The Newsletter of RoboSoft
Coordination Action for Soft Robotics

Issue 5, March 2016
Contents:

Editorial

At the beginning of the third year of the ICT FET-Open RoboSoft Coordination Action, the Community has reached the number of 38 institution members from 16 countries worldwide and the project reaches out hundreds of academic and industrial researchers through its mailing lists and publicity channels. People working around soft robotics, both from the academic and industrial side, are very proactive and willing to continue this road undertaken, maintaining the community unified and active, continuing in periodic joint scientific events, proposing new projects and publications, to boost the innovation of robotics systems by exploiting soft robotics technologies and design principles. Also important scientific journals show interest in the development of soft robotics, an approach that is well identified as a major research front for robotics in the past ten years.

Figure 1: *Nature News article "The soft touch", by Helen Shen, [link] to the article*

Several scientific and technological challenges are still open, as well as common methodologies and benchmarks still need to be identified. These are all hot topics for discussions during the meetings of the community of researchers as well as during other events together with industrial representatives.

For this third year, RoboSoft has proposed to set a milestone to measure the status of soft robotics and for further pushing its research and innovation perspectives, through the first Challenge for soft robots. The forthcoming Soft Robotics Week (April 25-30, 2016) will represent this milestone through the three events that will take place. The RoboSoft Spring School and the Plenary Meeting will represent networking and educational events during which experienced researchers students will show and discuss the current status of soft robotics, with the main trends, applications and challenges. 23 teams composed by students and researchers from 12 institutions worldwide have been selected to participate in the RoboSoft Grand Challenge and will compete against each other in a terrestrial race and in a manipulation competition. As the first outdoor challenge for soft robots, this will be an interesting tool for experimental evaluation and for benchmarking of soft robots.

In this Newsletter, you will read more about the forthcoming Soft Robotics Week and RoboSoft Grand Challenge, about community members and institutions working in our field.

Laura Margheri and Cecilia Laschi

RoboSoft Pills

This is the third and last year for the RoboSoft Coordination Action and we are proud of the large number of followers and the number of community members we have involved worldwide.
The number of participants and the outcomes of the events organized so far are proof of the proactivity of the RoboSoft Community and it is time now to discuss about the project achievements and future legacy.
Last year, RoboSoft has launched the first Soft Robotics Week, an event that obtained a great success in terms of number of participants, activity of the working groups, students activities and public visibility.
We have decided therefore to organize a second edition for this year, that will have the theme: "Trends, Applications and Challenges of Soft Robots" and will feature three major events:
- The RoboSoft Spring School (April 25-29, 2016): a one-week school for PhD students, with lectures and practical lessons
- The RoboSoft Plenary Meeting (April 27-28, 2016): the annual plenary meeting of the RoboSoft Community and partners, with talks from the community of soft robotics and other invited experts from relevant scientific fields and industries
- The RoboSoft Grand Challenge (April 29-30, 2016): the first outdoor competition for soft robots on terrestrial locomotion and manipulation

International experts across multiple fields in the scientific community of soft robotics, industrial leaders, young researchers and students, will meet together to show current research activities and technologies and to discuss fields of applications, the challenges and the future frontiers for the field of soft robotics.

Major themes will be related to the current applications and future challenges for:
- Soft robot legged locomotion
- Soft robot manipulation
- Underwater soft robotics
- Biomimetic soft robotic platforms
- Plant-inspired soft robots
- Flying soft robots
- Soft micro robots
- Soft robotics in endoscopy
- Assistive soft robots
- Soft robotics in rehabilitation
- Edutainment soft robots

Other information and the detailed program about the Soft Robotics Week and its events are available at:
http://www.robosoftca.eu/information/events/soft-robotics-week-2016

During these last months, the Coordination Action has focused the activities for organizing events with stakeholders.
The first one was organized in Bristol (UK) on October 8, 2015 and it was a day dedicated to Industrial Networking and Engagement on Soft Technologies, with about 40 attendees from academia and industry who met together and discussed about potential applications for soft robotics.
The second event was held during the ICT2015 conference in Lisbon (Portugal) on October 22. RoboSoft was in fact accepted to organize a Networking Session on "Soft Machines – The Next Technological Revolution!"

RoboSoft Grand Challenge

In June 2015, RoboSoft has launched the first outdoor Challenge for Soft Robots.
The RoboSoft Grand Challenge aims at inspiring and pushing innovations in robotics technology and includes tasks in two different competitions:
- Terrestrial race: a competition on different terrains with obstacles avoidance
- Manipulation: a competition in the manipulation task of different objects

The call was open to international teams of experts in soft robotics, young researchers and students, but also to the wide public and curiosity driven people able to compete in this field.
After the evaluation phase, 23 teams composed by students and researchers from 12 institutions worldwide have been selected to participate in the RoboSoft Grand Challenge.
9 robots will compete in the Manipulation scenario and 14 robots will compete in the Terrestrial race. 3 of them will compete in the whole Grand Challenge, showing their abilities in both the scenarios.
The total prize will be 5000 €, and there will be additional prizes and a financial support for participants.

