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Marie Skłodowska-Curie Initial Training Network

SMART-E: Sustainable Manufacturing through Advanced Robotics Training in Europe

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Issue 3

S M A R T e
SUSTAINABLE MANUFACTURING
THROUGH ADVANCED ROBOTICS TRAINING
IN EUROPE

http://smart-e-mariecurie.eu/

Editorial

Together with 7 International Partners from Higher Education and Industry and the collaboration of 13 additional industrial associated partners, SMART-E is currently training a team of Early Stage Researchers (ESRs) and an Experienced Researcher (ER), within a training programme in Advanced Robotics Technologies. During the past two years, after the first period of recruitment of the fellows, the selected researchers have started their own project with the tutor and a team of supervisors, they have participated in a series of training and networking events and they are now periodically having their experience abroad, working with one or more of the associated partners.

In this third issue of the SMART-E Newsletter, you will find the reports of the fellows, with their updates on their research project, collaborations and activities, a description of training and dissemination events that have been organized in the past 6 months, and information about forthcoming initiatives around SMART-E.

SMART-E Fellows & Supervisors – July 2015, Livorno, Italy

SMART-E Training and Networking Events

Major training and networking events during the last 6 months were the "Northern Robotics Network Showcase" in Salford (September 4, 2015); the "Complementary Skills Training" in Sheffield (September 7-11, 2015); the "WP2 Technical Workshop" in Salford (September 14-16, 2015); and the SMART-E Mid-Term Review and Conference, that included the Patent Workshop and the 8th International Workshop on Human-Friendly Robotics (Munich, October 20-23, 2015).

On 4th September 2015, all of the SMART-E ESRs presented their research at the InnovateUK **Northern Robotics Network Showcase** at MediaCityUK, Salford.

This was the first Northern Robotics Network (NRN) Showcase and it was a perfect opportunity for SME's and Partners involved in the Growing Autonomous Mission Management Applications (GAMMA) programme to demonstrate and exhibit their achievements.
For our SMART-E fellows, it was also a great opportunity to make links with the wide range of research groups from across the UK which attended, and the 150+ companies who took part, who are interested in the way in which robotics and autonomous systems could be used in their businesses.

Exhibition during the NRN Showcase

The GAMMA programme has been a three year £9.1 million programme aimed at driving SME engagement and developing technology within the emerging autonomous systems markets.

To create the widest possible awareness, the GAMMA programme collaborated with a range of other leading robotics and autonomous systems (RAS) groups to create the first Northern RAS Event at MediaCity UK. This provided a high profile platform for the GAMMA SME's to promote their achievements through their conference presentations and exhibitions.

Overall, the event was a huge success with over 300 participants, 39 presentations and 50 exhibitions & demonstrations. Representatives came from a diverse range of industry sectors including food technology, aerospace, rail, nuclear, advanced manufacturing and smart cities.

There were demonstrations of technology applications throughout the event, right across the MediaCityUK display areas on land, water and in the air. One of the main demonstrations from Manchester University displayed the possibilities the future can hold for Umanned Aerial Vehicle's (UAV) by showing a real life situation involving autonomous systems, aerial and water based vehicles, presented in real-time on large public screens. Other demonstrations included the advanced Gobotix driverless car and a display of demolition robots being used in nuclear and hazardous environments.

In addition, the event was the official public launch of the Northern Robotics Network (NRN) which will enable the legacy of GAMMA's investments to be fully utilised in further technology programmes.

Dr Paul Mort, chairman of the Northern Robotics Network, said: "We've got to really keep pushing and developing otherwise, quite quickly, the rest of the world will start taking over our leading positions."

The challenges in Advanced Manufacturing were set out by Siemens, ABB, Rolls-Royce, Festo and the Advanced Manufacturing Research Centre (AMRC).

Dr David Bailey, CEO of North West Aerospace Alliance raised the awareness of the importance that Robotics and Autonomous systems will have in the future by stating "Everyone talks about the skills shortage so if we're going to solve the capacity problem, if we're going to make all of the aircraft then we have to bring in new technology."

SMART-E fellows - Yasmin, Stefano and Aaron - during the NRN Showcase

As part of this event, SMART-E co-hosted a workshop on Flexible Automation in Food Manufacturing in partnership with FMEG and EU project PicknPack.

