手部康复机器人手套：学术、技术与产品（3）

基于图片浏览的文献综述

临菲信息技术港

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Fig. 1. Representation of instrumentation of the experiment. A) shows the entire SEM GloveŹ with force sensors placed on the grey circles, B) shows the SEM Glove with the white inertial measurement system.

[1]

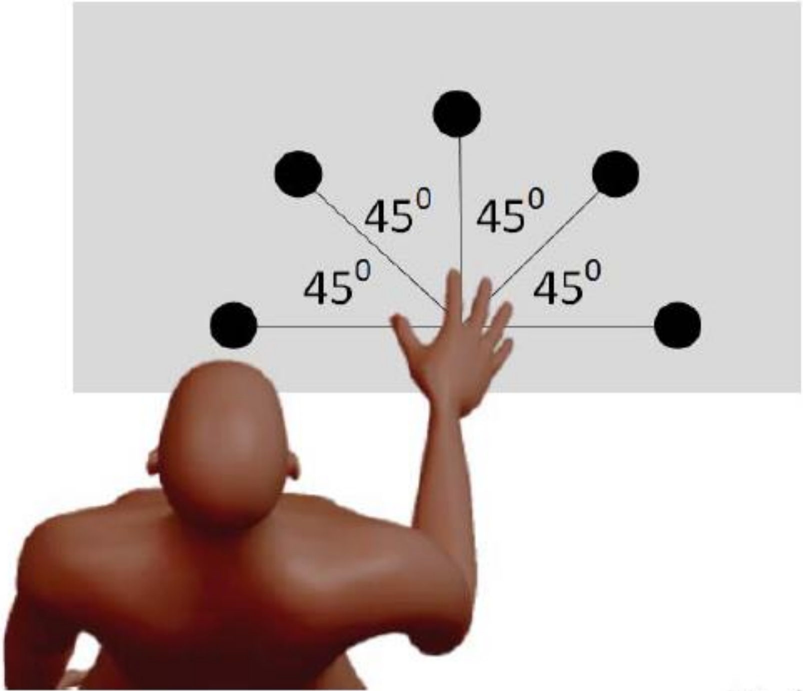


Fig. 2. Schematic representation of the task locations for the experiment.

[1]

Figure 1. Instrumentation of the experiment. The SEM^{TM} Glove is the soft-robotic glove worn by the subject. The white sensors are the IMUs.

[2]

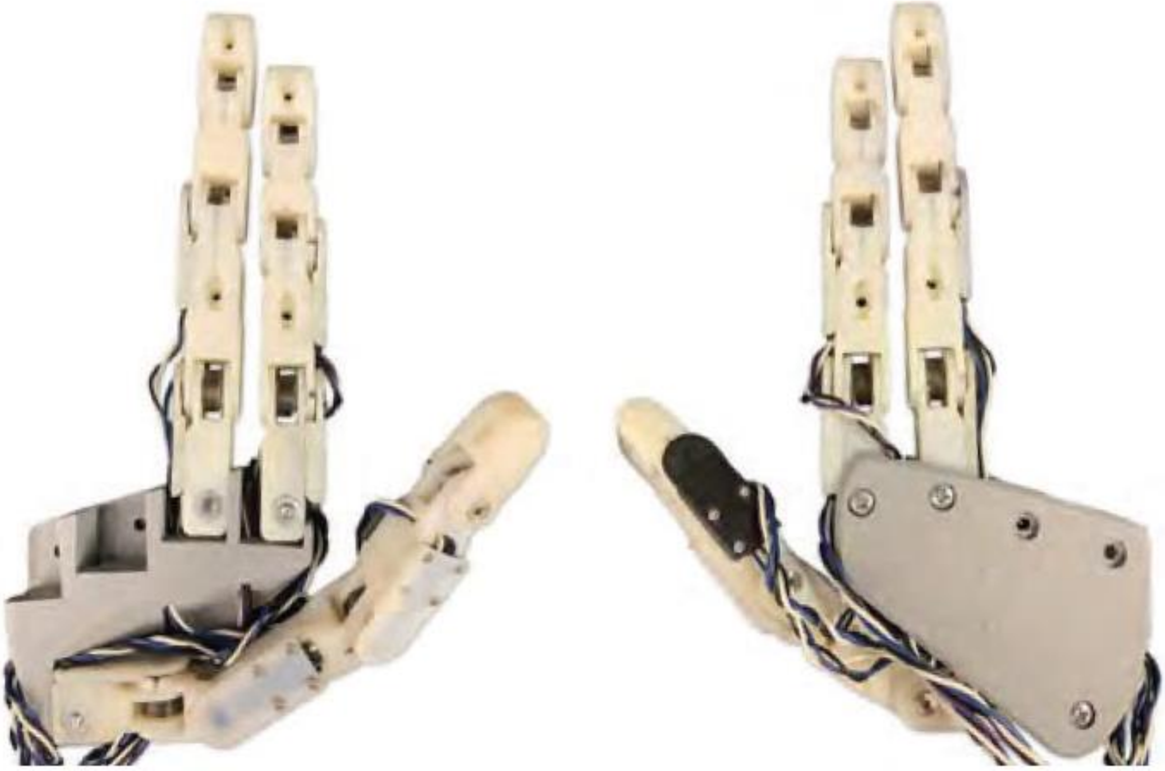


Fig. 1. The open-sourced Instrumented Hand for soft device validation measures joint level information from the thumb, index, and middle fingers. Palmar side (left) and dorsal side (right).

[3]

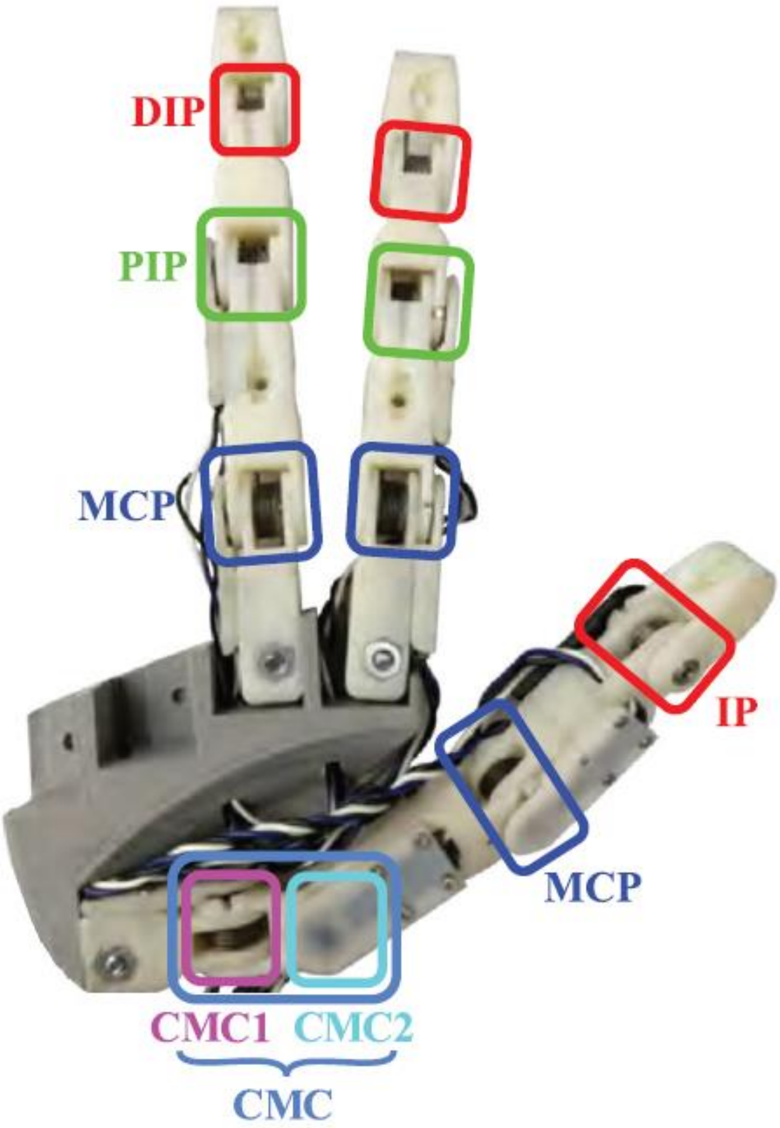


Fig. 2. The Instrumented Hand with all rotary joints labelled. The CMC joint is approximated by two rotary joints, CMC1 and CMC2. The link between the thumb CMC and MCP joints is rotated to enable a more natural thumb orientation and flexion motion.

[3]

Fig. 7. The SeptaPose Assistive and Rehabilitative (SPAR) Glove with individually actuated thumb, index, and secondary fingers is a soft exoskeleton which relies on the wearer's musculoskeletal system for reaction forces. This reliance on a wearer makes the SPAR Glove a good candidate for validation with the Instrumented Hand. Figure reproduced from [17].

[3]

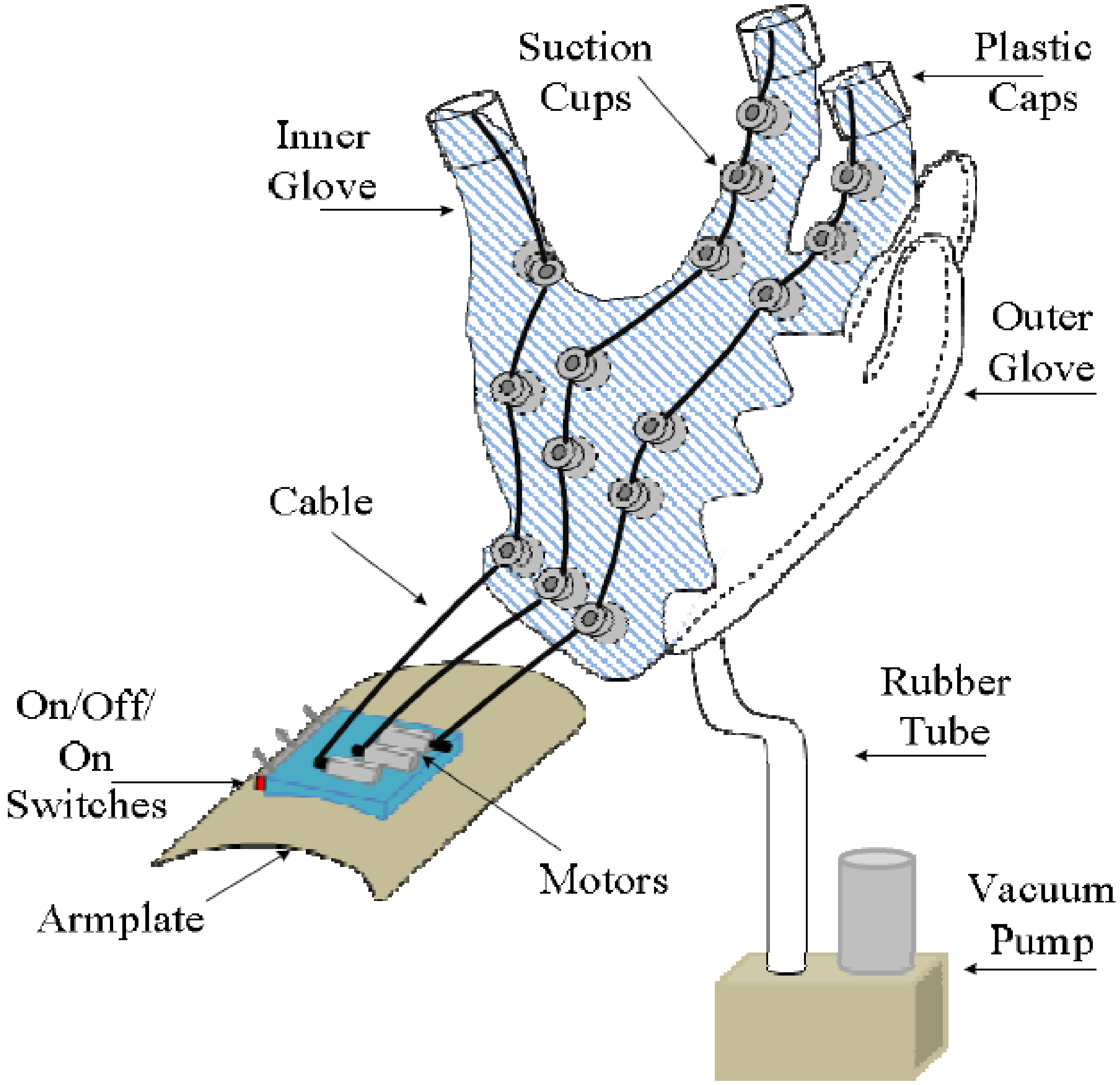


Fig. 1. Diagram of planned design for vacuum glove structure and required components.