The RoboSoft Grand Challenge will be the final event of the Soft Robotics Week.
Important Dates:
- April 29: teams setup and robots test-drive (only for authorized people and team members)
- April 30: Grand Challenge competition. Open event.

Venue:
- "Bagni Pancaldi", Viale Italia 56 - 57127 Livorno (find directions on Google Maps)

Soft Bites

People: Massimiliano Gei

On harvesting energy with dielectric elastomer annular membranes deforming out of plane

Renewable energy conversion is a key theme in the current political agenda and science and technology are facing fascinating challenges to provide convincing responses to the issue. Harvesting energy from natural resources by means of dielectric elastomer generators could be one of the solutions, once all fundamental aspects of this method will be thoroughly analysed and the shortcomings overcome.

A dielectric elastomer generator is a soft device based on a deformable parallel-plate capacitor made up of an elastomeric film coated with two compliant electrodes on its opposite faces able to produce electrical energy converting the mechanical work done by an external oscillating load [1,2]. In particular, the energy transformation is promoted by the significant capacitance change of the elastomeric capacitor occurring when the film is highly deformed.

In a real harvesting field, we can think that the mechanical action be outlined as an oscillating force, or pressure, that stretches and releases periodically the soft capacitor at a frequency on the order of the Hz. Therefore, electrical energy can be collected after a four-step cycle where (i) an initial, relatively slow, stretching of the material induced by the growing force is followed by (ii) a fast charging phase; then, (iii) the slow decrease of the force will relax the capacitor at constant charge and, finally, (iv) the charge is harvested at high electric potential at low force.

In [3] we assumed that the external source deforms, out-of-plane, an annular DE membrane (Fig. 2 a,b). Our article aimed at providing a complete analysis of this harvester layout along the lines traced in [4,5]. The adoption of the same methodology also enabled us to compare the different configurations on a common ground, offering the possibility to reflect on the best coupling between geometry and material for a particular energy harvesting application.

The analysed deformation of the DE annular membrane is particularly interesting for sea-wave energy conversion as it can constitute the power take-off system of a floating harvesting system based on a Gough/Stewart platform moored to the sea bottom by metallic legs; these are formed by a hollow cylinder constrained to the sea bed and a concentric inner cylinder anchored to the buoy [6]. A number of membranes can be placed between the two elements to exploit their relative motion and producing electrical energy (Fig. 3). A preliminary design performed in [6] on a prototype proposed for the Mediterranean Sea has indicated that each leg bears approximately 34 kN of total force and this value will be adopted for the comparison between materials presented later on.

The just described application highlights one of the advantages of this generator configuration: the membrane deformation can take place on both sides of the film, being potentially capable to fully exploit an oscillating mechanically source.

Optimisation in terms of both maximum efficiency (ratio between the theoretical gained energy to the total invested energy) and maximum harvested energy has been performed assuming, for the material, a hyperelastic neo-Hookean strain energy and an ideal dielectric behaviour.

In setting up the admissible configurations of the device, four failure modes have been considered: i) electric breakdown, ii) electromechanical instability, iii) loss of the tensile state in the membrane to avoid buckling, and iv) limitation of the tensile stretch to avoid membrane rupture.

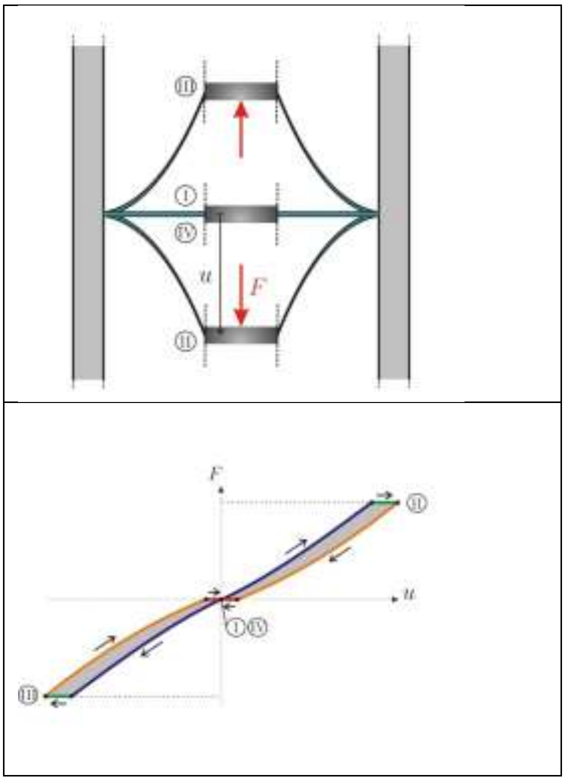

Figure 2: *Sketch of the investigated dielectric elastomer generator; a) membrane configurations; b) harvesting cycle in the force (F)-out of plane displacement (u) plane.*

