A 3D Targeted Kicking Motion Generator

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I. Introduction

The kicking motion is not a new research issue in humanoid robots. It has been previously addressed several times [1]; however, the research has mainly been focused on the motion itself and the stability of the robot without considering any specific goal position, not even in 3D. On the other hand, some works dealt with the trajectory of the ball without solving the inverse problem nor considering the complexity of a humanoid robot [2].

This talk, on the other hand, addresses the solution of the corresponding inverse mechanics problem for driving the ball to a desired 3D goal position by using a humanoid robot, for which a suitable stable motion capable of achieving the required impact conditions is also required [3].

II. Proposed Algorithm

1) Given a 3D *goal position* for the ball and some motion characteristics, calculate its required *initial linear and angular velocities*; that is, the *inverse motion model*.
2) Assuming that the ball is initially steady, calculate the *impulse* required to produce the change in momentum leading to the desired motion, as well as where to apply it; that is, some *impact coordinates* defined on the ball. Both, the impulse vector and its point of application are the *required impact conditions*.
3) By taking into account both, the *impulsive model* of the ball and the robot, the required *approaching velocity* of an operational point on the swing foot is calculated.
4) By knowing the contact point and, proposing feasible attitudes for the support foot and waist, calculate the *configuration of the humanoid robot* during the impact.
5) By proposing detaching and landing footprints, generate a *trajectory for the swing foot*, as well as feasible *ZMP trajectory* that ensures *dynamic stability*.
6) Finally, stabilize the generated motion by means of a proper *stable trajectory for the waist*, capable of realizing the ZMP trajectory.

This algorithm, summarized as a flowchart in Figure 1, is explained in detail in Cisneros et al. [3]

III. Experimental and Simulation Results

To assess the algorithm we tested the kicking motion on a volleyball with the HRP-2, using the experimental set-up shown in Figure 2. For the experiment the goal position for the ball was $\boldsymbol{p}_G^d = \begin{bmatrix} 0.4 & 0.05 & r_B + 0.03 \end{bmatrix}^T$ m, where $r_B = 0.099$ m is its radius.

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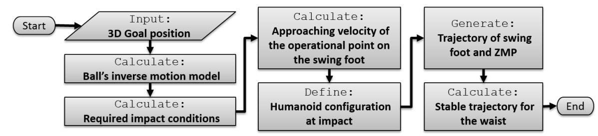

Fig. 1. Steps needed to solve the impulsive pedipulation problem.

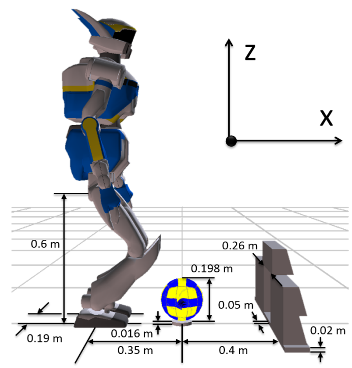

Fig. 2. Set-up.

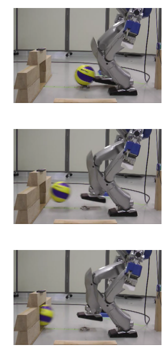

Fig. 3. Experiment.

Some snapshots of the experiment are shown in Figure 3, from which the estimated attained goal position was $\boldsymbol{p}_G^r = \begin{bmatrix} 0.408 & 0.05 & r_B + 0.028 \end{bmatrix}^T$, close to the desired one.

Also, to test the accuracy of the attained 3D goal position a batch of 1,952 simulations were performed, varying not just the position, but also other motion parameters. A couple of examples are shown in Figure 4 for which the desired 3D goal position was different. Finally, one of the several generated accuracy plots is shown in Figure 5, where high accuracy positions are shown in red and low ones in blue.

References

[1] J. Müller et al. Kicking a ball - modeling complex dynamic motions for humanoid robots. In *RoboCup*, pages 109–120, 2010.
[2] J.Y. Choi et al. Impact based trajectory planning of a soccer ball in a kicking robot. In *ICRA*, pages 2834–2840, 2005.
[3] R. Cisneros et al. Impulsive Pedipulation of a Spherical Object with 3D Goal Position by a Humanoid Robot: A 3D Targeted Kicking Motion Generator. *International Journal of Humanoid Robotics*, 13(2):43, 2016.

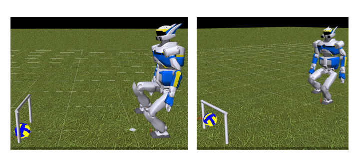

Fig. 4. Keyframes of two simulations for which different goal positions were specified.

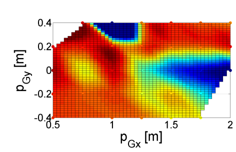

Fig. 5. Accuracy plot for $p_{G_z} = 0.1$ m.