[4]

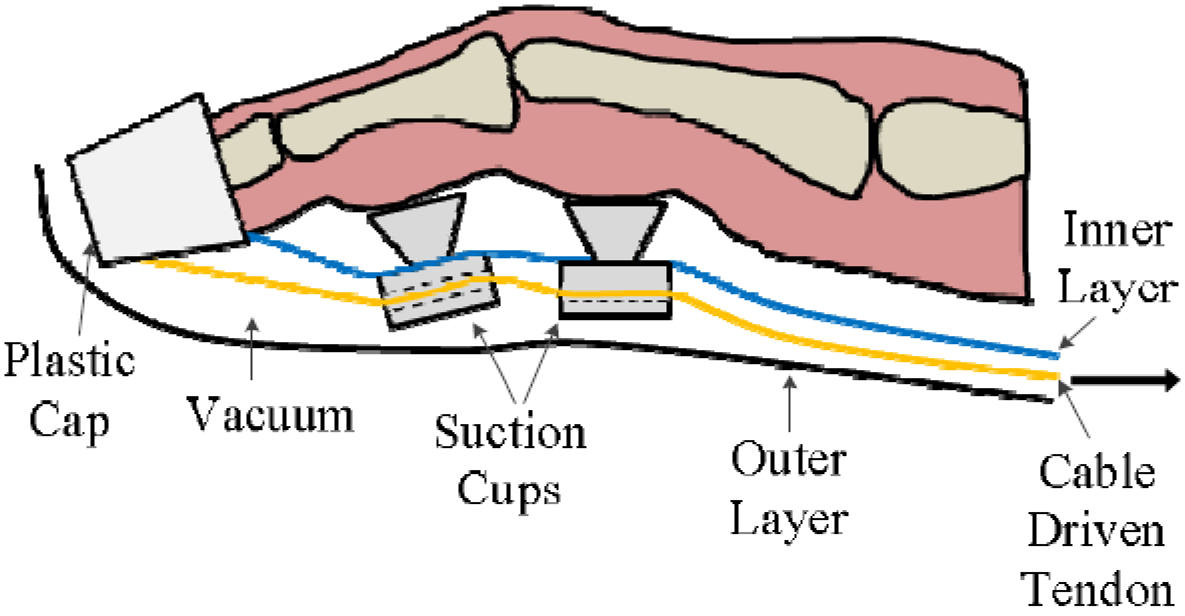


Fig. 2. Demonstration of the vacuum principle that will be used to move the finger.

[4]

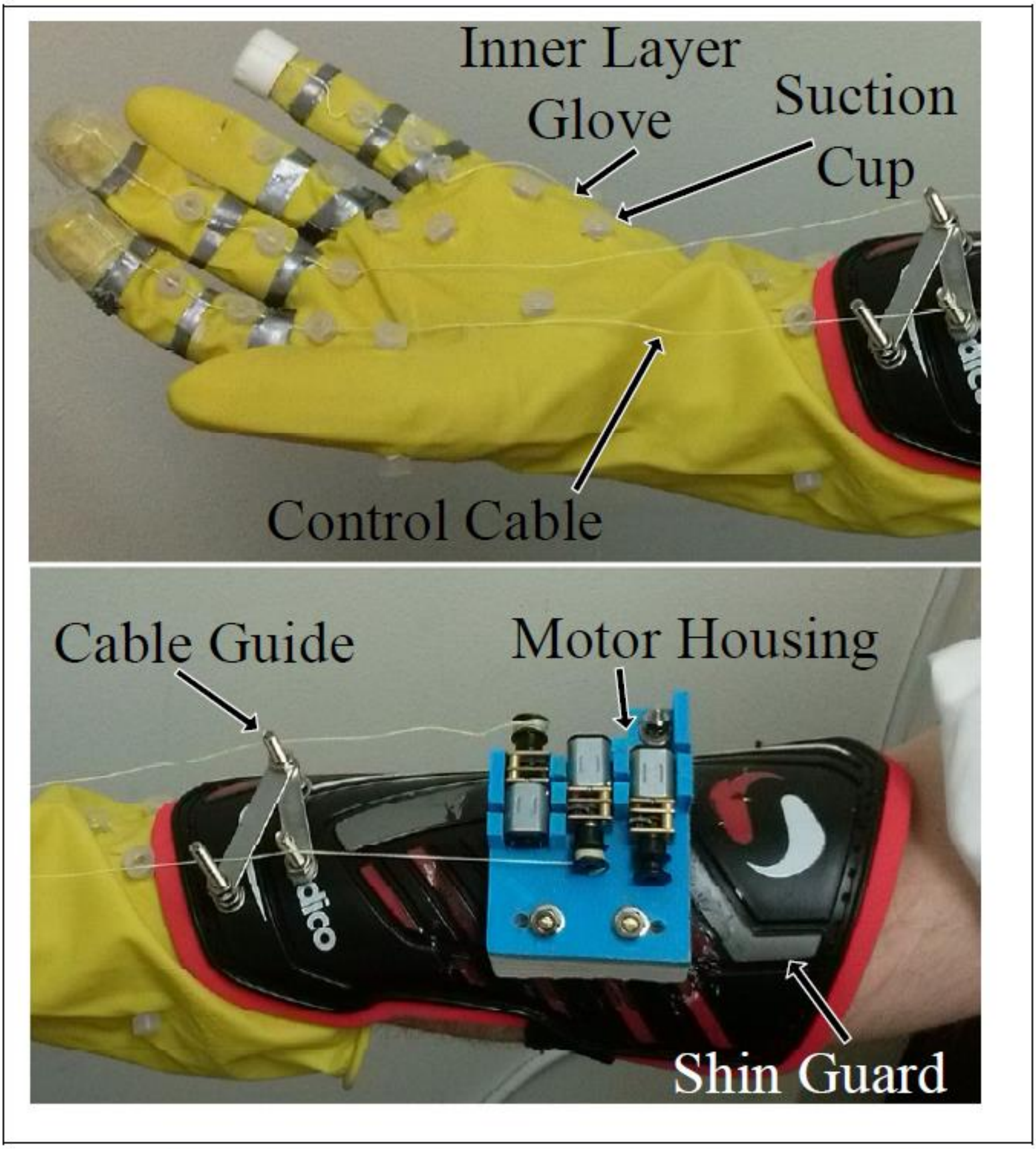


Fig. 3. Annotated images of an early stage inner layer prototype model (top) and the arm plate (bottom).

[4]

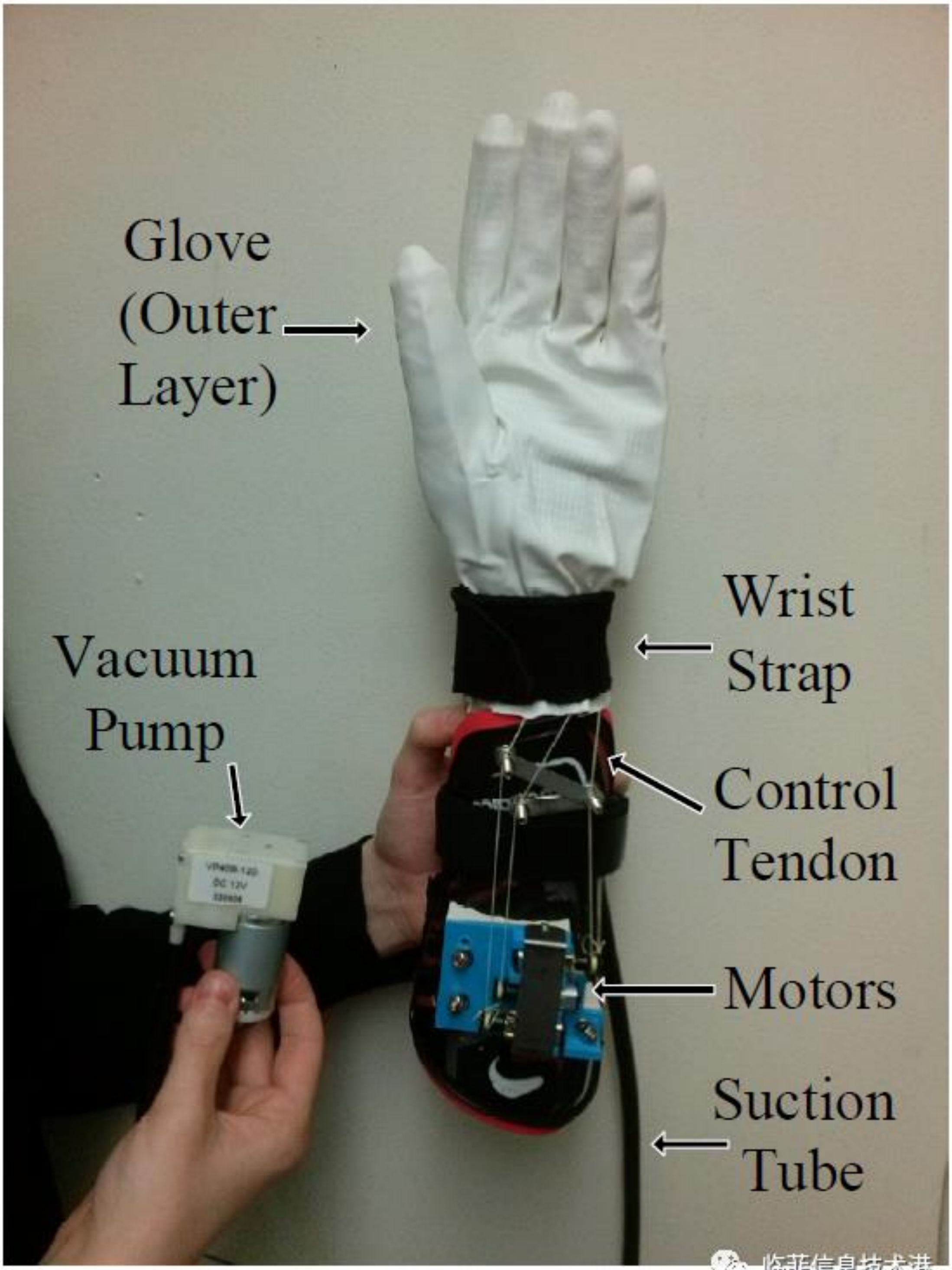


Fig. 4. Annotated Image of the completed prototype.

[4]

Fig. 5. Demonstration of how the device fits the user when worn.