The main findings of this research can be summarised as follows:

- an optimal initial prestretch of the membrane exists for which the energy conversion is more favourable: its value depends on the external-to-inner radius ratio and it is not larger than 25-30 % of the initial length/width. This is a very important design indication as typical imposed prestretches for acrylic films in dielectric elastomer devices are usually on the order of 300-400 %;
- a radius ratio close to one determines the ideal configuration to maximise the amount of energy per unit mass. Differently, efficiency of the energy conversion process reaches the top for radius ratios in the range between 2 and 2.5;
- similarly, at the optimal prestretch, while the gained energy is rather proportional to the applied load, the efficiency is maximised for loads of about one half of the

highest possible force to be applied to the generator.

The last two items show that a design based on maximisation of energy may lead to a quite different device with respect to the outcome of an efficiency-guided design. This study may help to find the best compromise between the two strategies.

In order to gain awareness on the quality of the analysed generator, a performance comparison between multi-membrane generators made up of a *soft* acrylic elastomer and a *stiff* natural rubber is proposed. The former is 3M VHB 4910 elastomer (shear modulus μ=35 kPa, dielectric constant ε_r=4.5), the latter is ZruElast A1040 [7] (μ=917 kPa, dielectric constant ε_r=3.4). A fair method to compare the two materials is to compute the amount of energy (H_{gtot}) that a certain number *n* of annular membranes (to be determined) connected in parallel are able to harvest at a given external force F_{tot} (Fig. 2).

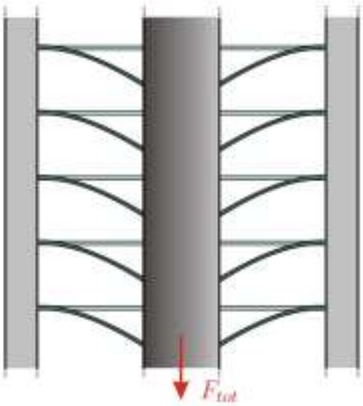

Figure 3: *Multi-membrane device subjected to the total force Ftot.*

The comparison of the systems (for F_{tot} = 34 kN) designed employing the two materials, working at maximum efficiency (η), is summarised in the right-hand side of Tab. 1. Due to the values of the harvested energy per unit mass (H_{gm}) of the single membranes, the number *n* of required acrylic layers is an order of magnitude higher than that of the ZruElast rubber. However, the total energy harvested by the multi-layer device (H_{gtot}) is higher for the VHB generator. The reason lays in the different maximum stretch (λ_{max}) reached by the two materials at maximum efficiency: that attained by an acrylic membrane is approximately 1.5 times higher than that reached by a rubber film, cf. Tab. 1. As it has been demonstrated, the energy increases proportionally to the maximum stretch attained by the DE membrane during the cycle [5].

	Single membrane device				Multi-membrane dev	
Material	F_{max} [N]	λ_{max}	η [%]	H_{gm} [J/kg]	n	H_{gtot} [kJ]
VHB	80	2.4	26.9	9.9	425	2.73
ZruElast	1500	1.7	21.1	95.0	23	1.24

Tab. 1*: performance comparison of devices working at maximum efficiency.*

	Single membrane device				Multi-membrane dev	
Material	F_{max} [N]	λ_{max}	η [%]	H_{gm} [J/kg]	n	H_{gtot} [kJ]
VHB	200	4	14.2	16.8	170	1.62
ZruElast	5000	4	7.2	187.3	7	0.75

Tab. 2: performance comparison of devices working at maximum energy.

The comparison with respect to the maximum gained energy is reported in the right-hand side of Tab. 2. A single VHB film entails a higher efficiency η, but an extremely lower gained energy per unit mass H_{gm} with respect to a ZruElast one. Analogously to the previous case, if we think to subdivide the total acting force F_{tot} of 34 kN on a number of layers, due to the relatively higher stiffness of the natural rubber, the ZruElast generator requires 7 membranes, while the VHB device 170. However, even in this case, the total energy harvested is higher for the latter generator.

The choice of the material depends on a number of factors, not only technical. Remaining on our two possible choices, VHB generally displays a higher viscoelastic response than that of the natural rubber, however the latter, being an organic compound, exhibits a marked ageing and degradation due to chemical interaction with the environment [8]. The rational analysis of the results listed in the tables indicates that VHB would be the best choice, but the outstanding limited number of membranes could favour ZruElast.

