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Marie Skłodowska-Curie Initial Training Network

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

Newsletter – July 2015
Issue 2

SMART e
SUSTAINABLE MANUFACTURING
THROUGH ADVANCED ROBOTICS TRAINING
IN EUROPE

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

Editorial

SMART-E ITN is gaining momentum with many training events that have taken place and the Fellows' research taking shape.

In this second issue of the SMART-E Newsletter you will find a report on the major training events that have been organized, a description of the results of the first Experienced Researcher (ER), Martin Eder, and the description of the ongoing research activities and results of our 13 Early Stage Researchers (ESR). The Consortium also welcome the new partner AGCO, you can read their message just below.

Some bits from SMART-E new partner: AGCO GmbH

"SMART-E is not a chocolate drop!

To provide sufficient food, energy and raw materials for mankind in the future the agricultural sector in particular is called upon. In a future world of intelligent and communicating machinery there will be, depending on the respective work to be done, on the one hand efficient high-performance machinery and on the other hand small, fully automated units like robots. "As a manufacturer of agricultural engineering we have to seize new trends and technologies to be in a position to offer in the future as well products that modern farmers will require" Dr. Benno Pichlmaier, responsible for research and advanced engineering at AGCO/Fendt, *affirms. "Beside renowned partners from universities and research institutions AGCO is the only representative from industry to participate in the research syndicate SMART-E". SMART-E is a Europe-wide research project which addresses Advanced Robotics Technologies. Under the Marie-Curie Fellowship Program of the European Union young researchers are trained in the field of robotics technology. The young scientists profit from Fendt, as the company provides specific issues and practical applications for possible products. „The project SMART-E funded by the EU unites international robotic experts to a network. This way the highly electrifying findings can be integrated first-hand in the development of future products", explains Dr. Benno Pichlmaier the reasons for AGCO/Fendt to participate in the project. In this symbiosis of academic research and practice-oriented application AGCO/Fendt enables a young scientist to work in the Fendt development team. In the field of agricultural robotics work focuses on a variety of topics. There are particular challenges resulting from the combination of complex sensor technology, e.g. for plant recognition under constantly changing ambient conditions like temperature, weather and soil. The required technology has to stand the test of time reliably during rough daily operation and the control algorithms have to conduct the entire orchestra of sensors, actuators and data communication in a flawless and above all safe way. AGCO/Fendt has made the next step forward with SMART-E. The vision of sustainable agriculture by advanced robotic technology motivates the scientists and the Fendt engineers to continue providing excellent products for the farmers."*

Credits to AGCO GmbH

Training Events

Network wide technical skills online workshop (January – February 2015)

A ShanghAI based teleconference workshop in the field of embodied intelligence, soft robotics and compliant systems/actuators was organized on January and February 2015 by the University of Zurich.
Videos are available at:
http://shanghailectures.org/locations/smart-e

First complementary skills workshop (February 2015)

The SMART-E complementary training programme has been designed to offer all of the SMART-E researchers a strong overview of the skills and methods that they can use both in their academic careers, and in working with and within industry settings. The training will cover a range of activities including developing business cases, project management and leadership skills over three week long workshops, spread across the programme. The first week long programme took take place from 23-27 February at the Advanced Manufacturing Research Centre at the University of Sheffield.

WP1 Technical Skills Workshop – (April 2015)

The workshop has been organized in two parts. The first organized by the Scuola Superiore Sant'Anna in the framework of the Soft Robotics Week (April 13 – 17, Livorno, Italy). The second part was organized by the Istituto Italiano di Tecnologia in Genova. International experts across multiple fields in the scientific community of soft robotics, industrial leaders, young researchers and students, met together to discuss current research activities and applications and to face future frontiers for the field of soft robotics. The programme followed a combined lectures and practical sessions (hands on/technical skills training) format. The working group sessions for the students trained them using on-line tools and hardware kit to design and build soft robots for target applications with relevance to "Dexterous, Soft and Compliant Robotics in Manufacturing".

