RAIN SEMESTER PROJECT · COHORT 21

A Compliant Multi-Modal Tactile Gripper for Safe Human-Robot Object Handover

Intelligent touch feedback and compliant fingertips for reliable, damage-free transfer.

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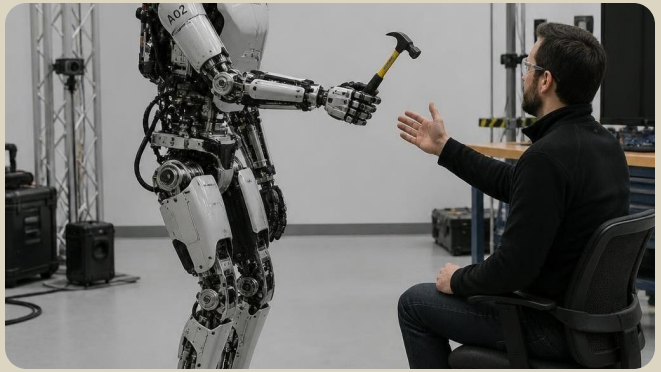
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Who has this problem?

Three illustrative domains for safe physical interaction.



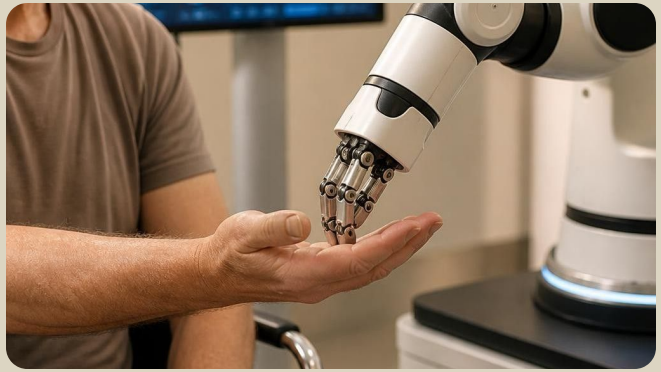
Tesla Robotics

Humanoid robots hand people tools, packages and fragile household items.



Zipline Fulfillment

Robotic sorting of medical payloads, from rigid boxes to fragile bags.



Future Iron Man

An assistant that handles a human hand without injury.

Illustrative use cases; not an endorsement or formal partnership claim.

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Why does it matter?

Vision is limited at the point of physical exchange.

1 The Occlusion Problem

During close handovers, a human hand can block cameras from seeing the contact point.

2 Friction & Stiffness Blindness

Vision alone cannot directly measure stiffness or surface friction.

3 The Force Boundary Dilemma

Too little force risks dropping a payload; too much can crush it or injure a person. Tactile feedback can detect contact and incipient slip.

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What will be built: structure and control

A parallel-jaw gripper adjusts grip force using touch-based feedback.

Mechanical

Name	Function	Image
3D-printed PLA/PETG chassis	Rigid, low-backlash parallel linkage; dual-rail or rack-and-pinion drive.	
TPU or cast-silicone pads	Cushion impact, enlarge contact area and increase friction against human tugs.	

Control

Name	Function	Image
Teensy 4.1 or STM32 Nucleo-F446RE	Target ≥1 kHz sensor polling to detect rapid slip before a drop.	
SimpleFOC shield or Dynamixel U2D2	Motor-dependent interface for commands, current limits and position packets.	

Other candidate boards: ESP32-S3, RP2040/Nano RP2040, Teensy 4.0/4.1 and Arduino Leonardo (32U4). Timing and compatibility, including interrupt latency and ADC multi-channel sampling overhead, require verification. Images are illustrative.

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What will be built: sensing and software

Name	Function	Equipment
Dynamixel XM430-W210-T smart servo or BLDC motor	Smart servo reports position and current; BLDC uses encoder and current sensing.	
FSR matrix or Velostat sheet; piezo disk or high-frequency FSR	Measure contact pressure and capture slip vibrations.	
Embedded C++ control loop	Monitors touch/slip every 1 ms; updates current limits every 10 ms.	
Python USB-serial telemetry	Logs timestamp, FSR voltage, motor current and encoder position over USB serial to CSV.	

Note: Unlike position-only hobby servos, a smart actuator can report position and current. Current is a proxy for torque, not a direct measurement; characterization is needed. Interface selection depends on the actuator.

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What makes it multi-modal?

Three channels distinguish normal force, micro-motion and bulk stiffness.

Sensor Mode	The sensor	What it measures	The role
Tactile pressure	FSR matrix or Velostat conductive film	Contact pressure and normal force	Detect touch; estimate fingertip grip force after calibration.
Micro-vibration	Piezo disk or high-frequency FSR	Slip and shear vibrations	Detect incipient sliding and trigger a reflex grip adjustment before gross slip.
Proprioception	Actuator current sensing and magnetic encoder	Motor current and finger displacement	Estimate torque and infer object response, deformation or stiffness after calibration.

Pressure, dynamic vibrations and motor state combine to support safe handover.

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The 3 core experiments to be performed

Experiment	Description	Expected result
A	**Blind object-stiffness identification** Grasp calibrated sponge, silicone, rubber and rigid wood cylinders without geometric models.	Grip force vs. time and encoder finger displacement vs. time graphs to classify stiffness bands.
B	**Dynamic slip-reaction efficiency** Apply sudden downward pulls to gripped payloads under varied surface friction.	Tactile sensor frequency output and motor response latency from slip trigger to force arrest.
C	**Human-to-robot handover safety matrix** Reciprocal handovers: people extract objects under autonomous reactive release thresholds.	Peak pulling force required by the human before the gripper releases the payload.

Proposed tests of compliance, latency and safety—not results. Measure human pull force with a suitable force gauge or load cell.

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Thanks for listening.

Don't hold back your questions.

Safe robotic handovers bridge human trust and machine compliance through responsive tactile feedback.

Connect & Discussion:

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