Legged anthropomorphic robots are a prime example of complex, highly nonlinear control systems. For example, the dynamics of the DLR C-Runner (Compliant Runner), a legged robot designed at the German Aerospace Center (DLR) [1], is described by a nonlinear, high-dimensional hybrid system, see Fig. 1. The different hybrid domains, defined by whether the feet of the robot are in contact with the ground, are defined by complex, physically motivated constraints. This makes the control of bipedal robots one of the most challenging controller synthesis tasks of today.

The goal of this master thesis is to develop a two-step approach, similar to [2], to synthesize a controller that generates a stable, physical realizable walking gait for the DLR C-Runner. In the first step, a classical controller is designed to drive certain outputs of the system to zero. The resulting controlled system evolves on a lower dimensional manifold and is described by the so-called hybrid zero dynamics. In the second step, the symbolic synthesis approach [3] is used to design a controller for the hybrid zero dynamics to enforce a given specification. Here, the specification has to be designed so that its satisfaction implies a stable, physical realizable walking gait on the bipedal robot. Relaying on the symbolic synthesis for the stabilization, a controller is obtained which guarantees the specification. Therefore resulting in an improvement as compared to state-of-the-art approaches based on numerical optimization. The resulting controller should be first, evaluated in simulation and second, implemented and analyzed on the DLR C-Runner. If time permits, an alternative, passivity-based technique (which is known to be less sensitive to modeling error than feedback linearization) should be applied and implemented to control the outputs of the system to zero.

Work Packages:
(1) Design the classical feedback controller to linearize and drive to zero the output dynamics
(2) Analyze hybrid zero dynamics and formulate the specification resulting in a stable, physical realizable walking
(3) Design a symbolic controller for the hybrid zero dynamics to enforce the specification
(4) Verify the design in a simulation
(5) Implement and evaluate the controller on the robot
(6) Comparison with existing approaches

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References