Push-Grasp Quality Evaluation for Polygonal Parts under Pose Uncertainty using Quasi-static Simulation

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Many tasks in automation involve grasping and manipulation of polygonal parts on planar work surfaces using parallel jaw grippers. However, the pose of the part is not always precisely known. A grasp quality metric that can take into account pose uncertainty could help improve the design process. We present a framework for efficient evaluation of such grasps using a Monte Carlo approach and simulation.

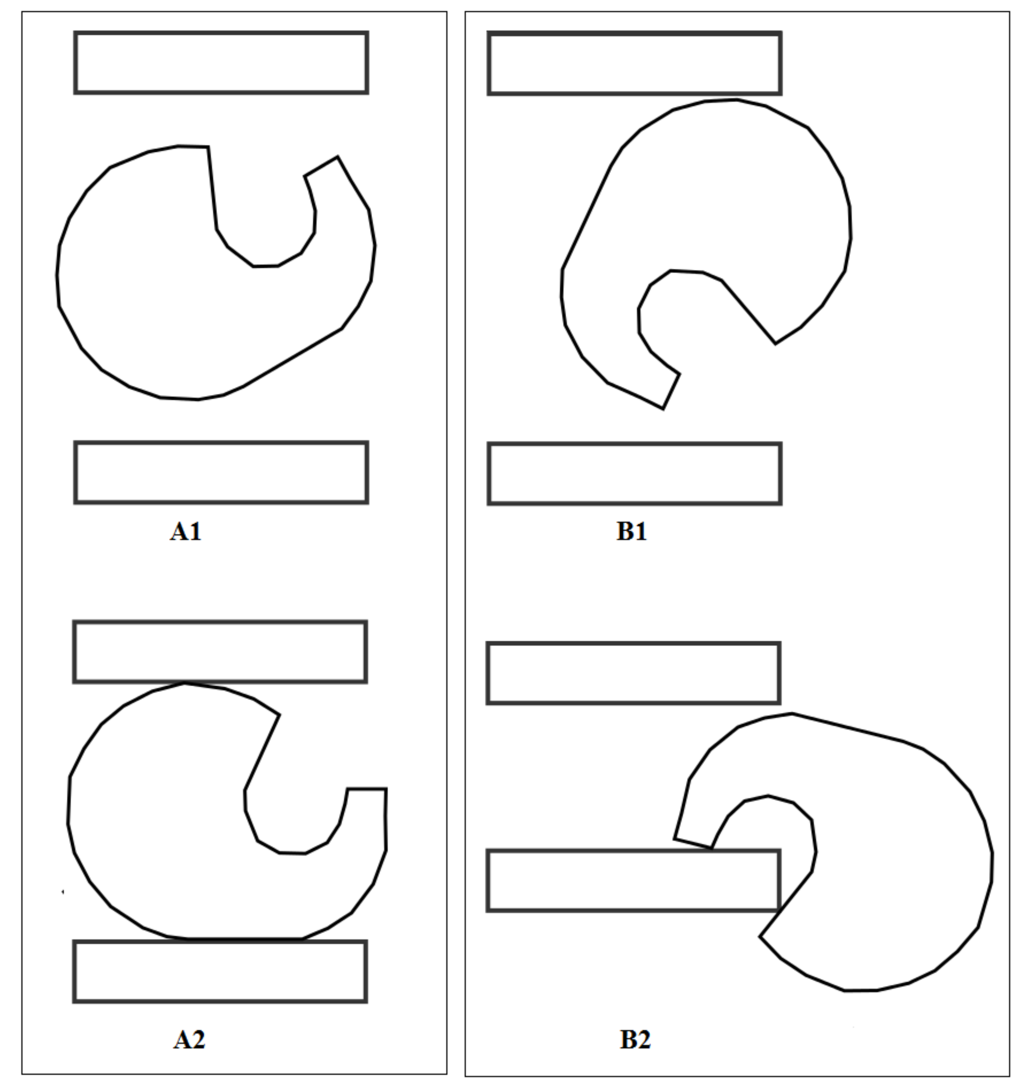

Figure 1: Two example grasps on a tape dispenser.

