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Pivoting Manipulation of a Large Object: A Study of Application using Humanoid Platform

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***Abstract*— Pivoting manipulation can be an alternative to pushing operation when the floor is not flat enough, or when the object to manipulate is too heavy. The technique of pivoting is used by humans to move large and bulky furniture from one place to another. The decomposition of the task of pivoting has already been studied, in particular with the use of two fingers of a robotic arm. This work intends to apply the technique of pivoting using an humanoid platform. The robot should be able to pivot the object and to walk with it to displace it to a specific remote location. The research achievements proposed here take place in a more long term objective aimed at improving the dexterity and the autonomy of humanoid robots. As a matter of fact, such robots should be able to handle objects and move around in the environment in an autonomous way. This paper describes the algorithm designed to perform the displacement of a large object using the pivoting technique. It also presents the results of the dynamic simulation and the results of the real hardware experiment of the HRP-2 platform performing the task.**

***Index Terms*— dexterity, pivoting manipulation, humanoid, autonomy.**

I. Introduction

Research on humanoid robots has lead to prototypes that can walk, turn on the spot or follow some specific trajectories. The most accomplished humanoid robots have the technical ability to cross irregular terrain, and even climb up stairs. However in most of the cases they do not have the intelligence to perform these tasks on their own, they need the assistance of a human operator. The autonomy of humanoid robots remains a big challenge. If humans want to use humanoid robots to assist them in their daily life, or to replace them to execute a specific task, they should equip the robot with some "intelligent" skills that allow the robot to exploit the capacity of its arms, its legs and its head in the same way a human knows how to do that. For example the robot should be able to open a door, a drawer or a window, cross a door frame, follow a path, move an object from one place to another, pick up and place an object, etc.

The objective of the current research conducted in the JRL is to increase the autonomy of humanoid robots by introducing a panel of intelligent skills. These skills should reproduce some of the techniques used by humans to move or displace objects.

The particular case this paper focuses on is the manipulation by a humanoid robot of cuboid heavy objects using the pivoting method [3]. If the robot can manipulate such an object, it will be able to displace it and furthermore to walk while displacing the object. The robot may also impose the trajectory of the object. The skill associated with this manipulation can be very useful because the robot would be able to move and displace heavy objects in an autonomous way. The concept of a humanoid manipulating an object in contact with the ground poses interesting research challenges. As a matter of fact the dynamic balance of the robot cannot be managed in the same way as in the case of the robot simply walking. The object it has to manipulate brings a new kinematic chain and exerts a reaction force on the robot that must be taken into account. Force and position controls must be used to manipulating the object. The shape, the mass and the friction coefficients of the object's faces are supposed to be known or downloaded wirelessly from some tags put on the object.

This paper is organized as follows. The next section presents the related work on the subject of manipulating tasks. Section III deals with the pivoting task. Section IV proposes an algorithm to deal with the manipulation. Section V gives simulation results using the dynamic simulator OpenHRP, whose results are verified by hardware experiments using HRP-2 humanoid platform described in section VI before concluding the paper.

II. Related Work

There are several kinds of non-prehensile manipulation. Pushing has been studied as a typical method [1], [2]. Aiyama et al. proposed a graspless manipulation using pivoting motion [3], and also the analysis and planning have been reported by Maeda et al. [4]. Pivoting is a useful way to move a heavy and large object precisely. We humans also make use of this method, for example to move an oil drum or a barrel.

Tasks involving interaction between humanoid robots and external environments or objects through contact have also been investigated. Yoshida et al. and Hwang et al