PhD Proposal

Visual Feedback to Assist Humanoid Balance

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CONTEXT

Although the use of force and inertial sensors are common preferences to perform humanoid robotics balancing, the usage of vision based sensors for that purpose is also possible with relative success as shown by the works of Oda *et al.* [1, 2]. In fact, vision sensors are omnipresent in humanoid robots for the purpose of general exteroceptive perception, such as detection of features or structures in order to perform scene classification and object recognition, or even to help plan routes intended for locomotion. Therefore, it seems expectedly natural to use the onboard vision system to assist internal mechanisms of stabilization or balancing, and even locomotion.

Despite this natural expectation, the problem of using visual cues to assist humanoid balance is complex at several levels. The main issues are the following: i) the perception itself and the selection of what parts of the image or objects are to be used as references, and ii) how that visual information can be used to assist balance or walking. As far as perception is concerned, it is relevant to consider the level of awareness that the robot has of its ego-motion. If it is very precise, then the subtraction of its own motion to the resulting moving image captured by the visual sensor is a way to easily detect which parts of the image are static and which are moving. However, the knowledge of its ego-motion, even in the unlikely case of supposedly being very precise by joint monitoring and inertial systems altogether, may not be enough to accommodate floor irregularities and other external perturbations. Indeed, even slight fluctuations on the ground surface can imply sudden variations of the orientation of a camera installed on the head, thus jeopardizing target detection in the image.

For all this, it is absolutely recommended that the robot includes techniques to analyze the image to extract and follow "useful" targets and ensure the existence of "proper" references to infer or enhance its ego-motion. Detecting static parts on the image, at least for some time interval, can then allow target locking and assist balancing. Research has to be carried out in order to filter out the relevant and non-relevant sections of the image based on their inferred dynamics (possibly static, but not necessarily) and to continuously track them and use them as references. The second issue concerns how to integrate and actually assist the balance, *i.e.*, how to drive the COP (or ZMP) in order to keep balance, but also to try to optimize image stability in order to ease tracking and, consequently, better image and ego-motion measurement.

Research on this field should cover and surpass the state of the art by, for example, exploiting sensorimotor approaches. The main research goal is to develop and test computational theories of how multisensory information from the visual and vestibular systems can be processed, integrated and transformed into either movement actions or perceptual decisions for balance assessment. The research activities will be conducted in the context of the Humanoid Project at the University of Aveiro [3].

OBJECTIVES

Image perception on humanoids is affected by robot own motion aggravated by imprecise knowledge of ego-motion due to limited models and external perturbations. The research work proposes to address this problem through the development and implementation of the following methodological approach. Firstly, state-of-the-art methods will be used to analyse the image and to extract "good" features that serve as reference and enhance the knowledge of the ego-motion. Secondly, with the known good features as references, different techniques will be integrated for driving the COP (or ZMP) in order to altogether keep balance and, simultaneously, to optimize further image acquisition. The work is directed along the following main lines:

1. **Study the determinants of functional balance in humans** and the complex array of associated control processes, focusing on the role of vision in the control of locomotion. For example, a fundamental aspect to address will be the understanding of the the visual stabilization mechanisms in biological systems, *i.e.*, the vestibulo-ocular reflex (VOR) and the opto-kinetic response (OKR). The intention is to extract principles to be used in novel engineering implementations leading to more effective machine function, rather than a simple copy of the biological models.
2. **Implementation of a gaze stabilization system** based on the inertial sensors. Oculomotor control in humanoid robots faces the same problem of their biological counterparts: stabilization of gaze relative to unknown perturbations of the body. In this context, the inertial information is crucial to enhance the performance of the vision system for several visual tasks and head stabilization. This work will address the head stabilization system based on models of the vestibulo-ocular reflex [4-7]. The approach should tackle the problem of head stabilization during locomotion, while the vestibular sensor (inertial measurement system - IMU) will be located in the head of the robot [8].
3. **Extraction of relevant features from the vision system** to serve as reference to infer or to enhance the knowledge of ego-motion. Maintaining stable gaze will rely on the interaction among the inertial measurement system and vision, and on their ability to deal with noise and parameter uncertainty. The visual scenes in which the robot concentrates its attention convey relevant information that should be extracted to generate compensatory movements of the head during robot locomotion.
4. **Study the sensorimotor transformations required for accurate motor actions** coordinated among trunk, legs and feet. The main goal is to develop and test computational theories of how multisensory information is processed, integrated and transformed into either commands for movement or perceptual decisions. A robust balance control requires the combination of several interdependent systems, including the gaze and the postural stabilization systems. One major component of the postural stabilization system is the combination of information from vision, proprioception and the tactile sense of contact with the support surface. The studied methodologies will be implemented and tested both in realistic dynamical simulations and in the available prototype humanoid platform.

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