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THEME ICT-2013.9.1
Challenging current Thinking, FET-Open

RoboSoft working paper

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1. Introductory note

This document reports the results of the work of the RoboSoft Community Members in analysing the status, setting a vision and discussing the perspectives of Soft Robotics.

A good part of this work was done through the brainstorming sessions of the Community Members during the Second RoboSoft Plenary Meeting (Deliverable D3.1.2), held on April 15-16, 2015, in Livorno (Italy). This year, the RoboSoft Plenary Meeting was organized as part of the first "Soft Robotics Week" organized by the RoboSoft Consortium, also including the School for PhD Students (Deliverable D3.3.1).

The programme of the meeting included a scientific workshop with plenary talks and a series of brainstorming activities of the RoboSoft working groups. Plenary speakers presented and discussed the current state of the art and growth of the soft robotics field, from the foundations based on the theory of embodied intelligence and its correlation and use in soft robotics and biology, towards the more recent use and applications, like in the field of architecture and entertainment, discussing future technological challenges and research roadmaps (Figure 1).

The RoboSoft Plenary Meeting involved the members of the RoboSoft Community (now counting 31 institutions), the students of the RoboSoft School (see Deliverable D3.3.1), industrial stakeholders and external experts working in the field of soft robotics and related disciplines.

Up to 100 attendees participated in the two-day event, with 15 represented countries and 46 represented institutions (universities, research centres, companies) worldwide.

Figure 1 Plenary talks during the RoboSoft Plenary Meeting.

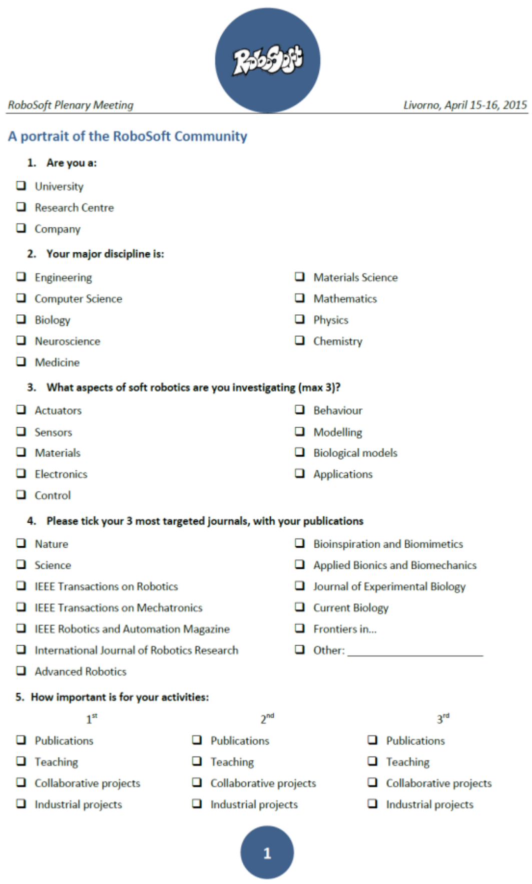
The brainstorming sessions were organised around 2 main activities:

- a questionnaire, intended to stimulate the discussion by giving a view of the community by the community itself,
- a creative session focused on the robots of the future.

2. Questionnaires

The questionnaire activity had the purpose of animating the discussion. The questions were aimed, first of all, at making a portrait of the RoboSoft Community and then to have an objective view of how the community sees itself and Soft Robotics.
The idea was to check if we share the same perception of Soft Robotics and of our Community, of the way we do research to progress Soft Robotics and how we think our competitors do. This was intended especially to uncover possible misperceptions and in general to come up with possible unexpected data that could stimulate the discussion.
The questionnaires were distributed to the representatives of the RoboSoft Community Members at the start of the meeting, at registration.
In particular, the questionnaires (Figure 2) were used to unveil:

- the portrait of the RoboSoft Community (number of universities/research centres/companies, discipline, type of technology investigated, preferred target journals, major activities);
- the vision on Soft Robotics nowadays (driving factors, most needed disciplines, major obstacles for the development of the sector);
- the vision of Soft Robotics in the future (top applications, top countries, top institutions, top sectors, most developed technologies).



RoboSoft Plenary Meeting — Livorno, April 15-16, 2015

A portrait of the RoboSoft Community

1. Are you a:
- ❑ University
- ❑ Research Centre
- ❑ Company

2. Your major discipline is:
- ❑ Engineering
- ❑ Computer Science
- ❑ Biology
- ❑ Neuroscience
- ❑ Medicine
- ❑ Materials Science
- ❑ Mathematics
- ❑ Physics
- ❑ Chemistry

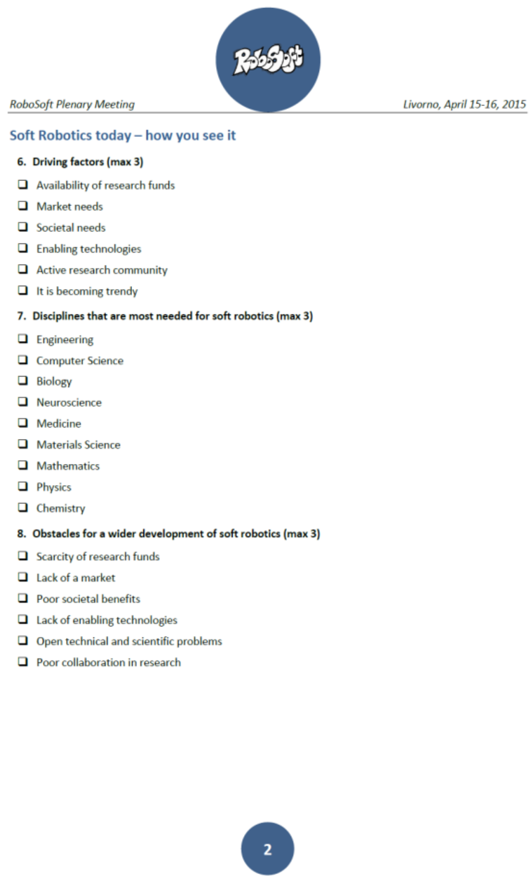
3. What aspects of soft robotics are you investigating (max 3)?
- ❑ Actuators
- ❑ Sensors
- ❑ Materials
- ❑ Electronics
- ❑ Control
- ❑ Behaviour
- ❑ Modelling
- ❑ Biological models
- ❑ Applications

4. Please tick your 3 most targeted journals, with your publications
- ❑ Nature
- ❑ Science
- ❑ IEEE Transactions on Robotics
- ❑ IEEE Transactions on Mechatronics
- ❑ IEEE Robotics and Automation Magazine
- ❑ International Journal of Robotics Research
- ❑ Advanced Robotics
- ❑ Bioinspiration and Biomimetics
- ❑ Applied Bionics and Biomechanics
- ❑ Journal of Experimental Biology
- ❑ Current Biology
- ❑ Frontiers in...
- ❑ Other: ____________

5. How important is for your activities:

1st	2nd	3rd
❑ Publications	❑ Publications	❑ Publications
❑ Teaching	❑ Teaching	❑ Teaching
❑ Collaborative projects	❑ Collaborative projects	❑ Collaborative projects
❑ Industrial projects	❑ Industrial projects	❑ Industrial projects

1



RoboSoft Plenary Meeting — Livorno, April 15-16, 2015

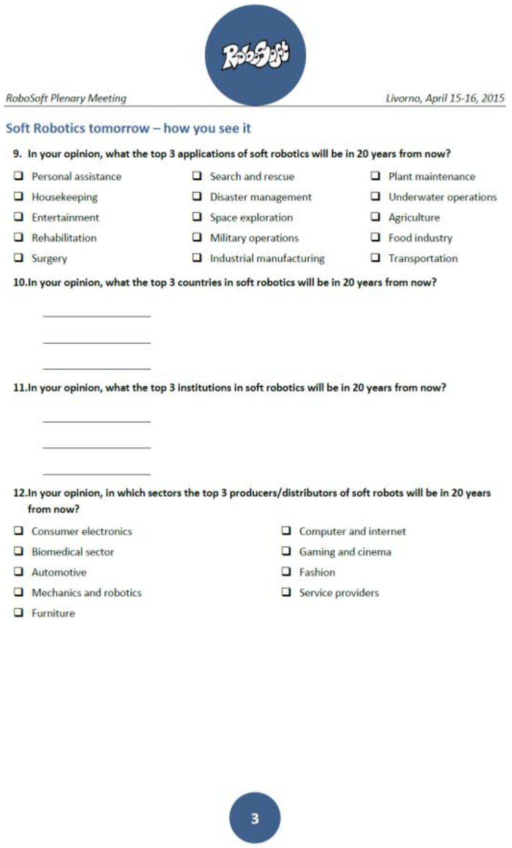
Soft Robotics today – how you see it

6. Driving factors (max 3)
- ❑ Availability of research funds
- ❑ Market needs
- ❑ Societal needs
- ❑ Enabling technologies
- ❑ Active research community
- ❑ It is becoming trendy

7. Disciplines that are most needed for soft robotics (max 3)
- ❑ Engineering
- ❑ Computer Science
- ❑ Biology
- ❑ Neuroscience
- ❑ Medicine
- ❑ Materials Science
- ❑ Mathematics
- ❑ Physics
- ❑ Chemistry

8. Obstacles for a wider development of soft robotics (max 3)
- ❑ Scarcity of research funds
- ❑ Lack of a market
- ❑ Poor societal benefits
- ❑ Lack of enabling technologies
- ❑ Open technical and scientific problems
- ❑ Poor collaboration in research

2



RoboSoft Plenary Meeting — Livorno, April 15-16, 2015

Soft Robotics tomorrow – how you see it

9. In your opinion, what the top 3 applications of soft robotics will be in 20 years from now?

- ❑ Personal assistance
- ❑ Search and rescue
- ❑ Plant maintenance
- ❑ Housekeeping
- ❑ Disaster management
- ❑ Underwater operations
- ❑ Entertainment
- ❑ Space exploration
- ❑ Agriculture
- ❑ Rehabilitation
- ❑ Military operations
- ❑ Food industry
- ❑ Surgery
- ❑ Industrial manufacturing
- ❑ Transportation

10.In your opinion, what the top 3 countries in soft robotics will be in 20 years from now?

