# PLANTOID: Building a robot to mimic plants

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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 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 PLANTOID1 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 (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 (NO3) and phosphate.

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

Europeanprojects, 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 plantinspired 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.

**More information:** www.plantoidproject.eu/

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