The Maersk Mc-Kinney Moller Institute

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Towards smooth & efficient manipulation on mobile robots using temporal integration

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Abstract

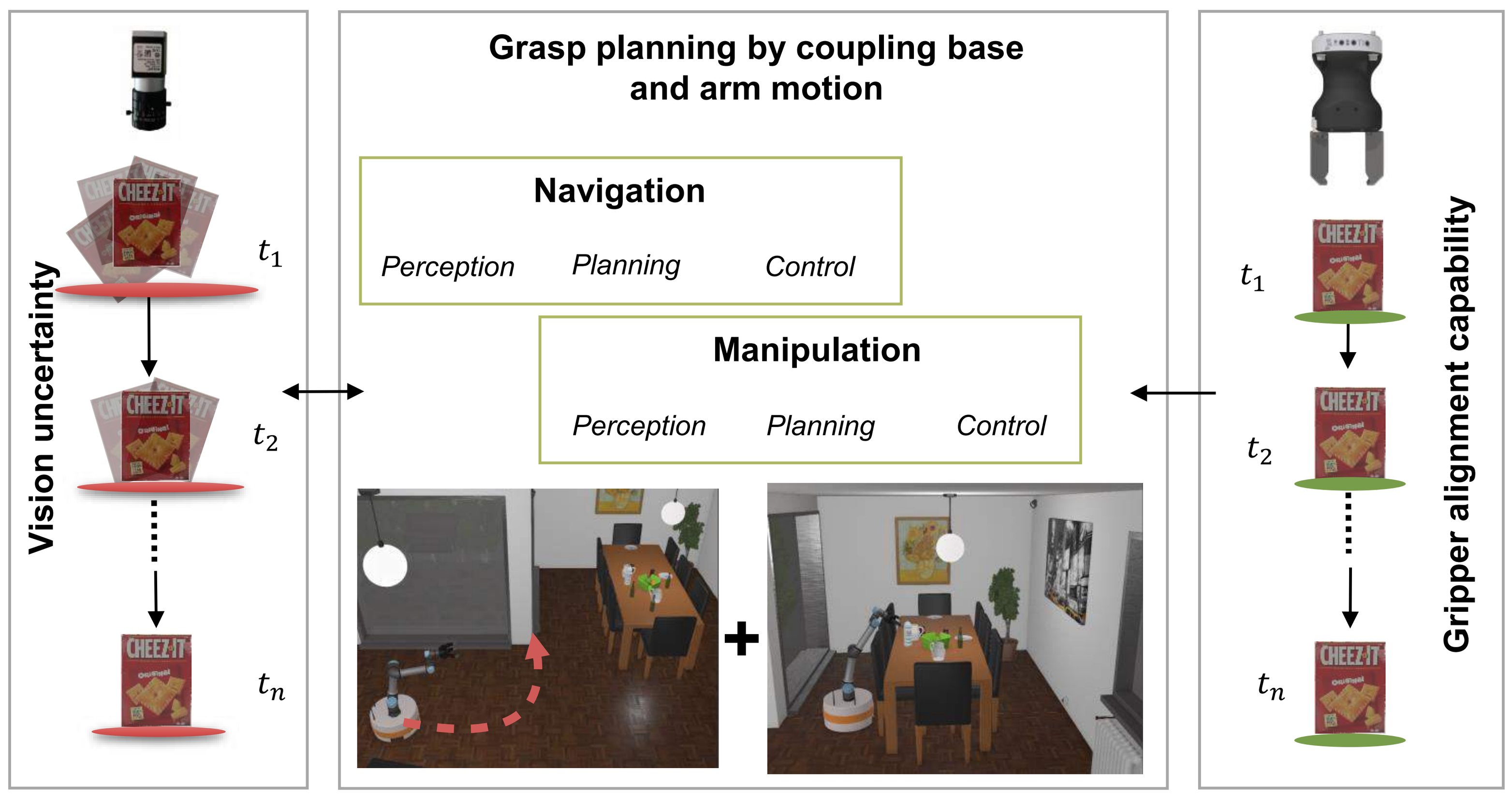
Many of the tasks performed by mobile service robots today require navigation (approaching objects) and manipulation (interacting with the objects). Navigation & manipulation are often solved sequentially as separate tasks. Ideally, the robot can use the approaching motion for the manipulation task to improve the object's perception as well as to pre-plan the manipulation for efficient execution. This PhD project is investigating how approaching motion can be used to optimize perception and planning to enable robust and efficient manipulation on mobile robots.

Why object pose distribution?

