2009-2019 ECHORD++

THE EUROPEAN COORDINATION HUB FOR OPEN ROBOTICS DEVELOPMENT

The secret of our success

ECHORD++

“The ECHORD project, funded by the European Commission, enabled the bringing of robotics technology from the lab to the market in more than 50 cases. Within the project we also successfully tested the funding of sub-projects via open calls.”

GÜNTHER OETTINGER, FORMER EUROPEAN COMMISSIONER FOR DIGITAL ECONOMY AND SOCIETY

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IN 10 YEARS THE EUROPEAN COORDINATION HUB FOR OPEN ROBOTICS DEVELOPMENT, ECHORD, AND ITS SUCCESSOR, ECHORD^{++}, HAVE PIONEERED A UNIQUE, NEW APPROACH, BRIDGING THE GAP BETWEEN ACADEMIA AND INDUSTRY TO THE LASTING BENEFIT OF EUROPEAN ROBOTICS.

ECHORD HAS NOW REACHED MATURITY. WITHIN THESE PAGES WE CELEBRATE THE PROJECT'S OUTSTANDING ACHIEVEMENTS AND ITS ENDURING LEGACY, WHICH WILL CONTINUE TO SHAPE THE ROBOTICS OF THE FUTURE.

COVER IMAGE: Silas Adekunle, CEO, Reach Robotics with the MekaMon robot
SOURCE: Reach Robotics

ECHORD comes of age

AS ECHORD'S COORDINATOR, PROFESSOR ALOIS KNOLL IS AT THE HEART OF THE PROJECT'S SUCCESS. HE TALKS TO ANNA PRINCIPATO ABOUT ECHORD'S ORIGINS AND ITS IMPACT.

Q. After 10 years of ECHORD and ECHORD^{++}, how do you feel now that such a groundbreaking project has reached its conclusion?

AK. It's a mix of feelings, of course, because it's been a very successful project. It was very difficult to get it started. There were lots of people involved - we had almost 90 experiments and there must have been over 500 proposals and lots of very, very enthusiastic participants. I think the original goal has not only been met but we have exceeded expectations by far.

In a way, it's a sad moment but, on the other hand, it was clear that we should not push for another ECHORD-type project, at least not with me as a coordinator. Because, in a sense, 10 years is enough. Actually, it's more than 10 years because the first exchange I had with the Commission was in July 2007, with Collette Maloney, who was very, very helpful in making this happen. It was Collette Maloney, Horst Foster and myself. Credit should also go to them.

Q. Why do you think 10 years is enough?

AK. If you do 10 years as a coordinator, it would be more of the same if you have another extension. This project had a lot of admin work, which was necessary at the time but there's a limit. We are science people and I think has now been established as a project funding scheme that goes well beyond the original Echord. The people at the [European] Commission sometimes refer to Echord as 'the Echord Model' because it really established a completely new funding model and that is the heritage that will outlast the project. New people can take over now, with new ideas. And base their proposals on what we have achieved.

Q. How did this new funding model — which you've called Cascading Funding —come up?

AK. It was an interchange of ideas between the Commission and myself. What we wanted was to establish is a slim interface between the researchers — or the research organisations — and the Commission, in the area of robotics and a little bit beyond. So we discussed how we could simplify the processes – this was long before Horizon 2020 – how we could make it attractive to small and medium-sized enterprises and how we could mobilise money usefully. It's worked out perfectly.

Q. During the runtime of the two ECHORDs, what were the biggest challenges and developments, in your opinion?

AK. First of all, we had to find general acceptance. That was not easy because a lot of the control that used to lie with the Commission was — in one way or another — transferred to the independent experts we hired, so there was this fear among member states that they would have to relinquish control. But it turned out that this had no substance. Of course, people had to be convinced and this wasn't easy. There were some hurdles in the beginning. Then, over the funding period — this may sound strange — but the biggest problem was that we received so many proposals, of which we could fund maybe only 20%, which, of course, caused some frustration. On the other hand, we also received very positive feedback from people who did not get their proposal granted, because they said 'the process of writing the proposal meant we got to know so many people this alone justified the effort'.

Of course, the proposers and the experimenters were relieved from this, but we, as a Project, had full responsibility for the results and we were accountable for everything. This was not always easy.

Q. So that's why 10 years is enough?

AK. 10 years is enough, at least 10 years for this kind of project — and don't forget that we handled about €50 million during the process, a lot more than the typical university project would be able to handle. We had to build up an infrastructure, a team. We had to hire lots of students to help us. It was a very interesting experience, a very dynamic experience, but — like I said — 10 years is enough.

Q. What, in your view, are the highlights?

AK. The highlights are in the experimental results and a number of SMEs and new companies have started up. There are two successful PDTI prototype schemes and then — of course — the RIFs, which have established many, many contacts which, hopefully, the community will be able to expand on in the future.

It's been a variety of things which tie in together, which is also one of the reasons that it's been so successful, it's not a monocausal success; it's been successful because of the people and because of the spread, or the [many] threads of the programme.

Q. The original ECHORD did not include RIFs, that's an innovation within the subsequent ECHORD++ project. How did that idea come up?

AK. I thought it might be a good idea to open up the gates of the universities and the research organisations to people who had not been exposed to robotics before. This was a new idea that was added together with pre-commercial procurement, which is now called the PDTI. Heaven knows what it means, we had problems with the naming (laughs).

I also thought it would be good for the researchers to get directly in touch with people, so that they could learn about the problems in the community — in society — in the neighbourhood of the robotics innovation facility. That also worked out very well.

The RIFs were intended to be pilots so it was not the case that we thought this was the ideal thing, they were experiments in themselves. We wanted to find out if such a scheme - such a measure of activity - would be accepted by the potential audience, and we can say that it was. Many people were interested in robotics, and they came.

There was a discussion in the beginning about whether it should be done in one place. The problem with robotics is that you cannot virtualise it completely, you have hardware and that has to be in a certain place.

There were questions raised by member states that they didn't get a RIF, but we had a limited budget so we had to restrict ourselves to implementing three RIFs.

Now, of course, drawing on our experience, every neighbourhood can decide if they want to set up something like this, it's all well documented and freely available.

Q. Would you say that RIFs were the predecessors of today's Digital Innovation Hubs?

AK. I would say the whole concept of Digital Innovation Hubs is very similar to what we did in ECHORD. The RIFs are one component. PDTI is also something that I think was successful, but it may take some time before the Commission takes it up and asks for more detailed insights into our experience with that particular line of activity.

Q. Right now, the Commission is focusing on Digital Innovation Hubs. What else do you think is in the future of EU funding in robotics?

AK. First of all, I think it's very important to fund robotics at large scale, with substantial amounts of money, because automation, robotics and AI are the future. Not just in production and manufacturing but also in medicine and in everything that has to do with our future society - it's at the core of the technology that society will rely on in the decades to come. So, it's very important to stay at the forefront.

I think this concept of giving money to very small enterprises should be much enlarged. This SME funding method is very helpful, particularly because robotics SMEs are always very small and they have to deal with hardware. It's a very tough business and one can only admire people who do it - they should receive a lot more support and a lot more funding. So I'd support enlarging the SME [funding] method – it's something that can be built upon in future funding rounds - because otherwise we will never cross the boundary between prototypes and real products.

ECHORD has many faces. Another aspect is tech transfer — in which we have also been very successful. Many people got to know each other and the best tech transfer is always the transfer of people, from universities to industry and the public sector.

Glossary of ECHORD terms

ECHORD: The European Clearing House for Open Robotics Development was a European Commission-funded programme. It ran from 2009-2013 and pioneered the funding of projects undertaken, jointly, by partners from academia and industry. It also developed the model of Cascading Funding (see below), later adopted by Horizon 2020.

ECHORD++: In light of its success, ECHORD was extended for a further five years and became ECHORD++. As well as further experiments, new measures to stimulate robotics' innovation transfer were introduced: Public end-user Driven Technological Innovation (PDTI) and Robotics Innovation Facilities (RIFs).

Cascading Funding: A new funding model, pioneered by ECHORD, whereby funding and responsibility for outcomes is given to a consortium (as opposed to a single research project). Cascading Funding has the objectives of lowering entry barriers for projects that apply for smaller grants and increasing autonomy for project stakeholders.

PDTI: The Public end-user Driven Technological Innovation (PDTI) scheme gives R&D consortia the resources to develop robotics technology for the needs of public bodies, such as hospital trusts and administrative authorities.

RIFs: Robotics Innovation Facilities. Labs which are open to the public and provide state-of-the-art robotic hardware and software, as well as scientific and technical support. The RIFs cover a wide range of application areas.

Digital Innovation Hubs: Widely seen as successors of RIFs, these are networks of SMEs, large and small enterprises, startups, researchers, accelerators and investors. They aim to create the best conditions for long-term business success.

ECHORD and ECHORD++ at a glance

ECHORD Runtime
01.01.2009 – 31.12.2013

51 experiments
ECHORD

243 proposals from **500** institutions

92 experiment partners
38 SMEs

ECHORD++ Runtime
01.10.2013 – 31.01.2019

32 experiments
ECHORD++

251 proposals from **639** institutions
218 SMEs

87 experiment partners
31 SMEs

7 initial partners

101 additional project partners

6 PDTI consortia
PUBLIC END-USER DRIVEN TECHNOLOGICAL INNOVATION

Over 500 proposals for funding

More than **200** project partners
100 ECHORD
108 ECHORD++

80% of funding outside the core consortium

3 Robotics Innovation Facilities (RIFs)

282 requests for funding
(PROPOSALS)

More than **170** independent experts evaluating the proposals

More than **1,000** people in academia, industry and the public sector involved

€38.8 million in EU funding
€19M ECHORD
€19.8M ECHORD++

Image: Kirill Makarov / Shutterstock

Cécile Huet (second from left) discusses the design and function of SIAR robot at IROS 2018 in Madrid

ECHORD in the European context

THE EUROPEAN COMMISSION'S CECILE HUET EXPLAINS HOW ECHORD HAS HELPED TO DEFINE THE FUTURE DIRECTION FOR ROBOTICS RESEARCH AND FUNDING IN EUROPE.

The ECHORD^{++} programme was funded by the European Commission in 2013 to consolidate and extend on the success of the original ECHORD, which ran for five years and focused on creating opportunities for robotics researchers to work directly with business, on a scale as never before.

Cécile Huet, Deputy Head of the Robotics Unit at the European Commission, was the project officer in charge of ECHORD^{++}. At the 2018 European Robotics Forum, in Tampere, Finland, she spoke to Sebastian Weisenburger about the programme's lasting legacy.

Huet began by explaining that the project's motto – 'from lab to market' – was to emphasise its role in streamlining the process of knowledge transfer. Thus ensuring that Europe's highly-esteemed robotics research was not left to languish in its laboratories. "We wanted to make sure that our economy can also benefit from this know-how, this investment we've made in research," said Huet. "And also to better understand the future needs of companies to foster further research."

To further optimise the competitiveness of the European robotics industry, the Commission resolved to boost access to European funding, as well as research and development, for small and medium-sized companies (SMEs) according to Huet.

Thus ECHORD was conceived as a test-bed for funding sub-projects via open calls, a process known as 'Cascading Funding'. "It's rare for the Commission to test funding models in this way," says Huet. "We wanted [the process] to be more attractive and agile for SMEs in particular."

ECHORD's funding process was designed to attract SMEs who may be put off by the more rigid requirements — such as the need for three project partners from different EU states — of mainstream programmes. The onus was on flexibility and a format which much better suited SMEs. "They could have a project of shorter duration and size", says Huet. "The time frame is faster, they have results more quickly and also the requirements were less."

This strategy was a resounding success. "It demonstrated the added value of having a very flexible model of redistributing the Commission's money," says Huet, "while still applying the highest possible standards in administering public funds." The model pioneered by ECHORD is now a core feature of the Commission's innovation arsenal.

There is also further, tangible evidence that ECHORD-funded projects helped to accelerate robotic innovations and delivered them to the marketplace. "We have concrete outcomes where new companies were created; where new products and prototypes were developed," said Huet.

And, in addition to Cascading Funding and the fruits of over 50 experiments, Huet counts the development of Robotics Innovation Facilities (RIFs) and the concept of Public end-user Driven Technological Innovation (PDTI) as further successes.

RIFs, she states, were "the proof of concept for the idea of developing an ecosystem around competence-centres with testing facilities." This is a programme the Commission continues to support with €500 million invested in developing what have come to be known as Digital Innovation Hubs.

Explaining the idea behind PDTI, she said: "This is basically bringing together some public authorities with common needs and then bringing the solution provider to answer to those needs. This is, again, a new avenue that we will continue exploring."

As ECHORD wrap ups, 10 years after the project was conceived, Huet is convinced that the knowledge and the networks accumulated and the networks it's established remain; the European robotics industry profits from better access to funding and an improved understanding of what research has to offer and, most importantly, innovative robotic solutions can more easily filter down to improve the lives of European citizens.

See the whole interview with Cécile Huet: youtube.com/watch?v=rEWHBhHKoAI

EXOtrainer, an exoskeleton for children affected by neuromuscular diseases

From lab to market: the Experiment Booster Programme

GETTING FROM LAB TO MARKET IS EASIER FOR SOME ROBOTICS TECHNOLOGIES THAN OTHERS. IN RECOGNITION OF THIS, AND TO SUPPORT THE PROJECTS THAT WOULD GAIN THE MOST, THE EXPERIMENT BOOSTER PROGRAMME WAS CREATED.

Societal norms, regulatory compliance and even looking too much like a human (a phenomenon known as the 'Uncanny Valley') are just some of the hurdles robotics technologies can face on the rocky road between the laboratory and the marketplace.

