The Newsletter of RoboSoft
Coordination Action for Soft Robotics

Issue 1 **www.robosoftca.eu** **March 2014**

Editorial

RoboSoft rationale

Soft robotics, intended as the use of soft materials in robotics, is a young research field, poised to overcome the basic assumptions of conventional rigid robotics and its solid theories and techniques, developed over the last 50 years. Using soft materials to apply forces on the environment, as expected in a soft robot able to locomote, grasp, and perform other tasks, poses new problems at the level of the different components as well as at the whole system level. The technologies for actuating the soft materials have not yet been demonstrated to exist in a general form, although specific effective examples exists. The same is true for sensors embedded in the soft materials and for soft robotic energy suppliers.

A **Coordination Action (CA) for Soft Robotics** is extremely necessary and timely in the current and future landscape of robotics and biorobotics and can capitalize on the competitiveness of European research in this new field.
A common forum will help soft robotics researchers to combine their efforts, to maximize the opportunities and to materialize the huge potential impact.

RoboSoft will create this missing framework for the soft robotics scientists, regardless of their background disciplines, and will enable the accumulation and sharing of the crucial knowledge needed for scientific progress in this field. **RoboSoft** will not only create and consolidate the soft robotics community, but will also create assets that go beyond the end of the three-year CA.

Issue 1, March 2014
Contents:

RoboSoft Pills

RoboSoft start

RoboSoft CA started on October 1, 2013 as an EU-funded Coordination Action (CA) for Soft Robotics under the Future and Emerging Technologies Open Scheme (FP7-ICT-2013-C project #619319). RoboSoft is coordinated by Prof. Cecilia Laschi (The BioRobotics Institute, Scuola Superiore Sant'Anna, Pisa, Italy) in partnership with the ETH Zurich (Switzerland) and the University of Bristol (UK),

The BioRobotics Institute is responsible of the project coordination and management, of the organization of the scientific community and initiatives, and supervises and contributes to the dissemination and outreach activities. Prof. Cecilia Laschi and her team have been working in the field of soft robotics since 2007 (http://sssa.bioroboticsinstitute.it/research/softrobotics). The past 6 years of research in Soft Robotics concerned the design and development of a soft-bodied robot inspired to the octopus, with locomotion and grasping capabilities (FP7-ICT FET OCTOPUS IP). The OCTOPUS soft robotics technologies are being exploited in biomedical applications, in building a soft endoscope for minimally invasive surgery (EU STIFF-FLOP IP), and in marine robotics, in building a soft robot for underwater explorations (PoseiDRONE Project). Among others, the BioRobotics Institute has participated in FP6-IST CAs, in FP7-ICT CA AALIANCE and was the coordinator of the FP7-ICT- FET Flagship Initiative Preparatory Actions CA-RoboCom.

The Swiss Federal Institute of Technology Zurich (Eidgenössische Technische Hochschule Zürich, Switzerland, http://www.birl.ethz.ch/) is responsible of the project web portal and online tools setup and management and supports and is involved in all the coordination action initiatives. In the recent years, Prof. Fumiya Iida and his team have been actively contributing the soft robotics community, as they organized Swiss-Japan Seminar on Soft Robotics (2010), the Summer School on Soft Robotics (in Zürich, 2012), and the International Workshop on Soft Robotics and Morphological Computation (in Ascona, Switzerland, 2013). Prof. Iida has been guest editor of a special issue on Soft Robotics in Advanced Robotics Journal (2012) and proposed and founded the IEEE Robotics and Automation Technical Committee on Soft Robotics (2012), where also Prof. Cecilia Laschi is a Co-Chair.