- The robot can determine if the uncertainty in pose estimate can be compensated by its gripper alignment capability
- It can accordingly plan a new action either to reduce pose uncertainty or execute the grasp

Why combine navigation and manipulation?

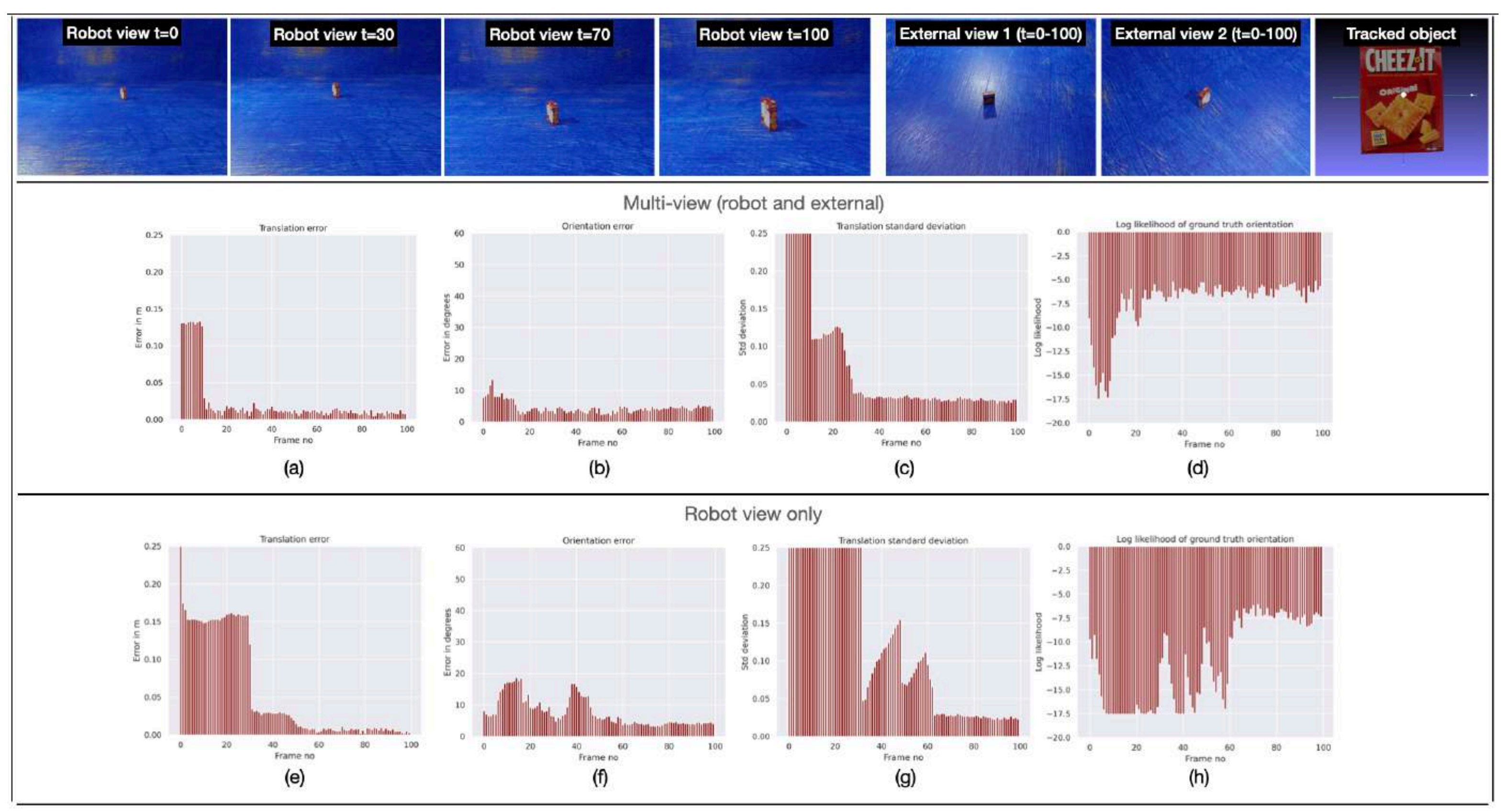
- The robot can pre-plan the grasps when it is still navigating towards the objects
- When robots is close to the object it can directly execute the grasps without spending time on object pose distribution estimation & grasp planning thus resulting in efficient execution



