Contact Planning for a Wheel-Leg Vehicle

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I. Introduction

A 'wheel-leg' Unmanned Ground Vehicle (UGV) (Fig. 1) can combine the benefits of wheels and legs. Wheels are more efficient on flat or moderately rough terrain, and legs are better for rough terrain (e.g. a pile of cinder blocks) and traversing obstacles taller than the wheel radius.

UGVs in the field are often driven remotely by a human operator. This is effective for moderately rough terrain, but navigating rough terrain is challenging. We are developing a contact planner for autonomous obstacle traversal.

Contact-implicit trajectory optimization [1] simultaneously finds a contact sequence and motion plan but is computationally costly. Mixed-integer programming has been used for a single rigid body with massless legs [2], but may be computationally costly for complex morphologies.

II. Methods

We used direct collocation with IPOPT as the underlying solver. Direct collocation typically requires a manually defined contact mode sequence, but this is impractical for contact-rich scenarios. Instead, we are developing an algorithm that searches the contact mode connectivity graph (Fig. 1) to find a feasible contact mode sequence. A direct collocation optimization is performed to determine if a connection between two graph nodes is feasible. All code was written in Matlab.

III. Results and Discussion

The proposed contact planning algorithm has been implemented on a single wheel rolling on concave terrain (downhill, flat, and uphill sections in series). The algorithm finds a contact sequence and motion plan in 3.9 seconds (MacBook Pro 2016 with Intel Core i7 processor).

We are currently generalizing the algorithm to include more complex morphologies and terrains. The minimum distance to the goal position may be a good heuristic for the graph search. An important question is how the computational cost scales for these complex scenarios.

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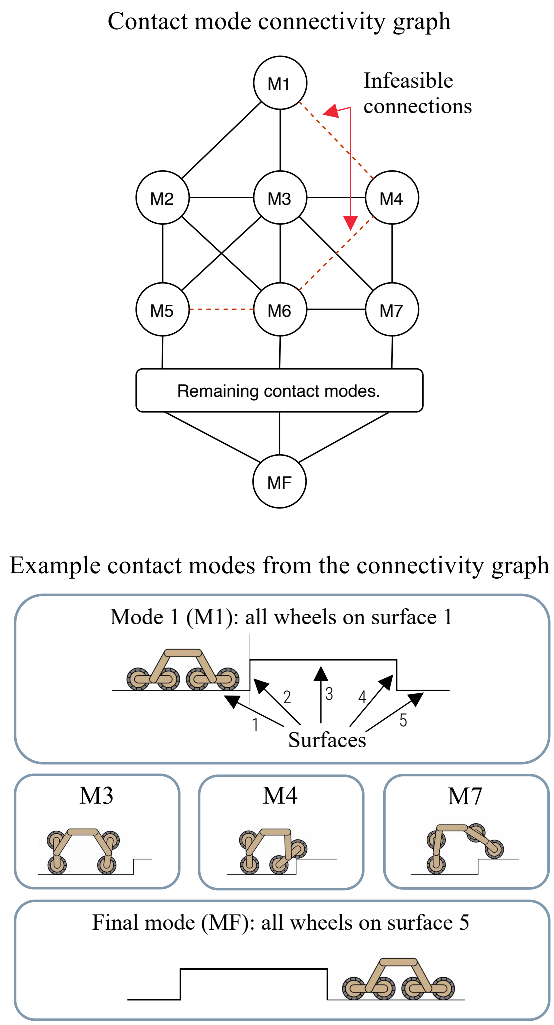

Fig. 1: The contact mode connectivity graph concept, where each graph node corresponds to a contact mode.

References

[1] M. Posa, C. Cantu, and R. Tedrake, "A direct method for trajectory optimization of rigid bodies through contact," *The International Journal of Robotics Research*, vol. 33, no. 1, pp. 69–81, 2014.
[2] Y. Ding, C. Li, and H.-W. Park, "Kinodynamic motion planning for multi-legged robot jumping via mixed-integer convex program," in *2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2020, pp. 3998–4005.