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11.In your opinion, what the top 3 institutions in soft robotics will be in 20 years from now?

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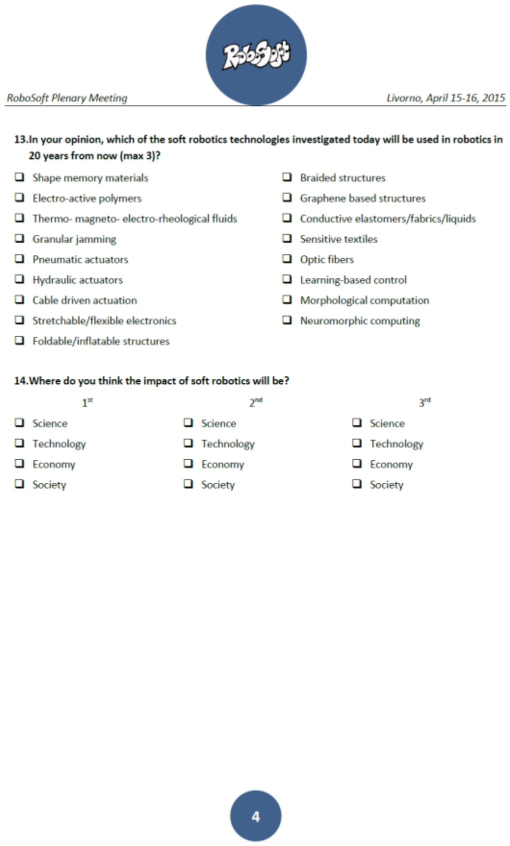
12.In your opinion, in which sectors the top 3 producers/distributors of soft robots will be in 20 years from now?

- ❑ Consumer electronics
- ❑ Computer and internet
- ❑ Biomedical sector
- ❑ Gaming and cinema
- ❑ Automotive
- ❑ Fashion
- ❑ Mechanics and robotics
- ❑ Service providers
- ❑ Furniture

3



RoboSoft Plenary Meeting — Livorno, April 15-16, 2015

13.In your opinion, which of the soft robotics technologies investigated today will be used in robotics in 20 years from now (max 3)?

- ❑ Shape memory materials
- ❑ Braided structures
- ❑ Electro-active polymers
- ❑ Graphene based structures
- ❑ Thermo- magneto- electro-rheological fluids
- ❑ Conductive elastomers/fabrics/liquids
- ❑ Granular jamming
- ❑ Sensitive textiles
- ❑ Pneumatic actuators
- ❑ Optic fibers
- ❑ Hydraulic actuators
- ❑ Learning-based control
- ❑ Cable driven actuation
- ❑ Morphological computation
- ❑ Stretchable/flexible electronics
- ❑ Neuromorphic computing
- ❑ Foldable/inflatable structures

14.Where do you think the impact of soft robotics will be?

1st	2nd	3rd
❑ Science	❑ Science	❑ Science
❑ Technology	❑ Technology	❑ Technology
❑ Economy	❑ Economy	❑ Economy
❑ Society	❑ Society	❑ Society

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Figure 2 Questionnaires for the RoboSoft Community Members

The results of the questionnaires, together with real data on publications taken from Scopus, were presented and discussed during the first session of brainstorming.

A portrait of the RoboSoft Community

The Community largely includes universities (76%), but also research centres and companies are part of team (Figure 3). Companies are less represented because we are organizing an additional network dedicated to industrial stakeholders.

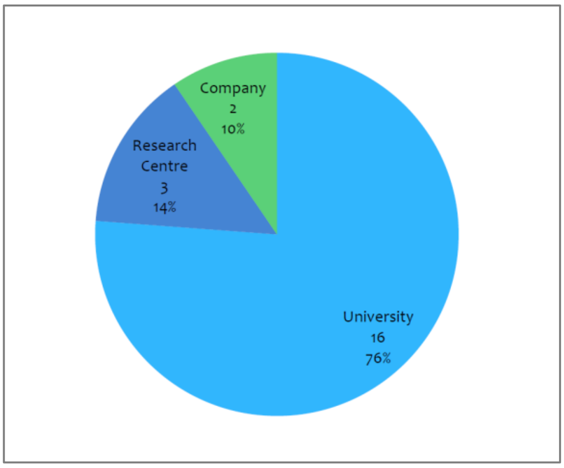


Figure 3 A portrait of the RoboSoft Community. Question 1: "Are you a:..."

Engineering is of course the most represented disciplines, but the community includes also expertise from computer science, materials science, mathematics and biology (Figure 4).

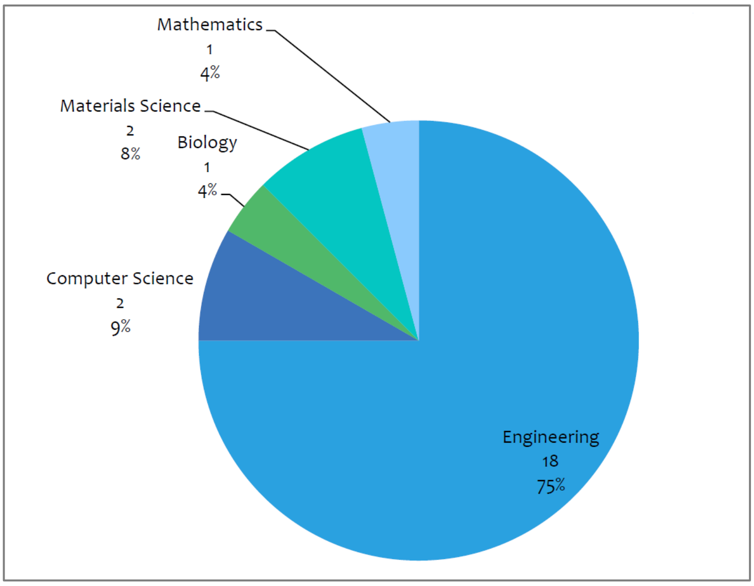


Figure 4 A portrait of the RoboSoft Community. Question 2: "Your major discipline is:…"

Research activities focus on different aspects of soft robotics technologies, and the focuses are well distributed in the community (Figure 5). All the technologies and several applications are covered, including soft actuators, sensors, the analysis of biological model, materials, modelling, possible applications, control, behaviour and electronics. It seems that the community is still then very much focused on enabling technologies, rather than on applications (11%).

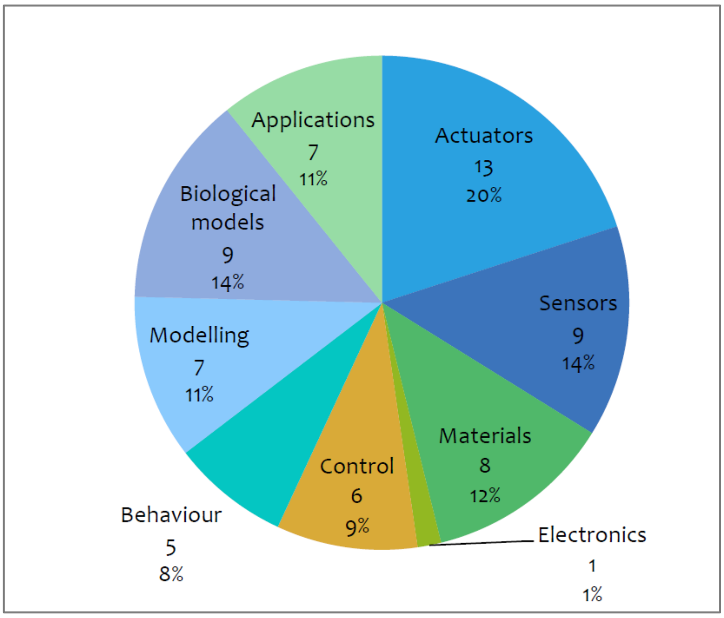


Figure 5 A portrait of the RoboSoft Community. Question 3: "What aspects of soft robotics are you investigating (max 3)?".