Bristol Robotics Laboratory (BRL, University of Bristol) is responsible for RoboSoft dissemination and engagement activities and interacting and supporting with RoboSoft stakeholders, including industrial and institutional partners. **The Soft Robotics research group** (http://www.brl.ac.uk/researchthemes/softrobotics.aspx) is led by Dr Jonathan Rossiter and develops new soft robotic smart materials, mechanisms, actuators, sensors and bio-inpired robots. These include electroactive polymers, shape memory materials, biodegradable soft robotics, energy autonomous soft robotic organisms, smart skins and artificial camouflage. Exploitation of compliant technologies centres on robotic, user interface and medical applications.

During the first months of the project, the RoboSoft Consortium has established the Executive Board and Advisory Board.

RoboSoft Executive Board is chaired by the CA coordinator, Prof. Cecilia Laschi, and composed of one person in charge of each partner: Prof. Fumiya Iida, for ETH Zurich, and Dr. Jonathan Rossiter, for the University of Bristol. The Executive Board will support the Project Coordinator with CA strategic orientation and in fulfilling the tasks and obligations on the basis of the provision of the EC Contract, the consortium Agreement, and the community Agreement.

RoboSoft Advisory Board is chaired by Prof. Rolf Pfeifer, Full Professor at University of Zürich, and Prof. George Jeronimidis, University of Reading (UK) is the other appointed member. The Advisory Board will participate in the meetings and will follow the progress achieved within the CA, supplying the consortium and the community with scientific, technological and management evaluations and advising for future activities.

RoboSoft objectives

RoboSoft aims at creating a common forum to help soft robotics researchers to combine their efforts and enable the accumulation and sharing of scientific and technological knowledge to maximize the opportunities and materialize the huge potential impact of soft robotics technologies.

The Coordination Action aims first at creating and consolidating a scientific community in the field of soft robotics. For this objective the RoboSoft Consortium will involve the major excellent research laboratories and institutions at European and international level working in the field of soft robotics to take part to the scientific initiatives of the RoboSoft Community (plenary meetings and workshops, Summer Schools, working groups, and more).

Besides, with the activities organized in the framework of the Coordination Action, RoboSoft aims at: (i) creating the common places for gathering and for exchange of ideas and experiences for researchers in soft robotics and in the many scientific and technological sectors related to it; (ii) promoting the visibility of soft robotics beyond its community and towards stakeholders and special interest research communities; (iii) providing means for better exploiting the potential of soft robots and technologies in future ICT.

RoboSoft Community Members

The RoboSoft Community is intended to comprise the major excellent research laboratories, at European and international level, working in the field of soft robotics, identified by RoboSoft Consortium on the basis of the following criteria:

- Vision of soft robotics in line with the RoboSoft philosophy;
- Scientific activities in soft robotics currently being carried on (publications, projects, educational activities, etc.);
- Potential contribution and commitment to Working Groups and to RoboSoft events and publications.

Membership to the RoboSoft community will be open for all the duration of the CA. The RoboSoft Executive Board will approve the membership of candidates. Members joining the RoboSoft community will be organized in a number of thematic Working Groups (WGs) to focus on critical or emerging topics and technologies.

The following list of WGs has been discussed and defined during RoboSoft kick-off meeting (November 13, 2013, Pontedera, Pisa, Italy):

- Smart Materials and Soft Actuators;
- Control Architectures and Paradigms for Soft Robots;
- Soft Sensors;
- Energy harvesting;
- Stretchable Electronics;
- Biological insights.

Each WG is composed of experts in the respective research topics. The number and type of WGs could change along the project duration on the basis of the members' needs and of strategic decisions under the supervision of the Executive Board and Advisory Board.

Coordinated by the RoboSoft consortium, the WGs shall deliver working papers derived from brainstorming sessions, describing the challenges and the expected milestones of soft robotics and providing research roadmaps for the soft robotics community and needed actions for the European Commission. The consultations should address both scientific and technological aspects as well as necessary supporting actions to materialize the potential impact of soft robotics.