There was extensive press and media coverage of the event including; Sky News, BBC national and regional TV, BBC Radio 5 Live and ITV Granada Reports totalling 51

items and reaching a national audience of 38.2 million. This helped to bring attention to the investment in R & D in the regions which generates supply chain growth and jobs.
The event has produced a tremendous platform with which to promote RAS networks and help to shape new wealth creation through powering productivity in the Northern Powerhouse and beyond through the application of autonomous systems.
Read more at:
http://smart-e-mariecurie.eu/events/Northern_Robotics_Network_Showcase
Press coverage:
http://www.harrogateadvertiser.co.uk/news/business/drone-programme-to-feature-at-new-event-1-7441028

The **Complementary Skills Training** event ran for four days at the University of Sheffield (UK). The first day, Geoff Pegman, from RURobotics (a SMART-E Associate Partner) gave a lecture on start-ups, the markets, the aspects of Intellectual Property (IP) and patents, the opportunities for having sources of finance and how to build a business plan. Fellows had the opportunity to develop and practice an elevator pitch. The second day, the staff from the Advanced Manufacturing Research Centre (AMRC), the Design & Prototyping Group (DPG) and the Integrated Manufacturing Group (IMG) presented all the steps involved on the development of new technology (design manufacture), followed by lectures about cost-benefit analysis, quality management, health and safety and about environmental and ethics issues. The remaining two days were dedicated to preparing and presenting a project to obtain funding and offer shares of a hypothetical company. This training was organized following the Dragons' Den presentations, with the fellows working closely in groups of 2-3 people and learning how to negotiate for funding their project in a simulated negotiation with venture capitalist. This was a very exciting and interesting experience for the Fellows according to their feedback.

The **WP2 Technical Workshop** in Salford brought together the researchers in SMART-E WP2 to learn about developments in the field of reconfigurable and logistics robotics, to consider how to apply their research in industrial contexts and to identify opportunities for synergies between projects and collaboration between researchers.
The first part of the workshop was focused on a site visit to HellermannTyton with the identification of solutions to specific industrial challenges. HellermannTyton is an International Company and one of the leading cable management manufacturers of products for fastening, fixing, identifying and protecting cables and their connecting components. The HellermannTyton group has been present in the UK for over 80 years with around 500 employees. They manufacture a wide range of injection moulding products that range from tried and tested standard cable ties to complex products for specific applications for customers. Research and development is a core part of their operation.

SMART-E fellows during the WP2 Technical Workshop

The second part of the workshop focused on a presentation on "Stochastic modelling for degradation, lifetime prognosis and maintenance planning" given by Antoine Grall, Université de Technologie, Troyes. This was followed by the ESRs scientific presentations (30 minute presentation, 15 minute discussion/feedback) and a final WP 2 round-table where the ESRs discussed the synergies between projects and opportunities for collaboration with feedback / support for upcoming research outputs.

The **Smart-E Mid-Term Review and Conference** took place in Munich at Technical University of Munich in October 2015 and included the Patent Workshop (Complementary Skills Training, WP4) and the 8th International Workshop on Human-Friendly Robotics.

The TUM **Patent Workshop** was given by Felix Rummler, Patent Lawyer and European Patent Attorney, and Dr. Ali Nassery, the Head of Research at Ophthalmology Department of Klinikum Rechts der Isar in Munich. In his talk, Felix Rummler introduced IP rights and general requirements for patents with a focus on technicality and software patents. Furthermore, he described the patenting process and patenting strategies, illustrated by several patent case studies. Dr. Nassery`s talk had a more practical focus and included his personal experience and advice for the Smart-E Early Stage Researchers (ESR).

The **8th International Workshop on Human-Friendly Robotics** (HFR 2015) took place on October 21-23, 2015, at Technische Universität München (TUM), Munich, Germany. The objective of the workshop was to bring together researchers to share knowledge on design, control, safety and ethical issues, concerning the introduction of robots into everyday life. A series of demonstrations were available to participants entitled 'HFR Workshop LAB Tour' which were hosted by TUM, Institute for Cognitive Systems (ICS), Human Robot Interactions (HRI) and at DLR (German Aerospace Centre). The demonstrations included Artificial skin, Robot TOM, H1 Humanoid robot (ICS); Object Tracking and Segmentation (HRI); Humanoid robot TORO (DLR); humanoid robot Justin (DLR) and more.

