Hardware of Dynamically Walking Biped Robot with Leg-Wheel Combined Structure

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Summary

Each of two categories of control method of biped robots, ZMP-based and dynamic walking, has limitations. The ZMP-based method is inappropriate for real-time balancing, and the dynamic walking method needs continuous stepping for balancing even in constant position. An active wheel applied on foot is proposed to solve the problem of the dynamic walking method. This Leg-Wheel combined structure provides biped robots with abilities of efficient walking in rough terrains, climbing stairs and maneuvering with wheels in flat terrains.

Introduction

Control techniques for walking biped robots can be categorized in two big methods, Zero Moment Point (ZMP) based method and dynamic walking. The ZMP-based method has been applied to robots such as ASIMO (Sakagami et al., 2002), HUBO (Park et al., 2005) and many other humanoid robots. It is versatile but requires too many times to calculate joint angles for posture and trajectory of feet. Also, it needs every information of surroundings such as slope angle, wind speeds and etc. So this method has disadvantages to keeping balance in real time. In the contrast, the method of dynamic walking is specialized in balancing and it can react promptly to any disturbances of environments. Most of the robots that operate based on dynamic walking have Point-Foot structure. However, in bipedal robots such as Hume (Zhao et al. 2015), the Point-Foot structure irresistibly cause the robot to keep stepping even in stationary posture. So dynamic walking method on biped robot is unstable when it tries to keep in one position.

There were attempts to use wheels on biped robots (Hashimoto et al. 2005, Matsumoto et al. 1998) but they were not based on dynamic walking so they had same constraints with the ZMP-based method. Recently, Boston Dynamics (2017) unveiled newly developed robot named 'Handle', which showed a great performance and a vision of leg-wheel combined robot. However, it contains only one degree of freedom on a hip joint, so it can jump but it is unable to walk or run.

In this paper, Leg-Wheel combined structure which has an active wheel on each foot is presented to give one solution for the limitations of dynamic walking. This robot will be basically based on the dynamic walking method but when it is not walking, it keeps balance using wheels as similar as Segway does. A control method for walking will be based on Raibert's method (Raibert, 1986). In Stationary posture, a method based on a sum of wheels' vectors is planned to be newly developed beyond the inverted pendulum technique of two-wheeled self-balancing robots, so that robot can stay steady and be balanced in any posture.

Design

The biped robot has 5-DOF on each leg, three for hips, one for knees and one for rolling wheels as presented in Figure 1. 3-DOF on hips contain motions in flexion / extension, abduction / adduction, and eversion / inversion. Each segments corresponding to thigh and calf are designed to have a length of 100mm. The maximum height of the robot is approximately 372mm. Each joint have a range of motion as Table 1.

Joints	Range of Motion
Hip eversion/inversion	-30˚~30˚
Hip abduction/adduction	-30˚~17˚,
Hip flexion/extension	-90˚~90˚
Knee	30˚~180˚

Table 1. Each joint's Range of motion

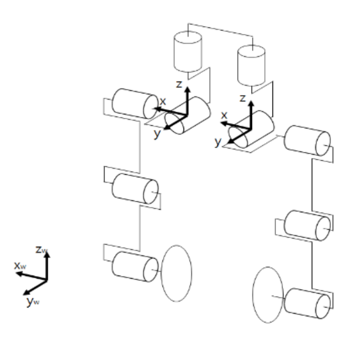

Figure 1. 10-DOF of the robot's Mechanical structure

structure is expected to move efficiently by walking in rough terrains and using wheels in flat terrains.

Hardware

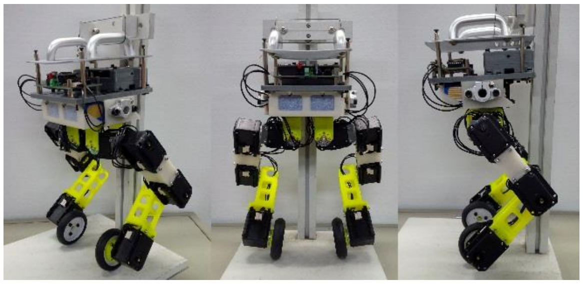

Figure 2. Isometric, front, side views of final design result

The robot's hardware is mostly fabricated by using a 3D printer as shown in Figure 2. Dynamixel MX-28T is used for actuating each joint. IMU sensor in Genuino 101 board is used for estimating attitude of the body. The Genuino board processes actuating Dynamixels. Raspberry Pi 3 Model B is mounted for calculating inverse kinematics and angles of each joint needed to walk and balance.

Experimental environment

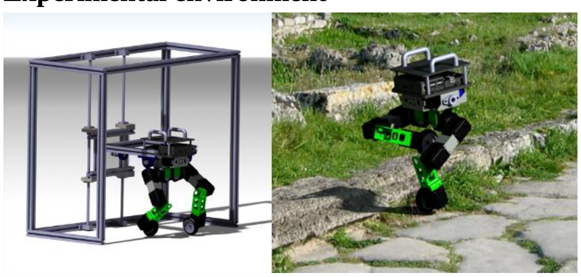

Figure 3. Experiment environment (Left) and example of future application (Right)

In experiment environment (Fig. 3), a body of the robot is limited to 3 DOF, rotation in x and y-axis and linear motion in the z-axis. Walking and balancing can be tested in this environment.

Discussion

The aim of this study is presenting one method that compensates the problem of the dynamic walking method by applying active wheel on feet of the bipedal robot. In this study, a newly designed leg-wheel combined structure is suggested. Compared to conventional dynamic walking robots, this structure has two additional DOF, each for actuating a wheel on a foot and for changing the orientation of a wheel on a hip. In addition, a novel algorithm for balancing of the bipedal robot on steady state is on a plan to be developed. As shown in Figure 3, this type of robot structure is expected to move efficiently by walking in rough terrains and using wheels in flat terrains.

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