RoboSoft Working Groups shall also participate in the organization of events for cross-fertilization with other scientific communities (i.e. biology, medicine, neuroscience, material science and chemistry, mathematics and model theory, etc.), like workshops or special sessions organized at major conferences of such disciplines where fertilization and promotion of soft robotics can take place.

Coordination Action Initiatives

The RoboSoft Consortium and Community will consolidate a network for scientists and roboticists, providing opportunities and common places for gathering and for exchange of ideas and experiences, promoting discussions on open issues, tracking technical developments and encouraging innovation, fostering the exchange of personnel and collaboration activities, and drawing up working papers and a book series collecting the knowledge of soft robotics.

RoboSoft workplan foresees the following major activities:

- 3 Periodic plenary meetings involving the scientific community and stakeholders;
- 2 Summer Schools for PhD students and young researchers;
- A series of interdisciplinary events for cross-fertilization with other scientific communities (i.e. biology, medicine, neuroscience, material science and chemistry, mathematics and model theory, etc.);
- A series of dedicated workshops and exhibitions for stakeholders
- The setup and maintenance of the RoboSoft website with online tools available to the Community Members;
- The periodic publication of the RoboSoft Newsletter and engagement material for RoboSoft Community, other scientific communities and stakeholders (each 6 months);
- The writing of Working Papers with the RoboSoft Community Members resulting from brainstorming and discussions in the WGs during and right after the first two Plenary meetings, definition of scientific and technical standards for soft robotics;
- A book series for soft robotics resulting from Working Papers and from brainstorming and discussions meetings.

Laura Margheri and
Cecilia Laschi, CA Coordinator

News and events

- RoboSoft Kick off meeting, November 13, Pontedera, Pisa, Italy

- RoboSoft Plenary Meeting, March 31 – April 1, Pisa, Italy:

  http://www.robosoftca.eu/events/first-plenary-meeting

- RSS workshop on "Advances on Soft Robotics" http://www.robosoftca.eu/events/RSS2014-workshop

Join RoboSoft

- Visit the RoboSoft web page and sign up: www.robosoftca.eu

- Facebook page https://www.facebook.com/pages/Robosoft-Coordination-Action/579415472150017

Call for Newsletter Articles

Articles for the RoboSoft newsletter are welcome. These can be in any of newsletter sections:

- **News**: latest news and announcements
- **RoboSoft Pills**: short snips of information
- **RoboSoft Bites**: longer articles, typically under one of the following headings:
  - *People*
  - *Places*
  - *Partners*
  - *Industries*
  - *Technologies*
- **Calls**: funding call and scientific calls (e.g. edited volumes, workshops)
- **Vacancies**: research, industrial and academic vacancies in Soft Robotics and closely related fields.

Please send articles and any questions about the newsletter to the editor: Jonathan.Rossiter@bris.ac.uk

RoboSoft Bites

Places: Auckland Biomimetic Lab

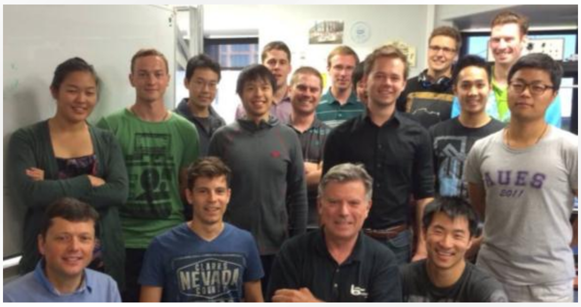
With Rugby being New Zealand's national sport, Kiwis are far from soft. But despite this the tough workers at the University of Auckland's Biomimetics Laboratory are interested in developing soft machines. Their vision is of a world with soft robots that can interact seamlessly with humans, who themselves consist of materials that are much softer than traditional robotics technologies based on servo-motors and rigid gears. To bring this closer to a reality the team has worked on embedded intelligence, control, self-sensing, and energy harvesting using dielectric elastomer artificial muscles.

