of Edinburgh
KNOWLEDGE MADE USEFUL

Scotland–China Research Workshop: Robotics and Artificial Intelligence

The Royal Society of Edinburgh and the National Natural Science Foundation of China, supported by Edinburgh Centre for Robotics, hosted a joint research workshop "Robotics and Artificial Intelligence - A twenty year view".
The workshop, chaired by Centre Directors Professors Lane and Vijayakumar, hosted ten top Chinese robotics researchers in Edinburgh for two days of discussions and scientific collaboration on the themes of Field Robotics and Autonomy, Control and Planning, Computer Vision and Machine Learning, and Human-Robot Interaction.

Image courtesy of RSE

Strategic Partnership with Oil and Gas Technology Centre

Professor David Lane presented a plenary during the Oil and Gas Technology Centre 's Robotics Week from 30th October until 2nd November 2017, kicking off a strategic partnership between OGTC and Edinburgh Centre for Robotics.

Our Future Scotland Premiere and Launch

Professor Sethu Vijayakumar was invited to join a panel of Scottish leaders at the Scottish Parliament on Wednesday 16th May to explore aspirations for Scotland in 2030.

The programme opened with the showing of a 15-minute documentary produced in collaboration with Scotland's Futures Forum , a think-tank of the Scottish Parliament. The Our Future Scotland film showcases leading figures from politics, business, education and the arts on their aspirations for Scotland in 2030. It will be used in conjunction with a national social media campaign to gather the aspirations of people everywhere about what Scotland could look like by 2030. This participatory process will be used to inform parliament debate and policy making.

The panel debate on the themes raised in the film followed the screening, with Professor Sethu Vijayakumar from the Edinburgh Centre for Robotics representing the Robotics and AI sector.

Robotics: Utilities and Beyond

This event organised by the Institute of Gas Engineers & Managers (Scottish Section) and The Institution of Engineering and Technology (Scotland South East Network) took place at the Apex Grassmarket Hotel, Edinburgh. The event was intended primarily for members of these organisations but was also open to the public, and its main aim was to update members on the latest developments in robotics within industry and academia.

Keynote speakers included Sam Wilson, Head of UK Business Development at ULC Robotics; Wez Little, Innovations Director at Synthotech Limited, and Wolfgang Merkt and Joao Moura, from the Edinburgh Centre for Robotics.

Joao's presentation focussed on the Cab Front Cleaning Robot project which is a feasibility study conducted by Heriot-Watt University and Cranfield University in partnership with Chiltern Railways, Bombardier and Shadow Robotics. The project details the benefits of robotics' systems in the inspection and remediation of industry.

Wolfgang delivered a presentation on the challenges of employing robotics and autonomous systems in highly complex and dynamic environments, and proposed shared autonomy as a potential framework for combining the best attributes of humans and robots when working in such environments.

Wez Little and Sam Wilson focused on the utilisation of robotics in maintenance and inspection of pipe systems underground.

Feedback from the audience was positive and the consensus was that the presenters showed a breadth of interesting applications that detailed how robotics are positively impacting some specific areas of industry and ultimately improving our lives.

New Research Programmes

THING - subTerranean Haptic INvestiGator Project

THING, a project funded by the European Union's Horizon 2020 programme, will advance the perceptual capabilities of highly mobile legged platforms through haptic perception and active exploration. THING aims to deliver novel foot designs for enhanced tactile perception and locomotion; improved perceptual capability, enriching existing modalities (lidar, vision) with haptic information, heightened physical sense of the environment, including friction, ground stability (difficult through vision alone), and enhanced mobility through improved perception, prediction, and control.

The Alan Turing Institute

Alan Turing Institute Sponsored Project on Safety-Critical Artificial Intelligence

The focus of this project will be to develop methods to enable the analysis of behavioural properties and synthesis of safe planning and control strategies in autonomous robots. This will include, for instance, program induction methods to explain the policies learnt by deep reinforcement learning techniques, and programming-by-discussion interfaces to learn safety specifications from human users. The techniques will be developed in the context of assistive robotics in a surgical environment, working in collaboration with Dr Paul Brennan from NHS Lothian, Centre for Clinical Brain Sciences and University of Edinburgh.