The next two days were devoted to invited talks, poster presentations, presentations during the sessions and a SAPHARI Workshop. The 6 session themes were Human-Robot Interaction and Cooperation, Safety and Reactive Planning, Kinematics and Feedback Control, Machine Learning and Vision for Robotics, Assistive and Medical Robotics, Mechanical Design and Low-level Control. During these sessions, 4 of our ESRs gave their presentations on the current status of their SMART-E research projects:

- Pereira, M. Althoff. Verifiably Safe Trajectory Planning for Human-Robot Interaction
- Giusti, M. Althoff. Automatic Model-Based Controller Design of Reconfigurable Manipulators for Human-Robot Cooperation.
- M. Zeestraten, S. Calinon. Learned Minimal Intervention Control Synthesis based on Hidden Semi-Markov Models
- S. Toxiri, J. Ortiz, D. Caldwell, A Wearable Device for Reducing Spinal Loads

From the Students' Desk

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Octopus-Based Technologies for Manipulation in Manufacturing

"Octopus-based technologies" refers to the rapidly growing research field of Soft Robotics where a new generation of robots have emerged by taking inspiration from boneless structures found in nature such as octopus tentacles. Soft robots combine deformable materials (elastomers) with lightweight actuation mechanisms (pneumatics, shape memory alloys etc.) so that simple feed-forward actuation sequences results in high dexterity and compliance. These properties make soft robots superior to their rigid counter-parts in two aspects: the first being safe human-robot interaction due to compliance and the second that high dexterity allows to operate in unstructured environments. Manufacturers can leverage these two key technologies to revolutionize the industrial environment (aka Industry 4.0) by incorporating soft robotic manipulators on the work-floor to directly assist humans without being enclosed in cages. Recent advances in soft manipulators modular designs comprised of a single module is designed to accomplish omni-directional bending, contraction, extension, and variable stiffness. The successful application of these soft continuum manipulators is dependent upon its ability to automate low-level sensorimotor skills which is still a less explored but active area of research in the field of soft robotics.

A promising approach lies in the application of data-driven motor learning mechanisms to develop internal models through "goal-oriented exploration" of the environment. Internal models correlate sensory and motor spaces so that a forward model helps the robot to predict the outcome of its motor actions while an inverse model helps to generate the required motor commands to achieve a certain task. Soft robots present a number of non-trivial challenges to motor learning algorithms such as high-dimensionality, catastrophic interference, etc. Additionally, higher dimensions also increase redundancies rendering exhaustive motor exploration inefficient.

We investigate goal-oriented autonomous exploration using a Multi-Agent Reinforcement Learning (MARL) paradigm. The underlying idea is to assign each actuator of the robotic system as an autonomous agent, forming a Multiple Agent system, which reside within and share the 3D environment. They must learn to co-operatively coordinate their behaviour by repeated and independent exploration in order to achieve a certain task. Learning in this set-up is achieved through Reinforcement Learning (RL) which is an adaptive computational framework where an optimal control policy is obtained by optimizing the long-term reward received from the system. MARL has gained rapid success in the learning community due to its inherent nature to decentralize and decompose complex problems that accounts for a speed-up in learning. We find many applications in simulated 2D environments such as RoboCup Soccer, however, take up the challenge to develop it further to be used by robotic systems in 3D environments. Such a framework is expected to then assist in platform-independent decision-making irrespective of the underlying actuation technology of the manipulator.

To further enhance and complement my work, I began my academic secondment at Flowers Lab, Inria in December 2015 where I am graciously hosted by Dr Pierre-Yves Oudeyer. His expertise lies in intrinsically motivated goal-oriented exploration through the use of active learning algorithms. In the duration of my three month stay at this institute, I aim to collaborate with his team to develop this algorithm further to follow a trajectory that can be applied to a soft robotic arm.

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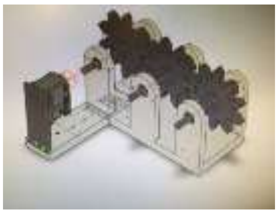
Mathematical modelling for self-healing robotic cell

A secondment took place at Marel from 7th - 11th December 2015.