To provide soft machines with the ability to think, the Biomimetics laboratory developed a technology called the dielectric elastomer switch (DES). DES allow information to flow in two manners: mechanically and electrically. The power of this information flow was recently published in the Applied Physics Letters paper An Artificial Muscle Computer [1], describing an artificial muscle computer that can be adapted to simulate the logic of any computational algorithm.

As described at the recent Smart Structures NDE conference in the paper Enabling large scale capacitive sensing for dielectric elastomers [2], the Biomimetics Laboratory has also been working on using artificial muscles as a new way to interact with computers by sensing motion and gestures. At the same conference, the Biomimetics Laboratory demonstrated, the Artificial Muscle Power module (AMP,) that electronically controls an artificial muscle so that it harvests energy when mechanically stretched and that outputs the energy in a form that is suitable for powering portable devices (for more information visit www.biomimeticslab.com). Furthermore, a circuit was demonstrated in the SPIE conference paper Artificial Muscles Harvesting Sensational Power [3] that allowed an artificial muscle energy harvester to simultaneously generate electricity and sense its stretch state: An energy harvester with feelings. The ability for an artificial muscle to sense its own state will allow more sophisticated control strategies and therefore result in improved performance or self-sensing could even be used to develop a version of a soft generator that is a self-powered sensor.

Kiwis can't fly but they can dive! The lab is currently preparing an entry for the European Submarine Races in Gosport UK in July. To read about our progress please check our web page at: www.abi.auckland.ac.nz/taniwha

An artificial muscle computer (left) and an artificial muscle sensor for human computer interaction.



The Biomimetic lab, led by Iain Anderson (front, third from left) i.anderson@auckland.ac.nz

[1] B. O'Brien and I. Anderson, *Applied Physics Letters*, 102(10), (2013)

[2] D. Xu, T.G. McKay, S. Michel, and I.A. Anderson, *Proc. SPIE*, 90561A, (2014). 10.1117/12.2044356

[3] T.G. McKay, T.A. Gisby, and I.A. Anderson, *Proc. SPIE*, 905603, (2014). 10.1117/12.2045359

People: Robert Shepherd

Rob Shepherd received his B.S. (2002) and Ph.D. (2010) in Material Science at the University of Illinois where his research focused on developing polymeric and colloidal suspensions as 'inks' for 3D printers. He also fabricated microfluidic devices to synthesize single micron to millimeter scale parts (e.g., glass and silicon microgears). Concurrently to performing this research, he received his M.B.A. (2009) at U of I and started a company, worked with several other startups, and gained significant experience with the details of market research, financials, accounting issues, and legal aspects of entrepreneurship. In 2010, he continued his education as a post-doctoral fellow at Harvard University in George Whitesides's research group in the Department of Chemistry and Chemical Biology. In this group, he developed pneumatic actuators in soft elastomers that took the form of a machine capable of moving in multiple gaits: walking and undulating. These actuators have also been used for low-cost manipulators, and in concert with a microfluidic system for biomimetic camouflage & display. Additionally, Rob is the recent recipient of the 3M Non-Tenured Faculty Award and University of Illinois Young Alumnus Award in Material Science.

Rob on soft robotics:

Q. What does soft robotics mean to you?
"To me, a useful soft robot is one that performs mechanized tasks a human can't or won't do, but deforms at mechanical stresses sufficiently low that they can operate in close proximity to humans without the possibility of their harm."

Q. What can soft robotics deliver now and in the future?
"Presently, soft robots are very good at open-loop grasping and object manipulation (e.g., grippers, tentacles). They are less good at mobility and other tasks that require sensing and controls. As we develop a better understanding of controlling non-linear, compliant actuators and, simultaneously, improving their applied force and actuation speed, we will see land-based robots that have similar mobility and manipulation modes as cephalopods."

Q. What needs to be done to advance soft robotics?
"I see three primary areas for development:

(1) Control methods and sensors compatible with soft actuators. The robots need to know what they look like while interacting with unpredictable environments.

