The Newsletter of RoboSoft
Coordination Action for Soft Robotics

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Editorial

This is the last issue of the Newsletter of RoboSoft, the EU-funded Coordination Action for Soft Robotics, which is going to finish on September 30 2016, after 3 years of activity.
This time spent together was great and rich of successful experiences and results that are leaving a promising legacy for the future of soft robotics community.
We are grateful to the RoboSoft Consortium Partners, the Members of the RoboSoft Community, and all the followers and stakeholders who have been protagonists of the initiatives organized within this Coordination Action.
RoboSoft has become a major landmark for the community of soft robotics worldwide thanks also to your strong commitment and the proactive collaboration during the networking events and scientific consultations.
The numerous initiatives launched by RoboSoft have helped the community of soft roboticists to become more extended and integrated, with researchers who are now further motivated and coordinated to meeting together, having scientific and technical discussions, sharing educational tools, and having more opportunities with stakeholders and special interest research groups for exploiting the potential of soft robotics in future ICT.

Soft Robotics is now considered one of the most promising frontiers for robotics research and technological innovation. The enormous growth of this field in the last few years has been evidenced by a large increase in the number of publications, special issues in journals, focused sessions and workshops at international conferences, summer schools, competitions, EU funded projects, as well as new laboratories, companies and faculty appointments.

We are glad to have been part of the growth of the field of soft robotics up to now, and we are confident that this growth can continue in the forthcoming years.
This challenge can be achieved by exploiting the solid bases poses by RoboSoft: a strong and committed community of both young and experienced researchers, a network of followers and stakeholders, and a number of periodic events for meeting and having scientific discussion. This RoboSoft legacy can be effective thanks to the commitment of its community and the general will of continuing meeting at the annual Soft Robotics Week, proposing and getting funding for new joint initiatives and projects, having coordinated teaching methods, and involving more researchers and industrial stakeholders.
So we look forward to carry on these initiatives, inviting you to stay connected with us for making the legacy of RoboSoft a real opportunity for the future of soft robotics in the next years.

Laura Margheri and Cecilia Laschi

RoboSoft Pills

Most important topics of the RoboSoft initiatives during these last six months of the project focused on major research trends, current applications and future challenges of soft robots. These were in fact also the themes of the 2016 Soft Robotics Week, the yearly event for the community of soft robotics started last year by RoboSoft.

This second edition of the Soft Robotics Week featured 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 activities of scientific discussion and plenary 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, met 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.

The main themes were related to soft robot legged locomotion, soft robot manipulation, underwater soft robotics, biomimetic soft robotic platforms, plant-inspired soft robots, flying soft robots, soft robotics in surgery, as well as methods for their modelling and control.

The event was larger than the previous one, with more than 140 registered participants among scientists and roboticists worldwide, selected PhD students who participated to the working group activities of the School, invited speakers who presented the latest technologies and systems in soft robotics during plenary talks at the School and at the Plenary Meeting and who participated in the panel discussion sessions.

The School programme was organized in five days, from Monday to Friday, with technical lectures in the mornings and hands-on sessions in the afternoons. During the hands-on sessions, the students were grouped in teams and provided with a series of different toolkits for an “Experienced Learning” time.

The two central days of the week were focused on the RoboSoft Plenary Meeting, involving members of the RoboSoft Community, the students of the School, industrial stakeholders and external experts. Invited speakers presented the cutting-edge technologies and applications related to various fields of soft robotics. Part of the meeting was dedicated to plenary discussion among the participants on current state of soft robotics, robotics competitions, future opportunities and needs for soft robotics, as well as on the legacy of RoboSoft for the next years.

The outcomes of the closing discussion of the last RoboSoft Plenary Meeting revealed the strong commitment of the Community to continue creating opportunities for scientific discussion and collaboration beyond the end of RoboSoft Coordination Action. This could be achieved by continuing the annual Soft Robotics Week, by proposing and getting funding for new joint initiatives and projects, by coordinating teaching methods for the benefit of the new generation of “soft roboticists” and removing barriers between universities, departments and countries, and by involving more researchers from those disciplines who are fundamental for the progress of soft robotics.

Technical and cultural tour were also organized during the week, in order to further stimulate networking among participants in a less-formal situation.

