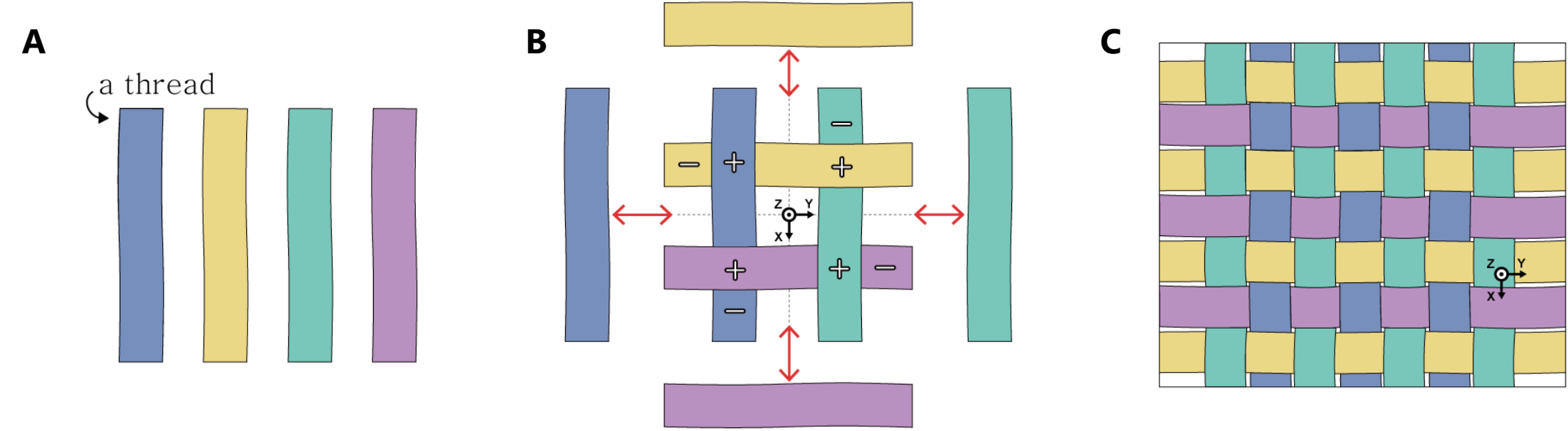


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➤ Motivation – Overcoming Payload Limits in Soft Robotics

► Background

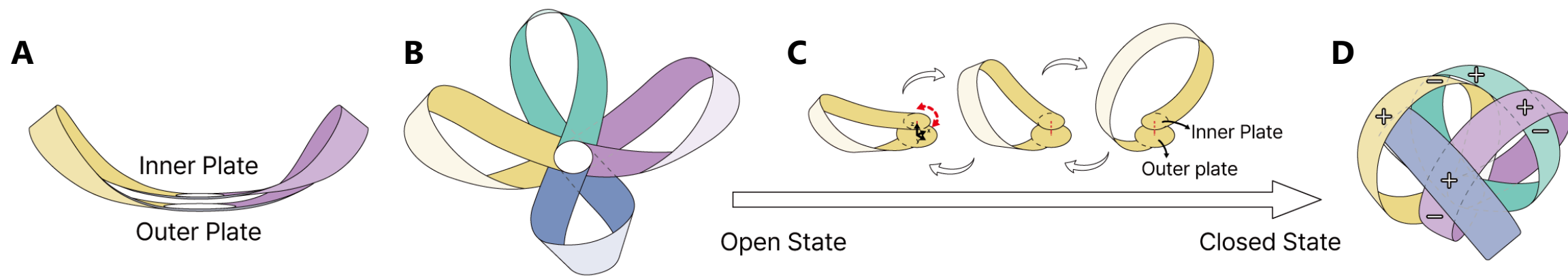
Soft grippers offer safe and adaptive grasping without complex control, yet their softness typically limits payload and robustness. The weaving gripper overcomes these limitations by combining soft material compliance with mechanically stable woven entanglement.