Soft robotics is clearly interdisciplinary and many technologies are still to be consolidated, therefore publications cover different journals and many disciplines (Figure 6). Also compared with real publication data, bioinspiration seems to be an important driver for Soft Robotics.

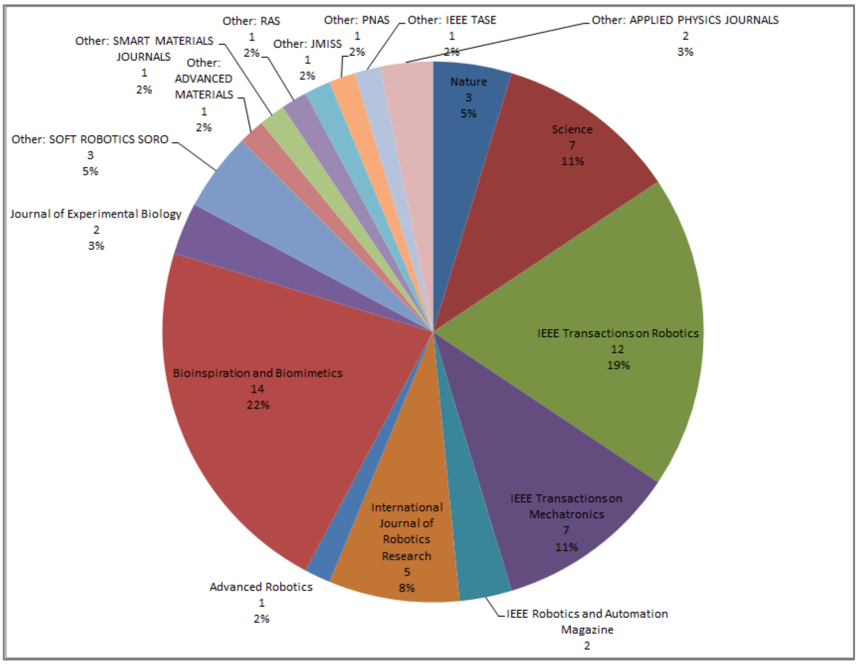


Figure 6 A portrait of the RoboSoft Community. Question 4: "Please tick your 3 most targeted journals, with your publications".

Publications is the most important activity for most members, followed by working for collaborative projects and teaching (Figure 7). Industrial project are less important for the moment, probably because most of the technologies in soft robotics still need to find a good industrial application.

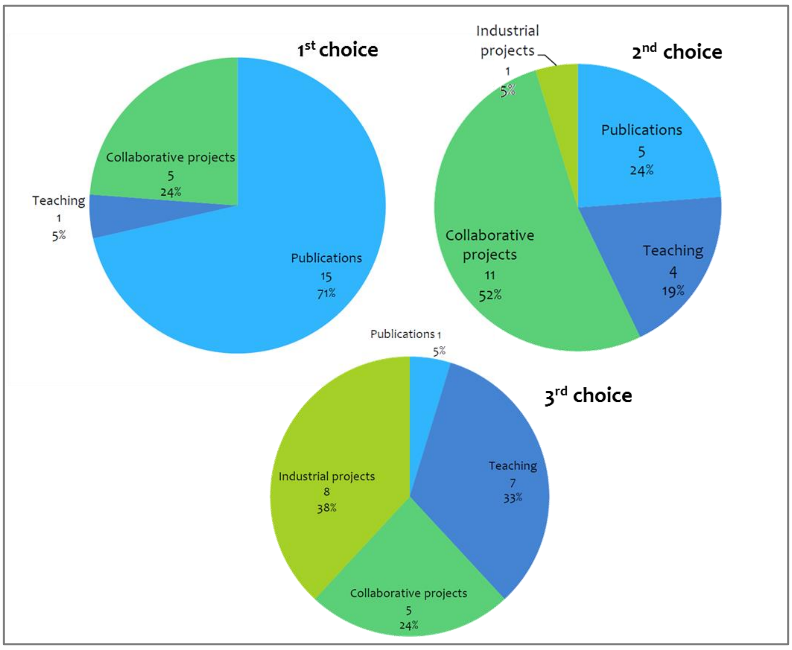


Figure 7 A portrait of the RoboSoft Community. Question 5: "How important is for your activities…", select 1st, 2nd and 3rd choice among: Publications, Teaching, Collaborative projects, Industrial projects.

Soft Robotics today – how the RoboSoft Community sees it

We can proudly see that the existence of a community is a driving factor for research in Soft Robotics. Again, we see that market needs, i.e. applications, are not a main driving factor, at the moment (Figure 8).

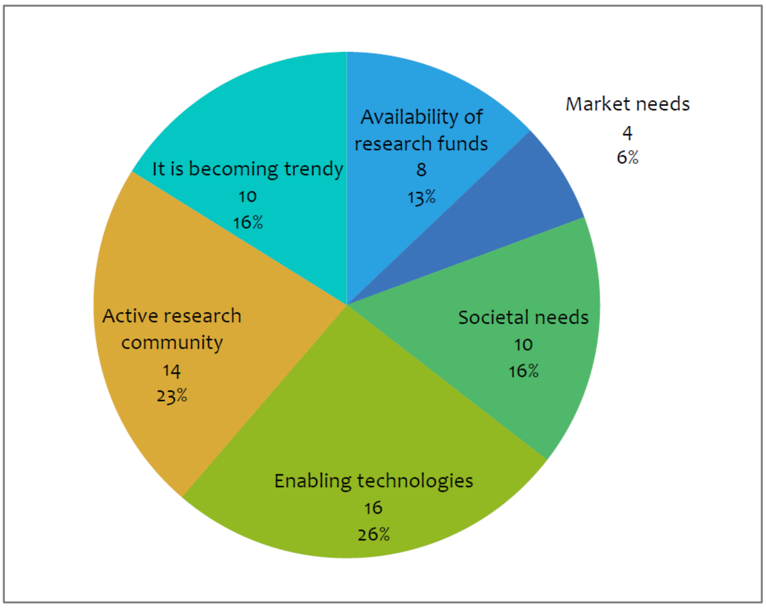


Figure 8 Soft Robotics today – how you see it. Question 6: "Driving factors (max 3)".

The community is well aware that engineering research is still much needed is Soft Robotics (for enabling technologies), but it is also clear that scientific disciplines are needed and especially materials science (Figure 9).

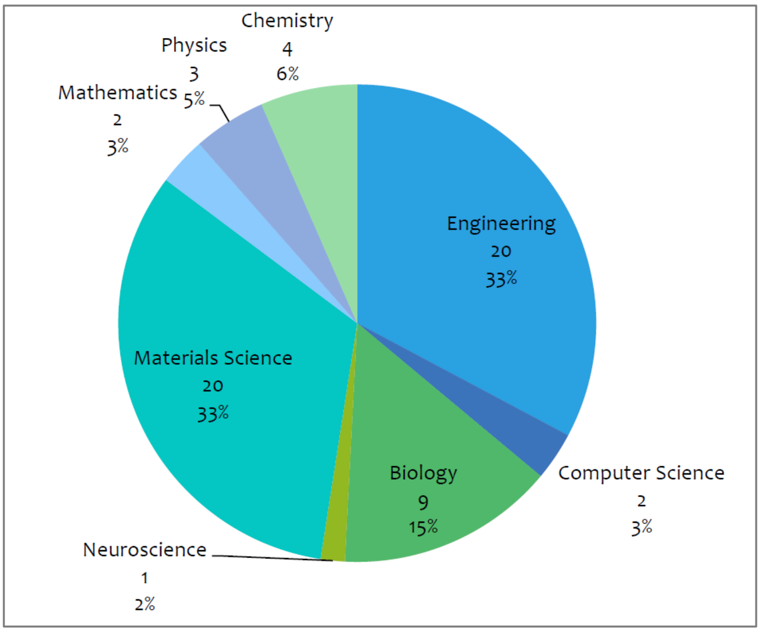


Figure 9 Soft Robotics today – how you see it. Question 7: "Disciplines that are most needed for soft robotics (max 3)".

The major obstacles for soft robotics are now the open technical and scientific problems and the lack of enabling technologies (Figure 10). There are more enabling technologies around which can provide a lot of hardware background to soft robotics – state of the microelectronics has a large variety of technologies and approaches to design, build up, and connect parts electronically and mechanically. Developments of dedicated build-ups could be envisioned in EU funded projects, since typically the cost of such developments are high.
Opportunities are just being recognised, but the lack of a well identified market and scarcity of research fund are impediments for a wider development of soft robotics. There is not only academic, but also major industrial impact of soft robotics. To get the industrial players together into a consortium there is the need of a meaningful shared goal, with specific industry requirements and robot concepts. Examples that demonstrate promising applications can include soft fuel tanks for racing cars (for higher levels of robustness and safety), aero elastic and morphing wings (for higher flight performance), airbag systems (for modulated impact forces), wearable sensors, exoskeletons and soft implants (human friendly soft systems), origami inspired solar cell sails for satellites (compact and light weight) etc. On the system level each of them can be seen as a soft robot.

