Development of a Bio-Inspired Robotic Head-Neck Architecture for Object Tracking and Catching

Bailey Alex, Mechanical Engineering
Mentor: Jiefeng Sun, Assistant Professor
School for Engineering of Matter, Transport, and Energy

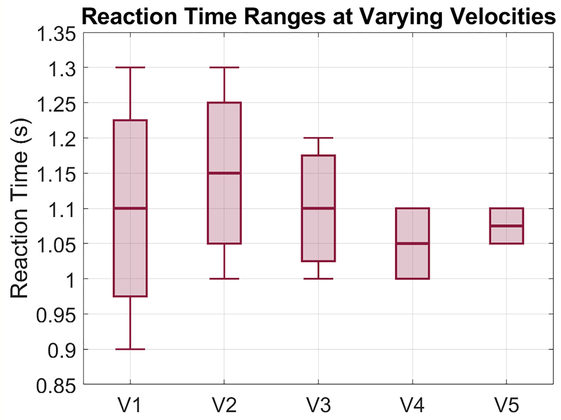
Research Question

What dynamic and control requirements are necessary to enable reliable robotic catching motions?

Background

- Dynamic robotic manipulation requires rapid hand-eye coordination, yet current end-effectors remain limited in speed and adaptability.
- This research **analyzes gripper reaction times against object velocity** to advance hand-eye coordination for autonomous manufacturing.

Results



Data Point	Velocity (ft/s)	Height (ft)	Drop Time (s)	Range (s)
1	5.675	0.500	0.176	0.9-1.3
2	7.320	0.832	0.227	1-1.3
3	8.695	1.248	0.278	1-1.2
4	10.610	1.748	0.329	1-1.1
5	12.225	2.332	0.381	1.05-1.1

Fig 4: Reaction time ranges yielding repeatable catches across varying impact velocities. Outside this range, the gripper fails to catch; no feasible times were found beyond V5.

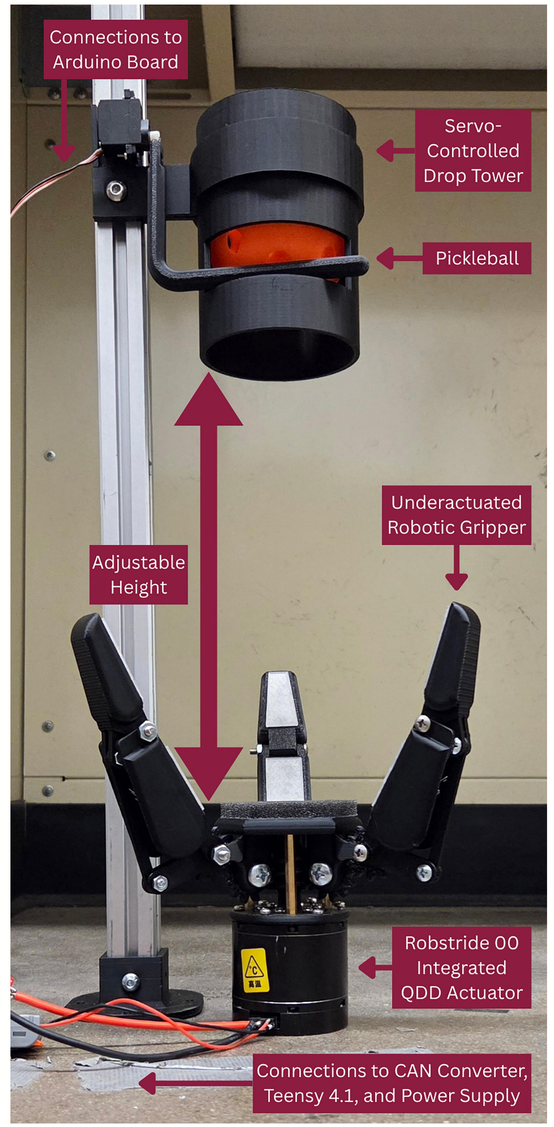
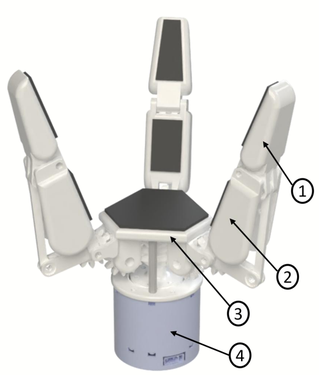
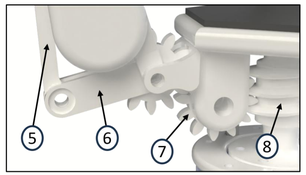


Fig 5: Experimental test setup, with a Python script controlling drop and reaction time.

Methodology





1. Distal Phalanx
2. Proximal Phalanx
3. Palm
4. Quasi-Direct Drive Actuator
5. Linkage Arm 1
6. Linkage Arm 2
7. Spur Gear
8. Worm Gear

Fig 1 (above): Labeled gripper CAD rendering.

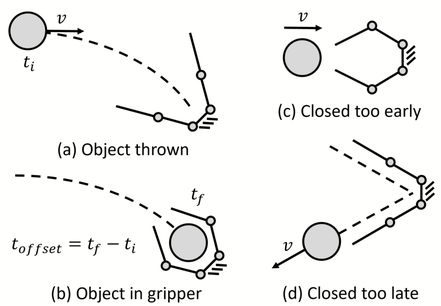
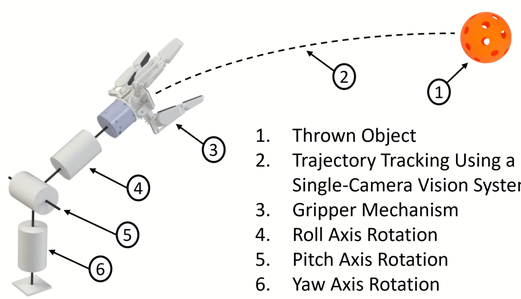


Fig 2 (top-right): System reaction time diagram, where t_{offset} represents the offset delay. Catching fails if the gripper closes too early or too late.



1. Thrown Object
2. Trajectory Tracking Using a Single-Camera Vision System
3. Gripper Mechanism
4. Roll Axis Rotation
5. Pitch Axis Rotation
6. Yaw Axis Rotation

Fig 3 (bottom-right): Proposed design solution, featuring a 3 degree-of-freedom spherical joint.

Discussion

- Average human throw speed: **22-44 ft/s.**
- Wider window, higher catch probability.
- **Reaction time window narrows with velocity.**
- Reliable at low speeds; higher speeds require reaction time within 0.05s.
- Worm gear reduction hinders actuation speed.
- Maximum tested speed was half that required for an average throw.
- System **does not catch reliably**.

Future Work

- Worm gear removal and finger repositioning for faster, more accurate actuation.
- Spherical joint with inverse kinematics and a single-camera vision system.

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Robotic Acuators & DynamicsLab

References: Telegenov, K., Tlegenov, Y., & Shintemirov, A. (2015). A low-cost open-source 3-D-printed three-finger gripper platform for research and educational purposes. IEEE Access, 3, 638–647. https://doi.org/10.1109/access.2015.2433937

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Ira A. Fulton Schools of Engineering
Arizona State University