SMART-E Summer School on "Advanced Robotics for Sustainable Manufacturing" (July 6-10 2015)

The first SMART-E Summer School on Advanced Robotics for Sustainable Manufacturing has been organized by the BioRobotics Institute of the Scuola Superiore Sant'Anna in Livorno (Italy). Invited speakers at the School were industrial leaders of manufacturers and automation companies in Europe, as well as experts in industrial applications of robotics research, technology transfer and entrepreneurship. The programme of the School included the Meeting of the Management Committee and during the meeting, fellows presented their research activity in preparation to the SMART-E mid-term conference and discussed their results and their future plans with the supervisors and partners.

A series of sessions of students' meeting have been dedicated to brainstorming among fellows who discussed together about their project and identified possible synergies, complementarities and collaborations within and between workpackages, as well as dissemination and outreach activities which could showcase the SMART-E project and robotics in general to industry, academia and the wider public.

Report of Experienced Researchers Martin Eder

Research Topic:

Morphological computation based control of soft robotic structures

Introduction:

Soft robots feature rich body dynamics. Their structures are nonlinear, complex and high-dimensional, which results in sophisticated models and control. The idea of morphological computation considers the dynamics of such soft bodies as computational resources, and works as a model-free approach. These resources are exploited to control the soft robotic structure.

Method:

Within an initial learning phase all sensors of the soft robot are read and stored. Considering actual trajectory target data, the sensor readouts are processed to gain linear readout weights. During the control phase the system uses current sensor data and these weights to realize the input stream for its actuators.

Implementation setup:

Our Morphological Computation approach is implemented on a soft robotic arm, called “worm”. This robotic platform has 12 DOF driven by pneumatic muscles and integrates 28 sensors that generate 48 different sensor signals. The decentralized control architecture of the robot is rearranged, such that all sensor values can be read out in a synchronized way. Various experiments are conducted, including circular, oval and spiral trajectories. The experiments are carried out with different control parameters and external disturbances/forces during learning and evaluation phases.

Results:

The experiments show that circular, oval and logarithmic spiral trajectories can be reproduced consistently and in a robust way. The more (external) disturbances are considered within the initial learning phase, the more tolerant the system behaves during the actual control phase.

However, it turns out that axial movements (moving the system back and forth on a plane) are challenging to implement. Here, the morphological computation based control of our system has problems with respect to deciding about the direction of motion.

In contrast to previous theoretical foundations of prior art, the implementation on our real robot could deal without any additional artificial bias and sensor noise (white noise). Noise coming from the sensors (in particular stretch sensors for length detection of our pneumatic muscles) was enough to achieve robust control behaviour.

The full report is also available in the SMART-E Website at: http://smart-e-mariecurie.eu/news_and_results

From the Students' Desk

Yasmin Ansari
The BioRobotics Institute, Scuola Superiore Sant'Anna, Italy
Email: y.ansari@sssup.it

Control of Soft Robots

The use of mechanically elastic aka "soft" manipulators with variable stiffness result in a highly dexterous robotic platform that is adaptive to the environment. Such robots are often inspired by biological structures like the octopus arm taking into account the embodiment principles. This allows to partially off-load the computational burden from the "brain" of the robot to the mechanical properties of the physical system, a phenomenon known as morphological computation. Industries will be able to leverage a significant competitive advantage from the use of these intrinsically compliant manipulators as they have the potential to create an environment of safe human-robot interaction i.e. humans and robots working side-by-side. In order to perform high precision and repeatable tasks in highly dynamic, unstructured, and unpredictable industrial environments, these manipulators require a new framework of intelligent control strategies that (while taking into account their non-linearity, time-dependence, and high dimensionality) are capable of i) autonomous open-ended learning ii) platform-independent decision-making iii) generalizing from experience and iv) adaptability. The overall goal is to endow the manipulator to correlate the motor and the sensory spaces to develop sensorimotor representations from interaction with the environment to learn its kinematics and dynamics which can be exploited for industrial control tasks such as pick and place. Autonomous open-ended cognition is a result of the developmental process found in humans and animals where they acquire new skills and knowledge driven by intrinsic, extrinsic, and social motivations. This idea can be utilized to design intelligent robotic systems where the agent is driven to explore an environment to decide between various action strategies with the objective to learn one that will lead to optimal behavior. The key design parameter for such systems, then, is the motivation that is driving the exploration. My research focuses to address this topic through the implementation of "goal-oriented" motivations in Cartesian state space using online model-free reinforcement learning algorithms. with function approximation. Model-free learning is necessary to allow the agent to adapt to various environments whereas function approximation can be exploited to generalize experience.