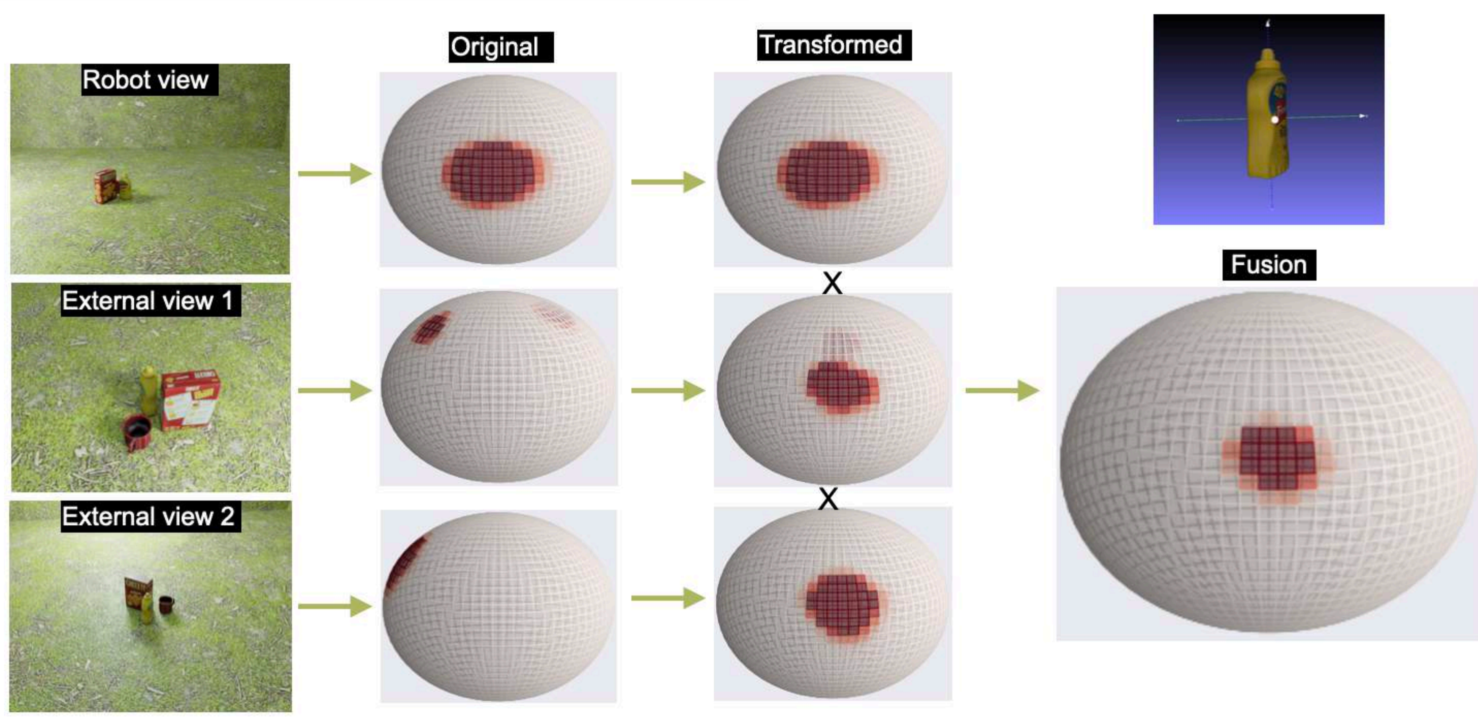
Right: gripper alignment capability (this can be optimised offline and stays constant over time), **Left:** uncertainty in object pose estimate robot wants to grasp (this can be reduced by getting better object views), **Center:** grasp planning by coupling base and arm motion (based on uncertainty in pose estimate can be compensated by gripper, robot plans action either to get better observation or executes the grasp)

Multi-view object pose distribution for pre-grasp planning

- Existing works have addressed object pose distribution estimation problem when a robot is already very close to the objects it wants to grasp
- Object pose distribution from distance is difficult due limited view of the robot camera
- We show that robot can use the information provided by external cameras in the environment to compensate for the limited view of the robot camera and enable 6D object pose distribution tracking from distance



