

Robotic Uses of Tails: Self-Righting

Chad C. Kessens and Craig T. Lennon
United States Army Research Laboratory

Keywords-autonomous, self-right, design, morphology

The ability to self-right, meaning return to a preferred orientation for mobility, has been identified as a critical robotic capability by soldiers and law enforcement officials [1]. In nature, self-righting can literally mean the difference between life and death. As such, we endeavor to develop a general framework whereby any given robot can autonomously generate a self-righting path whenever possible given its morphology. Further, we seek to understand the relationship between a robot's morphology and its ability to self-right, thereby allowing one to design robots that are able to right themselves under a more diverse set of circumstances.

One possible feature of a robot that could prove very useful for self-righting is a tail. Nature has shown numerous examples of animals utilizing tails for this activity, including geckos [2] and horse-shoe crabs [3]. Tails have the potential to be useful for altering the orientation of the body through strategies such as pushing, pulling, center of mass control, and momentum change.

In this work, we begin by discussing our general framework [4], whereby we construct a conformation (state) space map and represent it as a directed graph with associated costs. Each node represents a manifold that is continuously connected through quasi-static stability. Edges represent unstable transition points where the robot rolls from one state to another. Costs are associated with minimum changes in energy between states. We then discuss a metric that can be used to evaluate any given robot's ability to self-right and compare disparate designs [5]. Using a parameterized notional robot design (Fig. 1), we examine the effect of various tail parameters on the robot's ability to self-right, such as mass (Fig. 2) and length (Fig. 3). An application of this technique is then demonstrated for optimizing the tail mass on a physical system. Next, we discuss how the tail might be used as part of a dynamic strategy for righting the robot from states that are unable to reach the goal quasi-statically. Finally, we discuss how we hope to further understand the tail's role for this important function.

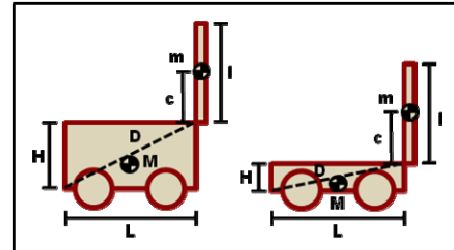


Figure 1. Notional Robot Design

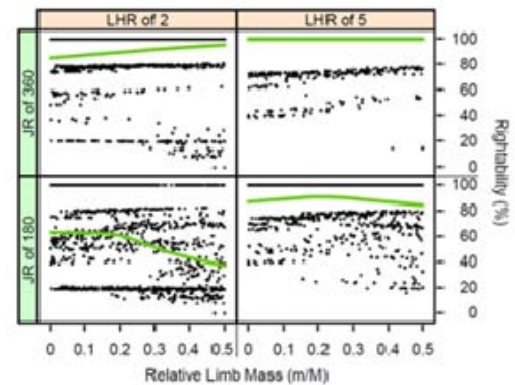


Figure 2. Tail Mass Effect

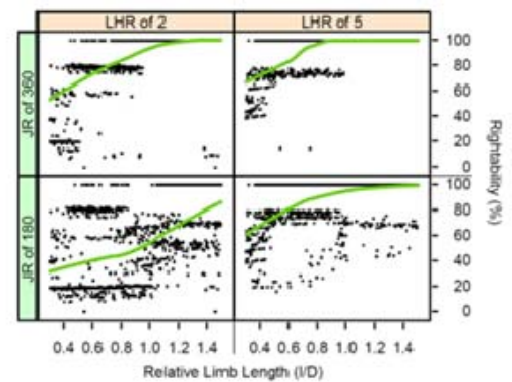


Figure 3. Tail Length Effect

This work is supported by the United States Army Research Laboratory.

- [1] H.G. Nguyen and J.P. Bott. "Robotics for Law Enforcement: Application Beyond Explosive Ordinance Disposal." SPIE: Enabling Technologies for Law Enforcement and Security. Bellingham, WA, USA. Vol. 4232. 433-454. 2001.
- [2] A. Jusufi, D.I. Goldman, S. Revzen, and R.J. Full. "Active Tails Enhance Arboreal Acrobatics in Geckos," *Proceedings of the National Academy of Sciences*, 105(11):4215-4219. 2008.
- [3] G. Krummel, K.N. Kaipa, and S.K. Gupta. "A Horseshoe Crab Inspired Surf Zone Robot With Righting Capabilities." ASME 2014 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. 2014.
- [4] C.C. Kessens, D.C. Smith, and P.R. Osteen. "A Framework for Autonomous Self-Righting of a Generic Robot on Sloped Planar Surfaces." IEEE International Conference on Robotics and Automation (ICRA). St. Paul, MN, USA. 4724-4729. 2012.
- [5] C.C. Kessens, C.T. Lennon, and J. Collins. "A Metric for Self-Rightability and Understanding Its Relationship to Simple Morphologies." IEEE International Conference on Intelligent Robots and Systems (IROS). Chicago, IL, USA. 2014.