Currently, I am testing the proof-of-concept of these algorithms on simulated high-dimensional robots based on rigid links. This work will then be further extended to be tested on both simulated and hardware-based soft robots.

Roy Assaf
University of Salford, UK
Email: R.Assaf@salford.ac.uk

Mathematical modelling for self-healing robotic cell

A key to creating highly adaptable, autonomous and flexible maintenance systems is the embedding of cognitive and cybernetic capabilities for machines inside the factory. A factory will then reason using knowledge and models that are continuously updated through on-line observation, it will autonomously plan its own actions, learn new models, new actions and new skills. This project will develop a novel mathematical model of imperfect repair for complex systems in an autonomous factory, and integrate this model within a maintenance and spare parts decision-making tool with an autonomous capability. In this way, the project will take a significant step towards the development of a system that will plan and execute its own maintenance, in a manner that gives the appearance of “self-healing”. We will Model Reliability based on dependencies between sub-systems and components. We will develop a maintenance system with an autonomous capability. The maintenance system will be based on a cognitive framework and through machine learning techniques we will provide a predictive model for faults and failures and thus move closer towards condition based maintenance.

Alex Bousaid

AGCO/Fendt GmbH, Germany

Email: alexandre.bousaid@agcocorp.com

Although navigation systems have long been used in watercrafts and aircrafts, it has only been integrated in commercial mobile robots, specifically mobile robots for agriculture, since the early 2000s. For farming applications, high precision positioning and navigation is essential. The existing GNSS positioning technologies, which are expensive and large in size, are not very suitable for this specific application. Also navigation and positioning tasks of autonomous robots in outdoor environments are constrained by environmental, technical, agricultural and safety aspects. The use of RTK (Real-time Kinematic), a GNSS Enhancement system, for farming, is still a problem in terms of cost and size.

In this work we present approaches and techniques on developing a cost effective, small-sized and robust positioning system for navigation of robot swarms. The localization strategies used in these approaches are Absolute Localization with reference based. This means that the initial position of the robots is unknown and the robots will estimate its distances by means of active landmarks at a predefined locations, and these landmarks should actively send out information about the location of the robots. This positioning system for navigation of robot swarms could be true alternative to the conventional agricultural equipment.

Andrea Giusti

Technische Universität München, Germany

Email: giusti@in.tum.de

Control design of compliant and reconfigurable modular robots

Cooperation between humans and robots in a shared workspace introduces several advantages to overcome the limitations of classical industrial automation systems. Classical industrial robotic systems do not guarantee safety in a shared workspace between humans and robots and have limited adaptability for different tasks. Promising systems to pursue both safety and adaptability are compliant and reconfigurable modular robots.