Qualitative example: robot approaching the object from around 3m



Fusion of orientation distributions from multiple camera views

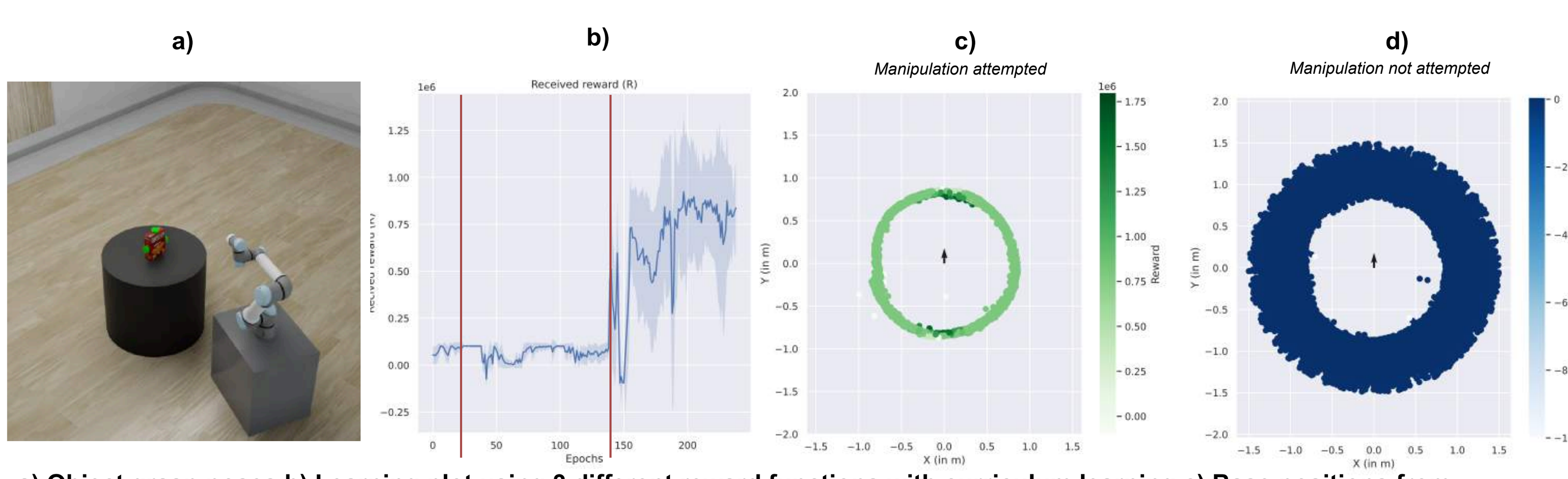
Proposed methodology

- We propose a particle filter-based multi-view full 6D pose distribution tracking framework that simultaneously fuses information from multiple cameras and then sequentially tracks it over time [1]
- We model the object pose posterior as a multi-modal distribution which results in a better performance against uncertainties introduced by large camera-object distance, occlusions, and object geometry.
- To enable the use of full pose distributions for practical applications, we present a method that quantifies object pose uncertainty as a reduced set of object poses with predictive confidence, which is computed from an estimate of the posterior pose distribution. [2]

Pre-grasp planning by coupling base and arm motion

We investigate how a mobile manipulator can approach the object it intends to grasp using its base and arm motion while:

- respecting the constraints of its vision system (e.g. keeping the object in the field of view while tracking)
- reducing execution time for grasping motion by learning suitable pre-grasp position for the arm
- finding base poses to stop such that an inverse kinematics solution exists to the grasp pose



a) Object grasp poses b) Learning plot using 3 different reward functions with curriculum learning c) Base positions from which robot attempts to grasp the object during learned policy evaluation d) Base positions from which robot does not attempt to grasp the object during learned policy evaluation

Policy learnt by the robot to approach the object it intends to grasp by respecting the vision constraints (keeping object in the center of image to allow better object pose tracking) using its base and arm wrist joint motion.

Proposed methodology

- We split the task into "reaching with vision constraints", "finding base poses with IK solutions" and "time-efficient grasping"
- We show that Soft Actor Critic (SAC) algorithm can be used to learn to approach and reach near the object while respecting the vision constraints.
- We show that identifying suitable base positions to grasp cannot be learned directly with SAC, and requires the use of curriculum learning to create a curriculum with increasing difficulty to learn the task.
- Our current work is investigating how to learn a single policy for solving both of these subtasks while reducing grasp execution time by determining a suitable pre-grasp position for the manipulator arm.

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[1] Naik, L., Iversen, T. M., Kramberger, A., Wilm, J., & Krüger, N. (2022). Multi-view object pose distribution tracking for pre-grasp planning on mobile robots. In 2022 IEEE International Conference on Robotics and Automation (ICRA). IEEE.

[2] Naik, L., Iversen, T. M., Kramberger, A., Wilm, J., & Krüger, N. (2023). Object uncertainty quantification for mobile manipulation. In 2023 IEEE International Conference on Robotics and Automation (ICRA). IEEE. [Submitted]