Massimiliano Gei *is Professor of Solid Mechanics and Structures at Cardiff University, where he is leading the Applied and Computational Mechanics group. After graduating in Civil Engineering at the University of Bologna in 1997, he was awarded a Ph.D. in Solid Mechanics from the University of Trento in 2001. He joined Cardiff in 2015 after spending ten years in Trento as Lecturer and Associate Professor. His research activity is mainly carried out in nonlinear mechanics of soft materials and metamaterials. In the last eight years he has been working in the area of modelling dielectric elastomer devices and recently studied optimization of soft energy generators.*

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People: Conor J. Walsh

Soft robotics is a rapidly growing research field that combines robotics and soft materials such as elastomers and textiles. These soft systems are engineered using low-cost fabrication techniques (e.g. molding and sewing) and are ideally suited for interacting directly with humans, for example in medical and wearable applications. My research group, the Harvard Biodesign Lab, brings together researchers from the engineering, industrial design, apparel, clinical and business communities to develop new disruptive robotic technologies for augmenting and restoring human performance. This research includes new approaches to the design, manufacture and control of wearable robotic devices and characterizing their performance through biomechanical and physiological studies so as to further the scientific understanding of how humans interact with such machines. Example application areas include, enhancing the mobility of healthy individuals, restoring the mobility of patients with gait deficits and assisting those with upper extremity weakness to perform activities of daily living.

Our approach to the development of soft wearable robots is to look for technologies that enable us to have lightweight, compliant and non-restrictive end effectors that are comfortable and do not restrict the movement of the wearer coupled with actuation approaches that allow for cable-based transmissions for applying forces to the wearer's limbs. To date we have developed systems based on pneumatic or hydraulic actuation of elastomeric soft actuators as well as Bowden-cable based systems that are actuated by electric motors.

Many activities of daily living involve precision grasping and manipulation, such as putting toothpaste on a toothbrush or feeding oneself. However, people afflicted by stroke, cerebral palsy, muscular dystrophy, or spinal cord injury may lose the ability to actively and accurately control the wrist, thumb, and fingers. Figure 4 demonstrates our preliminary work to create a soft robotic glove that can apply forces and motions to the hand. Specific soft actuators were designed and fabricated for each digit and demonstrated the ability to replicate the finger and thumb motions suitable for many typical motions [1, 2]. Furthermore, the actuators were mounted to the dorsal side of the hand, providing an open palm interface so as to not impede object interaction [3-6]. Human testing of the glove is ongoing in healthy and patient populations to evaluate its performance and obtain feedback from end user that will guide ongoing development to maximize the ability of this technology to assist with activities of daily living.

Figure 4: *The soft robotic glove in: A. index finger -thumb opposition contact, B. small finger -thumb opposition contact, C. index finger flexion, D. grasping a bottle of water using all fingers, E. picking up a telephone using all fingers, except of the small, and F. grasping of a television remote control using a tripod pinch. Figure reproduced from [4].*

Full lower extremity exoskeletons are powerful machines that have typically provided large joint torques at the hip and knee of both legs (e.g., for supporting non-ambulatory individuals with a spinal cord injury). These rigid systems can enable a person who cannot walk, to walk again. In contrast, we are developing soft exosuits that target specific joints with small-to-moderate assistive torques to better suit the needs of augmenting the mobility of healthy individuals and restoring ambulatory ability for individuals with walking difficulty. With exosuits, gait-restorative forces can be transmitted comfortably through lightweight and flexible apparel that adds minimal inertia and restrictions to the wearer. This approach enables assistance to be provided only when needed during key phases of the gait cycle. Moreover, this approach can be completely modular—allowing assistance unilaterally, or targeted to a specific joint.

We have developed multi-joint exosuit systems [7-13] that comfortably deliver up to 30% of the biological torque required of the hip and ankle joints during healthy walking in a manner that translates to a 15% reduction in the body's total metabolic energy load when walking if not carrying the weight of the device [11] and a 7% reduction if carrying the

6.5kg device [12, 13]. Our development of exosuits necessitated innovative work in the area of structured, functional textiles. Sensors—a combination of gyroscopes, IMUs, and load cells—enabled us to measure gait kinematics and robot-human interaction forces to specify control policies that modulate the timing and magnitude of assistive forces. Various portable and autonomous exosuits have been evaluated on soldiers completing a 3-mile cross-country course (*see short video of testing at the ARMY*) [14].

