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## FOREWORD

# Living Machines 2012: The First International Conference on Biomimetic and Biohybrid Systems

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The development of future real-world technologies will depend strongly on our understanding and harnessing of the principles underlying living systems and the flow of communication signals between living and artificial systems. *Biomimetics* is the development of novel technologies through the distillation of principles from the study of biological systems. The investigation of biomimetic systems can serve two complementary goals. First, a suitably designed and configured biomimetic artefact can be used to test theories about the natural system of interest. Second, biomimetic technologies can provide useful, elegant and efficient solutions to unsolved challenges in science and engineering. *Biohybrid* systems are formed by combining at least one biological component from an existing living system and at least one artificial, newly engineered component. By passing information in one or both directions, such a system forms a new hybrid bio-artificial entity.

Progress in developing either biomimetic or biohybrid systems requires a deep understanding of the operation of living systems, and the two fields are united under the theme of 'living machines': the idea that we can construct artefacts, such as robots, that not only mimic life but share the same fundamental principles; or build technologies that can be combined with a living body to restore or extend its functional capabilities. The strength of these ideas is evident in the rapid rise of new advances coming from these research fields. For example, the Convergent Science Network (CSN) of biomimetic and biohybrid systems, has completed a survey on the state-of-the art in biomimetics, also published in *Bioinspiration and Biomimetics* (Lepora, Verschure and Prescott 2013). As part of the survey, we counted how much work on biomimetics is published each year. This revealed a compelling trend in the research field: from only tens of articles before the millennium, it has exploded in the decade since to well over a thousand papers each year, and is still growing!

This special issue of *Bioinspiration and Biomimetics* gathers three invited, peer-reviewed articles whose results were partially presented at *Living Machines: The First International Conference on Biomimetic and Biohybrid Systems*, held at La Pedrera in Barcelona, Spain, from July 9th to 12th, 2012. This new international conference was targeted at the intersection of research on novel life-like technologies inspired by the scientific investigation of biological systems, *biomimetics*, and research that seeks to interface biological and artificial systems to create *biohybrid* systems. This special issue presents a selection of the best research from that conference, which were selected by a panel of experts to be invited for publication in this special issue. All papers are based on full papers from the conference proceedings (Prescott *et al* 2013), which were then significantly expanded and revised for journal publication.

The first article (Umedachi *et al* 2013) won the best paper award, and presents a study of a true-slime-mound-inspired hydrostatically coupled oscillator system exhibiting versatile behaviours. For this purpose, they focused on an amoeba-like unicellular organism: the plasmodium of true slime mould.

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Despite the absence of a central nervous system, the plasmodium exhibits versatile spatiotemporal oscillatory patterns and switches spontaneously among these patterns. Inspired by this organism, they built a real physical robot using hydrostatically coupled oscillators that produced versatile oscillatory patterns and switched spontaneously among them. Their experimental results show that exploiting physical hydrostatic interplay—the physical dynamics of the robot—allows simple phase oscillators to promote versatile behaviours. These results contribute to an understanding of how a living system generates versatile and adaptive behaviours with physical interplays among body parts.

The second article (Ognibene *et al* 2013) presents a study of contextual action recognition and target localization with an active allocation of attention on a humanoid robot. Inspired by the cognitive mechanisms underlying human social behaviour, they designed and implemented a system for a dynamic attention allocation that could actively control gaze movements during a visual action recognition task. Implementing these mechanisms on a humanoid robot, enabled it to observe a partner's reaching movement to contextually estimate the goal position of the partner's hand and the location in space of the candidate targets. Their experimental results showed that this mechanism of active gaze control has advantages over other action perception approaches. Moreover, their model reproduces and extends experimental results on human attention.

The third article (Daltorio *et al* 2013) presents a study of efficient worm-like locomotion concerned with the control of soft-bodied peristaltic robots. In their work, they presented a dynamic simulation of an earthworm-like robot moving in a pipe with radially symmetric Coulomb friction contact. Under these conditions, peristaltic locomotion is efficient if slip is minimized. They then characterized ways to reduce slip-related losses in a constant-radius pipe and, using these principles, designed controllers that could navigate pipes even with a narrowing in radius. Their work suggests that peristaltic locomotion may be more efficient than previously believed; moreover, minimizing slip makes robotic worm applications in search and rescue, medicine, and inspection even more promising.

This collection of papers highlights the broad range of exciting international research taking place in these fields united by theme of *Living Machines*. For facilitating the conference and hence this special issue to take place, we thank the sponsors: The Convergence Science Network for Biomimetic and Biohybrid Systems (CSN) (ICT-248986) funded by the European Union's Framework 7 (FP7) programme, the University of Pompeu Fabra in Barcelona, the University of Sheffield, and the Institucio Catalana de Recerca I Estudis Avancats (ICREA). We also thank the reviewers and conference participants for enabling the conference to be a successful, interesting and enjoyable event for all concerned.

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