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**Optimal bipedal interactions with dynamic terrain: synthesis and analysis via nonlinear programming** CHRISTIAN HUBICKI, DANIEL GOLDMAN, AARON AMES, Georgia Institute of Technology — In terrestrial locomotion, gait dynamics and motor control behaviors are tuned to interact efficiently and stably with the dynamics of the terrain (i.e. terradynamics). This controlled interaction must be particularly thoughtful in bipeds, as their reduced contact points render them highly susceptible to falls. While bipedalism under rigid terrain assumptions is well-studied, insights for two-legged locomotion on soft terrain, such as sand and dirt, are comparatively sparse. We seek an understanding of how biological bipeds stably and economically negotiate granular media, with an eye toward imbuing those abilities in bipedal robots. We present a trajectory optimization method for controlled systems subject to granular intrusion. By formulating a large-scale nonlinear program (NLP) with reduced-order resistive force theory (RFT) models and jamming cone dynamics, the optimized motions are informed and shaped by the dynamics of the terrain. Using a variant of direct collocation methods, we can express all optimization objectives and constraints in closed-form, resulting in rapid solving by standard NLP solvers, such as IPOPT. We employ this tool to analyze emergent features of bipedal locomotion in granular media, with an eye toward robotic implementation.

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