[4]

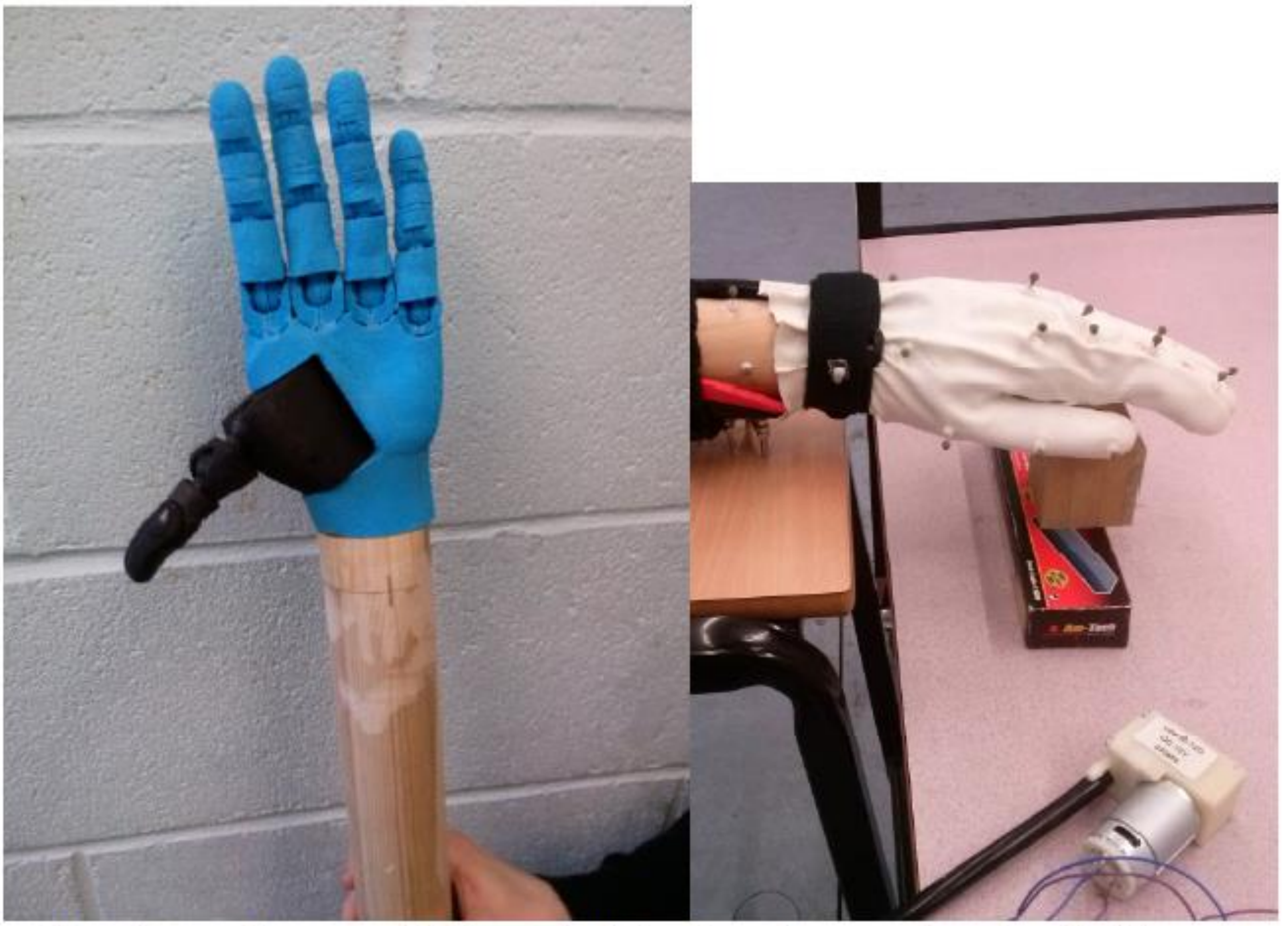


Fig. 6. Image of 3D printed hand and arm extension (left) and demonstration testing protocol (right).

[4]

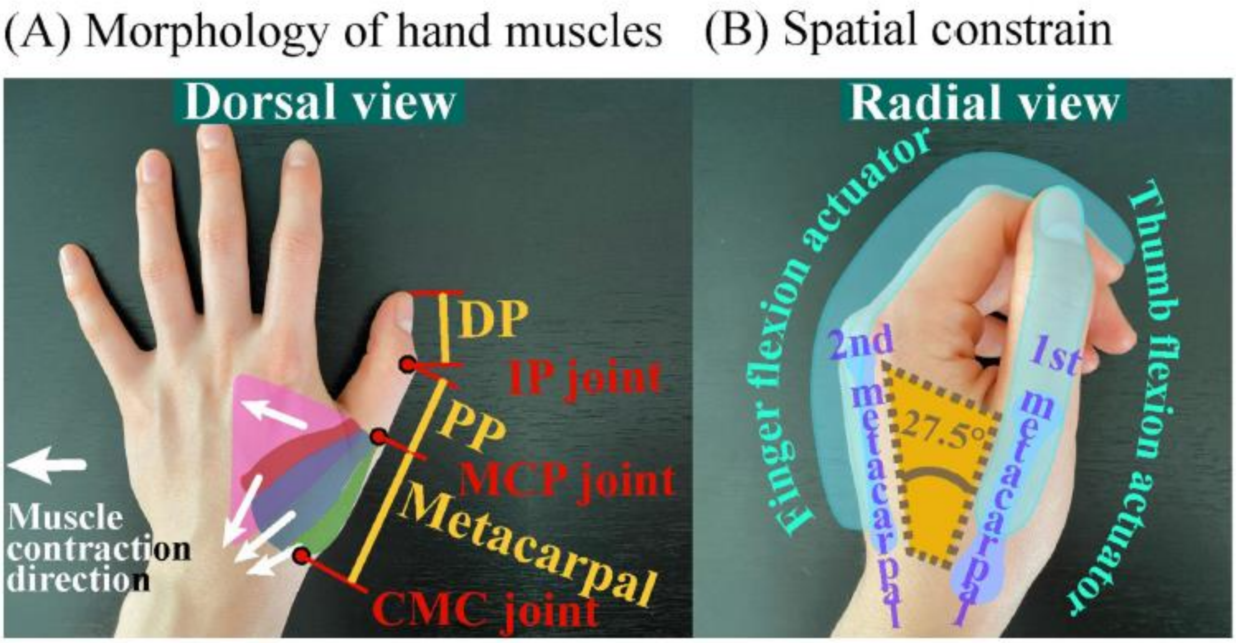


Fig. 1. The morphology of hand muscles (A, marked in different colors) and the spatial constraint of the hand's dorsal side (B).

[5]

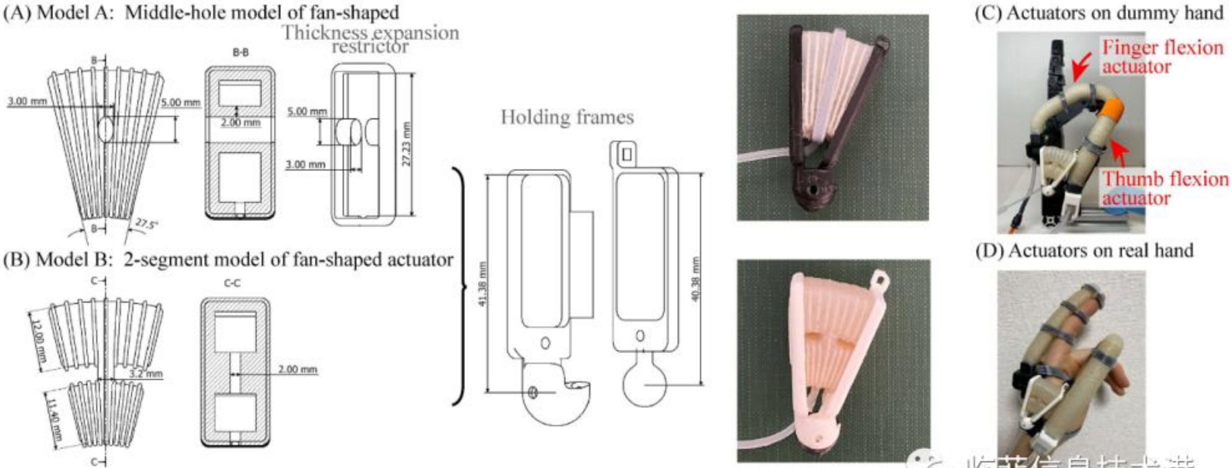


Fig. 2. The two models of the fan-shaped actuator.

[5]

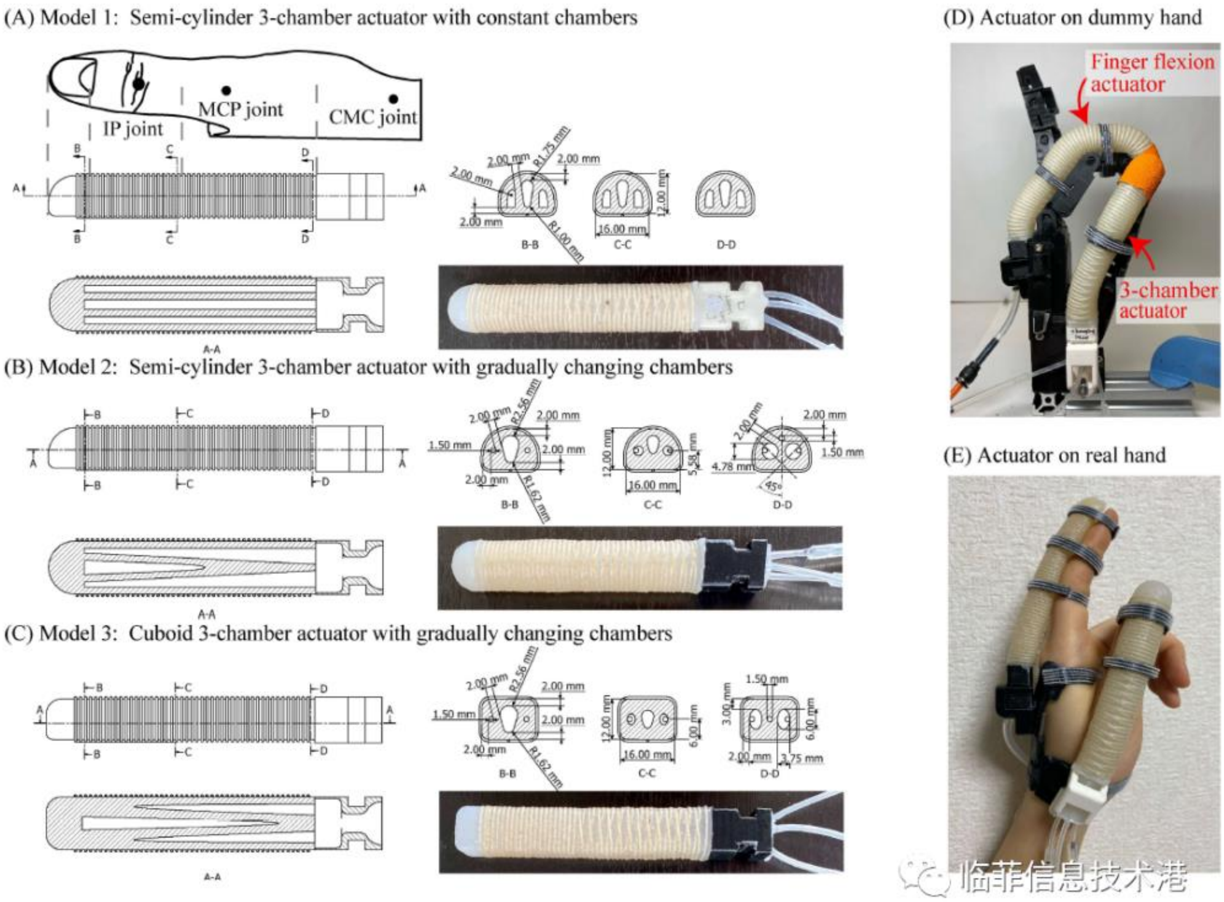


Fig. 3. The three models of the 3-chamber actuator.

[5]

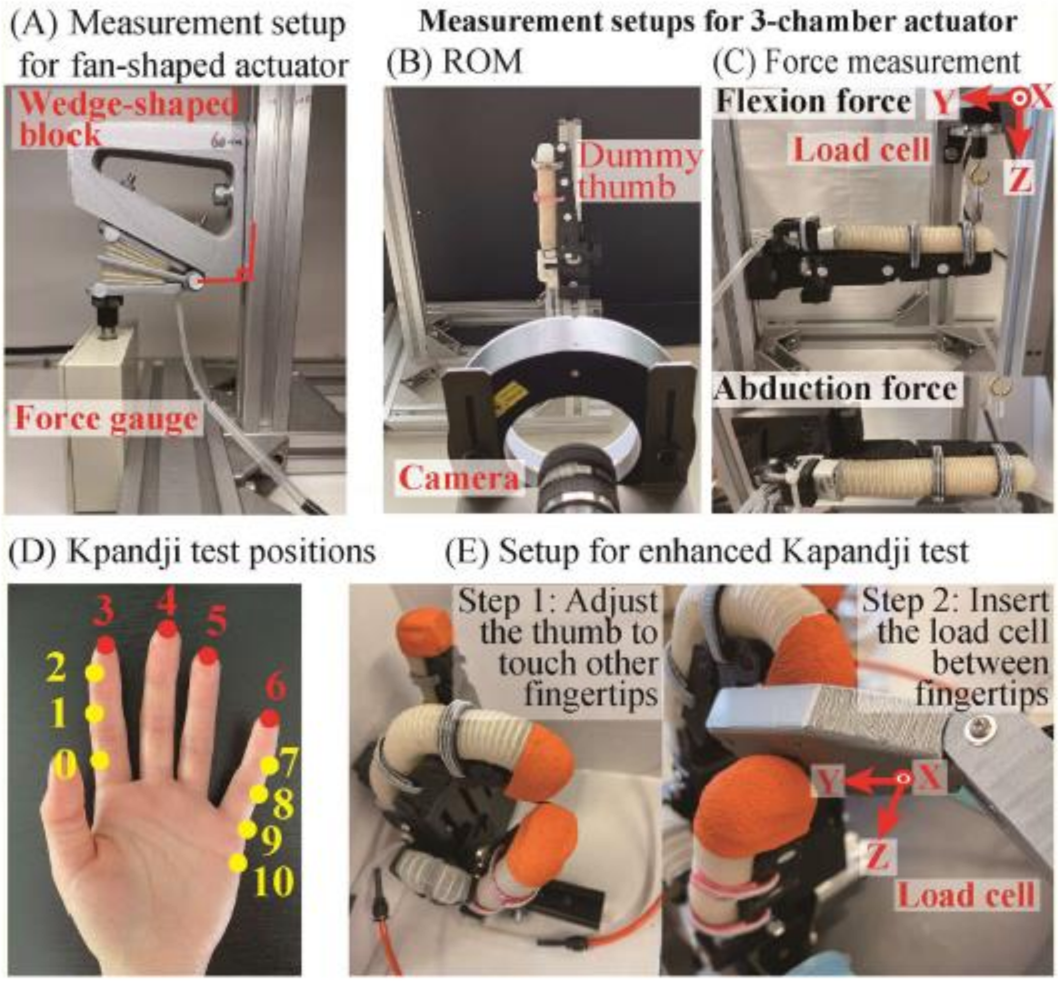


Fig. 4. Measurement setups.