Schematic illustration of the weaving mechanism (A) Individual soft threads aligned before weaving (B) Definition of thread intersections, where threads cross each other with height differences along the z-axis to create overlapping states. (C) The completed plain-woven structure, forming a mechanically stable 2D plane through uniform entanglement.

► Working Principle

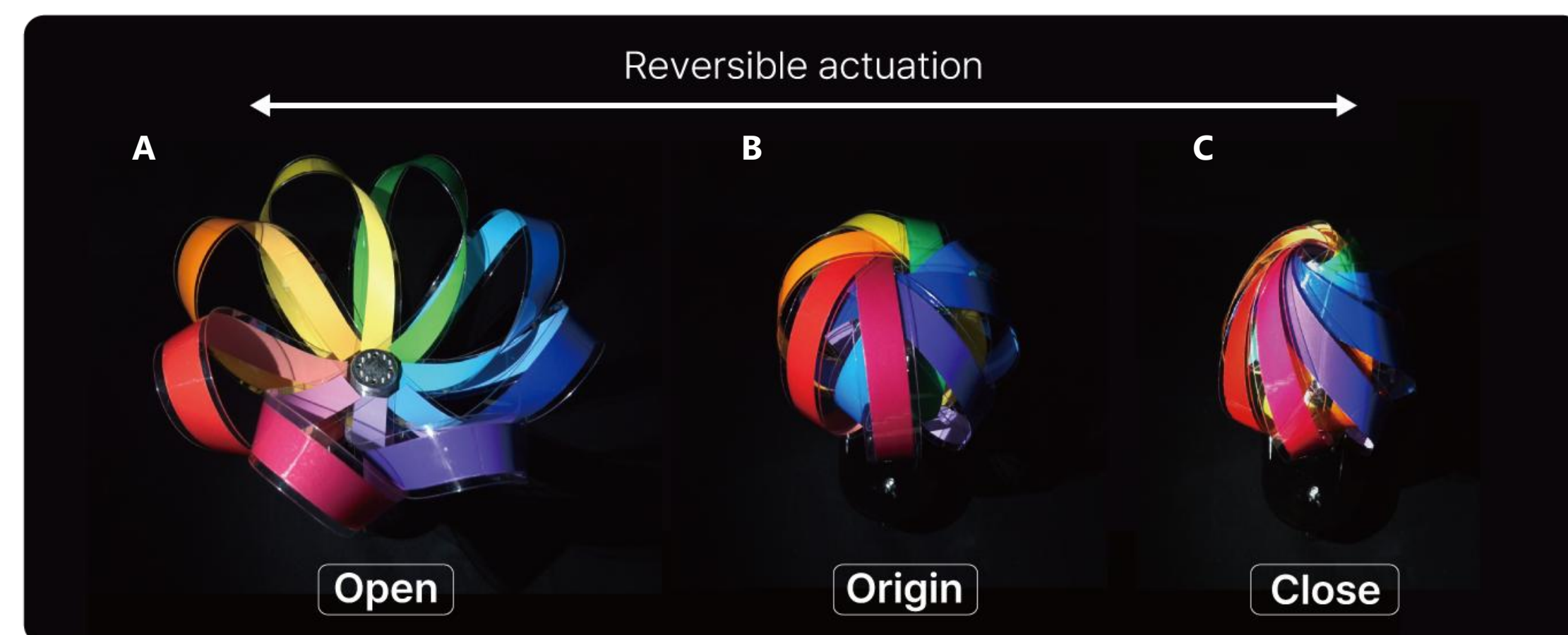
The gripper consists of multiple flexible closed-loop strips. By applying relative rotational motion, the strips transition from an unwoven open state to a mechanically entangled woven state, forming a stable enclosure around the target object.



Operational mechanism and state transitions of the weaving gripper. (A) Cross-sectional configuration showing the layered assembly of the inner plate and outer plate. (B) Fully deployed open state of the gripper. (C) Sequential transition from the open to the closed state driven by the relative movement and curvature change between the plates. (D) Fully closed state, forming an interlocking woven structure to securely cage the target object.