(2) Tougher materials and fabrication routes that allow for larger applied forces and reliable operation. In cases where humans are not present (e.g., search and rescue), picking up heavy objects will be required.

(3) Power sources are required that can drive these machines untethered for long durations. This problem is general to robotics, but current mobile soft robots are particularly low in efficiency and typically use power sources that are relatively low in energy density."

Dr Robert Shepherd
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http://www.mae.cornell.edu/research/groups/shepherd/

Industries: StretchSense

StretchSense: Robots of the future will be soft and lifelike. However soft robots require soft sensors and until now there has been no sensor with the compliance and precision demanded by the soft robotics community.

StretchSense is a company spun out of the Biomimetics Lab to bring a new type of soft stretch sensor to the market. Our sensors are based on flexible capacitor technology. As the sensor (polymer) structure deforms its capacitance changes which we capture and transmit. The sensors come packaged with all the electronics and software required to get started.

Stretch sensors allow robot designers to embed precise stretch sensors directly into deformable structures. This allows for

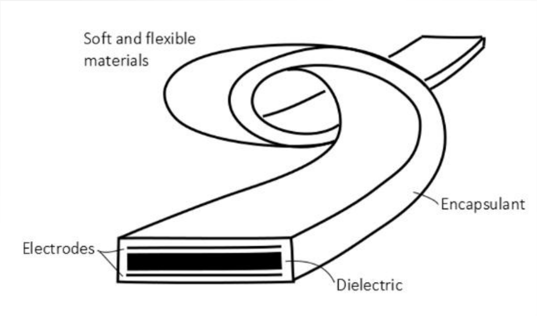
- Lighter, softer, simpler designs
- Direct measurement of robot kinematics for control purposes
- Use of different sensor modes including shear and pressure sensing

As well as soft robotic applications stretch sensors open up the possibility to directly measure human body motion. This can inform waldo systems, replace human machine interfaces, and allow for intuitive control of soft prosthetic devices.

StretchSense is keen to work with researchers and developers of soft robotic systems to explore new applications of their technology.

For more information please visit www.stretchsense.com

Scientists and engineers have long been searching for materials which exhibit similar characteristics to natural muscle, namely being soft, able to quickly change shape, and to provide controlled amounts of force. In this search for an artificial equivalent of muscle, electroactive polymers (EAP) have gained considerable attention as they come closest to mimic muscles characteristics.



Stretch Sensors are flexible polymer capacitors. When the structure deforms the capacitance changes.

Stretch sensors mounted on a hand showing flexibility, a Bluetooth sensor interrogation and transmission circuit and app.

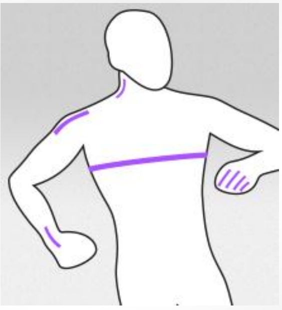
Industries: Leap Technologies

Leap Technologies: Electroactive polymers (EAPs) have received a great deal of academic interest over the last fifteen years and more recently industry has been investing in the production methods of EAP material. Although potential users of EAP have been paying attention to the technology and its developments, few have taken it on into serious product development programs.

LEAP Technology has been formed to specialise in the development work required to integrate EAP materials (specifically, dielectric elastomers) into products and applications. Our work is therefore mainly driven by application specific industrial and commercial requirements making us a technology integrator in the value chain. In collaborative product development projects, we offer a wide range of consultancy services from concept, feasibility and testing through to manufacturing and mass production setup.

