CRAFT: A Tendon-Driven Hand with Hybrid Hard-Soft Compliance

Leo Lin*[1] Shivansh Patel*[1] Jay Moon*[1] Svetlana Lazebnik†[1] Unnat Jain†[2]

[1]University of Illinois Urbana-Champaign [2]UC Irvine

*Equal contribution †Equal advising

***Abstract*—We introduce CRAFT Hand, a tendon-driven anthropomorphic hand with hybrid hard-soft compliance for contact-rich manipulation. The design is based on a simple idea: contact is not uniform across the hand. Impacts concentrate at joints, while links carry most of the load. CRAFT places soft material at joints and keeps links rigid, and uses rolling-contact joint surfaces to keep flexion on repeatable motion paths. Fifteen motors mounted on the fingers drive the hand through tendons, keeping the form factor compact and the fingers light. In structural tests, CRAFT improves strength and endurance while maintaining comparable repeatability. In teleoperation, CRAFT improves handling of fragile and low-friction items, and the hand covers 33/33 grasps in the Feix taxonomy. The full design costs under $600 and will be released open-source with vision-based teleoperation and simulation integration.**

I. Introduction

Dexterous manipulation is fundamentally about making and managing contact. A robot hand must be accurate enough to place contact where the policy expects it, yet robust enough to survive the inevitable collisions, slips, and off-nominal interactions that occur during real data collection. Classical dexterous hands built around rigid linkages and joint-mounted actuation have demonstrated precise, repeatable kinematics and strong actuation across decades of work [11, 24, 30, 3, 9]. More recently, low-cost open platforms have made anthropomorphic dexterity substantially more accessible for robot learning research [26]. However, as interaction scales up, contact becomes the dominant failure mode: rigid structures transmit impacts directly into joints and linkages, and even minor collisions can interrupt long-running data collection.

Soft robotic hands address fragility by using compliant materials that deform under load [7, 14]. This passive compliance is appealing: the hardware absorbs uncertainty that would otherwise require precise control [19]. But compliance introduces a different problem. Without a rigid structure, soft hands exhibit configuration-dependent kinematics and limited load capacity. A soft finger can bend differently depending on how much it is already supporting, making its motion and force transmission difficult to model and repeat.

We resolve this tradeoff with a practical observation: contact forces in manipulation are not uniform across the hand. Fingertips and knuckles frequently collide, slide, and conform, while the links between joints primarily transmit loads to the motors. This motivates a hybrid style of compliance: *place compliance at joints where impacts and contact uncertainty concentrate, and use rigid links where geometric predictability and load paths matter*. The goal is not "soft everywhere," but "soft where it helps," so passive deformation absorbs shocks and regulates forces without sacrificing kinematic structure.

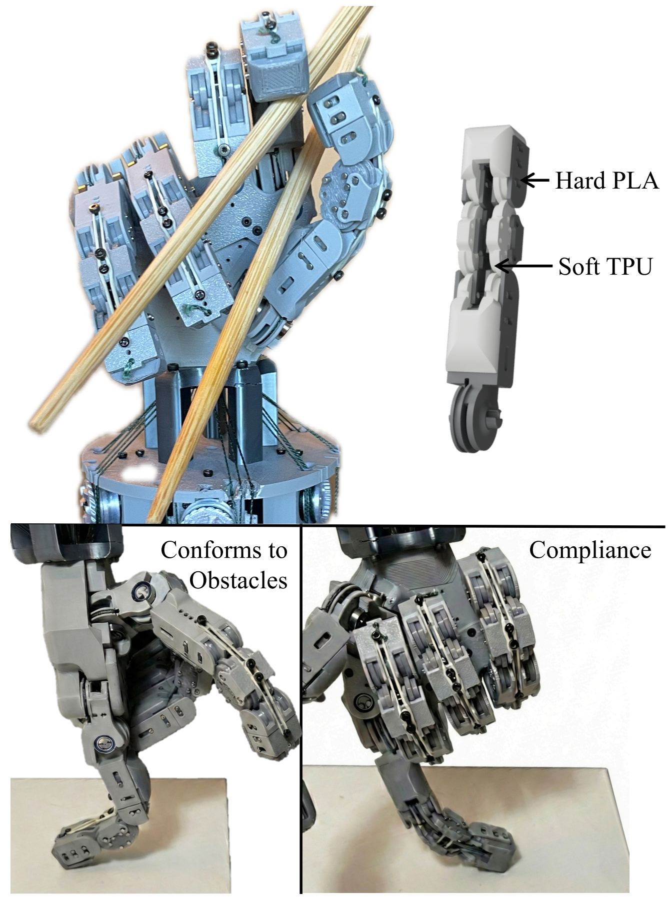

Fig. 1: CRAFT Hand is an anthropomorphic hand. Bottom left: careful choice of hard and soft materials that do not break under external forces. Bottom-right: CRAFT Hand's compliance when in collision, conforming to the obstacle's shape.