► Actuation Reversibility

The gripper performs repeatable transitions between states via a single-actuator drive. The multi-colored loops visualize the interlacing paths, ensuring stable and consistent morphological changes for reliable grasping and release cycles.

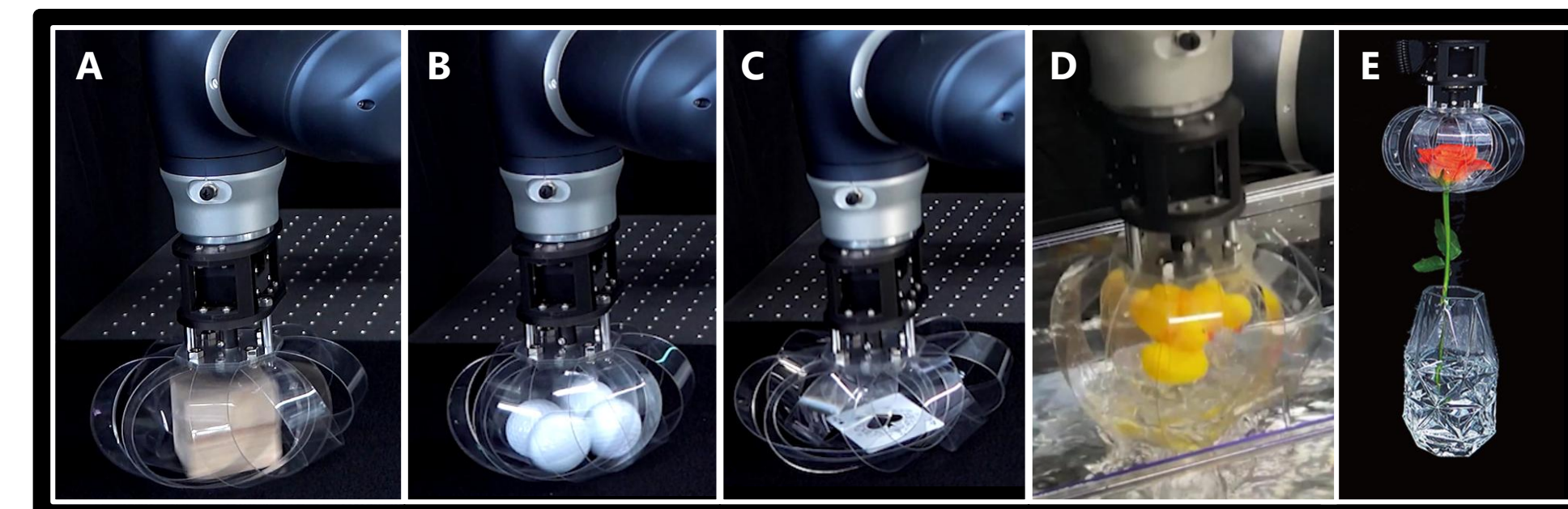


Reversible morphological transitions. (A) Fully expanded Open state featuring decentralized, compliant loops to maximize the grasping workspace for object approach. (B) Intermediate Origin state where the individual loops begin to converge and twist, initiated by the relative plate rotation. (C) High-density Close state where the overlapping loops form a secure, interlocking woven structure to stably cage the target object.

