Reactive Load Carrying with Quadruped Robot CENTAURO

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***Abstract*— We propose a reactive legged locomotion planning framework and implement a demanding application where our robot, CENTAURO, walks with a maximum of 20 kg payload on arms. Center-of-mass (CoM) trajectories are generated online in a model predictive control (MPC) fashion, trading off between larger stability margins and more leg utilities. Vertex-based zero-moment-point (ZMP) constraints are also implemented to ensure quasi-static motions. A Kalman filter is further employed to estimate the CoM states together with the impact caused by external loads, the estimation of which is then fed back to update the motion planner. This allows the robot to react to unknown weights mounted on it, and we illustrate the effectiveness of the proposed planning scheme through several load-carrying simulations and experiments.**

I. Introduction

CENTAURO, a hybrid legged-wheeled quadruped robot designed in our lab recently, features significant strength to execute tasks with heavy payloads such as in disaster rescue situations or demanding collaborations. It is reported to possess an exceptional ability of carrying a maximum 12 kg payload on one arm or a 60 kg payload on the pelvis. [1].

However, the center-of-mass (CoM) of the whole system can be shifted by about 10 cm when the robot takes its maximum capacity on arms, which could lead to severely unstable walking in load-carrying tasks. When applying the motion generation strategies proposed in our previous works [2] [3], the robot is unaware if a load is mounted and what is its potential influence to locomotion, and thus is unable to walk stably when carrying heavy payloads on arms. Therefore, we are motivated to generate reactive locomotion by estimating the impact of external loads and feeding it back to update the planner. We conduct several tests in both simulations and experiments to demonstrate the effectiveness of the proposed framework and compare the performances of applying different strategies in load-carrying tasks.

II. Overview

We follow a commonly employed way of generating legged locomotion to develop a two-level hierarchical scheme, with the upper layer to select prospective footholds and generating trajectories of the CoM and legs, and the lower layer to compute joint commands through a whole-body controller. Major components of the proposed scheme are shown in Fig. 1.

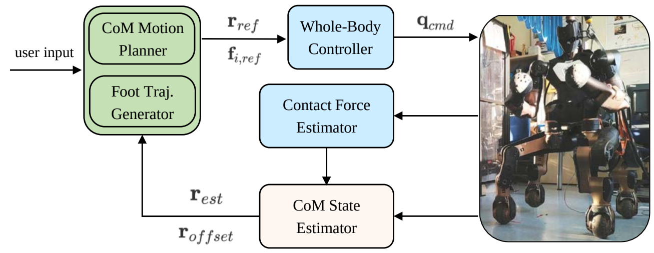

Fig. 1. Overview diagram of the locomotion planning and control framework. Blocks with light green shades run at 10 Hz, blocks with light yellow shades run at 100 Hz, and blocks with light blue shades run at 200 Hz.

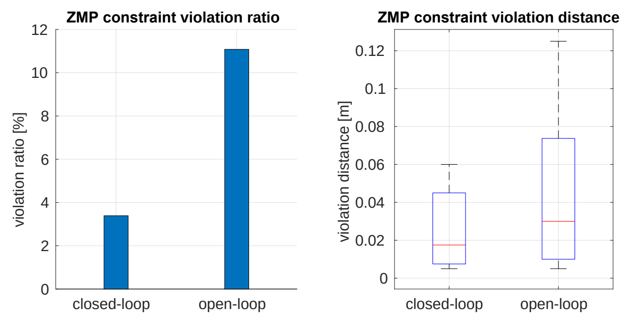

Fig. 2. Comparison of locomotion stability between closed-loop walking and open-loop walking when CENTAURO moves with 20 kg weights on arms. Left: Among all the sample points during walking, the proportion of cases where the ZMP constraint is not satisfied. Right: A box plot of the shortest distance between ZMP and the corresponding support polygon for those unstable cases.

III. Result

The improvement of walking stability can be seen in Fig. 2, where the robot is carrying some weights of 20 kg on arms and walks around in experiments. The closed-loop walking is generated by applying the currently proposed strategy while the open-loop walking is generated without knowing the impact of loads.

References

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