Dexterous Manipulation from Object Recognition and Accurate Pose Estimation using RGB-D Data

Udaka A. Manawadu and Naruse Keitaro

Robot Engineering Lab, University of Aizu, Aizu-Wakamatsu, Fukushima, Japan

Introduction

The surge in research pertaining to object recognition and pose estimation systems can be attributed to the growing popularity and cost reduction of RGB-D camera sensors in recent years. When dealing with Point Clouds (PC), the additional color information provided by RGB-D cameras has the potential to enhance accuracy in scenarios that necessitate both RGB and depth data, such as object recognition tasks. The seamless integration of 3D object recognition, 3D pose estimation, and dexterous manipulation holds paramount importance in the realm of factory automation systems, especially those involving robotic hands. As depicted in Figure 1, these integrated systems typically commence with 3D object recognition as the initial step to identify the target 3D objects. Subsequently, 3D pose estimation is employed to ascertain the precise location of these objects. Finally, the robot hand is deployed for manipulation, facilitating the manipulation of the target objects. In this research, we explore a scenario that involves the utilization of a robot hand to manipulate and control various valves by opening and closing them. Globe valves and, ball valves are primarily used for this research as target objects.

Figure 1: A simple Systematic diagram of integrated systems used by previous research

In our earlier work, we developed an approach integrating object recognition, pose estimation, and dexterous manipulation to control valves. However, this work faced limitations, including constrained scenarios, long execution times, and suboptimal object recognition. Our current research aims to address these challenges and provide an improved solution.

Key Contributions

- Create the trinity model: A Novel, more accurate object recognition, pose estimation, and dexterous manipulation method using a model-based approach.
- A new method of increasing the accuracy of pose estimation of the target by moving the camera to different positions and collecting more accurate RGB-D data as in Figure 2.
- Develop a conventional robot motion model for dexterous manipulation to open and close different valves.