To this end, we propose CRAFT Hand (Fig. 1), a tendon-driven anthropomorphic hand with hybrid hard-soft compliance. The load-bearing links are printed in hard PLA (a rigid 3D-print plastic), while the finger joints use soft TPU (a rubber-like elastomer), as highlighted in Fig. 1. A key challenge is making compliant joints behave predictably under off-axis loads. We therefore use rolling-contact joints at the intermediate and distal finger joints (PIP and DIP, i.e., the two joints closest to the fingertip): the TPU compresses along a constrained curved interface, producing repeatable motion while still providing passive give under collision. In practice, the compliant joints reduce the frequency and severity of damage during contact-rich operation.

Our actuation comes from 15 motors located behind the wrist, with three motors per finger driving flexion and side-to-side motion through tendons. Placing motors away from the hand removes them from contact zones and keeps the fingers light, which simplifies full-system teleoperation. Tendon routing also provides mechanical advantage, improving holding strength and reducing effort during sustained grasps. The hand is modular and 3D-printable, so damaged components can be replaced quickly.

Because the hand is intended for data-driven learning, we pair the hardware with tools for demonstration collection and policy learning. A single-camera, vision-based teleoperation setup enables full arm and hand control, and we provide URDF and MuJoCo XML models that preserve the hand's kinematics while using practical approximations for the hybrid joints.

We evaluate three questions. First, does localized compliance compromise structural performance? Benchmarked against the rigid LEAP hand [26], CRAFT matches kinematic repeatability and survives impacts that break the baseline, while avoiding the modeling complexity of fully soft designs. Second, does compliance improve manipulation? Teleoperation across five tasks, from rigid objects to fragile and low-friction items, shows CRAFT achieves consistently higher success by passively regulating contact forces that would otherwise demand advanced control algorithms. Third, how well does this design support dexterity? We cover the Feix grasp taxonomy [8], demonstrating success on all 33/33 grasps from power grips to precision pinches. Our contributions are:

- **Open-source hand and framework**: We release CRAFT as open-source hardware (under $600) along with ready-to-use teleoperation and simulation assets for robot learning.
- **Hybrid hard-soft design**: We localize compliance at joints while keeping links rigid, improving contact tolerance while preserving predictable kinematics.
- **Rolling-contact joints**: We use rolling-contact joints that constrain deformation to a repeatable path under load while remaining compliant during collision [29, 1].
- **Functional validation**: We benchmark repeatability and endurance against a widely used open hand, evaluate teleoperated manipulation on rigid, fragile, and low-friction objects, and validate grasp coverage with the Feix taxonomy [8].

II. Related Work

Direct-Drive Robotic Hands Historically, dexterous manipulation research has relied on fully actuated, direct-drive hands [30, 3, 9, 4]. These systems employ rigid linkages with motors at joints or in the palm for high torque and precise control. The DLR-HIT Hand II [9] integrates motors into finger bases and phalanges for a compact design. However, it comes at steep costs ($15,000–$80,000) and has kinematic limitations. Meanwhile, the Allegro Hand [30], while robust, lacks abduction/adduction degree of freedom (DoF), restricting its ability to perform human-like opposition and power grasps.

Recent efforts focus on bridging this gap through affordable, open-source hardware (approx. $2,000). The LEAP Hand [26] addresses kinematic shortcomings of direct-drive predecessors; its universal abduction-adduction mechanism eliminates workspace dead zones. Similarly, the D'Manus [4] offers affordable dexterity. However, housing motors within fingers or palms increases thickness, creating a bulky form factor exceeding human dimensions. Furthermore, these rigid hands rely on complex active impedance control rather than mechanical compliance to manage contact forces. Consequently, inaccuracies cause high-force collisions, risking damage. In contrast, our hand integrates a hybrid soft-rigid structure with tendon-driven compliance, adapting to contact while retaining a human-like form factor.

Tendon-driven and compact designs While direct-drive hands offer simplicity and robustness, placing motors within the fingers or palm creates bulky, non-anthropomorphic form factors. To achieve the compact size of a human hand, researchers use tendons to relocate motors to the forearm [24, 11, 13, 20, 15, 33, 6]. The Shadow Hand [24], a long-standing benchmark in this category, uses a complex array of tendons to actuate 24 joints, mimicking human kinematics. However, its high cost and closed-source nature have limited its use in large-scale learning experiments.

Recent open-source initiatives have sought to democratize this morphology. The RUKA hand [33] achieves a 15-DoF anthropomorphic design, more compact than direct-drive alternatives by housing servos in a forearm unit. Similarly, the ORCA Hand [6] addresses tendon fragility via "popping" joints that dislocate under stress rather than breaking, ensuring reliability for operation. Despite these advancements, most tendon-driven hands remain rigid. Stiff tendons transfer motor torque directly to joints, meaning these systems still rely on active impedance control rather than passive compliance to manage interaction forces. Our hand utilizes soft materials, providing inherent compliance that allows fingers to naturally conform without complex control.

