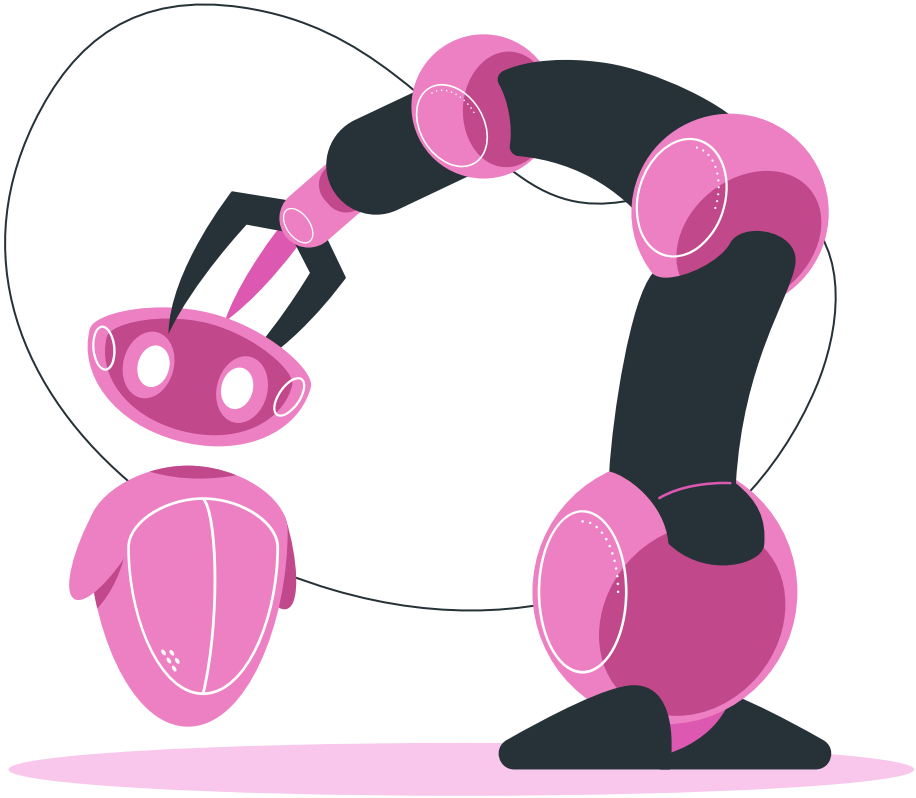
Shape-Based Sorting with a Robotic Arm

Automating the Classic Shape Sorter Task

Risheeka Mitra, Kirin A. Chhikara,
Paul J. Mason, Thanh Nguyen



Background: Why This Matters

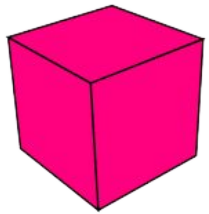
Robot manipulation of objects remains a challenge

Shape sorting ends up being the ideal testbed for developing and evaluating integrated robotic systems

In academia, shape sorting mirrors the classic childhood toy, making it an intuitive problem for demonstrating fundamental robotics concepts

Noisy sensor data, workspace calibration, grasp planning, and system integration are challenges to be addressed, amongst others

A solution must offer reliability and interpretability for consistent operation in structured environments.



Our Solution: Teach-and-Replay

Idea: The robot is taught a specific procedure, and then it repeats the exact procedure with the push of a button!

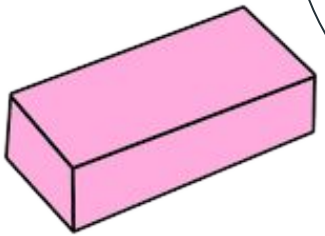
Teaching Phase

- Guide the robot arm through the motions you want it to perform.
- In this case, guide the arm to pick up a shape and drop it into the appropriate spot in the container.
- At each step, the robot records the positions, like following a “script” that you teach it.

Replay Phase

- The robot plays back the recorded joint positions, thus following the “script” you teach it.
- In this case, the robot arm moves through the sequence recorded during the teaching phase, going through waypoints that are already established.

