The 2nd UK Robot Manipulation Workshop

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dyson Imperial College Robotics Lab London

ocado TECHNOLOGY

Shadow Robot Company

IET Communities The Institution of Engineering and Technology

Programme: Monday 10th July

Registration, refreshments, posters and demos are held in the main foyer of the SAF Building.
Talks are held upstairs in room G34 of the SAF Building.

09:30-10:30 **Registration and Refreshments**

10:30-10:45 **Welcome and Introduction**

10:45-12:00 **Invited Talks: Learning and Interaction** (Chair: Ed Johns)

10:45-11:10 Petar Kormushev (Imperial College London)
Learning for Robotic Loco-Manipulation

11:10-11:35 Raia Hadsell (DeepMind)
Deep Reinforcement Learning for End-to-End Grasping

11:35-12:00 Yiannis Demiris (Imperial College London)
Human-Centered Robot Manipulation and Learning

12:00-13:00 **Lunch**

13:00-14:00 **Tutorial** Gerhard Neumann (University of Lincoln)
Policy Search Methods for Robotics

14:00-14:45 **Poster Spotlights** (Chair: Maurice Fallon)

14:00-14:15 Luke Cramphorn (University of Bristol)
Tactile Manipulation through Biomimetic Touch

14:15-14:30 Josie Hughes (University of Cambridge)
Tactile Sensing using Conductive Thermoplastic Elastomer for Manipulation

14:30-14:45 Edward Johns (Imperial College London)
Scalable End-to-End Visuomotor Control

14:45-15:45 **Posters, Demos, and Refreshments**

15:45-17:00 **Invited Talks: Computer Vision** (Chair: Mehmet Dogar)

15:45-16:10 Andrew Davison (Imperial College London)
From SLAM to Manipulation

16:10-16:35 Maurice Fallon (University of Oxford)
Mapping, Tracking and Motion Planning for Complex High Degree of Freedom Humanoids

16:35-17:00 Jeremy Wyatt (University of Birmingham)
Machine Learning for Grasping and Pushing

17:30-19:00 **Drinks Reception** (At Eastside Restaurant and Bar)

19:00-21:00 **Dinner** (At Eastside Restaurant and Bar)

Programme: Tuesday 11th July

Registration, refreshments, posters and demos are held in the main foyer of the SAF Building.
Talks are held upstairs in room G34 of the SAF Building.

08:30-09:00 **Registration and Refreshments**

09:00-10:40 **Invited Talks: Haptics and Design** (Chair: Nicolas Rojas)

09:00-09:25 Nathan Lepora (University of Bristol)
Biomimetics and AI for Tactile Robotics

09:25-09:50 Fumiya Iida (University of Cambridge)
Model-Free Design Automation of Soft Robotic Hands

09:50-10:15 Lorenzo Jamone (Queen Mary University of London)
Some Important Ingredients for Robotic Manipulation: What Do You Need to Grasp an Object?

10:15-10:40 Ravinder Dahiya (University of Glasgow)
Energy-Autonomous Electronic Skin

10:40-11:00 **Refreshments Break**

11:00-12:15 **Invited Talks: Industry** (Chair: Jeremy Wyatt)

11:00-11:25 Graham Deacon (Ocado Technology)
Soft Manipulation in the Delivery of On-line Grocery Orders

11:25-11:50 Jeremy Hadall (The Manufacturing Technology Centre)
Robot Manipulation of Manufacturing

11:50-12:15 Ugo Cupcic (Shadow Robot Company)
Our Roadmap to Useful Robotics

12:15-13:15 **Lunch**

13:15-14:15 **Tutorial** Michael Mistry (University of Edinburgh)
A Tutorial on Impedance Control and Physical Human-Robot Interaction

14:15-15:00 **Poster Spotlights** (Chair: Nick Hockings)

14:15-14:30 Ermano Arruda (University of Birmingham)
Uncertainty Averse Pushing with Model Predictive Path Integral Control

14:30-14:45 Alexandros Giagkos (Aberystwyth University)
Assessing Humanoid Multimodal Grasping towards Object Recognition

14:45-15:00 Lipeng Chen (University of Leeds)
Multi-Step Manipulation Planning Given a Sequence of External Forces

15:00-16:00 **Posters, Demos, and Refreshments**

16:00-17:15 **Invited Talks: Sensorimotor Control** (Chair: Nathan Lepora)

16:00-16:25 Dario Farina (Imperial College London)
Investigating the Neural Control Strategies of Movement by Decoding Spinal Motor Neuron Activity in Humans

16:25-16:50 Thrishantha Nanayakkara (Imperial College London)
Co-Emergence of Perception, Embodiment, and Action

16:50-17:20 Aldo Faisal (Imperial College London)
Haptic SLAM and the Natural Hand Behaviour Beyond Grasping

17:15-17:20 **Closing Remarks**

Invited Speakers

Petar Kormushev

Bio: Petar Kormushev is Lecturer in Robotics and Computing at the Dyson School of Design Engineering, Imperial College London. He is also Director of the Robot Intelligence Lab, which focuses on machine learning methods for robotics. Dr Kormushev holds a PhD in Computational Intelligence from Tokyo Institute of Technology, an MSc degree in Artificial Intelligence and an MSc degree in Bio- and Medical Informatics. Previously, he has been a Research Team Leader at the Italian Institute of Technology, and a visiting researcher at King's College London. Dr Kormushevs research interests are focused on robot learning algorithms, especially reinforcement learning for intelligent robot behavior.

