

Mini-symposium “bio-inspired robotics”

August 30th, 2017, Louvain-la-Neuve, Belgium

Place: Auditorio Sainte-Barbe, room BARB93

Program at a glance

14:00 – Talk by **Prof. Auke Ijspeert** (EPFL) - <http://biorob.epfl.ch/>

"Neuromechanical models of locomotion: from biology to robotics"

The ability to efficiently move in complex environments is a fundamental property both for animals and for robots, and the problem of locomotion and movement control is an area in which neuroscience and robotics can fruitfully interact. Animal locomotion control is in a large part based on spinal cord circuits that combine reflex loops and central pattern generators (CPGs), i.e. neural networks capable of producing complex rhythmic or discrete patterns while being activated and modulated by relatively simple control signals. These networks are located in the spinal cord for vertebrate animals and interact with the musculoskeletal system to provide "motor primitives" for higher parts of the brain, i.e. building blocks of motor control that can be activated and combined to generate rich movements. In this talk, I will present how we model the spinal cord circuits of lower vertebrates (lamprey and salamander) using systems of coupled oscillators, and how we test these models on board of amphibious robots. The models and robots were instrumental in testing some novel hypotheses concerning the mechanisms of gait transition, sensory feedback integration, and generation of rich motor skills in vertebrate animals. I will also discuss how the models can be extended to control biped locomotion and lower-limb exoskeletons.



NB: This talk will take place within the series of the institute seminars of the [“Institute of Mechanics, Materials, and Civil Engineering”](#).

15:15 – Coffee break

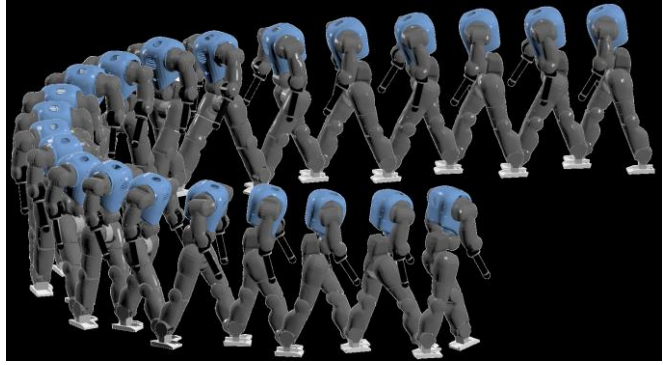
16:00 – PhD public defense of **Nicolas Van der Noot** (UCLouvain and EPFL) - <https://perso.uclouvain.be/nicolas.vandernoot/>

This is the first public defense in the framework of the joint PhD supervision agreement (accord de cotutelle) between UCLouvain and EPFL.

Rich and Robust Bio-Inspired Locomotion Control for Humanoid Robots

Biped locomotion is a challenging task in the sense that it requires to maintain dynamic balance while steering the gait in potentially complex environments. Yet, humans usually manage to move without any apparent difficulty, even on rough terrains. This requires a complex control scheme which is far from being understood.

In this thesis, we take inspiration from the impressive human walking capabilities to design neuromuscular controllers for humanoid robots. More precisely, we control the robot motors to reproduce the action of virtual muscles commanded by stimulations (i.e. neural signals), similarly to what is done during human locomotion. Because the human neural circuitry commanding these muscles is not known, we make hypotheses about this control scheme to simplify it and progressively refine the corresponding rules.



This thesis thus aims at developing new walking algorithms for humanoid robots in order to obtain fast, human-like and energetically efficient gaits. In particular, gait robustness and richness are two key aspects of this work. In other words, the gaits developed in the thesis can be steered by an external operator, while being resistant to external perturbations. This is mainly tested during blind walking experiments on COMAN, a 95 cm tall humanoid robot. Yet, the proposed controllers can be adapted to other humanoid robots.

In the beginning of this thesis, we adapt and port the reflex-based neuromuscular model of (Geyer and Herr, 2010) to the real COMAN platform. When tested in a 2D simulation environment, this model was capable of reproducing stable human-like locomotion. By porting it to real hardware, we show that these neuromuscular controllers are viable solutions to develop new controllers for robotics locomotion.

Starting from this reflex-based model, we progressively iterate and transform the stimulation rules to add new features. In particular, we include a central pattern generator (CPG), a neural circuit capable of producing rhythmic patterns of neural activity without receiving rhythmic inputs.

Using this CPG, the 2D walker controllers are incremented to generate gaits across a range of forward speeds close to the normal human one. By using a similar control method, we also obtain 2D running gaits whose speed can be controlled by a human operator. The walking controllers are later extended to 3D scenarios (i.e. no motion constraint) with the capability to adapt both the forward speed and the heading direction (including steering curvature). In parallel, we also develop a method to automatically learn stimulation networks for a given task and we study how flexible feet affect the gait in terms of robustness and energy efficiency.

In sum, we develop neuromuscular controllers generating human-like gaits with steering capabilities. These controllers recruit three main components: (i) virtual muscles generating torque references at the joint level, (ii) neural signals commanding these muscles with reflexes and CPG signals, and (iii) higher level commands controlling speed and heading. Most of these developments are performed on a simulated model of the COMAN robot, in which hardware limits are taken into account. More precisely, actuators are modeled and noise components are incorporated, such that the computed torque references differ from the actual ones, as would happen on a real robotic device.

Moreover, only sensory information available to the real platform is used in the simulation environment. Using this framework, the algorithms developed in this thesis could thus be tested on real robots.

Interestingly, these developments target humanoid robots locomotion but can also be used to better understand human locomotion. In particular, the recruitment of a CPG during human locomotion is still a matter open to debate. This question can thus benefit from the experiments performed in this thesis. In turn, these developments could possibly be valuable in the fields of prostheses, orthoses, exoskeletons, rehabilitation robotics and computer graphics animation.