Utilizing Multiple Point Cloud Scenes for Precise Robotic Bin-Picking Tasks

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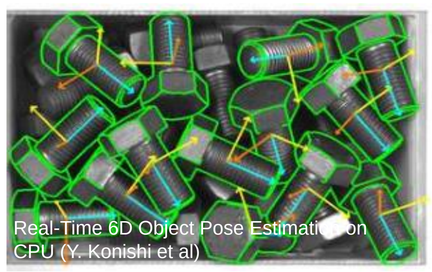
Introduction

- Autonomous bin-picking system
  - Picking up workpieces inside the cluttered bin and placing into a designated position.
  - Industrial manipulators and 2D/3D vision systems are crucial components.
- 6D object pose estimation
  - Determining the position and orientation of objects in the physical space.
  - Low accuracy while using a single camera due to high occluded environment.
  - Require high-accurate or multiple 3D camera system → ***not cost-effective.***

Industrial bin-picking system



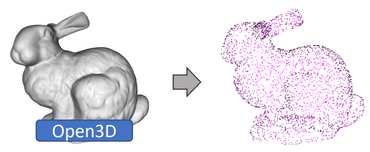
Object pose estimation in the cluttered bin

Research Objectives

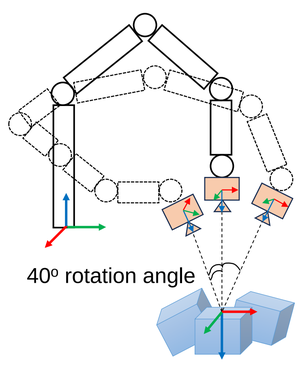
- Proposing a **multiple-view scan-matching algorithm** to **improve accuracy** of object **pose estimation** with **a single low-cost RGB-D camera**.
- Applying **YOLOv5s** model for **object detection and localization**.
- Developing an **autonomous platform** for **precise bin-picking tasks**.

Multi-view Scan-matching for Pose Estimation

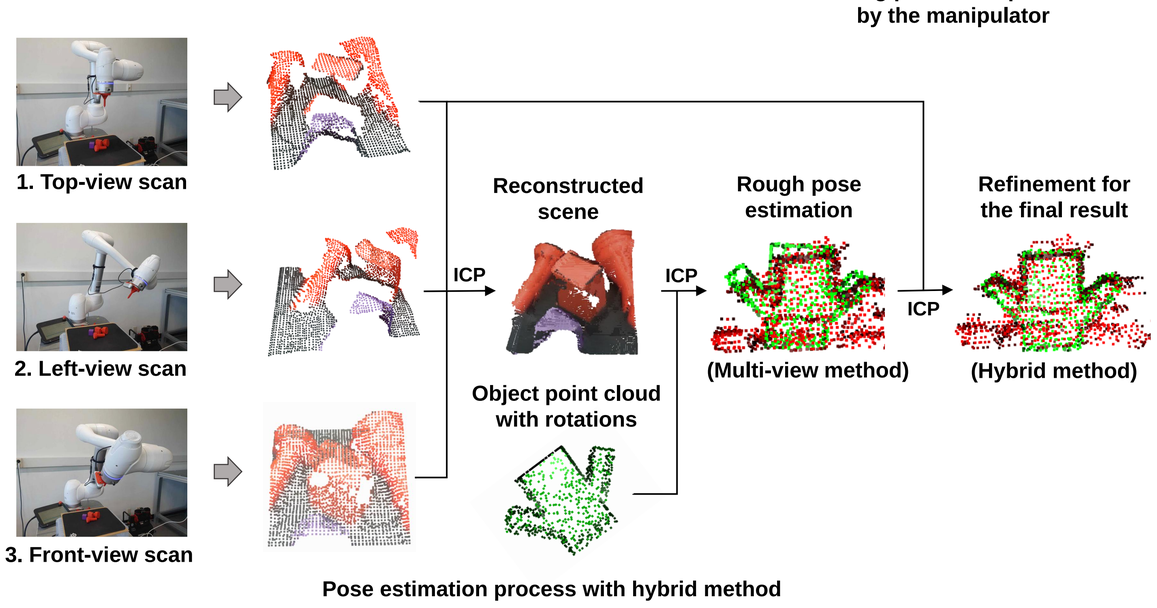
- Reconstruct point clouds:
  - Template object point cloud from **CAD model**.
  - Manipulators placed RGB-D camera into designate **3 different scanning views**.
  - Scene point cloud was reconstructed by **combination of scanning point clouds**.
- **Hybrid method** for point cloud registration:
  - **Rough estimation step:** template point cloud with rotations was aligned to reconstructed scene by **Iterative Closest Point (ICP).**
  - **Refinement step:** rough estimation result was the initial guess to align template point cloud into the top-view point cloud.



