Title

Highly dynamic whole-body motion generation/planning for humanoid robot using full state feedback in closed-loop quadratic programming control

Abstract

The DARPA Robotics Challenge (DRC) featured humanoid robots that proved capable of solving in a semi-autonomous manner various tasks with a level of dexterity and versatility close to those of human operators. The fastest humanoid completed the challenge in 50 minutes and 26 seconds (ending up in the second position overall, the competition was won by a wheeled humanoid robot in 44 minutes and 28 seconds). A human operator could have completed all the tasks in around 5 minutes. After years of research, humanoid motion generation, for anything other than cyclic walking, is still confined to “slow”, “cautious”, and “quasi-static” motions.

The aim of this thesis is to study and solve the motion generation problem of a humanoid robot in order to realize highly dynamic yet robust motions. The targeted level of dynamism will be that of off-line trajectory optimization approaches, using on-line quadratic-programming (QP)-based whole-body controllers. Recent advances in humanoid robot state estimation will be exploited to design a feedback strategy on the full state of the humanoid robot, including the 6D position and velocity of the free-floating base, in order to effectively close the loop of the QP controller. The closed-loop controller should be able to reject perturbations (external forces, collisions) and be robust to modelling errors (e.g. unmodeled passive compliance) and to the real contact state with respect to the planned one. Moreover, the QP approach itself will be redesigned by studying alternative formulations to the cost function consisting in a weighted sum of acceleration errors, where the desired acceleration is derived from a mass-spring-damper model of the tasks with gains (stiffness, damping) hand-tuned by the operator, and that are fixed to conservative values to ensure a safe motion. The thesis will study how to automatically derive values for these gains to ensure highly dynamic motions or explore alternative models other than the mass-spring-damper model. One of the tasks (Center of Mass) is particularly critical in the motion generation. The thesis will also study alternative formulation for this task to replace the mass-spring-damper model, e.g. as inspired by Model-Predictive-Control (MPC)-based approaches extensively used in bipedal walking pattern generators.

The research will be carried out at LORIA lab in Nancy France, in the LARSEN team. Implementation will be done on the team’s humanoid platforms, namely the iCub robot the team already has, and the expected new-generation humanoid robot the team will acquire by the year 2019.

Requirements

The candidate will have excellent knowledge of robotics theory (modeling, kinematics, dynamics, control), optimization (quadratic, nonlinear, optimal control, trajectory optimization), and control theory (state estimation, observers, feedback control, stabilization). He/she will also have demonstrated strong skills and proficiency in ROS (Robot Operating Systems), Linux environment, C++ and Python development.

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