Talk: **Learning for Robotic Loco-Manipulation**
Disasters such as the Fukushima power plant and, more recently, the Grenfell tower fire, highlight the acute need for robots to go out of the research labs and into the real world. To be truly useful in everyday scenario, robots need not only manipulation skills, but also mobility. Combining the two produces platforms that are capable of mobile manipulation, or alternatively loco-manipulation, which is the use of locomotion directly for the purpose of manipulating objects. Examples will be given for each approach on challenging tasks such as dual-arm tool-based manipulation, whole-body humanoid contact task learning, and one-shot learning of visuospatial skills. In all examples the focus will be on the use of machine learning and in particular reinforcement learning for rapid acquisition of robot skills without having to manually program the robot.

Raia Hadsell

Bio: Raia Hadsell, a senior research scientist at Google DeepMind, has worked on deep learning and robotics problems for over 10 years. Her thesis on Vision for Mobile Robots won the Best Dissertation award from New York University, and was followed by a post-doc at Carnegie Mellon's Robotics Institute. Raia then worked as a senior scientist at SRI International. Raia joined DeepMind in 2014, where she leads a research team studying robot navigation and lifelong learning.

Talk: **Deep Reinforcement Learning for End-to-End Grasping**
Deep reinforcement learning has rapidly grown as a research field with far-reaching potential. However applying deep RL to solve real world tasks is challenging due to hard data constraints and environmental variability. As the field matures, we are turning to more sophisticated learning systems in order to solve harder problems such as robotic manipulation. I will describe some recent research from DeepMind that allows end-to-end learning in such challenging environments.

Yiannis Demiris

Bio: Yiannis Demiris is a Professor of Human-Centered Robotics at Imperial College London, where he directs the Personal Robotics Laboratory in the Department of Electrical and Electronic Engineering. He is a graduate of the department of Artificial Intelligence of the University of Edinburgh, where he did his BSc and PhD studies. He does research in artificial intelligence, human-robot interaction, machine learning, humanoid & assistive robotics, and in-vehicle intelligent systems, with a particular emphasis on the mechanisms of lifelong machine learning and personalisation. A special interest of his is the design and implementation of long-term user modelling and assistive mechanisms, particularly for children and adults with disabilities.

Talk: **Human-Centered Robot Manipulation and Learning**
In his talk he will present his labs research on robot learning of objects and how they can be manipulated for assistive tasks, for example, helping humans with dressing. The importance of user modelling, and multimodal interaction with the human beneficiaries will be emphasised.

Gerhard Neumann

Bio: Gerhard Neumann is a Professor of Robotics & Autonomous Systems in College of Science at the University of Lincoln. Before coming to Lincoln, he has been an Assistant Professor at the TU Darmstadt from September 2014 to October 2016 and head of the Computational Learning for Autonomous Systems (CLAS) group. Before that, he was Post-Doc and Group Leader at the Intelligent Autonomous Systems Group (IAS) also in Darmstadt under the guidance of Prof. Jan Peters. Gerhard obtained his Ph.D. under the supervision of Prof. Wolfgang Mass at the Graz University of Technology.

Talk: **Policy Search Methods for Robotics**
Policy search is a subfield in reinforcement learning which focuses on finding good parameters for a given policy parametrization without relying explicitly on the estimation of a value function. It is well suited for robotics as it can be used with efficient parametric movement representations, can cope with high-dimensional state and action spaces and deal with high-dimensional sensory inputs such as cameras. In the recent years, there has been significant progress in terms of theory and applications. This lecture introduces a unified, information theoretic view on policy search methods and explains the most important existing algorithms in the light of this framework.

Many current policy search methods rely on stochastic policies to explore the state and action space of the agent. The information contained in such stochastic policies represents our belief of the location of the optimal solution. By using an information-theoretic view on policy search, we can find principled trade-offs for combining information from the current policy with the information contained in the newly experienced samples, also known as exploration-exploitation trade-off in reinforcement learning. Most of the currently used policy search methods can be understood in the light of this information theoretic principles. We will present the latest results in policy search for robotics and discuss recent applications for robot manipulation.

