ABSTRACT

Human-Inspired Control of Bipedal Robots

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Abstract:

Bipedal robots provide an important example of a cyber-physical system (CPS). As a result, understanding the process of realizing formal results experimentally, and the software structures needed to do so, can yield important insights into software synthesis for complex CPS. This talk presents the process of formally achieving human-like bipedal robotic walking by synthesizing controllers inspired by human locomotion data, discusses the software structures used in realizing these controllers and demonstrates these methods through experimental realization on two bipedal robots: AMBER and NAO.

Motivated by the hierarchical control present in humans, the fundamental principle behind this process is that the essential information needed to understand walking is encoded by a simple class of functions canonical to human walking. In other words, we view the human as a complex system, or "black box," and outputs of this system (as computed from human locomotion data) are presented that appear to characterize its behavior—thus yielding low dimensional characterization of human walking. By considering the equivalent outputs for the bipedal robot, a nonlinear controller can be constructed that drives the outputs of the robot to the output of the human; moreover, the parameters of this controller can be optimized so that stable robotic walking is provably achieved while simultaneously producing outputs of the robot that are as close as possible to those of a human. The end result of this process is the automatic generation of bipedal robotic walking that is surprisingly human-like. Extensions of these ideas to different walking behaviors, e.g., stair climbing, will be discussed, along with their application to simulating and designing controllers for prosthetic devices. Finally, the experimental realization of these formal results on two robotic platforms—an underactuated 2D biped, AMBER, and a fully actuated 3D robot, NAO—will be demonstrated.