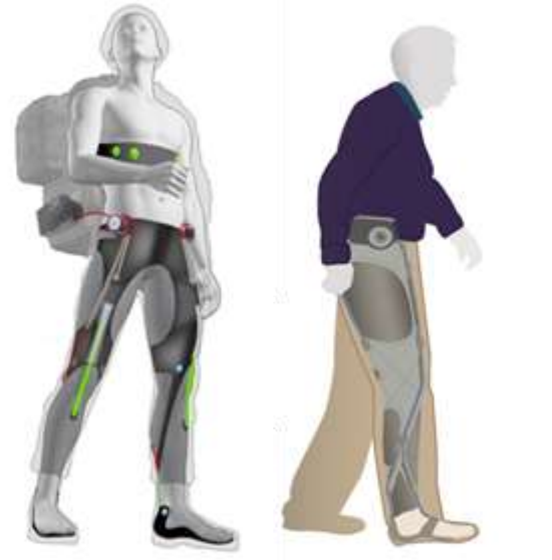

Figure 5: *Soft exosuits for enhancing mobility of healthy individuals when overburdened when carrying heavy loads (left) and restoring mobility for patients poststroke (right).*

These exosuits also have the potential to help restore mobility for persons requiring small to moderate levels of assistance during walking. For example, patients poststroke with limited walking due to foot drop and impairments in push off and forward progression may immediately benefit from dorsiflexion and plantarflexion assistance provided at the ankle, respectively, by the exosuit [15]. Going forward, in order to create more optimized soft exosuits, they will need to work synergistically with the wearer and thus the human-machine interaction needs to be well characterized and understood in order to create a robust, safe and adaptable system.

Conor J. Walsh is the John L. Loeb Associate Professor of Engineering and Applied Sciences at the John A. Paulson Harvard School of Engineering and Applied Sciences and a Core Faculty Member at the Wyss Institute for Biologically Inspired Engineering. He is passionate about educating future innovators and he has established the Harvard Medical Device Innovation Initiative that provides students with the opportunity to collaborate with clinicians in Boston and emerging regions such as India. In addition, his research group is also dedicated to STEM education and have launched the Soft Robotics Toolkit that is an open source resource to promote and disseminate materials for soft robotics. He is the winner of multiple awards including the MIT Technology Review Innovator Under 35 Award, Best Paper Award at the 2015 International Conference on Rehabilitation Robotics, National Science Foundation Career Award, the Robotics Business Review Next generation Game Changer Award and the MIT 100K Entrepreneurship Competition Grand Prize. Conor received his B.A.I and B.A. degrees in Mechanical and Manufacturing engineering from Trinity College in Dublin, Ireland, in 2003, and M.S. and Ph.D. degrees in Mechanical Engineering from the Massachusetts Institute of Technology in 2006 and 2010.

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Place: A/S Research Team, ETH Zurich

Until today, building envelopes tended to be static and unable to adapt to changing conditions. Now, for the first time, the A/S Research Team at ETH Zurich has managed to develop and implement an adaptable façade using soft robotics.

Under the leadership of Prof. Arno Schlueter, the A/S Research Team at the Chair of Architecture and Building Systems comprises an interdisciplinary group of researchers with backgrounds in architecture, engineering, and computer sciences. The team is engaged in various research projects, investigating active and passive systems for the energy supply and climate control of buildings. Our projects range from components to neighborhoods, from design to operation.

The Adaptive Solar Facade (ASF) consists of movable thin-film photovoltaic modules which can be mounted onto a lightweight structure on the building envelope. Besides generating energy, these modules offer shading and daylight control for the interior as well as individual adjustments to the view by the occupant.

The ASF modules are adjustable thanks to a new device – the soft robotic actuator. While such actuators are mainly used for prosthetic and biomimetic robots, we are exploring and developing them for future energy and climate systems in buildings. Our soft actuator is made of flexible materials and manufactured in a specially developed hollow casting process. The hollow chambers are then filled with air and valves control the air flow by pumping or releasing air to deform the actuator and adjust the angle of each module. With soft actuators, we can control each adaptive solar façade module individually and rotate it on two axes, either on its own or in groups. This enables the modules to track the sun's movement and generate power, use or limit solar power, create privacy or open up the view. An intelligent and adaptive regulator allows the façade to adapt to changing weather conditions and the habits and preferences of users.

Figure 6: *Detail view of an ASF module*

Without soft actuators, such functionality would only be possible through a complex combination of several mechanical parts. These would be less durable and more expensive – making it unlikely that they would achieve widespread use in façades.

Figure 7: *50 modules mounted onto the façade of the HoNR at ETH Zurich.*

In contrast, our actuator costs only a few dollars when produced industrially. The soft actuator has been proven to be robust in cyclic tests in the laboratory; now it has to prove that it is just as effective in the harsh conditions of a building façade.

Mounted onto the newly inaugurated House of Natural Resources (HoNR) on the ETH Zurich campus, the façade prototype consisting of 50 modules is the largest object showcasing soft robotics in architecture. A second implementation will be realized as part of the NEST HiLo Project, currently under construction on the EMPA/EAWAG campus in Dübendorf, Switzerland.

For further information regarding the A/S Team or our research projects please refer to our website: www.systems.arch.ethz.ch

Recent Publication

B. Svetozarevic, Z. Nagy, J. Hofer, D. Jacob, M. Begle, E. Chatzi, and A. Schlueter: **SoRo-Track: A Two-Axis Soft Robotic Platform for Solar Tracking and Building-Integrated Photovoltaic Applications,** Paper will be presented at the IEEE International Conference on Robotics and Automation (ICRA), Stockholm, Sweden, May 2016.