For this class of robots, the change of the system dynamics after reassembling as well as the inherent (passive) compliance of the actuators, result in a source of degradation of the motion control performance. In order to address these challenges, nonlinear model-based control methods are developed paying special attention to: i.) the automatic design of the controller, ii.) to the robustness against model uncertainties, and iii.) to variable stiffness actuators. A method for automatic and centralized controller design of reconfigurable modular robot manipulators has been proposed, and the corresponding paper was submitted to the 2015 IEEE/RSJ International Conference on Intelligent Robots and Systems. With this work we introduce a novel centralized method for controlling reconfigurable modular robots using information stored in each module, a notation for characterizing heterogeneous modules which is based on an extension of the standard Denavit-Hartenberg convention, and finally the procedure for the automatic generation of model-based control laws using the modular information. Preliminary activities for the implementation of the proposed method on a commercial modular robot are ongoing and a new robust control method is currently under investigation.

Esra Icer

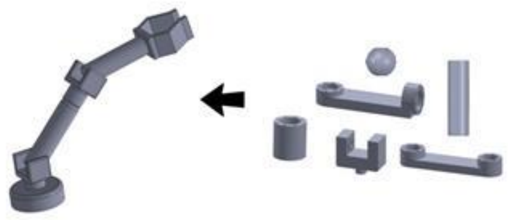
Technische Universität München, Germany

Email: esra.icer@tum.de

Optimal Configurations of Modular Robots for Specific Tasks

Industrial robots are utilized in numerous fields offering high versatility, robustness and accuracy. Due to the high cost of modern robots, using new robots for each task in a manufacturing process becomes expensive. To address this problem, the use of modular robots could enable the same robots to be used for different tasks.

Reconfigurable robots attract the interest of researchers due to their unique properties such as high versatility, easy maintenance, interconnectability and robustness. However, a limiting factor on their uptake is the inability to determine the best configuration for certain tasks or sets of tasks. With the help of appropriate optimization algorithms, a solution can be obtained for optimal configuration of the robot for single or multiple objectives.



Based on previous studies, fundamental aspects of my thesis are as follows: First, modules and all possible combinations of them are defined considering the kinematic and dynamic constraints of the robot structure. Next, a fast off-line trajectory planning and obstacle avoidance algorithms are developed to achieve the desired aspects of the task. Finally, optimization algorithms are applied to obtain the optimum configuration of the robot for desired objectives. At the end of the thesis, a time-efficient toolbox that optimally configures modular robots which can achieve the any given tasks from given modules considering desired objectives will be developed.

Mateo Leco

The University of Sheffield, UK

Email: m.leco@sheffield.ac.uk

Monitoring and control system for collaborative robot machining

Robotic machining cells are an emerging area with robotic machining limited by the dynamic and static signatures of the robots, the dynamic motion of the robots and the positional accuracy. In order to advance the field of robotic machining, there is a need of developing a flexible & reconfigurable robotic machining structure to address the need for low volume, low materiel removal.

The research project consists on developing a real-time monitoring and control system in the field of collaborative robot machining. Using a co-operating multi-robot machining cell as a platform, the research aims to progress this field and advance the cell capability. The challenges to enable such a system are the integrated sensor system and data fusion for monitoring and control and fault detection, as well as the coordination and cooperation in controlling the interaction of multiple robots and spindles operating as a single 'cell'. These robots will be able to cooperate together in close proximity, to carry out machining tasks, together or by decomposition.

Two main contributions have come out by preliminary work: the first referring to data fusion aspects, such as identifying the sensors' types and signals for process monitoring and defining a suitable framework for merging all the retrieved data; the second addressing multi-robot cooperation, such as identifying an intelligent control strategy dealing with collective behavior and swarm robotics, motion coordination, collision avoidance and path optimization, and dynamic behavior of the workpiece and interaction of robots (chatter control).

Constantin Neacsu

Istituto Italiano di Tecnologia, Italy

Email: constantin.neacsu@iit.it

Compliant Robotic Actuation Platform For Use In Unstructured Manufacturing Spaces

Robots are widely used today throughout the industry for manufacturing, assembly and logistic purposes. In their steady introduction and now mainstream use, they have required special care due to their inability to safely operate near human counterparts. However, the tasks that they are performing are becoming more complex and require cooperation and intervention from human workers. Implementing compliance into their design will allow these industries to increase their efficiency and productivity by allowing the joint operation of robotic and human systems within the same environment in a safe, fast and convenient manner.