To tackle obstacles such as these, and provide a smoother route into the wider world for technologies that required additional support, the Experiment Booster Programme came into being. Assistance was tailored to each project, with personalised coaching and mentoring provided by industry partners.

With input from participating projects, the Booster Programme was designed by UnternehmerTUM, a leading centre for innovation and business creation at the Technical University of Munich (TUM).

Areas where support was provided included: market analysis and business plan refinement, entrepreneurship coaching, IP support and help with navigating the treacherous waters of the certification process.

Links to potential customer companies, venture capital and serial entrepreneurs, as well as market-driven incubation programmes, were all provided to assist in turning entrepreneurial visions into reality.

All the ECHORD++ experiments were invited to apply for the Booster Programme and four were selected: **EXOtrainer,** the first therapeutic, wearable gait exoskeleton for children affected by neuromuscular diseases; **MODUL**, agile, four-legged units for use by the operators of chemical facilities and power plants for inspection and surveillance; **SAGA**, which is introducing robot swarms into precision agriculture and **LINarm++**, a device to promote speedy recovery after a stroke or injury to the upper limb.

Paving the way

The four projects chosen to be supported for 10 months by the Experiment Booster Programme are among the most successful resulting from ECHORD.

EXOtrainer spin-off, Marsi Bionics gained valuable exposure to the healthcare market in Germany through its participation in the programme. Key to this was the opportunity to demonstrate the technology at industry-specific events and introductions made to influential healthcare networks and forums. This has paved the way for the project's entrance onto the European stage and beyond.

The Booster Programme also assisted Marsi Bionics in their efforts to secure venture capital investments to support their expansion strategy.

"ECHORD++ gave us the opportunity to give hope to families and kids all over the world," says Elena García, co-founder of Marsi Bionics.

The Booster worked with **MODUL** spin-off ANYbotics, to supplement the company's own efforts. It was instrumental in securing a reduction in the manufacturing cost of actuators for ANYBotics' quadruped robots, and assisted with documentation. The result was the successful transition of pre-commercial prototypes to market-ready products, reduced manufacturing costs, greater profit margins and an expanded customer base.

"ECHORD++ gave us the opportunity to give hope to families and kids all over the world."

ELENA GARCÍA, CO-FOUNDER OF MARSI BIONICS

Through the Booster, Dutch startup Avular - developer of the hardware solutions, on-board computer and navigation sensor suite for the **SAGA** project - was able to solidify its business plan and secure additional customers. Specialised in developing industrial-level drones for monitoring and inspection, the SME followed Booster recommendations to widen its target market to include mobile robotics (ground, aerial and marine vehicles). The Booster also assisted with the project's marketing and financing strategies and technical documentation and provided introductions to potential investors and customers via industry events and face-to-face meetings.

Unlike SAGA and reflecting the personalised nature of the programme, the **LINarm++** project team was told to narrow their focus. As a result, the project focus pivoted from a physical rehabilitation device (an objective which turned out to be too ambitious) to developing one of the building blocks for the device, a Series Elastic Actuator (SEA) which has a number of other medical as well as industrial applications

In order to work more closely with the Booster team, part of the project group relocated to Munich for five months. There they were given access to resources, communities and a MakerSpace in order to prepare their SEA prototype for production. Further support included help with a fresh business plan, personalised coaching, guidance on approaching investors and a stint at the XPRENEUR incubator. A near-final product, pre-sale orders, as well as redefined business and investment plans will enable them to carry the activity forward.

Commenting on his involvement in ECHORD and the Booster Programme, LINarm++ project researcher, Matteo Malosio said it was "a great occasion to collaborate with people from all over Europe in the rehabilitation field."

No fewer than seven out of 32 ECHORD++ experiments are active in the domain of agriculture and food robotics.

The GRAPE robot is designed for monitoring vineyards

Feeding the future: Agriculture 4.0

IN OCTOBER 2017 THE WORLD'S POPULATION REACHED 7.5 BILLION. BY 2100, THE UNITED NATIONS ESTIMATES IT WILL EXCEED 11 BILLION. HOW TO SUSTAINABLY FEED SUCH A LARGE POPULATION IS A MAJOR CHALLENGE. FOR THIS REASON, AGRICULTURE AND FOOD ROBOTICS FEATURED PROMINENTLY IN ECHORD++, WITH EXPERIMENTS PRODUCING SOME OUTSTANDING RESULTS.

The earth's surface is finite, so an increase of the area given over to farmland is not easily achieved. Even where this is possible, it often comes at very high cost: the destruction of natural resources. This means that a drastic increase in productivity is needed to sustain the world's population, with the introduction of technology and farming methods which would have been dismissed as science-fiction just a couple of years ago. In particular, precision farming and automation can help farmers bring yields in fields and greenhouses to impressive new levels.

Investment bank Goldman Sachs estimates that precision farming — the combination of agriculture and technology — could be a $240 billion market by 2050, with automation a key piece of the puzzle. Considering the demand for smart solutions to be brought from the lab to the farm, it's no surprise that no fewer than seven out of 31 ECHORD++ experiments are active in the domain of agriculture and food robotics.

Fuelling a paradigm shift

Award-winning **MARS** (Mobile Agricultural Robot Swarms) is a project with lofty ambitions: to fuel a paradigm shift in agriculture.

MARS uses small robots, operating in swarms, and a cloud-based solution to plan, monitor and accurately document the precise planting of corn. The twin strategies of this approach are a radical reduction in weight and size compared to conventional farming equipment and the simplification of machinery in contrast to other agricultural robot prototypes, with a particular focus on the minimal use of on-board sensors.

"These measures lead to a significant cost reduction of the overall system, paving the way towards robots as a true alternative in the agricultural domain," says MARS project partner Christian Schlegel, from Hochschule Ulm University, in Germany.

MARS swarm robots are now marketed under the name XAVER by AGCO Fendt.

A MARS system consists of some 6 -12 units. It can therefore cover a considerable amount of ground – around 1 ha/h, which is about the size of a football field. The small size and light weight of the robots not only makes maintenance easier, it also means that there is hardly any soil compaction, a common side effect of agricultural machinery. The robots also need around 70% less energy to do the same work as conventional farming equipment and produce less CO_2. Since neither diesel nor oil is required to operate them, there is no leakage and there are no local emissions.

In addition, satellite navigation and data management in the cloud allow operations to be conducted round the clock, with permanent access to all data. This ensures that not only is the position and planting time of each seed accurately recorded but new avenues for efficiency open up. Knowing exactly where the seed has been planted means that subsequent operations over the cycle, such as protecting the plant or fertilising it, can be performed precisely according to the individual plant's needs.

Schlegel's team and their industrial partner, the agricultural equipment manufacturer AGCO/Fendt, have successfully completed field tests. They are now servicing their first customers and have renamed the project XAVER.

Also working to introduce robot swarms in precision farming is **SAGA** (Swarm Robotics for Agricultural Applications). The project uses a group of drones to detect and monitor weeds in a sugar beet field. Inspired by the behaviour of bees, SAGA leverages the power of robotic group thinking to keep crops weed-free. Its other defining characteristic is cost efficiency.

"We can use low-cost robots and low-cost cameras. [Individually], they can be prone to error, but thanks to their cooperation they will be able to generate precise maps at centimetre scales," explains SAGA coordinator Vito Trianni, a researcher at the Institute of Cognitive Sciences and Technologies at the Italian National Research Council.

"The drones will initially spread over the field to inspect it at low resolution but will then decide on areas that require more focus," he adds. Importantly, the drones make these decisions themselves, as a group.

In practice, a swarm of the quadcopters is released over a sugar beet field. They stay in radio contact with each other and use algorithms learnt from the behaviour of bees to cooperatively put together a map of weeds. This allows for targeted spraying of weeds or, on organic farms, their mechanical removal.

Smarter spraying not only saves farmers money but also lowers the risk of resistance to agrichemicals. Furthermore, there are environmental benefits from spraying less herbicides.

On the business side, deploying swarms of drones for mapping crop fields can be offered as a service to farmers, while larger farm co-operatives could even buy swarms themselves. "There is no need to fly them every day over your field, so it is possible to share the technology between multiple farmers," says Trianni.

The project has also been instrumental in forging links between research and business working to a common goal: "Participation in the EU-funded ECHORD^{++} programme brought together three complementary partners on a subject that will have a great impact on how we see precision farming in some years from now," says Ramon Haken, founder of Avular BV, which specializes in drone solutions for industrial and agricultural applications and was a key partner in the SAGA experiment.

A harvest for the world

Agricultural robots are not only used for seeding and inspection, they have also entered the domain of harvesting. The first ECHORD^{++} project in this area was GAROTICS (Green Asparagus Harvesting Robotic System).

Asparagus must be selectively picked when the crop reaches the desired height, a process that favours manual harvesting in order to leave younger, smaller stalks undamaged. It's a challenging and work-intensive process, making agricultural operators vulnerable to labour supply shortages and high processing costs. In order to address this, GAROTICS built a robotic harvester, with a camera to view the asparagus dam and two harvesting tools, each with two blades, positioned to work like scissors.

"Field tests demonstrated reliable robotic selective harvesting," says researcher Holger Raffel from the University of Bremen, Germany. "We found that several harvesting tools could be mounted on the machine, which can then work in different environmental conditions, which is important bearing in mind short seasonal harvesting."

The project was able to show that, with automation, cost-effectively speeding up accurate asparagus harvesting is possible. Malte Bethke, Director, Centiv GmbH was project leader of the Garotics project at Strauss Verpackungsmaschinen GmbH. He recollects the moment the team realised they were onto something big, with the potential for commercial success:

"We had this moment when we noticed that the camera/IPP system had successfully detected up to 98% of asparagus

CATCH is harvesting cucumbers for the European market and shall be evolved to other fruits e.g. coffee.

stalks which were ready for harvesting and the harvesting tool closest to the camera managed to pick 95% of those stalks without damage."

To meet market requirements, project partner STRAUSS now wants to scale-up the prototype, from a single dam harvester to a three-dam harvester, and is seeking additional funding.

STRAUSS plans to manufacture and sell the harvesting machines through its existing channels, including licenses. It is also negotiating with a machine manufacturer from Australia who is willing to buy a prototype and to customise the harvester for the local market.

The second ECHORD++ experiment using robots for harvesting was **CATCH** (Cucumber Gathering – Green Field Experiments), which had the objective of introducing automation to cucumber harvesting.

For cucumbers, the current, predominant method entails having up to 40 workers picking the vegetable, lying on a vehicle slowly moving over the field. Gerhard Schreck of the Fraunhofer Institute for Production Systems and Design Technology (IPK), a project partner, estimates that up to 13 cucumbers per minute can harvested in this fashion. However, rising wages and a shortage of skilled labour are nudging the industry towards automation.

The CATCH solution was to harvest the cucumbers using robotic arms mounted on a harvesting vehicle. Multi-spectral cameras, able to detect light invisible to the human eye, help to direct the arms to the right place.

The team faced a number of challenges. Detecting the cucumbers is a particular issue, as they can be partially obscured by leaves of a similar colour. Compounding the problem are variable light conditions and the irregular and randomly scattered positions in which the vegetables are located.

Common to all the agricultural projects is the fact that replicating complex human tasks takes considerable ingenuity; not every job performed by robots involves repeating the same simple patterns. A further challenge specific to experiments in agricultural robotics is being able to freely choose dates for field tests, says Schreck. Instead, researchers must work around the maturity cycles of the produce.

These experiments in automating agriculture and precision farming are not only key to the overall challenge of feeding a rapidly expanding population. Often, automation can also help retain markets and can widen employment opportunities, creating new jobs and fresh, fertile ground for innovation.

Further experiments on agriculture and food robotics

The objective of the **GRAPE** (Ground Robot for vineyard Monitoring and Protection) experiment was to develop an automated robot programmed for monitoring and maintenance tasks in a vineyard. Capable of navigation on rough and sloped terrains, as well as plant detection, health monitoring and assessment of crop conditions, the robot is fitted with a dispenser to protect fruit from the grape moth, whose larvae feed on its interior.

GRAPE's contribution to precision agriculture holds the promise of less need for chemicals and thus a reduction in negative environmental impact. It will also provide wine-growers with useful data on the status of their crops.

A key part of the horticultural production industry in Europe, the technique of 'grafting' involves joining parts from two or more plants. The upper part (stem) of one plant is grown on the root system (rootstock) of another. The aim of the ECHORD++ experiment **INJEROBOTS** was to develop a flexible and universal robotic system to automate the grafting of seedlings, with industrial robot arms and machine vision used for analytics and quality control of the operating system.

Once the rootstock and stem of the plant are selected, the system transfers them to an area where two automated knives remove non-useful parts, such as the bottom of the seedling's stem and the top of the rootstock. After these are accurately severed, the robots move the stem and rootstock to a precise, common point for assembly. As a final step, the robots deposit the newly grafted plant on a fresh tray.

Grafting is especially common for the solanaceae family of plants (including tomatoes, pepper and eggplant), with more than 200 million plants grafted annually. It's also popular for the cucurbitaceae family (watermelon, melon and cucumber), which sees more than 120 million plants grafted per year.

3DSSC (3D Smart Sense and Control) addresses a real-life industrial application involving the mechanical surface treatment of variously shaped products or work pieces. A typical example, encountered in the food industry, is the removal of the coating from blocks of cheese with a shaving or planing tool.

The robot starts from a predefined point, moving over the unknown surface area of a workpiece. It adapts the height and orientation of its tool to the shape of the surface. This process, called on-line surface tracking, has a large variety of applications which also include grinding, polishing and cleaning. The technology dispenses with the need to produce a 3D model of the workpiece before the surface can be processed, as scanning and manipulation are carried out simultaneously.