Andrew Davison

Bio: Andrew Davison is Professor of Robot Vision and Director of the Dyson Robotics Laboratory at Imperial College London. His long-term research focus is on SLAM (Simultaneous Localisation and Mapping): computer vision algorithms which enable robots and other artificial devices to map, localise within and ultimately understand and interact with the 3D spaces around them. With his research group and collaborators he has developed and demonstrated several breakthrough systems, including MonoSLAM and KinectFusion, and has won several prizes including Best Paper at ECCV 2016. He has also had strong involvement in taking this technology into real applications; most recently through his work with Dyson on the design of the visual mapping system inside the new Dyson 360 Eye robot vacuum cleaner.

Talk: **From SLAM to Manipulation**
Over the past two decades, we have seen visual SLAM research evolve towards a general real-time spatial perception capability using vision, able to built dense and increasingly semantic maps of scenes. However, big questions remain as to what level and type of scene representation will enable the advanced manipulation that will allow new categories of robot operation in everyday environments. I will talk about some of our recent work in this direction, based on methods from both estimation and machine learning.

Maurice Fallon

Bio: Maurice Fallon is a Departmental Lecturer at the University of Oxford. His research is focused localization and mapping for robots. He has also made research contributions to state estimation for legged robots and is interested in dynamic motion planning and control. Of particular concern is developing methods which are robust in the most challenging situations by leveraging sensor fusion. He worked as a post-doc and a research scientist in the Marine Robotics Group at MIT from 2008-2012. From 2012-2015 he was the perception lead of MITs team in the DARPA Robotics Challenge a multi-year competition developing technologies for semi-autonomous humanoid exploration and manipulation in disaster situations. After a period as a lecturer in Edinburgh, he moved to Oxford in Spring 2017. In October 2017 he will become a Royal Society University Research Fellowship.

Talk: **Mapping, Tracking and Motion Planning for Complex High Degree of Freedom Humanoids**
In this talk I will present ongoing research on visual perception, mapping and motion planning focused on manipulation. Each piece of work is motivated by the challenge of having a complex humanoid robot grasp objects and interact with the world. The first topic will focus on creating volumetric maps suitable for collision free motion planning by incorporating humanoid proprioception into a surfel-based dense visual mapping system. Visual SLAM systems are notoriously fragile - either reliant on the presence of structure or assumes no dynamics in the scene. A second topic explores collision free motion planning with humanoid robots with high dimensionality. We demonstrate how inverse reachability maps can be used to store sample configurations which are dynamically feasible and that trajectories can be quickly found on-line to solve complex 30 degree of freedom reaching problems. Finally we present initial research on visual manipulator tracking. We explore the problem instead by tracking the robot's manipulator using dense vision and present initial research showing how we can recover from manipulator tracking using random forests.

Jeremy Wyatt

Bio: Jeremy Wyatt is Professor of Robotics and AI at the University of Birmingham. He gained his PhD from Edinburgh, and has published more than 100 papers. He works on robot task planning, machine learning for robotics, and robot manipulation. He has participated in projects on AI for robotics such as CoSy and CogX and projects on robot manipulation such as GeRT and PaCMan.

Talk: **Machine Learning for Grasping and Pushing**
In this talk I will give an overview of two updates from our lab in the last year. First, on an extension of our work on data efficient grasping to improve grasp reliability for objects in challenging poses from a single view. Second, I will sketch a new software framework we have been developing for push manipulation, machine learning and control suitable for deployment on a variety of robots, but tuned for use on Baxter.

Nathan Lepora

Bio: Nathan Lepora is a Senior Lecturer in Robotics at the University of Bristol, and leads the Tactile Robotics Theme at Bristol Robotics Laboratory. He has been involved in tactile robotics for about seven years, working on both fingertip and whisker-based tactile sensors. The Tactile Robotics group at BRL is currently supported by EPSRC and was recently awarded a 1M Leverhulme Leadership Award to investigate 'A biomimetic forebrain for robot touch'.

Talk: **Biomimetics & AI for tactile robotics**
The tactile robotics group at Bristol Robotics Laboratory works on three interrelated research themes: (i) design and fabrication of 3d-printed biomimetic tactile sensors and tactile hands based on the BRL TacTip optical tactile sensor (recently winning the Harvard Softrobotics competition and on display in the Science Museum, London); (ii) statistical and machine learning methods for perception and robot control from artificial touch; (iii) biological mechanisms for perceptual decision making based on active perception and embodied intelligence. In this talk, we discuss recent work in these three areas, and how each informs progress towards the overall research goal of reaching human dexterous performance in robots.

Lorenzo Jamone

Bio: Lorenzo Jamone recently joined the Queen Mary University of London as Lecturer in Robotics (at ARQ - Advanced Robotics @ Queen Mary), and he is interested in robot cognition, with a focus on sensorimotor learning, perception and control (body schema, affordances, eye-hand coordination, manipulation, tool use), and in the development of novel technologies for tactile and force sensing.

Talk: **Some important ingredients for robotic manipulation: what do you need to grasp an object?**
In the talk I will touch upon a few recent works related to robotic manipulation, and more specifically about: benchmarking of robotic hands (how to understand if a robot hand is "good"?), robotic reaching and self-calibration (how to reach for an object precisely?), haptic active exploration of objects (what can we learn of an object by touching it?), tactile and force sensing (how to detect light contacts robustly?), object affordances (how to "see" the possible actions in the objects?).