Design Choices



Teach-and-Replay

- Utilizes demonstrated trajectories for manipulation tasks
- Prioritizes reliability and precision over adaptability; widely used in industrial automation for repetitive tasks where consistency is critical

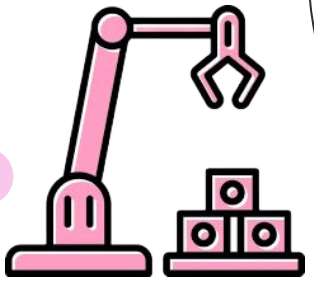
Camera Configuration

- Camera mounted on robot end-effector
- Provides adaptable viewpoint and high-resolution observation of target objects

Fixed Staging Positions

- Objects positioned in known staging locations
- Leverages environmental structure to reduce perception and planning complexity; common approach in manufacturing and warehouse automation

Limitations & Future Work



Limitations

Workspace Constraints

- System requires objects in predefined positions
- Performance depends on consistent lighting conditions

Shape Variability

- Trained on specific shape geometries

Scalability

- Each new object requires manual teaching of grasp motions
- Sequential processing (one shape at a time) limits throughput

Future Work

Dynamic Grasp Planning

- Implement real-time IK and camera calibration to compute grasps for arbitrary object positions

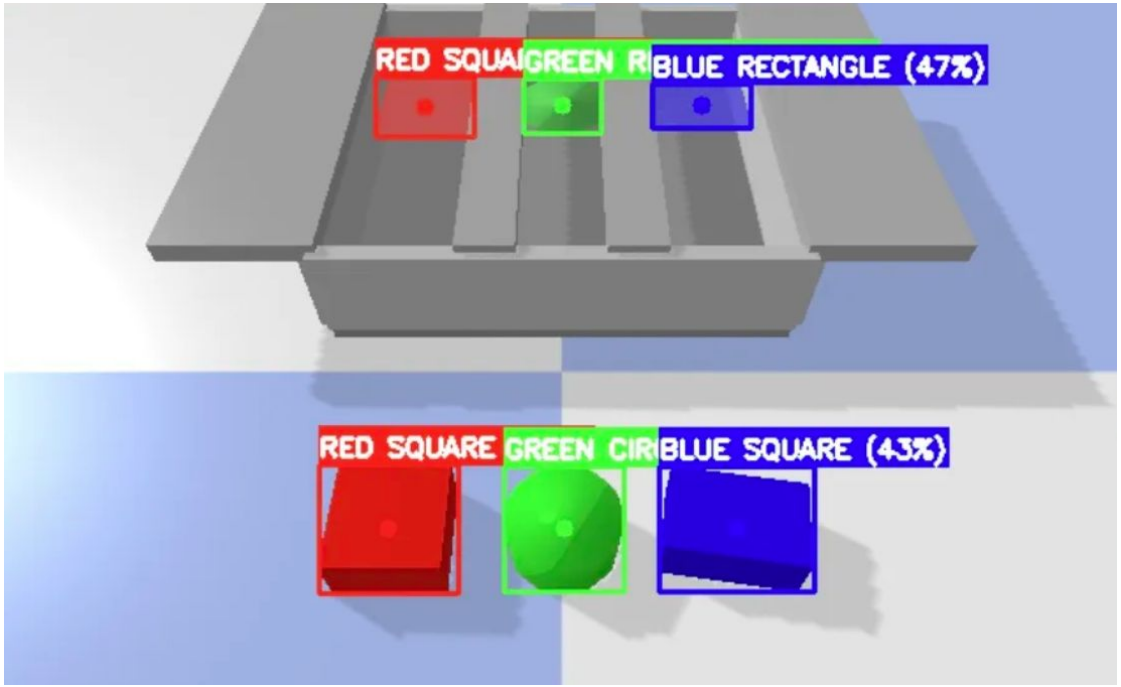
Learning-Based Approaches

- Leverage imitation learning or deep learning grasp estimation to adapt to novel shapes without reprogramming

Multi-Object Manipulation

- Develop parallel detection and task planning to process multiple objects simultaneously, increasing throughput