A model of a Machine consisting of multiple components, gears in this case has been developed and 3D printed, the Rig has been fitted with 2 Servo Motors and 3 Accelerometers that will measure vibration in the system. The change in vibration will indicate wear on the gears and thus after performing the relevant processing procedure we are hoping results will prove the mathematical model that has been developed regarding prognostics which would gives a more accurate insight on the lifetime of components in multiple components systems.

Development on Cost modelling and Optimisation has started with the use of opportunistic maintenance and will be developed using data provided by Marel in the upcoming month.



CAD Design of Gear Test Rig (on the left) and 3D Printed Gear Test Rig (on the right)

This work is heading towards the automation prognostics procedure that takes place in manufacturing environments which will lead the way for automated optimised schedules for servicing ultimately taking a step towards a fully automated factory of the future.

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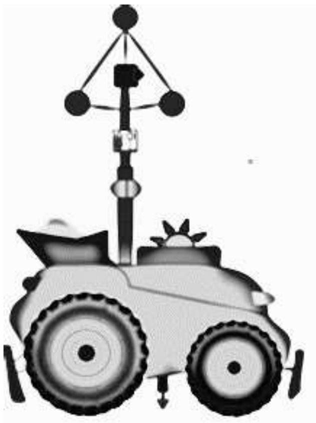
Dynamic Control Architecture for Navigation system.

Farming applications nowadays require high precision positioning systems which are currently high in cost, large in size and sometimes lack reliability when facing shadows and harsh conditions. The use of RTK (Real-time Kinematic), a GNSS Enhancement System for farming, is still a problem in terms of cost and size. The project "Dynamic Control Architecture for Navigation" under development addresses these two issues of farming positioning system.

During the first stage of the work, we demonstrated approaches and techniques for developing a cost effective and robust system for navigation. The approaches were based on absolute localization with reference based strategies where we used mobile landmarks mounted on mobile robots. These landmarks help each robot to localize itself and to determine its coordinates and position with high accuracy.



Mobile landmark mounted on a small robot

Our current target is to prove feasibility of the approaches. The focus is on conducting experiments using computer vision and image

processing for object tracking. The goal of object tracking is to keep track of the landmark over time and calculate the distance to the object by analyzing the shape of the object. The tracking algorithm should detect all mobile landmarks and differentiate between multiple shapes. It should also handle occlusion and exposure.
Future work will also focus on development of the dynamic control for positioning of multiple robots so that these robots can navigate in swarm behavior.

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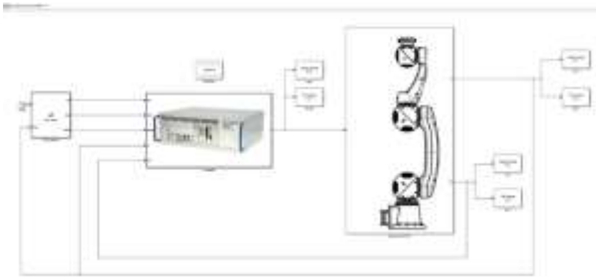
Control design of compliant and reconfigurable modular robots.

In order to address the control challenges of modular and reconfigurable robot manipulators, current work focuses on two main aspects: the automatic design of the controller for arbitrary assembly/reconfiguration and the robustness against model uncertainties.
The research results that led to a method for automatic design of model-based control laws for modular and reconfigurable robot manipulators have been published in Giusti & Althoff (A. Giusti and M. Althoff, "Automatic centralized controller design for modular and reconfigurable robot manipulators," IEEE/RSJ International Conference on Intelligent Robots and Systems, 2015, pp. 3268-3275). The proposed method is generalized: it introduces a novel notation for characterizing heterogeneous modules (based on an extension of the standard Denavit-Hartenberg convention) and a procedure for the automatic generation of model-based control laws using the modular information. In ongoing work, the assumption of perfect knowledge of the dynamical parameters of a manipulator has been relaxed and a novel robust control method has been developed. A paper that presents these results is currently under review. The realization of a test bed for implementation of the control methods on a commercially available modular robot manipulator has been completed with the use of a rapid control prototyping system. An overview is shown in the figure below:



Results from implementation and testing of the control approach proposed by Giusti & Althoff using this test bed are anticipated soon. From a teaching point of view, a new lab course on control of modular robots has been organized (http://www6.in.tum.de/Main/TeachingWs2015modrob). During this course, as an addition to the standard lectures, a special session was organized where Martijn Zeestraten (ESR 13 on his secondment at TUM) introduced his research area and let students practice with software tools on imitation learning.