[5]

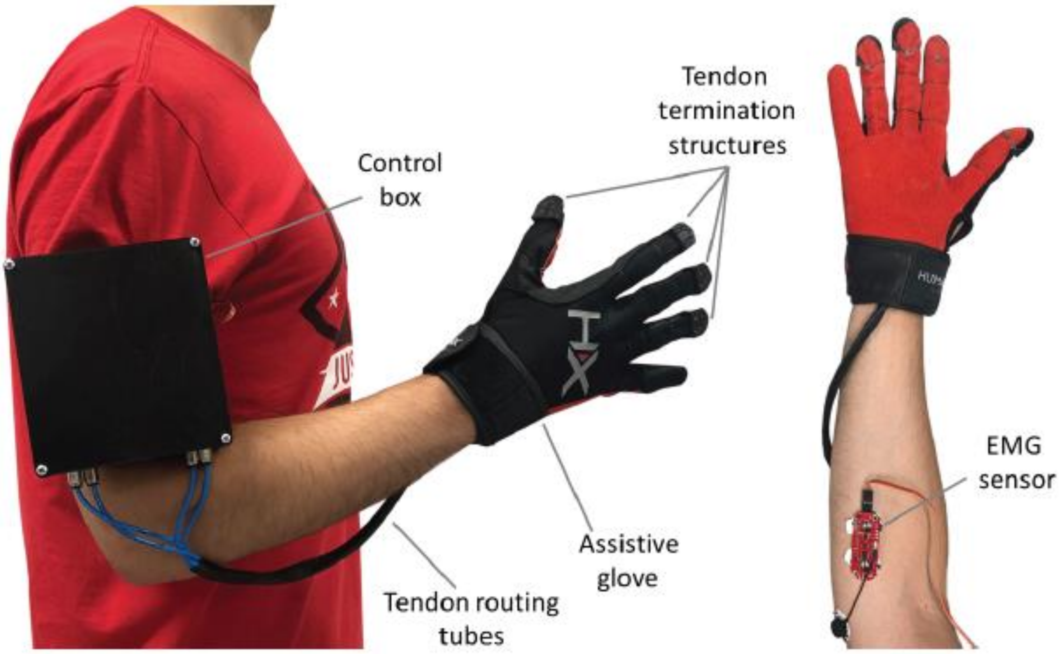


Fig. 1. The underactuated, tendon-driven, assistive exo-glove is composed of a control box, a glove, and an EMG sensor. The control box contains the motor that is connected to the proposed four-output differential mechanism. The differential is connected to four artificial tendons which are routed through tubes to reach the soft exo-glove. The tendons are connected to tendon termination structures stitched onto the fingertips of the exo-glove. The system is controlled by an EMG sensor located at the forearm.

[6]

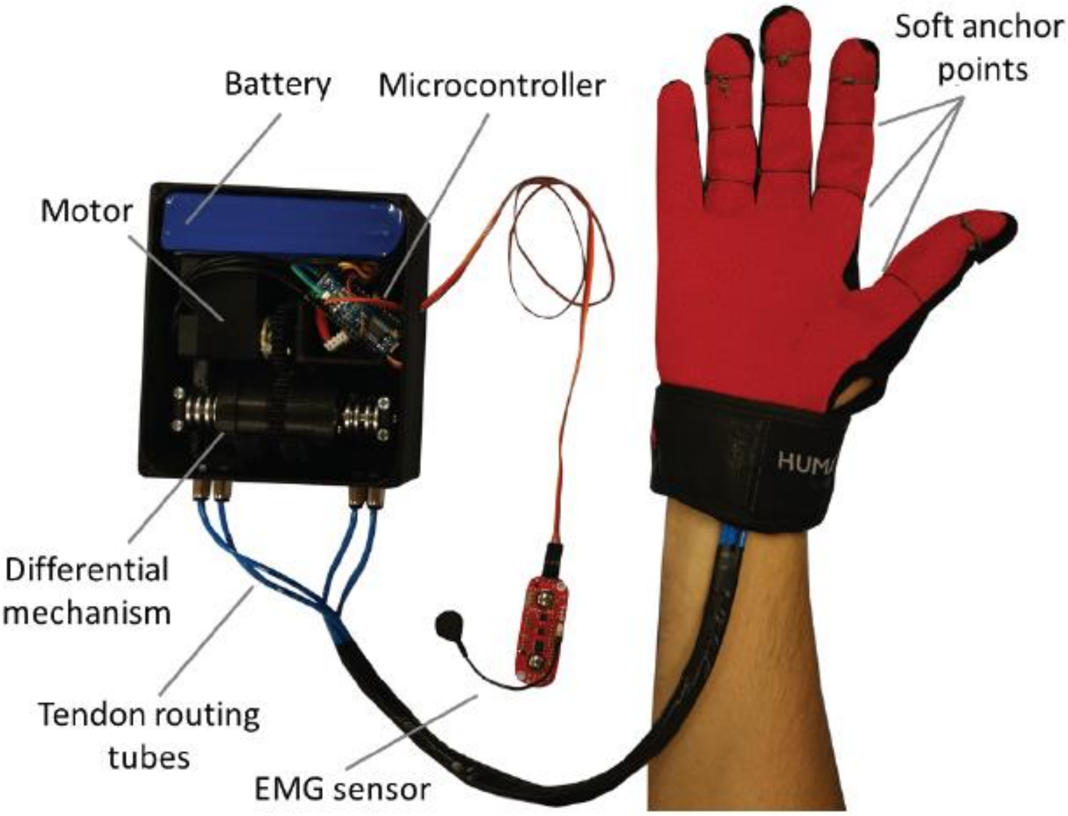


Fig. 4. The proposed exo-glove is composed of an assistive glove, an EMG sensor, and a control box that contains a Dynamixel XM430 smart motor, a battery, a microcontroller, and a four-output differential mechanism. The assistive glove has seven anchor points to reroute the tendons and four termination structures at the fingertips for the artificial tendons. The tendons run at the inside of the glove and through appropriately selected routing tubes connecting the ”control unit” box and the glove.

[6]

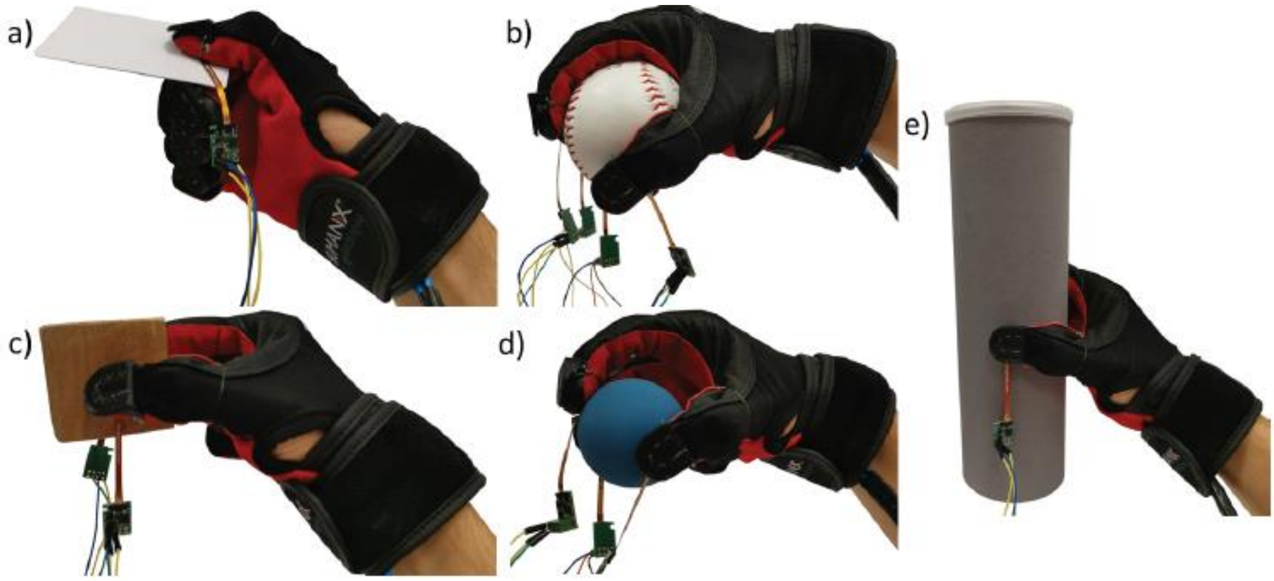
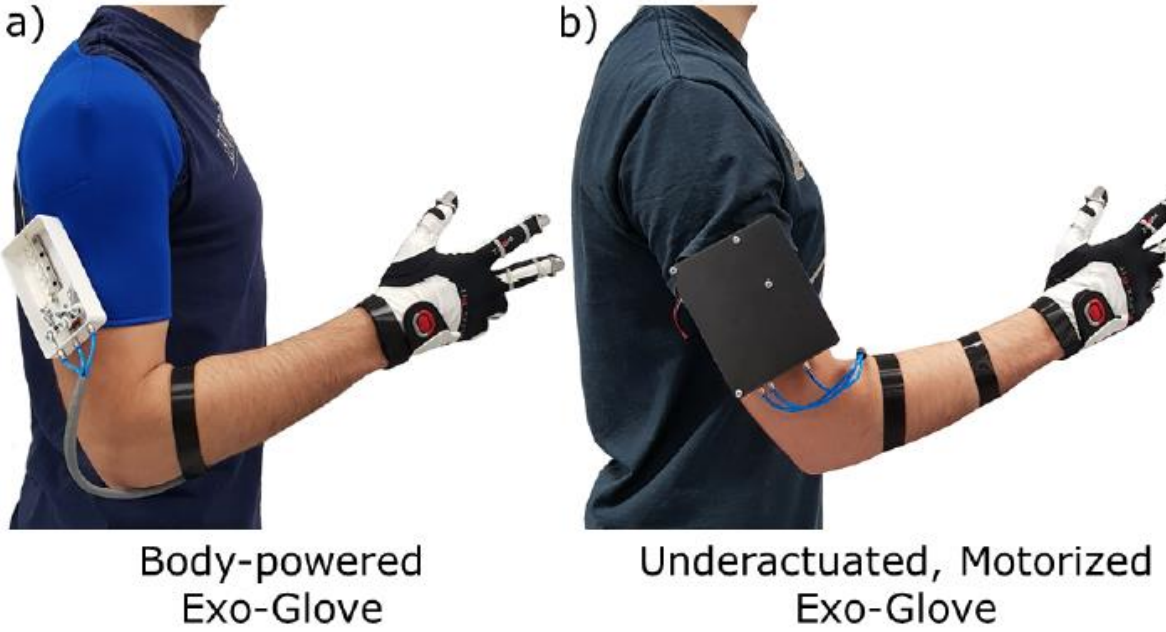


Fig. 5. The force exertion experiment measured the fingertip forces exerted by the proposed exo-glove for five popular grasp postures: lateral (a), spherical (b), pinch (c), tridigital (d), and cylindrical grasp (e). For this experiment we used force sensors (SingleTact S8-100N) mounted on the fingertips. The maximum contact forces that could be exerted were recorded.