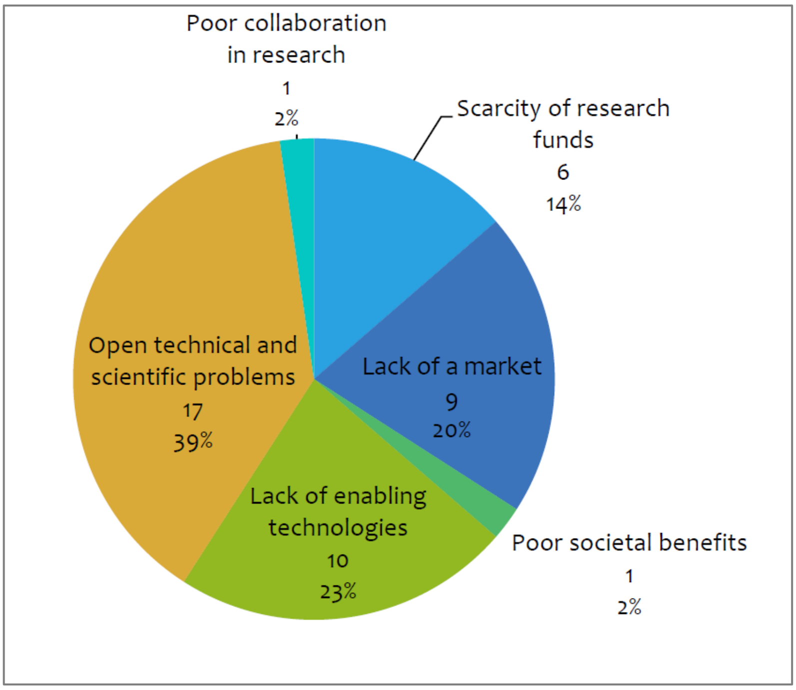


Figure 10 Soft Robotics today – how you see it. Question 8: "Obstacles for a wider development of soft robotics (max 3)".

Soft Robotics tomorrow – how the RoboSoft Community sees it

Rehabilitation, personal assistance and surgery are considered the top 3 applications where soft robotics technologies will be in the next 20 years, followed by the fields of agriculture and industrial manufacturing (Figure 11).

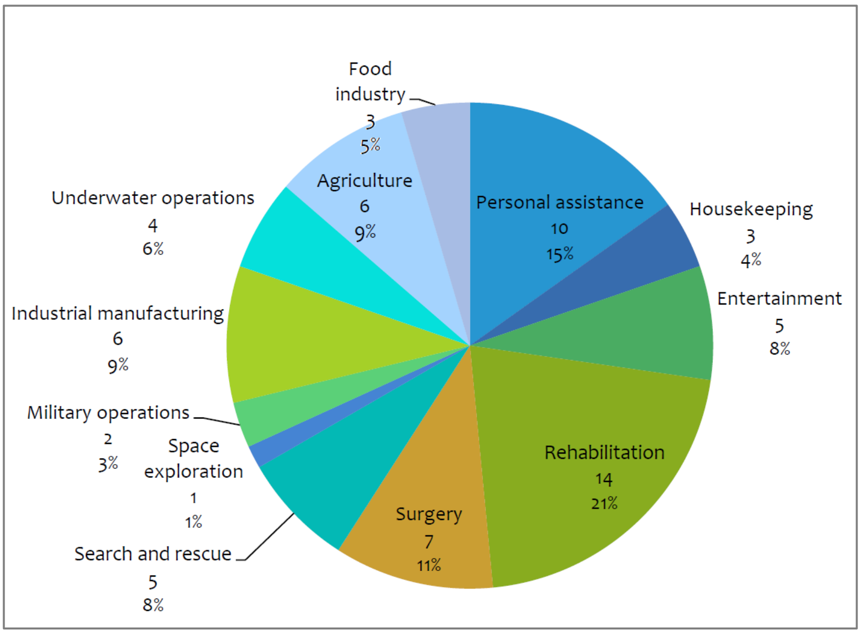


Figure 11 Soft Robotics tomorrow – how you see it. Question 9: "In your opinion, what the top 3 applications of soft robotics will be in 20 years from now?"

Consequently, the top 3 producers and distributors will be in the biomedical sector and then in mechanics and robotics, and consumer electronics (Figure 12).

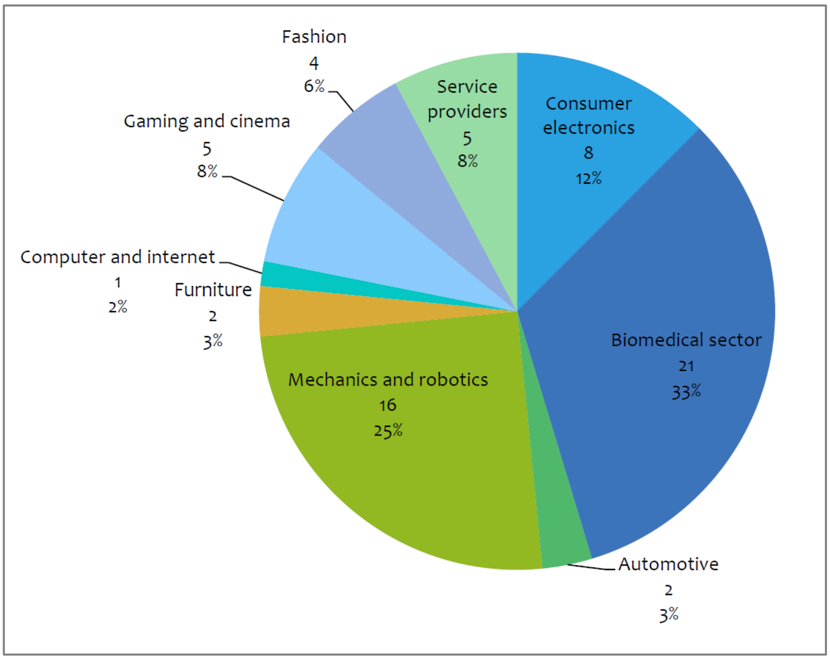
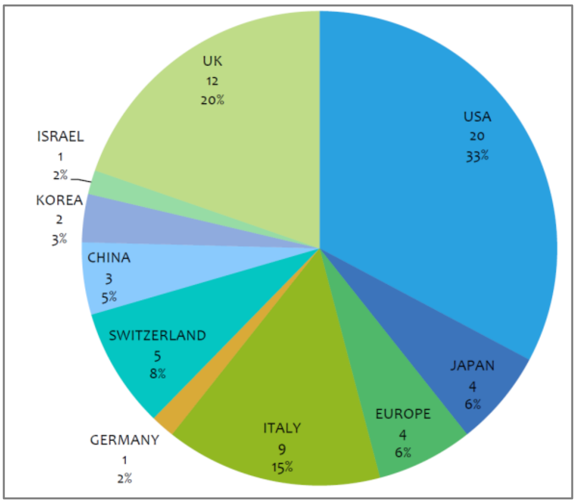


Figure 12 Soft Robotics tomorrow – how you see it. Question 12: "In your opinion, in which sectors the top 3 producers/distributors of soft robots will be in 20 years from now?"

The US, UK and Italy are considered the top 3 countries for soft robotics in the next 20 years, and Harvard, SSSA and the University of Bristol the top Universities in this field (Figure 13). The community thinks that US, and Harvard, have better possibilities than we (Europe) have, in soft robotics – why?



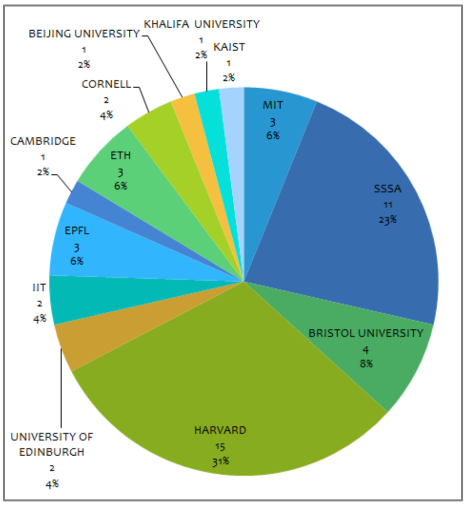


Figure 13 Soft Robotics tomorrow – how you see it. Question 10: “In your opinion, what the top 3 countries in soft robotics will be in 20 years from now?” (on the left); and question 11: “In your opinion, what the top 3 institutions in soft robotics will be in 20 years from now?” (on the right).

Not all the soft robotics technologies investigated today will be used in robotics in 20 years from now. Stretchable and flexible electronics (including modular Electronics, distributed sensors and controllers, cascaded control) actuators based on Electro-active polymers, granular jamming or pneumatic technologies, and morphological computation techniques are those most considered (Figure 14).

