

Comparative Study of Adaptive Robotic Arm Grasping with Human-Like Capabilities

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Research Question:

Service robots in bubble tea shops often cause spills or damage when grasping cups of different materials, as they lack human-like material perception and tactile feedback



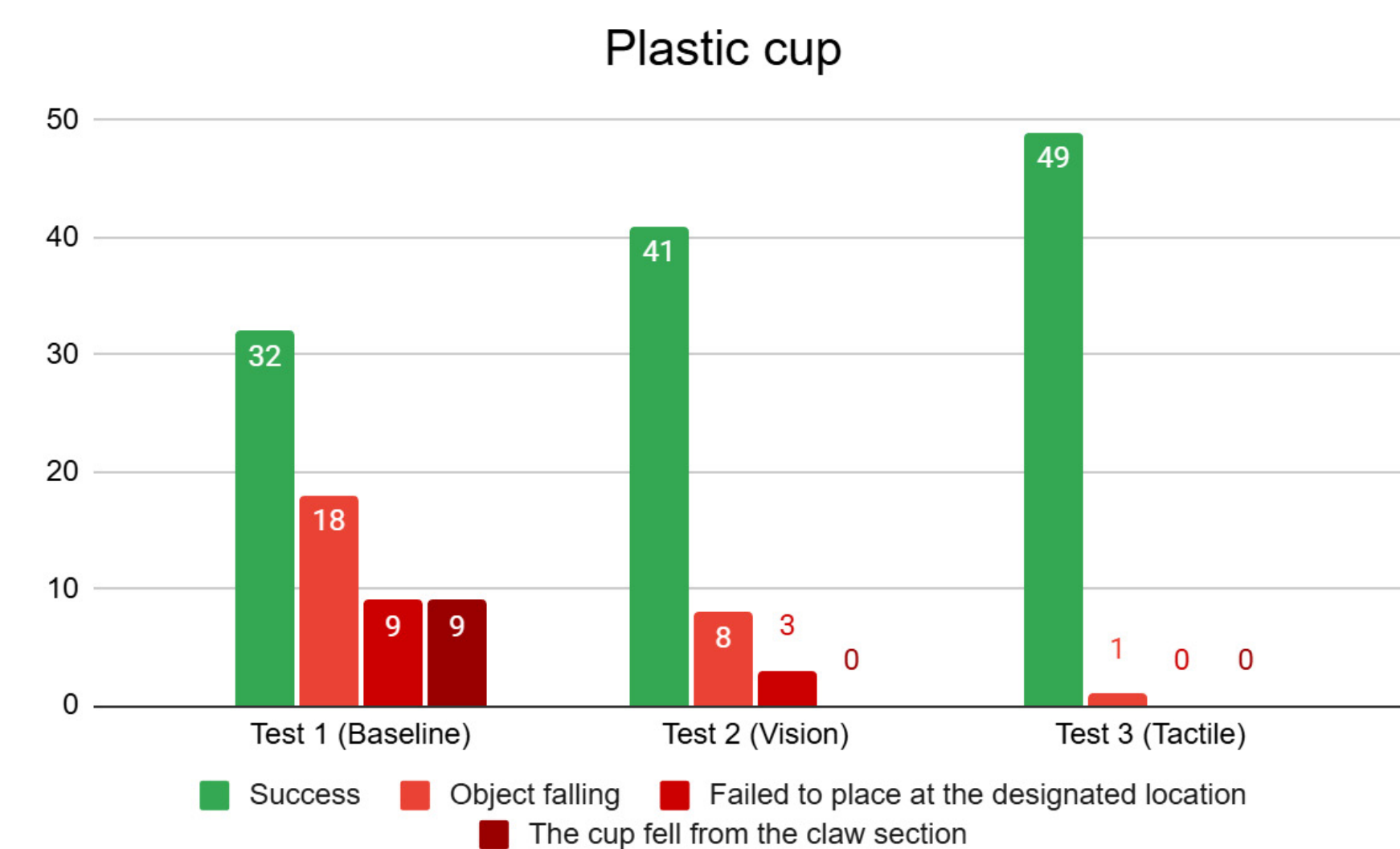
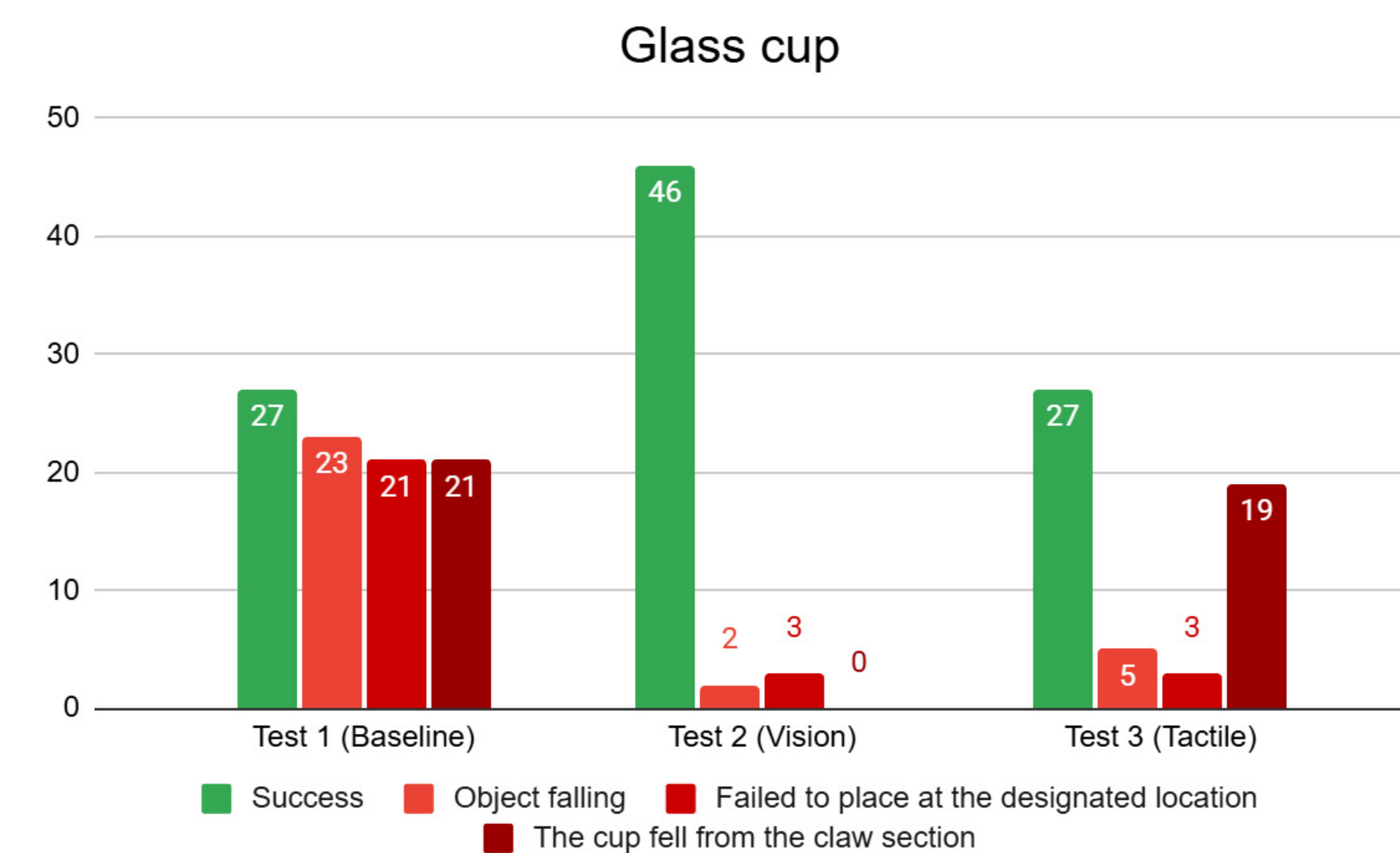
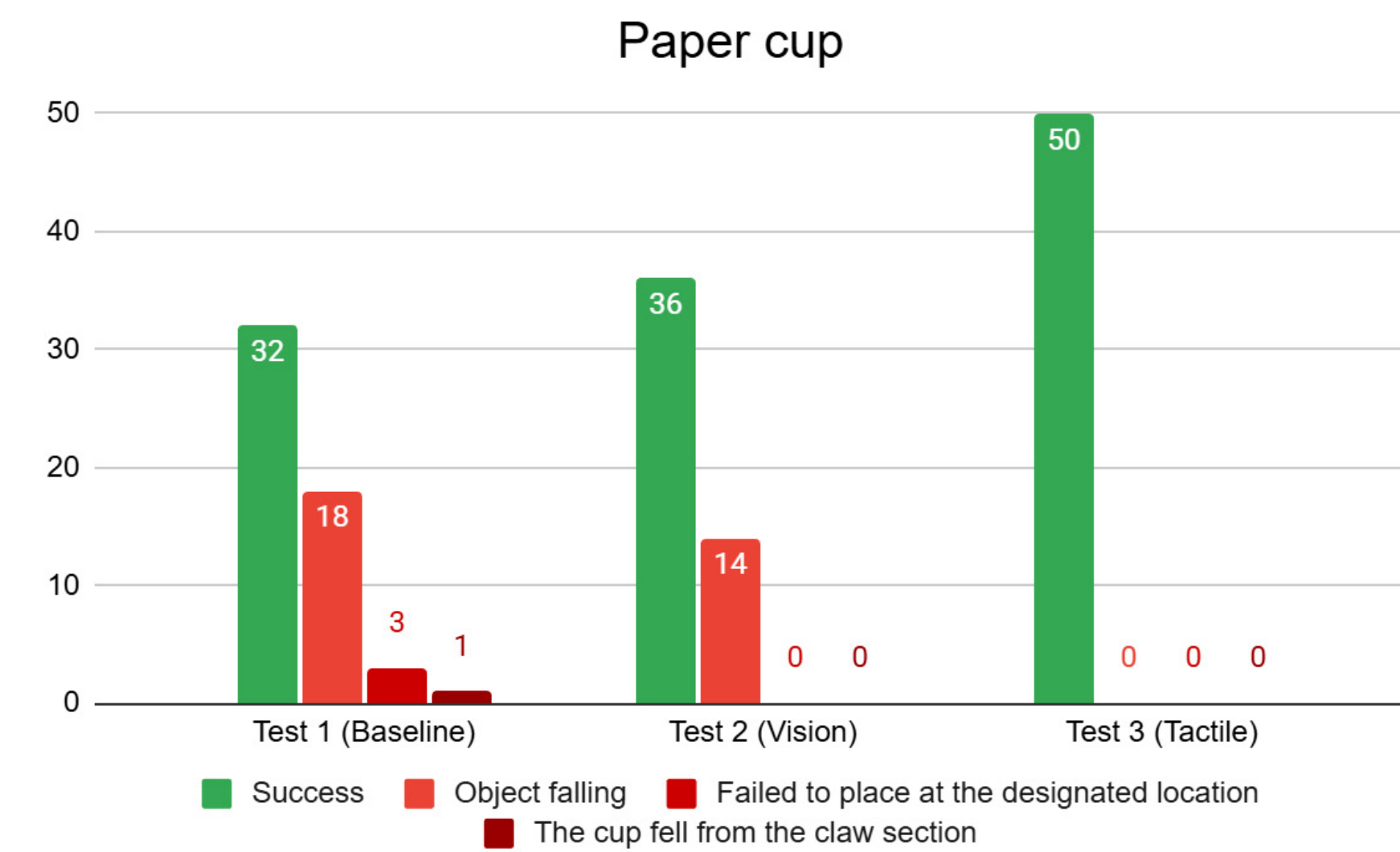
Background:

- In bubble tea shops, cups are non-standard objects: materials vary widely, shapes are often tapered, surface friction can change due to condensation, and many cups contain liquid.
- Beyond “picking up,” robots must maintain stability and placement accuracy during motion/turns/stops; even micro-slippage inside the gripper can change the cup pose, amplify sloshing, and cause misplacement or spillage.
- A key challenge is the lack of physical commonsense about material and internal-state differences (e.g., liquid-filled vs. empty), so robots may apply the same grasp strategy; meanwhile, vision can recognize shape but cannot directly sense physical properties like weight, friction, and stiffness—together leading to poor generalization and failures such as spillage or damage.

METHOD

Item	Method 1 (Baseline)	Method 2 (Vision)	Method 3 (Tactile)
Object	Plastic, Glass, Paper Cups	Plastic, Glass, Paper Cups	Plastic, Glass, Paper Cups
Method	No Sensors / Blind Execution	Camera + Cognitive Commonsense	Pressure Sensor
Parameter	Fixed Force & Trajectory (Repeats same values regardless of material)	Retrieve Parameters via Material ID (Identifies cup type and loads specific force/motion values for that object)	Adjust Degrees based on Pressure (Detects pressure during the grasp and decides whether to modify gripper angle to optimize force)
Results	Success: Task Complete Fail: 1. Liquid Spilled 2. Misplaced 3. Cup Dropped	Success: Task Complete Fail: 1. Liquid Spilled 2. Misplaced 3. Cup Dropped	Success: Task Complete Fail: 1. Liquid Spilled 2. Misplaced 3. Cup Dropped

Experimental results



- Paper cup: Performance improves from Baseline → Vision → Tactile; tactile feedback provides the largest benefit, reducing the baseline’s dominant failure mode (“object falling”) and ultimately eliminating it in the tactile condition.
- Plastic cup: Results also improve from Baseline → Vision → Tactile; tactile feedback is the most stable, as it nearly removes the baseline’s distributed failure modes (falling / misplacement / slipping), while vision already reduces failures substantially.
- Glass cup: The glass cup benefits most from vision (largest improvement), whereas tactile does not improve performance; the key bottleneck is “cup slipped from the claw”, indicating slip prevention is critical for further gains.



Experimental Video