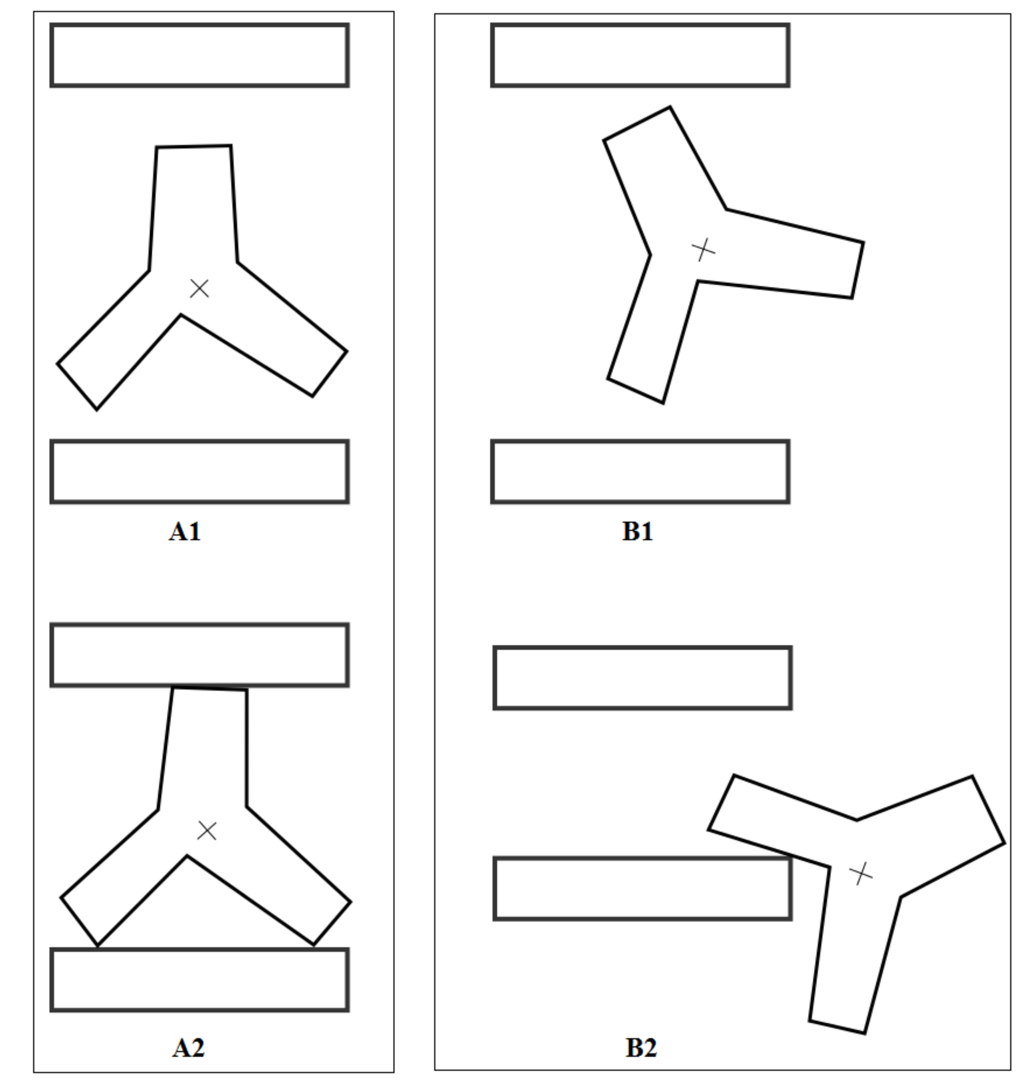

Figure 2: Two example grasps on a nearly axially symmetric part.

Problem Statement

We consider a parallel jaw gripper and part that can be modeled as an extruded polygon. The gripper-part interaction is assumed to be quasi-static, with a conservative estimate of the coefficient of friction. We assume that uncertainty in part pose can be modeled as independent Guassian distributions on position and orientation.

Method

We use a quasi-static simulator based on the Box2D physics engine along with a Monte Carlo sampling approach. We sample a fixed number of poses from the distribution, and simulate the grasp on each one. Once the simulation has converged for a grasp, we determine if force closure is achieved.

Given the results for all sampled poses, the quality of the grasp is calculated as the weighted average of the results, where the weights are probability of each pose occurring.

Results

We demonstrate an example analysis for two grasps, those shown in A1 of Figures 1 and 2. The results are shown in Figures 3 and 4. We tested the parts varying both position and orientation uncertainty. We used 100 samples per position-orientation uncertainty pair. We found that grasp quality decreases in a straightforward manner under increasing position uncertainty, but that orientation uncertainty had more complex effects. This suggests that a simulation-based evaluation of the grasp quality can be beneficial.

