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TWO BENCHMARKS FOR OPTIMIZATION OF LEGGED ROBOTS – HYBRID SYSTEMS WITH IMPULSE EFFECTS

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Abstract. There has been an increasing trend towards using optimization to create legged robot gaits while maximizing or minimizing one or other performance metric (e.g., energy usage, speed). Because legged systems have discretely changing equations of motion, i.e., a hybrid system, such optimizations are challenging. If the optimization is incorrectly formulated it can produce infeasible or non-optimal results. There is a need to create benchmarks that can be used to test optimization softwares and techniques for legged robots. In this paper, we present two benchmarks for legged robots; passive dynamic walking and energy-optimal level ground walking. Next, we show how to use these benchmarks to validate optimization code for the given robot model, not necessarily similar to the benchmark model, by appropriate simplifications. Our hope is that such benchmarks will provide the legged robot researcher with a useful tool to not only check the optimization code but to aid in proper selection of the optimization method and/or software.

Keywords. Passive dynamic walking, Legged locomotion, Optimization benchmark, Energy-optimal control, Hybrid system.

1 Introduction

The use of optimization to create controllers for legged robots has become a popular research topic. Using optimization one can create gaits that achieve multiple objectives simultaneously. For example, creating a walking gait that minimizes the energy use but achieves a given speed and/or step length.

While there is a plethora of general purpose optimization softwares and techniques (e.g., single shooting, direct collocation), it is unclear if a given tool is able to produce the 'best' result. Although the software might be tested on generic benchmark problems (e.g., [9]) they may not work well on legged locomotion problems because of the hybrid nature of locomotion (equations of motion change with time). Sometimes the poor performance or