[6]



Body-powered Exo-Glove

Underactuated, Motorized Exo-Glove

Fig. 1. Side view of the proposed assistive devices (exo-gloves). Both devices are tendon-driven. The body-powered exo-glove of subfigure a) transmits the forces of the upper body (e.g., shoulders) to the human fingers, while the motorized exo-glove of subfigure b) uses a single smart motor (Dynamixel XM430-W350-R) for actuation purposes.

[7]

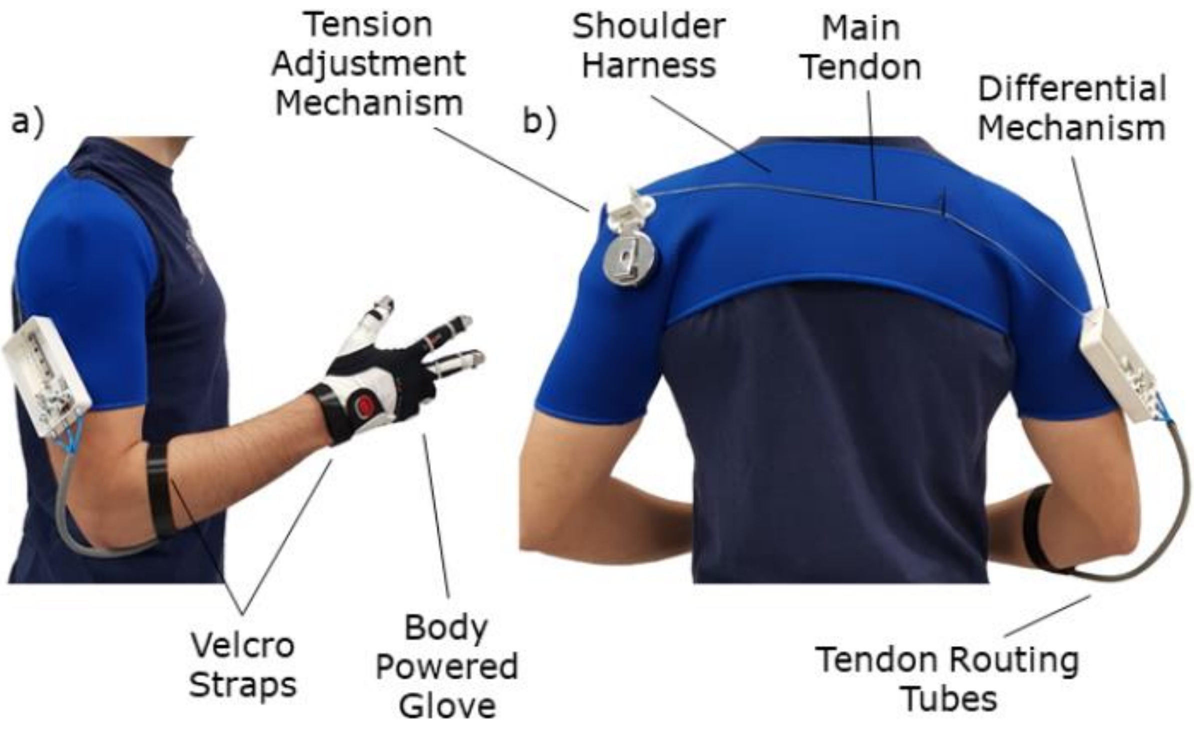


Fig. 2. Annotated presentation of the body-powered device in side view (subfigure a) and back view (subfigure b). The device consists of a harness, a glove, a differential mechanism, a tendon tensioning and adjustment mechanism, tendon routing tubes and artificial tendons. The body-powered mechanism relies on the transmission of forces from the upper body (e.g., shoulders) to the fingers through the tendon routing system. Simple body movements can increase the tension of the tendon, actuating the soft exo-glove. The differential mechanism is used to evenly distribute the forces to the participating fingers.

[7]

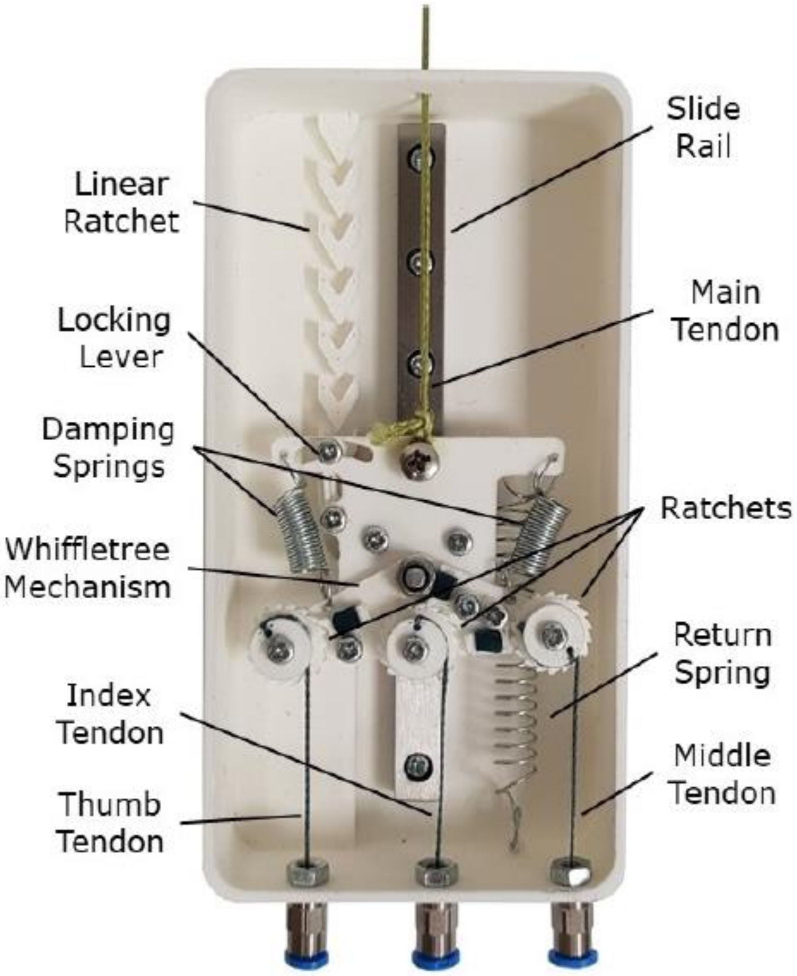


Fig. 3. The proposed spring loaded differential mechanism is a solution for tendon termination, tensioning and locking that can be applied not only to assistive exo-gloves but also to robot and prosthetic hands. The concept is based on an even distribution of the body-powered mechanism forces to the participating finger tendons using the whiffletree mechanism. The differential can be efficiently locked in different positions using a linear ratchet and a locking lever. When the main tendon is pulled, the locking lever is pushed by a spring against the teeth of the linear ratchet until the system is locked at the desired position. The finger tendons are terminated on the whiffletree differential mechanism using the ratchet clutch system proposed in [20].

[7]

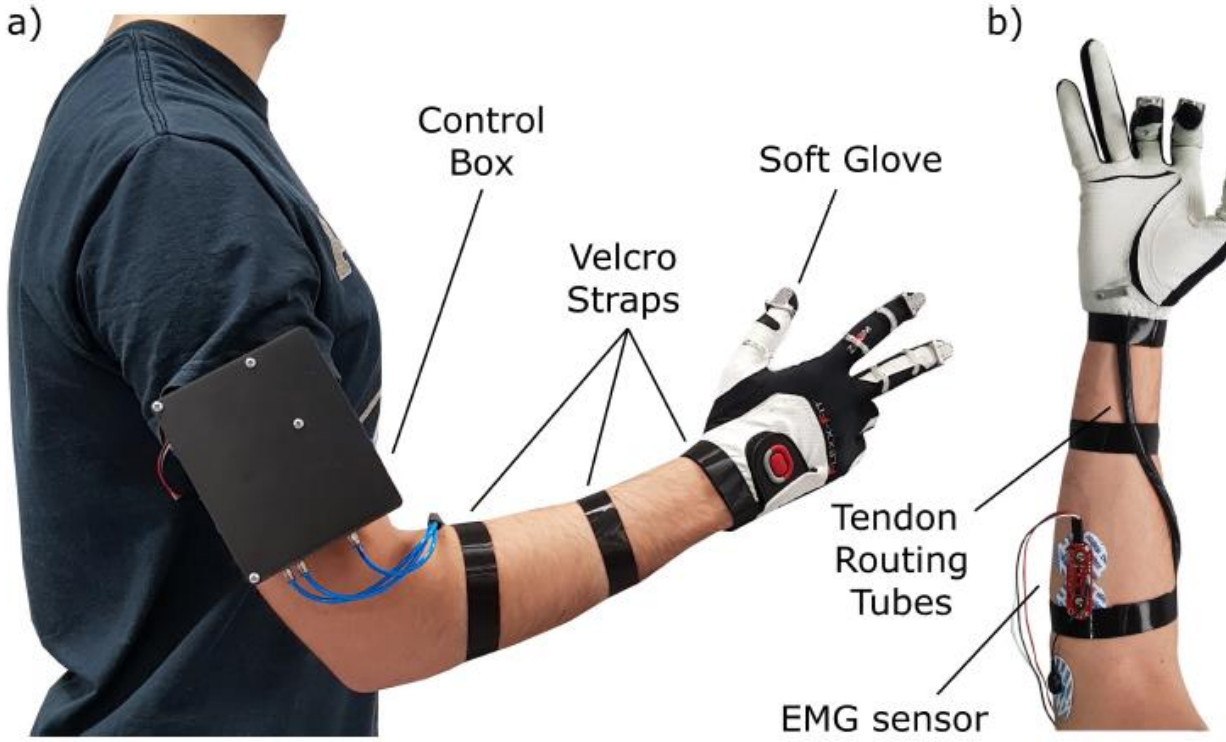


Fig. 4. Annotated presentation of the motorized assistive device in side view (subfigure a) and forearm view (subfigure b). The device consists of a control box, an EMG sensor, and a glove. The operation of the device is based on a simple surface Electromyography (EMG) interface. An EMG sensor is used to measure the activity of the muscles of the forearm (e.g., flexor digitorum superficialis) and the EMG signals are processed, rectified, filtered and used to control (via simple thresholding) a smart motor that actuates the tendon-driven, exo-glove.

[7]

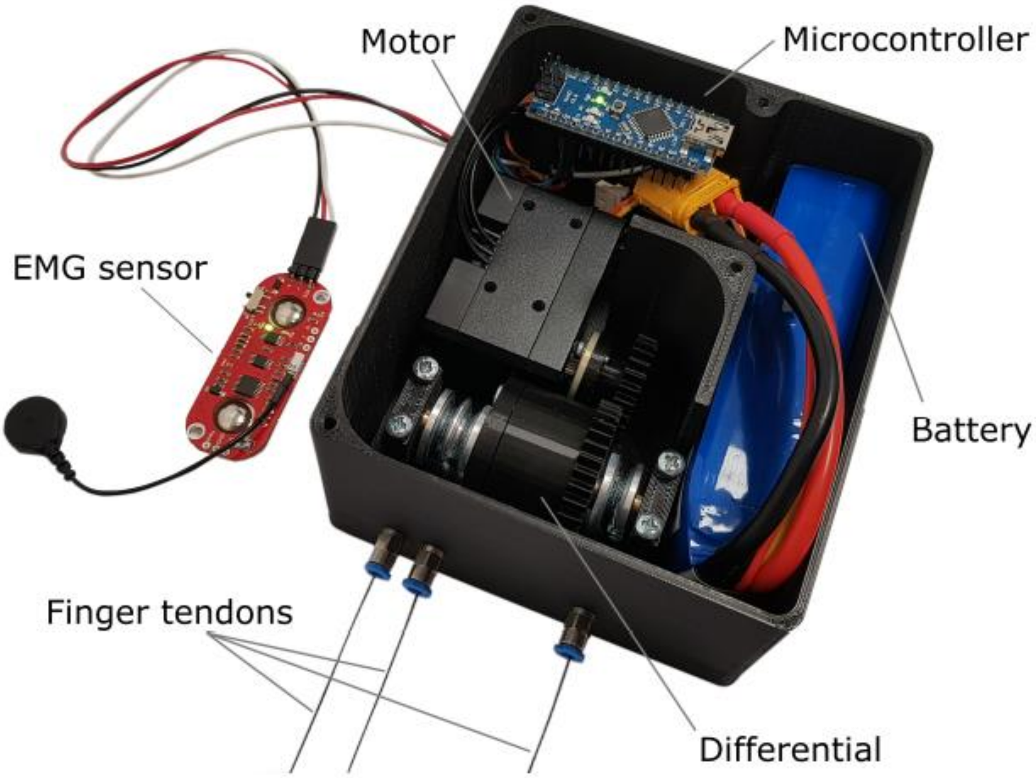


Fig. 5. The control box consists of a smart motor (Dynamixel XM430-W350-R), a battery (Li-Po 2200mAh 3S 30C), a microcontroller (Arduino Nano), and a differential mechanism. The EMG sensor (MyoWare muscle sensor) is attached on the forearm skin, and is used to detect the muscle activities that will lead to a grasping motion. The EMG signals are processed, rectified, filtered, and used to control the motor, actuating the soft exo-glove via simple thresholding. The motor is connected to a differential mechanism that distributes the power of the motor to two shafts that are connected to finger-specific pulleys. The differential mechanism allows for an even torque distribution but also the pulleys to rotate in different speeds when the force distribution is uneven.