A/S Research Team, ETH Zurich

Webpage : www.systems.arch.ethz.ch

Industry: G Growers

The Challenges of Automating Lettuce Harvesting

The East of England, where Cambridge is located, is a major arable agricultural region in Britain for grains and vegetables, due to the vast **expanse** of low lying, well-drained land and the warm summers. The area includes many innovative companies who are ready to engage with Universities to explore how new technologies could be applied in Agri-tech. G's Growers, a major producer in the region have been working with the University of Cambridge for a number of years and in recent months have been exploring the use of soft robotics for automation.

Through their operations in East Anglia and Spain, G's Growers produce a range of crops including wholehead and babyleaf salad, celery, radish, onions, beetroot, mushrooms, Chinese leaf and leeks. One of the most significant crops is iceberg lettuce. G's supply around 60% of the iceberg lettuce consumed in the UK and have a sophisticated operation from harvest to shelf delivering high quality produce to meet the rigorous demands of retailers. Much of the process is automated, with state-of-the art rigs in which the lettuces are packed, sorted and labelled with minimal human intervention. However, the actual harvesting of lettuce crops is something which currently has to be done manually for a variety of reasons.

Identification of lettuce heads

Young lettuce plants are automatically spaced in the fields using a tractor which ensures rows are aligned using GPS technology (Figure 8). For the first several weeks of growth, it is easy to identify the lettuces in the field. However, as the lettuce plants mature this becomes much harder as the outer leaves spread out and meet both within and between the rows (Figure 9). Even an untrained human eye would find it difficult to locate lettuce heads and distinguish between plants where the head had not formed or those that are suitable for harvest.

Figure 8: *Transplanted Iceberg Lettuce*

Figure 9: *Mature crop meeting in the rows*

Lettuce shape

The way in which lettuce plants grow also makes harvesting challenging.

Iceberg lettuce is unlike many other forms as the lettuce grows down into the ground and up to form a near spherical head. In order to harvest the whole head, the plant therefore needs to be carefully tilted by hand and cut with a special tool.

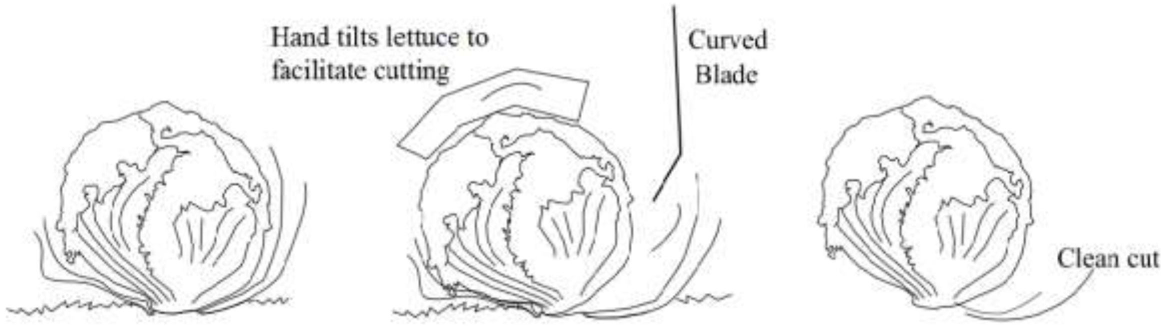

Figure 10: *The tilt and cut operation used for manual harvesting of iceberg lettuce (reproduced with permission of Dr Andre Rosendo)*

Damage Issues

As with other lettuce varieties, iceberg lettuce can be easily damaged through handling, resulting in oxidation in the areas where stress has been applied. This causes the lettuce to discolour in these areas, and as a result the lettuce would not meet the stringent retailer requirements. To complicate matters further, such damage is not always clearly visible at the time the stress is inflicted and only becomes obvious after several hours.

Preparing the lettuce

When the lettuce is cut from the ground, the outer leaves are removed at the same time, and so the lettuce, which is then passed into the rig is ready for packaging (Figure 10).

Meeting retailer standards

Retailers each have different criteria for what constitutes an acceptable lettuce in terms of size. A trained agricultural worker will be able to tell by sight which heads are suitable for which retailers.

Steps towards automation

As outlined above, the harvesting process for iceberg lettuce is very complex and has therefore not been automated to date. Several elements need to come together to provide a solution, which comes close to the performance of skilled agricultural workers:

- Accurately identifying and locating viable lettuce plants.
- Removing the lettuce from the ground without causing damage to the underside of the crop.
- Handling and preparing the lettuce ready for packaging.
- Checking the lettuce against varying retailer requirements.

Furthermore, a skilled harvester will perform the steps above in an impressive 2-3 seconds, which is a challenging target for any automated solution. Having said this, if a solution could be developed that could operate 24 hours a day then this would bring in efficiencies, which may compensate for a slower operating performance.