Compliance and Soft Robotics To overcome the challenges posed by the stiffness of rigid and tendon-driven mechanisms, where imperfect state estimation can lead to damaging collisions, researchers have turned to passive compliance as a hardware-level solution. Early efforts [16, 32, 7, 20, 18] utilized elastomer flexure joints to achieve this, allowing fingers to conform passively without complex control. However, these designs are typically underactuated (low DoF), limiting their ability to perform complex in-hand manipulation.

To combine robustness with dexterity, recent works [29, 14] have explored hybrid soft-rigid architectures. The closest to our work is Leap V2 [25], which successfully integrates elastomer joints into a high-DoF (22 joints) system. However, while mechanically capable, the Leap V2 remains expensive ($5000) and relatively bulky. In contrast, our hand achieves a significantly more compact, anthropomorphic form factor at a fraction of the cost ($600), without sacrificing the high-DoF compliance essential for robust manipulation. Furthermore, our use of rolling contact joints improves durability compared to flexure-based joints, which break under repeated use.

III. Kinematic Design

This section presents the mechanical implementation of our hybrid design principle, describing the hand architecture, joint mechanisms, and tendon routing.

CRAFT hand structure An X-ray view of CRAFT is shown in Fig. 2. To maintain a human-like form factor, CRAFT has 95 mm palm and 103 mm finger length, totaling 198 mm (340 mm with the forearm motors). These dimensions align with median male hand measurements [10], ensuring the system is compact for teleoperation. CRAFT integrates 15 motors for 15 active and 5 passive degrees of freedom (DoF). To maintain compactness, all motors are located in the forearm.

Joints Structure We denote the finger joints using standard anatomy: the metacarpophalangeal (MCP) joint at the finger base, the proximal interphalangeal (PIP) joint in the middle, and the distal interphalangeal (DIP) joint closest to the fingertip. These are shown in Fig. 2. We assign three motors to each finger to control *(i) coupled flexion of the PIP and DIP joints*, (ii) *abduction/adduction of the MCP joints and* (iii) *flexion/extension of the MCP joints*.

Most robotic fingers implement PIP/DIP motion using pin joints [26, 33], providing simple revolute axes sensitive to off-axis forces. CRAFT instead uses rolling contact joints [1] at PIP and DIP. Two circular surfaces roll relative to each other, constraining motion to a repeatable path while permitting elastic deflections. A bidirectional mechanical linkage (Fig. 3**B**) couples the PIP and DIP joints so motion at one drives the other, yielding equal rotation. This preserves a moving DIP joint while reducing complexity, as a single tendon drives both distal joints. Passive elastic bands (Fig. 3**E**) returns joints to neutral when tendon tension is released.

At the MCP joint, we have a cylindrical snap-fit interface motivated by Christoph *et. al.* [6] that simplifies assembly and pops out under excessive force, reducing risk of joint breakage. Two tendons actuate the MCP: a forward tendon for flexion and extension and a side-to-side tendon for abduction and adduction. Both are backdrivable, allowing external forces to drive the transmission in reverse, useful for calibration. In contrast, the coupled DIP and PIP mechanism uses a single tendon to deliver strong finger closing for grasping while allowing the finger posture to adapt to external forces.

The thumb is mounted laterally, per Fig. 2, to replicate human anatomy. Although thumb joints use distinct anatomical names—CMC, MP, and IP—we implement them with the same mechanical structure as the fingers. The CMC joint functions as the thumb's base, utilizing the same snap-fit interface for 2-DoF motion. Similarly, distal MP and IP joints employ the rolling-contact design and coupled-linkage mechanism found in the finger PIP and DIP joints.

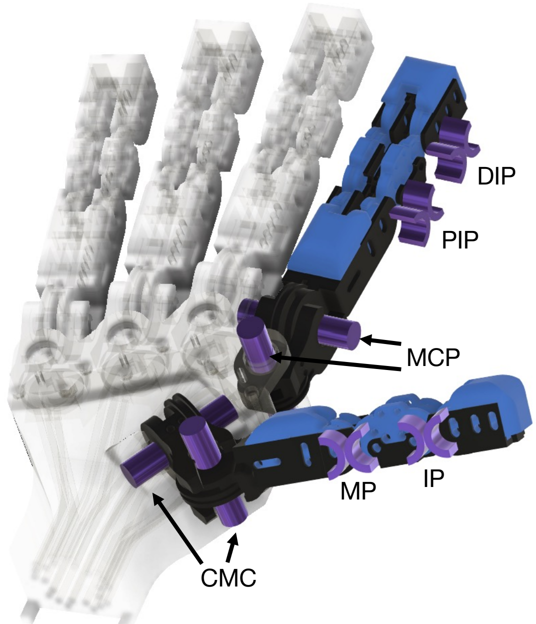

Fig. 2: **Joints Structure.** Grey denotes the rigid components, while white denotes the compliant (TPU) components. The index finger and thumb are highlighted to illustrate kinematics, with purple components indicating joint axes. Fingers feature a 2-DoF MCP and coupled PIP/DIP joints; the thumb mirrors this with a 2-DoF CMC and coupled MP/IP joints. PIP/DIP and MP/IP employ rolling contacts, while MCP/CMC use the cylindrical snap-fit interface.