[7]

Fig. 6. Annotated view of the soft exo-glove used by both devices. It consists of a thin, tight-fit, high sensitivity glove, three internal tendons, a tube connection, three stainless steel termination structures (at the fingertips) and five anchor points for tendon rerouting. The tubes connect the differential mechanism to the exo-glove and they are fixed at the exo-glove side by a tube connection made out of aluminum. The force transmission is done by artificial tendons that are terminated on the whiffletree at the differential side and on the termination structures at the exo-glove side. All the tendons are routed inside the glove. The soft anchor points offer better sensibility of the grasped objects than the rigid anchor points, making also the design more lightweight, more compact and aesthetically pleasing.

[7]

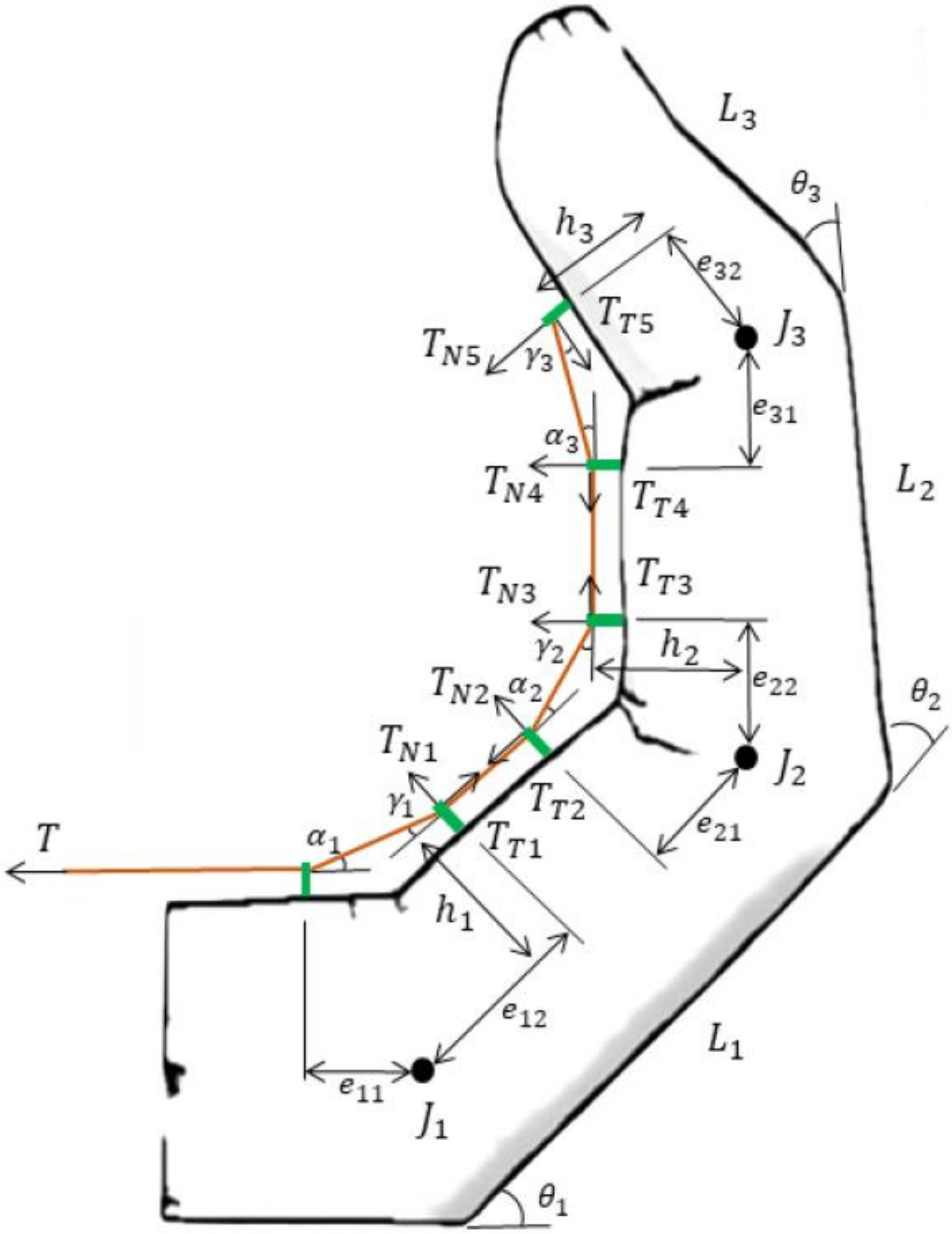


Fig. 7. Model of the tendon routing of a generic finger. L_1, L_2 and L_3 represent the proximal, middle and distal phalanges, while the black circles, J_1, J_2 and J_3, represent the finger joints. The brown line represents the artificial tendon used and the green rectangles represent the anchors points.

[7]

Fig. 8. Both devices were tested for grasping different types of objects: a) a ball, b) a mustard bottle, c) a jar, d) a glass bottle, e) a spray bottle, and f) tweezers.

[7]

Fig. 10. Experimental setup used for force exertion experiments conducted with an exo-glove fingertip. The setup consists of a model hand (mannequin hand) wearing the proposed soft, assistive, exo-glove, a miniature force sensor (SingleTact S8-100N), an indexing plate with a increment value of 15° and a smart motor (Dynamixel XM430-W350-R) for driving the tendon. The force profiles were acquired for a total of 12 equally spaced angles. The maximum force exerted at each angular position was captured.

[7]

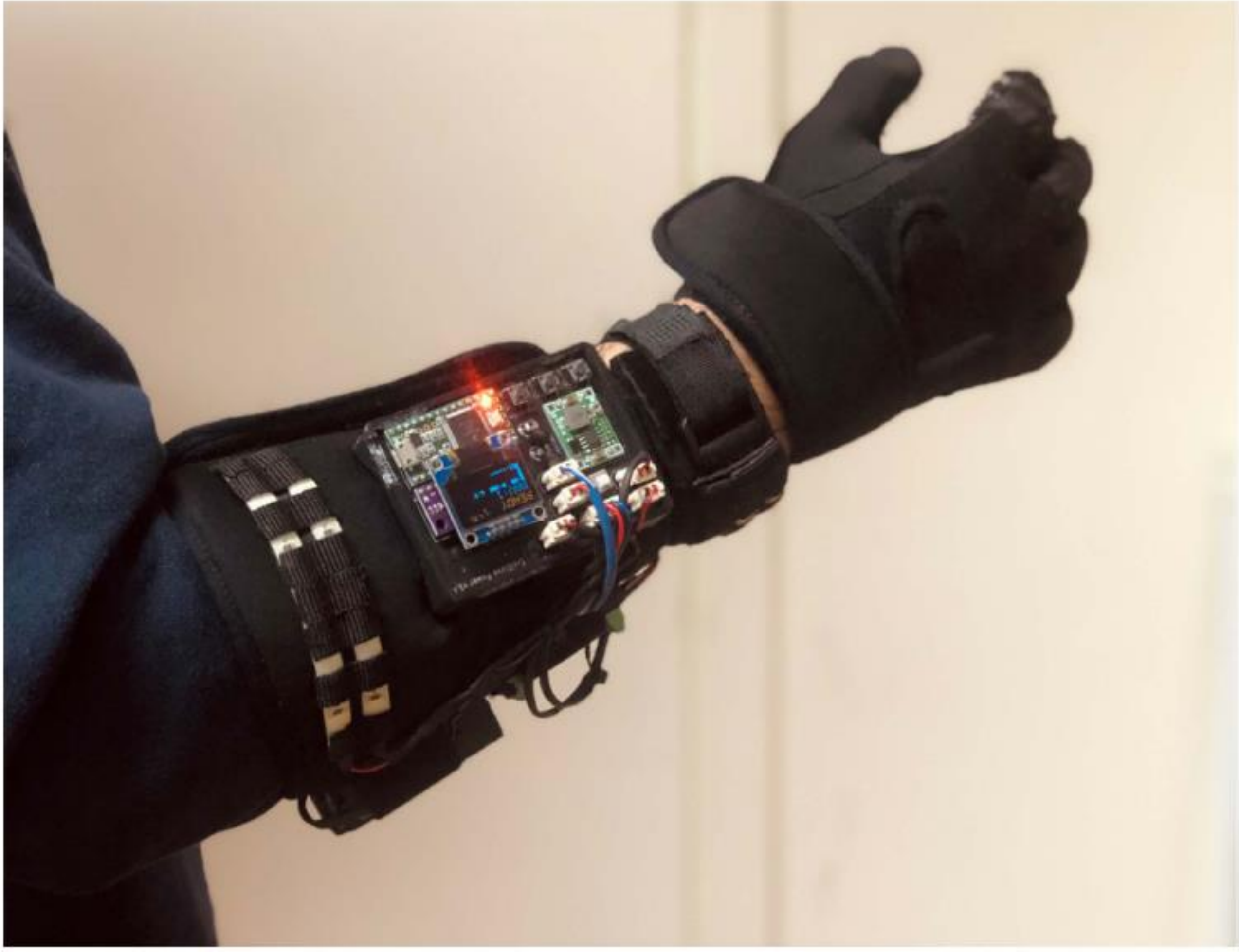


Fig. 2. System overview. Exo-Glove Power (EGPO) is a compact/portable soft robotic glove for augmenting the grasping force while the user intends a firm power grasp to secure an object. The single EMG sensor-based myoelectric interface in EGPO identifies the user's power grasp intention to actuate the robot.

[8]

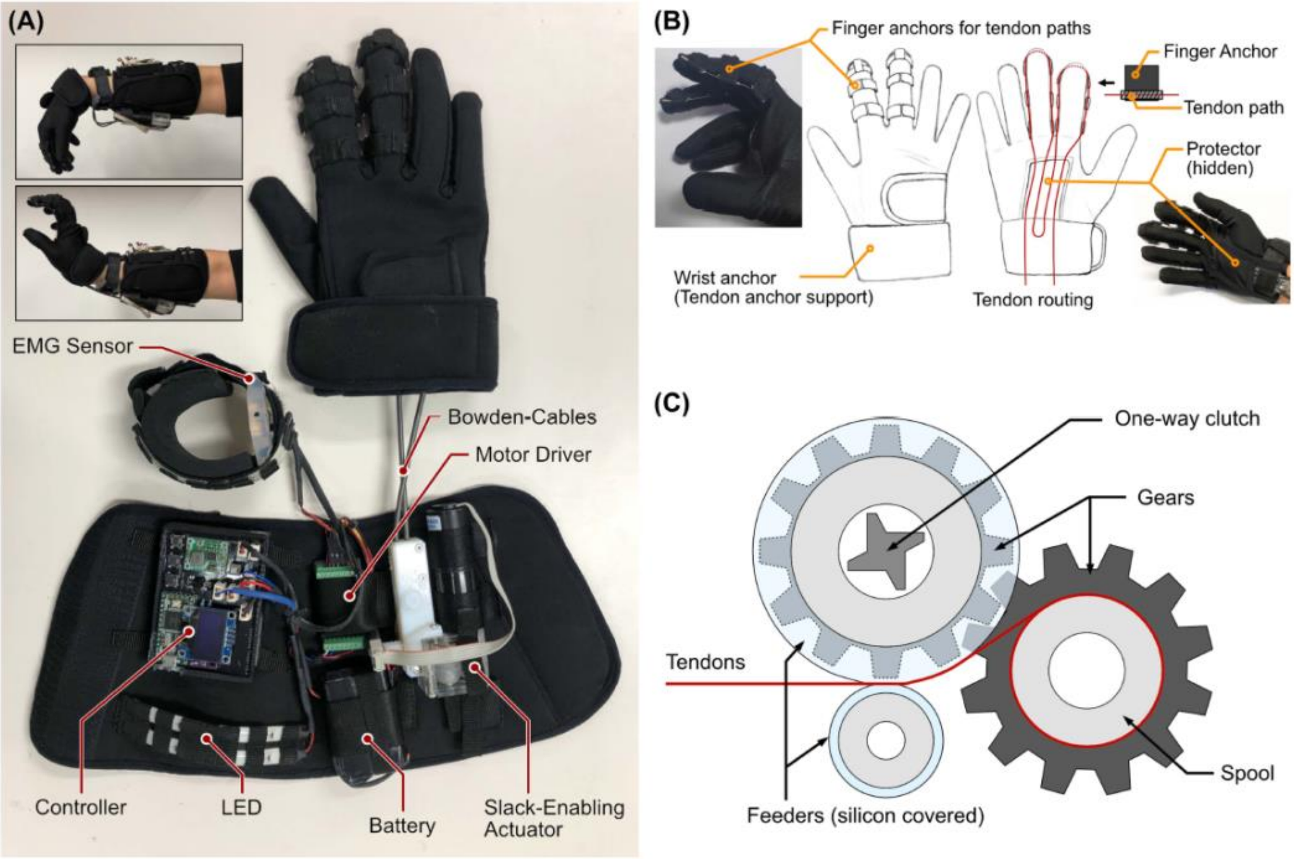


Fig. 5. System Design. (A) Hardware structure of Exo-Glove Power. The robotic glove does not restrict wrist motions. (B) Glove structure. The differential mechanism from the tendon routing allowed the robotic glove to adapt when grasping objects of various shapes. (C) Structure of the slack-enabling actuator.

