Paper Review: Planning Optimal Grasps

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1 Paper Summary

This paper presents a formulation for quantifying the quality of different grasp configurations on objects with known (parameterized) shapes. The quality value represents a lower bound on the maximum wrench that can be resisted per unit force exerted by the gripper. The quality value can also be geometrically interpreted as the radius of the sphere that is inscribed inside the set of reachable wrenches. This paper also provides computationally feasible algorithms for computing such quality values as well as example algorithms for planning optimal grasps on polygonal objects.

2 What I Learned

Force Closure. The state where all forces and moments introduced by the different contact locations are canceled out. It can also be verified by checking if the origin is contained in the set of reachable wrenches or not.

Friction Cone. Static friction forces, or wrenches to be more general, can be modeled using a geometric cone inside the wrench space, where all wrenches inside the cone results in non-slipping situations.

Convex Hull. This operator can be used to represent sets of elements that can be obtained by convex combinations of the vertex elements.

3 Opinions

3.1 Up Votes

- This paper provides beautiful geometric interpretation of its derived theories, i.e. the closest distance from the boundary of the set of reachable wrenches to the origin is equivalently the proposed quality value.
- I like the design of using a flexible norm definition of the generalized force vector. This allows us to optimize for different objectives (maximum force vs. total force).

3.2 Down Votes

- I don't think computing the Minkowski sum is efficient, especially when we are using large number of primitive wrench vectors to approximate the friction cone boundary. The number of vertices on the convex hull can potentially reach m^n.
- For non-convex objects such as anything that has a handle, it becomes sub-optimal if we plan the grasps based only on the convex hull of the object.
- The definition of $\|w\| = \sqrt{\|F\|^2 + \lambda\|\tau\|^2}$ is not very well thought out. Even though the paper adds the λ to account for the scale difference between forces and torques, it is still somewhat unsure how λ will affect the overall optimal criteria.

4 Evaluations

The goal of this paper is to provide a unified formulation of optimal criteria for grasp related tasks. The paper delivers such formulation nicely with flexible choices of optimization objectives as well as algorithms that quantitatively and feasibly computes for the optimal criteria. The most significant contribution, in my opinion, is the unified formalization such that both independent and combined forces of the grippers can be optimized.

The overall quality of this paper is great, due to its sound derivation of the proposed quality value formulation as well as the algorithms with finite computation. However, this paper does lack a quantitative evaluation of how good the planned grasps are compared to previous work. The assumption it makes is also somewhat unrealistic given real world uncertainties in all kinds of modeling. The proposed methods require prior knowledge of the exact friction model as well as geometric model of the object to be grasped, which is sometimes too complicated to obtain in real-world situations.

5 Questions

1. I am a little confused by the definition $B\boldsymbol{g} = \{\boldsymbol{w} \mid \boldsymbol{w}A\boldsymbol{g} \text{ is true, and } \|\boldsymbol{g}\| = 1\}$. How does $\boldsymbol{g}$ ends up being a constraint on the set (of $\boldsymbol{w}$)?
2. What happens if part of the surfaces of an object is parameterized by some continues curvature (e.g. sphere, ellipsoid, etc.)?
3. How do you estimate forces exerted by the gripper when the gripper is some complicated shapes with multiple joints?