Variable Speed Control … for a Compact Humanoid Robot

Milton Ruas†, Filipe M. Silva†, Vítor M. Santos*
a23570@alunos.det.ua.pt, vsantos@mec.ua.pt, fsilva@det.ua.pt
†Department of Electronics and Telecommunications
*Department of Mechanical Engineering
University of Aveiro, 3810-193 Aveiro, Portugal

Abstract: no fim ☺

1. Introduction

In recent years, the field of humanoid robotics has attracted the attention of a growing community, both from the industry and academia. It becomes increasingly evident the dichotomy in the styles used to design compact humanoid robots. On the one hand, several companies have unveiled walking robots with impressive designs and skills, as represented by Honda's ASIMO [1] and Sony's QRIO [2]. On the other hand, the continuous progress in robotics technology and the advances in computing hardware have promoted research on low-cost and easy-to-design humanoids, such as PINO [3], ESYS [4] and HanSaRam [4]. Here, the major challenge is to provide good performance of the control architecture and modularity at the system's level.

In this paper, we describe parts of the control system architecture for a small-size 22 degrees of freedom (DOF) humanoid robot. The research focuses on the distributed control architecture, with the emphasis being placed on how actuators are driven to achieve a desired performance. For the dimensions involved, off-the-shelf actuation technologies do not offer significant alternatives other than small servomotors, such as those from FUTABA, HITEC and similar. There are several general characteristics that have made them actuators of choice in a large number of other applications: small, compact and relatively inexpensive. In fact, the servomotor itself has built-in motor, gearbox, position feedback mechanism and controlling electronics.

However, this common method of driving a robotic joint can deeply influence the system's performance. First, it is well known that the control of the individual joints of the humanoid robot involves variation of the load inertia. Most certainly, such variations should be taken into account when trying to determine the proper control action; otherwise a decrease in performance will occur.

A second problem concerning the mentioned servomotors, is that they do not offer directly velocity control. Those servos can be controlled to move to any position just by using simple pulse width modulation (PWM). By design, servos drive to their commanded position fairly rapidly depending on the load (usually faster if the difference in position is larger).

A distributed set of microcontroller units is a key element to implement an adaptive scheme that compensates for the large changes in reflected inertia and providing variable velocity control. Instead of changing the motor internals, as some other authors do, it was decided to improve its operation by software. That is achieved by a variable PWM throughout the full excursion of a joint. The algorithm is based on dynamic PWM tracking using the servo own potentiometer for feedback. In other words, the software tracks motor position with time and adjusts the PWM in order to accelerate or pause motor motion (the loop is closed back to the controller). Further, generating the control signals in each controller unit will reduce significantly the overhead on the controlling software.

2. Project Overview and Framework

The main scope of the project beneath this paper 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. Purchasing a commercial platform carries prohibitive costs and it would reduce the involvement at the lowest levels of machine design, which was posed as a relevant pursuit for the desired engineering approach.

The ultimate goal of the project is to build a prototype capable of participating in the RoboCup humanoid league where a wide range of technologies need to be integrated and evaluated, giving added value for project-oriented education.

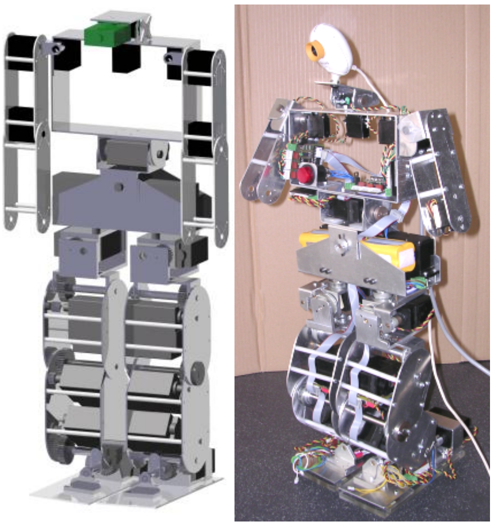


Fig. 1 - Model of the humanoid robot and current stage of implementation.

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.