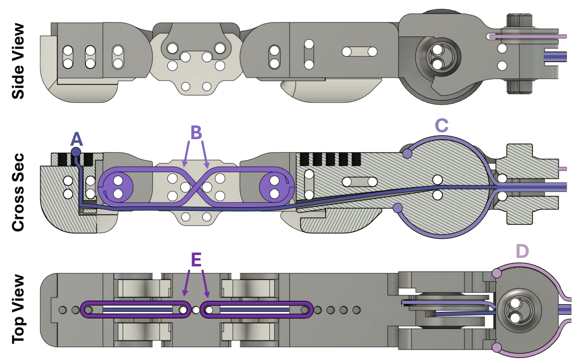

Fig. 3: **Finger Structure.** Grey denotes the rigid components; white denotes the soft (TPU) components. (A) PIP/DIP Tendon. (B) Bidirectional Linkage. (C) MCP Flexion/Extension Tendons. (D) Abduct/Adduct Tendons. (E) Elastic bands.

Finger Structure As shown in Fig. 3, the hybrid design comprises distinct rigid (PLA) and soft (TPU) parts. The cross-section **(Cross Sec)** reveals the bidirectional TPU linkage coupling PIP and DIP joints, mimicking a reverse pulley mechanism. Metal dowels provide structural support and low-friction tendon guidance. In the **Top View**, elastic bands passively return PIP/DIP joints to neutral, while side tendons drive MCP abduction/adduction. In Fig. 2, rigid and soft components are represented by grey and white. Material composition varies to balance stiffness and flexibility: rigid PLA wraps soft TPU along segments to maintain alignment, while PIP and DIP joints consist entirely of soft TPU. This allows elastic deformation under impact, ensuring durability during contact-rich manipulation. The modular design allows finger replacement without disassembling the hand or rewiring tendons. Detaching dowel pins enables users to swap designs or iterate on configurations easily.

Tendon Routing Finger routing is shown in Fig. 3. Two opposing pairs control MCP flexion/extension and abduction/adduction, while a single tendon drives coupled PIP/DIP flexion. We use high-strength braided line to withstand substantial tension. To minimize friction, metal dowel pins serve as smooth guide surfaces. These tendons transmit motor forces to the joints. Our routing layout is designed for visual and mechanical simplicity, allowing users to readily identify tendons during maintenance. The motors are arranged in a compact pentagonal shape, with each face serving a single finger. Similar to Christoph *et. al.* [6], we use a ratchet spool to quickly (re-)tension the tendons.

IV. Compatibility with Robot Learning

For imitation and reinforcement learning, we demonstrate a smooth integration with teleoperation that controls both a robot arm and the hand. We also enable simulation compatibility by providing URDF [17] and MuJoCo XML [28] files for use in widely adopted simulators [2, 22, 5].

We employ a vision-based teleoperation [31, 12] framework to collect data for imitation learning. We utilize HaMeR [21] for hand pose estimation and FrankMocap [23] for whole-body tracking. This approach follows the vision-based teleoperation introduced by Sivakumar *et. al.* [27]. This system maps human kinematics to the robot's configuration space by synchronizing hand calibration with whole-arm retargeting. Refer to Fig. 4 for an example of the teleoperation setup.

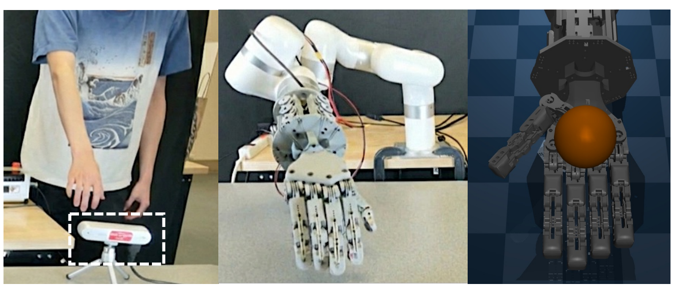

Fig. 4: **Whole-Arm Teleoperation and Simulation.** Left: An operator controls the robot arm and hand using a single RGB camera (highlighted with a dashed box) placed in front of the operator. Middle: Operator performing teleoperation with hand pose overlay. Right: CRAFT model in MuJoCo simulation environment.

Building on prior work on tendon-driven hands [6], we employ a joint-wise calibration procedure to align the operator's hand movements with CRAFT hardware. We begin by manually moving each robot's joint to its extreme to record that joint's value. Subsequently, we capture the teleoperator's biological limits by recording the output of HaMeR as they move their fingers through their full range of motion, covering both flexion-extension and abduction-adduction.

During teleoperation, we map the operator's current finger configuration to the robot's workspace using a linear function. This function translates the operator's relative joint position, normalized against their specific biological range, into the corresponding angle within the robot's calibrated limits, ensuring accurate retargeting across all degrees of freedom.