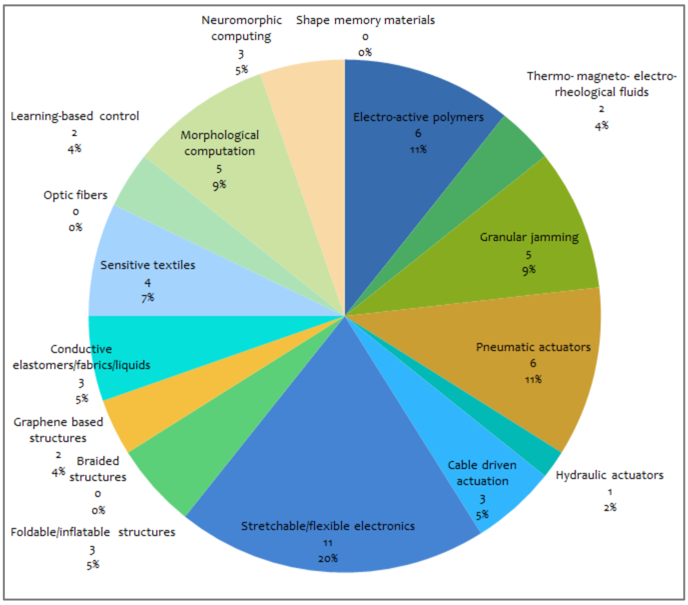


Figure 14 Soft Robotics tomorrow – how you see it. Question 13: “In your opinion, which of the soft robotics technologies investigated today will be used in robotics in 20 years from now (max 3)?”

Soft Robotics will have an impact in technology at first, but also in science and society as well as economy.

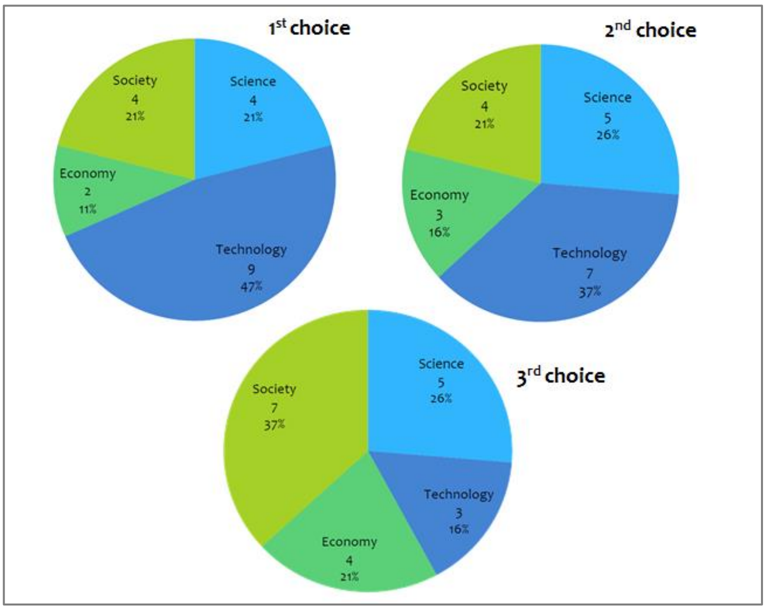


Figure 15 Soft Robotics tomorrow – how you see it. Question 14: "Where do you think the impact of soft robotics will be? Select 1st, 2nd and 3rd choice among: Science, Technology, Economy, Society".

In conclusion:

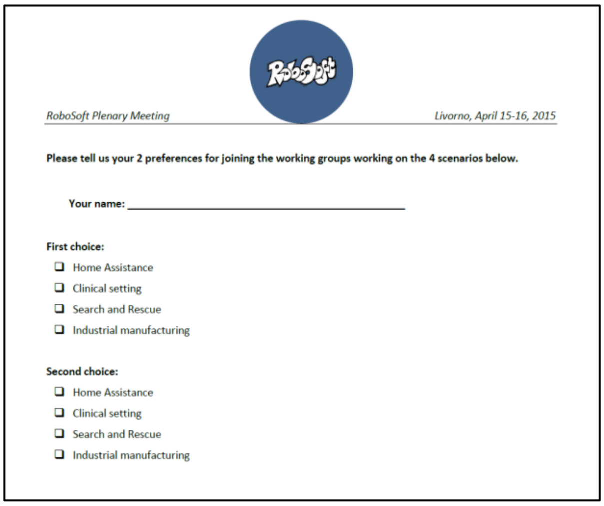
- We are mostly engineers (at least here today).
- But we need biology and material science, for soft robotics. In fact, there are many efficient biological strategies, which are well known. however, the translation into an engineering approach seems to be lacking so far. As proposed example: (I) a cascaded arrangement of controllers could be an effective distributed computing approach: distributed electronic for sensing and data processing in miniaturized modules, which are interconnected by a data backbone (I2C-bus structure), can be in fact similar to a nerveous system; (II) the continuous throughput of matter and energy enables biological systems to self repair (more or less successful). As of now, a similar similar mechanism for engineered systems is not in view. However, given a proper self-monitoring systems a robot could repair itself, by replacing defective parts from a stock. A necessary technical condition for such replacements is mechanical and electrical connectivity and re-programmability of replaced parts. All this could be realised in joint interdisciplinary research and development projects in reasonable time scale (3 – 6 years).
- We publish a lot, not only in engineering journals.
- We do not think there is a market yet, even if there are examples that include aeroelasticity (facebook and nasa drones), soft manipulators, adaptive prostetics, exoskeletons, wearable soft sensors, implantable medical devices, robotic skins.
- Main impact we think is in technology, but also with strong relevance in both Science and Society. Missing points for future technologies regard conformable and modular electronics (for example to have sensors and actuators in bio-inspired light weight hard shells parts of a soft robot, to have a distributed sensor network and distributed computing and data evaluation in a versatile tool box to build up a diversity of soft robots) and also the use of the self-repair concept, to enable (self-) repair of defective parts, and the self re-fuel concept for robots.

As a societal background topics like the aging society could be inspiring – providing support in daily life business of elderly in order to keep them less reliant on other people.

- We think US, and Harvard, have better possibilities than we (Europe) have, in soft robotics. Europe has in fact the potential to be world leader but more investment is needed, to catch up with US and Japan.
- What we need to progress in Europe is dedicated insterdisciplinary funding initiatives (such in future FET calls). Important is that these include robotics, material science, and biological inspiration which are the key enabling disciplines
- From the results of the questionnaire, one may conclude that for now the field seems to be thriving mostly out of scientific curiosity and the need for publications of the scientific community, and therefore that the major source of funding today are science projects. The apparently limited interest of industrial partners in the field can be a simple consequence of little information reaching these players. However, divulging the field amongst industrial partners is a challenge that is already a goal of this Coordination Action.
- This gap that seems to exist between the researchers and the market (the lack of a market was perceived as one of the three major “Obstacles for a wider development”) can only be closed with a closer cooperation with industry. Perhaps this is the reason why most of the community perceives the US institutions to have better possibilities to gain the lead in the field, since a common opinion is that US research institutions, nowadays, still work in closer cooperation with industry than EU institutions. However, the interaction with “classical” industry partners in robotics may not be the only (not even the better) way to reach the market: more interaction with the creative industry (industrial design studios, interior design studios, computer game designers, etc.) may open a more effective way to the first successful consumer product, unleashing the true economic potential of Soft Robotics.

3. Working Group creative session: scenarios for the robots in 2051

This session was aimed at going a step forward current Soft Robotics by a creative effort in imaging robots in the future, done by the very experts of robotics and soft robotics. In this way, the expectation is that the soft robotics experts distil the legacy that Soft Robotics will leave to the robotics of the future, from their qualified and privileged point of view. In relation to this, the participants were asked a work more similar to a project than a creative concept. They were also asked to identify the technologies they think could be used at that time.
Differently to the first RoboSoft Plenary Meeting (Deliverable D3.1.1), the Working Groups (WG) did not focused the discussion on a specific soft robotics technology, but on their possible application in various scenarios for the robots of the future: Home Assistance, Clinical setting, Search and Rescue, Industrial manufacturing. The imaginative date was set to 2051, by inverting the current date of 2015.
Community Members were asked to express the preferences for the WG to join and their answers were used to form the WGs.



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Please tell us your 2 preferences for joining the working groups working on the 4 scenarios below.

Your name: ____________________

First choice:
- ❑ Home Assistance
- ❑ Clinical setting
- ❑ Search and Rescue
- ❑ Industrial manufacturing

Second choice:
- ❑ Home Assistance
- ❑ Clinical setting
- ❑ Search and Rescue
- ❑ Industrial manufacturing

The other attendees (i.e. non-members of RoboSoft and students) were free to choose any WG. At the end, we had four well-balanced WGs in terms of number of participants and expertise (with both experienced scientists and students).

In order to help in the quasi-projectual work, each working group was provided with a poster to fill up, some evocative pictures of robots (machine-like, animal-like, human-like, etc.), some evocative general pictures (referring to biology, high tech, well-being, toys, etc.) and especially some pre-cut shapes to help draw the body of the robot, its locomotion system, its limbs, other equipment.

- In addition to a large central area for drawing, writing, and pasting shapes the poster had blank areas for writing the name of the robot
- its main function(s)
- who the users are
- what the operating environment is
- type of actuators, sensors, materials, in a feasible, credible way.