2.1 Mechanical Design

In what concerns the physical and functional requirements, the initial considerations were largely imposed by the rules of the RoboCup, namely, the robot dimensions, the mobility skills, the high level of autonomous operation and the selected tasks.
In order to ensure proper and versatile locomotion, the robot is doted with six DOFs per leg, namely one universal joint at the foot, a simple joint on the knee and a spherical joint on the hip. Connecting the legs to the upper structure of the abdomen was decided to be done with two DOFs mainly aiming at greater flexibility in balance control and account for the perturbations of the centre of mass (CoM). So far, arms have been only partially defined and the head accounts for two DOFs for the vision based perception.
A complete humanoid model and a view of the current stage of implementation are illustrated in Fig. 1. This is a small-size robot with 22 DOF's, about 64 cm height and 6 kg weight.

2.2 Actuators and Sensors

For the dimensions involved, off-the-shelf technologies of actuation do not offer significant alternatives other than small servomotors, such as those from FUTABA, HITEC and similar. HITEC servomotors were chosen in our application. Power to drive the motors is another central issue since servos require a high current, namely at start-up and when producing motion in some configurations. Two ion-lithium batteries were installed and the system counts with a 7.2 V/9600 mAh pack, with maximal sustained current specified at more than 19A.

Perception assumes a major role in an autonomous robot and, therefore, it must be reliable and abundant. For this platform the following perception is available: each joint position (reading servo own potentiometer), joint motor current (related to torque), force sensors on the feet to measure ground reaction forces, inclination of some links (using accelerometers), angular velocity of some links (using a gyro) and vision unit. Up to now, only vision has not yet been implemented on the system. The remainder sensors were addressed with different levels of accuracy, but all potentially usable with current hardware.

2.3 Distributed Control Approach

From the very beginning of the project, one major concern has been the development of a flexible control system to allow for short and possibly longer term developments. The key concept for the control architecture is the distributed approach, in which independent and self-contained tasks may allow a standalone operation. The platform was given a network of controllers connected by a CAN bus in a master-multi salve arrangement. Master and slave units are based on a PIC microcontroller. Fig. 2 shows a generic diagram of controlling units.
The master unit relays all slave units by dispatching medium and high level orders and by collecting sensorial data to be exchanged with the central unit. The central unit is currently an off-board computer but will be migrated to a local controller based on a PC104+ board with image processing capability. Slaves can drive up to three servomotors, monitor their angular positions and electrical current consumption. The system joints have been grouped by vicinity criteria and are controlled by a dedicated board. Concerning additional sensors, each slave unit has the possibility of accepting a piggy-back board where additional circuit can lay to interface to other sensors (e.g., force-sensors, accelerometers and gyroscope).

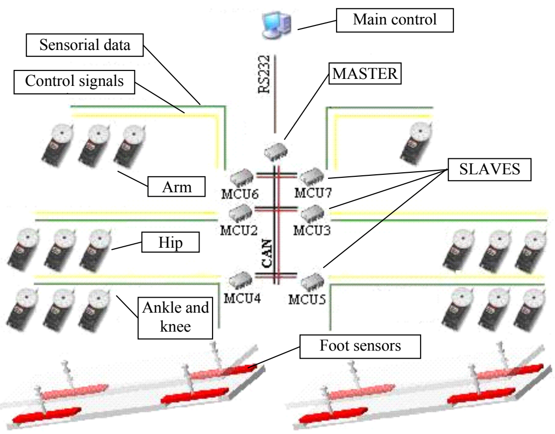


Fig. 2 - General architecture layout.

3. Servomotors and Their Control

3.1 Experimental Setup (section 2?)

3.2 Open-Loop Performance

- Load variation (step response)
- Set point control (table and graphs)
- Speed and current versus torque

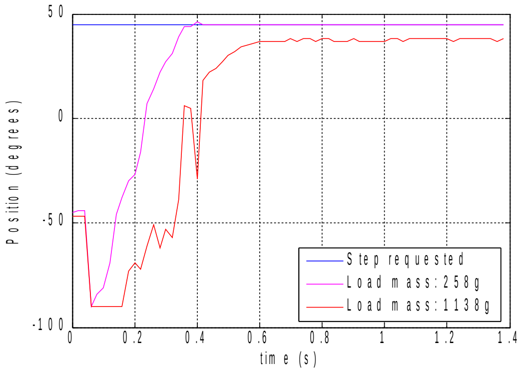


Fig. X – Step response for two loads from the position -45º to +45º.