Relevant Media



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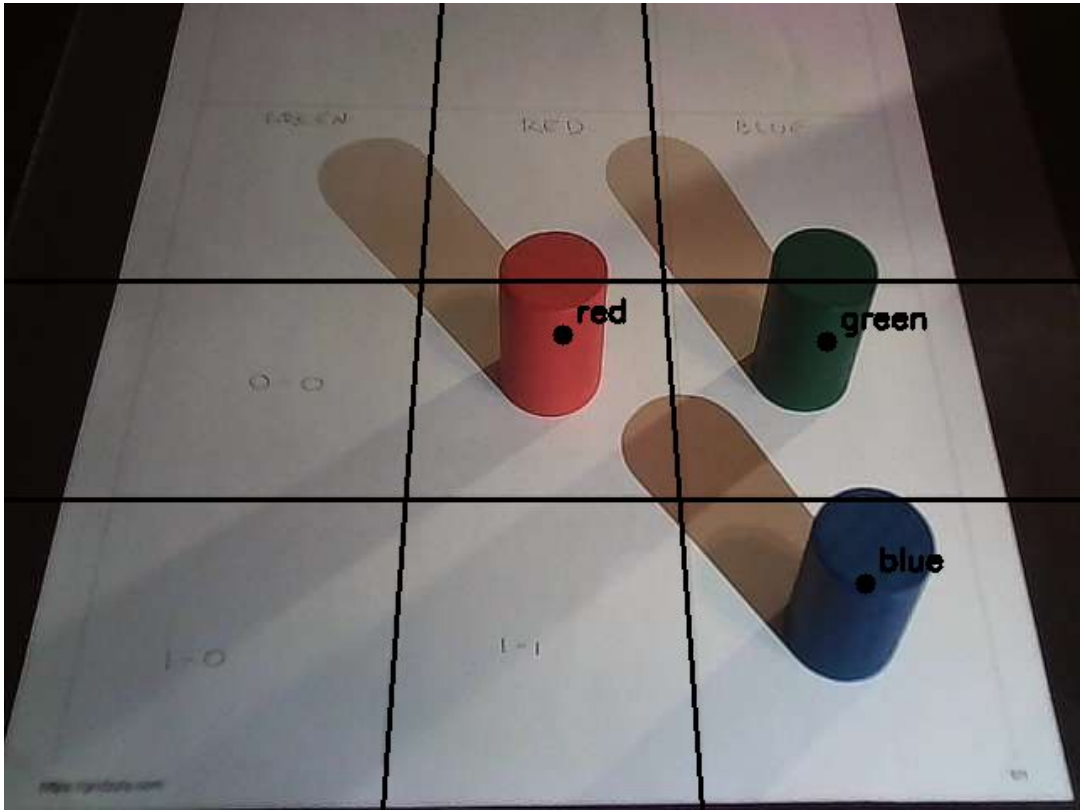

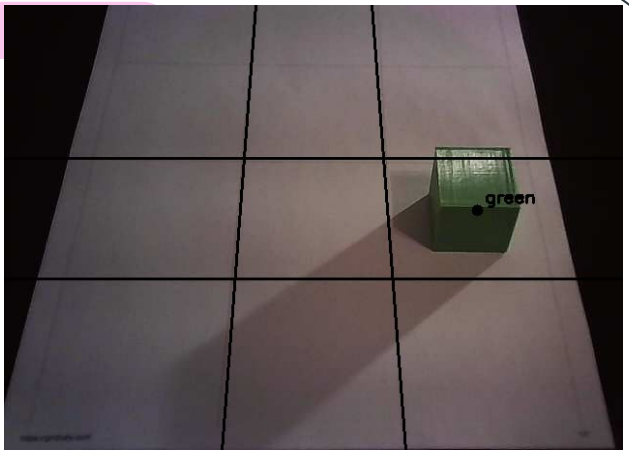

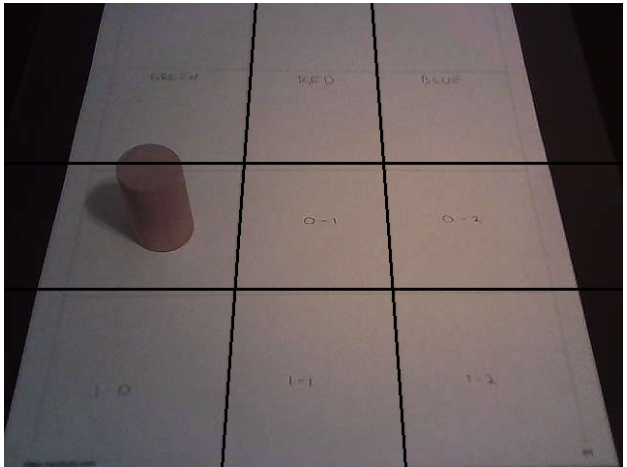

Relevant Media

Final Product

Demo