➤ Research Results

► Adaptability

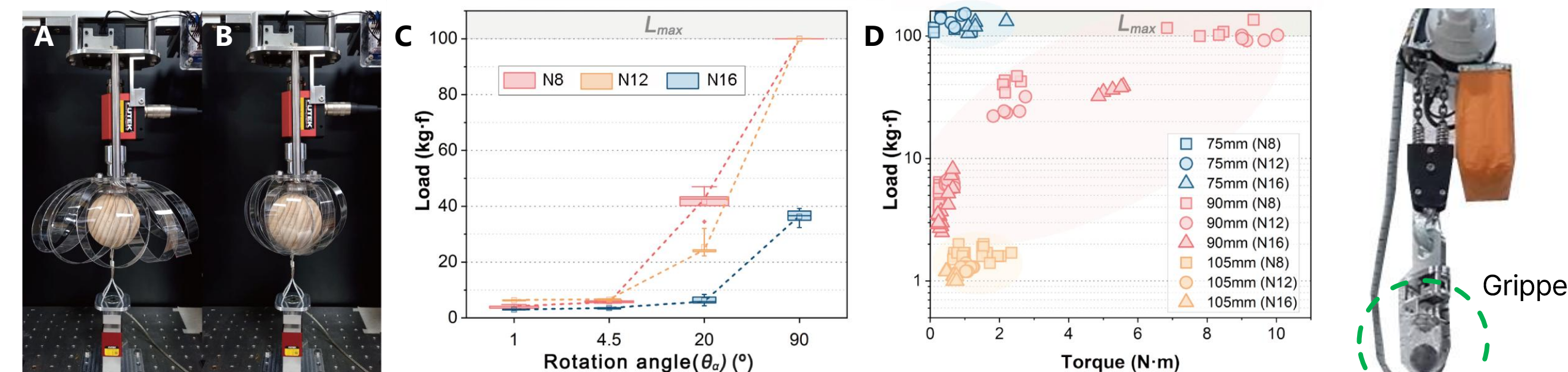
The weaving gripper adaptively conforms to objects with different shapes, sizes, and fragility through its flexible closed-loop strip structure. This enables stable and gentle grasping without complex sensing or control.



Adaptive grasping performance of the weaving gripper. (A) Wood block (60 x 60 x 60 mm) (B) Four golf ball (Dia.: ~ 43mm) (C) Playing card (Thickness: ~ 0.15mm) (D) Three rubber duck on the water (E) a flower

► High-Payload Capacity

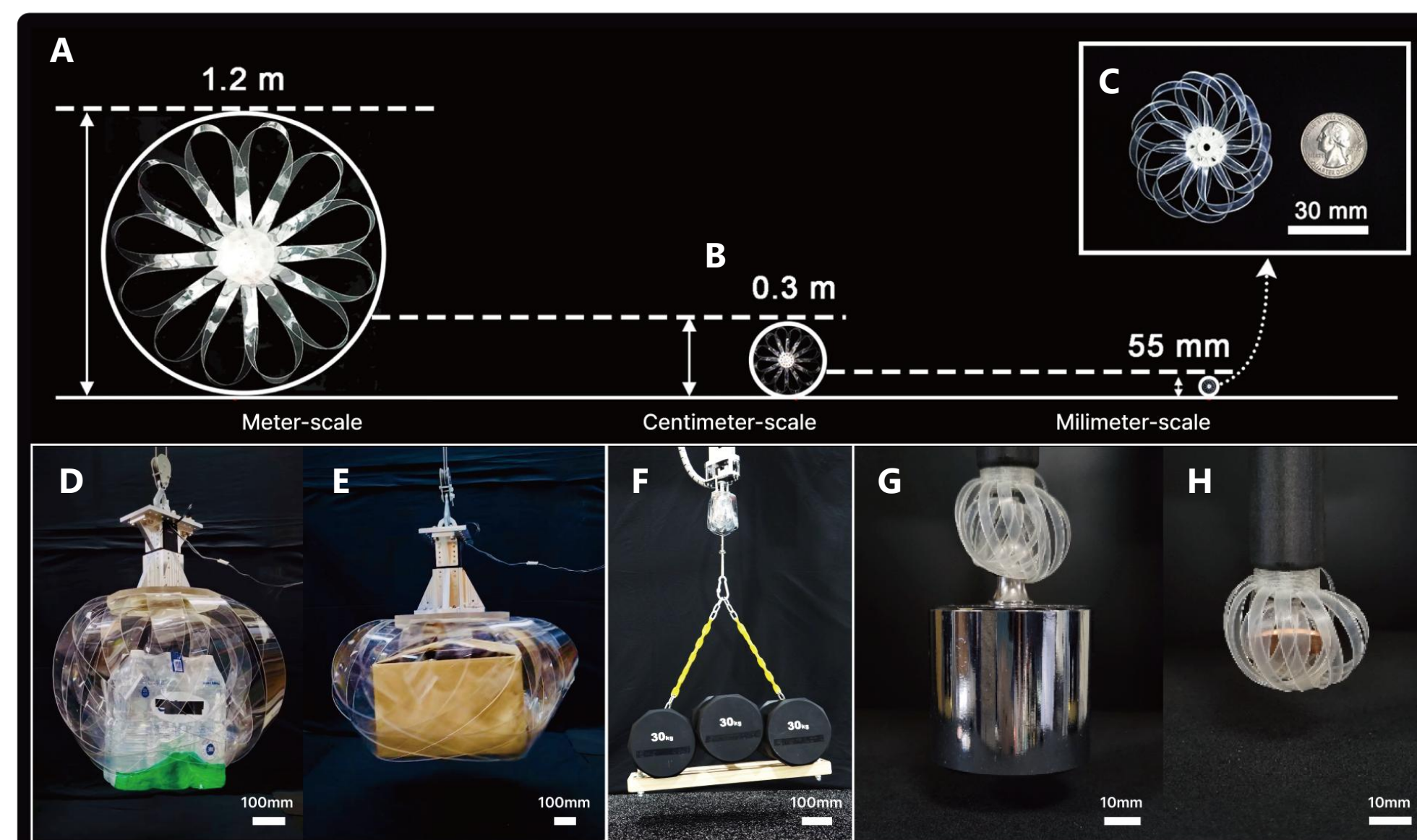
The weaving gripper achieves high payload capacity through mechanically entangled closed-loop strips that distribute the applied load. A lightweight 130 g gripper supported a load of up to 100 kg, corresponding to a payload-to-weight ratio of 770.