Figure 1. Soft robotics community: group picture at the RoboSoft Plenary Meeting

The closing event of the week was the RoboSoft Grand Challenge, the first outdoor competition for soft robots in manipulation and terrestrial locomotion. 17 robots from 9 international universities competed in the Grand Challenge and the 3 winners of the Grand Challenge, the Terrestrial Race and the Manipulation competition were awarded with the 5.000 € prize and a publication in the Journal of Frontiers in Robotics and AI.

Figure 2. The team of the Seoul National University, Korea, winner of the RoboSoft Grand Challenge

The design process, the implementation and the results of this novel robotic contest addressing soft robots has been described in Calisti et al, 2016 ("Contest-driven soft-robotics boost: the RoboSoft Grand Challenge", Front. Robot. AI).

Soft bites

People: Kenji Suzuki

Wearable and Assistive Soft Robotics

A conventional hard robotics with a rigid-body system is described by the equation of motion. It has the motion subsystem which is the physical structure that carries out desired motions. The physical interaction is determined according to the relationship between the forces acting on the system and the accelerations they produce [1]. On the other hand, soft robots such as the grasping robot, the crawling robot, and biologically inspired robots [2][3] have soft and deformable structures. They are capable to change their shape and to adapt themselves to the surrounding environment for different purposes. There are several similar approaches to make the robotic system soft with the aid of the mechanisms and actuators in hard robotics. The use of a non-classical actuator in an unknown and dynamic environment including humans is gaining increasing interest such as variable impedance/stiffness actuators, and series elastic actuators. These non-classical actuators are deviated from its set equilibrium position in accordance with the physical structure of the system and external forces [4]. In both hard and soft robotics, the actions in the physical world are basically considered as the same from the view point of physics because they are subject to physical laws under the geometric constraints. The forward dynamics are therefore described as the acceleration response of the system to a given applied force in either a rigid-body or soft-body system.
We have been doing several researches in the field of wearable and assistive robotics. In particular, we are interested in understanding the human body dynamics, control, and motor learning. The current exoskeleton robot has a

typical mechanical design of assistive wearable robot with rigid link mechanism and actuators [5]. We consider that developing an integrated robotic system with rigid, soft, and flexible mechanisms provide the appropriate solution for the future wearable robots. It is very important to ensure safety for both the objects and humans in the physical human-robot interaction. We, therefore, are investigating a theoretical foundation of an integrated robotic system with rigid, soft, and flexible mechanisms. The system which consists of both rigid and soft mechanics is designed to accomplish a given task in a situated environment with an efficient way of robot control. This is regarded as smart mechanics, and the control is extended not only to each joint or link but also to the spring and damping effects as the energy flow in the robotic system and dynamical characteristics of the human.

So far we have developed a standing mobility vehicle and step-climbing wheelchair [6][7]. The developed mobility vehicle with a passive exoskeleton without using any electrical actuators can assist the user's voluntary postural changing: sitting to standing solely with a passive mechanism as well as support the convenient transferring from the wheelchair into a bed, toilet, tub or a regular chair. In addition, we have realized a step-climbing wheelchair also with a passive mechanism. We focused on the passive operation for posture transition, which is cheaper, lighter, water resistant and easy to attach. The operation realized through gas-springs and a linkage system enables easy fitting into existing self-powered or electrical wheelchairs.

We also presented an elastic link mechanism integrated with a magneto-rheological (MR) fluid and a compression spring. The link, called MR Link, changes its apparent stiffness according to the magnetic field generated by the applied electric current in the embedded coil. We have developed a wearable ankle and elbow motion assist device by using the MR link [8]. The developed wearable robot is able to apply torque on the motor joint by the stiffness of the MR fluid, and also by way of the spring force whose compression and release can be controlled by the stiffness of the MR fluid. This is a kind of semi-passive mechanism without powered actuator, and is extremely low energy consuming, light-weight and compact.

The Robot Mask with shape memory alloy based actuators is another example of the integration of hard and soft bodied structure, which follows an approach of manipulating the skin through minimally obtrusive wires, transparent strips and tapes based pulling mechanism to enhance the expressiveness of the face [8]. The Robot Mask is the world's first wearable robot for hemifacial paralyzed patients and is designed to assist their rehabilitation. From a patient study, we found that the developed robot mask could support the physiotherapy tasks of rehabilitation of facial paralysis.

