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Subject: ME 5286 Lab 5: Computer-Vision Based Tool Sorting

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In this lab, we trained a convolutional neural network to identify tools, then used a UR5 robot with a Robotiq wrist camera to perform pick-and-place tasks into bins identified with ArUco markers. The robot successfully completed the sorting task with minimal misclassification.

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1. Lowest Confidence in Model

The tool with the lowest confidence level was the pliers, misclassifying 1 out of 2 test images. This likely occurred due to visual similarity to the wrench in the training dataset.

2. Adding a 5th Object

To add a 5th object like a steel file, we need to:

- Retrain the CNN with 1000 new images.
- Add a new bin and ArUco marker.
- Include a new pick waypoint and inference class in the code.

3. Unknown Object on Table

a) Current response:

If a foreign object overlaps with a known tool in the camera frame, the model may misclassify the tool (e.g., hammer seen as pliers).

b) Adaptation:

Use a confidence threshold. If below the threshold, the model should classify as “unknown” and sort to a dedicated 5th bin with its own marker.

c) CNN weaknesses:

- Highly dependent on clean, controlled environments.
- Resource-intensive to retrain with new objects.
- Poor interpretability of misclassification.
- Sensitive to camera calibration and changes.

4. Dynamic Gripping Location

After identifying the tool, extract its shape. Locate flat, opposing surfaces suitable for the gripper, rank them by reachability and stability, and grip at the best points.

5. Tool Pose Estimation

- Attach an ArUco marker to each tool for pose detection.
- Train a CNN to predict translation and orientation, converting results to robot coordinates.

6. Conveyor Belt Scenario

a) Feasibility:

Not possible. Our model needs controlled conditions and will fail in cluttered or degraded contexts like trash sorting.

b) Requirements:

Train a new model on diverse trash data, including occlusion, damage, and background variation.

c) Camera type:

A stationary overhead camera is preferable for consistent, birds-eye view monitoring of the conveyor’s picking zone.

7. Alternate Image Processing Algorithms

- Edge-based template matching
- Interest-point matching with pose estimation