Experimental payload evaluation of the weaving gripper. (A, B) Load test setup for measuring grasping stability under vertical pulling (C) Load capacity according to rotation angle and strip number. (D) Relationship between applied torque and load capacity for different object sizes.

► Scalability

The weaving gripper demonstrates scalability from meter to millimeter scale. Its lightweight, compliant structure enables grasping of objects with various sizes and weights, showing potential for scalable capture applications.



Scalability of the weaving gripper from meter to millimeter scale. The gripper was fabricated at (A) Meter-scale, (B) Centimeter-scale, and (C) Millimeter-scale dimensions, demonstrating its structural scalability. Load-carrying tests were performed with (D) six packs of 2 L bottled water, 12 kg, (E) a 5 kg box, (F) three 30 kg dumbbells, 90 kg total, (G) a 0.5 kg weight, and (H) a 1-cent coin.

➤ Active Debris Removal(ADR) Mission

★ The gripper is planned for **space launch in 2027** as part of South Korea's upcoming ADR mission, demonstrating the practical application of soft robotics for orbital debris removal.

► ADR Mission Concept

The proposed soft gripper offers a high-potential solution for the active capture of noncooperative, free-floating space objects on orbit. It can be compactly stowed and then deployed into a large-scale caging structure to enclose and capture debris.