AAWSBE can distinguish between standard and rechargeable batteries

Robots in the wasteland

WHO DOESN'T KNOW WALL-E (AN ACRONYM THAT STANDS FOR WASTE ALLOCATION LOAD LIFTER – EARTH-CLASS)? IN THE 2008 MOVIE OF THE SAME NAME, THE GARBAGE-COLLECTING ROBOT IS THE LAST SURVIVOR ON EARTH, FINDING TREASURE IN TRASH. DURING THE PAST 10 YEARS NEW WASTE HANDLING ROBOTS HAVE BEEN SPRINGING UP IN EUROPEAN WASTELANDS. THEY MIGHT JUST BE WALL-ES-IN-WAITING.

In Europe, there is a drive to improve garbage handling methods to prevent household trash and other municipal waste from ending up in landfill sites. Due, in part, to environmental policies, recycling rates throughout the continent have increased markedly over the past decade. Recent statistics show that in 2014 EU countries recycled 36% of waste*.

As a matter of course, people have been shifting rubbish for millennia and could, in theory, continue to carry out all types of recycling, says David Peck, professor in critical materials and circular cities at Delft University of Technology. But these are not necessarily jobs to wish on people. "This is dirty, dangerous and difficult work," he says.

Meanwhile, the mountains of rubbish we produce continue to increase, with EU inhabitants generating 4.9 tonnes of waste each in 2014*. Also growing is a belief that it's technology that can help further boost recycling rates and divert valuable resources away from landfill; companies are coming around to the view that more sophisticated sorting technology has a role to play in bringing our waste crisis under control.

Robotic waste sorting systems combine computer vision, machine learning and manipulation with arms synchronised to sort and grasp recycled materials from moving conveyor belts. Hazardous materials are already often handled by semi-autonomous robots which clear up toxic sludge, dangerous barrels of chemicals, and more.

Two ECHORD++ experiments have homed in on the areas of waste and recycling.

The goal of the **AAWSBE1** (Adaptive Automated WEEE Sorting 1: Battery Extraction) experiment has been to sort the batteries found inside Waste Electrical and Electronic Equipment (WEEE), by detecting items that potentially contain batteries.

Objectives include working at realistic waste densities – a step change from current technologies that rely on identifying and picking isolated items. Developed by the Danish Technological Institute (DTI), the system also aims to be cost-effective and runs on real-world WEEE mixtures obtained from end-user partner Refind Technologies. It's also being designed to work with either manual or robot sorting stations, alone or integrated into a smart factory, with promising results.

"We have succeeded in integrating deep learning software within the framework of DTI Vision Box 2.0, so it runs smoothly in live situations," says Rasmus Johansson from project partner, Refind Technologies. "This means that it is now possible for the robot to detect objects even though they overlap."

A step or two away from recycling is dealing with nuclear waste. Nuclear waste facilities, many of which were created as far back as 50 years ago, are now being reconsidered, with many countries believing they can pose a safety and environmental risk. The challenge in decommissioning nuclear waste is sorting it according to its radioactivity levels and compressibility, in order to achieve efficient storage in safer, more modern facilities.

Decommissioning is a complex and expensive process. It's also the scope of the **RadioRoSo** (Radioactive waste Robotic Sorter) experiment, which seeks to demonstrate that this job may be done by robots autonomously, much more quickly and at significantly lower cost.

The RadioRoSo consortium is leveraging state-of-the-art machine vision, robotic manipulation and grasping to solve this real-world task. It has achieved some impressive results demonstrating unseen object and garment grasping, with significant cost reduction due to the speed of the system.

The project received interest from the Slovakian research institute, ZTS VVU Kosice, and the team is in discussion with UK project partner NES on future products and/or services.

Negotiating challenging new environments and dealing with the dirtiest of tasks doesn't deter these systems. From deep learning robots to gripping technology that breaks new ground – these innovative companies and research institutions are designing the future of the waste industry.

* https://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics

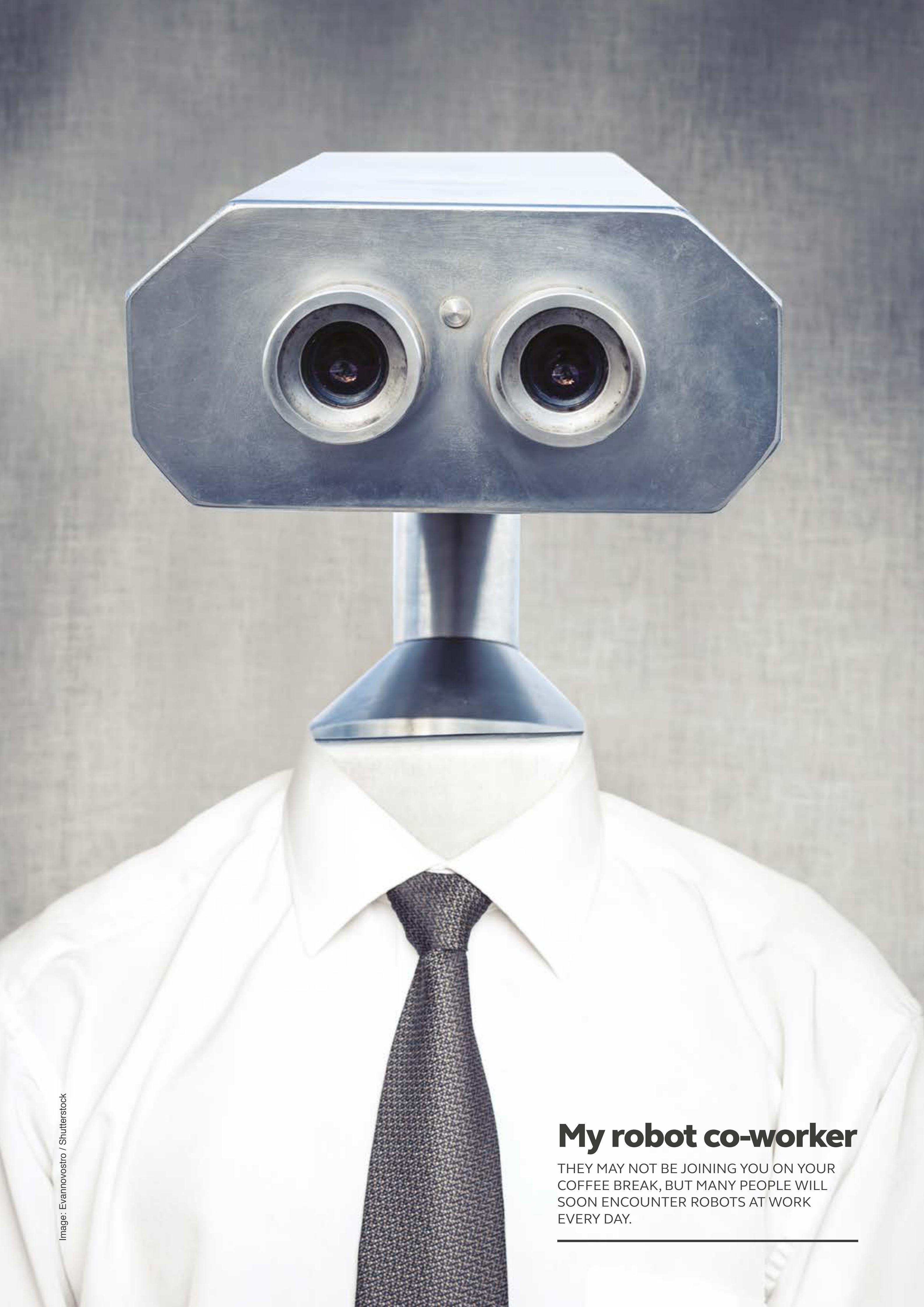


Image: Evannovostro / Shutterstock

My robot co-worker

THEY MAY NOT BE JOINING YOU ON YOUR COFFEE BREAK, BUT MANY PEOPLE WILL SOON ENCOUNTER ROBOTS AT WORK EVERY DAY.

Safe, user-friendly cobots are being developed to assist humans in tasks where heavy labour is involved or in situations where they can counteract vocational disability, health or accident risk.

These are not the massive industrial machines that have to be guarded behind fences, but co-workers made out of silicon and steel. Cobots, short for collaborative robots, are about to enter the workspace, combining advanced capabilities in human-robot-interaction with novel safety features.

Three ECHORD++ experiments serve to illustrate the large variety of applications that already exist in collaborative robotics and their enormous potential within the factories of the future.

TIREBOT

An incredible number – over 330 million tyres – for cars, trucks and other vehicles, need to be replaced every year in Europe alone. Tyre servicing requires workers to manually handle and transport the wheels, from a car lift to a wheel balancer or other apparatus, and then back to the vehicle. These manual operations are time consuming, tiring and in other ways detrimental to the health of the handler. Consequently, there is room for much improvement in tyre processing efficiency and working conditions.

TIREBOT was an experiment to introduce robots in tyre workshops to improve the processing process, with partners including the ARSControl Lab of the University of Modena and Reggio Emilia and CORGHI S.p.A., a leading producer of equipment for wheel servicing. The goal of the experiment was to develop a mobile robot assistant to transport wheels between car lifts, tyre changers and wheel balancers, thereby helping the operator to handle the task.

The original aim was to use the robot predominantly in garages but, as the project progressed, the use-case changed. “Our starting point was the work done in ECHORD++,” says Gabriele Finelli, product manager at CORGHI.

Based on the results of the ECHORD++ experiment, CORGHI and its affiliate HPA were able to develop a marketable solution. In Spring, 2017, Italian car manufacturer Lamborghini had it installed in its newly built factory.

The TIREBOT robot’s task appears straightforward: when a car arrives at the point where the tyres need to be fitted, the robot leaves its charging station, picks up two wheels from a nearby box and brings them to a worker positioned at the left side of the car, where they are fitted. The robot repeats the process for the right-hand side of the car before it returns to the charging station.

“It may sound simple, however, handing over this task to a robotic assistant has two major advantages,” Finelli explains. Firstly, it saves time which the worker can spend on other tasks while waiting for the tyres. Secondly, they no longer need to carry heavy tyres, which helps to improve working conditions.

So far, Finelli and his team are happy with the first robot installed at Lamborghini. There is also the potential to sell the system to other car manufacturers. Having successfully completed the journey from lab to the market, TIREBOT is motoring towards a bright future.

2F

The construction industry is replete with hazardous and time-consuming tasks. The Flooring Fellow (2F) experiment seeks to dispense with two of them. It’s a co-working robot developed specifically for two floor-building functions: grout removal and acid washing.

After a floor is tiled, excess grout has to be removed,

2F ‘Flooring Fellow’ robot

SAPARO safety system

a task which is currently done either by hand – with workers cleaning the floor with brushes and sponges – or necessitating heavy equipment which needs to be operated manually. The connecting cables of these machines often present latent safety risks, as tripping hazards or because of the dangerous combination of electric cables and wet floors.

2F is a mobile, cable-free robot equipped with a sponges and water containers. The robot is placed on the floor that needs treating and, using the walls as a guide, it explores the space and constructs a map. It then autonomously plans a path and proceeds to clean the floor. Its visual quality control system allows it to detect unclean spots and it’s programmed to repeat the process until any excess grout has been completely removed.

The system is powered by a replaceable lithium battery, avoiding the use of heavy power cables.

“ECHORD++ allowed us to realize and demonstrate – in less than two years – a working prototype of a robot starting from scratch, and gave us the opportunity to explore new markets for robotics,” says Giancarlo Teti, R&D Manager with 2F partner ROBOTECH srl.

Further development is needed, but, says Teti, it’s already evident that the use of 2F can positively impact the flooring construction working cycle. 2F can decrease the risk of construction workers suffering an electric shock and also exposes them to less noise and vibration than current machinery. It has the potential to reduce total labour time needed for floor building, allowing workers to focus on tasks more important than cleaning.

SAPARO

Safety is of utmost importance in human-robot collaboration, especially in industrial applications where high payload robots are involved.

Building on the results of previous projects, the partners in the SAPARO experiment developed a novel solution to safeguard collaborative human-robot workplaces. The result of the experiment is a pressure-sensitive, tactile floor, able to detect the position of a human worker. A key aspect is a projection system to visualise safety-relevant information – the dynamic boundaries of the safety zones – through the use of appropriate colours.

In contrast to other fenceless safeguarding technologies with static safety zones, such as laser scanners and camera-based workspace monitoring, the SAPARO safety system provides a dynamic zone based on the current joint positions of humans and robots. It can also be adjusted to account for the velocity of a robot, thus offering a maximum of free space to the user at any time. As this system allows for co-existence and collaboration between humans and robots, it acts as a baseline technology and can be used with other systems to allow for a deeper level of cooperation.

SAPARO is already in use. Its first buyers, in academia, have installed the system on their lab floors to bolster further applied research in human-robot-collaboration.

The CLARC robot accompanies the patient through the diagnostic process

Robots, because we care

ROBOTICS, AI AND KNOWLEDGE SHARING ARE DRIVING A REVOLUTION IN HEALTHCARE. AN AGING POPULATION AND A SHORTAGE OF CARE WORKERS MEAN THAT THESE ECHORD PROJECTS MEET A CLEAR AND OUTSTANDING NEED.

According to World Health Organization estimates, if current trends continue, the global needs-based shortage of health-care workers is projected to exceed 14 million by 2030. Demographic changes in many countries, together with improved procedures leading to better outcomes, mean that healthcare systems are coming under increasing pressure as they strive to cater to an aging population. The application of technology, including robotics, is generally seen as part of the solution.

Robotics is transforming healthcare. Robots can be used to help people who are ill or injured, and to support caregivers. They can assist in surgical procedures and diagnosis, dispense medicine, provide rehabilitation and movement therapy and help people to remain independent for longer, reducing the need for hospitalisation and care homes.