Figure 3. Wearable and assistive robots (from left): Body-synergy based control for exoskeleton [5], ankle-foot orthotic device with the MR-link [8], a standing mobility vehicle with the passive assistive limb [7], and robot mask designed to support rehabilitation of facial paralysis [9].

Hard robotics is not the enemy of soft robotics. The starfish changes the property from soft to rigid for different purposes. As many have noted, the challenges to using soft robots is making their behavior precise and efficient enough to accomplish the given task in a reasonable amount of time. However, we believe that the control of rigidity is one of the most important research challenges in soft robotics. Referring to the human muscle-skeletal system, the integration of both hard and soft robotics technology allows us to proceed to the next step of wearable and assistive robots.

Kenji Suzuki is currently a Professor at the Faculty of Engineering, Information and Systems, University of Tsukuba. He received the B.S. in Physics, M.E. and Dr. Eng. in Pure and Applied Physics from Waseda University, Japan, in 1997, 2000 and 2003, respectively. Prior to joining the University of Tsukuba in 2005, he was a Research Associate with the Dept. of Applied Physics, Waseda University. From 1997 to 1999, he was a visiting researcher at the Laboratory of Musical Information, University of Genoa, Italy. In 2009, he was a visiting researcher at LPPA, Laboratory of Physiology of Perception and Action, at the College de France, Paris. He is a member of IEEE, served as the chair of the chapter and international activities committee at the member activities board of the IEEE Robotics and Automation Society since 2010. His primary research interests include wearable and assistive robotics, Cybernics, affective computing, and artificial intelligence.

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People: Martin F. Stoelen

Putting soft robots to work, for the scientist and for the farmer

When robots finally make it into our daily lives, what will they look like? Chances are they will be soft enough to forgive a moment's carelessness, or the unlucky timing of a sensory occlusion, but precise and responsive enough not to spill when pouring hot tea from a rapidly emptying pot. A bit like you and I, in other words, as such variable passive compliance seems key to many of our own dexterous skills. If our bodies shape the way we think [1], softer robot bodies will also have serious implications for the complexity of the control algorithms required. Though thankfully not always in the direction of increasing complexity, as computations can be outsourced to the soft body itself [2].

On the other hand, soft bodies sometimes resist being exactly modelled and replicated. Controlling them could therefore require a developmental paradigm of getting "comfortable in one's own skin", perhaps. Certainly soft robots will enable us to learn more about our own development [3], as a developing mind requires a forgiving body. Soft, but variable-stiffness robots then, with self-calibrating features. That sounds expensive! Progress could also be slow if the average researcher cannot replicate a new design, or a scientific experiment, easily [4]. However, judging by the rapid rate of innovation in the Maker movement [5], low-cost 3D printing technology might just save the day.

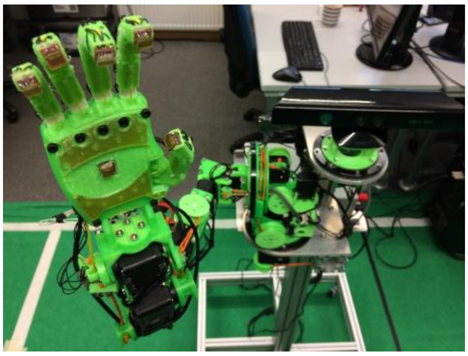

Figure 4. High five! The 7+3 DOF GummiArm as of September 2015, at approximately $4750. See full version history of the open-source printables and code, links to videos, and detailed build instructions, here: http://mstoelen.github.io/GummiArm/

There have already been wonderful developments in soft robotics though 3D-printing, including soft hands [6], variable-stiffness actuators [7], soft robot toolkits [8], and printable hydraulic systems [9]. The GummiArm [10], a 7+3 Degrees Of Freedom (DOF) printable arm, was inspired by these developments. See Fig. 1. It combines structural components that are printable on hobby-grade 3D printers, and rubbery tendons in an agonist-antagonist configuration. This enables easy replication, robustness even to fast impacts, a repair cycle of minutes when something does break, and stiffness and damping when required. The design has come a long way over the last 2 years, and we are keen to build a thriving community of makers, engineers and scientists.

