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The Yobotics-IHMC Lower Body Humanoid Robot

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Abstract—**This video highlights work to date on the Yobotics-IHMC Lower Body Humanoid Robot. The robot is a twelve degree-of-freedom robot with force controllable Series Elastic Actuators at each degree of freedom. Control algorithms utilize Virtual Model Control, and foot placement is determined using Capture Regions. The robot can recover from moderate disturbances and walk on flat ground. Ongoing work is focused on improving robustness to disturbances, walking more quickly and efficiently, and walking over rough terrain.**

I. Introduction

THE Yobotics-IHMC biped (Figure 1) is a twelve degree of freedom lower-body humanoid robot. It has 3 degrees of freedom in each hip, one in each knee, and two in each ankle [1]. The robot was built during 2007 and 2008 and control algorithms were first implemented on the robot in late 2008.

Linear Series Elastic Actuators [2] with brushless DC motors are used at each joint. These actuators allow for high fidelity force control, which enables low impedance control methods. All 12 of the actuators used in the robot (Figure 2) are identical, except for their plunger end.

Virtual model control [3] is used to control the orientation and height of the body. Virtual springs and dampers are connected to the robot and their resulting forces are distributed between the support legs. The location of the Center of Pressure on the feet is used to control the forward and lateral center of mass position and velocity. Since we do not directly servo the joint angles of the robot, our control method is very compliant and robust to disturbances. While the robot is standing, the knee and ankle joints and even the foot location can externally be forced to any kinematically reachable position without affecting the control of the body.

During balancing and walking, we continuously update an estimation of the Capture Region [4][5]. The Capture Region is the region on the ground in which the robot must place its Center of Pressure in order to stop. As long as the Capture Region intersects the support polygon, the robot can stay balanced. Once the Capture Region no longer intersects the support polygon, the robot must take a step in order to regain balance. To compute the Capture Region, we use a simplified model based on the Linear Inverted Pendulum Model [6] with feet. With this model, the Capture Point dynamics are linear and first order and the Capture Region can be geometrically determined.

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Authors are with the Institute for Human and Machine Cognition, Yobotics, Inc., University of Michigan, Delft University, and Bucknell University. Updated project and contact information is available at http://www.ihmc.us/research/projects/HumanoidRobots/

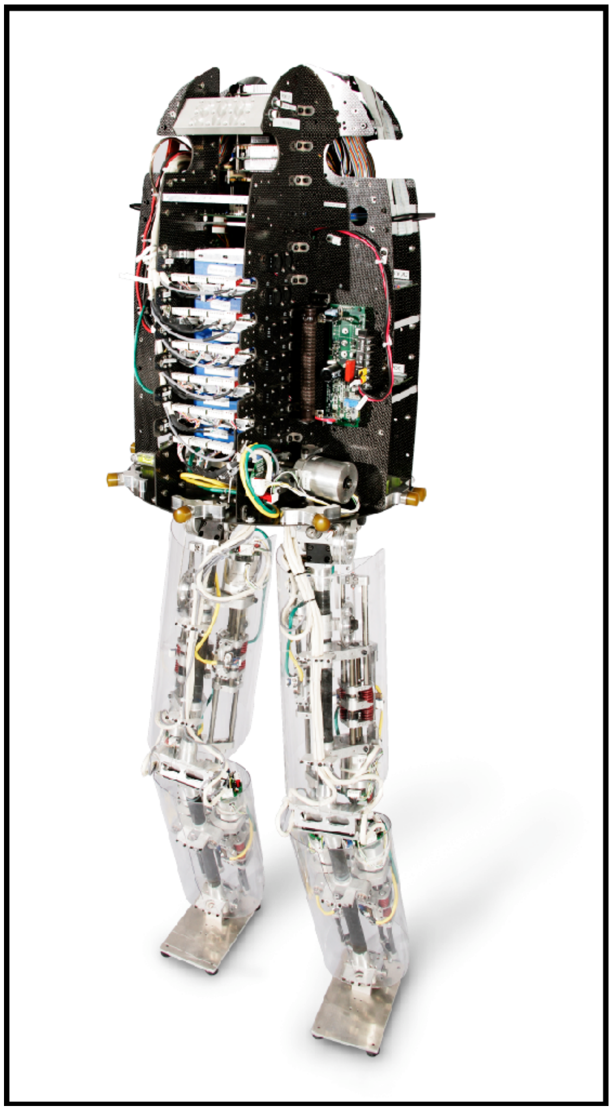

Figure 1: Front view of assembled robot body and legs.