To enable full manipulability, CRAFT is mounted as the end-effector of a robotic arm. We utilize FrankMocap to estimate the 3D pose of the operator's wrist relative to their torso. This wrist pose is mapped to the robot's workspace via a linear transformation. To mitigate noise inherent to vision-based teleoperation, we apply an exponential moving average to smooth the targets.

For simulation-based policy learning, we construct kinematic models that capture the hybrid nature of CRAFT. Creating URDF and MuJoCo XML files with well-tested approximations for soft materials presents unique challenges. The hybrid hard-soft design of CRAFT requires careful material parameter tuning. We model the rolling contact joints using equality constraints that enforce surface contact conditions. Given these properties, we model the joints as revolute constraints rather than attempting complex soft-body physics. This simplification maintains computational efficiency while capturing the essential kinematics for policy learning.

V. Experiments

We evaluate CRAFT along three axes. First, we test structural performance to determine whether the hybrid structure degrades precision or strength compared to a rigid baseline. Second, we assess manipulation performance to measure whether passive compliance improves task success in complex manipulations. Third, we validate grasp versatility to confirm that the hybrid design maintains the kinematic range required for general manipulation.

A. *Structural Tests*

To evaluate the physical robustness of CRAFT hand, we conduct three structural assessments. We evaluate the strength, precision, and endurance of CRAFT hand to the LEAP hand [26] using standardized structural tests, consistent with prior work [33, 6]. It is a widely used, rigid, direct-drive hand. To ensure a fair comparison, we assembled the LEAP hand using the same motors as CRAFT hand (Dynamixel XL330-M288-T)[1], hereafter denoted as `LEAP`. This allows us to make a head-on comparison between the soft, tendon-driven architecture (CRAFT) and a rigid, direct-drive linkage (`LEAP`).

Pull-out Test (Strength). This experiment quantifies the maximum payload a finger can retain before mechanical failure. We command the finger to a fully flexed position and apply an external force opposing the flexion direction. The failure threshold is defined as the point where the finger slips or deflects by more than 15° from the target pose. We track the deflection angle using ArUco markers attached to the finger. As detailed in Tab. I, CRAFT withstands 15.29 N of pull-out force, nearly double the 8.67 N measured for the `LEAP` hand. This performance gap highlights the mechanical advantage of the tendon routing system. By distributing the load through

[1] instead of the $4\times$ expensive Dynamixel XC330-M288-T

the tendon, CRAFT reduces the direct torque demand on the motors compared to the direct-drive linkage of the LEAP, allowing for higher holding forces with identical actuation hardware.

Hand	CRAFT	LEAP
Visual		
Strength	15.29	8.67

TABLE I: **Pull-out Strength Comparison.** We measure the resistance of a flexed finger against an opposing external force (in N). The maximum force is recorded immediately prior to a fingertip deflection exceeding 15°. CRAFT demonstrates significantly higher retention strength due to the mechanical advantage of its tendon.

Repeatability Test (Precision). We investigate whether the tendon-driven mechanism introduces position errors or slack over prolonged operation. We program both hands to perform a grasp-and-release sequence on a plush toy continuously for one hour. Fig. 5 presents the joint angle tracking error over the duration of the experiment. The error is calculated using the motor encoder values. Both CRAFT and LEAP maintain consistent performance with mean tracking errors remaining below 0.01 rad. This result demonstrates that CRAFT achieves consistency similar to rigid hands, confirming that the benefits of compliance do not come at the cost of repeatability.

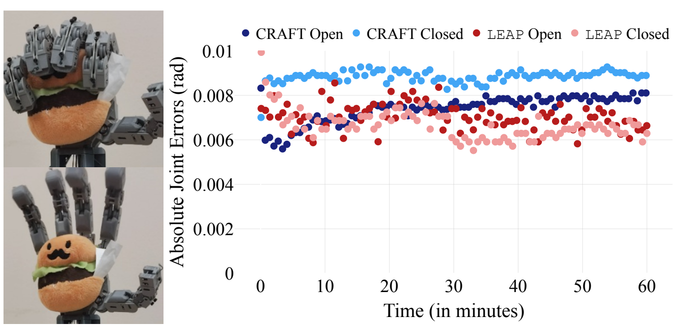

Fig. 5: **Repeatability under Cyclic Load.** *Left:* CRAFT performing continuous grasp-release cycles on an object. *Right:* Joint angle tracking error over one hour of operation. Despite the use of flexible tendons, CRAFT (blue dots) maintains a tracking error of < 0.01 rad, comparable to the rigid LEAP baseline (red dots), demonstrating consistent control. (shades depict joints closing and opening)

Holding Test (Endurance). Finally, we evaluate the hand's efficiency during high-load static holding. Both CRAFT and LEAP are commanded to grasp and hold a 5 lb dumbbell vertically for one hour (Fig. 6). We monitor the current draw to assess motor strain and thermal throttling.
The results show that the average current consumption of CRAFT is approximately 50% lower than that of LEAP. While current draw in both hands rises initially as motor temperature increases, CRAFT stabilizes well below the motor's 600 mA limit. The friction inherent in the tendon routing acts as a passive braking mechanism, assisting in load retention and reducing the active torque required from the motors. In contrast, the direct-drive LEAP must constantly supply higher torque to combat the moment arm of the weight, leading to higher power consumption and thermal stress.