I think there is interesting science to be made, and I am excited about a platform that can be soft, bio-inspired and adaptive. Perhaps it could make possible assistive robots that safely learn from the collisions made, and help the user avoid them next time? We humans do effectively trade off speed for accuracy, even on combined movements [11]. However, the human motor control scientist lacks physical hardware for testing the underlying mechanics of this trade-off. There are also compelling models for how we adapt to disturbances during movement [12], but testing is limited to human participants or virtual models. Perhaps soft platforms like the GummiArm could help shine new light on these issues? The arm is also being used for teaching, locally and through the international ShanghAI Lectures [13].

If we get our soft robots right, there are also real-world tasks awaiting a robust and safe solution. For example, manual picking operations of soft fruit for fresh consumption. This work can be a mechanical drudgery, but it also requires dexterity, a gentle touch, and speed. Swarms of low-cost autonomous platforms seem feasible for this type of operation [14], as numbers can trump size when you take the human operator out of the agricultural machine. However, these platforms still have to be robust enough to survive mistakes. The sensory data from the farmer's field is noisy at best, and picking requires fast movements in close proximity to hard obstacles like wooden poles. It will be hard to achieve 100s or 1000s of hours between breakdowns in this environment, but a soft embodiment would likely help, while also being safe for humans and crop.

I believe the scientific and market opportunities are there. Now it is up to us to put our soft robots to work, for the scientist and for the farmer.

Martin F. Stoelen

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Places: Centre for Autonomous Systems and Advanced Robotics, University of Salford

Soft Robotics for Industrial Applications

The University of Salford's research in the area of soft robotics began in the mid-1990s with the development of soft actuators, research in the field of soft robotics has continued ever since. Salford is applying soft robotics in the healthcare, rehabilitation, service robotics and industrial/manufacturing fields.

In industrially, the future will likely require robots to work close to, and in collaboration with humans. However, although traditional stiff robotic systems are well proven and provide high accuracy and repeatability, their high masses and associated inertias mean they are not suited to close human interaction. Collisions between humans and robots can lead to significant injury and therefore the traditional approach has been to keep the two separated by a physical barrier which prevents all but the most basic of cooperation.

To address this issue and make robot human interaction in industrial scenarios safer a number of approaches have been explored. These have included coating robots in compliant materials, introducing passive elastic elements into the transmission system and numerous variable stiffness/damping designs. Although these approaches remove forces associated with actuator inertia from collisions the systems still have massive and rigid links which still have potential to cause significant injury if they collide with a human at anything other than very low speed. Soft robotics has potential benefits in this regard.

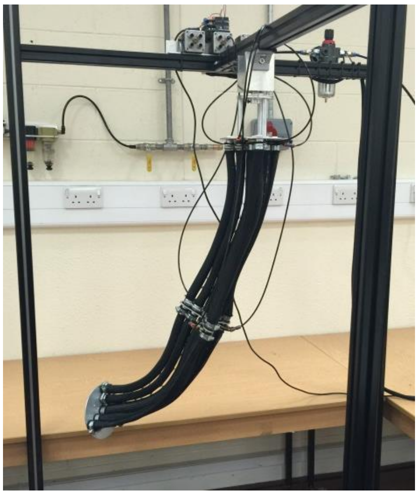

Figure 5. Variable Stiffness Soft Arm developed at the University of Salford

Soft robotics is essentially studying animals which do not have rigid skeletons and using this knowledge to develop robots without rigid links. The way in which these creatures interact physically with each other and their environment can be used to inform the design of the next generation of industrial robot manipulators. From an industrial safety point of view soft robots have the benefit that contact stresses are distributed over a larger area meaning localised forces are lower and injuries are potentially less serious.