In order to walk, the robot moves its Center of Pressure on its foot to guide the estimated Capture Region towards the desired location to step. The robot then swings its leg, stepping into the Capture Region and transferring support to the new stance leg. During double support the robot transfers its Center of Pressure on the trailing foot to the toe resulting in toe-off.

The controller does not use desired reference trajectories of the joint angles on the support legs. This allows for a straight legged gait and enhances robustness to disturbances such as small pushes.

Figure 2: Linear Series Elastic Actuator. All 12 actuators in the robot are identical except for the plunger ends.

In developing control algorithms for the robot, we make extensive use of the Yobotics Simulation Construction Set software and visualization tools (Figure 3). Our software is written in Java and runs using the Real Time for Java runtime environment from Sun Microsystems. The software that runs on the robot is identical to that which runs in the simulation. In addition, the simulation includes sensor noise and actuator limitations. Therefore, we can confidently develop and test algorithms in simulation knowing that we will get similar behavior on the real robot.

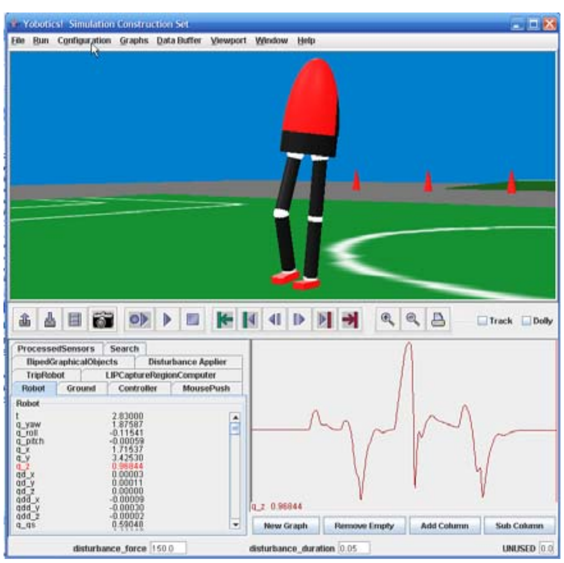

Figure 3: Screen capture of the Yobotics Simulation Construction Set software package. The exact same software that controls the simulated robot also controls the real robot and the user input GUI is the same for both.

The robot can currently stand and balance on one or two legs, recover from moderate sideways and forward pushes when standing on one leg, walk slowly stepping to desired stepping locations, and recover from small pushes while walking.

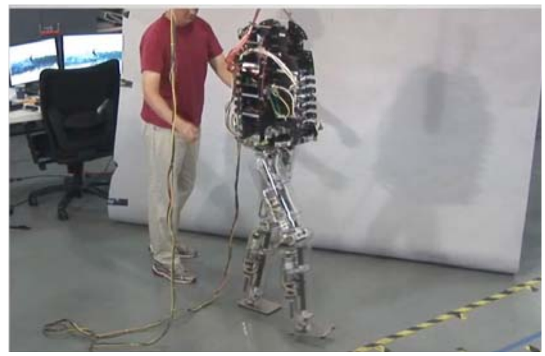

Figure 4: Recovering from a moderate forward push while standing and balancing on one leg. The robot continuously computes the Capture Region. Once the Capture Region no longer intersects the support foot, the robot determines where to step such that the Capture Region will intersect the support polygon once the step is complete.

II. Future Work

We are currently working on improving our algorithms to allow for recovery from larger pushes and other disturbances, faster and more efficient walking, and walking over rough terrain. We are designing an improved force-sensing foot and a vision head for the robot.

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