Fumiya Iida

Bio: Fumiya Iida is a lecturer on mechatronics at University of Cambridge, Department of Engineering. He received his bachelor and master degrees in mechanical engineering at Tokyo University of Science (Japan, 1999), and Dr. sc. nat. in Informatics at University of Zurich (2006). In 2004 and 2005, he was also engaged in biomechanics research of human locomotion at Locomotion Laboratory, University of Jena (Germany). From 2006 to 2009, he worked as a postdoctoral associate at the Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology in USA. His research interest includes biologically inspired robotics, embodied artificial intelligence, and biomechanics, where he was involved in a number of research projects related to dynamic legged locomotion, navigation of autonomous robots, and human-machine interactions.

Talk: **Model-free Design Automation of Soft Robotic Hands**
There are many soft robots, the behaviours of which are very difficult to mathematically modelled or simulated. If we consider machine design problems that cope with such physical dynamics, we need heuristic search of design in physical systems, without (or with very little) help of simulation, which we call the model-free (robotic) design automation. We are exploring how such a new paradigm of design automation processes can be realised, though there are a number of known challenges such as the dimensionality problem, the scalability problem, and the reality gap. In this talk, I would like to introduce some of the attempts in our laboratory and discuss challenges and perspectives.

Ravinder Dahiya

Bio: Dr. Ravinder Dahiya is Reader and EPSRC (Engineering and Physical Science Research Council) Fellow in the School of Engineering at University of Glasgow, UK. He is the Director of Electronics Systems and Design Centre (ESDC) in the University of Glasgow. He is the leader of Bendable Electronics and Sensing Technologies (BEST) group, which conducts fundamental research on high-mobility materials based flexible electronics and electronic skin, and their application in robotics, prosthetics and wearable systems. His multidisciplinary research interests include Flexible and Printable Electronics, Electronic Skin, Robotic Tactile Sensing, and Wearable Electronics.

Talk: **Energy-Autonomous Electronic Skin**
Tactile or electronic skin is critical for haptic perception in robots, prosthetics, as well as, wearable electronics. The energy autonomy of skin in these applications is a needed as to enable portability and longer operation times. In this direction, we have recently obtained novel energy-autonomous flexible and tactile skin and this will be the focus of this talk. The tactile skin consists of graphene based a transparent touch sensitive layer integrated on top of a photovoltaic cell. The transparency of the touch sensitive layer is a key feature which allows photovoltaic cell to harvest energy using the light. The touch sensitive layer consumes ultra-low power (20 nW/cm2) and this means the photovoltaic area required to drive the tactile skin is not too large. In addition to its energy autonomy, the fabricated skin is sensitive to touch, mainly due to a transparent polymeric protective layer spin-coated on the sensor's active area makes the co-planar capacitor sensitive to touch, detecting minimum pressures of 0.11 kPa with a uniform sensitivity of 4.3 Pa-1 along a broad pressure range. Finally, the tactile skin patches were integrated on a prosthetic hand, being the response of sensors for static and dynamic stimulus evaluated by performing tasks ranging from simple touching to grabbing of soft objects.

Graham Deacon (Ocado Technology

Bio: Graham Deacon is the Team Leader of the Robotics Research Team at Ocado Technology. He received his PhD from the Department of Artificial Intelligence at the University of Edinburgh in 1997, for showing how an inherently back-drivable robot could use sliding motion primitives to raise the level of programming abstraction in robotic assembly. He has also worked on error recovery, force-guided assembly, sensorless manipulation, skill acquisition, vision-guided handling, image-guided surgery and sheet metal folding. He has worked in the high volume environment of the automotive industry to the high precision environment of medical robotics. He is currently working on the handling and packing of groceries.

Talk: **Soft Manipulation in the Delivery of On-line Grocery Orders**
Ocado is the world's largest on-line only grocer. We already employ high levels of automation throughout the business and a natural next step is to employ robots to achieve the mass customisation of the assembly of grocery shopping baskets. Robot manipulators are typically deployed in circumstances where the environment is engineered to be predictable and there are a small number of parts that are a regular shape and/or have CAD data describing them. In our case we want to handle 48K different objects whose locations are difficult to constrain, there is wide variation in size, shape and materials, no CAD data, there are not only deformable but also easily damaged items as well as those whose load distribution changes when they are picked up. This talk will describe how we expect soft manipulation to help us address these challenges.