The main focus on the project is the development of robotic manipulation platforms that combine the features of passive compliance with active impedance regulation techniques to produce a robotic manipulation system that can allow the execution of tasks in environments where uncertainties are expected, both in the environment features as well as from perception data. The combined intrinsic and active impedance features will potentially make the new system highly adaptable during physical interactions and less prone to damage under non-anticipated collisions and impacts.

The robotic system is comprised of an upper platform using a human torso with arms design, capable of dextrous manipulation using hand-like grippers. This is attached to a mobility platform, similar to a standalone quadruped robot design which uses a wheeled leg configuration, allowing it to tackle both even and uneven terrain for maximum mobility and flexibility. The system will use high power high torque electric actuators with active and passive compliance, strong and lightweight materials and a modular design.

The project incorporates existing technologies developed at IIT with new concepts to create an adaptable platform capable of meeting the fast changing manipulation needs of existing environments.

Aaron Pereira

Technische Universität München, Germany

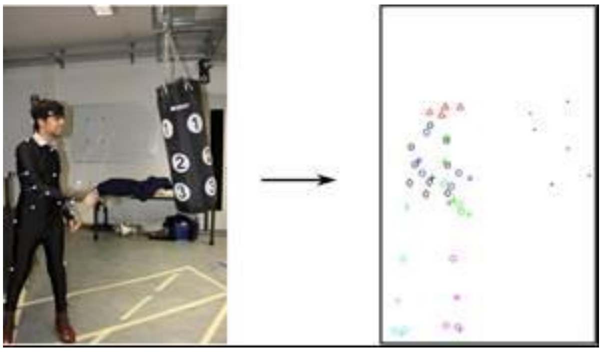
Email: aaron.pereira@tum.de

Formal Guarantees and Trajectory Planning for Safe Human-Robot Interaction

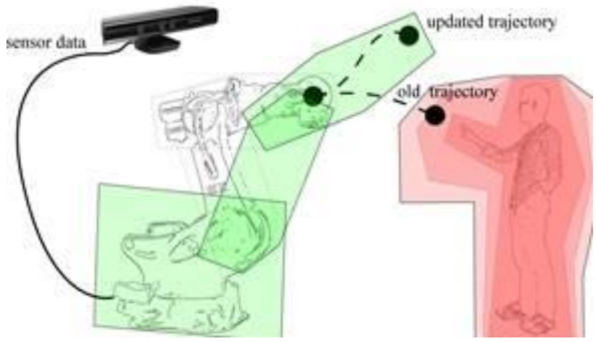
Where humans work alongside robots, safety is key. Strict international standards restrict where and how robots and humans may interact; I aim to use formal methods to guarantee operator safety in industrial settings.

Reachability analysis provides a formal guarantee of the safety of a system by ensuring that the set of all possible states of a system – the reachable set – does not intersect pre-defined unsafe sets. To determine the reachable sets of the robot and the human, novel methods for online computation and verification of robot trajectories are developed, as well as collision-avoidance and trajectory-planning algorithms.

Building on previous work on formal methods applied to hybrid (cyber-physical) dynamic systems, my thesis tackles the unique challenges of the complex coupled dynamics in serial-link robots, aiming to use pre-computation and overapproximation to keep the running time of the safety control to within real-time. Preliminary attempts have been published (A. Pereira, M. Althoff: Safety Control of Robots under Computed Torque Control Using Reachable Sets. Proceedings of IEEE International Conference on Robotics and Automation, Seattle 2015) and will be trialled on indus-trial robots at SMART-e partner RURobots in Manchester, UK.