The United Nations has estimated that by 2050 one out of every five people will be over 60 years old. With its focus on the elderly, Comprehensive Geriatric Assessment (CGA) is a standard method to evaluate a range of data and create a personalised plan for treatment and follow-up. However, its interdisciplinary nature means that it can be time-consuming as well as expensive. A typical CGA session takes about three hours of a clinician's time and delegating many standardised tasks to a robot would allow clinicians to focus on activities with more added value. In addition, the transparency and objectivity of the assessment is improved.

Selected as the focus of an ECHORD^{++} PDTI (Public end user Driven Technological Innovation) programme in healthcare, CGA was the focus of two prototypes.

Project Manager, Jean Patrick Mathieu, at the Agency for Health Quality and Assessment of Catalonia (AQuAS), explains just what makes these projects invaluable:

"A team of multidisciplinary experts define the rules of competitive and collaborative processes that challenge industrial and academic partners to step up their game and be innovators using robotics technologies. This is the kind of project that makes European funding programmes so worthwhile for Europe."

The first prototype, **ASSESSTRONIC,** focuses on improving user experience through the use of natural interfaces – such as voice, touch or gesture – and fine-tuning diagnosis through multi-modal analysis. For optimum cost-effectiveness, the project also leverages existing technologies (such as cameras, Kinect systems, standard computers and tablets).

> **"This is the kind of project that makes European funding programmes so worthwhile for Europe."**
> JEAN PATRICK MATHIEU, AQUAS

Project coordinator, Dr. Consuelo Granata, believes that involvement in ECHORD^{++} provided the team with the necessary boost they needed to make their project a success: "The multidisciplinary team that leads and manages this project gave us the support and the motivation to match the research advances in robotics with the manufacturing industry's ability to translate the innovations into real, saleable products. This is all we needed to progress and to finalise our system."

With a focus on direct engagement with end users and clinical professionals, the second prototype in this arena, **CLARC** (Smart Clinic Assistant Root for CGA), is centred on the development of a mobile robot to greet patients and help their physicians capture and manage CGA data.

The robot is fitted with a touch panel, microphone and RGB-D sensors, allowing it to collect data safely, automatically and without the need for supervision (although it can ask the clinician for help, if needed). For instance, while performing a 'Barthel' test, CLARC offers the patient an external device to help him or her answer questions. Its abilities significantly reduce total times for CGA sessions and increase the quality and quantity of the data collected.

The team has translated insights gained from user studies into design decisions and is working to further develop the interface and implement new functionality, with the goal of testing the latest CLARC prototype in hospital settings.

Robots for rehabilitation

Neurological conditions, particularly strokes, are a major cause of disability among older people. Approximately 75% of stroke sufferers survive for a year or longer after a stroke, a proportion which is expected to increase, but most suffer some form of reduced mobility. Rehabilitation and assistive robotics can potentially improve their recovery and/or support

> **The experiment originates from a clear need to improve the efficacy of at least 20 different surgical procedures.**

them in everyday tasks. However, many of these robots are large and immobile. The work of converting their complex mechanical design into a compact system for home-based post-stroke therapy, without loss of performance, is the subject of the **HOMEREHAB** project.

HOMEREHAB's tele-rehabilitation robotic system supports rehabilitation therapies in three dimensions and features an adaptive controller to optimise patient recovery and smart monitoring of the patient's physiological state.

Another experiment focused on rehabilitation is **KERAAL** (Kinesiotherapy and rehabilitation for Assisted Ambient Living). Alleviating lower back pain – a leading cause of disablement among the elderly – is the objective. Musculoskeletal conditions, in particular, require joint mobility, increased muscle force and coordination. Utilising Poppy, an open source, 3D printed robot, the experiment has developed a robot coach capable of demonstrating rehabilitation exercises to patients and providing feedback and encouragement to improve performance.

Poppy performs exercises with the patient and, via a depth sensor, can judge whether the movement has been carried out correctly, advising them on how they can improve. The robot was successfully demonstrated at the Innorobo conference in 2017 and is currently in clinical trials, enabling the team to gather a larger data set from real-world users.

Bytes and bits to replace blood and guts

"The future of surgery is not about blood and guts, it's about bytes and bits," believes Dr. Alexander Mottrie, a leading expert in robotic surgery.

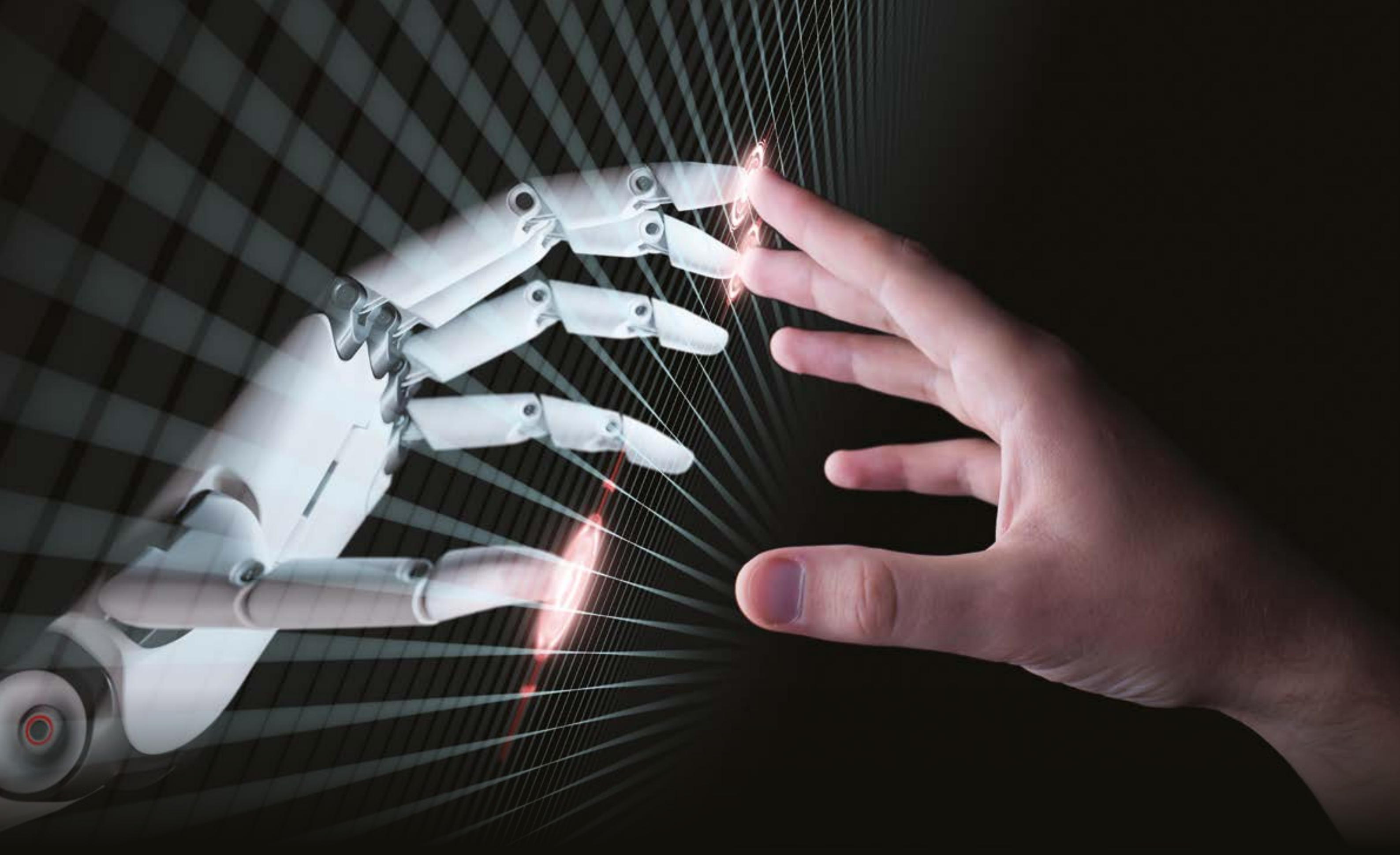
With attractions that include bringing down the cost of healthcare, eliminating human error, reducing operating time and freeing-up staff, the global market in tele-operated surgical robots has grown rapidly in the last five years.

Many common procedures are suitable for robotic surgery, including laser-based corneal transplantation. **LA-ROSES** (Laser Assisted Robotic Surgery of the anterior Eye Segment) is an experiment to develop a vision guided robotic platform for the process. The experiment originates from a clear need to improve the efficacy of at least 20 different surgical procedures, including the suturing of the cornea endothelium, which is impossible to seal using other surgical techniques.

Trials have demonstrated that laser welding of the cornea is preferable to needles and stitches, with a reduction in inflammation and recovery time. Nevertheless, it is a tricky process, requiring great manual dexterity. The surgeon has to accurately align and move the laser, keeping the correct orientation and distance in order to focus the beam onto the wound.

The experiment consortium estimates an increase in procedure precision and efficacy of around 100-150%. The knowledge acquired in this project will have an impact on several industrial projects using a robot for positioning medical devices. Application areas include neurosurgery, urology, spinal surgery and eye surgery.

In March 2016, LA-ROSES received an award from the Giovanni and Annamaria Cottino Foundation and the team are working with Italian Venture Capitalists Innogest SGR.



Industry 4.0 – a buzzword full of robots?

FLEXIBLE PRODUCTION PROCESSES AND INTERCONNECTIVITY ARE AT THE HEART OF THE DIGITAL TRANSFORMATION IN MANUFACTURING.

Industry 4.0., the digitisation of manufacturing, is being driven by the astonishing rise in data volumes, computational power and connectivity. This combines with increased pressure on manufacturers: to improve productivity and lower costs, while providing consumers with the customised products they expect.

PricewaterhouseCoopers International forecasts that the shift to digitisation will increase global GDP by as much as 14 percent by 2030. According to Deloitte, hybrid ‘smart’ factories – where people, machines, systems, software and devices work together – are the future of manufacturing and Industry 4.0.

Europe must move fast to avoid being left behind in the race to introduce digital technologies. Challenges, including complex legacy systems and huge volumes of data, must be addressed. Five ECHORD^{++} funded projects have set out to pave the way.

Used in the manufacture of agricultural machines, cars and other vehicles, many of today’s robotics systems are cost- and time-intensive. They require expertise in programming before they can be applied in tasks such as welding, grinding or varnishing.

Enter **CoHRoS**, a project to develop a practical and robust method for assistive teaching, enabling a robot to learn and generalise after just a few demonstrations by the programmer.

The goal of **DexBuddy**, meanwhile, was to reduce customisation costs in industrial automation through the development of a flexible gripping device and intuitive programming. Usability was at the centre of the experiment, enabling the collaboration of robots and human workers.

Shadow Robot’s dexterous hand was used in combination with the ArtiMinds’s software prototype and KIT vision systems, which were integrated by experts from industrial equipment supplier, Loccioni.

Among the finishing operations for die casting – a manufacturing process for moulding light alloys, such as aluminium – is deburring. The process removes any metal residue or raised edges. The DEBUR experiment set out to design an automated platform for the laser deburring of complex, 3D parts. Flexibility, low maintenance and low environmental impact were key considerations. DEBUR team member Carlos Soriano welcomed the opportunities ECHORD^{++} presented: “ECHORD^{++} is a project where all the important partners in Europe are on board,” he said.

Humans have two arms for good reason. But today’s most popular collaborative robots feature only one. This is because the process of designing optimal joint configuration is challenging. So this was the objective of **DUALARMWORKER**, a system for flexible industrial component assembly. The project planned to remedy the lack of accessible software in this area.

Wiring components is tedious, manual work. ECHORD^{++} project **WIRES** developed a robotic system to autonomously wire the switchgears that protect electrical equipment. The robot’s custom gripper is agile enough to deal with thin gauge wiring. Guided by 3D vision, it has tactile sensors and a three-axis screw driver holder. The WIRES team estimates that it can reduce wiring time by 40 percent.

Industrial partner IEMA is currently working to introduce the WIRES system into its production lines. The project team has applied to patent the technology and is expecting to spin out and to explore further applications.

Image: maxuser / Shutterstock

What is PDTI?

ITS NAME DOESN'T TRIP OFF THE TONGUE, BUT THIS ECHORD++ SCHEME GAVE R&D CONSORTIA THE OPPORTUNITY TO DEVELOP ROBOTICS TECHNOLOGY TAILORED TO THE NEEDS OF PUBLIC BODIES. ECHORD'S MARIE-LUISE NEITZ AND FEDERICA PEPPONI EXPLAIN PDTI.

FEDERICA PEPPONI

MARIE-LUISE NEITZ

What do you call a device that provides public bodies, hospital trusts and other administrative offices with cutting-edge technology specific to their requirements and – at the same time – allows researchers and developers to experiment in the wild? PDTI, which stands for Public end-user Driven Technological Innovation, is the name ECHORD came up with.

It's an unwieldy title for a what is, essentially, a very workable solution, with lower entry barriers than the key European Commission-supported innovation tools PPI (Public Procurement of Innovation) and PCP (Pre-Commercial Procurement). Forming an important part of ECHORD's legacy, PDTI has potential to make a significant economic impact, given that public procurement currently accounts for an estimated 17-19% of EU gross domestic product.

Unique to ECHORD++, the PDTI scheme considered six potential application areas, identifying two: healthcare and urban robotics. Experts then selected a challenge for each application: geriatric assessment in healthcare, and inspection and clearance of sewers in urban robotics. Both projects were located in the Spanish region of Catalonia. R&D consortia were invited to submit proposals addressing these challenges. Three projects were chosen and two progressed to phase 2.

Project Manager Marie-Luise Neitz, Chair of Robotics and Embedded Systems at TUM, and Project Management Assistant, Federica Pepponi, share some insights gleaned from the PDTI process.