Precision Farming – the end goal

Adding more automation to current rigs would be a big step forward. However, ultimately the end goal would be to move to precision farming, where plants are tended and harvested on a subfield or plant level. The rigs, which are currently used will only do a single pass of the field to harvest the crop. This means that a decision has to be made about the right time to harvest a large and varied area. As a result of this there is significant crop wastage. Furthermore the large scale of the rigs and vehicles that are used at harvesting causes damage to the soil. If it is possible to handle and inspect plants automatically, without causing damage, then much smaller machines or robots could be used in place of these larger vehicles, not only increasing productivity but preserving the land.

The Bio-Inspired Robotics group, which is led by Dr Fumiya Iida is exploring how soft robotics can be used to tackle some of these issues. The group works closely with the Computer Vision group and the Department of Plant Sciences.

Helen Francis is a Research Manager and Knowledge Transfer Facilitator at the University of Cambridge.

G's Growers Background

G's Growers Ltd is an independent Producer Organisation comprising more than 20 grower members in the UK and Spain. By working together G's Growers members are able to share expertise, experience and knowledge to allow them to take advantage of economies of scale to ensure the efficient supply and year-round availability of quality produce for our customers and consumers across the UK, Europe and North America.

All G's Growers members meet or exceed the rigorously high standards that are demanded by modern consumers, retailers and governments, as well as our own brand expectations, whilst farming with a focus on preserving and enhancing the environment around us for future generations.

G's Growers

Website: http://www.gs-growers.com

Industry: Ocado

Ocado is the world's largest online only grocery retailer. We have a product range of over 47,500 stock keeping units (SKUs) and growing all the time. Each day we pick and pack over 2 million items from our two highly automated warehouses in Dordon and Hatfield in the UK, the largest of their kind in the world. Almost all the software that powers our end-to-end ecommerce, fulfilment and logistics platform is developed in-house by Ocado Technology.

We are in the process of building two more of these automated facilities but with a completely new modular and scalable materials handling technology that we have developed. This technology is part of the Ocado Smart Platform (OSP) that we will use to put very large bricks & mortar grocery retailers around the world online using our disruptive business model.

If our future warehouses were able to leverage robotic picking for much of the product range, then the benefits to operational efficiency would be truly revolutionary.

At the moment robots are typically used in highly predictable environments where there are a small set of rigid body objects to be grasped that are constrained to lie in well-defined locations. Usually these objects are a regular shape and/or CAD data about the shape is available.

In our case we have a massive variety of items with a wide range of form factors and materials, but with no CAD data. Not only is it difficult to constrain the location of each item, many are deformable and/or susceptible to damage and some products change their load distribution when picked up. In addition, when packing a partially populated shopping bag we may know what items are already in it, but we will have no idea about their precise location and orientation within the bag.

For rigid objects with simple geometric shapes there is typically an off-the-shelf gripper available or it is relatively straightforward to develop a viable dedicated gripping solution.

However, not all of our range of 45K SKUs provide a suitable gripping affordance for this type of end-effector. To date our investigations have not uncovered any off the shelf gripper for handling:

- irregular objects and items that are never the same shape twice, e.g. bags of potatoes, bunches of bananas, ...
- easily damaged items, e.g. fruit and vegetables, yoghurt pots, ...

To address these challenges we are researching a "soft manipulation" approach where we are investigating the use of soft materials and inherently compliant mechanisms. As part of this effort we are working with a number of European universities as part of the EU Horizon 2020 research project called SOMA; see: http://soma-project.eu for a description of the work and a summary of the results so far.

Ocado

Contact: graham.deacon@ocado.com
Website: http://www.ocadotechnology.com

Industry: Soft Robotics

The ability to pack a box of randomly ordered items for an ecommerce company, sort heads of lettuce in a processing plant, pack delicate baked goods, and reliably hand components to a human collaborator. This is the coming age of robotics that we know is on the horizon, but there is a problem. Lab instruments, Polo shirts, vegetables, and human beings vary widely in size and shape, are soft and curvy, and easily damaged. Unless this problem is solved, in a cost effective manner, our industry will not fully realize the collaborative and adaptive robotics opportunity before us.

Soft Robotics Inc. was spun out of the George Whitesides research group at Harvard University to commercialize ground breaking soft actuator technology. The company has brought to market a new class of robotic end-of-arm tools that can delicately and adaptively manipulate items of varying size, shape and weight. By leveraging the science of soft robotic actuators, the company is automating facilities that have traditionally depended on manual labor for material handling applications in the fresh-cut produce and consumer packaged goods industries.

The Soft Robotics Adaptive Grasper system is plug and play with standard industrial robots and vision systems. These systems bring the highest level of adaptability to industrial automation, but with a lower level of complexity than traditional robotic solutions.