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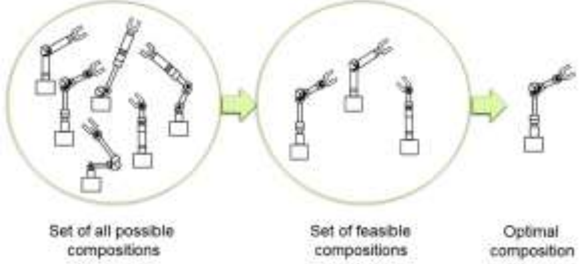
Optimal Configurations of Modular Robots for Specific Tasks

Although industrial robots generally offer high robustness, accuracy, performance and cost efficiency, it is difficult to adapt them to different tasks or environments. As an affordable solution, reconfigurable robots enable us to configure different robots from various modules, consisting of different kinds of link modules and joint modules, such that they can be used for different tasks. One of the main challenges for adopting reconfigurable robots is the problem of determining the optimal combination of modules for given tasks.

In work so far, a time-efficient task-driven configuration synthesis algorithm for modular robots has been proposed and the corresponding paper was submitted to International Conference on Robotics and Automation 2016. Moreover, a paper about hierarchical path planning for modular robots was presented in Workshop on Task Planning for Intelligent Robots in Service and Manufacturing on 2015 IEEE/RSJ International Conference on Intelligent Robots and Systems. Recent work has focused on obtaining the optimal modular composition to achieve the given tasks in the optimal way considering the given objectives. I am currently working on the optimal control methods to obtain optimal trajectories for modular robots and optimization algorithms to select the optimal composition.

Collaboration with Andrea Giusti (ESR 6) was carried out to automatically obtain the kinematic and dynamic model of the reconfigurable robots and some results were included in the submitted paper. Moreover, collaboration with Andrea Giusti (ESR 6) and Martijn Zeestraten (ESR 13) is still ongoing.



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Real-time monitoring systems for 'Swarm Cells'

The main objective of the project is the development of real-time monitoring systems for 'Swarm Cells'. An important step in the development of monitoring systems is the identification of the sensors' data which best describe the machining process itself. This is currently done by generating descriptors (features) from the sensor signals and then selecting among them the most meaningful to model the process. According to the literature review, a common issue in the selection procedure of these features is the lack of automation since very often it requires scientific manual intervention. In order to develop monitoring systems that can be used in real shop floor situations, the feature selection procedure needs either to be autonomous or with minimal, preferably not high-skilled, manual intervention. Therefore the first part of the project is focused on the development of an automatic procedure for signal feature selection. This method autonomously generates the features from the sensors' signals and then selects among them the ones that are most correlated with the process and, at the same time, are less correlated with other features. This leads to a small number of descriptors for each sensor and thus less computational burden for the subsequent step of data fusion which is essential in real-time applications. A case study with Rolls-Royce which involves multi-sensor surface inspection & monitoring is already planned and next to the start. The following step is the software architecture implementation of the monitoring system. The last step will be the integration of the monitoring system with a multi-robot architecture introducing to the concept of 'Swarm Cells'.

No secondments have been done so far, but two are already planned to start shortly at Rolls-Royce show case and at the University of Salford (Jan/Feb 2016).

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Formal Guarantees and Trajectory Planning for Safe Human-Robot Interaction.

Increasingly in industry, robots and humans work together in collaborative workspaces. The top priority here is the safety of the human - if this cannot be guaranteed in a certifiable way, this is a limiting factor to the uptake of robots, especially in Small-Medium enterprises.

Following an approach used in guaranteeing safety of other Cyber-Physical systems (i.e. systems with both continuous and discrete dynamics) such as automated vehicles and power systems, my work uses reachability analysis to guarantee human safety. Work currently focuses on studying how far it is possible to predict the future movement of the human from motion-capture data and known biomechanics. Our models of human future occupancy can be used in a path-planning approach.