Q. What are the benefits of the PDTI scheme for public bodies?

FP. The main benefit for a public body involved in this process is the possibility to shape the final solution based on its own specifications and needs. For example, sewer networks tend to be very distinctive and every city has its own, so it would be very difficult to find a general product on the market. In PDTI, adaptation is not needed because the technological solution is developed to satisfy specific requests from the public body and, eventually, extended to other environments.

MLN. Public institutions have slowly realised that they need to get involved in the technology development process in order to get a product that will serve their needs. So while the technology development teams get an idea of how public authorities assess and evaluate technology, the public authorities get an idea of the shortcomings and obstacles, technology-wise, from the teams. If it's done well, the public authorities are potential ambassadors for the technology in the future.

Q. How did you decide on the challenges that needed to be addressed and the development teams?

MLN. It was a decision by the members of the core consortium to select healthcare and urban robotics, because there is huge market potential in both areas. Then we contacted public authorities in different countries, to encourage them to submit proposals sharing their challenges with us. These were evaluated and a selection was made by a panel of independent experts.

FP. There were almost 20 challenges submitted focused on different aspects of urban robotics, from urban transportation to maintenance and inspection issues and providing information to citizens.

MLN. We had a panel meeting where the proposals were discussed and evaluated. Based on this, the selection of the challenges was made. The two public authorities submitting the successful challenges became part of our consortium and we then shaped the open call to look for development teams. We collected proposals, these were again assessed and evaluated by independent experts.

Q. Aside from funding the projects, what role did the ECHORD++ core consortia play?

FP. We provided a support structure for the public body, helping them shape their requirements and managing the open call and selection of the team. For the teams, we provided support, legal and administrative guidance at every stage. They went through a process of mentoring and expert coaching, allowing them to refine their contributions.

MLN. During the process, the focus of the coaching changed. In the beginning it was more about technology development, later it evolved to include experts with a business background, to facilitate the commercialisation of the product.

Q. Now that ECHORD is wrapping up, what will happen to the PDTI projects?

MLN. The sewer teams are considering a proposal for PPI, to bridge the last gap. In addition, they all have potential customers on board. In Barcelona, the service provider for the owner of the sewer is interested in adopting the technology to partly replace manual inspection. Now we are linking the development teams with other city authorities and potential investors (also using the newly funded DIH network) in order to scale the impact and facilitate commercialisation.

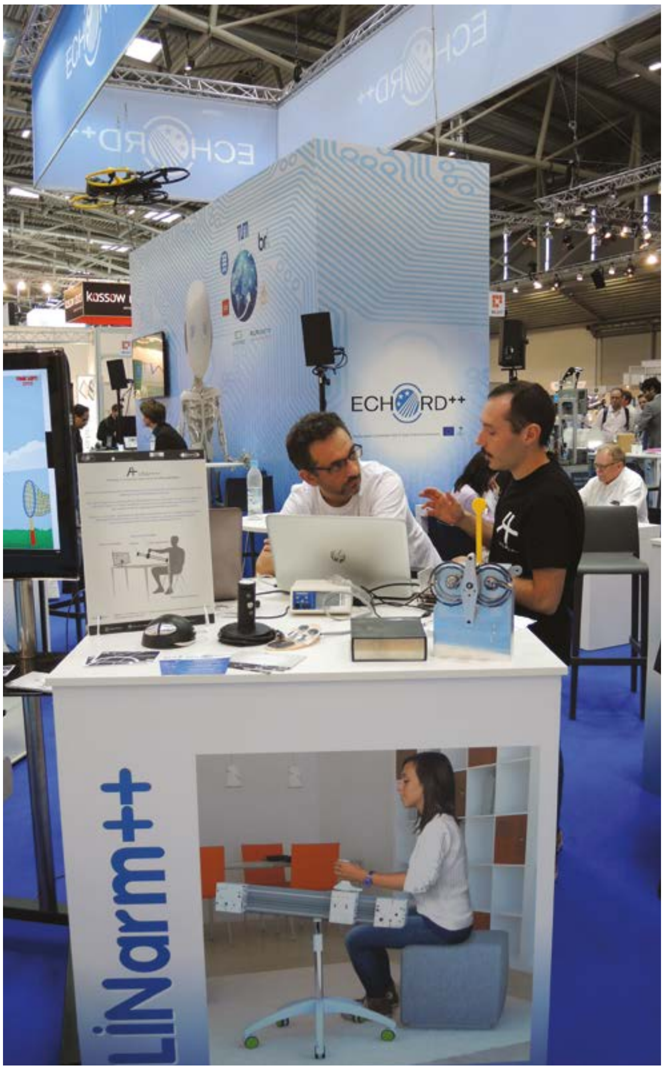
FP. The healthcare teams are still finishing their final phase. They're testing in facilities other than the [original] hospital and they've found other potential customers – hospitals, but also care facilities and retirement homes, not just in Spain but also in France.

Q. The original aim was to bridge the gap between industry and academia. Did the PDTI achieve this aim?

FP. The teams are at the stage where they have a prototype that works. They now need to streamline and industrialise the design. Details need to be sharpened before they can reach market.

MLN. The CLARC team was very satisfied with the way the PDTI was done and with the support they got, even though we made their lives very difficult. I think Assesstronic has a really good chance of making it, and that wouldn't have been possible without the PDTI. The European Commission also gains from our experience. They can use it in any kind of collaboration with the public sector. The fact that you really have to make sure you have all the stakeholders on board, when you shape the process at the beginning, is probably the most important thing. And that the authority using the technology is well aligned with the organisation procuring, they aren't necessarily the same.

To present the newly developed prototypes ECHORD++ participated in many events and fairs all over Europe, pictured here at AUTOMATICA in Munich



Science isn't finished until it's communicated

AN INDUSTRY STANDARD STILL OFTEN REGARDED AS AN ANNOYING TASK IN SCIENCE IS EFFECTIVE PUBLIC RELATIONS.

Showcasing projects at AUTOMATICA 2018, in Munich

No successful company refrains from presenting itself and its products attractively to the general public. It's through the triangle of marketing, public relations (PR) and sales that developed products find their way to the customer. Yet, the need to explain a solution, to 'sell it' and prove its efficacy to the consumer often provokes a frown in science. "Public relations? What is that good for?" is a question that scientists often ask when confronted with the subject. At best, public relations is viewed as an annoying duty, which is demanded by funding agencies, but regarded as a distraction from the 'actual' scientific work.

As ECHORD^{++} project managers, naturally, we have a different view of the topic, based on our motto 'from lab to market'. Successfully combining research and development with public relations is core to what we do. The outreach and communications on ECHORD^{++} are inextricably linked to scientific work. This is in accord with the opinion of the UK Government's Chief Scientific Adviser, Sir Mark Walport, who famously stated: "Science is not finished until it's communicated."

The success of our approach is impressive. ECHORD^{++} was, and still is, present on all media channels. It has its own website, social media and video channels. Experiments have been featured in numerous newspapers, magazines, radio, television and, of course, on the internet. In addition, there are the tens of thousands of stakeholders we have reached via workshops, conferences, trade fairs and other events.

This success came not by chance but was the product of a clear strategy and hard work. Since the beginning of the project, we have always defined our target groups and the channels through which we wanted to reach them. This strategy includes clear definition of the messages we want to send to the various stakeholders, the right timing and accurate measures of success. In the course of the project, we repeatedly adapted this strategy to reflect the different project stages and to maintain channels of communication.

In a project such as ECHORD^{++}, with 110 partners involved, there is a tendency for communication to become centralised. Therefore, the beneficiaries of Cascading Funding have been obliged to participate in outreach and dissemination of their activities. To successfully bring the prototypes they've developed under the umbrella of ECHORD^{++} to the market, their work must be well prepared and accompanied by clear communication. A good reflection in the media can lead to many potential customers, even in the developmental phase of a project, and can later facilitate the actual launch of the fully-developed product.

As diverse as the structures of our project partners is their existing experience with PR and their available capacity for it. Some are large companies with their own PR departments supporting the research and development teams in the best possible way. At the other extreme are small and medium-sized enterprises in which an employee may have to take responsibility for several different areas, so that there is little time left over for PR activities.

Multiplying the effect

In order to meet these diverse needs and to equip all project partners for successful PR, we, as ECHORD^{++} project managers, have invested a great deal in consulting with partners. Our main goal was to enable them to successfully carry out their own PR activities, thereby multiplying our own efforts.

In particular, with the support of a professional PR consultant, we organised joint workshops with project partners to inspire them about the potential of public relations. At the same time, we analysed each project from the point of view of PR, defining target groups and developing compulsory PR plans together with the consortia, which could then be implemented by them. In addition, we organised booths at major industrial fairs and thus offered the partners a platform to showcase their work to a broad audience. In this way, even small institutions have been presented with the opportunity to appear at trade fairs which would otherwise have been closed to them because of the organisational and financial efforts involved.

Feedback from project teams demonstrates that this approach produced very good results.

"The support received during the intermediate reviews by E++ team was fruitful," relays a member of the LINarm team, Matteo Malosio. "Suggestions given during the kick-off-meeting, among which was also how to manage public relations, were interesting. Support received during the preparation of exhibitions (e.g. Automatica) was important."

The success of our strategy in multiplying our efforts is also reflected in the statistics. Of the hundreds of media reports on ECHORD^{++}, more than half came from initiatives by experiment consortia and PDTI partners. In addition, ECHORD^{++} increased its visibility through the websites and social media channels of individual partners, as well as through their active participation in workshops, conferences and trade fairs (where it would otherwise not have been present).

This work-intensive exchange with project partners has paid off handsomely. However, our experience shows that no plan and no workshop can replace the personal investment of the partners involved. Where communication is connected to scientific work, it is more successful. When this is the case, tips and suggestions fall on fertile ground and lead to joint success for the core consortium and the beneficiaries of Cascading Funding.

It has been our goal to create enthusiasm for successful communication among even more project partners and to provide concrete examples of how research and development and PR can mutually reinforce each other.

What is CE marking and what is it good for?

A CE MARK GIVES A COMPANY EASIER ACCESS TO THE EUROPEAN MARKET, ENSURING ITS PRODUCTS CAN BE SOLD IN ANY MEMBER STATE. FOR SOME MEDICAL EXPERIMENTS WITHIN ECHORD^{++}, CE MARKING IS A PRE-REQUISITE FOR COMMERCIAL SUCCESS.

> **"The intensive and very hard work we faced during real trials with patients was compensated by the enormous satisfaction of seeing a smile on the face of a kid staring at his feet while walking for the first time."**
>
> DR. ELENA GARCÍA, CO-FOUNDER, MARSI BIONICS

When people say 'CE marking' it's not unusual for puzzled looks to be followed by questions such as: "How do we do that, who does that and what does it mean?"

The letters 'CE' are the abbreviation of French phrase 'Conformité Européene'. So to put it simply, CE marking is a declaration from the manufacturer that a product complies with all relevant EU Directives.

With a CE mark, a product meets the minimum legal requirements which allow it to be legally sold, without the need for adaptation or rechecking, in any European member state. This also applies to the European Economic Area which contains Iceland, Liechtenstein, and Norway. According to the European Commission, the total value of the European market for medical devices is currently around €110 billion.

A CE mark also corresponds with almost 90% of the requirements of the United States' health administrator, the FDA. It thus opens the possibilities of access to the huge north American market.

For many medical devices sold within Europe, CE marking is a mandatory requirement. Custom-made devices and those intended for clinical investigation are excluded. A 'medical device' means any instrument, apparatus, appliance or software, used for diagnostic or therapeutic processes. Several ECHORD^{++} projects came under this umbrella.

The process for attaining CE marking is rigorous. The product team must: identify the EU requirements that are applicable; check these requirements against the product; check whether the product must be tested by a notified body; test the product; compile a technical dossier and, finally, affix the CE marking and draft a declaration of conformity.

The process takes between six to 24 months; the amount of time needed depends on how much is known about the requirements the product must meet. Under the current system, CE certificates are generally valid for three years, but status is dependent on maintaining quality system certification.

Knocking on Europe's door

Undeterred by all of these, two ECHORD^{++} projects have now completed the CE certification process.

The first of these is **EXOtrainer**, a therapeutic, wearable gait exoskeleton for children affected by neuromuscular diseases, particularly the genetic condition Spinal Muscular Atrophy (SMA).

The project led to a spin-off, Marsi Bionics. The company applied for a H2020 grant to support them in completing the CE certification process and in developing a Europe-wide marketing strategy. The product underwent European clinical trials and attained CE marking, ensuring it the best possible chance of success in the European market.

Although it was a tough process, Marsi Bionics co-founder, Dr. Elena García, who was part of the original EXOtrainer scheme, says the gains were extremely worthwhile.

"The intensive and very hard work we faced during real trials with patients was compensated by the enormous satisfaction of seeing a smile on the face of a kid staring at his feet while walking for the first time. The transfer to market and society of this project's results are a reality thanks to ECHORD^{++}."

The project's clinical partner, the Hospital Sant Joan de Déu, in Barcelona, Spain, has installed the exoskeleton, as part of its rehabilitation service for SMA-afflicted children.

Marsi Bionics is now planning to make exoskeletons that are suitable for sufferers of different diseases. The team has obtained funding for a new version for sufferers of Duchenne Muscular Dystrophy, the most frequent neuromuscular disease in childhood.

The second project to receive CE certification is **MOTORE++**, a portable robot for the rehabilitation of the upper limbs after a stroke. The aim was to build the first robot small enough to be easily carried and so suitable for in-home rehabilitation.

The prototype was further developed, tested in home-based rehabilitation sessions and attained CE certification. At least six units have been sold.

"Starting from 2019 we'll be in the European market to propose an improved version of the MOTORE system," says Andrea Scoglio, owner of Humanware, a developer of assistive technology, which formed part of the project consortia, together with Scuola Superiore Sant'Anna in Italy.

