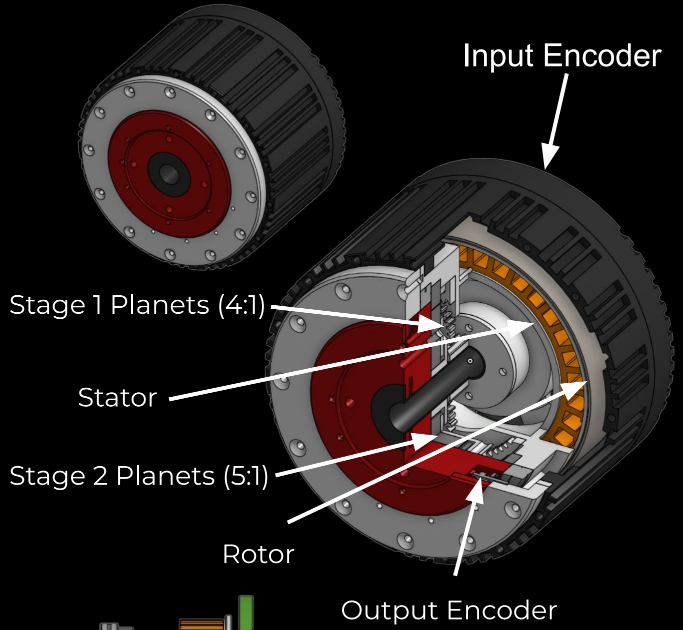
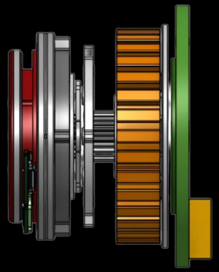
Engineering Portfolio

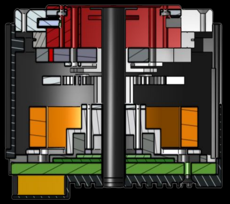
Grant Gao

2022-2026

Custom Dual-Encoder QDD Actuator







Spec Sheet	
Stator:	CubeMars RO100 Stator
Ratio:	20:1 (2-stage Planetary)
Sensors:	Dual Absolute Ring Encoders
Peak Torque:	60 NM [EST.]
Mass:	~2KG [EST.]

Key Engineering Challenges:

- **Packaging + Thermals:** Maximized hollow bore (12.6mm) to enable internal routing of EtherCAT and power buses. Integrated radial cooling fins on the housing to dissipate thermal buildup from the enclosed outrunner motor.
- **Control:** Implemented dual-loop architecture (input + output encoders) to close the position loop directly at the joint, compensating for transmission backlash and elasticity.
- **Transmission:** Engineered a high-density 20:1 two-stage planetary gearbox nested within the stator volume to minimize axial length.

Exoskeleton Data Glove

Spec Sheet (Per Hand)	
Degrees of Freedom	16
Encoders per DOF:	RDC506018A
State Estimation:	IPhone SLAM
Size	185mm (Wide) x 230mm (Long)
Mass:	~800g [EST.]

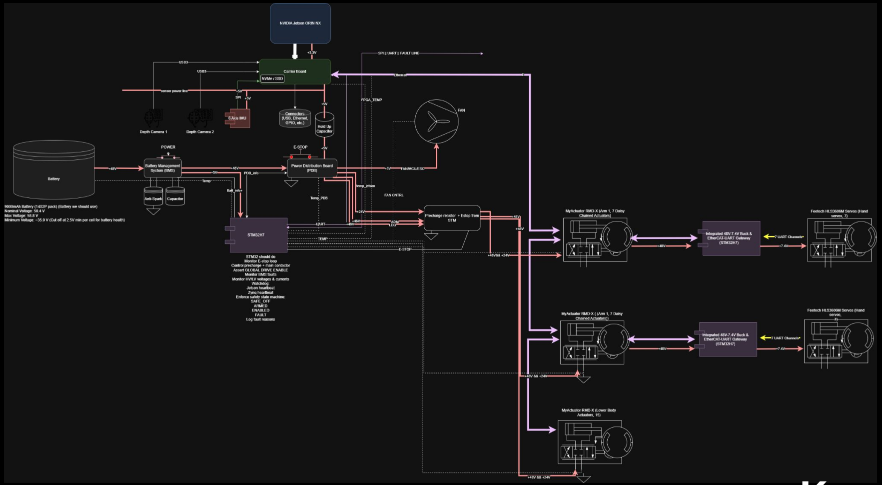
Key Engineering Challenges:

- **Human Interfacing:** Iteratively optimized linkage geometry to align mechanical pivots with biological joint centers (MCP, PIP, DIP) preserving natural dexterity during teleoperation.
- **Joint Tracking:** 1:1 kinematic mapping to the Orca hand with RDC506018A Encoders at each DOF to capture joint angles for imitation learning.
- **State Estimation:** Integrates an IPhone to do SLAM to leverage commercial VIO (iPhone/ARKit) for future 6-DOF end-effector tracking, reducing the need for expensive external motion capture systems.

