Autonomous Interaction of Mobile Manipulators in Industrial Environments

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***Abstract*—The primary focus of this paper is to achieve autonomous interaction between a mobile manipulator and a target object. To accomplish this, a three-phase approach comprising Object Recognition, Pose Estimation, and Mobile Manipulation is presented. Furthermore, a method is introduced to calculate an appropriate base pose, serving as the starting pose for manipulator movements.**

***Index Terms*—autonomous manipulation, mobile manipulator, object recognition, pose estimation, industrial environment**

I. Introduction

Mobile manipulators have emerged as a promising solution to achieve autonomous interaction with objects in different environments. This paper presents a novel system that can adapt to different environments without requiring modifications to the surroundings. Achieving autonomous interaction with unknown objects poses significant challenges associated with detection and pose estimation. Successful interaction with objects also requires careful consideration of the approach strategy. The mobile manipulator needs to execute precise and controlled movements to reach the target object without causing any damage.

II. Related work

Several papers have addressed the challenges of autonomous mobile manipulation. One work is [1] which focuses on adjusting the manipulator's end-effector pose to be perpendicular to the target button's plane, allowing only moves towards the panel in the direction of the plane's normal vector. In [2] the authors propose a method that relies only on pixel positions to adjust the camera frame until the pixel position of the target button approaches the center of the image.

III. Methodology

The approach is divided into three phases: Object Detection, Pose Estimation, and Mobile Manipulation.

Object detection is performed using YOLOv8[1]. In this initial stage, the object detection process relies solely on the pre-trained model without any retraining or fine-tuning. The algorithm detects objects and provides bounding box coordinates. The bounding box center is then projected onto the point cloud data to determine the object's position in three-dimensional space. Furthermore, the surface normal in the vicinity of the object's center is estimated, allowing the computation of the object's orientation.

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[1] https://ultralytics.com/yolov8

MoveIt was employed to facilitate motion planning and execution for mobile manipulation tasks due to its capabilities to compute movements based on object pose information and integrated obstacle avoidance functionalities. To address dynamic obstacles in the environment, the system incorporates the use of OctoMap.

Fig. 1. Igus Rebel and Agilex Scout in Gazebo simulator

MoveIt planner uses the object's pose information to compute a movement that displaces the end-effector perpendicular to the object by a specified distance. afterwards, a planar movement is executed to guide the manipulator until it successfully reaches the object.

In cases where the manipulator is unable to directly reach the position of the object due to its distance or physical limitations, a valid base pose is computed by leveraging the capabilities of the MoveIt planner. To achieve this, three virtual joints (one rotational and two translational) are added to the manipulator's definition, considering the mobile base as part of the manipulator.

IV. Experimental activity

The experimental activity was conducted extensively in simulation. Several tests were performed using various objects available in the Gazebo simulator. The results obtained so far have been promising, demonstrating the manipulator's ability to detect and reach the identified objects. However, some challenges were encountered during the planar movement phase, primarily due to the physical limitations of the manipulator. For real-world deployment, an Agilex Scout 2.0 mobile base, an Igus Rebel manipulator and an RGBD camera eye in hand will be used.

V. Conclusions and future work

Looking ahead, future work includes training the object recognition network to identify specific industrial objects, such as emergency buttons. Furthermore, the potential to expand the system's capabilities to read industrial sensors, such as manometers, can be also explored. The scalability of the system makes it a valuable starting point for different applications in various scenarios.

REFERENCES

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