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Guest Editorial Special Issue on Progress and Open Problems in Motion Planning and Navigation for Humanoids

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Humanoid robots have become more and more popular, which is illustrated by the increasing number of available platforms and the huge number of high-quality publications in the research area of navigation and motion planning for humanoids. Recently, a lot of progress has been made in the areas of 3D perception, efficient environment representation, fast collision checking, as well as motion planning for navigation and manipulation with humanoids, also under uncertainty and real-time constraints. All these techniques work well for their independent application scenario, however, currently no system exists that combines the individual approaches. Thus, we are still far from the deployment of a humanoid robot in the real world. The goal of this special issue is to identify gaps in the research directions and to discuss which aspects need to be considered for combining the different approaches so as to enable humanoids to reliably act and navigate in real environments for an extended period of time.

Keywords: Humanoid; Walking; Dynamics; Vision

1. Introduction

In December 2013, the first trials of the DARPA Robotics Challenge took place and have shown the maturity of the mechatronics platforms. Some of the teams have been able to build amazing robots in just one year. Teleoperation has been a deliberate choice to control the robots, and therefore they have been quite slow. In addition the human operator had to spend quite some time to make decisions about adequate motions for those very complex mechanical systems. It is very unlikely that this solution is sustainable for fast decision making. Long time runs would involve a high cognitive load for the human operator. Deployment of humanoid robots in factories of the next decades will also demand for motion planning based on 3D perception. The difficulties are many: the noise involved by the perception, the complexity of the number of actuators, and the non-linear constraints to which the motion is submitted. Despite such difficulties the last 5 years have seen tremendous breakthroughs leading to humanoid robots going outside laboratories, walking on relatively uneven terrains, and playing soccer. Still if there is a recognized body of knowledge on making humanoid robots walking on flat floors, efficient deployment on complex environments needs for efficient and pragmatic solutions. This special issue describes research directions in tackling these problems regarding navigation, collision detection, whole body control, and motion planning in realistic environments.

2. Guide to the special issue

Park et al. present an algorithm to plan motions for high degree of freedom robots in dynamic environments. A key point to break the complexity is to divide the high-dimensional motion planning problem into a sequence of low-dimensional subproblems. It corresponds to a functional partitioning of a humanoid robot for instance. Optimization based planning and trajectory perturbation are used to compute collision-free and smooth paths for each sub-problem. The trajectory of an obstacle is considered over a short time, and the collision free trajectory of the robot is computed incrementally. Extensive simulations of the algorithm implemented on a massively parallel GPU card are presented.

Nishi et al. propose a method to plan motions in a complex environment considering both the dynamics of the robot and the geometrical constraints. It is realized by first planning connected double support foot poses. This ensure a first feasible solution which is thin out by inserting bypasses nodes that are optimized by Dijkstra's method. Discontinuities are removed by several smoothing techniques including boundary conditions on point-mass model, NURBS interpolation to ensure that no collision occurs, and timing of the motion to enforce dynamical constraints. The method is tested in simulation against a kitchen like environment.

Hornung et al. propose a method for a humanoid robot to localize itself accurately in a given 3D world model. The method relies on Monte Carlo localization and integrates range measurements from a laser scanner or a depth camera, together with attitude date and information from the joint encoders. To climb stairs, the needed accuracy is obtained by monocular vision within an improved proposal distribution. The methods are tested in extensive real-world and simulation experiments.

Ramos et al. present a method to handle walking on rough terrain using inverse dynamics control and information from a stereo vision system. It shows how to adapt the feet pose from the solution given by a pattern generator assuming classically a flat ground. Then using an inverse dynamics scheme the overall equilibrium of the robot is maintained by solving a quadratic problem including strict constraints (such as the limits on the joint position). Real data are used on the OpenHRP accurate simulator of the HRP-2 humanoid robot.

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