Hybrid Reduction of a Bipedal Walker from Three to Two Dimensions

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Abstract

Because the complexity of bipedal walking robots doubles when increasing a model's dimensions from two to three, many previously established analytical techniques are computably impractical for three-dimensional models. If bipedal walkers can be analyzed in three dimensions, we can more accurately reproduce the humanoid walking that we observe in our three-dimensional world. This paper offers a systematic approach to reducing a 3D biped model into two dimensions, on which 2D analytical methods can be used, such as numerical analysis to find the limit cycles that result in asymptotically stable walking. The hybrid reduction consists of five stages: hybridization of the robot's motion, Lagrangian formulation of the continuous dynamics, formulation of the discrete impact transition map, dependency simplification, and the Lagrangian reduction. We present the results of this method's application on a simple compass-gait biped using a fixed angle simplification and Routhian reduction. We show that the reduced model is related to the analogous 2D model by a computable augmented potential component. The model is easily brought back into 3D using the Routhian relation and can be implemented in a simulation for analysis. Moreover, we provide supporting evidence for periodicity in the reconstructed 3D model given periodicity in the reduced 2D model. The outcome of this paper is a general framework by which previously established techniques can be applied to three-dimensional biped models.