The evocative pictures were useful to start the discussion and help imagine the appearance and the perception of the robot of the future. At the end of the session, each group leader presented the poster and the concept, discussing it in a plenary session.

Industrial Manufacturing

By 2051 the earth human population will have peaked (in the range 9-11 bn, depending on the estimates) and the climate change will have entered a new harder phase. The objectives of giving everybody an acceptable quality of life, and of preventive dangerous conflicts for the access to resources, a novel paradigm sustainable ‘circular economy’ will be needed. This will be possible by a step by step, but radical, transition to a low/zero carbon economy (based on renewable energy sources and possibly controlled fusion) and a low/zero impact manufacturing (based on the ‘circular economy’ paradigm, aiming asymptotically at a complete recycle of materials and zero landfill waste and exploiting novel dismantling and decommissioning processes). The new industrial paradigm will be based on massive distribution of intelligence, sensing and actuation (beyond Internet of Things) intelligent soft robotics exploiting new materials (polymer and fibre fabric composites with distributed intelligence, sensing and actuation), compliant intelligent structures, such as deformable press moulds, new soft manipulation and assembly ‘arms’ and ‘ends’, a massive exploitation of machine learning and novel self-organizing control methods (currently subjects of research), hardware and software evolution and novel low learning threshold human system interfaces (including seamless BCI).

Several industrial sectors such as agriculture, construction and transport can benefit from exploiting the characteristics of soft robots for industrial manufacturing. Achieving cost-effective material and structural systems to take advantage of the compliance, large deformations and significant shape changes and adaptation that soft robotics can offer will require exploring materials and combination of materials which can provide the required functionality. Soft robot designs based on morphing capacity, pneumatic actuation and variable stiffness can provide significant benefits to industrial manufacturing, especially in relation to the manipulation, sorting and assembly of soft materials (fruit and other crops, for example) and complex shapes (building and engineering components). The materials and structures needed for industrial manufacturing applications of soft robots (elastomeric polymers, EAOs, fibre systems of various kinds, fabric structures and composites made with these materials) need to be explored further and integrated more effectively in the design of suitable components for manufacturing. Polymeric or metallic shape-memory materials (SMAs and SMPs) especially those operating at relatively low temperatures, can add significant additional functionality to soft robotic designs. Embedding flexible and compliant substrate photovoltaics in the robotic structures will be able to provide autonomous energy harvesting for operations in the field, in construction sites and in transport. State-of-the art technologies such as 3D printing need to be exploited further in order to achieve the beneficial integration of several material systems (polymers, EAPs, fibres, SMA, SMP) into performing composite structures for soft robotics.

The poster of the Industrial manufacturing Working Group is shown in the following Figure 16.

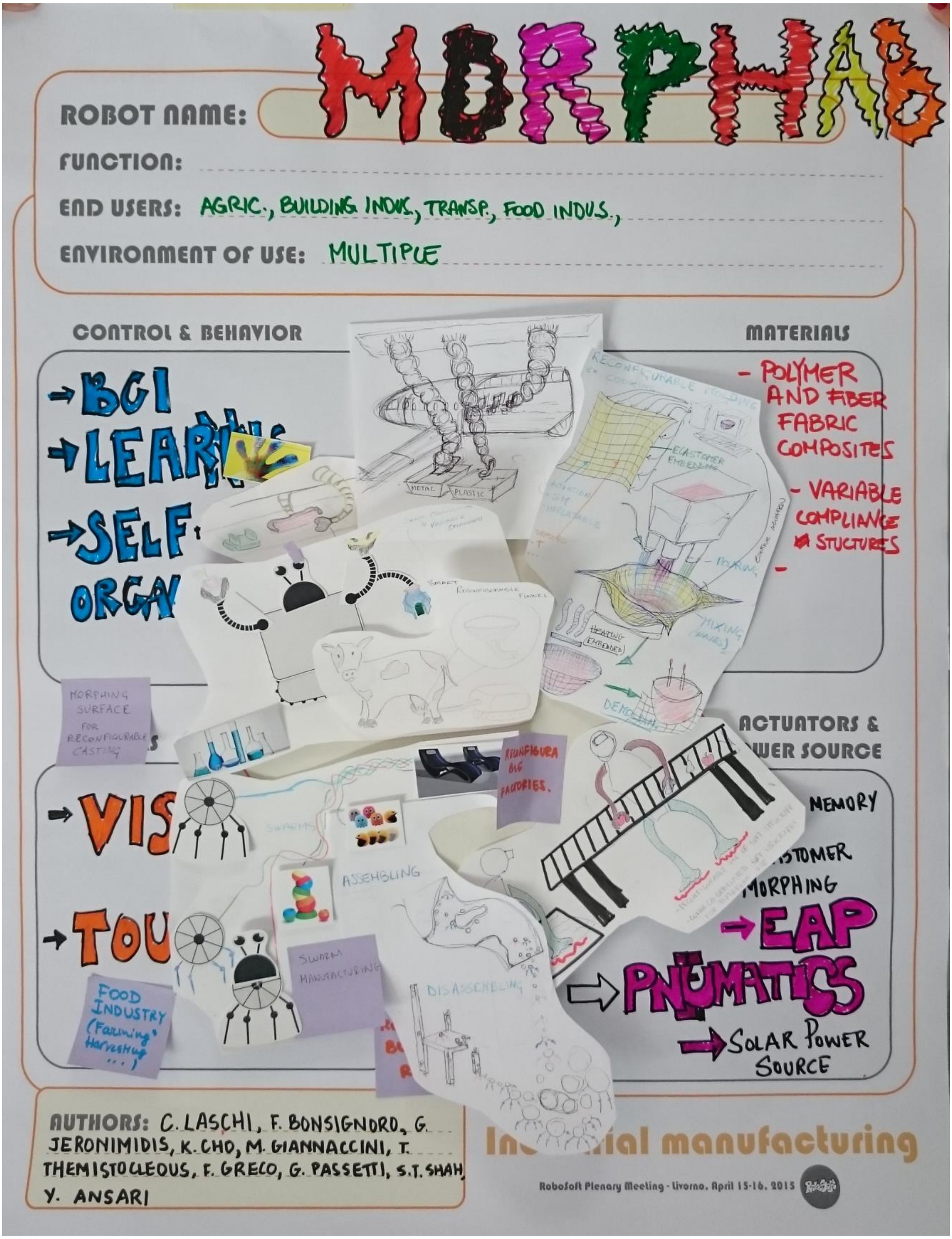

Figure 16 Picture of the poster of the "Industrial manufacturing" Working Group.

Home Assistance

Technological innovations to home assistance will provide an enormous impact to the society because the number of users as well as the economic size are gigantic. Therefore it is of our utmost importance to pursue the contributions of soft robotics technologies in this domain. By targeting the large target users and market, we expect to radically reduce the cost baseline of the technologies, as well as the users' conception landscape about robotics and machinery in general. On the other hand, to convince the large number of users, it is crucial to provide values and usefulness of soft robotics applications.

The Home Assistant working group has identified a long list of potential applications and use-cases in which soft robotics technologies could be useful.

Soft robotics applications in home assistance can be characterized by safe interactions with human users and the use of large variations of functional materials that would make the machines not only wearable but also more practically functional and "fashionable". The potential use cases that have been discussed include: food/cooking, healthcare (diagnostic, disease prevention), childcare, petcare, washing, cleaning, ironing, shopping, home interiors and assistance, communication, mobility, manipulation.

The main research challenges that have been identified are threefold. First there is the need of a significant improvement of basic soft robotics technologies, including functional material development, soft sensing, soft actuation, and overall control of systems. There are rapidly growing technological domains such as soft electronics, sensors, and unconventional additive fabrication techniques, which will help this direction of activities. Second, the integration research is also of crucial importance to make them more autonomous, adaptive, and intelligent. Here the research foci should be the pertinent use of AI and ICT in a distributed fashion that could maximize the embodied interactions between the human users and the real-world environment. And finally, another important activities expected in the near future is the application-oriented research. How unconventional devices and machines can be "conflated" into user spaces? What are the design principles for ergonomics of users? What are the user perceptions of cost-benefit? All these questions need to be answered scientifically.

The poster of the Home Assistance Working Group is shown in the following Figure 16.

