TECHNISCHE UNIVERSITÄT MÜNCHEN
Human-centered Assistive Robotics
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MASTER'S THESIS
for
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Online Virtual Repellent Point Adaption for Biped Walking

Problem description:

Legged robot locomotion is a challenging problem due to its hybrid dynamics (discrete contact sequencing and continuous whole-body motion), and the constraints imposed on the contact forces. Recently, the related concepts of the three-dimensional Divergent Component of Motion (DCM) and the Virtual Repellent Point (VRP) were introduced in [1], decomposing the second-order center-of-mass (CoM) dynamics into two first-order dynamics, with the CoM converging to the DCM (stable dynamics), and the DCM diverging away from the VRP (unstable dynamics). Based on this formulation, continuous closed-form DCM and CoM trajectories can be generated using a piecewise interpolation of the VRP trajectory over a sequence of waypoints [2]. This highly compact motion representation is a natural way of handling the locomotion hybrid dynamics, with the discrete contact sequencing being mapped onto the VRP waypoints. This approach has been used successfully for bipedal locomotion in [1], and dynamic multi-contact motion in [3].
For a practical implementation on a real robot there are two important aspects to consider: First, during the swing leg motion, the whole-body dynamics requires a compensating torque to be applied at the point of contact. This corresponds to a shift of the center-of-pressure (CoP) within the foot from the nominal position (typically the middle of the foot). Second, model uncertainties lead to imperfect tracking of the reference trajectories, and require adjustments of the commanded VRP. Both aspects thereby limit the maximum walking speed and reduce the robustness with respect to external disturbances. A compensative Zero Moment Point (ZMP) trajectory addressing these two aspects in the context of the Linear Inverted Pendulum (LIP) model was proposed in [4].
This thesis will apply the iterative learning control approach similar to the one presented in [4] for the LIP to the three-dimensional DCM framework. The goal is to learn and generate online a VRP compensation trajectory which reduces the CoP motion within the foot and keeps the commanded VRP close to the center of the foot. The algorithm will be tested in simulation using a point-mass model and a whole-body simulation, and in experiments with the humanoid robot TORO.

Tasks:

- Literature research on 3-D DCM-based control, and online iterative learning approach for ZMP compensation
- Build an online learning framework for VRP compensation against unmodeled uncertainties
- Test the approach in simulation and on the real robot

Bibliography:

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