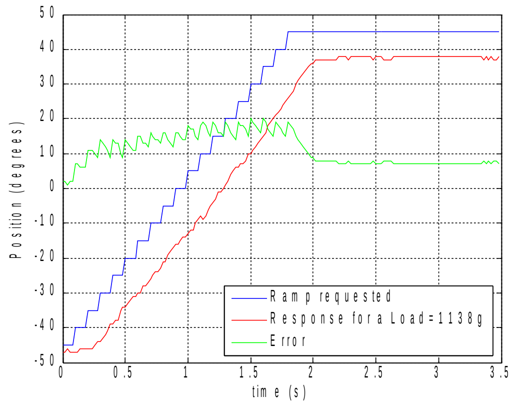


Fig. X – Ramp response for a load of 1138g from the position -45º to +45º.

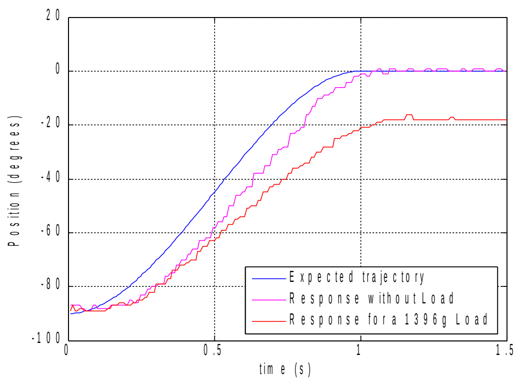


Fig. X – 3^{rd} order polynomial response for a

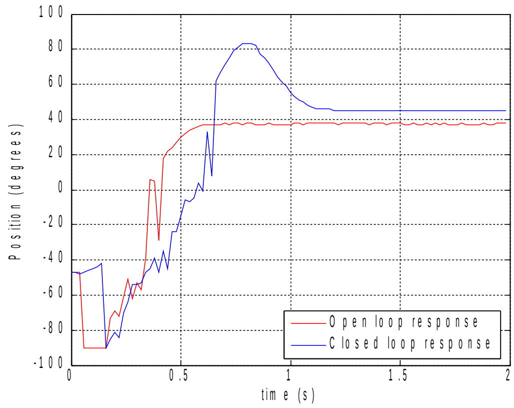
4. Adaptive Controller

4.1 Position Feedback Control Loop

- Blocks diagram

4.2 Adaptation to Load Variation

- Current measurement
- Adaptive algorithm added to 4.1
- Step response (overshoot, steady-state error!)



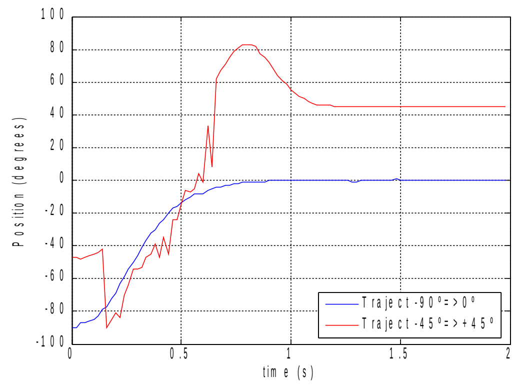


Fig. 3 – Comparacy between different trajects for a 1138g Load with external controller.

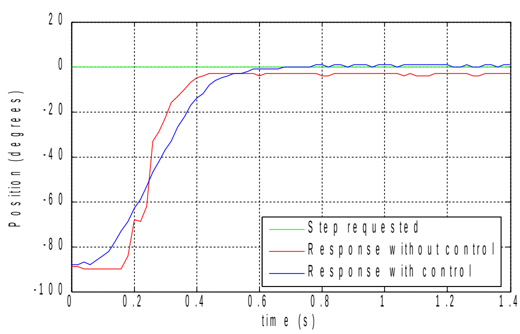


Fig. 4 – Step response with and without external controller with a 675g Load (K_P=0.07, K_D=0.00).

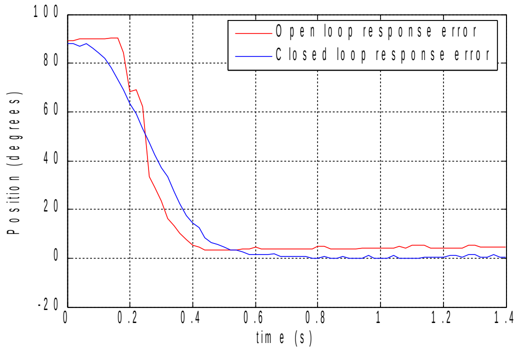


Fig. 5 – Error signal with and without an external controller (K_P=0.07, K_D=0.00).

4.3 Variable Velocity Control

- Trajectory generation
- Experimental Results

5. Conclusions