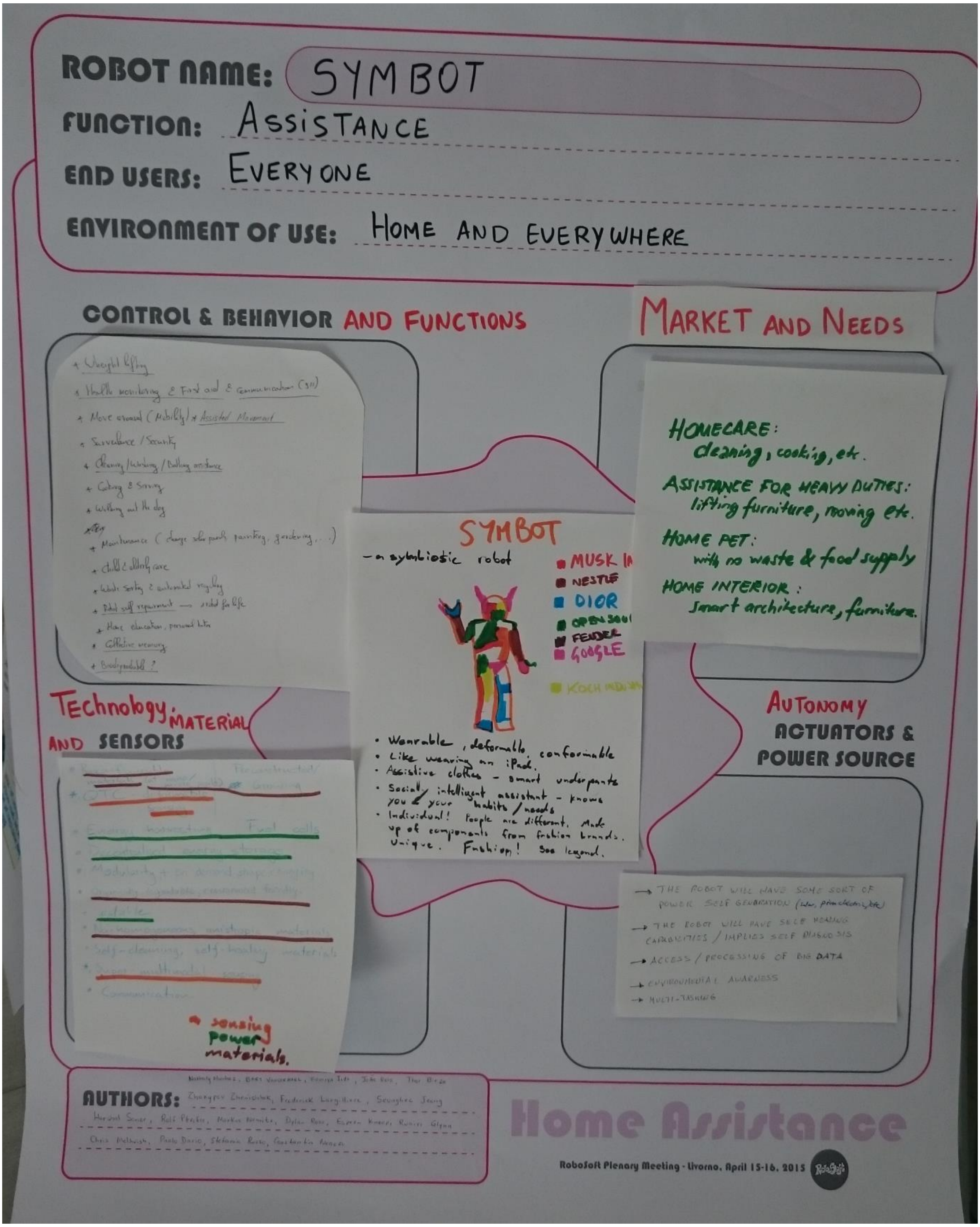

Figure 17 Picture of the poster of the "Home Assistance" Working Group.

Clinical Setting

In the Clinical Setting Working Group, a long session of fruitful discussions led to the consensus that the robots of the future for a clinical setting have to be a bio-integrated soft robotic implants. The Working Group imagined those implants first and foremost to replace physically malfunctioning portions of the human body, malfunctioning either because of an accident or aging. Those implants should also serve the purpose of augmenting and tuning existing senses and functionalities of the human body. Examples for such implants are replacements for human limbs like muscles, bones, and tendons; sensing body parts like eyes, ears, and tongue; and internal organs like bladder, and lung.

The individual milestones that need to be fully researched in order to fulfil the vision of functional bio-integrated soft robotic implants were then divided up into five main categories: materials, controls, sensors, actuators, and power sources. The materials should be biocompatible and work like artificial fibers/cells or smart active composites with specific functions. The implants should be self-controlled to allow for auto integration with existing tissue, that is to build nervous and endocrine interfaces. Different control strategies for voluntarily and involuntarily functioning organs need to be developed. Novel sensors within the implants allow for nerve system interfacing as well as proprioception and environment sensing. The new actuators will be tendon-attached muscles that are using actin-myosin interaction, electro-active polymers, or chemically active polymers.

In this working group, two case studies were also discussed analysing their feasibility: fat-eating swarm robots to help with weight loss of extremely obese humans and internal bioreactors that supply additional energy to the human body.

The poster of the Clinical setting Working Group is shown in the following Figure 18.

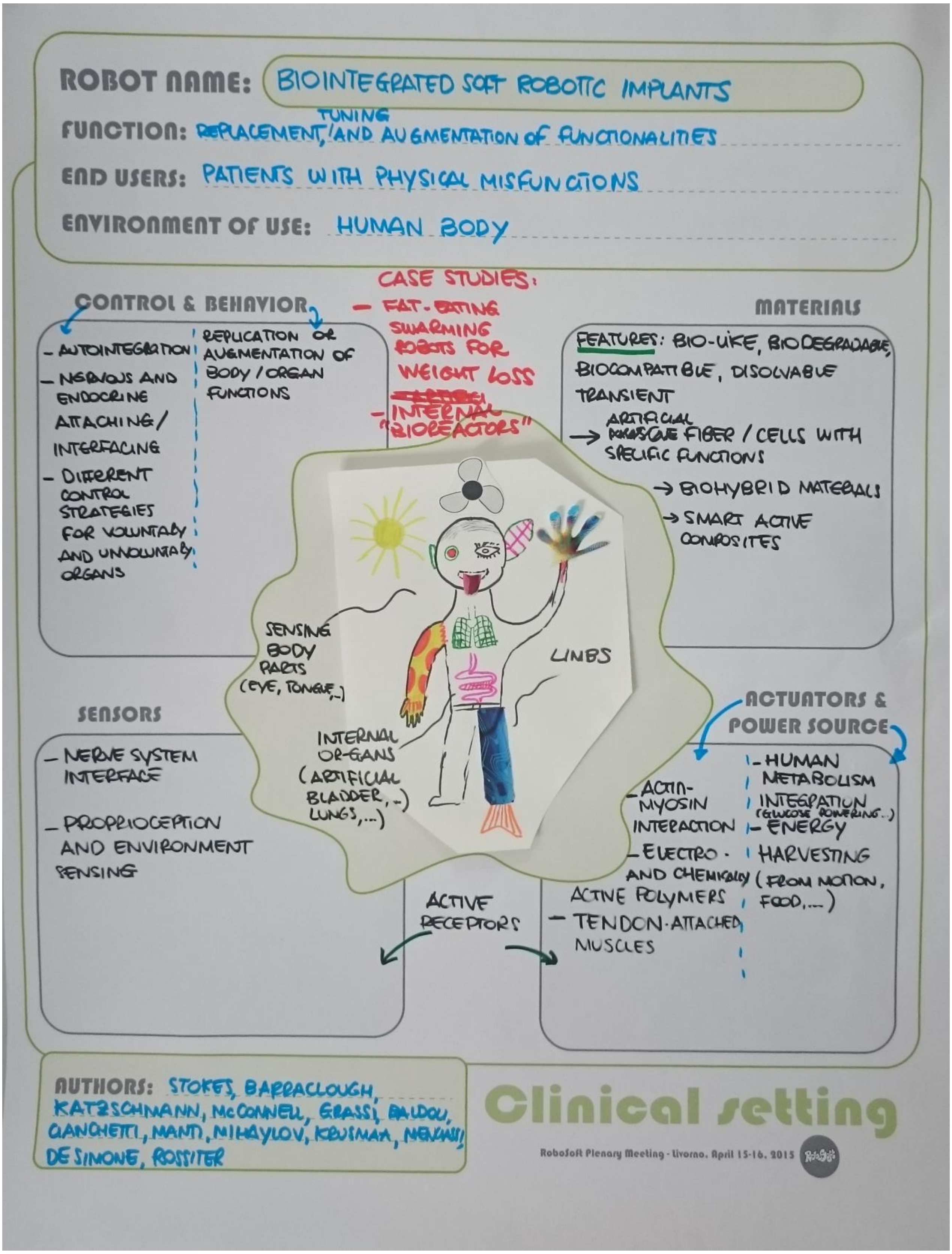

Figure 18 Picture of the poster of the "Clinical setting" Working Group.

Search and Rescue

The Search and Rescue group presented a new concept of soft robot with advanced multi-modal locomotion capability, aimed at addressing autonomous search and rescue operations in natural disaster scenarios, like, for example, after a tsunami. This represents a very challenging scenario characterised by an unstructured heterogeneous environment in which the robot should be able to use different locomotion modalities, such as walking, exploring ground in presence of debris, or swimming, in water-submerged sites, and gliding, when released directly from a flying vehicle (see central inset of the "Search and Rescue" poster).

The system, called "COBRAS - COnforming Biological Autonomous Systems", is composed by a swarm of soft snake-like robots, able to work autonomously as a single unit or together, in cooperative behaviour, to accomplish more challenging tasks.

