Chapter 3
Head Motion Stabilization During Quadruped Robot Locomotion:
Combining CPGs and Stochastic Optimization Methods

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ABSTRACT

In this work, the authors propose a combined approach based on a controller architecture that is able to generate locomotion for a quadruped robot and a global optimization algorithm to generate head movement stabilization. The movement controllers are biologically inspired in the concept of Central Pattern Generators (CPGs) that are modelled based on nonlinear dynamical systems, coupled Hopf oscillators. This approach allows for explicitly specified parameters such as amplitude, offset and frequency of movement and to smoothly modulate the generated oscillations according to changes in these parameters. The overall idea is to generate head movement opposed to the one induced by locomotion, such that the head remains stabilized. Thus, in order to achieve this desired head movement, it is necessary to appropriately tune the CPG parameters. Three different global optimization algorithms search for this best set of parameters. In order to evaluate the resulting head movement, a fitness function based on the Euclidean norm is investigated. Moreover, a constraint-handling technique based on tournament selection was implemented.

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1. INTRODUCTION

Visually-guided locomotion is important for autonomous robotics. However, there are several difficulties; for instance, the locomotion of quadruped, biped or snake-like robots induces head shaking that restricts stable image acquisition and the possibility to rely on that information to act accordingly.

This kind of disturbances, generated by locomotion itself, introduces image oscillations, increasing the difficulty in achieving image depending tasks like: search, visual navigation, distance measurement, etc. On the contrary, the robotics counterpart biological mechanisms are able to stabilize the head movement, even when they change the type of gait or adapt to the terrain.

In this work, we propose a combined approach to generate head movement stabilization on an ers-7 AIBO quadruped robot that walks with a walking gait, using Central Pattern Generators (CPGs) and an optimization algorithm. Our aim is to minimize the head movement induced by locomotion. We propose to generate head movement on a feedforward manner, such that the head moves in a manner opposed to the head movement induced by locomotion, in an open loop fashion. For this, we save the head movement induced by a certain walking gait, on a certain floor, during a certain amount of time. The generated head movement has to be opposed to this one.

We propose two movement controllers based on CPGs, one to generate locomotion and another to generate head movement. The first one generates movement for the joints of the robot limbs and the second one generates trajectories for tilt, pan and nod head joints. The CPG controller generates movement according to a set of parameters. A different tuning of these parameters results in a different movement. Moreover, this CPG approach enables to modulate the generated trajectories according to explicit changes in the controller parameters, such that movement is generated as required. This provides for a set of controller parameters that constitute the feedforward model, setting in an open loop manner.

In order to determine the best set of CPG control parameters that generates the head movement opposed to the one induced by the locomotion when no stabilization movement was performed, we apply optimization algorithms. We apply three stochastic optimization methods: evolution strategies (Schwefel, 1995; Goldberg, 1989) and the electromagnetism-like mechanism (Birbil & Fang, 2003). These approaches were adopted since, from the optimization point of view, this problem can be seen as a black-box type because the evaluation of the objective function implies running the model that is testing the solution by simulation. We want to remark that these optimization methods have been developed for problems with simple bounds. Hence, because several constraints are imposed in this optimization problem two constraint-handling approaches are implemented: a repairing method and the tournament based constraint method (Deb, 1998).

The usefulness of the proposed controller is verified in a physically realistic simulation environment, and the experimental results show the effectiveness of the proposed controller in reducing head motion during walking. These results enable to compare the performance of the three optimization algorithms and the distinct constraint-handling techniques, in terms of the simulation time, rate of convergence and robustness.

This represents a first step towards the achievement of head stabilization. The final solution should integrate both feedforward and feedback controllers, probably according to visual sensory information.

Considering real-world applications of visual sensors, such as visually-guided locomotion, errors in the head orientation rather than in head position should be considered and taken into consideration. However, the available degrees-of-freedom of the used ers-7 AIBO robot do not enable to directly