Concerning the human, studies are being carried out with the aim of determining the worst-case movement scenarios of humans in a collaborative setting. Using overapproximative dynamic models of humans informed by recorded data, we predict reachable sets of the human as dynamic obstacles.



Stefania Russo
University of Salford, UK
Email: s.russo1@salford.ac.uk

Cognitive multi-agents systems framework for reconfigurable systems

In the last years, the field of robotics has seen an increase in the field of human-robot interaction research because there is the need for robots to have capabilities to interact safely, fluently and interactively with humans. Usually, and artificial sensitive skin is considered as a stretchable and flexible array of small and light sensors, covering the robot's surfaces. The fabrication should be simple and low-cost and result in durable skin, with an electronic side with minimum power consumption for also battery-powered operations. The presence of the skin on the robot should not compromise its movements and not interfere with the host mechanical properties.

This project will develop a Multi-Agent framework of soft and flexible sensors skin for proving the soft and continuum robots the self-monitoring abilities required for conducting self-optimizing and autonomous processes. By embedding this sensor skin within the compliant mechanism of an actuated structure, the robot will be adaptive: in this way, the project will take a significant step towards the development of a robotic system with an embedded sensor framework that will need the minimum human intervention.

For developing this sensors framework, being inspired from the current technologies, the project will focus on the development on different solution based on cutting-edge technologies:

- EIT tomographic imaging and Inverse analysis
- Design and fabrication of the sensor system
- Data acquisition and data analysis with Image reconstruction
- Application of the developed system in real-world environments for Safe Human-Robot interactions

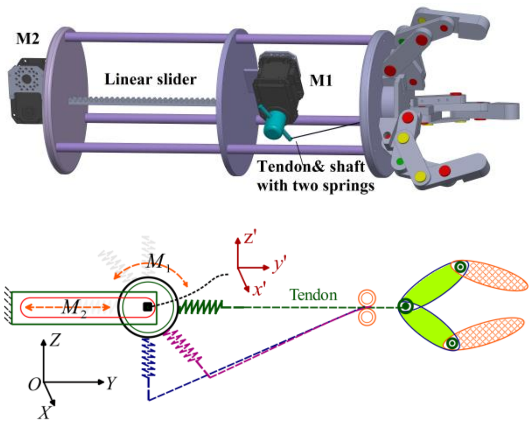
This artificial skin will presents some advantages:

- It will be made of a thin and homogeneous material providing continuous sensing.
- Without internal wires the sensor will be highly stretchable and easily implementable over 3D surfaces.
- It will present real time conductivity reconstruction.
- It will handle tactile stimuli for touch recognition
- In robotics, EIT-based artificial skins will be suitable for human-robot interaction purposes.

Mahboubi Saber
University of Salford, UK
Email:
S.MahboubiHeydarabad@salford.ac.uk

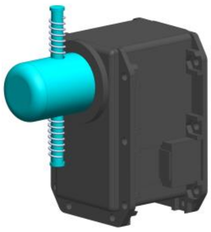
Adjustable Stiffness Hand for Industrial Applications

Compliant robots are one of the latest interests in robotics. The idea of adjustable stiffness and controllable impedance is an inevitable challenge for roboticist, especially in recent decade, for the growing demand of human-robot interaction. In my project I will present a new design of variable stiffness synergy based tendon driven hand for pick-and-place applications. With respect to this task, it is essential to have a variable stiffness hand to modify the rigidity of the fingers due to different objects. To control the stiffness of the hand we will provide a mathematical model of the stiffness. Although the hand presented in this report utilizes just one synergy, the extension of this design to more degrees of freedom is possible and it will be our future plan. A CAD model of our variable stiffness gripper can be found in the figure below:

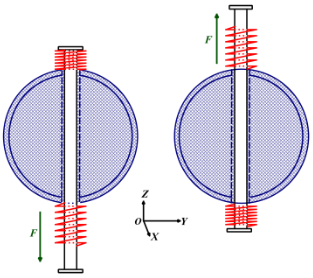


CAD model and schematic design of VSG

As shown in this figure, the model consists of two servo motors. One of the servos provides rotational motion, and the second one is used to produce a linear displacement along the arm of the gripper. We used a rack and pinion gear arrangement for this purpose. There is a slider between upper and lower parts of the gripper, which uses the linear motion of M2 to slide between these two parts. The first motor M1 is fixed on this slider and it can move by moving the slider. To transfer the torque from the actuators to the gripper, we used a tendon-pulley mechanism as shown in the figure. The tendon establishes connection between the compliant shaft of M1 and the gripper. We used two linear mechanical springs, which are connected to the shaft of M1 through a rigid rod as shown in figures below. As you can see from the figures there is a hole in the center of the shaft, and the rod goes through this hole in a way that it can slide into the shaft easily.



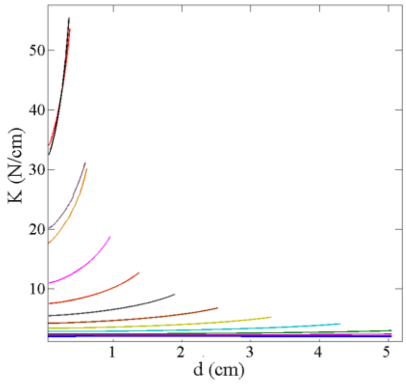
M1 and its compliant shaft



The way of the contraction of the springs in the presence of an external force

Figures below show a prototype of our variable stiffness gripper in two different stiffness modes. The second one illustrates the changes in stiffness of the gripper by changing the α. In this diagram the x axis is the displacement of the end point of the tendon because of change of the length of the springs, and the y axis is the stiffness of the gripper.

The stiffness of the gripper is adaptable due to weight and rigidity of the object



Stiffness of the gripper σ_O in different α.

Seyd Taimoor Hassan Shah

The BioRobotics Institute, Scuola Superiore Sant'Anna, Italy

Email: s.shah@sssup.it

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

The soft robotics domain deals with the design and development of robotic systems able to interact with unknown environments and also to interact/corporate with humans in a safer manner. Today's industrial robots with their large size/weight and high speeds prove to be a threat to human coworkers and are thus enclosed by protective fences. In contrast soft robots can share the workspace and workload with human coworkers providing

higher flexibility to product diversity and short production life cycles.
My research project focuses on the development of an "octopus-like" robotic arm based on soft mechatronic technologies. The system will have high dexterity and maneuverability enabling it to be used in industrial environments. Moreover the robotic arm will present high softness and compliance (mainly due to the intrinsic passive properties of the used materials) but when necessary it will be able to change its stiffness (exploiting material or structural changes) to produce higher forces. Currently fluidic actuation and cable driven mechanisms are taken into consideration and are being explored. In fluidic actuation we are working on an innovative and novel type of pneumatic artificial muscle (patented), which is able to produce bi-directional forces and motion. The actuator is being characterized and optimized. The manipulator design will meet the dexterity and softness criteria imposed by the specific manufacturing tasks, but it will also possess the ability to be employed in several other fields where soft interaction is a major issue e.g. Pick and place, inspection, assembly, co-worker applications, food industry and agriculture. The system will have the ability to work autonomously and can also be operated in a master-slave configuration.