In addition to the advantages of safer human-robot interaction soft robots have the potential to provide greater dexterity than traditional robots when performing manufacturing and other industrial tasks. Unlike conventional manipulators many of the soft robots we are currently developing do not have discrete joints. This means they are often able to continue to operate when partially constrained or in contact with obstacles. They can therefore be used in industrial scenarios where a traditional robot cannot, for example inside a pipe or in a highly unstructured environment. Often tasks that cannot be performed using conventional robots have to be performed manually. In certain industrial sectors, such as the nuclear industry, this can be highly undesirable as it involves people having to enter highly hazardous environments because there is no appropriate automated solution. Soft robots have the potential to remove people from these hazardous locations.

One drawback of soft robots is that due to their compliance very precise position control is a significant challenge and this makes them unsuitable to many industrial and manufacturing tasks. However, work being undertaken at Salford is exploring variable stiffness soft robots for industrial use. Such systems can be highly compliant when they are moving at speed and thus have high amounts of kinetic energy. However, they can become much stiffer when moving more slowly allowing for more precise positioning accuracy.

In summary, soft robots have the potential to greatly increase the industrial tasks which can be performed using robots. They have the potential to lead to inherently safer robots able to truly collaborate with people in manufacturing, maintenance, cleaning and a range of other industrial applications. Furthermore soft robots are able to operate in scenarios and perform tasks where current robots are unsuited.

Steve Davis obtained his PhD on Soft Robotics from the University of Salford in 2005. He then became a Team Leader at the Italian Institute of Technology before returning to Salford in 2012. His research interests include actuators, biologically inspired systems, biomimetics, 'soft' robotics, end-effectors and industrial automation. He has published extensively and has attracted research funding.

Samia. Nefti-Meziani is Director of the Centre for Autonomous Systems and Advanced Robotics at University of Salford. She is Coordinator of the European Marie Curie Innovative Training Network SMART-E and the coordinator and CO-I of three further major programmes worth more than £14M. She is one the Founder members of the Northern Robotics and Autonomous Systems Network which is part of the Innovate UK network.

Centre for Autonomous Systems and Advanced Robotics, University of Salford

www.salford.ac.uk/softrobotics

Places: Soft robotics team at Industrial Design Engineering, TU Delft

3D-printed soft robots

At the faculty of Industrial Design Engineering in Delft, we work on Additive Manufacturing (AM) for soft robotics. The short lead-time, and freedom in both geometry and material composition offers great potential for use of (multi-material) AM in soft robotics. Our team at the Design Engineering department focuses on developing tools that allow designers to exploit the design freedom to realize desired behaviour in 3D printed soft robots.

A pneumatic soft robotic hand that can shake hands shows how AM can be used to integrate actuators, sensors and structure in a single part product [1]. The behaviour of the eight integrated actuators is tuned through the geometry of the air chambers. More work focuses on the development of an interactive tool that can be used to design the deformation behaviour of 3D printed (robotic) structures by changing the shell thickness [2].

Figure 6. Soft Robotic Hand

A second approach that is used to tune the behaviour of soft robots is through material distribution of rigid and soft materials. An example is the gripper shown in fig. 4. A multi-material structure that is implemented in the gripper fingers makes the fingers easy to bend but hard to twist.

Figure 7. Gripper with multi-material structures that prevent twisting of the fingers.

Using a bitmap printing method and digital workflow, material composition can be defined based on voxel resolution [3]. This can be used to fabricate a design object with locally varying material stiffness, aiming to satisfy the design objective.

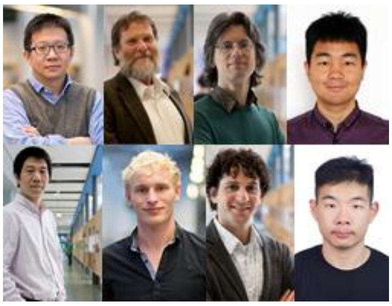

Figure 8. Soft robotics team at Industrial Design Engineering, TU Delft

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Places: At-Bristol

Soft robotics outreach: interview with Ruth Murray from At-Bristol

1. Can you tell me a little about At-Bristol?

At-Bristol is one of the UK's leading interactive science centres. We have two floors of interactive exhibits, a 3D 4k digital planetarium and a whole host of spaces where you can meet our fantastic Live Science Team to take part in a hands-on experiment or investigation. As an educational charity our mission is to make science accessible to all and to encourage a sense of adventure in our visitors. Annually, over 300,000 people are launched on a journey of discovery through engagement with our programmes.