Sampling point cloud from CAD model



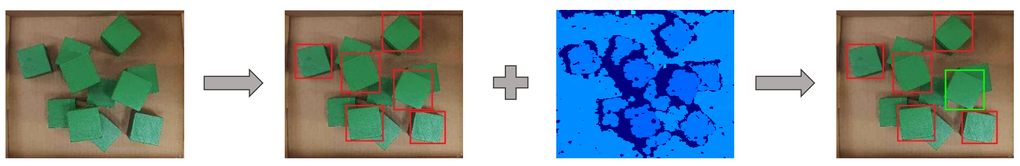
Scanning process implemented by the manipulator



Pose estimation process with hybrid method

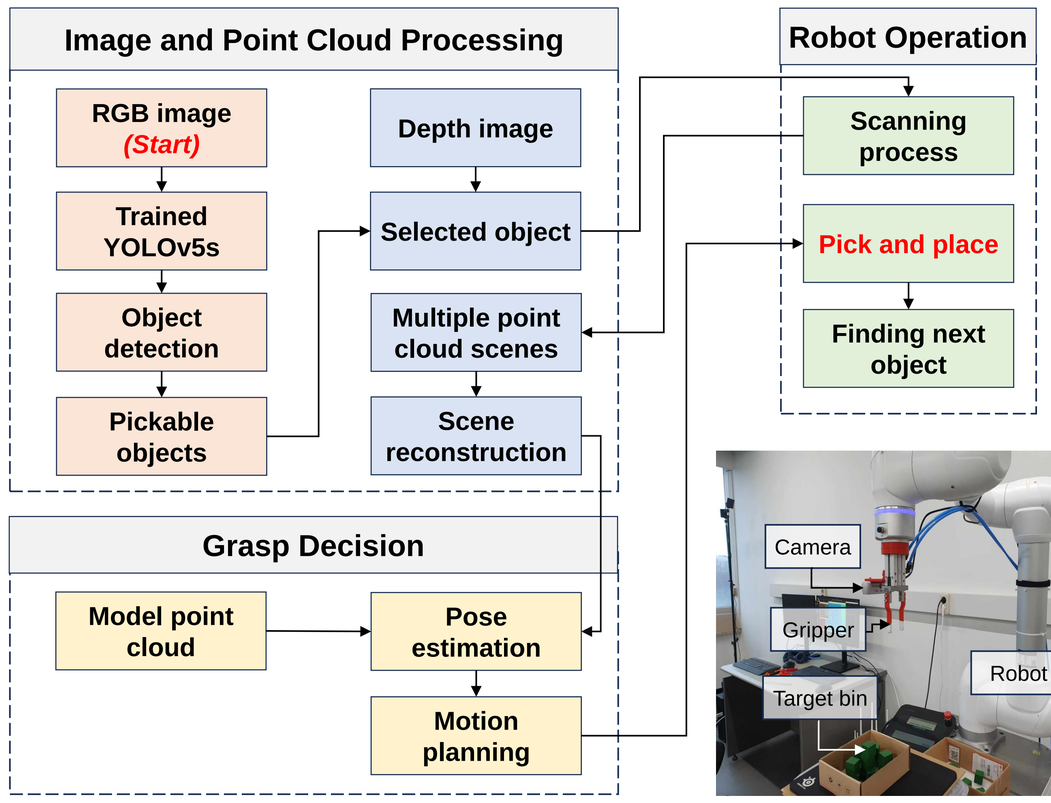
Object Detection and Localization with CNN model

- Training CNN model for pickable object detection
  - Dataset: objects without occlusion was labelled as pickable in color images.
  - **YOLOv5s** model was trained to detect and localize pickable objects.
- Selecting target picking object
  - The robot pick objects on top of the bin.
  - Depth image with hole-filling filter was utilized to find the object closest to the camera.