In August and September 2015, I spent a month in Salford working with RURobots on implementing verification on the GRAIL Sandwich assembly robot, a project which is ongoing. I also spent some time with ESR 13 Martijn Zeestraten in November and December 2015, investigating how his and my approach can be merged to incorporate the advantages of both imitation learning and formal methods.

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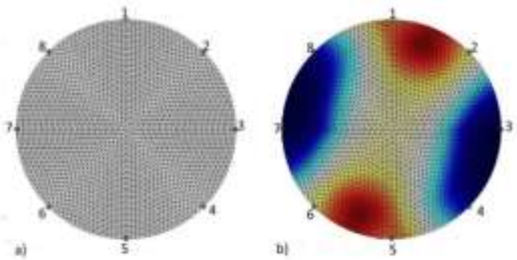
Cognitive multi-agents systems framework for reconfigurable systems

Current sensing technologies are very challenging to implement over 3D surfaces, sometimes expensive and difficult to replace, while a soft and low-cost solution able to reproduce some of the properties of our skin is needed, especially on high-deformable areas as the robotic-joints. In this way it is possible to enable and maximise the quality of the robot interactions' with the surrounding environment.

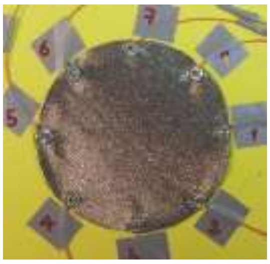
We are developing a new sensor made of pressure sensitive fabric material which responds to external stimuli by changing its electrical properties. We introduce a method called Electrical Impedance Tomography (EIT) which is a method of imaging the internal conductivity distribution of a domain through boundary measurement. In this technique, multiple electrodes are placed equidistantly around a conductive body and a small current is applied across two of the electrodes, while the resulting voltage is measured between the remaining electrode pairs, thus eliminating wires from the most of the sensing area, making the sensors extremely soft and stretchable. When an external stimulus is applied, local variations in the internal impedance of the body will alter the distribution of current inside it, resulting in changes of potential on the boundary. These values are then sent to a software for reconstructing the image of the internal conductivity distribution, as shown in the figure below:



On the left, the Finite Element Model of the sensor. On the right, the simulated reconstructed image when pressure is applied simultaneously at two opposite points near electrode pairs 1-2 and 5-6 (in red).

Secondment in December 2015 in Centro di Ricerca "E. Piaggio", Pisa.

During this period the first prototype of the experimental Set-up for Electrical impedance tomography has been developed (EIT): it includes the set-up for configuring the current injection and the acquisition system for measuring the resulting voltage between the remaining electrode pairs. This is shown in the following figure:



For further references: S. Russo, S. Nefti-Meziani, T. Gulrez and A. Tognetti, "Towards the Development of an EIT-based Stretchable Sensor for Multi-touch Industrial Human-Computer Interaction Systems", HCI International 2016, Toronto, Canada, 17 - 22 July 2016.

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Object Slip Preventing Sliding Mode Control

Sliding mode slip prevention controllers is implemented for a two fingers industrial gripper. The controller provides a robust design for slip prevention with the aim of reducing the amount of deformation imparted to the grasped object to stop slip.

The experimental results from this controller show that the sliding mode slip prevention controller produces the least amount of deformation to the grasped object while simultaneously preventing the object from being dropped.

The control is designed in a way to realize the predetermined force by the operator. To overcome the slippage we added an error of the slippage, esl in the error function. The error function is

$$e = ef+esl$$

Where ef is the force error measured by force sensor in the fingertip. A sliding manifold S is written based on this error state as

$$S = ne + de/dt$$

Here, n is a positive constant to ensure exponential decay in the error state. The control law for the actuation system of the gripper is

$$Vm = -Csat(S)$$

Where Vm is the speed of the shaft of the motor. The Experimental results showed that the error state can be driven to the sliding manifold and then asymptotically to zero.

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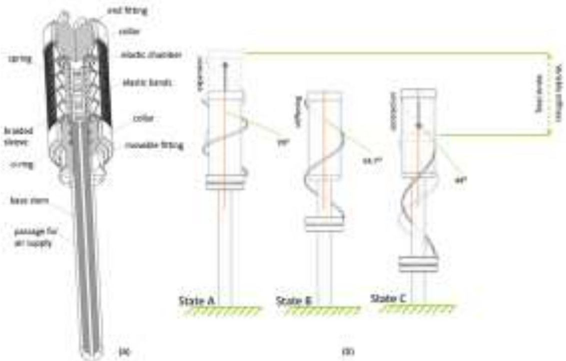
Design and development of a highly flexible arm (with Omni-directional bending and stiffness changing capabilities) and its mechanical interface for a human operator.

