PhD Proposal

Scientific Adviser: Cristina Manuela Peixoto dos Santos and Auke Ijspeert

Title: Coordination and cooperation among robots based on biological concepts

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

Contact: cristina@dei.uminho.pt

Abstract

The aim of this project is to develop a complete framework that can autonomously generate, control and plan complex motor behaviour for different entities (or degrees-of-freedom), and coordinate them in the context of robotics, generating adaptive and robust movements, with the particularity that the movements of all the entities are coordinated in time among each other. Therefore, each entity will exhibit intelligent and flexible cooperative behavior. Specifically, we address two different robotic setups and task scenarios, which imply temporal coordination among entities: 1) the cooperation among two simulated manipulators (or one robot and a person) such that it is possible to transport one object from one point to another; 2) the cooperation among two vehicles such that they are able to keep a desired formation and distance among them (as if they were transporting an object), while avoiding obstacles and reaching a visually acquired goal, without prior knowledge of the environment. Both systems have to deal with time constraints, such that vehicles and manipulators have a fixed time to reach the goal location. We also attempt to demonstrate that the approach can be extended for a larger number of vehicles.

The design and development of these controllers will:

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

2) apply autonomous differential equations to model:

a. the autonomous generation of rhythm patterns as verified in specialized neural networks (“central pattern generators-CPGs”) at the nervous system when executing motor control. These dynamical architectures generate trajectories with timing constraints;

b. the temporal synchronization of the robots movements;

c. the dynamical principles underlying the integration of spatio and temporal constraints onto a unique controller;

d. the generation and coordination of discrete movement patterns based on previous work.

e. A dynamical architecture that autonomously specifies if a tendency to synchronize or to sequentialize should be verified, based on the current sensorial context.

f. The dynamical principles underlying the feedback pathways that enable to do online trajectory modulation and to deal with external perturbations.

The field of multiple autonomous robots operating in formation is emerging as a key technology in mobile robots and is currently under intense effort. The use of multi-robots synchronized, coordinated or cooperating in production processes where there is a high requirement on flexibility and manoeuvrability is highly desirable. This is an option to be considered in complex and integrated production processes including assembling, transporting, painting and welding tasks.

The applied approach enables synchronization of the different entities providing an independence relatively to the specification of their individual parameters such as movement time, movement extent, etc. This synchronization reduces computational requirements for determining identical movement parameters across robots. The inherent advantages from an engineering viewpoint are huge, since the control system is released from the task of recalculating the movement parameters of the different components.

The main motivation is that once solutions for this problem are found, they can be applied in search and rescue operations, landing removal, remote terrain and space exploration, and also to the control of satellites and unmanned aerial vehicles. In this domain, the achievement of robots able to exhibit intelligent and flexible cooperative behaviour is a first issue. Given previous work in this domain, there is confidence that this project can be realized and therefore contribute to some fundamental problems in temporal coordination of degrees of freedom or individual entities.

Objectives

This work is an innovative multidisciplinary undertaking, combining insights of dynamical systems theory, computational neuroscience and robotics. We aim at generating online flexible timed behavior stably adapted to changing online sensory information, such that different entities may achieve autonomous timed and flexible cooperative/coordinated behavior. We apply an attractor based dynamics as recent studies have shown that this theory helps synchronize systems and reduces the computational requirements for determining identical movement parameters across different coupled movements. The approach is demonstrated in the cooperation among two manipulators and in the cooperation among two vehicles. The objectives pursued are:

- to implement vision modules for obstacle and target locations detection;
- to engineer a solution for the gripper of the manipulator such that transport of an object is possible;
- to develop the dynamical architecture that integrates spatio and temporal constraints for the manipulators;
- 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 design higher level architectures that autonomously specify if movements synchronize/sequentialize.
- to make the control architecture fully adaptive on the basis of dynamic systems theory though several kinds of feedback pathways such that online trajectory modulation is achieved and external perturbations can be taken into account;
- to avoid singular configurations and limits of workspace.
- to integrate the control architectures;
- to simulate the developed models (in Webots);
- to implement in the real vehicles the developed models.