"Literally, ECHORD^{++} helped us to go from the lab to the market," added project researcher, Giovanni Cappiello.

The MAX-ES experiment developed navigation software for delivery robots

Faster, stronger, safer – robots in logistics

IN LOGISTICS, AN IRRESISTIBLE CONFLUENCE OF RISING CUSTOMER EXPECTATIONS AND LACK OF LABOUR IS LEADING COMPANIES TO INVESTIGATE ALTERNATIVE SOLUTIONS. ECHORD++ HAS FUNDED PROJECTS THAT ARE READY TO FULFIL THEIR NEEDS.

Logistics is the biggest growth area in the service robotics sector and accounts for more than half its overall market. International Federation of Robotics (IFR) figures indicate that 2016 sales in logistics saw an increase of more than 30 percent over the preceding year.

However, distribution networks across the global supply chain, require a high volume of varied and complicated tasks. This presents challenges for automation, which is easiest and cheapest to implement where there are easy and repetitive tasks.

Recent advances in reducing the engineering effort needed to teach a robot what to do are now making it possible to develop systems that integrate with existing technology, teams and warehouses, which is key to bringing service robotics into the world of logistics. In order to speed this along, ECHORD++ has funded projects to develop safe, flexible and inexpensive logistics systems, with outstanding results.

Commonly used in logistics, laser guided vehicles (LGVs) have a rotating system to detect the position of mirrors installed in the operational area. The triangular set-up of the mirrors enables the LGV to fix its position and establish the distance to be covered. However, in the past, safety considerations have meant that, in order to operate safely, emergency stops were executed to avoid collisions.

The **SAFERUN** experiment developed unique technology that reacts autonomously, even to unexpected events, thus optimising safety without compromising productivity. Designed to account for the needs of existing plants, as well as new ones, SAFERUN's navigation system allows the vehicles to operate alongside human coworkers.

The project is a collaboration between the University of Parma, the Elettric80 company – a world-renowned producer of LGVs – and the PreGel company, which provided a warehouse to test the novel navigation system. Outcomes were so promising that Elettic80 decided to implement the SAFERUN prototype system in all its new plants.

The project team also credits ECHORD++ with attracting external technical feedback which was adopted and further enhanced performance.

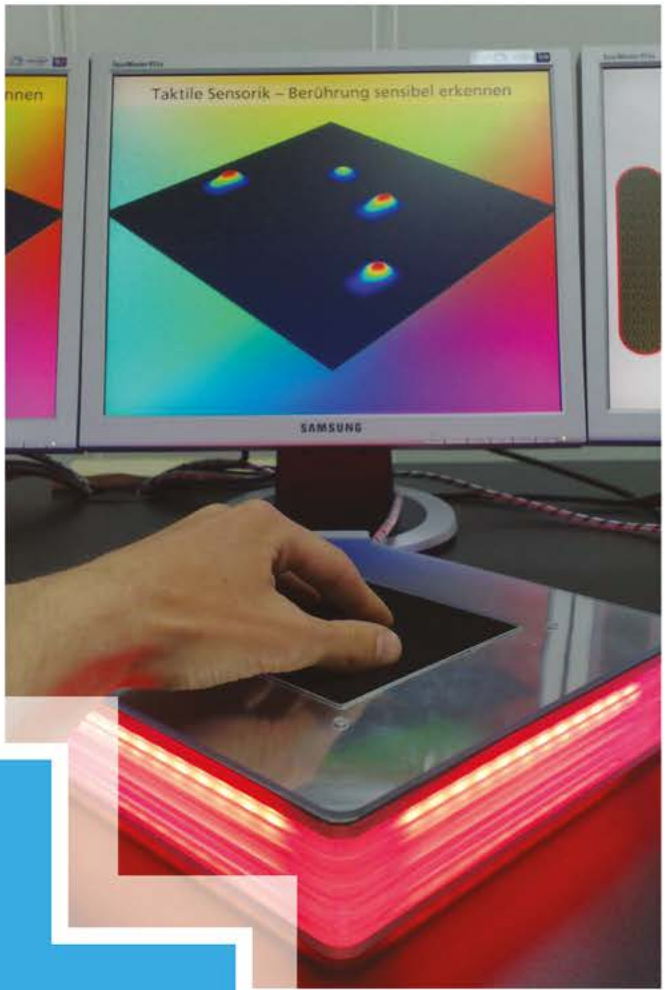
Also having the objective of integrating fully autonomous vehicles into an existing industrial plant, **MAX-ES** was an experiment to develop navigation software for delivery robots. Challenges included the design of safe and robust navigation suitable for delivering heavy loads that is also safe for use around people in indoor or outdoor operations.

The MAX-ES software has no need for guiding infrastructures and uses existing road networks, alongside other vehicles and pedestrians.

Suitable for use on the factory floor, **FASTKIT** is an automated goods-to-person picking technology. The experiment centred on a mobile Cable Driven Parallel Robot (CDPR) with the objective of developing a system that is simple to integrate into existing infrastructures and capable of covering large areas. The result was a reconfigurable, lightweight and robust system, offering much more flexibility than existing solutions and with low investment cost.

FASTKIT is also highly versatile and so ideal for the needs of the automotive and aeronautics industries, where kit preparation requires highly-specific algorithms and manipulators.

The project team have now patented the technology and, with interest from industrial partners running high, are working on a proposal to further develop the original project and expand its areas of application.



With its high quality equipment and fittings PICKIT is one of the most versatile robots

How robots understand the world around them

WE HUMANS HAVE TWO EYES TO CONVERT LIGHT INTO ELECTRICAL SIGNALS WHICH ARE SENT DOWN OUR OPTIC NERVES AND ARE IMMEDIATELY PROCESSED BY OUR BRAIN. WE BACK THIS UP WITH AUDITORY AND OLFACTORY DATA FROM OUR EARS AND NOSE. BUT WHAT ABOUT ROBOTS? DO THEY NEED EYES, EARS, AND NOSES – OR CAN THEY BE EQUIPPED TO SENSE THE WORLD IN BETTER WAYS THAN HUMANS?

Transport it to an unknown environment and a robot must work quickly to build up a representation of the world it finds itself in. Its operating system can draw up a basic map of the immediate environment which tallies with features its software is programmed to look for. It must collect the relevant information, form an understanding of the world around it and, finally, act accordingly. These are vital functions for robots across multiple applications and thus worthy objectives for three groundbreaking ECHORD experiments.

At present, there are hardly any are general-purpose robots. Most robots are task-specific, designed to do one job and repeat it over and over again. A common task is locating a part in free space, within an unstructured environment where the parts keep shifting position every time something is removed, from a bin for instance. This calls for a delicate balance between robotic dexterity, machine vision, software, computing power and the ability to crunch all that data in real time, together with a grasping solution to extract the parts from the bin. A tall order, but not impossible.

Existing systems' shortcomings

Picking single parts out of a bin is usually the work of technology that combines vision sensors, grippers and software for image processing and process planning, enabling a robot to execute the gripping process automatically.

Bin-picking technology has become more reliable in recent years and is now available in a variety of products. Complicated programs and tricky interfaces are becoming a thing of the past; 'easy to use', 'versatile' and 'human-friendly' are today's buzzwords.

But there are still obstacles to overcome. Objects with challenging surfaces that cannot be processed in a reliable manner, due to inadequate optical sensor input, for example. This means that the position of the gripped object can't be effectively monitored and controlled. These are the challenges that the **PICKIT** experiment seeks to address, enabling a commercially available vision-based, bin-picking system to handle a variety of objects.

A tactile gripper, PICKIT integrates with all leading brands of robot. A 3D camera and software detect parts' positions, even in poor visibility and when items overlap or come in varying sizes and materials.

A tactile gripper, PICKIT integrates with all leading brands of robot. A 3D camera and software detect parts' positions, even in poor visibility and when items overlap or come in varying sizes and materials, thus overcoming the shortcomings of current bin-picking systems.

While systems are now more capable than ever, robotic bin picking still holds challenges. The PICKIT team plan to ramp up their work in this area and follow up with another EU-funded project, PICKPLACE, as well as ProTaktilUS, which will be funded by Germany's Fraunhofer Institute.

A 'pick & place' application following a similar approach, but with a focus on rigid and deformable objects, the aim of the **FlexSight** experiment was to build a prototype smart camera – the compact FlexSight Sensor (FSS) – which can be integrated in the chassis of an existing robot, empowering it with detection and localisation capabilities. The goal is to enable a robot to perceive a large and widespread class of rigid and deformable objects in an accurate and reliable way, with a particular emphasis on the system's computational speed.

The team are currently in the final stages of launching a startup and are integrating their FSS within a working system and testing it in various industrial and logistic use cases.

Better than human

A major advantage that robots have over humans is that they can easily share what they have learned. This not only applies to new technology but to extending the purpose of systems that already exist. For example, the **CoCoMaps** experiment uses an expanded version of the existing Cognitive Map Architecture which is implemented on Honda's ASIMO robot. The architecture is being put to use in an environment with tasks of greater complexity than those that have already been attempted. Thus giving the robot the ability to interact in more complex ways. In particular, enabling it to interact with another robot and with more than one person at a time.

The project is aiming for effective interaction between a group: two robots and two humans. Such a system will enable social cooperation in a robot-human team while the system attends to (and completes) practical tasks in the workplace.

The experiment has already achieved impressive results, as CoCoMaps team member Thor List explains: "Just over 12 months into the project we got the two robots running together for the first time. Seeing how they collaborated in real-time, both in terms of search area coverage and when speaking to the humans at the scene, was an amazing moment."

Their experiment also offers unexpected insights. "We had a daughter of one of the researchers present and she interacted completely naturally with the robots – and so did the robots back," Thor List recollects. "Adults are much less natural when speaking to robots which, in turn, makes the interaction less fluent."

CoCoMaps places particular emphasis on human detection, tracking algorithms and an improved dialogue system. The technical term for what the team is seeking to achieve is task-oriented coordination of multi-party task completion.

Both the project's partners are now busy commercialising the technology developed and combined during the project. One partner, IIIM, is planning to use it for their multi-human/multi-robot communication system and the second, CMLabs, is working with partners in Israel and France on commercial use of the project's Psyclone platform.

Between them, powered by advanced vision technology software and innovative gripping solutions, these three pioneering ECHORD experiments are making crucial strides to enable robots to find their way in unchartered territories.

The SIAR robot has completed initial trials in Barcelona's sewers

ANYmal is a multitasking robot for hazardous environments

To boldly go...

... WHERE NO ROBOT HAS GONE BEFORE AND WHERE HUMANS WOULD BE UNWISE TO TREAD. THINK SEWAGE PIPES FILLED WITH ACRID HUMAN WASTE, VOLCANIC FISSURES AND DEEP FORESTS. THESE ROBUST, MOBILE MACHINES WERE CREATED TO DO THE JOBS THAT ARE TOO DANGEROUS FOR US TO DO.

It's cold and dark. The terrain is pock-marked and uneven and there's no air to breathe. No problem. Whether it's fighting fires, stepping on things that may explode or exploring sewers, robots feel no pain and have no need for food or oxygen. These qualities and successful collaborations between research and industry have enabled these ECHORD^{++} experiments to penetrate depths impossible for humans, with outstanding results.

Introducing robots to hazardous and unpleasant tasks, such as sewer inspections, not only mitigates the risky and unhealthy conditions humans have been forced to endure, it makes economic sense. For sewer maintenance, less water is needed for the cleaning process and, with robots designed specifically for the task, less machinery too. In addition, robots are potentially faster and more accurate.

As part of the ECHORD^{++} Urban Robotics PDTI (Public end-user Driven Technological Innovation) project, the city of Barcelona opened up its 1,500 km sewer network as a use-case and test site. The aim was to develop a robotics solution to determine the state of the sewers and identify segments where functionality was compromised, either through erosion or structural defect. Sewer monitoring and collecting samples of water, air and sediments were additional requirements.

A sewer network is characterised by wide, underground waste-lined pipelines and galleries. The ground can be irregular and littered with obstacles, making automated collection of data a complex task. But not for **ARSI** (Aerial Robot for Sewer Inspection), the first of the projects selected for the task. Equipped with multiple sensors to monitor water and air quality, a 3D camera to calculate its position and a laser to detect walls and calculate flight paths in real time, ARSI can avoid many of the obstacles that impede the operability of terrestrial vehicles. It can move fast through the sewer network and requires simple logistics in deployment and operation. It's small and agile to deal with pipeline sections that can be less than 100cm wide.

The second project to brave Barcelona's waste network is **SIAR** (Sewer Inspection Autonomous Robot). A fully autonomous ground robot, it offers the option of manual control when required.

SIAR has recently received substantial media interest (being featured by the BBC and ZDNET), following the robot's appearance at the Automatica 2018 tradeshow. Project partner IDMind aims to continue the development process using its robot platform RaposaNG. Objectives include a more robust robot frame, increased power autonomy and more flexible inspection capabilities, together with improved communication, autonomous navigation and inspection capabilities.

Rather them than us

Creating a robot to help responders and save human life during a disaster is challenging work. Vehicles with wheels and tracks have met with limited success. Obstacles, including stairs strewn with rubble, are a feature of the unstructured environments these robots must traverse. Two ECHORD projects are prominent among a new generation of all-terrain vehicles. With legs – instead of wheels and tracks – demonstrating superior mobility on rough terrain.

For sewer maintenance, less water is needed for the cleaning process and, with robots designed specifically for the task, less machinery too.

Developed to support rescue activities and perform other tasks in hazardous and dirty environments, the **HyQ-REAL** four-legged robot can run, jump or walk over rough terrain, indoors and out.