Jeremy Hadall (The Manufacturing Technology Centre)

Bio: Jeremy Hadall has been developing automation systems for industry since leaving the University of Hertfordshire with a Masters in Engineering degree. His work has taken in a diverse range of industries, through which he has had the opportunity to work with some of the worlds leading manufacturing and automation companies. Since 2010, he has led the development of advanced automation systems for the Manufacturing Technology Centre where he is Chief Technologist for Robotics and Automation. Building and developing a team of highly skilled engineers, the MTC has spearheaded the wider uptake and the development of new automation concepts within UK manufacturing. Jeremy Hadall is also a Chartered Engineer with the Institution of Engineering Technology and chairs its Design & Production Executive Committee. He also chairs the Automation Forum of the UKs High Value Manufacturing Catapult and is a member of the British Automation and Robotics Associations council.

Talk: **Robot Manipulation of Manufacturing**
Whilst there have been and continue to be significant breakthroughs with manipulation technologies, most of these are still confined to the laboratory. In this talk, Jeremy Hadall (Chief Technologist; Robotics & Automation) will examine the needs of industry in regards to manipulation, its traditional approach to the problem and its reticence to use novel technologies. Finally, hell address how this can change and why it must.

Ugo Cupcic (Shadow Robot Company)

Bio: After studying at INSA Lyon and the Universit Pierre et Marie Curie (Bioinformatics and Artificial Intelligence, respectively), Ugo worked in software, before joining the Shadow Robot Company in 2009 as a Software Engineer. Ugo worked his way up to his current role of Chief Technical Architect, which sees him drive the technical roadmap for Shadow. He has four published papers, including 'A Case Study of ROS Software Re-usability for Dexterous In-Hand Manipulation'. He writes a blog which focuses on the roadmap, and also his passion for remote working. Now based in Brest, France, in his spare time you can find Ugo playing water polo, or chasing his two children around the garden.

Talk: **Our Roadmap to Useful Robotics**
To deliver the best hands in the world, weve collaborated with the best researchers but what does it take to reach out of a research oriented market? To solve real world problems using robots? Were convinced that tailoring a custom solution for each problem is not the way forward. We want the people facing those problems to be able to use our solutions themselves. And we have a roadmap to get there.

Michael Mistry

Bio: Michael Mistry is a Reader in Robotics at the School of Informatics, University of Edinburgh, where he is also a member of the Institute for Perception, Action and Behaviour. Michael is broadly interested in human motion and humanoid robotics, with a research focus on operational space control, redundancy resolution, stochastic optimal control, dynamics and model-based control, particularly in environmental contact. Previously, Michael has been a lecturer at the University of Birmingham, a postdoc at the Disney Research Lab at Carnegie Mellon University, a researcher at the ATR Computational Neuroscience Lab, and a Phd student at the University of Southern California.

Talk: **A Tutorial on Impedance Control and Physical Human-Robot Interaction**
This tutorial provides an introduction to the impedance control framework, i.e. the control of interaction between a robot and an uncertain environment. We will cover the classical theory (e.g. Hogan 1985), as well as more recent developments applied to whole-body, redundant, force-controllable robots (including those with legs, wheels, hands). A particular emphasis will be on maintaining safe interaction with humans.

Dario Farina

Bio: Dario Farina is Professor and Chair in Neurorehabilitation Engineering, in the Department of Bioengineering, Imperial College London. He received Ph.D. degrees in automatic control and computer science and in electronics and communications engineering from the Ecole Centrale de Nantes, Nantes, France, and Politecnico di Torino, Italy, in 2001 and 2002, respectively. He has previously been Full Professor at Aalborg University, Aalborg, Denmark, (until 2010) and at the University Medical Center Gttingen, Georg-August University, Germany, where he has been founding Director of the Institute of Neurorehabilitation Systems (2010-2016) and the Chair in Neuroinformatics of the Bernstein Focus Neurotechnology Gttingen (2010-2015). His research focuses on biomedical signal processing, neurorehabilitation technology, and neural control of movement.

Talk: **Investigating the Neural Control Strategies of Movement by Decoding Spinal Motor Neuron Activity in Humans**

Thrishantha Nanayakkara

Bio: Thrish is a Reader in Design Engineering and Robotics at the Dyson School of Design Engineering, Imperial College London. Prior to this, he has been a Senior Lecturer in the Centre for Robotics Research (CoRe), Department of Informatics, Kings College London (KCL). Thrish has been a Radcliffe Fellow, Harvard University, USA, and research affiliate at the Computer Science and Artificial Intelligence Laboratory, MIT, USA, a postdoctoral research fellow at the Department of Biomedical Engineering, Johns Hopkins University, USA. His research interests are in morphological computation in soft robotics and human-robot interaction.

