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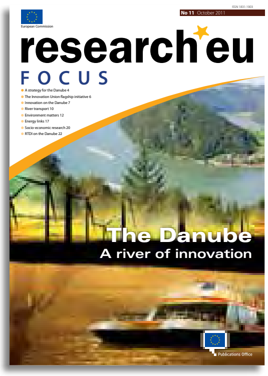

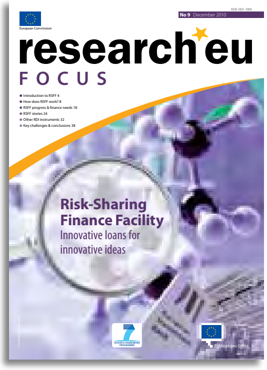

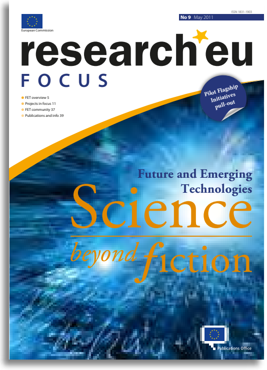

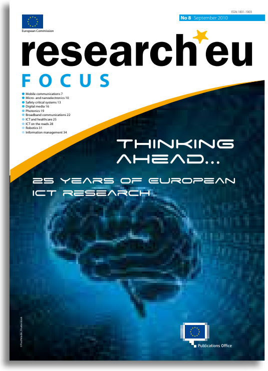

Learning from nature

Science and technology have often learned from observing nature. The streamlined forms of ships have been developed thanks to observation of the swift, efficient shapes of fish, while engineers building aeroplanes and other winged craft have been inspired by birds in flight.

Today, scientists are looking even further afield to study natural processes that could help us to build better and more efficient technologies. We can learn from photosynthesising leaves in order to improve solar-power generation. We can study the body's natural defence mechanisms against disease in an effort to boost them or apply them to new ailments.

Furthermore, the more we understand about nature, the better our understanding of basic scientific principles. And this can have applications far beyond the field initially in mind.

In the world of robotics, for example, we have become increasingly used to seeing robots that mimic living examples — not just humanoid robots, but robots that swim like fish or swarm like insects. Dr Barbara Mazzolai of the Center for Micro-BioRobotics at the Istituto Italiano di Tecnologia (IIT) in Pisa, Italy, is taking these ideas even further. She is developing robots that mimic the abilities of plants — plant roots, in particular. In this month's Q&A interview, *research*eu results magazine* asked Dr Mazzolai to explain further her concepts for technologies to mimic plants, and their possible applications. Astonishingly, these extend from medical endoscopes, and environmental monitoring, to space probes.

Our 'biology and medicine' section (starting on page 6) includes many more examples of technology mimicking nature, such as 'Virus-like particles for vaccine development' or 'Elucidating the natural mechanisms of tumour suppression'. Equally, the 'energy and transport' section (which starts on page 16) goes from 'Copying nature's elaborate surface chemistries' to 'Peptide-based electronics for solar technology'. The 'environment section (on page 21) looks at how studying nature can lead to improvements such as 'Cloud watching improves climate models' and 'Synergising eco-friendly pesticides'.

The feature story in our 'social sciences and humanities' section (page 14) examines a serious issue for our common historical heritage: 'Protecting archaeological sites from wild fire and extreme weather'. A second Q&A interview — with Tom Pearsall, of the European Photonics Industry Consortium (EPIC), in France, and Peter Van Daele, of IMEC at the University of Ghent, Belgium on 'Bridging the "Valley of Death" for photonics SMEs' — closes off our 'IT and telecommunications' section, which starts on page 25.

Finally, the 'industrial technologies' section showcases 3D printing and its role in the factory of the future (page 32), while the 'space' section (page 37) takes a lesson from Hollywood film *Gravity* to see how EU-funded efforts are 'Preventing space overpopulation from man-made debris'.

The usual preview of events and conferences concludes issue 30.

We look forward to receiving your feedback on this issue and on the *research*eu* publications in general. Send questions or suggestions to:

cordis-helpdesk@publications.europa.eu

The editorial team

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Special topic

Each issue of the *research*eu results magazine* sheds light on a specific science topic. To find out more about the latest results and findings, look out for this icon next to article headlines.