2. What current outreach activities do you have?

We've just spent the summer out and about all over Bristol at community events as part of The Crunch, a Wellcome Trust-funded initiative that encourages people to think about our food, our health and our planet. Each year we host six community weekends where families from areas of our City which we know are underrepresented in our visitor of profile are invited to visit for free and enjoy a day of family learning together. We've found that going out into the community with our programmes, combined with an invite to come and explore in At-Bristol is an approach that works. This year alone we've had nearly 7,000 people visit as part of this initiative.

3. You collaborate with many researchers from academia. Do you think they in general are doing a good job at translating their science to wider communities?

Part of our mission as a science centre is to support and develop researchers' skills in public engagement. We provide training and advice to over 100 researchers a year across our various programmes. It might be working with them on a research proposal to devise and resource their pathways to impact, co-developing a special event for an After hours evening or even working with them to collect data from our visitors as part of their At-Bristol day out. Just like our visitors – all researchers are individuals with their own needs, motivations and preferences. We try and support them to think of innovative ways to engage people with the themes of their research and provoke interested two-way conversations with people rather than lectures or talks. For some people this can be a step out of their comfort zone.

4. What are the common mistakes? How could they be doing a better job?

I think academics are increasingly open to new platforms for engagement and policy changes like the Concordat for Public Engagement mean that it is necessarily given more prominence. For me personally, I'd like to see more academics starting their engagement earlier in their research rather than just as part of the dissemination at the end. I think there is potential for people to be more deeply engaged when you're at the beginning of the story and trying to find something out, rather than getting a download or retrospective of what has already happened. I also think that for areas of research, like Robotics that will affect day-to-day lives, starting these conversations earlier might also begin to change the nature of the questions being posed by researchers and increase the relevance of science to everyday lives.

5. What three qualities do you believe an outreach worker should possess?

Curious about people – being empathetic to the needs and interests of your audience is key to finding your hook to get them interested

Open to new ideas – I think this actually comes naturally to lots of academics as it's is kind of the key quality behind scientific enquiry

The ability to adapt and think on their feet - Once you're in conversation with someone you're bound to be asked something you didn't/couldn't prepare for and that's great – you've got them interested and generating new ideas!

6. What do you think about soft robotics? Is there a need for more demos from this field?

We've just hosted a whole summer of 'Robot encounters' here in At-Bristol which we developed in collaboration with researchers at Bristol Robotics Laboratory. When you say 'robot' people normally have an image of a hard shiny industrial machine – soft robotics is the antithesis of this and a really exciting area of contemporary research that challenges preconceptions about the future applications of robotics. We really want people to feel involved in shaping what that future looks like and inspired by how new, intelligent soft materials could be applied. Three of the key themes we wanted to engage people with in relation to second wave robotics were that it is a multidisciplinary field, that researchers are inspired by nature and they are developing robots to live and work alongside human beings – soft robotics is a great example of all of these. I think when you start to show examples of robotic technologies that confound people's expectations you broaden access to the field. You create hooks for people who identify as artists or naturalists or philosophers rather than purely engineers or programmers. And on a very practical level the 'soft' nature of the materials involved often lend themselves well to being adapted into public engagement activities that people can really get hands-on with. I actually thought Disney did a good job recently of reimagining Baymax and countering the dominant science fiction narratives around the future of robotics. Who'd have thought the star of a robot blockbuster would be a big inflatable softy designed to help humans?!

7. Finally, could you tell me a few words about your future plans?

We opened a brand new Tinkering Space this summer – it's a new creative environment in our permanent galleries that is designed to inspire the inner inventor in us all. You can design, make and modify shadow boxes, marble runs and aerodynamic flyers and event meet a collaborative robot – Baxter. We've already hosted a whole range of multidisciplinary events in the space and hope that's just the start or a vibrant programmer that taps into the wider Maker movement. We're really keen to embed STEM in people's everyday lives as part of wider 21st century culture in the same way that they might think about other leisure activities, like sport or films. The world is a mesmerising place and everyone has something they want to know more about. We believe these journeys of discovery are not only vital for all our futures but satisfying and enjoyable too. We want as many people as possible to feel they can pursue their interests in a playful and curious way.

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