Online Dynamic Motion Planning and Control for Wheeled Biped Robots

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***Abstract*—Wheeled-legged robots combine the efficiency of wheeled robots and versatility of legged robots. This paper introduces a planning and control framework to realise dynamic locomotion for the wheeled biped robots. The framework has a hierarchical structure and is implemented in a model predictive control (MPC) fashion. To generate the hybrid rolling-walking motion, motion synthesis approach has been used. More specifically, the Cart-Linear Inverted Pendulum Model (Cart-LIPM) and the under-actuated LIPM are proposed to model rolling and walking motion. The hybrid motion is composed from these two. The generated motion is then tracked by a inverse dynamic whole-body controller which coordinates all joints including the wheels. To validate the proposed approach for hybrid motion generation, two scenarios involving different types of obstacles are designed in simulation. The robot overcomes the obstacles successfully with newly enabled hybrid locomotion capability. To the best of our knowledge, this is the first time that such online dynamic hybrid locomotion has been demonstrated on wheeled biped robots.**

***Index Terms*—Wheeled Robots, Legged Robots, Wheeled Biped Robots, Hybrid Locomotion, Cart-LIPM, Under-actuated LIPM, Optimal Control, Model Predictive Control, Hierarchical Control**

I. Introduction

Wheeled robots move faster and more efficient than legged robots in structured environment. However, Legged robots offer more possibilities in terms of more challenging terrains such as stairs and narrow trenches. Wheeled-legged robots have the potential to combine the best of both worlds.

II. Control Framework

The hierarchical control framework as shown in Fig. 1 has been used to generate the hybrid motion for the wheeled-biped robot. The inputs for the entire control hierarchy is the user given center of mass (CoM) reference velocity $\boldsymbol{v}_c^* = [\dot{x}_c^*,\ \dot{y}_c^*,\ 0]^T$. The other input for the motion planner is the contact sequence generated by the state machine.

In the motion planner, we compose two template models to plane the hybrid locomotion for the wheeled biped robots. For the lateral direction walking motion, we use the under-actuated LIPM. For the forward rolling motion, we propose the Cart-LIPM as the template model to plan the rolling. Based on the desired CoM velocity and the contact sequence, the motion planner will generate the CoM and end-effector trajectories in

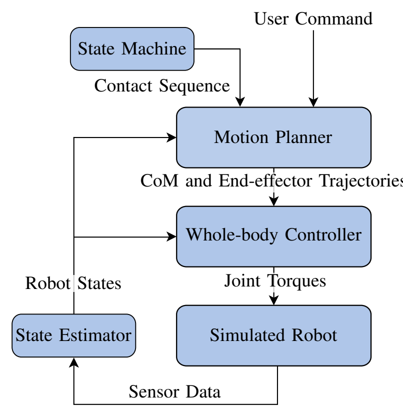

Fig. 1: Control Framework.

Cartesian space. A whole-body controller is then used to track these generate trajectories by finding the optimal joint torques while considering all sorts of constraints. In the whole-body controller, nonholonomic constraints on the wheel is defined as a combination of three constraint: pure rolling constraint, non-sliding constraint and unilateral constraint. Simulation results are given below and it shows that the hybrid locomotion mode do help in certain scenarios and it provides the robot more possibilities to traverse cluttered environment.

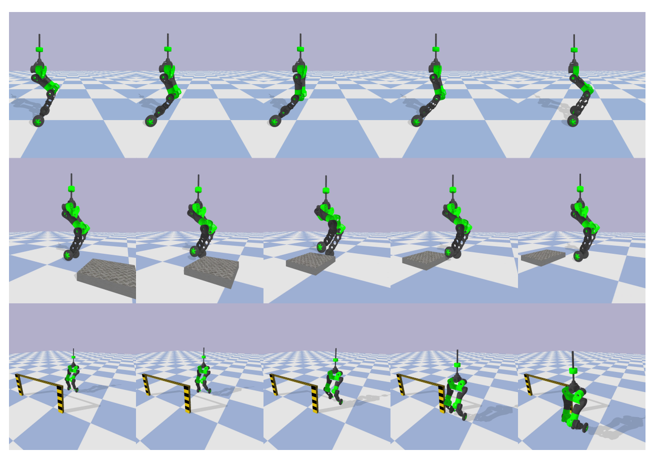

Fig. 2: Wheeled biped robot different types of motions. The first row depicts the rolling motion. The second row and third row shows the hybrid motion enabling the robot to overcome different types of obstacles.

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