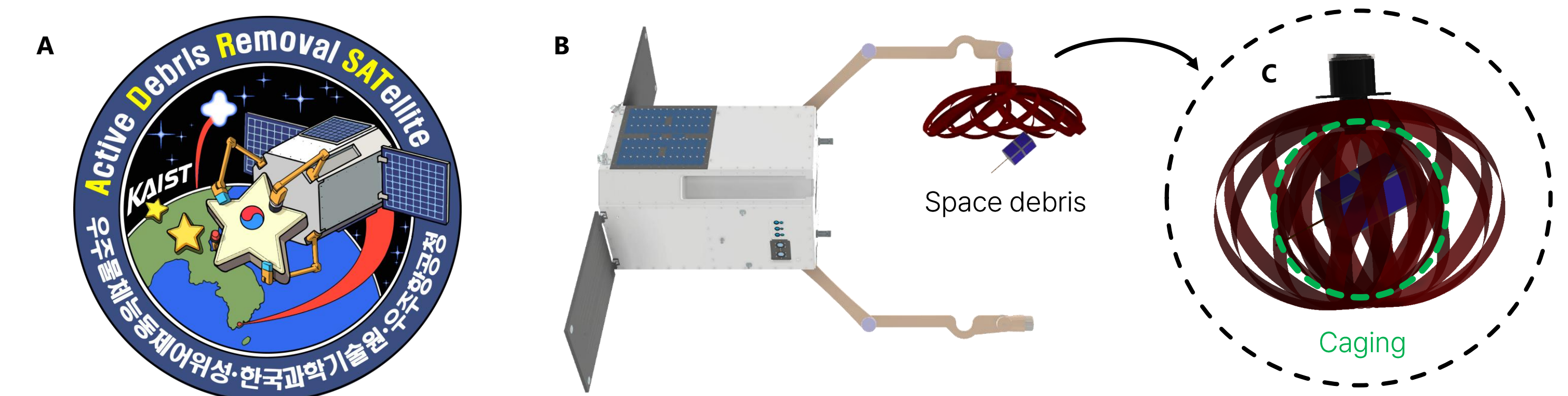
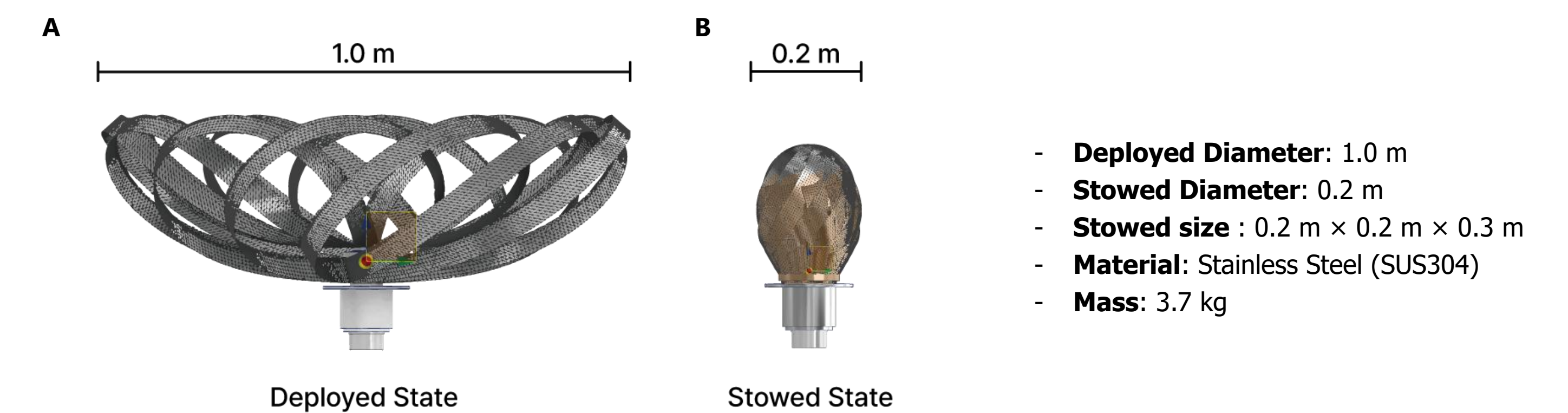


Figure 3. Concept of Operations of the woven-based soft gripper for space debris removal missions. (A) Mission patch representing South Korea's Active Debris Removal Satellite mission. (B) In the rendezvous phase, the system transitions to the Ready-to-Capture state. (C) The gripper performs capture tasks via a caging (or encapsulating) motion.

