PhD Proposal

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Title: Flexible Quadruped Locomotion in Irregular Terrain: a Biological Approach

Scientific Domain: Robotics, Computer Science, Mathematics, Artificial Intelligence

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Abstract

The aim of this PhD is to develop a bio-inspired architecture for adaptive and autonomous generation of complex motor behaviours, with application to robots with many degrees-of-freedom (DOFs). As a main application we address the topical issue of robust, flexible visually-guided quadruped locomotion on irregular terrains, modelled as discrete, sensory driven corrections of the locomotion rhythmic patterns. Our architecture will be tested on an Aibo of Sony.

The design of the architecture will:

1) be in analogy with solutions exhibited by the nervous system;
2) be based on the concept of dynamical systems for modelling:
    - i) trajectory generation;
    - ii) the interaction between the central nervous system and the peripheral information. This issue has received little attention so far and is crucial for autonomous and adaptive control;
    - iii) the adaptability of the control architecture to unknown environment using biologically inspired feedback pathways;
    - iv) the dynamic principles for feedback pathways, to achieve balance and obstacle avoidance;
    - v) the steering of action by the sensory-motor information.

We expect that results may be used in the development of control software that will allow robots to deal with unknown environments. The motivation is that the approach will find a number of applications in service tasks and will contribute towards better rehabilitation of movement control in amputees. In this domain, a niche of research is autonomous adaptive locomotion.

Objectives

This PhD is an innovative multidisciplinary undertaking, combining insights of dynamical systems theory, computational neuroscience and robotics. It aims at developing a closed loop control architecture based on dynamical systems for the autonomous generation, modulation and planning of complex motor behaviours for legged robots with many DOFs.

To tackle the complexity of movement generation, we assume that any movement can be decomposed in rhythmic and discrete primitives. As a main application, we address the problem of adaptive quadruped visually-guided locomotion in unknown, rough terrain that we model as discrete, sensory driven corrections of a basic rhythmic motor pattern for locomotion. This task involves close-loop control and we will thus particularly focus on the integration of sensory-motor information in the architecture. Trajectories are online modulated according to these feedback pathways thus achieving balance, pendulum effects compensation and obstacle avoidance.

The development of this architecture is in collaboration with the Biologically Inspired Robotic Group (BIRG) at EPFL. They focus on the development of a robust, open loop architecture for the generation of trajectories, whereas we address the challenging issue of closing the loop.

The objectives pursued are:

- to implement vision modules for obstacle and spot locations detection;

- to develop a dynamical architecture for a generic CPG that generates trajectories for each DOF which smoothly superimpose and/or switch between discrete and rhythmic primitives;
- to develop and implement biologically inspired sensory-motor control schemes for interlimb gait coordination;
- to develop a controller architecture that generates adaptive and robust coordination of the DOF movements for interlimb gait coordination;
- Adjust the controller architecture such that it autonomously bifurcates to different types of gait patterns according to sensorial context.
- to make the control architecture fully adaptive on the basis of dynamic systems theory though several kinds of feedback pathways, in order to achieve: lateral stability, pendulum effects compensation, phase resetting and obstacle avoidance.
- To achieve balanced locomotion (lateral and frontal) by implementing discrete adjustments of the CPG discrete movement components. This implies online adaptation of the CPG parameters such that trajectories smoothly change according.
- to include feedback loops to do online trajectory modulation and take external perturbations into account.
- to apply adaptive oscillators and thus enable locomotion adaptation to time-varying parameters of the robot body;
- to avoid singular configurations and limits of workspace.
- to enable autonomous switch between discrete and rhythmic movements, such that online sensory information steers action;

The robustness of this architecture will be tested on real robots, and in particular on an Aibo of Sony.