V2 Pivot:
V1 Issues: Rigid linkages constrained Thumb CMC dexterity.

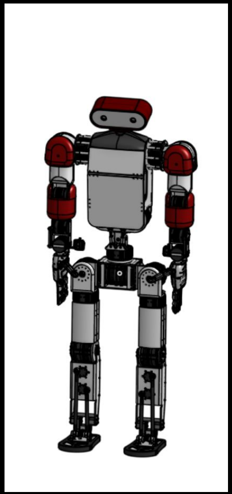
V2(WIP): Magnetic elastomer glove with 3-axis Hall Effect arrays for shear/pressure mapping and 6-DOF IMUs for linkage-less tracking.

Humanoid System Architecture:



Electronics System Architecture:

- **Communication Protocol:** Conducted a trade study between CAN FD, EtherCAT, and a hybridized architecture. Selected Pure EtherCAT to eliminate sequential latency from CAN and reduce software complexity.
- Figured out electronics stack as well as data and power pipeline.

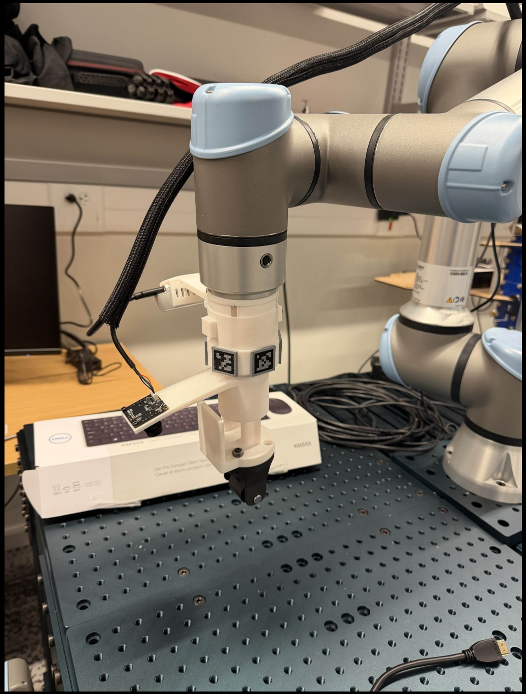


Mechanical Design Specifications:	
Total System Mass (Target)	35 Kg +- 5Kg
Height (Target):	1.28 m
Leg DOF (per limb)	6
Arm DOF (per limb)	7
Torso DOF:	3

Key Engineering Challenges:

- **Leg Actuator Order:** Conducted a trade study between 9 different State of the Art humanoids. Decided on FAR (Flexion-Abduction-Rotation) for Hips, actuator at the knee, and a RSU linkage system for the 2 DOF ankles. Thus, reducing the moment of inertia of the swing leg.
- **Arm Workspace:** Selected a 7-DOF kinematic chain to replicate the redundancy of the human arm, optimizing the manipulator's workspace for high-fidelity UMI data collection and imitation learning.
- **Backpropagating from first principles:** Derived the required torque and velocity specifications for the actuator selection by working backward from specific subgoals per mechanism.

Current Research: Robot Learning(In Development)

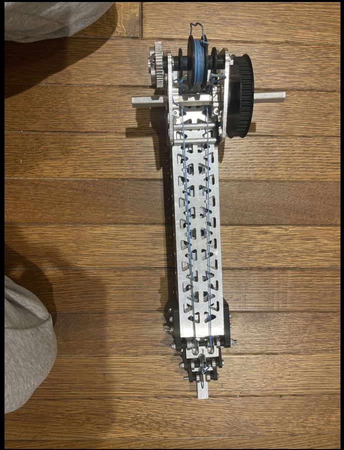


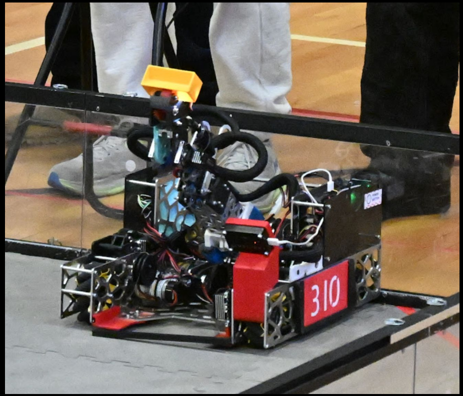
Research Question: How does the composition of multimodal demonstration data collected with a unified tool interface influence the robustness and execution quality of learned manipulation policies in contact-rich Tasks?