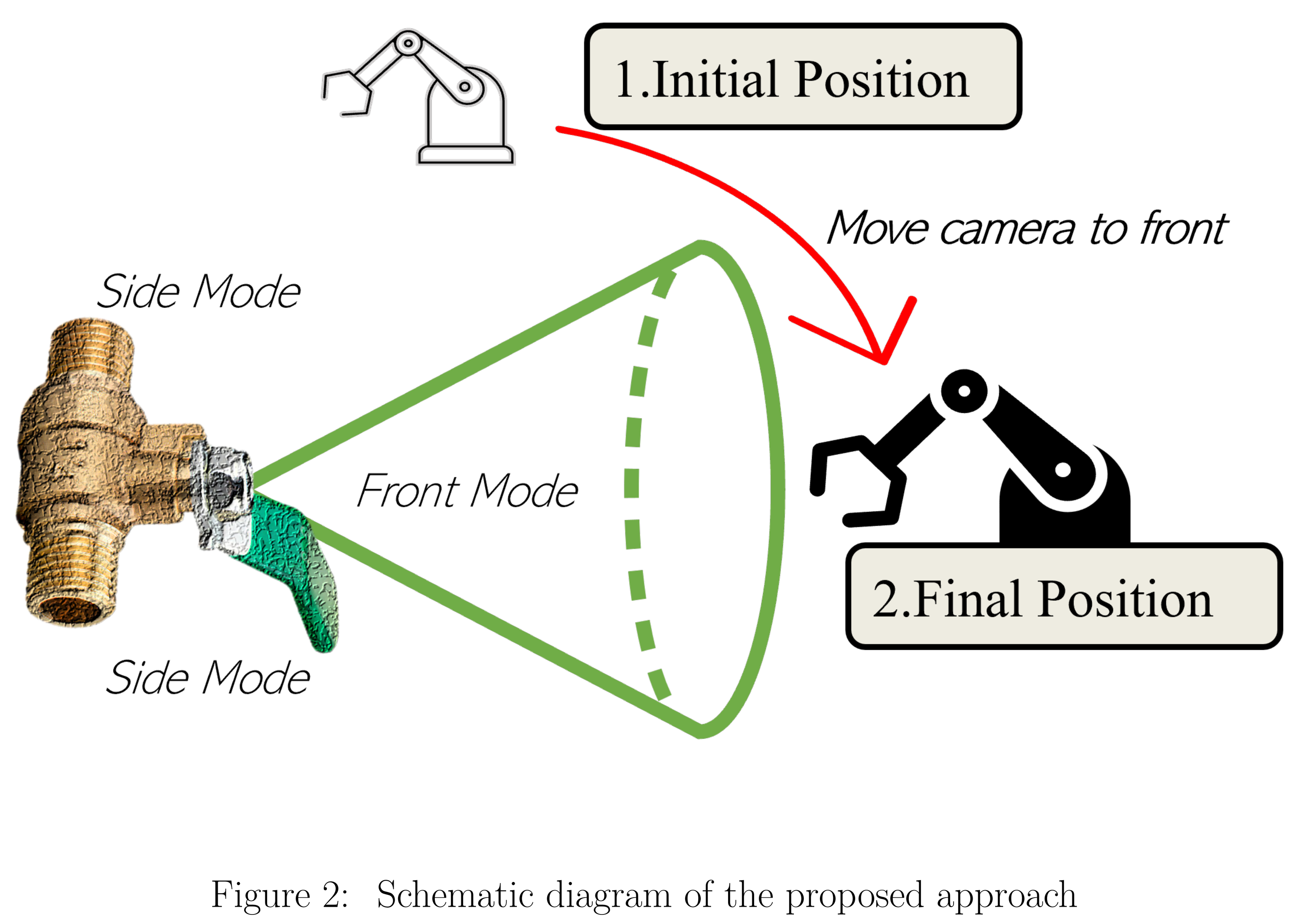

Figure 2: Schematic diagram of the proposed approach

Approach

- Object recognition begins with regional segmentation of the scene based on color, resulting in a Point Cloud (PC) representation of the valve. Subsequently, valve components are filtered based on their color.
- To determine the valve's orientation (whether front or side-facing), we employ singular value decomposition. If the valve is in the front orientation, pose estimation is achieved through the RANdom SAmple Consensus (RANSAC) algorithm. In cases where the valve is in the side orientation, the body's position and pose are determined by considering their relationship with the handle part, employing the pose integration Hough-Voting method.
- Depending on the valve's orientation, the robot arm executes inverse kinematics to perform either rotational motion of the valve or arm movement.