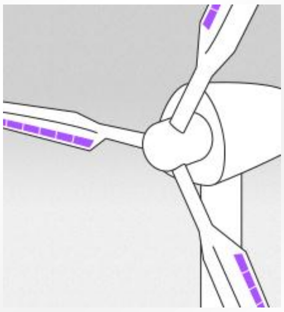
Our team has well over twenty years collective industrial experience with all aspects of design, development and testing of EAP sensors, actuators and energy generators and their integration in applications. This includes a relevant academic background meaning we have all the necessary research and engineering expertise; mechanics, electronics, software, modelling, simulation, and experimentation. We also have a broad network within the international EAP community, meaning that LEAP Technology can provide world leading expertise when it comes to the development of EAP based products.

For more information visit http://leaptechnology.com



Human movement

Robotics and Automation



Aerodynamics

Consumer Products

Technologies: Nylon artificial muscles

A recent paper in Science has raised much interest with its potential for high energy density artificial muscles and soft robotic actuators [1]. The attraction of this work is two-fold: 1. The actuators offer extremely high relative performance compared to most existing artificial muscle technologies, and 2. the materials they are made from are cheap and readily available. This has meant that anyone, in research labs, in schools and even at home, can make these actuators. If ever there was an artificial muscle technology that could become widely used in a short space of time, perhaps this is it.

The general principle of the nylon filament actuators exploits spiral winding resulting in twist-induced plastic deformation and the formation of tight coils. These coil can be extended under load and will develop contracting forces when thermally stimulated. The paper is very bold in its claims that the muscles,

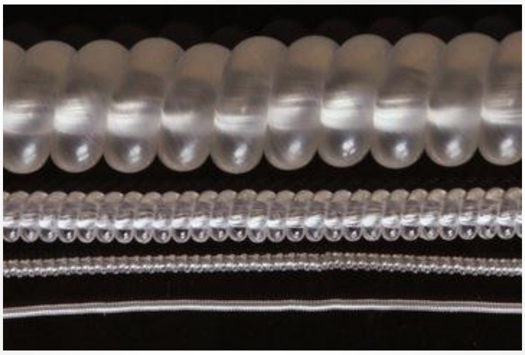
"can contract by 49%, lift loads over 100 times heavier than can human muscle of the same length and weight, and generate 5.3 kilowatts of mechanical work per kilogram of muscle weight, similar to that produced by a jet engine."

The question we now ask is: *does it work?* and just as importantly, *is it really as good as they claim?*

We replicated this approach in Bristol Robotics laboratory using commercial fishing line (Okuma UltraMax 0.5mm low abrasion copolymer, approx. €6/500M). Lengths of line approximately 50mm long were cut and one end was clamped in a vice and one end was clamped into the chuck of a hand drill. The line was held 'hand taught' and the drill was operated at an slow speed estimated to be about 10 rotations per second. As the nylon line twisted it shortened slightly and then buckled. This buckled took one of two forms: it buckled sideways so that a 'whisker' of line extended out perpendicular to the line, or it twisted into the tight coil as shown in the paper. This behaviour is load dependent.

After a twisted muscle line was fabricated it was removed from the vice and drill and mounted vertically by clamping the top end and attaching a weight to the bottom end. The coil extended under weight and the application of gentle heat from a heat gun caused the coiled actuator to contract by an estimate 5%. If the load was too great, or the temperature was too high, the coil would unwind and the weight would fall. The solution to unwinding under load is thermal annealing. The solution to thermal unwinding is to ensure that actuation temperature is kept away from the melting point of the polymer.

Conclusion: This is a very interesting and novel technology, with great potential for cheap and high power artificial muscles.
Drawbacks: This technology is thermally actuated, as are shape memory alloys and shape memory polymers. This means that for high frequency applications significant energy must be input into the actuators, and more importantly, removed. This removal can be extremely difficult and can limit performance and potential applications.



Science/AAAS. Nylon coil actuators from a range of filament diameters.

[1] Haines et al., Artificial Muscles from Fishing Line and Sewing Thread. Science, 343 (6173): 868-87, 21 February 2014. DOI: 10.1126/science.1246906

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