Object Pose Estimation from High DOF Humanoid Gripper Tactile Sensors using Features Found by In-Hand Manipulation

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ECTS	40
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Project Description

The structure of this section is to present the context of the project followed by which problem has been identified along with the corresponding sub-problems needed to be solved. Related work will here be presented along with suggested techniques which, given the current understanding, would provide solutions to the found sub-problems. Finally an expected timeline of the project in its entirety will be presented.

Context

Within robotics a common and well researched problem is bin picking, which often is solved using computer vision (CV) techniques to pose estimate objects. These techniques however suffer from the weaknesses of CV such as outliers in solving the correspondence problem. Here specifically occlusions, reflecting, transparent or homogeneous surfaces, and repetitive structures are common problems which as of the writing of this project have jet to be completely solved.
This project attempts to solve the pose estimation problem by processing tactile sensor inputs from a humanoid robot hand, more specifically a Shadow Dexterous Hand[6] with 20 degrees of freedom (DOF). Using tactile inputs rather than visual, eliminates the weaknesses mentioned above. A schematic showing the hand can be seen in figure 1

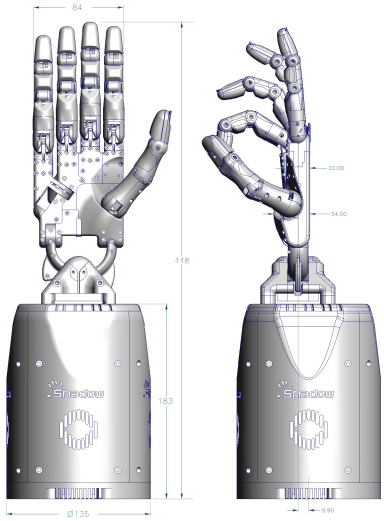

Figure 1: Shadow dexterous hand from Shadow Robots[6]

Problem

Using this approach, the overall problem can be partitioned into 3 sub-problems labeled problem 1, 2 and 3.

Problem 1 involves modeling the contact between the gripper's fingers and the object. Problem 2 is to convert the data collected through the contact model to meaningful surface data, treat these data as features and use these to estimate pose candidates. Finally problem 3 involves in-hand manipulation, such that further information is gained by probing the object. Here new desired surface points are found such that strong surface features are found to better identify the object's correct pose.

Related Work

Within the field of robotics the problem of in-hand pose estimation is separated into different categories based on the methods applied. Here the approaches which address the sub-problems presented in Problem will be considered. To solve problem 1 two different models are generally used for representing the contact information: point-cloud based[4] and image-based [2] tactile information. The point-cloud based approaches are generally preferred in hybrid systems with vision.

For problem 2 one method for feature mapping include global tactile and shape mapping [2]. This method can localize the sensor point cloud in the world's frame by assuming that the transformation between sensor, gripper and robot arm is rigid and calibrated. The point clouds generated from the measurements are then stitched together into a single point cloud. A different approach is to use the

found measurements and treat them as features for a optimization solver to align a sampled model and the measured data. One such optimization technique is GNC [7].

Problem 3 presents challenges of significant magnitude due to the complexity of modelling gripper and object in contact and of coordinating finger motion for complex manipulation actions. From this different approaches has emerged involving reinforcement learning [1], hierarchical control [5] and control optimization [3].

Proposed Solution

To solve the problem presented for this project the work will be done in simulation using kinematic models of the robot hand and the object of interest. Here the pose estimation will only be done on one object type for simplicity. For problem 1 the solution chosen is the tactile image-based contact model, due to the promising results showing in similar applications as referenced in Related Work. The solution methods chosen for problem 2 is GNC due to its high robustness and low computation time is as presented. Finally optimization based control of the robot hand is chosen as the solution for problem 3.

Timeline

The expected timeline for the project can be seen in figure 2 where the deadline for solving problem 1 is the first of January 2023 meaning an estimated 4 months is needed to solve this problem. Likewise 4 months are reserved for solving problem 2, ending with one month for finishing the report.