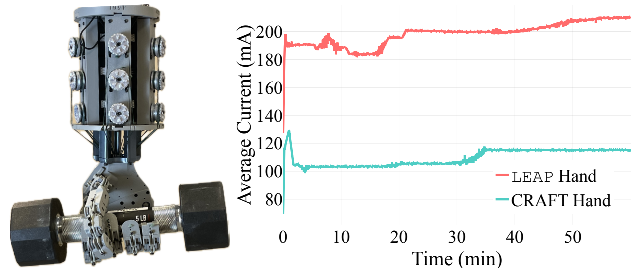

Fig. 6: **Holding Test**. We make CRAFT and LEAP hand grasp a heavy 5lb weight in its palm for one hour. On the vertical axis, we show that the average current running through CRAFT Hand is two times less compared to LEAP. The right axis shows that the current use initially increases. However, it still holds the weight and uses around one-third of its maximum possible current of 600mA.

B. Teleoperation Tests

Fig. 7: **Teleoperation User Study Objects.** To validate real-world utility, we evaluate teleoperation performance on five objects: (1) a ball (rigid grasping), (2) a wine glass (large and fragile), (3) an egg (low friction and fragile), (4) a raspberry (small and deformable), and (5) a frito chip (extremely delicate).

To validate whether CRAFT's compliance translates into improved utility in real-world manipulation, we conduct a teleoperation user study comparing CRAFT against the rigid LEAP baseline. We hypothesize that the passive compliance provided by the soft components will allow for higher success rates with fragile objects and faster completion times by reducing the cognitive load required for precise alignment. To test this, we experiment on five objects shown in Fig. 7, each selected to isolate a specific manipulation challenge:

1) **Grasping a Ball:** requires no compliance, as the ball is solid. This is a reasonably easy object to grasp.
2) **Lifting a Wine Glass:** requires handling a large, fragile object susceptible to shattering under excessive force.
3) **Handling an Egg:** requires managing low-friction fragility, demanding a grasp that is delicate enough to prevent crushing but firm enough to prevent slip.
4) **Picking a Raspberry:** requires extreme delicacy at a small scale, where the object is easily deformed by minor force.

5) **Lifting a Frito Chip:** requires extreme delicacy, serving as a test for passive compliance.

To strictly evaluate the grasping capability of the hand, the robot arm is fixed at an optimal pre-grasp pose for each task. Users control only the hand's fingers via teleoperation. Prior to testing, participants were briefed on the mechanical differences between the hands and given two minutes to familiarize themselves with the teleoperation interface. A strict time limit of 150 seconds was enforced per trial. We run 10 trials for each hand with different people. We plot the results in Fig. 8 and discuss them below.

We measure both success rate and completion time across trials. Success rate captures whether the hand can complete the task at all, while completion time reflects the cognitive and control effort required from the operator. We run 10 trials for each hand with different people. We plot the results in Fig. 8 and discuss them next.

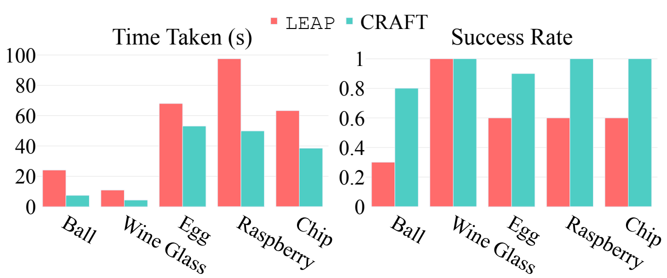

Fig. 8: **Teleoperation User Study Results.** Comparison of average completion time and success rate for five manipulation tasks. CRAFT consistently outperforms the LEAP hand, particularly in handling fragile objects (Raspberry, Chip) where compliance prevents damage, and in dynamic grasping (Ball) where adaptation simplifies capture.

We first examine the grasping ball task to test performance on rigid, non-deformable objects. The bulky structure of LEAP proved a confounding factor, making effective grasps difficult and resulting in taking a longer time and achieving a lower success rate. Since the ball is rigid, CRAFT's passive conformity played a minor role compared to other tasks.

Next, we evaluated lifting the wine glass to assess the manipulation of large, fragile objects. While the glass's substantial size made grasping it straightforward, the task highlighted a significant difference in user confidence. Those operating the rigid hand exhibited noticeable hesitation, moving slowly to avoid applying excessive force that might shatter the glass, taking more than twice as long to complete the task. Conversely, users with CRAFT leveraged the hand's passive compliance to close the grasp rapidly, trusting the soft hand to compensate for contact force. Since the glass's substantial size made grasping straightforward, both hands achieved a 100% success rate.