[8]

Fig. 8. Human subject testing of dual-threshold control. One healthy subject ($n = 1$; male fire fighter; age, 38 y) participated in this experiment. The participant was neither trained to use EGPO prior to the experiments, nor instructed to perform a power grasp.

[8]

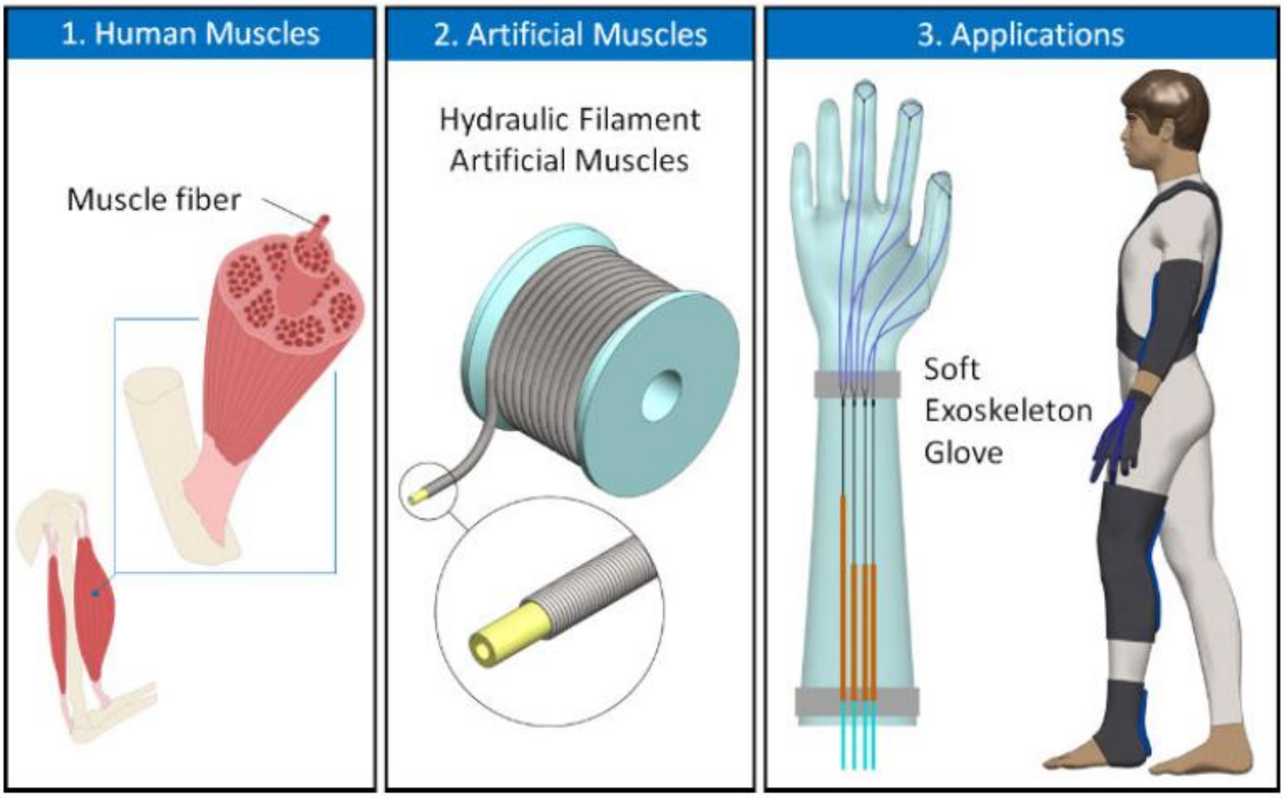


FIGURE 1. **Bio-inspired soft hydraulic filament artificial muscles (HFAM) and one of its application areas (soft wearable assistive device).**

[9]

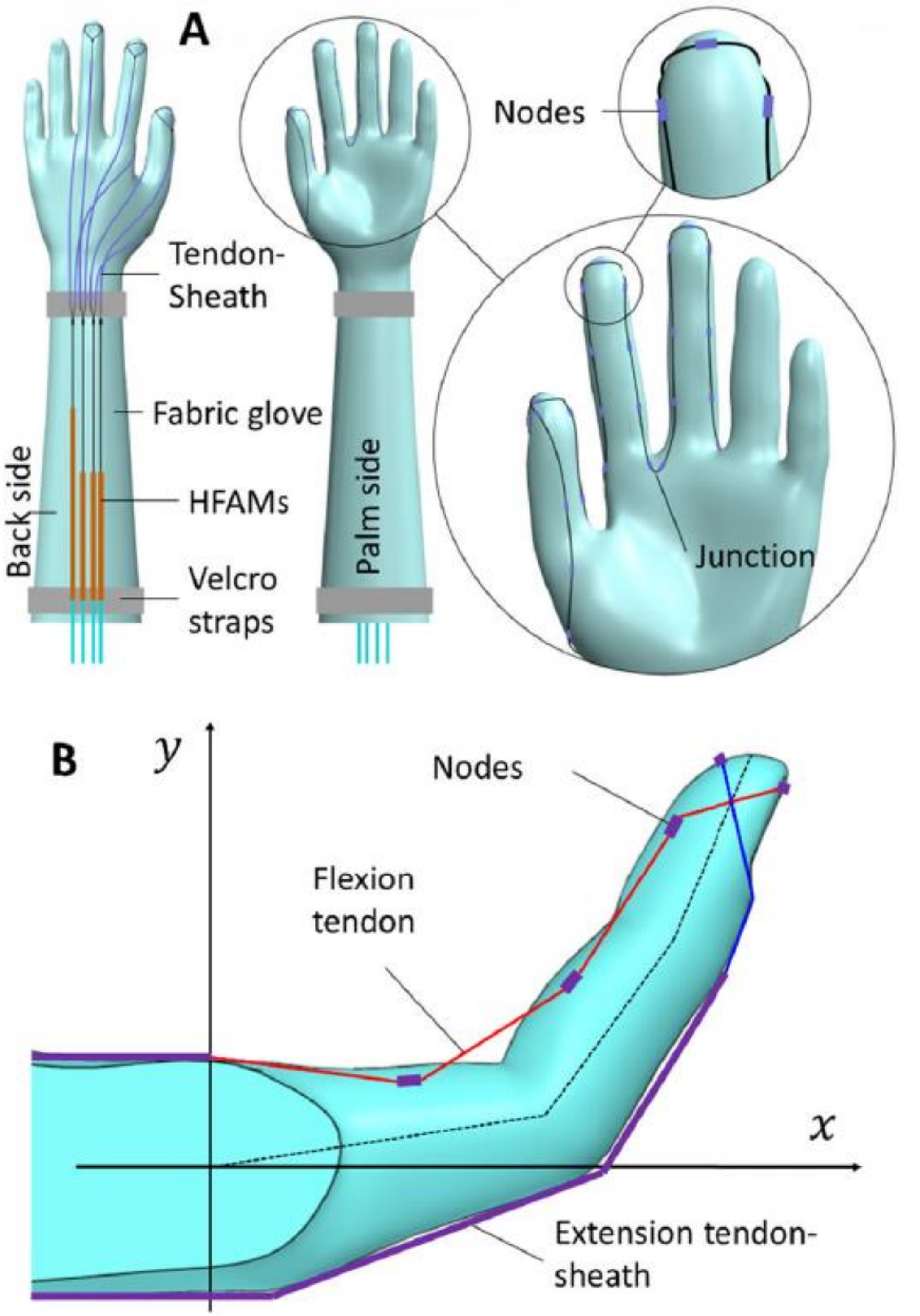


FIGURE 11. Overview of the soft exoskeleton glove with its components. A) Design model with routing tendon-sheath and HFAMs-like tendon sheath mechanisms. B) Kinematic diagram in the *x-y* plane of a single finger driven by both flexion and extension tendons via miniature routing nodes.

[9]

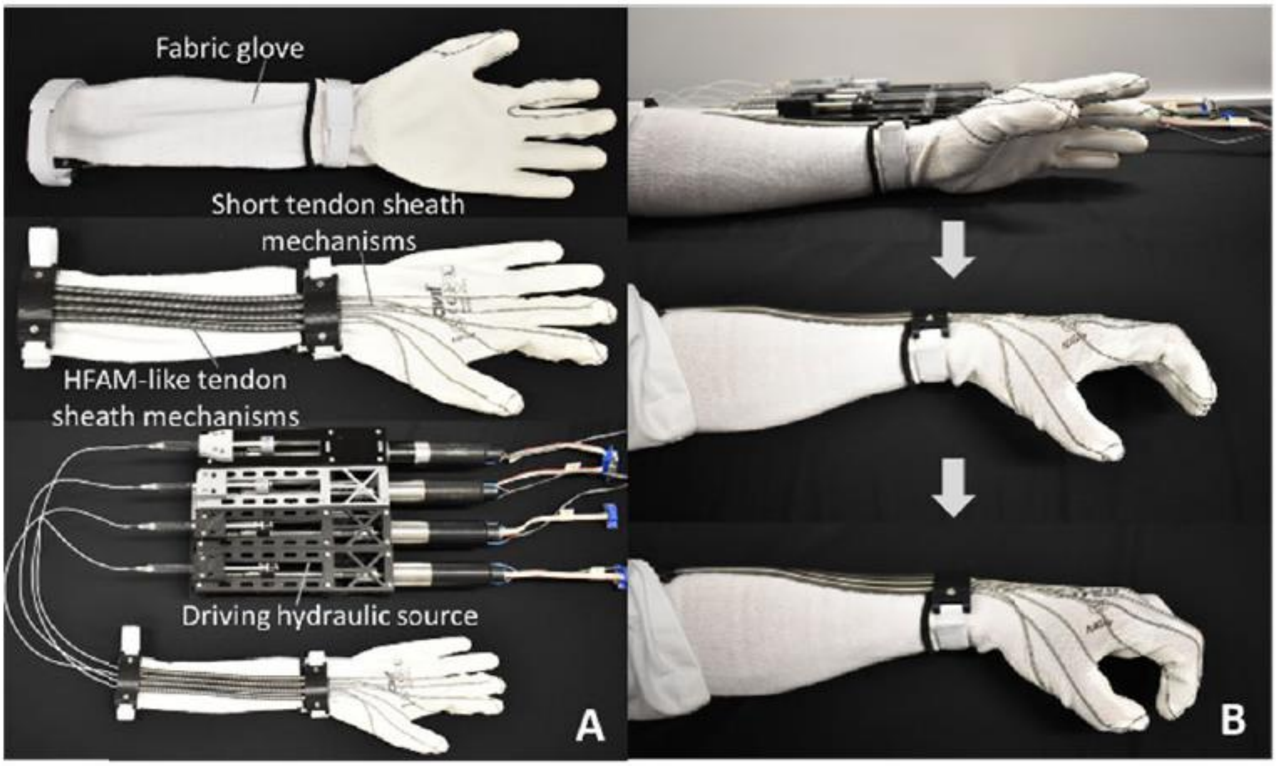


FIGURE 12. **Final prototype of the HFAMs-driven soft fabric glove. A) Overview of components of the soft glove including a soft fabric glove, driving hydraulic source (DC-motors, linear ball screws, and miniature syringes), HFAM-like tendon-sheath mechanisms, and short conventional tendon-sheath mechanisms. B) Grasping gestures of the soft glove in free space without objects.**