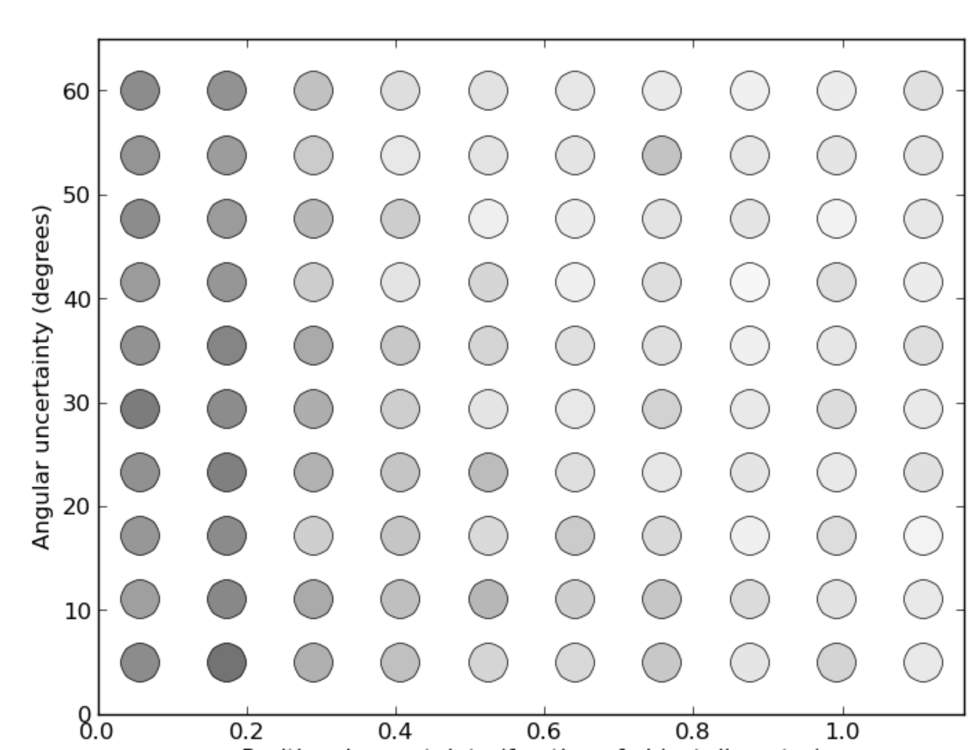

Figure 3: Results for the grasp labeled A1 in Figure 1

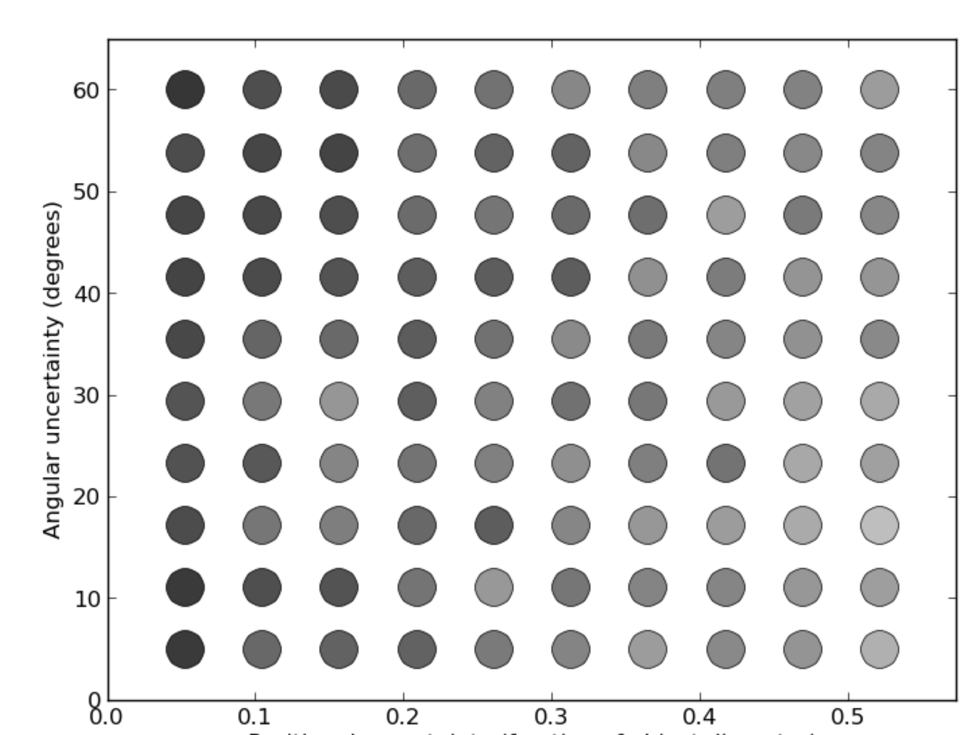

Figure 4: Results for the grasp labeled A1 in Figure 2

Future Work

In future work we will improve our grasp analysis to include non-binary grasp quality metrics, reduce simulation time, and include uncertainty in part shape.

We will extend our grasp quality analysis to grasp planning. We will sample over the grasp configuration space in an adaptive manner, homing in on good grasps with more dense sampling.

Finally, we will use Google Compute Engine to parallelize our implementation in the cloud.

Selected Related Work

Hao Dang and Peter K Allen. *Stable grasping under pose uncertainty using tactile feedback*. Autonomous Robots, pages 1–22, 2013.

Mehmet R Dogar, Kaijen Hsaio, Matei Ciocarlie, and Siddhartha Srinivasa. *Physics-based grasp planning through clutter*. In Proc. Robotics: Science and Systems (RSS), 2012.

Kaijen Hsiao, Leslie Pack Kaelbling, and Tomas Lozano-Perez. *Robust grasping under object pose uncertainty*. Autonomous Robots, 31(2-3): 253–268, 2011.

Junggon Kim, Kunihiro Iwamoto, James J Kuffner, Yasuhiro Ota, and Nancy S Pollard. *Physically-based grasp quality evaluation under uncertainty*. IEEE Trans. Robotics, 29(6): 1424–1439, 2013.