Soft robotics is an emerging new type of robotic systems that usually take their inspiration from nature. These systems utilizes soft materials in construction, are inherently compliant and exhibits large strains during normal operation in contrast to their "Hard" counterparts, the traditional robotic manipulators. These properties makes them the best choice for applications such as, but not limited to, personal robots (they can interact with humans without causing any harm), service and painting robots (high dexterity required to reach confined spaces), medical robotics (for use in surgery), and defense and rescue robotics (can operate in unstructured environments).

One of the promising soft actuation technologies are the fiber reinforced elastomeric enclosures. The pneumatic artificial muscles (PAM) or generally known as the fluidic or Mc-Kibben muscles has been a popular choice among engineers and researchers due to their high power to weight ratio, light weight, ease of installation, hazard-free use and inherent compliance. PAM's consists of a hollow cylindrical elastomeric chamber covered by an outer braided sleeve, consisting of individual fibers made of flexible yet un-stretchable material that are arranged in an anti-symmetric helical configuration. When the inner elastic tube is pressurized the muscle either expands or contracts or stiffens depending on the initial angle of the braid fibers with the longitudinal axis of the muscle. The commercially available PAMs has a fixed initial braid fiber angle and are usually designed to produce a contractile force upon actuation, hence producing uni-directional force and motion. This single acting nature of traditional PAMs poses a drawback when utilized for robotic applications, i.e. for bi-directional actuation of a robotic joint; two actuators are required in antagonistic configuration. This increases the overall size and complexity of the actuation mechanism. To overcome this challenge, we designed a novel, multifunctional pneumatic artificial muscle which is able to contract, expand and stiffen. The figure below (a) shows the schematics of the device.



(a) Schematics of the bi-directional muscle. (b) Working concept of the bi-directional muscle. A single braid fiber is shown instead of the whole braided sleeve for clarity.

The working principle is based on the traditional Mc-Kibben muscles but some fundamental changes to the design, enables the user to change the initial braid fiber angle independently during operation, hence achieving bi-directional motion and forces. The working concept is shown also in the figure above (b).

It is believed that this bi-directional actuation capability can notably simplify the design of PAM actuated robotic mechanism/joints. The ability to change the initial braid fiber angle enables the actuator to achieve variable stiffness at each point along the total stroke of the actuator, whereas the traditional PAMs lack this ability. These actuators will form the basic building blocks of the "octopus-like" robotic arm. The robotic arm has a modular design, with each module consisting of three to four of these muscles arranged in a circular configuration. Combining the bi-directional muscles in parallel will enable the module to have omni-directional bending, shortening, elongation and stiffening properties.

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Development of a high-performance haptic tele-operation system

This research is concerned with exploring novel ways for humans to tele-operate robots through physical interfaces. Key elements are the physical interface itself and the overall control scheme that regulates the tele-operation.

Humanoid robots are used as application (see WalkMan and D.R.C.), as they offer an excellent platform for physical tasks that involve human environments. The growing complexity of this class of robots makes it very challenging to program them to operate autonomously. This motivates the interest in tele-operation systems to allow human operators to remotely control such advanced machines. The design of the physical operation interface as well as the overall control scheme pose significant technical challenges.

The project has so far focused on the development of a hardware and software platform for actuated wearable interfaces. The prototype of an actuated interface spanning torso and upper legs is now available (see Toxiri et al. "A Wearable Device for Reducing Spinal Loads during Lifting Tasks: Biomechanics and Design Concepts", IEEE Conference on Robotics and Biomimetics – ROBIO, Zhuhai, China, December 6-9, 2015).

With the aim of maximising the usability of this device, recent work has addressed its capability to minimally hinder the user's movements and only apply significant altering forces when required by the general operation scheme. In this direction, state-of-the-art control techniques for physically interactive robots are being explored and possibly expanded on.

Additional upcoming technical challenges are concerned with employing the interface and its sensorised passive joints to acquire the posture of the human user as part of the tele-operation scheme.