Talk: **Co-emergence of Perception, Embodiment, and Action**
The emerging area of morphological computation views the body not only as a mere anatomical structure, but also as an important resource that contributes to the computation of perception and action. The nature of sensorimotor coupling and its implications on the very nature of computation of action-perception arbitration in soft robotics and biological motor control is not yet well understood. For instance, the spindle sensors (provide position and velocity) and tendons (provide force/torque) are physically embedded among muscle fibres. That makes sensing entangled with action, offering opportunities to take control over haptic perception by changing action and vice versa. E.g., when asked to estimate the weight of an object, one would hold the object and bob it up and down before arriving at a final estimate of the weight. Similarly, people probe several times when asked to mark a hard area in a soft object. This opens up an unexplored question as to how internal impedance of the embodiment should be controlled to arbitrate perception and action as co-occurring phenomena rather than as a sequential phenomena where sensing conditions action. In other words, optimization of action and haptic perception has not been viewed as an integrated problem where one imposes constraints on the other while at the same time improving the other. In this talk, I will show some results of the recent work in my laboratory for morphological computation and learning to suggest the benefit of viewing the whole body as a unified computational machine.

Aldo Faisal

Bio: Aldo Faisal is a Senior Lecturer in Neurotechnology (US equivalent: Associate Professor, tenured) jointly at the Dept. of Bioengineering and the Dept. of Computing at Imperial College London. He is also Associate Group Head at the MRC Clinical Sciences Center (Hammersmith Hosptial) and is affiliated faculty at the Gatsby Computational Neuroscience Unit (University College London).

Talk: **Title Haptic SLAM and the Natural Hand Behaviour beyond Grasping**
Dynamic tactile exploration enables humans to seamlessly estimate the shape of objects and distinguish them from one another in the complete absence of visual information. Such a blind tactile exploration allows integrating information of the hand pose and contacts on the skin to form a coherent representation of the object shape. A principled way to understand the underlying neural computations of human haptic perception is through normative modelling. We propose a Bayesian perceptual model for recursive integration of noisy proprioceptive hand pose with noisy skinobject contacts. The model simultaneously forms an optimal estimate of the true hand pose and a representation of the explored shape in an objectcentred coordinate system. A classification algorithm can, thus, be applied in order to distinguish among different objects solely based on the similarity of their representations. This enables the comparison, in realtime, of the shape of an object identified by human subjects with the shape of the same object predicted by our model using motion capture data. Therefore, our work provides a framework for a principled study of human haptic exploration of complex objects.

Posters

- **Multi-Step Manipulation Planning Given a Sequence of External Forces**
  Lipeng Chen and Mehmet Dogar (University of Leeds)

- **Personalized Robot-assisted Dressing using Hierarchical Multi-task Control and User Modeling**
  Fan Zhang, Antoine Cully, and Yiannis Demiris (Imperial College London)

- **End-to-End Visuomotor Control for Eye-in-Hand Pushing**
  Edward Johns and Andrew Davison (Imperial College London)

- **Development of TenRo: A Tensegrity Robot**
  Ben Salem and Sam Mitchell (University of Liverpool)

- **Learning Loco-Manipulation Skills for an Autonomous Mobile Rescue Robot**
  Roni Permana Saputra and Petar Kormushev (Imperial College London)

- **Clinical Testing of an Advanced Myocontrol Prosthetic System in Transradial Amputees**
  Ivan Vujaklija, Sebastian Amsuess, Timothy Hasenoehrl, Aidan D. Roche, Agnes Sturma, Dario Farina and Oskar C. Aszmann (Imperial College London)

- **Assessing Humanoid Multimodal Grasping Towards Object Recognition**
  Alexandros Giagkos, Raphael Braud, Patricia Shaw, Mark Lee and Qiang Shen (Aberystwyth University)

- **Efficient Informed Search in Task Parameter Space for Bimanual Robot Skill Learning**
  Nemanja Rakicevic and Petar Kormushev (Imperial College London)

- **Tactile Manipulation Through Biomimetic Touch**
  Luke Cramphorn and Nathan Lepora (University of Bristol)

- **Regression-based tactile perception**
  Kirsty Aquilina, David A. W. Barton, and Nathan F. Lepora (University of Bristol)

- **Interactive Perception based on Gaussian Process Classification Applied to Household Object Recognition & Sorting**
  Aamir Khan, Gerardo Aragon-Camarasa, and J. Paul Siebert (University of Glasgow)

- **End-to-End Haptic Grasping with Deep Reinforcement Learning**
  Miklos Kepes and Edward Johns (Imperial College London)

- **Printable Soft Grippers with Embedded Sensing for Handling Complex and Delicate Objects**
  Khaled Elgeneidy, Niels Lohse, and Michael Jackson (Loughborough University)

- **Deep Reinforcement Learning for Robotic Manipulation in High-Dimensional Action Spaces**
  Arash Tavakoli and Petar Kormushev (Imperial College London)

- **Uncertainty Averse Pushing with Model Predictive Path Integral Control**
  Ermano Arruda, Michael Mathew, Marek Kopicki, Michael Mistry, Morteza Azad and Jeremy L Wyatt (University of Birmingham)

- **Grasp it! Let me see how can I achieve post-grasp objectives!**
  Amir-Masoud Ghalamzan-Esfahani, Nikos Mavrakis, and Rustam Stolkin (University of Birmingham)