HyQ-REAL was designed by the Istituto Italiano di Tecnologia (IIT), working with MOOG, known for its high-performance actuation systems for aerospace and motorsport. The focus of the project was to improve on a previous prototype and develop control algorithms for self-righting and intelligent teleoperation and equip the robot with highly-reliable and efficient hydraulic actuators. Work continues to perfect the system, with the robot now set to receive an important update in the form of a battery-powered hydraulic system, which will give it power autonomy and allow it to run untethered.

Envisaged for use by the operators of chemical facilities and power plants for inspection and surveillance, but also in search and rescue missions in disaster areas, ECHORD project **MODUL** (Modular Drive Units for Legged Locomotion) was also developed to deal with rough terrain and harsh environments. The project's leaders, from Swiss University ETH Zurich, designed modular, four-legged, energy-efficient units for speedy, multi-purpose transport. Simple to use, maintain and upgrade, the system operates with a high relative payload (50% of its body weight).

"The ECHORD++ project was the starting point for our business. With the mature prototypes we had at the end, we could acquire significant other funding to launch our company."

PROF. DR. MARCO HUTTER, ETH ZURICH

A further focus was modular actuation to propel wheeled or tracked systems, as well as those with legs.

The project garnered much interest and led to further funding for the consortium (from Wyss Zurich, Horizon 2020, ESA Business Incubation Centre, Switzerland, the NCCR Robotics Spin Fund and directly from industry), as well resulting in a patent (EP16181251).

"The ECHORD++ project was the starting point for our business," says Prof. Dr. Marco Hutter, Department of Mechanical and Process Engineering, Institute of Robotics and Intelligent Systems, ETH Zurich. "With the mature prototypes we had at the end, we could acquire significant other funding to launch our company. In just the first year we were able to sell a number of drives and a quadrupedal robot. Moreover, we secured new projects with industry and academia."

The direct descendants of MODUL are an impressive quadrupedal robot named ANYmal and the system's core component, ANYdrive, an integrated modular robotic joint actuator.

ANYmal's ability to navigate and move dynamically in challenging terrain was first demonstrated in 2016, during the ARGOS challenge, organised by the French oil and gas group Total, where the robot successfully completed numerous advanced autonomous surveillance and intervention tasks on a replica industrial platform.

A multi-purpose system, its four legs allow the robot to crawl, walk, run, dance, jump, climb, carry… whatever the task requires. It's equally at home on natural terrain, engaged in search and rescue tasks, or even on a stage providing entertainment.

Meanwhile, the ANYdrive component guarantees precise, low-impedance torque control and high-impact robustness, together with safe interaction. The actuator allows a structure, such as a robot arm or leg, to be attached without additional bearings, encoders or power electronics.

ANYmal and ANYdrive are now being distributed and further developed by ETH spin-off ANYbotics. Several units of both products have been sold and the system was crowned winner of the ICRA 2018 Robot Launch competition.

ANYbotics is also engaged in various pilot programs with end-users, in diverse sectors including industrial inspection, forestry, surveillance, sewers and mines. The company continues to commercialise the technology and to use it as the basis for further research at ETH Zurich.

"We can combine the best teams and technology Europe has to offer and that would probably not be available on a national level. This is the key success of European projects," says Francisco Giraldez Gamez, Robotics Solutions Engineer at ANYbotics.

From RIFs to Digital Innovation Hubs

THE EUROPEAN COMMISSION IS WORKING TO ESTABLISH A DIGITAL INNOVATION HUB IN EVERY REGION OF EUROPE. ECHORD'S ROBOTIC INNOVATION FACILITIES WILL PROVIDE THE TEMPLATE.

Free access to high-tech robotic equipment and expertise at zero risk is an attractive proposition for companies - large and small. Having opened up their laboratories to industry, the three Robotics Innovation Facilities (RIFs) established by ECHORD^{++} provide this and more. Established as collaborative test beds for academia to successfully interact with enterprise, they're now sharing their knowledge, resources and infrastructures as a prototype for a new, European Commission-funded vehicle, the Digital Innovation Hub.

When ECHORD^{++} funding ends in January 2019 the three established RIFs - in France (Paris), Italy (Peccioli) and the UK (Bristol) - will continue as self-sustainable collaborative networks, but will also feed their knowledge into Digital Innovation Hubs, with the goal of creating the best conditions for long-term business success.

Financed to the tune of €500 million in the Commission's innovation programme, Horizon 2020, Digital Innovation Hubs are a sector-wide initiative to provide companies – especially small and medium enterprises (SMEs) – with access to technology-testing, financing advice, market intelligence and networking opportunities.

According to Cécile Huet, Deputy Head of the Robotics Unit at the European Commission and project officer in charge of ECHORD^{++}, a pan-European network of Digital Innovation Hubs is the ideal vehicle to transport the fruits of R&D to business. So that "every single company can benefit from the digital transformation".

By making the Hubs accessible to companies – having one in every region – the Commission aims to provide industry with "the knowledge and the right experience to integrate these results into their projects and businesses," says Huet.

Best Practice

At the heart of both RIFs and Digital Innovation Hubs are competence centres resourced by highly-qualified researchers, associated with research institutions and empowered to undertake strategic research for the benefit of industry.

"[ECHORD] started to develop this concept of building an ecosystem around competence centres: bringing know-how, integrators and users together, so that they can develop together," says Huet. "It's a precursor of the concept."

Digital Innovation Hubs will expand on the RIF concept by creating a one-stop-shop – whether physical or virtual – for businesses to access support in understanding digital technologies and prepare to invest for digital transformation.

Commission survey data suggests that around 60% of large industries and 90% of SMEs feel they lag behind when it

The Peccioli RIF

comes to digital innovation. In addition, there are strong digitalisation discrepancies between industrial sectors, as well as regional differences.

Current demand for digitisation from SMEs in traditional sectors is limited, partly, it’s suggested, because of insufficient awareness about its potential transformative role.

The idea is for the Hub to create awareness about digitalisation in each region, to connect research to business development and build an innovation ecosystem. They should combine manufacturing and product development with shared infrastructure and expertise.

Hubs will be able to provide information about finance for digitisation programmes, access to benchmarked products and services, as well as skilled personnel to assist in their use. Open source, electronic diagnosis tools (upgraded to pan-European level) will help to assess needs and develop a tailor-made package to suit each challenge or to link the user with network partners who can help in providing solutions.

However, much needs to be done, including integrating the existing network of competence centres into Digital Innovation Hubs; developing collaborative funding models combining funds from international and national sources; and designing well-defined business plans for the Hubs and digitisation programs for SMEs.

Lessons learned

Having already made many business dreams a reality, paving the way for their products and systems to enter the marketplace, the RIFs have accumulated valuable tools, networks and knowledge of best practices to assist in developing a Hub network.

“Apart from the technological legacy, when ECHORD^{++} ends, it’s the network that will survive - so [there are] new contacts, new collaborations and a lot of new knowledge that we will leave,” said ECHORD^{++} Project Manager Marie-Luise Neitz, Chair of Robotics and Embedded Systems at TUM.

Competence centres are being integrated within existing organisations, with structures and processes for technology transfer already in place. The ECHORD^{++} experience suggests that allowances must be made for this. It also suggests that Digital Innovation Hubs will benefit from an agile approach to management in order to best adapt to customers.

Adaptability is key as Hubs will vary in their level of maturity, their history, cultural challenges, customer types and regional business ecosystems, says Neitz. She also advocates trust, time and stability, with dedicated resources and face-to-face meetings; common values and rules and clearly defined targets, with a focus on the meta-level where synergies can be identified and exploited.

The MekaMon robot by Reach Robotics
IMAGE: Reach Robotics

Success stories from the RIFs

ECHORD'S ROBOTICS INNOVATION FACILITIES (RIFS) PROVIDE A SUPERHIGHWAY TO AUTOMATION FOR COMPANIES LARGE AND SMALL.

During the past couple of years Silas Adekunle has had the kind of big breaks most startup founders only dream of: a $10 million funding raise, a place on the Forbes 30 Under 30 in Technology list and an exclusive distribution deal with Apple for his $300 platform combining robotics, gaming and AR.

But in 2014, when he first stepped into the newly-opened Robotics Innovation Facility (RIF) in Bristol, UK, success was by no means certain.

"Starting a company like this is quite difficult, especially when you're selling to consumers," says the 26-year-old Adekunle. He credits the RIF with not only introducing him to one of his co-founders, Chris Beck, but also for providing valuable manufacturing contacts, prototyping facilities and software development for their new startup, **Reach Robotics**. "Having access to the prototyping environment and facilities really helped us," he says, "because in business you have to iterate fast and learn fast, time is not your friend."

The facilities, market validation and tailored support provided were, he says, key to enabling Reach Robotics to pitch to potential investors and take the company to the next stage.

Lack of testing facilities has been identified as one of robotics' major handicaps, particularly for small and medium enterprises (SMEs) and startups, like Reach Robotics, who can't afford to pay to test systems or products. To remedy this, three RIFs were established by ECHORD^{++}, with free access to state-of-the-art robotics technology, hardware and software expertise, legal advice and more. Their success stories in testing out new automation ideas and helping businesses develop innovative technology are numerous, but here is a small selection.

RIF Bristol, UK

Reach Robotics is far from the only success in the Bristol RIF's book. Housed in its own facility, adjacent to Bristol Robotics Laboratory (BRL), the UK's largest academic centre for multi-disciplinary robotics research, the RIF has completed 43 projects since 2015, and provided support to 26 SMEs, five startups, seven educational organisations and four large enterprises.

One of these is **Numatic International**, a cleaning equipment manufacturer which employs 900 people. Over an extended period, the RIF helped Numatic pilot and embed robotic assembly automation of the popular Henry vacuum cleaner, as well as imparting knowledge of the process. A particular focus was the use of collaborative robots, or cobots.

The effect has been to increase production capacity, improve consistency and quality, as well as reduce costs, thus sustaining the company's global competitive advantage. The commercial return on the initial investment was realised in less than six months. Altogether, the investment resulted in a cost saving of about 25%, and Numatic is planning staged introduction of automation to further processes, with modular, scalable systems.


The Peccioli RIF specialises in creatively engineered artificial hands


The Bristol RIF was instrumental in the design of Neha Chaudhry's Walk to Beat robotic aid

Aimed at minimising freezing and gait problems experienced by Parkinson's disease patients, Walk to Beat is a student-driven spin-off that has developed a unique walking stick, after approaching the Bristol RIF for help with design, prototyping and testing. The product launched in 2017. Without the support of the RIF, Walk to Beat would not have been able to build a prototype as the company had no engineering expertise.

Focused on nuclear fuel cycle activities, Orano provides robotics' modelling, simulation and electronics development for the energy and medical radiological research fields. It partners with the Paris RIF to develop teleoperation for computer-aided robotics, simulations for train operators, and radiation-tolerant electronics.

In collaboration with the Peccioli RIF, SME Geostech developed an internet of things solution to locate objects and people, with applications in personal security and vehicle maintenance. Geostech is planning further RIF collaboration.

RIF Paris, France

The Paris RIF is located 20km southwest of the French capital, at the Interactive Robotics Laboratory (IRL), on the premises of technological research institute, CEA LIST.

Since 2015, the RIF has completed 21 projects, with 90% in the manufacturing sector. After the initial advice, prototyping and testing phases are completed, the RIF passes users onto its project partners, who support the company in transforming their prototype into a commercial application.

ISYBOT, a project to develop cobots, has become a spinoff as a result of the assistance it received from the RIF. Developed by the IRL, the startup's cobots use a type of patented actuator technology that does not require force sensors, resulting in robots that are accurate and safe, as well as simple to use and lightweight. They can operate autonomously or as assistive devices to reduce the risk of repetitive-strain injury.

The RIF was instrumental in helping to develop and validate the technology and to demonstrate applications in several fields. The result of the project is a robot, SYB3, that has been on the market since March 2018. ISYBOT now employs a dozen people and counts the French rail company, SNCF and Dassault Aviation among its customers.

A producer of prefabricated kits for kitchens and bathrooms, **WM88** was aided by the RIF in automating parts of its production line. An SME with 150 employees, WM88 received help in understanding how robotics could be used in developing and benchmarking prototypes.

RIF Peccioli, Italy

The Tuscan town of Peccioli is the home of Italy's RIF, which is within the BioRobotics Institute of renowned Italian University, Scuola Superiore Sant'Anna (SSSA). Unlike the other two RIFs, Peccioli has no employed researchers, instead, projects are carried out by PhD and post-doctoral students and researchers from SSSA. The RIF also operates in conjunction with SSSA spinoff, TechnoDeal, which helps to finance projects and identifies opportunities.

The RIF has hosted two projects with defined problems to be solved, but where it excels is in its ability to create spinoffs. Since 2015, 10 startups have grown out of experiments and problem-solving undertaken at the facility, after the potential for commercialisation became apparent.

For instance, during the course of an experiment with an underwater robot, researchers identified the need for a tool to provide a smooth, waterproof finish, a process that uses plastic and cellulose acetate and does not exist on the market today. Offering considerable time-savings, the researchers realised that this process could be valuable to other industry sectors – such as eye-glass manufacturing companies – which use 3D printing in their production processes. A spinoff, **3DNexTech**, was formed. The RIF provided market analysis, business plan development and IP creation, with TechnoDeal assisting 3DNextech to secure financing from a business angel and additional regional funding. The product is now due to launch.

Demonstrating its ability to provide rapid prototyping assistance for SMEs, the RIF assisted KW, a cold-storage solutions provider for the biomedical, scientific research, and industrial sectors. The company approached the RIF when it encountered difficulties in meeting the EU regulations for a blood plasma product. The RIF assisted in helping KW to develop SMART freezing equipment, together with software and electronics. After validation at a hospital in northern Italy, the company has now received the necessary certification to use its product to store blood plasma.

