Title	数ショット学習による未知の摩擦面への新規物体の平面押し込みの研究
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Robot planar pushing is one of the primitive elements of non-prehensile manipulation skills, and has been widely studied as an alternative solution to complex manipulation tasks. To transfer this skill to novel objects, reasoning the pushing effect on object motion is important for selecting proper contact locations and pushing directions. However, complex contact conditions and unknown physical properties of the object cause difficulties in reasoning. In this work, firstly, we present a new large planar pushing dataset that contains a wide range of simulated objects, and a novel representation for pushing primitives for the data-driven prediction model.

The prediction model was evaluated both in simulation and real experimental settings. The results show that the prediction model purely trained using our simulation dataset is capable of predicting real object motions accurately.

Secondly, We exploit the few-shot learning model on object center of mass estimation as well as push planning for re-arranging object positions. For center of mass estimation problem, we estimate the center of mass (CoM) of an object by narrowing down its probable location with the proposed model and Mason's voting theorem. The result shows that the CoM estimation method has good mean squared error properties and small standard deviation.

For push planning, we propose a computation efficient planning method that employs a heuristic to reduce the possibility of making sliding contact between the pusher and the object. The experimental results showed that the push planning method effectively reduces the number of pushes required to move unknown real objects to target positions.

Apart from exploiting the few-shot learning model, we proposed to use dynamic pushing to estimate the center of mass online efficiently. We conducted simulation experiment and the estimation process was conduced both in isotropic and an-isotropic frictional settings. Comparing with the result of quasi-static pushing for CoM estimation, dynamic pushing significantly outperformed both in isotropic and an-isotropic frictional setting.

In addition, we propose the Zero Moment Two Edge Pushing (ZMTEP) method to translate a novel object without rotation to a goal pose. The proposed method enables a pusher to select the most suitable two-edge-contact configuration for a given object using the estimated CoM and the geometrical shape of the object. Notably, neither the friction between the object and its support plane nor the friction between the object and the pusher are assumed to be known. We evaluate the proposed CoM estimation and ZMTEP methods through a series of experiments in both simulation and real robotic pusher settings. The results show that the ZMTEP method significantly outperforms competitive baseline methods.

Keywords: Planar Pushing, Object Center of Mass Estimation, Path Planning, Non-prehensile Manipulation, Data-driven Automation