Handling the egg introduced the dual challenge of low surface friction and moderate fragility. The low friction proved to be the deciding factor, forcing LEAP users to operate with extreme caution and often taking significantly longer to attempt finding a stable grasp. CRAFT mitigated these risks through its compliant surface materials, which increased contact area, allowing users to secure the egg approximately 15 seconds faster on average than with the rigid hand. The rigid hand frequently failed to find a stable grasp before the time limit or slipped due to the lack of friction, resulting in a 60% failure rate. CRAFT achieved a 90% success rate.

Finally, picking the raspberry and the chip were extreme delicacy tests of small objects, requiring precise force application. While users still required significant time (approx. 40-50 s) to carefully align the grasp for these small targets, the task exposed a critical difference in force regulation. The rigid hand frequently crushed objects upon contact due to the lack of passive give, resulting in a 60% success rate. CRAFT achieved a 100% success rate on both tasks, as the soft fingers absorbed contact forces. CRAFT's compliance became the deciding factor.

C. Grasp Taxonomy Assessment

A crucial focus area in compliant robots is whether the introduction of compliance compromises the kinematic versatility required for general-purpose manipulation. To evaluate this, we assess CRAFT on the standardized benchmark of GRASP Taxonomy introduced by Feix et al. [8] and as attempted by previous works [33]. This taxonomy formalizes human grasp types into a classification system, organizing grasps based on contact type, opposition direction, and hand shape. Consistent with prior works on open, robot hands [33], we evaluate on this benchmark because it represents the widest possible range of practically useful grasps required for daily activities.

Fig. 9 reports CRAFT's performance on this standardized set of 33 grasp types, achieving 33/33 successes compared to RUKA's 29/33. Tendon-driven actuation provides the flexion torque to secure objects in power configurations, like the Large Diameter (row 1, col 1). Complementing this, soft material properties facilitate conformal contact for precision grasps, such as the Prismatic 2 Finger (row 2, col 2), stabilizing the hold through local deformation. We highlight performance on configurations typically challenging for compliant mechanisms. The Adduction Grip (row 4, col 5) demonstrates the index finger's ability to maintain lateral stiffness against the thumb's orthogonal force. Similarly, the Writing Tripod (row 4, col 2) shows distal links can maintain specific geometry without collapsing under contact pressure. Finally, the Extension Type (row 7, col 3) validates the hand's full range of motion, forming a stable, flat platform for supporting objects.

D. Whole Arm Teleopration

To evaluate the practical utility of CRAFT across diverse manipulation scenarios, we demonstrate teleoperation on open-world tasks shown in Fig. 11. We begin with picking up a plush toy, which validates the grasping of soft objects. Wiping a whiteboard with a sponge demonstrates the benefit of compliance during sustained surface contact, as the soft joints allow the hand to maintain consistent pressure. Twisting a key further illustrates the advantage of compliance in contact-rich scenarios, where the joints absorb reaction forces during torque. Finally, we examine tasks requiring delicate force

Fig. 9: **Grasp Taxonomy Validation.** CRAFT demonstrating 33 distinct grasp types from the Feix taxonomy [8]. The hand successfully executes a wide range of configurations, including power grasps (e.g., Large Diameter), precision grasps (e.g., Prismatic Pinch), and intermediate poses, confirming that the compliant design maintains the kinematic versatility required for general-purpose manipulation.

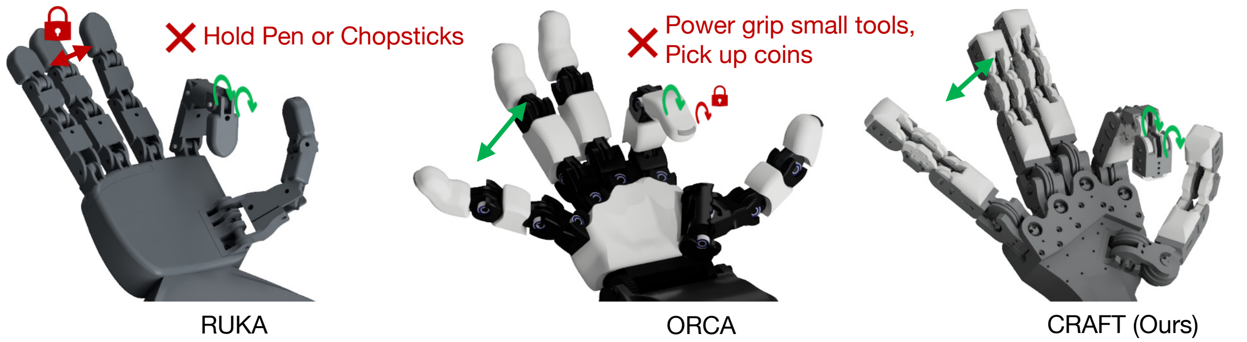

Fig. 10: **Finger Movement Comparison.** Unlike prior work, our hand incorporates both side-to-side movement from the base of the finger and active control of the first knuckle. In contrast, the RUKA hand [33] (RSS 2025) cannot move fingers sideways to squeeze objects, and the ORCA hand [6] (IROS 2025) lacks active control of the fingertips. By utilizing 20 degrees of freedom, our design enables significantly higher dexterity for tasks like picking up coins or using pens/chopsticks.

control: picking up a raspberry tests precision grasping of small delicate items, handling an egg requires managing low-friction fragility, and pouring from a wine glass validates stable manipulation of large breakable objects during dynamic motion. Each task was performed via teleoperation, with the hand successfully completing all demonstrations without object damage or grasp failure. These demonstrations confirm that the hybrid design maintains functionality across a spectrum of tasks.