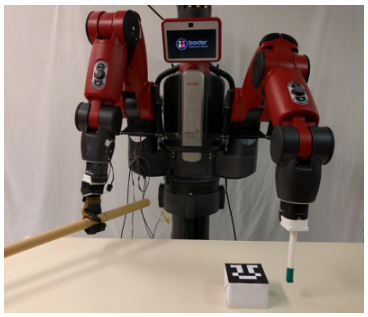
- **Tactile Sensing using Conductive Thermoplastic Elastomer for Manipulation**
  Josie Hughes and Fumiya Iida (University of Cambridge)

- **Transferring End-to-End Visuomotor Control from Simulation to Real World for a Multi-Stage Task**
  Stephen James, Andrew Davison and Edward Johns (Imperial College London)

Demos

Uncertainty Averse Pushing with Model Predictive Path Integral Control

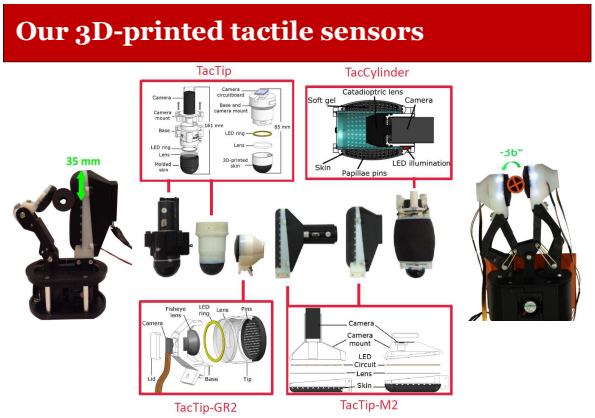
This is the demonstration system from our poster on uncertainty averse pushing. In this the robot learns forward and inverse models from randomised push data, and then produces push plans. The main benefit is that the model we use allows the robot to characterise the uncertainty in its model, and thus to trade-off between risk and reward in the plan.



Intelligent Robotics Lab, University of Birmingham

3D-Printed Tactile Sensors and Hands

The Tactile Robotics group at Bristol Robotics Laboratory has three main themes: (i) development and fabrication of novel 3D-printed tactile sensors and hands; (ii) algorithms for active perception, exploration and manipulation with these tactile robots; (iii) interpretation and inspiration of these algorithms and tactile hardware in terms of the computational neuroscience of perception and action. In this demo, we display a range of different 3D-printed tactile sensors and hands, along with videos of the hardware in action when mounted on robot arms.



www.softroboticstoolkit.com/tactip/

Tactile Robotics Group, Bristol Robotics Laboratory

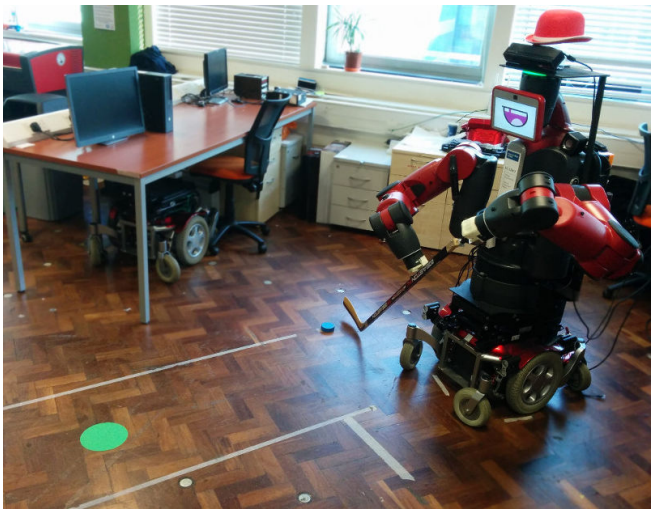
Shadow Dexterous Hand

The Shadow Robot Company was founded in 1987 by a group of robotics enthusiasts in London. The group has since evolved into one of the longest running robotics companies in the UK, developing dexterous robotics manipulation technologies ('hands for robots') and using them to solve real world problems. We are exhibiting our world-renowned Shadow Dexterous Hand, and advanced robot hand system that provides movements to reproduce as closely as possible the kinematics and dexterity of the human hand.