The main features of COBRAS robot is the capability to change shape and stiffness in a controlled manner. Moreover, the shape control allows the robot to pass through complex unstructured environments and small apertures (e.g. in presence of debris). The robot is equipped with a multispectral (visible and thermal) camera for the detection of human presence on the disaster theatre, and biometric sensors to monitoring vital parameters of rescued people. Geiger counter and specific pollution sensors are also integrated for monitoring possible human-dangerous environmental conditions. All these sensors are embedded in the "head" of the robot.

The ability of dynamically control shape and stiffness is given by the peculiar structure of the robot. The main tubular body skin is made by a layer of composite soft tuneable electro-rheological sponge. The electro-rheological sponge consists of a porous matrix containing a net of microfiber electrodes and an electro-rheological fluid (a suspension of polarisable micro-particles in dielectric liquid) that changes its viscosity of several order of magnitude when exposed to an electric field. Modulating the electric field in different areas of the skin it is possible to locally control the stiffness of the robot. The actuation and the shaping are demanded to Electro Active Polymers (EAPs). In fact the electro-rheological sponge layer (controlling the stiffness) is coupled with a net of EAP-based wires, individually addressable, which locally create the specific curvature needed to reach the targeted shape. EAP actuators are based on graphene and intrinsic conducting polymer (dry) composites. The actuation net is controlled by a distributed system of tiny controllers, embedded on the net junctions. The net itself also provides the proprioceptive sensing, based on resistive transduction, for the shape controller. An external capacitive touch-sensing layer, placed on the robot skin, is instead used for the interaction with the environment (during navigation) and human-robot interaction.

The power is provided by grapheme-based supercapacitor coupled with a nuclear batteries (providing thermo-chemical energy), allowing long term robot operation without recharging needs.

Soft robot structures, novel control architectures and soft-material based embodied intelligence will be the key enabling. Compared to the state-of-the-art in search and rescue robotics, using soft robotics promises a highly robust, versatil and human friendly system that is inherently adaptive and safe to operate.

The poster of the Search and Rescue Working Group is shown in the following Figure 19.

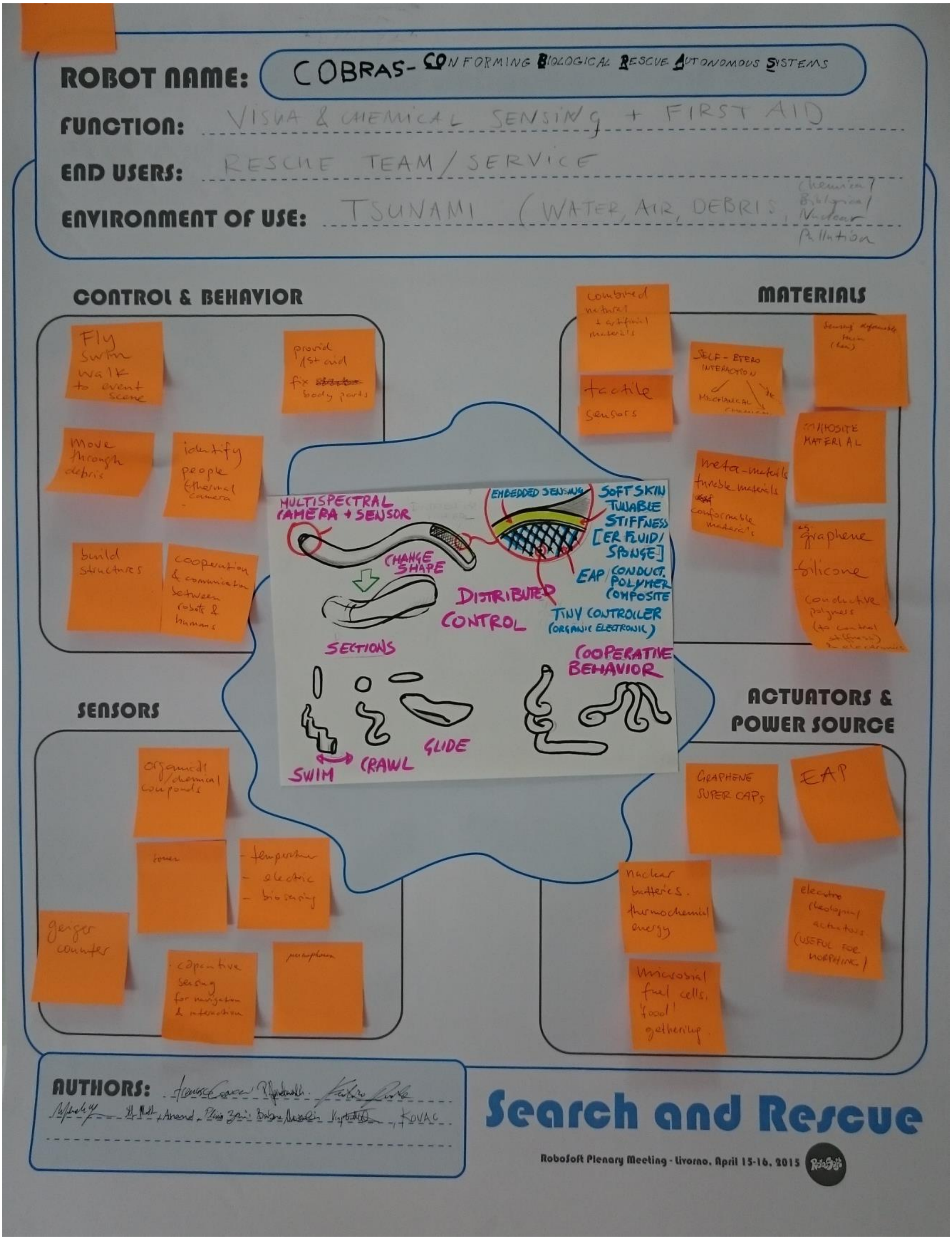

Figure 19 Picture of the poster of the "Search and Rescue" Working Group.

4. Annex I: RoboSoft Community Members and PI

1. **Tufts University** - Barry Trimmer
2. **Center for Micro-BioRobotics IIT@SSSA** - Barbara Mazzolai
3. **Heron Robots** - Fabio Bonsignorio
4. **Institut de Recherche en Communications et Cybernétique de Nantes** - Frederic Boyer
5. **UZH - AI Lab** - Helmut Hauser
6. **University of Tsukuba - Flexible Robotics Lab** - Hiromi Mochiyama
7. **Edinburgh University** - Adam A. Stokes
8. **Tallin University** – Centre for Biorobotics - Maarja Kruusmaa
9. **Cornell University** - Robert Sheperd
10. **Seul National University** - KyuJin Cho
11. **Osaka University** - Koh Hosoda
12. **EPFL - Laboratory of Intelligent Systems** - Dario Floreano
13. **EPFL - Reconfigurable Robotics Laboratory** - Jaimie Paik
14. **Carnegie Mellon University** - The Robotics Institute - Yong-Lae Park
15. **The Chinese University of Hong Kong** - Michael Wang
16. **University of Tokyo** - Takao Someya
17. **Fraunhofer IZM** - Thomas Loher
18. **University of Wollongong** - Gursel Alici
19. **Vrije Universiteit Brussel** - Francis Berghmans
20. **Max Planck Institute for Intelligent Systems** - Metin Sitti
21. **Università degli Studi di Trento** - Massimiliano Gei
22. **Imperial College of Science, Technology and Medicine** - Mirko Kovac
23. **I3P S.c.p.a., Incubatore Imprese Innovative del Politecnico di Torino** - Marco Cantamessa
24. **SISSA, International School for Advanced Studies** - Antonio De Simone
25. **Oregon State University** - Yigit Mengüç
26. **IDMEC, Instituto Superior Técnico, University of Lisbon** - João Reis
27. **Disney Research Zurich** - Markus Gross
28. **Biorobotics and biomechanics Lab, Beihang University** - Li Wen
29. **The Hebrew University of Jerusalem** - Benny Hochner
30. **Khalifa University of Science, Technology and Research** - Lakmal Seneviratne
31. **Institute Nationale de Recherche en Informatique et Automatique** - Christian Duriez

5. RoboSoft Consortium and Contacts

RoboSoft Consortium

Scuola Superiore Sant'Anna, The BioRobotics Institute (Pisa, Italy)
Project coordination and management, organization of the scientific community and initiatives, dissemination and outreach.
Key members: Cecilia Laschi, Paolo Dario, Matteo Cianchetti, Laura Margheri
http://sssa.bioroboticsinstitute.it

Swiss Federal Institute of Technology Zurich (Eidgenössische Technische Hochschule Zürich, Switzerland) and University of Cambridge (Cambridge, United Kingdom)
Project web portal and online tools setup and management; support and involvement in coordination action initiatives.
Key members: Fumiya Iida, Surya Girinatha Nurzaman, Luzius Brodbeck
https://www.ethz.ch/en.html

University of Bristol (Bristol, United Kingdom)
Dissemination and engagement activities and contacts with stakeholders; support and involvement in coordination action initiatives.
Key members: Chris Melhuish, Jonathan Rossiter
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