START MAKING SENSE: Cognitive and Affective Confidence Measures for Explanation Generation using Epistemic Planning (EPSRC)

This project addresses the need for dynamic trust maintenance by bringing together experimental research in cognitive science involving cooperative joint action with the practical construction of AI planning tools, to apply to the task of explanation generation. The project will study cooperative action in humans to identify the emotional, affective, or cognitive factors that are essential for successful human communicative goals; enhance epistemic planning techniques with heuristics derived from the cognitive science studies; and deploy the resulting system to generate human-like explanations which will be evaluated by human participants. The project is a collaboration between Dr Ron Petrick from Heriot-Watt University and Dr Robin Hill from the University of Edinburgh.

ORCA - Offshore Robotics for Certification of Assets

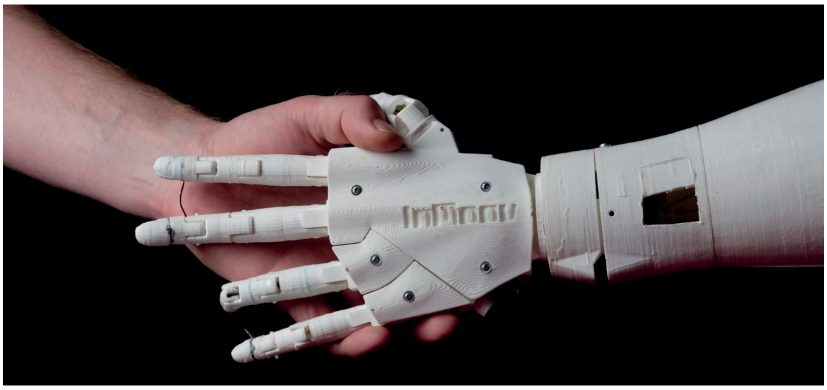
Edinburgh Centre for Robotics is leading the £36m UK consortium focused on applications in the energy industry. The hub which also involves the Universities of Oxford and Liverpool, and Imperial College London, seeks to develop, deploy and validate robotics and AI (RAI) for the inspection, maintenance and repair of offshore oil and gas and renewable sector installations.

FAIR-SPACE - The Future AI and Robotics Hub for Space

Researchers at the University of Edinburgh are bringing their expertise to a project focused on next-generation challenges in the space industry that will build on strong collaborative ties between the Edinburgh Centre for Robotics and NASA, forged by their ongoing Valkyrie humanoid project. The aim of the Hub, led by the University of Surrey, is to push the boundary of AI robotics for future space utilization and exploration. In the immediate term, the Hub will help advance knowledge and technologies in orbital manipulation, extra-terrestrial vehicles, and robotic support for astronaut missions. These directly address technical priorities in the space sector worldwide. In the long term, the Hub will help transfer the field to a new era by achieving long-lived robotic operations in space.

NCNR - the National Centre for Nuclear Robotics

University of Edinburgh academics will make use of their own robots in a research hub focused on the nuclear industry.
The £11.4m National Centre for Nuclear Robotics (NCNR), led by the University of Birmingham, seeks to exploit RAI to tackle challenges in nuclear decommissioning, exploration and asset maintenance.
Scientists and engineers at University of Edinburgh will use robots they have developed, such as the four-legged ANYmal, to contribute to research into navigating complex or extreme environments.



Research Outputs

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ROBOTARIUM

ROBOTARIUM
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The Centre's state of the art ROBOTARIUM comprises four integrated and interconnected components which create a capability, unique in the world, for exploring collaborative interaction between remote teams of human, robots and their environments at all levels. It is transformational in the range of robot scales and environments that can be experimentally configured, and in the way the study of physical interaction through robot embodiment can be linked to the study of human interaction/expression, robot collaboration and real in-field remote operations for mapping and intervention.

The four components are as follows:

Interaction Spaces for humans and robots to work together in physically separate indoor spaces.

Field Robotic Systems comprising humanoids and unmanned vehicles for operations inside or outside the spaces.

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Using this approach, the Centre's technologies and skills have created, seeded 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 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 inspecting inside pipelines and tubular structures externally. Other new designs of prosthetic hands have benefited from advanced control system design using machine learning. From our work, affordable fully programmable, customisable walking robots for children, makers and educators are revolutionising how robotics, AI and related 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 that is growing, with limited resources. 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.

We engage at the highest levels of Government in both the UK and Scotland to support development of the UK's industrial strategy. Through the AI Sector Council and creation of the National Robotics Enterprise and the Robotics Growth Partnership between UK industry and Government we 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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