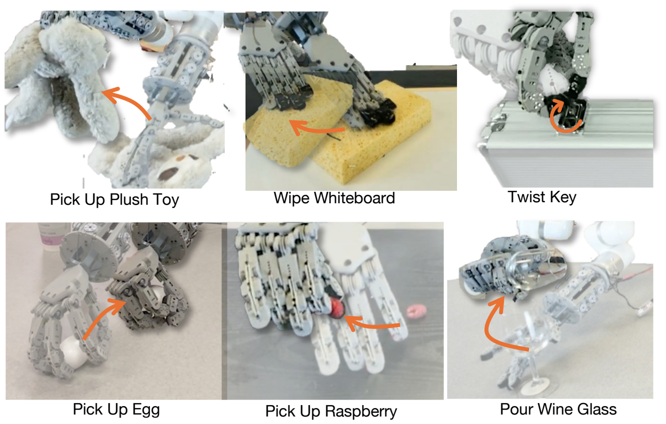

Fig. 11: **Whole Arm Teleoperation.** CRAFT executing various tasks, including wiping, picking fragile objects, and twisting a key.

E. Structural Comparison to Representative Robot Hands

We compare the design of CRAFT with representative anthropomorphic hands from recent work. While many contemporary designs simplify kinematics to reduce complexity, CRAFT maintains full articulation within a compact form factor. We specifically contrast our kinematic structure with the RUKA and ORCA hands in Fig. 10, and evaluate our compact physical profile against the Leap Hand V2 in Fig. 12

RUKA [33]: The RUKA hand utilizes a simplified structure that omits abduction/adduction DoF. While this reduces mechanical complexity, it completely eliminates the lateral workspace of the fingers. This limitation prevents inter-finger grasps, such as holding objects between fingers, and does not allow the manipulation of tools like chopsticks or pens,

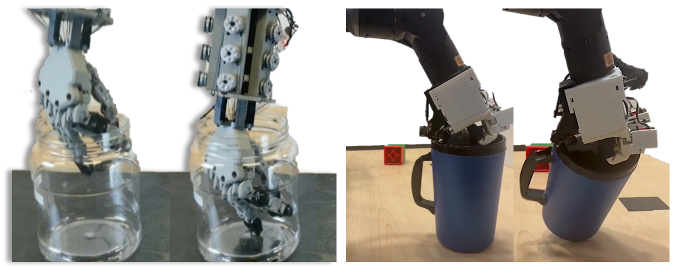

Fig. 12: **Narrow Space Accessibility.** CRAFT demonstrates the ability to fit into a narrow jar, while the bulkier Leap Hand V2 fails to enter the same workspace due to its rigid linkage size. Results reproduced with the help of the authors of Leap Hand V2 [25].

which rely on lateral forces between fingers. The RUKA hand evaluates performance on the Feix grasp taxonomy but is unable to execute four grasps due to this constraint.

ORCA [6]: Similarly, the ORCA hand simplifies structure by employing a fixed DIP joint. This reduces the effective curling range of the fingers and limits the hand's ability to adjust the fingertips necessary for precise tasks. This, again, limits its ability to perform tasks such as holding chopsticks and a pen.

Leap V2 [25]: As demonstrated in Fig. 12, CRAFT's slim, tendon-driven profile allows it to reach into narrow spaces, such as retrieving an object from a confined box, where bulky rigid hands would collide with the environment.

VI. Conclusion

We introduce CRAFT, an open-source anthropomorphic hand built for the reality of dexterous learning: lots of contact, repetition, and not much patience for broken hardware. CRAFT Hand follows a hybrid hard-soft design, using rigid links to carry loads and compliant joints to absorb impacts. Rolling-contact joint geometry maintains well-defined motion even under off-axis loading, so compliance does not come at the cost of unpredictable kinematics. In structural benchmarks, CRAFT Hand matches the repeatability of a rigid baseline while improving strength and reducing effort during sustained holding. In teleoperation, the same compliance makes delicate, low-friction interactions easier to execute safely, enabling reliable handling of fragile items. Finally, CRAFT Hand achieves full coverage of the 33 grasps in the Feix taxonomy, from power grasps to precision pinches. By releasing the full stack, we aim to make durable, repeatable dexterous data collection and policy learning easier to reproduce and scale.

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