Development of Task-Level Control for a Humanoid Robot

Workplan proposal for fellowship at IEETA

Scientific Areas: Electrical and Electronics Engineering, Computer Engineering

Keywords: Humanoid Robotics; Computational Resources; Gait Patterns; Motion Control.

Human Resources: 1-BIC/6-month fellowship for graduate student in Electronics

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Introduction

Driven by the need for helpful machines or simply as a dream of replicating humans, humanoid robots represent today one of the largest challenges in the field of autonomous agents and intelligent robotics. The impressive designs and skills of the Honda [1,2] and Sony's robots [3] have changed the common view in what concerns humanoid robotics. Though very vulnerable to balance problems, it is expected that more and more universities and research laboratories will manage to build their own humanoid robots. At the same time, the continuous progress in robotics technology opens up new possibilities for academic research on low-cost and easy-to-design humanoids, such as PINO [4], ESYS [5] and HanSaRam [6], among others.

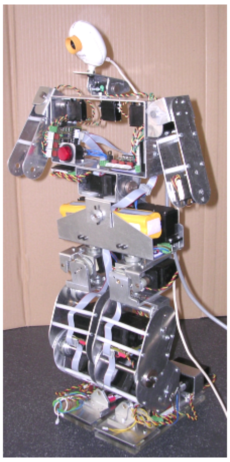
Among the major challenges in building low-cost and easy-to-reproduce humanoid robots, the performance of their control architectures and the constraints on actuator systems assume a special importance. From the control point of view, the computational resources and the sensing abilities impose additional limitations on the robot's performance. Some platforms, however, show up limitations due to centralized control approaches and lack of modularity, making them difficult for other to replicate.

Humanoid Project at the University of Aveiro

Objectives

The humanoid robot project, started in 2003, represents a collaborative research effort joining two research units of UA, namely the Institute of Electronics Engineering and Telematics (IEETA) and the Centre for Mechanical Technology and Automation (TEMA). The project aims to initiate a long-term multidisciplinary project by combining mechanical, electrical and software engineering. In the middle-term, the main scope has been the development of a humanoid platform to carry out research on control, navigation and perception, and also to offer opportunities for under and pos-graduate students to apply engineering methods and techniques in such ambitious and overwhelming endeavour. Another objective of the project is to promote the involvement of teams of researchers and students in international level stages such as robot competitions of the grade of ROBOCUP and similar.

Research to date



The early activities were concentrated on design concepts and technological solutions to build a small-size 22 degrees of freedom humanoid robot at reduced costs, but still aiming at a fully autonomous platform for research. The humanoid robot combines a number of special-purpose pieces of hardware, deals with inputs from a variety of sensors with different time scales, and responds to external events in real time while attempting to meet several goals. The most relevant achievements of this implementation include the distributed control architecture, based on a CAN bus, and the modularity at the system's level.

On one hand, the key concept for the control architecture is the distributed approach, in which independent and self-contained tasks may allow a standalone operation. This feature allows localised control capabilities based on feedback control from several sensors, ranging from joint position to force sensors. On the other hand, a major concern of the project was to provide modularity at the system level. The main advantage is the possibility of reusing specific modules, in terms of both hardware and software, with no major efforts.

Although some issues are yet to be addressed, the current stage of development is already mature for practical experiments and to obtain the first conclusions on the potential of the proposed solutions. Particular attention was given to the low-level control of RC servomotors, as a relevant and profuse component of the humanoid system, and the improvement of the motor control (position, velocity and torque).

International visibility

The project was conceived having in mind the development of a prototype capable of participating in the ROBOCUP humanoid league. The first step was taken in February 2006 when a research group from UA submitted the qualification material. As result, the UA-Team was qualified to participate in the soccer competition that will take place in Bremen (for additional detail refer to: http://www.humanoidsoccer.org/teams.html), being the first Portuguese platform to achieve this goal. Nonetheless, the authors recognized that the performance was not enough to reach all challenges of the competition and decided to postpone the participation to the next edition.

At the same time, several international connections to research groups in the area are already established and likely to be reinforced (e.g., Changjiu Zhou, Singapore Polytechnic, Singapore; Jong-Hwan Kim from KAIST, FIRA President, South Korea; Bruno Maisonnier, Aldebaran Robotics, France).

Publications resulting from the project

The research results have been disseminated through publication in international and national conferences and journals. The topics covered include the mechanical design, mechatronic components and technological solutions [12,13,15], the distributed control architecture [7,12], the low-level control [7,11], and advanced control algorithms [8,9,10,14,16].

Workplan (6 months)

Motivation

Most of the final platform hardware was built and results are promising since the system now is able to stand, lean on the sides and forward-backward. As result, many approaches and research issues suddenly opened and will provide opportunities to test distributed control systems with possibilities that go far beyond the classical control of robots.

The proposed workplan aims the prosecution of ongoing developments covering the remainder hardware components and the control issues that must be solved regarding the feasibility of upright biped walking. The first step comprises the inclusion of vision and its processing, possibly with a system based on PC104+ or similar. The second step is dedicated to the study, implementation and test of basic locomotion primitives. From a control point of view, the proposed ideas involve investigation of alternative control laws and the implementation of motion behaviours, planning of the movements, limb coordination and posture stability.

In this line of thought, stepped-up efforts involving graduate students are now essential to achieve current aspirations and, furthermore, to open up a large range of future possibilities in what concerns interaction with humans and the environment. Beyond the ultimate goal of applicability and validation of the platform, we foresee an increased motivation with respect to future participations in international competitions.

Tasks' Description

The overall organization contains two main phases: development phase and evaluation phase. All steps are particularly relevant since they will reveal much about the problems, challenges and tradeoffs of the complete humanoid platform, as well as guide the selection of alternative designs.

1. **Main control unit.** The central unit is currently an off-board computer, but will be migrated to a local controller. The open source operating system Embedded Linux will be the first choice with a system, possibly, based on a PC104+ board. However, this task involves the investigation of other alternatives where their capabilities are highlighted in detail. Another related aspect to be exploited is the integration of vision and processing capabilities in the system. There is an on-going research work concerning a partial implementation of this approach that includes one compact FireWire camera and the use of the OpenCV library for object identification, segmentation and recognition.

2. **Gait patterns.** This task aims to ensure that all motion behaviours related to the ROBOCUP competition are implemented. Thus, one of the major endeavours of this work is to be able to achieve primitive locomotion steps, such as balancing, walking, turning and penalty kick. With the complexity of humanoid mechanisms and their desired capabilities, there is a need for a generalized framework where the desired whole-body motion behaviour can be easily specified.

3. **Control algorithms.** The humanoid system reached a point where intermediate and high level control can now flourish. One of the main issues is to investigate how centralised and local modules may co-exist and concur to provide robust and versatile operation. A hypothesis is that feedback control from several sensors (e.g., foot force sensors and inertial devices) and more advanced algorithms, such as adaptive and learning strategies, will certainly be a key issue for the next developments. A closely related topic that deserves significant attention concerns impact effects, coordinated motions during the double support phases and smooth transfer of support.

4. **Evaluate performance.** Research along the above development phases has been conducted with the purpose of clarifying the system's performance according to the initial ideas and requirements, and the possibilities of practical applications. At the end, we must have a rather complete picture on how the robot will operate, what are the difficulties and where to expect the biggest problems.

5. **Final report and publications.** The last activity includes a final report in full detail and the submission of 1 paper in international conference and/or journal.

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