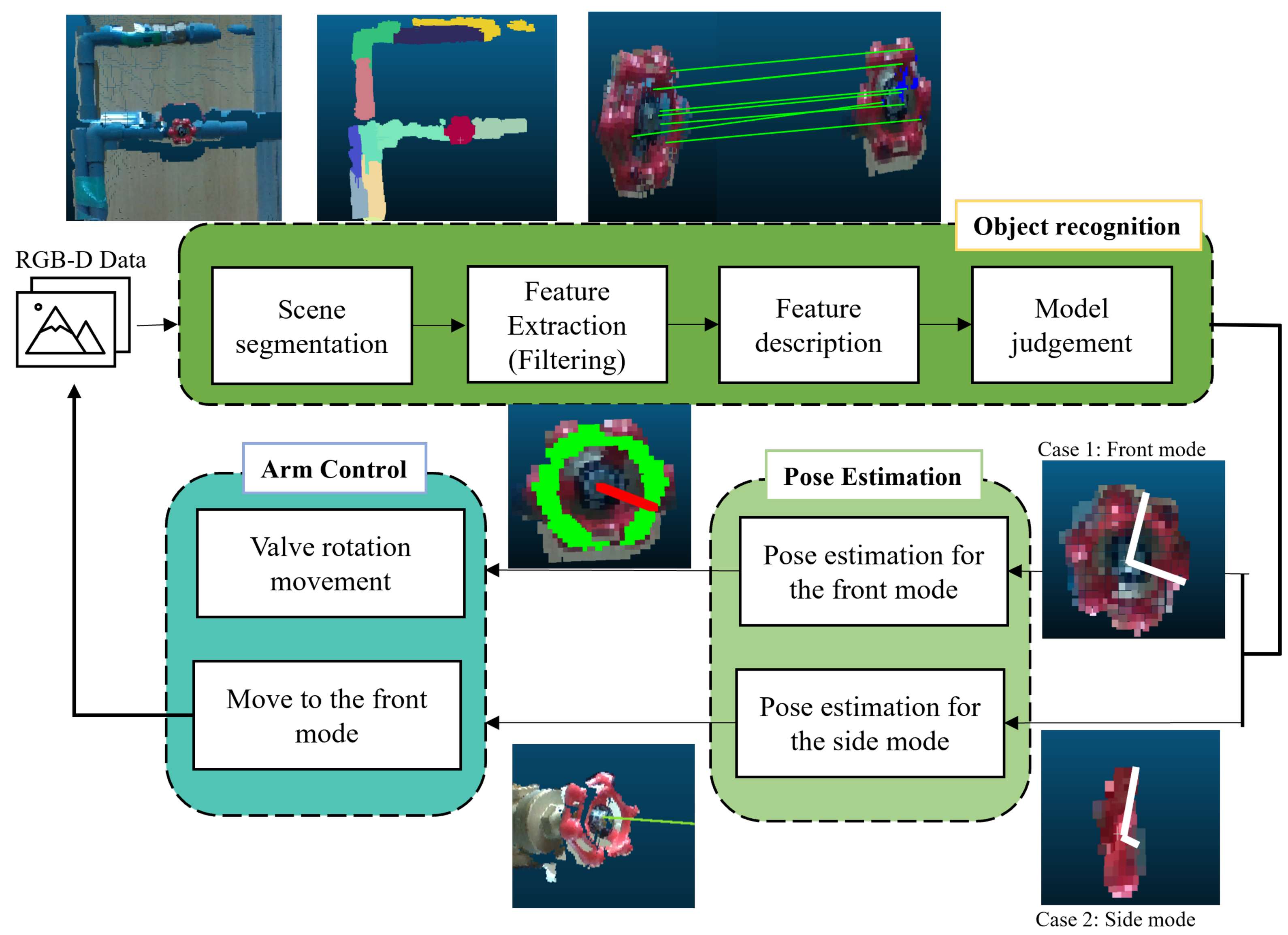

Figure 3: Proposed Object Recognition and Pose Estimation and Arm control model

Evaluation Criteria

- Time Compared with Previous Methods: assesses the efficiency and speed of the new system in comparison to existing methods or previous iterations of the system.
- Accuracy of the Built Method: focuses on the precision and correctness of the system's outputs, including the accuracy of object recognition, pose estimation, and manipulation actions.
- Calculate the Success Rate of Correct Hand Manipulation: focuses on the system's ability to manipulate objects accurately and successfully using a robotic hand or gripper.

Reference

[1] J. Lim, I. Lee, I. Shim, H. Jung, H. M. Joe, H. Bae, O. Sim, J. Oh, T. Jung, S. Shin, et al. Robot system of drc-hubo+ and control strategy of team kaist in darpa robotics challenge finals. *Journal of Field Robotics*, 34(4):802–829, 2017.

[2] U. A. Manawadu, S. Keito, and N. Keitaro. Object recognition and pose estimation from rgb-d data using active sensing. In *2022 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM)*, pages 165–170, 2022. doi: 10.1109/AIM52237.2022.9863241.

[3] C.-Y. Tsai and S.-H. Tsai. Simultaneous 3d object recognition and pose estimation based on rgb-d images. *IEEE Access*, 6:28859–28869, 2018.