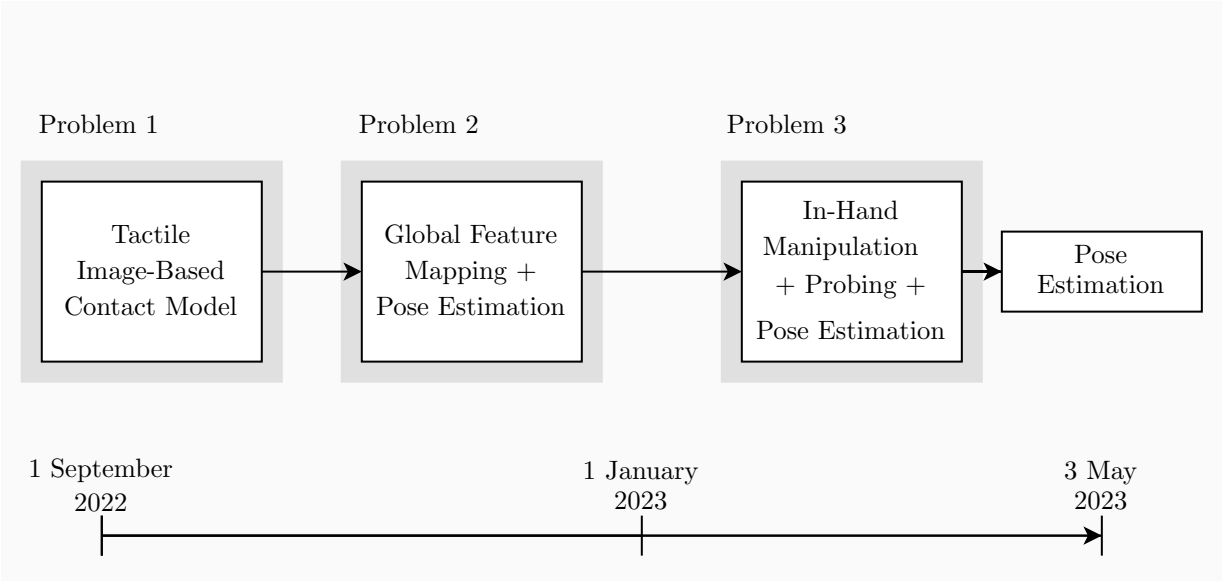

Figure 2: Suggested project timeline

Victor Melbye Staven	Date
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References

[1] OpenAI: Marcin Andrychowicz et al. "Learning dexterous in-hand manipulation". In: *The International Journal of Robotics Research* 39.1 (2020), pp. 3–20. DOI: 10.1177/0278364919887447. eprint: https://doi.org/10.1177/0278364919887447. URL: https://doi.org/10.1177/0278364919887447.

[2] Maria Bauza, Oleguer Canal, and Alberto Rodriguez. "Tactile Mapping and Localization from High-Resolution Tactile Imprints". In: May 2019, pp. 3811–3817. DOI: 10.1109/ICRA.2019.8794298.

[3] Katharina Hertkorn, Maximo A. Roa, and Christoph Borst. "Planning in-hand object manipulation with multifingered hands considering task constraints". In: *2013 IEEE International Conference on Robotics and Automation*. 2013, pp. 617–624. DOI: 10.1109/ICRA.2013.6630637.

[4] Gregory Izatt et al. "Tracking objects with point clouds from vision and touch". In: *2017 IEEE International Conference on Robotics and Automation (ICRA)*. 2017, pp. 4000–4007. DOI: 10.1109/ICRA.2017.7989460.

[5] Tingguang Li et al. "Learning Hierarchical Control for Robust In-Hand Manipulation". In: *2020 IEEE International Conference on Robotics and Automation (ICRA)*. 2020, pp. 8855–8862. DOI: 10.1109/ICRA40945.2020.9197343.

[6] *Shadow Robot*. https://www.shadowrobot.com/dexterous-hand-series/. Accessed: July 29, 2022.

[7] Heng Yang et al. "Graduated Non-Convexity for Robust Spatial Perception: From Non-Minimal Solvers to Global Outlier Rejection". In: *IEEE Robotics and Automation Letters* 5.2 (2020), pp. 1127–1134. DOI: 10.1109/LRA.2020.2965893.