A humanoid robotic leg balanced by its degraded virtual image submitted to electrostatic fields

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Overview

We propose a simple principle of humanoid robot balance through a mathematical description, some elements of simulation and finally some experimental results. We consider an alternative approach to ground reference points which seem to be too abstract to properly report the reality. We explore the feasibility of controlling the center of gravity of a multibody robotic system with electrostatic fields in order to guarantee its balance.

Principle

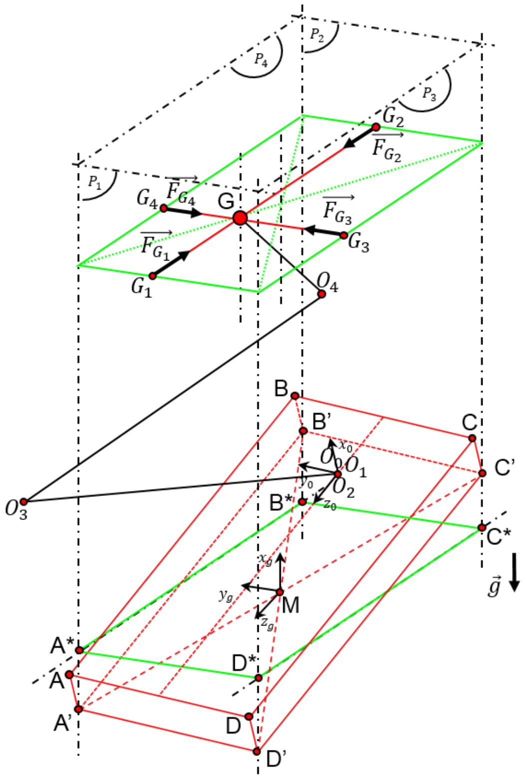
Let us consider a 4 DoF anthropomorphic robot leg embedded in the ground and the related modified Denavit-Hartenberg notation. This modelling is related to our experimental platform which also is a 4 DoF robotic leg.

In this study we will build a support polyhedron which is the extrapolation of the concept of support polygon. We generate a volume by translating, along the direction of the gravity $\vec{g}$, the support polygon projection of the foot on a plane that passes through M, orthogonal to vector $\vec{g}$. The support polyhedron is the intersection of this volume with the workspace of the robot.

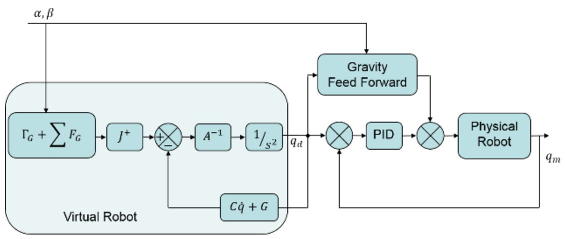
We begin with the generation of a surface $(A^*B^*C^*D^*)$ as a projection of the support polygon $(A'B'C'D')$ of the foot on a plane that passes through M, orthogonal to vector $\vec{g}$.

We define 4 planes P_1, P_2, P_3, P_4 generated by the support polygon $(A^*B^*C^*D^*)$ edges and the gravity vector. These planes will be the sources of the repulsive fields that will constrain the position of the CoG.

We also will suppose that each link's CoG is on the link principal. We will use a Coulomb law to represent through an electrostatic repulsive field, the natural tendency of a human to stay away from a position which will potentially lead to a fall.

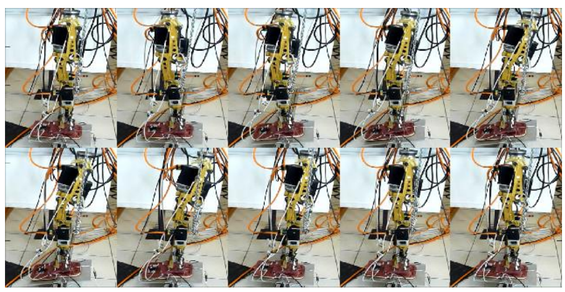


From a control point of view, we can summarize the balance algorithm on the following picture, with a robotic usual notation:



Experimental results

We use a B&R X20CP1586 CPU unit and ACOPOSmicro motor drives to run DC brushless motors. The robotic leg weights around 20 kilos.



The balance capability is restricted by the dynamics of the inclination sensor (ASM POSITILT PTAM 27). There is also an upper speed inclination limit dependent on the torque the motor can provides. In such a case, it will be preferable to consider a stepping strategy to recover balance.

Perspectives

In future works, we will explore the influence of the force fields parameters set on the balance capabilities of the robot, in order to find an optimal set achieving a good external disturbance rejection. We will also take into consideration different force fields and more advanced force field combinations.

Another work in progress concerns the balance algorithm expansion to a full 15 DoF locomotor system and the possibilities of a multiple CoG management by coherent electrostatic force fields.