► Gripper for ADR Specification

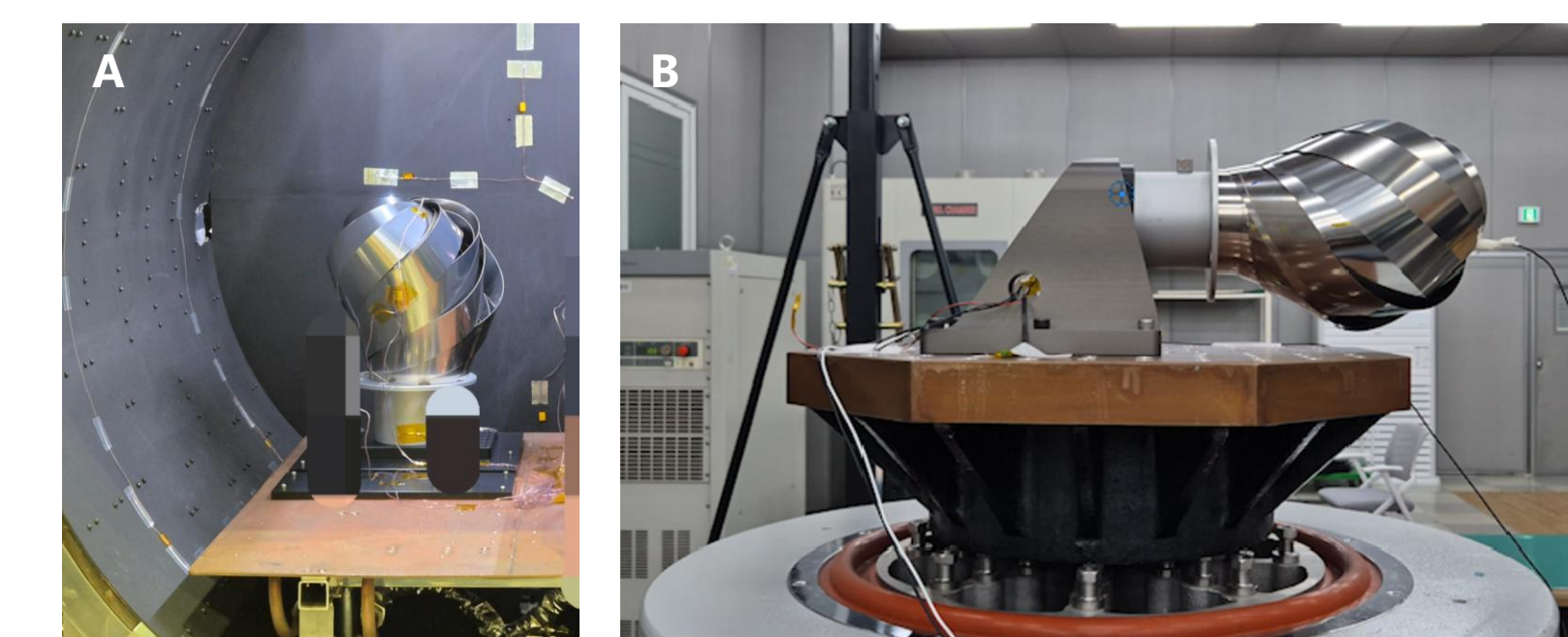
Exploiting the structural scalability, ADR missions can adopt a deployable gripper that ensures resource efficiency and deployment reliability.



3D Modeling of the Weaving Gripper with Scalable Stowage-to-Capture Configuration for ADR (A) Deployed state with a diameter of approximately 1 m. (B) Stowed state with a diameter of approximately 0.2 m.

► Space Environmental Test (Thermal Vacuum/ Vibration Test)

The structural reliability of this configuration was validated through launch environment vibration tests, and thermal vacuum test, ensuring the compliant woven structure can withstand mechanical stresses.



Thermal Vacuum Test

- Temperature range: -60 to +90°C
- Number of cycles: 2.5 cycles
- Chamber pressure: $\leq 1 \times 10^{-3}$ Pa

Vibration Test

- Test type: Qualification-level random vibration
- Frequency range: 20-2000 Hz
- Vibration level: 14 Grms

Space Environment Qualification Test of the Gripper Prototype (A) Gripper prototype mounted inside the thermal vacuum chamber. (B) Gripper prototype installed in a lateral configuration on the vibration test system, considering satellite integration. Vibration qualification tests were conducted along all three axes.