PhD Proposal

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Title: Rehabilitation Robot: a Biological Approach

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

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Abstract

The aim of this project is to develop a rehabilitation robot able to cope with the increasing rehabilitative needs of people with disabilities as well as the growing elderly population. This robot plays a role in the effort of trying to regain impaired functionalities (e.g. arm function training for stroke patients). Robotic therapy systems may not be able to provide a cure or fully compensate for impairments, but may be able to extend or enhance certain impaired functions in order to increase quality of life and independent living. Recent research indicates that impaired physical functions can be recovered after intensive training.

The general architecture of the system will be built on the concept of dynamical systems, an approach which has proven to be successful in many robotic applications. The developed architecture will be tested on a real PUMA arm.

The design and development of the required controllers for the robot will:

1) be bio-inspired by analogies with nervous systems;

2) apply autonomous differential equations to model:

a. trajectory generation as verified in specialized neural networks ("central pattern generators-CPGs") at the nervous system when executing motor control.

b. the interaction between the central nervous system and the peripheral information.

c. The adaptability of the control architecture to the pacient needs using biologically inspired feedback pathways;

d. The dynamical principles for feedback pathways, to achieve force control and online trajectory modulation and to deal with external perturbations.

g. The steering of action by the sensory-motor information.

The motivation arises in the sense that robotic technology may add to the solution of the increasing problem of shortage in available personal care. Increasing the quality of life of people, providing enjoyment in otherwise constrained conditions that are restricting expressions of personality, personal interests, and enjoyment, constitutes an area with a potentially large user group, including hospitalized people.

The role of robotics in rehabilitation has been increased after the recent advances of rehabilitation procedures, methodologies and tools that, by exploiting the new technologies for brain imaging, tend to include more and more the cognitive aspects of motor control. This allows to "close the loop" from brain to action. Therefore, robotics can be fruitfully employed in the rehabilitation of neuro-motor functions and motor capabilities, by providing tools that are in their nature flexible and programmable and that allow to set and assess procedures quantitatively.

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 the motor behaviour for a rehabilitation robot This robot should perform, monitor and adapt to the arm function training of stroke patients, constituting an effort of trying to regain impaired functionalities. Trajectories are online modulated according to sensory information, thus achieving force control. The objectives pursued are:

- to implement force measuring modules for force adjustment;
- to engineer a solution for the gripper of the manipulator such that holding of the stroke limb is possible;
- to develop a dynamical architecture for a generic CPG that generates trajectories;
- to apply the required inverse kinematics algorithms to calculate the corresponding angles for Cartesian position.
- to develop a controller architecture that generates adaptive and robust coordination;
- to develop and implement biologically inspired sensory-motor control schemes for coordination;
- To achieve online adaptation of the CPG parameters such that trajectories smoothly change according.
- to make the control architecture fully adaptive on the basis of dynamic systems theory though several kinds of feedback pathways, in order to achieve force control.
- to avoid singular configurations and limits of workspace.
- to include feedback loops to do online trajectory modulation and take external perturbations into account.- to avoid singular configurations and limits of workspace.
- to apply adaptive oscillators and thus enable trajectory adaptation to time-varying parameters of the robot body;
- to enable online sensory information to steer action;
- to integrate the control architectures;
- to simulate the developed models (in Webots);
- to implement in the PUMA arm the developed models.

The robustness of this architecture will be tested on real robots, and in particular on a PUMA arm.