As the subsequent and complementary part of the research, the present project will address strategies for tele-operation, including the control, i.e. sending commands from the user to the operated robot, as well as the feedback, i.e. sending information back to the user about the state of the robot.

The use of the actuated interface to operate a humanoid robot for the manipulation of remote objects will be the goal of future exploration.

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Dexterous teleoperation for a compliant robot within unstructured spaces

The SMART-E project evolves around the theme of sustainable manufacturing. As ESR, I study techniques that can be used to program robots by demonstration. This provides a faster and more user-friendly way of skill transfer compared to classical programming. For industrial applications, programming by demonstration could enable a more flexible application of robot resources since the cost of reprogramming can be greatly reduced.

In the first year of the SMART-E project, I studied various techniques that can be used to program robots by demonstration. One of the main challenges in this field is finding a generic model to represent motor skills (basic movements). I proposed a novel model to represent motor skills that allows to encode both temporal and spatial variability, properties which are important for safe human-robot interaction. During the past six months, I've experimentally evaluated this approach on a robotic platform. Part of the results have been presented at the Human-Friendly Robotics Workshop.

Currently, I am working on improvements and applications of the proposed method. I've started, for example, a collaboration with another ESR, Aaron Pereira, to combine his work on formal safety guarantees in robotics with the proposed method.

Secondment: Roboter und Lederhosen

During the SMART-E Summer School 2015, multiple collaboration opportunities were found within Work Package 3 (WP3); Safety and Human Robot Interaction. To start and further explore these collaboration opportunities, I planned a secondment in the Cyber Physical Systems group of Prof. Althoff at the Technical University in Munich (TUM).

At TUM I worked together with Aaron on a joint project that combines our research directions. My PhD topic evolves around the topic of Programming by Demonstration, a technique that allows one to program a robot solely by demonstration. This is a very promising technique for flexible industrial robotic solutions since it is enables quick reprogramming. A key requirement for robotic systems that operate in vicinity of humans is safety. This combines very well with Aaron Pereira's research topic: Formal Safety Guarantees in Human Robot Interaction. Since safety is paramount in industrial applications, systems that are programmed by demonstration should inherently be equipped with proper safety guarantees. We started developing a method that formally guarantees to avoid the human while executing the demonstrated task.

In addition to this research, Andrea Giusti gave me the opportunity to give a lecture at TUM about Imitation Learning. I liked to have the chance to share my knowledge on Imitation Learning with students since I do not have the possibility to lecture students at my home institution.

I truly enjoyed my secondment at TUM and I would like to thank Esra, Andrea, Aaron and Prof. Althoff for giving me a warm welcome in their group and showing me around the city of Munich.

The new SMART-E Experienced Researcher

Amr Mohammed El-Sayed

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Amr is the new Experienced Researcher (ER), Post-Doctoral Fellow, working in SMART-E at the BioRobotics Institute of the Scuola Superiore Sant'Anna.

He received a B.Sc. and M.Sc. in Mechatronics and Robotics from Assiut University, Egypt, in 2004 and 2010, respectively. He received a Ph.D. degree in biomedical engineering from University of Malaya, Malaysia in 2015.

His research interests include the design of robotic gripper based on soft robotics technologies for industrial manufacturing. Also, design of Mechatronics and Biomechatronics systems, control systems, smart sensors and actuators, control of upper and lower extremity prostheses, rehabilitation engineering, wearable robotics, and embedded system design.

The research project in SMART-E focuses on the development of a robotic gripper based on soft robotics technologies for industrial manufacturing. Based on the following stages:

- The definition of the detailed list of requirements based on limitations of the current industrial gripper for the selected scenario.
- The identification of the most suitable technologies for sensing, mechanisms and actuation.
- Finally, proof of concept by building simplified prototypes and fabrication of the device.

Next events

- Network Technical Skills Workshop 4: Human Factors and Industrial Robotics (Core Technical) – 5 days

  Facilitators: Prof Phil Webb (Cranfield), Prof Samia Nefti-Meziani (USAL)
- Summer school 2 on Industrial Robotics (1week) - USAL
- Complementary Skills Workshop 5: Leadership Training (1 week) – USAL

For further details about these events, please contact Janet Savage at: j.m.savage@salford.ac.uk

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