Living Machines

Embodied Interaction and Internal Models: Key Features of Autonomous Locomotion Systems

Date: 29.07.2014
Location: Milan, Politecnico di Milano**,** Building 25 “Emilio Massa”**.** http://www.polimi.it/.

Organisers:

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Abstract:
Legged locomotion is characterised by continuous and flexible interaction of a set of limbs with the substrate they are walking on. Although the goal of this interaction appears to be simple - accelerate the body’s centre of mass while maintaining balance - legged locomotion is far from being simple. Until today, any insect can do better than the best technical locomotion system available. An important reason for this discrepancy between natural and technical locomotion systems is the lack of integration: While engineers have proposed solutions to particular problems such as the spatial coordination of appropriate foot contacts, the temporal coordination of many degrees of freedom, or efficient distribution of joint torques, it is the integrated and simultaneous solution of these problems that make animals excel compared to machines.
In the tradition of *Leonardo da Vinci*’s bio-inspired approach to technical locomotion, this satellite symposium will bring together neuroscientists and engineers, addressing two major aspects of integration in legged locomotion: At the lower, physical level, we will discuss various issues of embodied interaction of sensorimotor systems. Experts on natural locomotion systems, sensorimotor control, sensor devices and novel actuators will discuss how to exploit body-substrate interaction. At the higher, cognitive level, we will discuss issues of internal representations for adaptive motor planning and execution of movement sequences. Here, our aim is to identify viable options for integrating bio-inspired models of higher-order motor control in walking machines.

Program

Part A: Embodied Interaction for Adaptive Locomotion
(Morning Session)

Chair: Paolo Arena

09:15 Welcome Address

09:30 *Natural six-legged locomotion: Beyond Gaits*
Volker Dürr (Uni Bielefeld, Germany)

10:00 *Compliant actuators and their control*
Axel Schneider (FH Bielefeld, Germany)

Coffee break

11:00 *Novel mechanoreceptive devices for the control of locomotion*
Istvan Matefi-Tempfli (SDU Sonderborg, Denmark)

11:30 *Load-dependent inter-limb coordination*
Dai Owaki (Tohoku Uni, Sendai, Japan)

12:00 *Active Sensing, locating and shape learning*
Thierry Hoinville (Uni Bielefeld, Germany)

12:30 *Spotlight Presentations:*

Monolithic Design and Fabrication of a 2-DOF Bio-Inspired Leg Transmission
Daniel Aukes (Harvard, Cambridge, USA)

Bipedal walking of an octopus-inspired robot
Federico Renda (SSSA, Livorno, Italy)

Lunch

Part B: Internal Models and Higher Order Motor Control
(Afternoon Session)

Chair: Volker Dürr

14:00 *Optimal and learning control for legged robots*
Jonas Buchli (ETH Zürich, Switzerland)

14:30 *Body size representation and motor learning in insects*
Roland Strauss (Uni Mainz, Germany)

15:00 *Modelling body size representation, motor learning and other insect capabilities*
Paolo Arena & Luca Patanè (Uni Catania, Italy)

Coffee break

continued overleaf

16:00 *Neural control, memory, & learning for complex behaviours in multi-sensorimotor robotic systems*
Poramate Manoonpong (SDU Odense, Denmark)

16:30 *Internal models for planning novel behaviours*
Malte Schilling (CITEC Bielefeld, Germany)

17:00 *Spotlight Presentations*

Neuromechanical Mantis Model Replicates Animal Postures via Biological Neural Models
Roger Quinn (CWRU Cleveland, USA)

How cockroaches employ wall-following for exploration
Roger Quinn (CWRU Cleveland, USA)

A predictive model for closed-loop collision avoidance in a fly-robotic interface
Holger G Krapp (Imperial College, London)

17:30 *Final Discussion*

18:00 Close

(some) Abstracts

Volker Dürr (Uni Bielefeld, Germany)

Natural six-legged locomotion: beyond gaits

Abstract: Historically, legged locomotion has often been dealt with as a matter of gaits and the associated temporal coordination among limbs. This has been supported by distinct biomechanical states in large animals, but also by the finding and detailed analysis of central nervous patterning mechanisms. As yet, the behavioural adaptiveness and flexibility of animals clearly is beyond switching between a small set of states or activity patterns. In my talk, I will present current approaches to (i) the quantification of locomotion variability in unrestrained walking and climbing insects, (ii) the role of distributed proprioception in adaptive control of locomotion, and (iii) spatial coordination among limbs. Based on these studies, I will argue that (i) natural locomotion may never reach a steady-state, (ii) important aspects of adaptive locomotion fundamentally require active, embodied interaction with the substrate, and (iii) an anterior-posterior flow of spatial information contributes to efficient foot placement in climbing.

Dai Owaki (Tohoku Uni, Sendai, Japan)

Load-dependent inter-limb coordination

Abstract: Legged animals exhibit surprisingly adaptive locomotion under unstructured environments. Such locomotor patterns are generated via coordination between leg movements, i.e., interlimb coordination mechanism. Numerous studies have been devoted to elucidate this mechanism from biological as well as robotic viewpoint; however, it has not yet clearly understood.
To address these issues, we reworked the design principle of central pattern generator (CPG)-based control for interlimb coordination in legged robots based on a minimalistic approach. In a previous study, we proposed an unconventional CPG model that fully exploits physical communication between legs via load sensing. In this talk, we will present our latest results showing to what extent our load-dependent coordination model reproduces locomotion patterns of quadruped animals.

Poramate Manoonpong (SDU Odense, Denmark)

Neural control, memory, & learning for complex behaviours in multi-sensorimotor robotic systems

Abstract: Walking animals, like stick insects, cockroaches or ants, are able to perform a variety of walking patterns and can traverse diverse terrains. During traversing, they can also adapt their locomotion to deal with terrain changes. Furthermore, their movements are elegant and versatile. They can also effectively navigate to find their goal in complex environments.

Neurobiologists suggest that solving these tasks basically results from a combination of biomechanics and neural mechanisms. In this talk I will present how we, inspired by neurobiology, develop biomechanics and neural mechanisms (i.e., control, memory, and learning) for our multi sensori-motor robotic systems (i.e., walking robots). The biomechanics and neural mechanisms allow the robots to interact with the environment and thereby generating complex behaviours. These behaviours include adaptive locomotion on difficult terrains, a multitude of different walking patterns, proactive behaviour, memory-guided behaviour, and goal-directed behaviour. I will also show that the developed neural mechanisms are general and transferable to different robotic and non-robotic systems.

Malte Schilling (CITEC Bielefeld, Germany)

Internal models for planning novel behaviours

Abstract: Internal models are crucial in planning ahead. Importantly, internal models that can be readily used to plan ahead have to fulfill two major aspects: On the one hand, they have to be grounded in the overall behaviour of the agent. On the other hand, these models have to be predictive. Only such models that are accurate enough to allow for accurate predictions of possible behavioural adaptations can be sensible employed in mental simulation as an implementation of planning ahead. In our approach, we first introduce a grounded internal body model that subserves the behaviour of a six legged walking system in coordinating all joints during the stance movements. Second, we show how such a predictive model can be employed for mental simulation and how the reactive control system can be extended to allow for behavioural adaptions that make it possible for the system to deal with novel tasks as modifications of already existing behaviours.