These features not only enable automation of challenging tasks, but also lower the time to a positive return on investment for the end user.

The Soft Robotics system is built to industrial standards to operate at high operating speeds in excess of four grip cycles per second and millions of actuations.

Soft Robotics

Website: www.softroboticsinc.com
YouTube: www.youtube.com/SoftRoboticsInc

RoboSoft's Industry Outreach Events

One of the aims of RoboSoft is to engage a wide range of stakeholders and one of the most important once are companies and industries. They have the skills and knowledge to help to transfer basic research in soft robotics and soft technology into real products. We recently organized two events directly geared towards industry, the RoboSoft Engagement Day in Bristol and a soft robotics workshop at the ICT 2015 conference in Lisbon.

RoboSoft Engagement Day

In October 2015 we organized a RoboSoft engagement day at Bristol to inform stakeholders from different industries about soft robotics and its great potential to improve industrial processes, solve open problems, and to build new products. Laura Margheri (SSSA), Jonathan Rossiter (UoB) and Andre Rosendo (Cambridge) gave inspiring presentations about the RoboSoft, soft technologies and possible applications. We had a total of 39 participants ranging from representatives of industry, architecture, KTN (UK's Knowledge Transfer Network), health research, as well academics working in collaborations with industry. The participants came from the UK, Spain, Denmark and Italy.

In addition to the talks we showcased many soft robotics demonstrators and led open discussions on possible applications of soft robotics in the industrial context and how to facilitate collaborations. Below are some impressions from the workshop.

Figure 11: *Impression from the Industry Engagement Day in Bristol*

ICT Conference 2015 – Innovate, Connect, Transform

On 21 October 2015 we also organized a soft robotics networking workshop entitled **"Soft Machines – The Next Technological Revolution!"** at ICT 2015 (Innovate, Connect, Transform) in Lisbon, Portugal. The conference and, consequently, the workshop were both organized with the goal to network with industry. We demonstrated many different soft demonstrators, including electroactive polymers, pneumatics, thermoactive nylon actuators, morphological computation structures, agricultural soft robotic manipulators and octopus-inspired robotics. These hands-on demonstrators were very effective in communicating the great potential of soft robotics. In addition talks on Soft Robotics were given by Cecila Laschi (SSSA), Andre Rosendo (Cambridge) and Jonathan Rossiter (UoB). Below you can see some impressions from the workshop.

Figure 12: *Cecilia Laschi presenting the RoboSoft Coordination action*

Figure 13: *Tim Helps (Bristol) demonstrating a variable stiffness mannequin hand*

Figure 14: *Jonathan Rossiter leading discussions on soft robotic industrial engagement*

Figure 15: *Cecilia Laschi demonstrating the Octopus Project*

Call for Fertilization Events

Soft robotics can be a source of inspiration, a useful tool, or a challenging application field for diverse disciplines: it can enable the realization of physical prototypes for the validation of theories and hypotheses in science; it can propose interesting case-studies for theoretical studies, mathematical analyses and techniques.

There are many potential interested scientists in other scientific communities who could fruitfully explore the field of soft robotics, which they may be not fully aware of, such as those working in the fields of neuroscience, biology, mathematics, material science, theory of modelling in fluido-dynamics or elasto-dynamics, medicine, and many others.

In consideration that scientists in these disciplines may not be easily attracted by soft robotics events, the strategy put in place in RoboSoft is to organize "fertilization" events at their main scientific meetings. These fertilization events can be special sessions or workshop or talks on soft robotics at, e.g. a biology or material science conference, mathematical modelling or medical symposia, or even exhibitions.

RoboSoft Community Members are invited to propose events for fertilization to promote soft robotics.

These events can be financially supported by RoboSoft. All RoboSoft community members are invited to contribute. If you are interested in this initiative, if you are planning a participation in a scientific event where soft robotics could be presented, and if you are available to give a presentation of RoboSoft, please write to Laura Margheri (laura.margheri@sssup.it).

Call for Pictures and Movies

One of the mission of RoboSoft is to increase the visibility of the soft robotics research and technologies. We organize events and prepare material for dissemination, such as flyers, potters, movies. If you want to publicize your research you can use the RoboSoft dissemination actions for free. Just send pictures and/or movies to us, with a description and the credits and we can include them in our website and printed material for dissemination (email to Laura Margheri: laura.margheri@sssup.it) .

Follow RoboSoft

Next events:

- Soft Robotics Week 2016, April 25-30, 2016, Livorno, Italy, with:
  - RoboSoft Plenary Meeting, April 27-28
  - RoboSoft School, April 25-29
  - RoboSoft Grand Challenge April 29-30, 2016, Livorno, Italy

http://www.robosoftca.eu/information/events/soft-robotics-week-2016

More at RoboSoft Website and socials:

- www.robosoftca.eu
- Facebook page
- Twitter

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