Stefano Toxiri
Istituto Italiano di Tecnologia, Italy
Email: stefano.toxiri@iit.it

Non-invasive estimation of user intention for controlling assistive devices
The area of interest is controls in human-robot interaction. The specific research topic is concerned with non-invasive methods for the estimation of user intention, aiming at intuitive control of assistive devices.
The current focus is on a wearable exoskeleton that physically assists industrial workers in tasks such as lifting, carrying and lowering heavy objects, thereby reducing the required effort and thus the risk of low back injuries. The mechatronics of the device have been designed to assist by applying torques onto its user's torso and thighs, while a control strategy is required to modulate the timing and extent of said torques based on user intention.
In addressing similar problems, academic research has commonly proposed intention estimation via surface electromyography (EMG), which however has limited applicability due to its associated model complexity and need for frequent recalibration. By contrast, distinctive requirements of this industrial application include ease of use and high reliability.
This project addresses the need for non-invasive and robust control strategies and adopts an approach based on system dynamics. Under the hypothesis that the user-generated muscular forces can be computed using known dynamic variables via biomechanical models, this project considers the concept of modulating the assistive torques according to said muscular forces. This scheme is similar to EMG-based strategies, while it may prove more suitable for industrial scenarios.
The present project may be interpreted as structured in the following parts: a) literature study and development of a dynamic biomechanical model of the human torso; b) experimental validation of the model with respect to the hypothesis introduced above; c) extension of the model to capture the exoskeleton and its assistive torques, and subsequent exploration of applicable control strategies via simulation; d) implementation and experimental evaluation of a suitable control strategy on an exoskeleton prototype.
The research activity conducted thus far includes extensive study of the relevant literature as well as simulation of simplified

models for characterisation of the system dynamics. The first steps have been taken towards extending the biomechanical model so as to capture the action of the muscular forces, which will lead to experimentally testing the associated hypothesis. The systematic evaluation of control strategies and their implementation and testing on a prototype will follow.

Martijn Zeestraten

Istituto Italiano di Tecnologia, Italy
Email: martijn.zeestraten@iit.it

Tele-operation is a branch of robotics in which a user controls a robot via some form of input device. Tele-operation could have various industrial applications; It allows one to perform tasks in hazardous environments such as paintshops, or it can allow users to perform tasks which are physically too demanding such as heavy lifting. In semi-autonomous tele-operation the robot is capable of performing parts of the tele-operation tasks on its own. One could imagine that the robot has a library of motion primitives which, depending on the context and user input, are sequenced to achieve a desired goal. This autonomy can be used to either assist the user, e.g. preventing mistakes, or, to simplify the users input device in such a way that he/she can easily control the robot using high-level commands. To learn the motion primitives a probabilistic imitation learning approach is used. Imitation learning provides a fast and user-friendly way of transferring skills; Users can transfer skills by simply showing the robot how to perform them without requiring extensive programming knowledge. I propose to encode the demonstrated skills using a Task Parameterized Hidden Semi Markov Model (TP-HSMM). This probabilistic encoding has several key features for the acquisition of the motion primitive library and for the motion synthesis. TP-HSMM can be combined with optimal control by constructing the control objective based on the state sequence generated by the TP-HSMM. Doing so, one obtains a variable stiffness controller; i.e. a controller that is more compliant when the accuracy allows it and stiff when accuracy is required. A key feature is that the regression of the probabilistic model and optimization of the control problem are combined in one step. This optimization step can be executed online. This feature thus allows us to adapt the controller online via the state sequence generated by the TP-HSMM. In future work I want to exploit the properties of the Hidden (semi) Markov Model to incorporate user intention and environmental context for motion synthesis.

Next events

- September 4, 2015 "UK Showcase in Robotics", Salford, UK
- September 7-11, 2015 “Complementary skills training”, Sheffield, UK
- September 14-16, 2015 “WP2 Technical Workshop” (for WP2 ESRs) Salford, UK
- October 19-23, 2015 “SMART-E Mid-term review and conference”, Munich, Germany

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Contacts

SMART-E Project Coordinator
Samia Nefti-Meziani,
University of Salford
(s.Nefti-Meziani@salford.ac.uk)

SMART-E Project Manager
Christian Clausner,
University of Salford
(C.Clausner@salford.ac.uk)

SMART-E Newsletter Editor
Laura Margheri,
The BioRobotics Institute,
Scuola Superiore Sant'Anna
(laura.margheri@sssup.it)