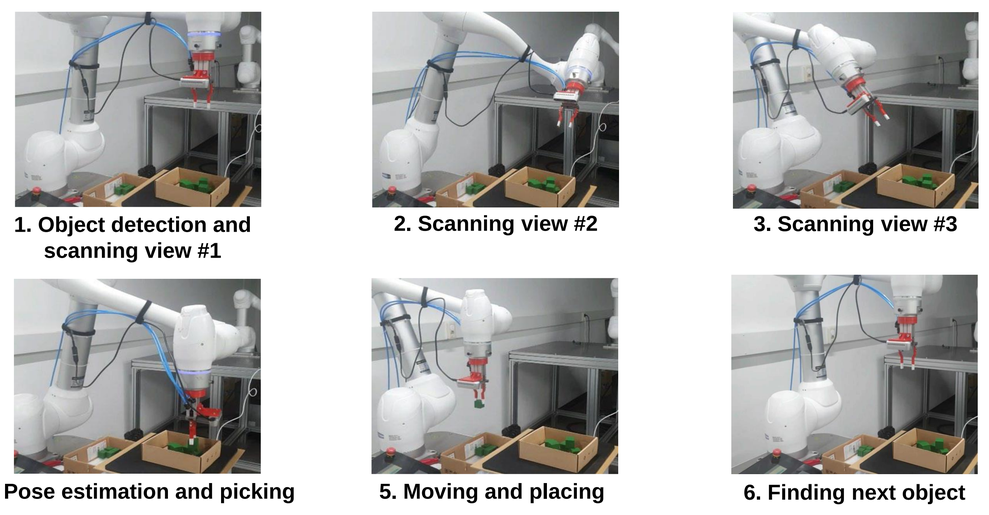


Input color image | **Pickable objects detected by CNN** | **Input depth image** | **Selected target picking object**

Proposed Autonomous Bin-picking Platform



Pick-and-place Process

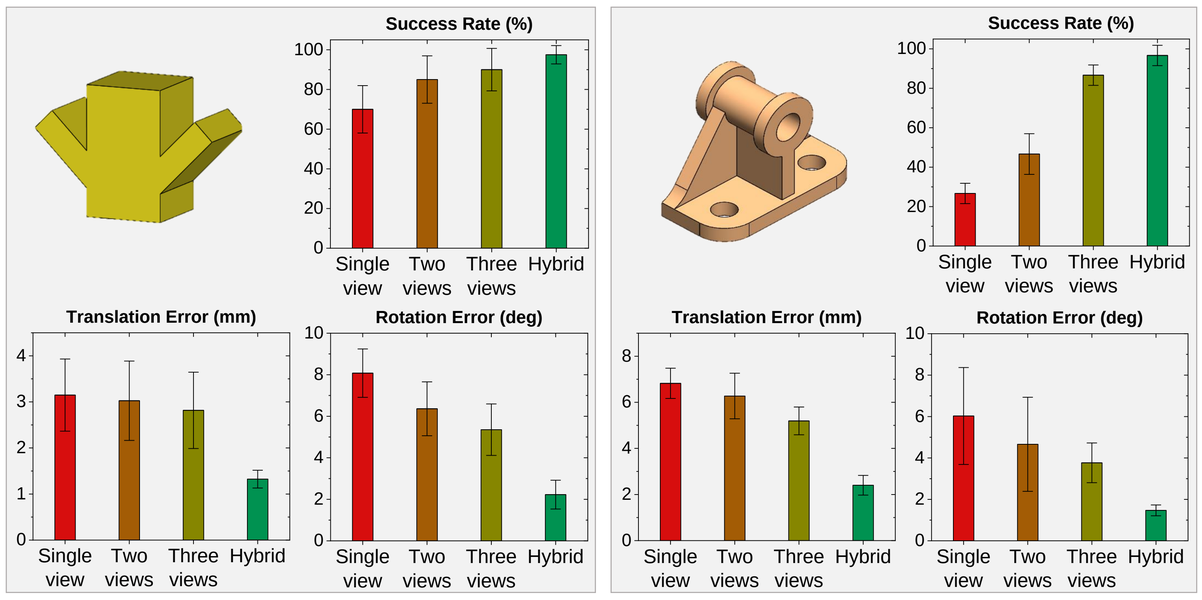


1. Object detection and scanning view #1 | **2. Scanning view #2** | **3. Scanning view #3**

4. Pose estimation and picking | **5. Moving and placing** | **6. Finding next object**

Result and Discussion

- Benchmarking for 6D pose estimation
  - The **hybrid method** increased the success rate in pose estimation by **25%** in the instance of simple object and **70%** in case of complex one.
  - Amount of translation error was <**3mm** and rotation error was <**3º**.



Benchmarking result for object with simple shape | **Benchmarking result for object with complex shape**

- Precise bin-picking tasks with hybrid method
  - **100%** success rate in estimating the poses of the objects inside the bin.
  - Success rate in removing objects out of bins was **97%**.
  - The failure in removing blocks mainly resulted from non-pickable poses.

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average Success rate
Success / Estimation	20/20	20/20	20/20	20/20	20/20	100%
Success removed / Total blocks	20/20	19/20	20/20	20/20	18/20	97%

Conclusion and Future Work

- The proposed hybrid method can enhance the accuracy, success rate and robustness in object pose estimation compared to the sing-view method.
- The autonomous bin-picking platform can successfully remove all pickable object inside the cluttered bin without an intensive training process.
- Optimization of scanning process and segmentation of 3D point clouds will be further studied.