

Design and Optimization of an 8-links 3D Humanoid Robot with 16-DOF

Context of the work:

Design of humanoid robots is a complicated task while there are a high number of solutions for the realization of each articulation and many degrees of freedom (DOF). The optimization of the robot trajectories has a very significant impact on the design of the joint and on the control [1][2][3]. Recently, joint with rolling contact has been introduced in the design of the type of robots. The objective is to reduce the energy consumption and to improve the endurance of the structure.

Precedent works in the same area at the LCFC

The project R2A2 supported by the French National Agency for Research (ANR) is currently underway in the laboratory with three other academic partners and one industrial partner. The objectives of this project are to investigate the optimization of the design of a humanoid robot, to improve his autonomy and to build a platform for the tests.

Our task in the project is to optimize the trajectories of a seven-body humanoid robot composed by a trunk, two thighs, two shinbones and two feet, in 2D. To perform this, the optimization problem is changed in a parametric one. The walking trajectory considered is a succession of single support phase followed by an impact or a succession of double support phase, single support phase and impact. The chosen criterion for the optimization is the quadratic function of torques, which is called a sthenic criterion. It permits to know the energetic state of actuators to be able to select them, and also the lost of energy by Joule effect.

A Nelder-Mead algorithm (Simplex method) is used to minimize the criterion. The flexibility of this algorithm allows us to find a global minimum easier.

Two robot structures have been studied, a normal one which knees are articulated with a pivot, and an anthropomorphic one, with a rolling contact between the shinbone and the femur.

Description of the subject:

Now we wish to consider an eight-link robot composed by two feet, two shins, two thighs, a trunk and a pelvis (now we propose to differentiate the trunk and the pelvis). To achieve this, we introduce two degrees of freedom between these two bodies to simulate a spinal column.

Our aim is to extend this study over a 3D robot and to test the validity of our results on this new robot.

The optimization of the walking of a humanoid robot involves the two following difficulties: having to deal with the optimal control of a robot that has a lot of degrees of freedom, and that also has an extremely nonlinear dynamic model.

We shall transform this difficulty into a parametrical problem that involves a large number of parameters and into a convergence algorithm that finds the global minimum.

We will have to choose the type and order of the functions to use for the trajectories' generation. We also wish to test other types of criteria to achieve the trajectories' optimization.

[1] Grizzle J.W., G. Abba, F. Plestan (2001), Asymptotically Stable Walking for Biped Robots: Analysis via Systems with Impulse Effects. *IEEE Trans. Automatic Control*, 46(1):51-64, January 2001. This paper received the 2002 George S. Axelby Award for the Best Paper in the IEEE Trans. Automatic Control during the years 2000 and 2001.

[2] Chevallereau C., G. Abba, Y. Aoustin, F. Plestan, E.R. Westervelt, C. Canudas de Wit, J.W. Grizzle, (2003), RABBIT: A Testbed for Advanced Control Theory. *IEEE Control System Magazine*, 23(5):57-79, October 2003.

[3] Chevallereau C., G. Bessonnet, G. Abba, Y. Aoustin (2009) *Bipedal robots: modeling, design and walking synthesis*. Wiley ISTE Eds., New York, Control systems, Robotics and Manufacturing Series.

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Application:

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