Videos

Want to see EU research projects in motion? Some of the projects presented in this issue have a dedicated video available on the internet. To view a video, just open the digital version of the magazine (available at http://cordis.europa.eu/research-eu) and click on this icon.

See you next month!

Coming up in issue 31 of *research*eu results magazine* — a special dossier called 'A world of apps'.

Building a robot to mimic plants

Many of us probably picture robots as roughly human-shaped — as seen in countless science fiction films — or perhaps as little more than mobile computers. But one EU-funded project is taking inspiration from the smart, efficient strategies of plants in order to develop a new generation of robots and ICT technologies, such as sensing or distributed adaptive intelligence.

In particular, plant roots are excellent natural diggers, points out Dr Barbara Mazzolai of the Center for Micro-BioRobotics at the Istituto Italiano di Tecnologia (IIT), the coordinator of the project. The characteristics of roots — such as adaptive growth, energy-efficient movements, and their ability to penetrate soil at any angle — are interesting from an engineering perspective, she says.

In fact, owing to their sessile lifestyle, plants have evolved the ability to respond to a wide range of signals and efficiently adapt to changing environmental conditions. Plant materials are optimised to reduce energy consumption during motion and these capabilities offer a plethora of solutions for the world of robotics, using approaches that are muscle-free and thus not necessarily animal-like.

*Research*eu results magazine* asked Dr Mazzolai to tell us more about her work in the PLANTOID[1] project.

What are the main themes and objectives of the PLANTOID project?

The goal of the project is to design, prototype, and validate a new generation of robotic systems, as well as ICT hardware and software technologies, inspired by plant roots. Just like their natural counterparts, these robotic systems have distributed sensing, actuation and intelligence to perform soil exploration and monitoring tasks.

There are many features of plants or plant roots that we are investigating in this project, including: capacity of growth and movement in response to external stimuli; growth from the tip of the root by adding cells and production of lateral hairs, to reduce the friction and pressure needed to penetrate the soil; sensory capabilities to detect a range of different physical and chemical quantities in the environment; osmotic actuation, used for triggering fast movements or driving slow movements in plants; and emergent behaviour by coordination of the roots of the whole organism towards optimal targets.

What is new or innovative about the project?

Plants have rarely been considered as a model of inspiration for designing and developing new technology — especially in robotics. This is probably due to their radically different operational principles compared to animals and difficulties in studying their movements and features. As a consequence, plants are often considered as passive organisms, which are not able to move, to communicate, and to escape from a hostile environment.

The first innovative aspect of this project is to observe plants from another perspective, and to consider their structural, functional and physiological properties as a revolutionary source of inspiration in robotics and ICT technologies. Plants are based on evolutionary strategies aimed at reducing energy consumption and optimising the use of local resources. PLANTOID is the first robot designed to actually grow in a way inspired by plant roots — using similar strategies to penetrate and explore soil in an energy-efficient way.

What first drew you to research to learn from nature in designing technology?

My personal aim in working in the biorobotics area is to better understand the nature and workings of living creatures in order to conceptualise, design and fabricate new artificial devices and bio-inspired robots.

The approach I follow is first to select the biological systems — plants, in this case — which have the relevant characteristics we wish to implement in robots. We then identify and extract the key principles underlying these biological functions and translate them into a technological solution.

At the same time, my goal is to increase the knowledge of the biological system that we use as models. To this end, one cannot simply copy nature, but rather one must carefully select biological models from which the underlying principles can be extracted and translated to an artificial device.

What are some of the difficulties you have encountered, and how did you solve them?

Moving in an unstructured environment such as soil requires new approaches. The proposed new concept of a root-like growing robot penetrates soil while extending its own structure using an additive layering technique.

Layers of new material are deposited adjacent to the tip of the device to produce a motive force at the tip and a hollow tubular structure extending to the surface of the soil. The addition of material at the tip reduces friction to almost zero, as the sides of the tube do not move, cutting down the energy consumption needed for penetration of the soil.

What are the concrete results from the research so far?