Happily ever after

HOW SUCCESSFUL WAS ECHORD IN BOOSTING THE LONG-TERM EFFECTS OF RESEARCH FUNDING?

Europe has a very strong robotics industry, world-class research and technological knowledge – spread throughout the continent. However, studies have identified a disconnect between its manufacturers and the research community, especially when it comes to setting the future direction of robotics research – a fundamental for optimal success within the booming, global robotics marketplace.

To remedy this, between 2009-2013, the European Commission funded ECHORD, a project to pioneer a unique, new approach, one which involved major interaction and exchange of ideas between academia and industry. The goal was to meet the ever-changing demands of industry, on the one hand, and fulfil the problem-solving drive of research on the other.

Using this as a base, the two main concepts of ECHORD – experiments and 'structured dialogue' – were designed to super-boost collaboration between academia and industry.

Information gathering and consensus finding between all stakeholders was behind the idea of structured dialogue, with a view to identifying upcoming robotics trends, enabling Europe to emerge as a trendsetter in the robotics sector.

Experiments, meanwhile, were designed as small-scale, funded projects, which saw researchers and manufacturers collaborate on specific, concrete challenges – using state-of-the-art equipment provided by a manufacturer. They were geared towards enabling development of robots, components, networks and systems; and to demonstrate feasibility in a real-world setting.

A submission process that was straightforward and streamlined, with minimum bureaucracy, was designed to be attractive to those proposing experiments. Evaluation was quick and negotiation rapid.

Funding of €300,000 per experiment, from a budget of approximately €25 million (and a runtime of 12 to 18 months) made it feasible to tackle some of the robotics industry's burning technology needs.

ECHORD adopted an experimental policy of funding sub projects via open calls, known as 'Cascading Funding', to ensure that the scientific community was able to take control of its own destiny. Projects were assessed by international experts.

From around 250 initial proposals, 51 experiments were selected. Mixed consortia made up of academic research labs and potential industrial users often resulted in collaborations lasting beyond the funding period, an ECHORD objective.

In the case of the **MODUL** experiment, a collaboration between Swiss university ETH Zurich and Greek SME CDD M.E.P.E., to produce a torque controllable robot joint, a spin-off company with eight employees was founded and is now working on a four-legged robot for inspection and transport.

Another project, **SAPARO**, saw the partners, research institute Fraunhofer IFF and robot-safety experts from automation technology company, Pilz, collaborate on developing a tactile floor, able to visualise safety zones. The project already has its first customers in academic institutions and potential for further commercialisation is said to be high.

Meanwhile, **MARS** (Mobile Agricultural Robot Swarms) was a very fruitful collaboration between the German university of applied sciences, Hochschule Ulm and the multi-billion-euro agricultural equipment manufacturer, AGCO Fendt, with the goal of building cloud-controlled robot swarms for planting corn. The team is now servicing customers.

The MARS project in field trials

SAPARO safety system

ECHORD enabled researchers to use industrial-level equipment for their experiments, encouraged researchers and manufacturers to identify and work together on emerging technology scenarios and to disseminate the knowledge and progress gained to the wider robotics community, a unique and ground-breaking approach for European robotics. These activities are well-documented.

Impact analysis also revealed unexpected outcomes, such as the large amount of media interest in many of the projects, and the fact that open source technology was produced by 50 percent of academic partners. There is evidence that job creation and economic growth has been a consequence of the project.

ECHORD facilitated the introduction of robotics technology into industry in more than 50 cases and innovated the funding procedure of the European Commission itself. The project can be regarded as the pilot for the funding model introduced within Horizon 2020.

The novel structure of ECHORD also provides a blueprint for future EU projects – tapping untold potential and application possibilities and defining the future direction of robotics research.

Follow up project ECHORD^{++} consolidated on the success of its predecessor. Probably the most application-oriented EU-funded robotics research project ever attempted, it introduced PDTI (Public end-user Driven Technological Innovation) and RIFs (Robotics Innovation Facilities), bringing robotics technology from lab to market.

As a whole, ECHORD has gathered a wealth of experience, developed structures, systems and best practice standards that can be utilised in myriad areas. Thus, while the project's impact is already immense, it will continue to shape the robotics community for many years to come.

ECHORD^{++} Core Consortium

Technical University of Munich

The Robotics, Artificial Intelligence and Embedded Systems Group at the Department of Informatics, Technische Universität München (TUM) is the coordinator of the ECHORD and ECHORD^{++} project. The group is chaired by Professor Alois Knoll.

www.i6.in.tum.de

brl Bristol Robotics Laboratory

Bristol Robotics Laboratory (BRL) is the largest multi-disciplinary robotics facility in the UK. BRL, led by Professor Chris Melhuish, is a partnership between the University of Bristol and the University of the West of England.

www.brl.ac.uk

Sant'Anna School of Advanced Studies – Pisa

The Biorobotics Institute at Scuola Superiore Sant'Anna (SSSA) in Pisa, Italy, conducts theoretical and experimental research in biorobotics. The Director of the BioRobotics Institute is Professor Paolo Dario.

www.sssup.it

cea

The robotics lab within the French Atomic Energy Commission (CEA) develops robots and haptic devices, working in close collaboration with humans. Dr. Christophe Leroux is business manager for ICT and health applications there.

www-list.cea.fr/en/

UPC Universitat Politècnica de Catalunya

The Institut de Robòtica i Informàtica Industrial (IRI) is a Joint Research Institute of the Universitat Politècnica de Catalunya (UPC) and the Spanish Scientific Research Council (CSIC). Professor Alberto Sanfeliu is Scientific Director at IRI's Unit of Excellence Maria Maeztu.

www.iri.upc.edu

Blue Ocean Robotics - for humans

Blue Ocean Robotics (BOR) develops and deploys new, innovative, early-stage robotic solutions for a wide range of business segments. Claus Risager is a director and partner at the company.

www.blue-ocean-robotics.com

RURobots Cognitive Science at Work

R U Robots Limited is an independent, advanced robotics company, providing custom solutions for a range of clients. Geoff Pegman is its Managing Director.

www.rurobots.co.uk

TechnoDeal

TechnoDeal Srl is a spin-off company of SSSA. It offers consulting and management services and an international network well versed in technical, scientific and economic issues.

www.technodeal.eu

I would like to take this opportunity to thank the ECHORD team for being very professional, hard-working and tenacious. Without their ongoing efforts, the huge success of ECHORD and ECHORD^{++} could not have been achieved! It was my pleasure to lead the team, even though at times it was challenging. Over the course of the 10 years of the project, all of the team members, with their individual areas of expertise, contributed and did an absolutely fantastic job. We all learned a lot, both the Commission and the robot community, and hopefully these newly-won insights can be used to further enhance and strengthen the European robotics industry and research community.
We are looking forward to the next adventure!

PROF. DR. ALOIS KNOLL

Project partners

ECHORD++ CORE CONSORTIUM:

Technical University of Munich (TUM)
Bristol Robotics Laboratory (BRL)
Universitat Politècnica de Catalunya (UPC)
Blue Ocean Robotics (BOR)
Scola Superiore Sant'Anna Pisa (SSSA)
Commissariat et aux Énergies Alternatives (CEA)
R U Robots (RUR)
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Universite Pierre et Marie Curie (UPMC)

See contact information on http://echord.eu/experiment-partners/

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AGCO GmbH
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PreGel SpA
Refind technologies
RioTinto
RoboTech Srl
Robotnik SLL
ROBOX motion control
Scape Technologies A/S
Shadow Robot Company Ltd.
Stena Recycling
Strauss Verpackungsmaschinen GmbH
Vitirover SAS

Events and fairs

2013

Oct 22 2013: **ECHORD++ Kick-Off-Meeting in Paris**
Nov 20 2013: **Smart City Expo in Barcelona**

2014

Jan 13 2014: **H 2020 Infoday in Luxembourg**
Jan 22 2014: **Robotics in Horizon 2020 in London**
Feb 10 2014: **PCP Concertation Meeting in Brussels**
Feb 11 2014: **Infoday in Pontedera**
Feb 21 2014: **Barcelona Living Lab in Barcelona**
Mar 7 2014: **Evolution - Development - Innovation in Peccioli**
Mar 12 2014: **European Robotics Forum (ERF) in Rovereto**
Apr 11 2014: **Industrial technologies in Athens**
May 26 2014: **RoboBusiness in Billund**
Jun 1 2014: **IEEE International Conference on Robotics and Automation (ICRA) 2014 in Hong Kong**
June 3 2014: **Automatica in Munich**
Jun 14 2014: **Science & Technology Party in Barcelona**
Jun 18 2014: **I4MS in Berlin**
Jul 15 2014: **IAS13 in Padova**
Sep 24 2014: **Japan Academia Industry in Munich**
Oct 9 2014: **ICT Proposers Day in Florence**
Oct 23 2014: **Info Day in Bristol**
Oct 24 2014: **Info Day RIF Bristol**
Oct 28 2014: **fortiss Munich**
Nov 12 2014: **Medica in Düsseldorf**
Nov 18 2014: **Smart City Expo in Barcelona**
Nov 26 2014: **RIF Opening in Bristol**
Dec 3 2014: **Market consultation day – PCP Pilot in healthcare in Munich**

2015

Jan 14 2015: **RIF Opening in Paris-Sarclay**
Feb 9 2015: **RIF Opening in Peccioli**
Apr 27 2015: **RoboBusiness in Milan**
Aug 26 2015: **BBC Panorama in Bristol**
Sep 8 2015: **Smart Agriculture Conference in Birmingham**
Sep 29 2015: **Venture Fest Wales in Cardiff**
Sep 30 2015: **FT Future of Manufacturing in London**
Oct 2 2015: **IROS in Hamburg**
Nov 17 2015: **Smart City World Congress & Expo in Barcelona**
Nov 18 2015: **euRobotics Brokerage Day in Brussels**

2016

Feb 24 2016: **SME Day (FET) in Bristol**
Mar 2 2016: **ESTnet Awards 2016 in Cardiff**
Mar 3 2016: **Intro to Robot in Bristol**
Mar 11 2016: **British Science Week in UK**
Mar 16 2016: **Venture FEST East Midlands in Leicester**

2016 (continued)

Apr 11 2016: **bauma in Munich**
Apr 15 2016: **MOD Presentation in Filton**
Apr 25 2015: **Hannovermesse**
May 18 2016: **Glos Business Show in Cheltenham**
May 24 2016: **Innorobo 2016 in Paris**
Jun 1 2016: **European Robotics Forum in Odense**
Jun 18 2016: **Festa de la Ciencia in Barcelona**
Jun 21 2016: **Automatica in Munich**
Jul 4 2016: **Science Museum Robot Show in London**
Sep 6 2016: **EFTA in Berlin**
Sep 28 2016: **Venturefest Wales in Cardiff**
Oct 9 2016: **IROS 2016 in Daejeon**
Oct 18 2016: **Venturefest South West in Exeter**
Nov 17 2016: **Smart City World Congress and Expo 2016 in Barcelona**

2017

Feb 2 2017: **Global Robot Expo in Madrid**
Mar 22 2017: **ERF 2017 in Edinburgh**
Apr 24 2017: **Hannovermesse**
May 10 2017: **EC Committee of Regions in Brussels**
May 16 2017: **Innorobo Open Stage in Paris**
May 27 2017: **Festa de la Ciencia in Barcelona**
May 28 2017: **FIABCI 2017 in Andorra**
Jun 2 2017: **IEEE International Conference on Robotics and Automation in Singapore**
Aug 22 2017: **17th International Conference on Computer Analysis of Images and Patterns in Ystad**
Sep 7 2017: **International Robotics Festival in Pisa**
Sep 14 2017: **Hubs, Platforms and Pilots in Horizon 2020: for clusters, companies, researchers in Oslo**
Oct 3 2017: **Hi Tech & Industry Scadinavia in Herning**
Nov 14 2017: **Smart City Expo World Congress in Barcelona**
Nov 17 2017: **European Robotics Week in Brussels**

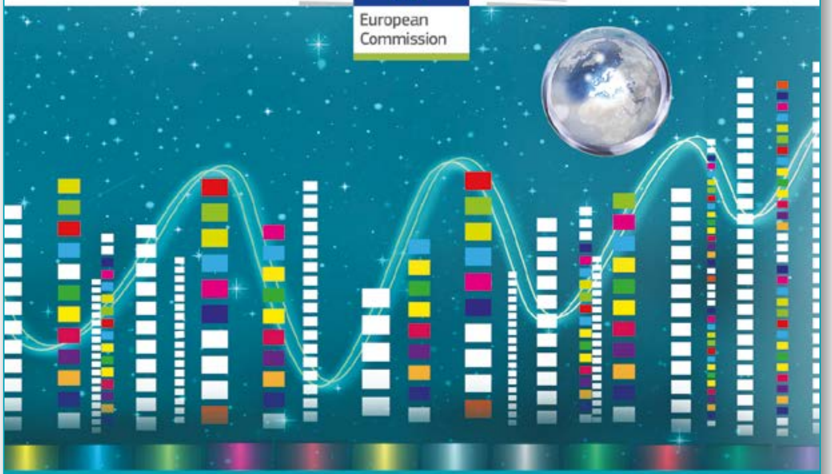
2018

Mar 13 2018: **European Robotics Forum in Tampere**
Jun 19 2018: **Automatica in Munich**
Oct 3 2018: **IROS in Madrid**
Nov 12 2018: **GovTech Summit in Paris**
Nov 12 2018: **MEDICA in Düsseldorf**
Nov 13 2018: **Smart City Expo World Congress in Barcelona**
Nov 27 2018: **DIH annual event in Warsaw**

2019

Mar 20 2019: **European Robotics Forum (ERF) in Bucharest**

European Commission



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