The Shadow Robot Company, London

Bimanual Robot Skill Learning for the Ice Hockey Puck-Passing Task

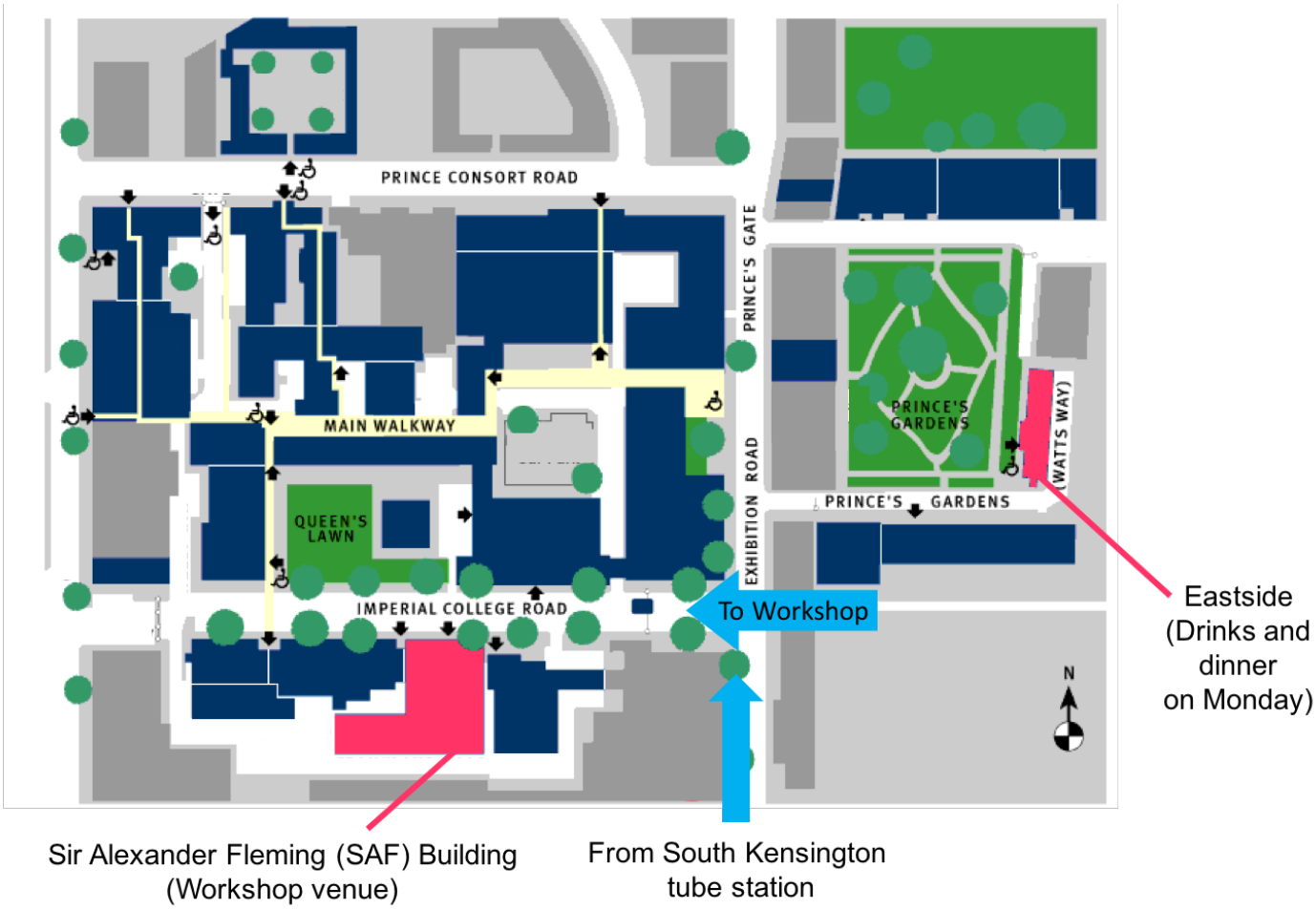
We consider the problem of autonomously learning the ice hockey puck-passing task with a bimanual robot DE NIRO (Design Engineerings Natural Interaction Robot) with two 7-DOF-arms. DE NIRO learns to successfully hit a standard ice hockey puck using a standard ice hockey stick on a hardwood floor and pass it to a desired target position. The puck-passing motion that the robot performs consists of a swing motion, making the contact with the puck and transferring the necessary impulse to move the puck to a certain location. The robot learns this through trial and error without any target positions provided during the training phase, but just by exploring different swing movements and recording their outcomes.



Robot Intelligence Lab, Imperial College London

Imperial College Map

For many, the most convenient way to travel to the workshop will be by taking the London Underground to South Kensington tube station. From here, walk north along Exhibition Road, or take the subway which runs parallel to Exhibition Road. After passing the Natural History Museum and the Science Museum, you will reach the Imperial College campus. Turn left and walk along Imperial College Road for about 150 metres, and the Sir Alexander Fleming (SAF) building will be on your left. Go through the doors to the building, and you will see the registration desk. Alternatively, you can search for "Sir Alexander Fleming Building" on Google Maps.



Workshop Map

The workshop will be taking place in the Sir Alexander Fleming Building. Registration, demos, posters, and refreshments, will all be in the main foyer area on the ground floor, and talks will be just up the main staircase, in lecture theatre G34.

Wi-Fi

For guests who have a university account, you should be able to connect to the *eduroam* Wi-Fi network using your university username and password. If this does not work, or for guests who are not affiliated with a university, then you will be able to create a temporary guest account here. In the "Unique ID" field, please enter "conf26086". Once you are assigned a username and password, you should be able to use these to connect to the "Imperial" Wi-Fi network.