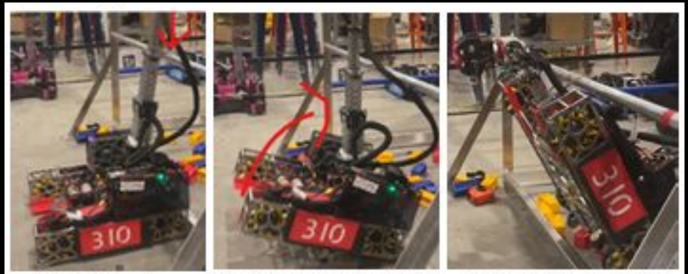
Key Engineering Challenges:

- **Hardware Interface:** Iterated upon the VDI architecture (originally developed by Prof. Hagenow) to optimize it for the UR7e and include an integrated wrist camera specifically for Natural Demonstration mode. This isolates the tool from the hand in the visual frame, preventing out-of-distribution (OOD) failures during autonomous rollouts where the hand is no longer present.
- **State Estimation:** Working on a real-time optimization algorithm that drives the robot to actively follow the handheld tool during Natural Demonstrations. This minimizes marker occlusion and keeps the tool centered in the camera frame, extending the effective workspace beyond the static camera's field of view.
- **Data Logging:** Architecting a synchronized logging framework to align asynchronous sensor streams (robot proprioception vs. external tool tracking) into a unified observation space. This alignment is critical for training Visuomotor Diffusion Policies that generalize across heterogeneous data sources.

Pivoting Telescoping Arm 24’ - 25’

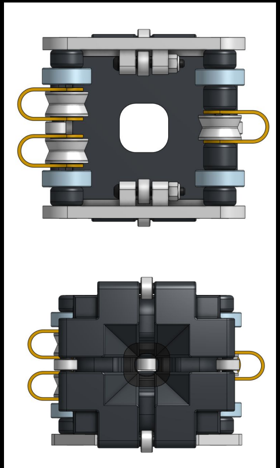






Motors stall | Pivot motors activate | Final climb position

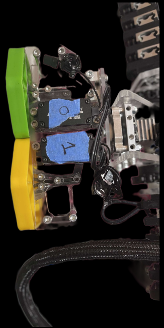
Spec Sheet	
Telescoping Speed:	2.6 m/s
Peak Pivot Torque:	12.7 Nm
Moving Stages:	3



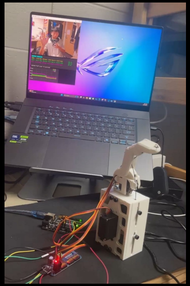
Key Engineering Challenges:

- **Manufacturing:** Used a custom box-tube jig for multi-sided CNC operations (Fusion 360 CAM) to maintain hole-pattern tolerances across four telescoping stages. This precision was critical to ensuring a sliding fit with minimal binding under high-speeds.
- **Rigidity:** Developed a dual-plane, 8-point bearing constraint system (4 top, 4 bottom) per stage to manage cantilevered loads. This configuration limited tip deflection to <0.5 inches at maximum extension, preserving extension efficiency under combined axial and torsional loading.
- **Speed:** Conducted a time-matching analysis between drivetrain traverse speed and arm extension (2.6m/s) to ensure the mechanism reached scoring height mid-transit, minimizing mechanism idle time and optimized the intake-to-outtake scoring cycle.

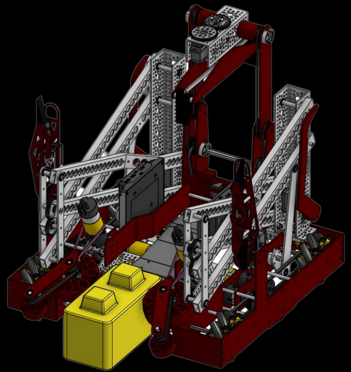
Archive (22'-26')



Over-center linkage based claw for zero power object retention.

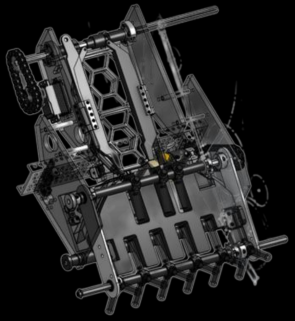


Finger Test Bed: Validated Nitinol wire flexible properties for tendon driven approach. Mediapipe for joint angle detection.



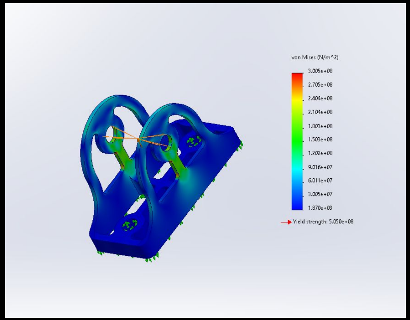
Double Reverse Virtual four Bar Lift with integrated compliant intake and linkage gripper.

2024 Robot: Designed, self fabricated and built the drivetrain, lift, intake, outtake subsystems.



Flip Up Intake to allow for faster, lighter end effector.

Open Source Lightweight 3DP Parallel Jaw Gripper for SO-101



Weight optimization for FSAE clevis(7075 T6 Alum) under 700 lbf with a safety factor of 1.5

Calhacks 2025: Integrated SmolVLA to to map human gestures to robot actuation commands.