Smart solutions from the plant kingdom

2013 Bioinspir. Biomim. 8 020301

(http://iopscience.iop.org/1748-3190/8/2/020301)

Bioinspir. Biomim. 8 (2013) 020301 (2pp) doi:10.1088/1748-3182/8/2/020301

FOREWORD

Smart solutions from the plant kingdom

Guest Editors

Barbara Mazzolai
Center for Micro-BioRobotics, Istituto Italiano di Tecnologia (IIT), Viale Rinaldo Piaggio 34, I-56025, Pontedera (Pisa), Italy
barbara.mazzolai@iit.it

Stefano Mancuso
Department of Plant, Soil and Environment, Università di Firenze, Sesto F.no (FI), Italy

Plants represent almost 99.9% of the biomass of our planet. This means that virtually every environment that can be colonized by life has been explored and populated by plants. To achieve such amazing results while being unable to move from the site of seed germination, plants have evolved an arsenal of solutions that make them suitable for life in the most demanding and extreme conditions. In addition, it is well established that plants are able to show considerable plasticity in their morphology and physiology in response to variability within their environment and to survive extremely diverse environmental conditions and stresses (Fujita *et al* (2006)). Thus the mechanical properties of plants, the morphology of their structures and their characteristic movements represent a goldmine of solutions that, with appropriate investigation, could be used to obtain new design rules for advanced bioinspired systems and materials in countless applications. Meanwhile, advances in technology, partly related to the adoption of such bio-inspired approaches in design, are opening new opportunities for the application of bioinspired artefacts in biological research.

This special issue of *Bioinspiration and Biomimetics* gathers four peer-reviewed articles whose results were partially presented at the International Workshop on Smart Solutions from the Plant Kingdom, held at the Accademia dei Georgofili in Florence, Italy, on 24 October 2011. The workshop was dedicated to presenting and discussing the importance of studying plants to learn from their structure and behaviour, and mimicking these plant features to develop new technologies and systems. This special issue offers multiple perspectives on how plants can represent a source of inspiration for developing new materials, components and mechanisms. At the same time, new tools for better investigating the properties of plants are presented.

The first article (Thielen *et al* 2013) presents a study on the biomechanical properties of the foam-like pomelo peel (*Citrus maxima*) for the development of biomimetic impact damping structures. This pomelo fruit represents an outstanding example of impact resistance, since it can drop from heights of up to 15 m without showing significant outer damage. This impact resistance is due to the hierarchical organization of the fruit peel, and mechanical tests confirmed that the pomelo peel behaviour under cyclic compression can best be interpreted as elasto-plastic hysteresis. The findings of the authors described in this work provide very interesting cues for the development of biomimetic foams with high energy absorption capacity.

With Sinibaldi *et al* (2013) we move to the concept of new actuators based on the osmotic principle, characterized by high energy efficiency and low power consumption. Osmotic pressure is responsible for different growing and actuation mechanisms in plants, including fast and reversible movements such as in the cases of *Mimosa pudica*, *Dionaea muscipula*, etc. The study provides a dynamic model of two implementations of an osmotic actuator concept. The performance indicators derived by this analysis give a preliminary indication of design targets/constraints (e.g. characteristic size and actuation time, maximum force, energy density) of the envisaged osmotic actuator. These new actuators based on the osmotic principle exploited by plants can find applications in many fields, including biorobotics.

The focus of Pandolfi and Izzo (2013) is on the investigation and exploitation of plant strategies in seed dispersal for space applications. The typical features of a space mission do not differ so much from the strategies plants need to implement for their seeds' survival (e.g. operating in harsh environments, the necessity to anchor the structure, requirement of material and packaging efficiency, etc). A classification of different seed dispersal methods is provided, as well as a presentation of analogous bioinspired artificial solutions. Plants, in fact, have conquered almost any surface on our planet and they are the first settlers in a hostile environment, making a path for a habitat that can then be settled by almost all living beings. Consequently, they can offer many interesting ideas for the colonization of extra-environments and space missions.

The last paper (Russino *et al* 2013) gives a complementary perspective on the study of plants and, in particular, on the necessity to develop new tools for the investigation of their behaviour and movements in *in vivo* conditions. Specifically, this work presents novel software to study the kinematics of the plant root tip (apex) and to perform 2D tip detection. This image analysis tool can deal with new growing root tips, with no need of markers, and can handle a massive amount of data with minimal user interaction. The development of computer-aided tools allows us to perform more complex studies on plant behaviour (e.g. kinematic, physiological, and phenotypical studies) and to formulate hypotheses on some unknown aspects of plants. At the same time, an increased knowledge of plant mechanisms leads to new ideas for developing a new generation of artificial bioinspired solutions.

We are confident of the present and rising role of plants as models to illustrate physical principles or to construct mechanical devices and we hope that this issue can be of great interest, use and benefit to readers.

References

Fujita M, Fujita Y, Noutoshi Y, Takahashi F, Narusaka Y, Yamaguchi-Shinozaki K and Shinozaki K 2006 Crosstalk between abiotic and biotic stress responses: a current view from the points of convergence in the stress signaling networks *Curr. Opin. Plant Biol.* **9** 436–42

Pandolfi C and Izzo D 2013 Biomimetics on seed dispersal: survey and insights for space exploration *Bioinspir. Biomim.* **8** 025003

Russino A, Ascrizzi A, Popova L, Mancuso S and Mazzolai B 2013 A novel tracking tool for analysis of plant root tip movements *Bioinspir. Biomim.* **8** 025004

Sinibaldi E, Puleo G, Mattioli F, Mattoli V, Di Michele F, Beccai L, Tramacere F, Mancuso S and Mazzolai B 2013 Osmotic actuation modelling for innovative biorobotic solutions inspired by the plant kingdom *Bioinspir. Biomim.* **8** 025002

Thielen M, Schmitt C N Z, Eckert S, Speck T and Seidel R 2013 Structure–function relationship of the foam-like pomelo peel (*Citrus maxima*)—an inspiration for the development of biomimetic damping materials with high energy dissipation *Bioinspir. Biomim.* **8** 025001