The first PLANTOID prototype includes two functional roots, one embodying artificial growth and penetrating the soil by an additive process of material; the other root implementing bending capabilities in three directions: the sensory systems for temperature, humidity, gravity and touch, and the electronics required for sensor conditioning and actuation control.

The two roots are integrated in a trunk containing a microcontroller main board with communication capability. The branches of the trunk integrate artificial leaves made with materials that "respond" to environmental changing conditions (e.g. humidity and temperature). This result is a prelude to more complex studies on the hierarchical structure of the plant cell walls.

In terms of components, new osmotic actuators have been developed which can be used as components per se

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Dr Barbara Mazzolai

(e.g. for a passive drug release) or applied to achieve the bending of the robotic root. Several sensors will be integrated in the robotic root to detect the following parameters: gravity, temperature, touch, humidity, sodium (Na^+), potassium (K^+), pH, nitrate (NO_3) and phosphate.

What are the advantages of participating in such an EU project?

European projects, like PLANTOID, offer the opportunity to integrate different competences and skills, increase multidisciplinarity, solve complex problems, as well as establish new scientific and technological collaborations. Moreover, these projects represent a training opportunity for young researchers who are open and exposed to a European context.

What are the next steps in the project, or next topics for your research?

The next steps will be focused on the integration of the identified functions into a single robotic root that embeds sensors, actuators, control units, an elongation/growing zone, and a bending area. The robot roots will be able to penetrate and steer in the soil, guided by gravity or the proximity of water or other chemicals.

On the engineering side, our goal is to develop new flexible plant-inspired robots able to grow by adding new materials. This will require the development or use of new flexible sensors based on soft materials, as well as distributed control and robotic architectures. One interesting topic for study is plant structures that exploit external environmental energy to move or implement efficient motion strategies.

Another important question we intend to address is whether plants exhibit intelligent behaviour. A simple definition of plant intelligence could be adaptively variable growth and development during the lifetime of the individual. Exploiting adaptive abilities in plants could lead to the development of smart devices — not only with the ability to sense, but with the capability to follow stimuli and take decisions to accomplish the required tasks.

Applications for such technologies inspired by plants include soil monitoring and exploration for contamination or mineral deposits — whether on earth or other planets — but could also include medical and surgical applications, like new flexible endoscopes, able to steer and grow in delicate human organs.

The project is coordinated by the Istituto Italiano di Tecnologia (IIT) in Italy.

1 'Innovative robotic artefacts inspired by plant roots for soil monitoring'.

Funded under the FP7 specific programme 'Cooperation' under the research theme 'Information and communication technologies' (ICT).
Project website:
http://www.plantoidproject.eu/

Microprocessors need liquids to beat the heat

Efficient heat removal is one of the most important challenges in sectors from electronics to power generation. EU-funded scientists demonstrated that nanofluid coolants applied to microprocessors could more than double computing capacity.

As current coolant technologies are approaching their technical limits, nanofluids have been reported to have superior thermal properties compared to conventional ones. Published reports of performance at the lab scale have suggested a more than 40 % improvement. However, the mechanisms are not clear.

Scientists initiated the world's largest collaborative project, NANOHEX[1], for the research and development of nanofluid coolants to methodically explore this potential. Researchers focused on formulations for use in data centre cooling and traction power electronic cooling.

Thermal tests of a variety of nanofluids enabled the population of a comprehensive database, the largest in existence, and the selection of two nanoparticle (NP) species for further development. Scientists prepared and optimised dispersions of silicon carbide (SiC) and aluminium oxide (Al_2O_3) in two different carrier fluids, water and water/ethylene glycol (EG). They demonstrated enhanced thermal conductivity between 10 and 20 % for the NPs dispersed in water/EG.

Although lower than that expected, based on published laboratory results, the enhancement is certainly promising. Investigators also found that the addition of NPs has important effects on viscosity, a consideration for future research. The team developed an assessment model to predict thermal performance of novel nanofluids using experimental data on viscosity and conductivity.

Two demonstrator units were produced for each application and a life-cycle analysis and economic viability study were conducted. Results showed that a nanofluid-cooled data centre has important environmental benefits compared to