[9]

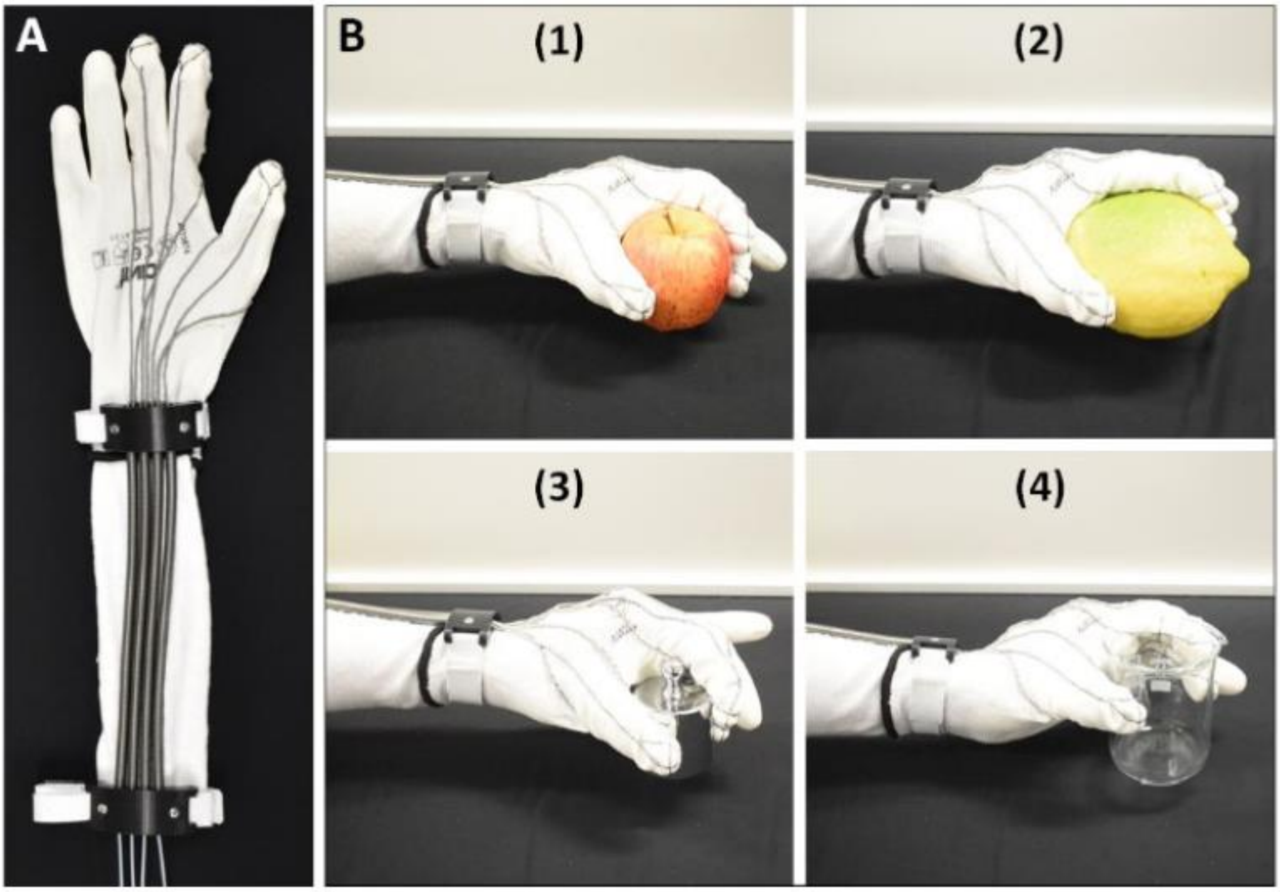


FIGURE 13. Prototype and performance of the soft exoskeleton glove. A) Backside view of the prototype with HFAMs being covered inside stainless-steel coils. B) Grasping demonstration with multiple objects: (1) Apple; (2) Lemon; (3) Weight 500 g; (4) Glass beaker.

[9]

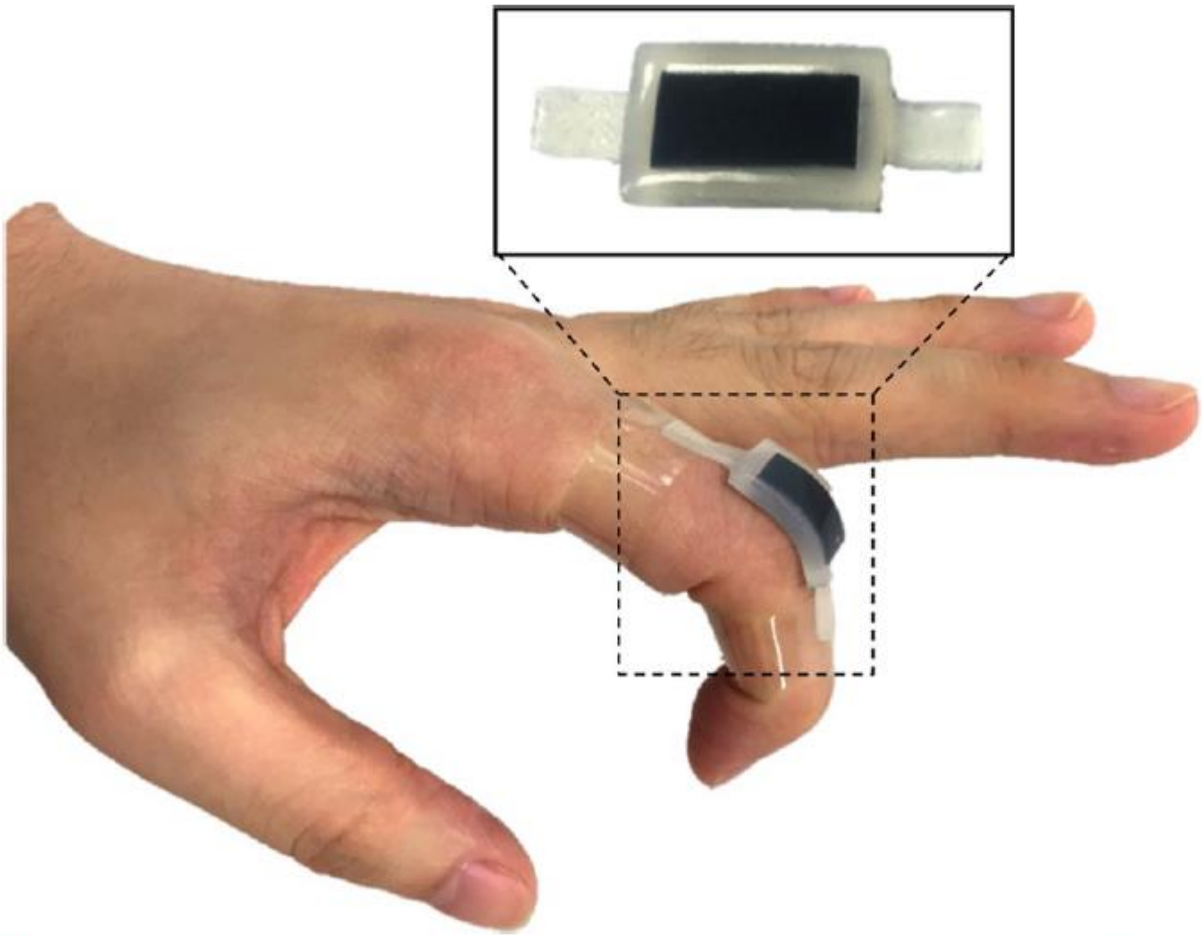


Fig. 1 Illustration of a soft stretchable bending sensor mounted on an adult's hand. The sensor uses EPR embedded in a soft stretchable base. The soft and stretch abilities of the sensor allow it to attach firmly on the finger joint

[10]

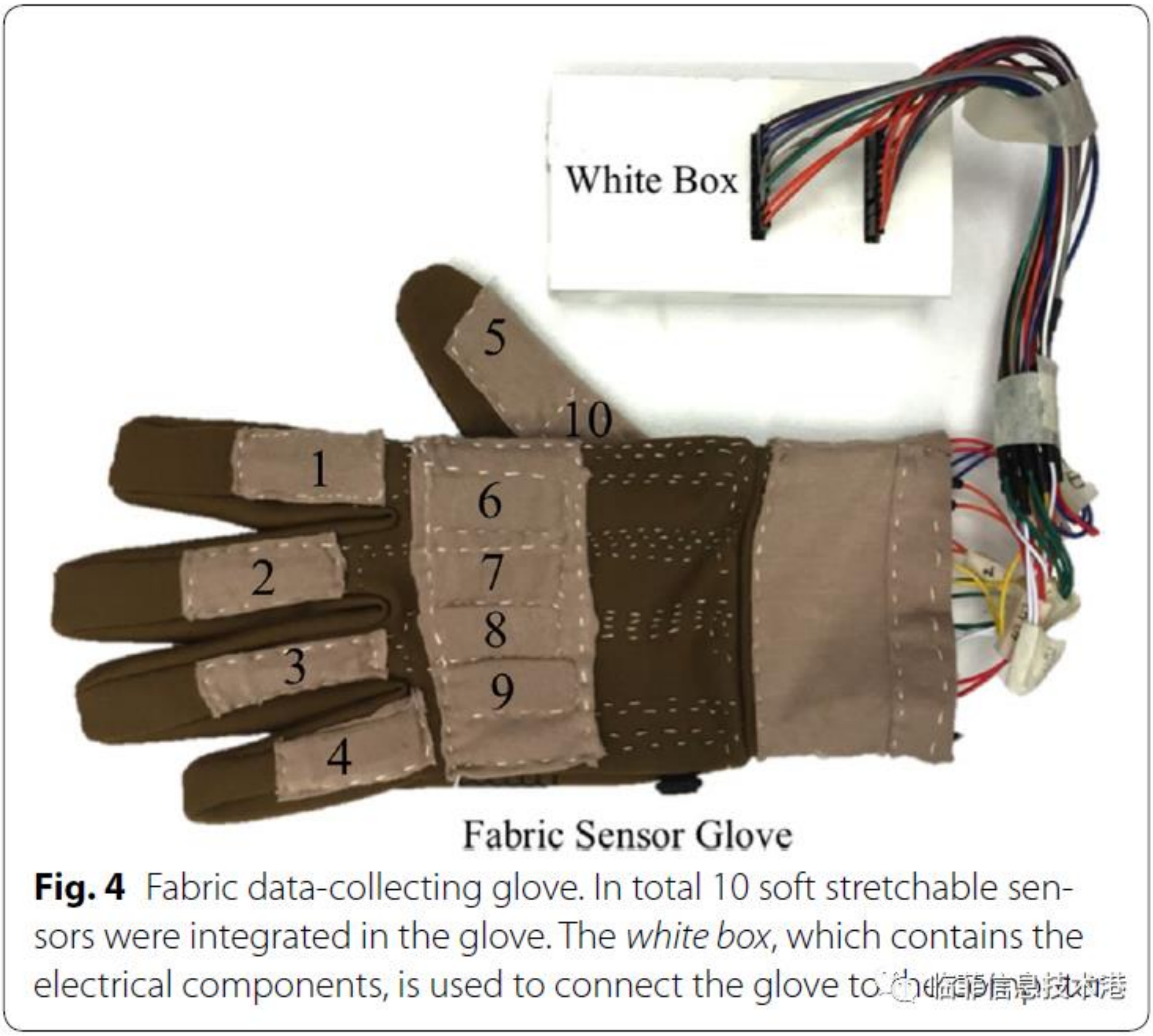


Fig. 4 Fabric data-collecting glove. In total 10 soft stretchable sensors were integrated in the glove. The *white box*, which contains the electrical components, is used to connect the glove to the

[10]

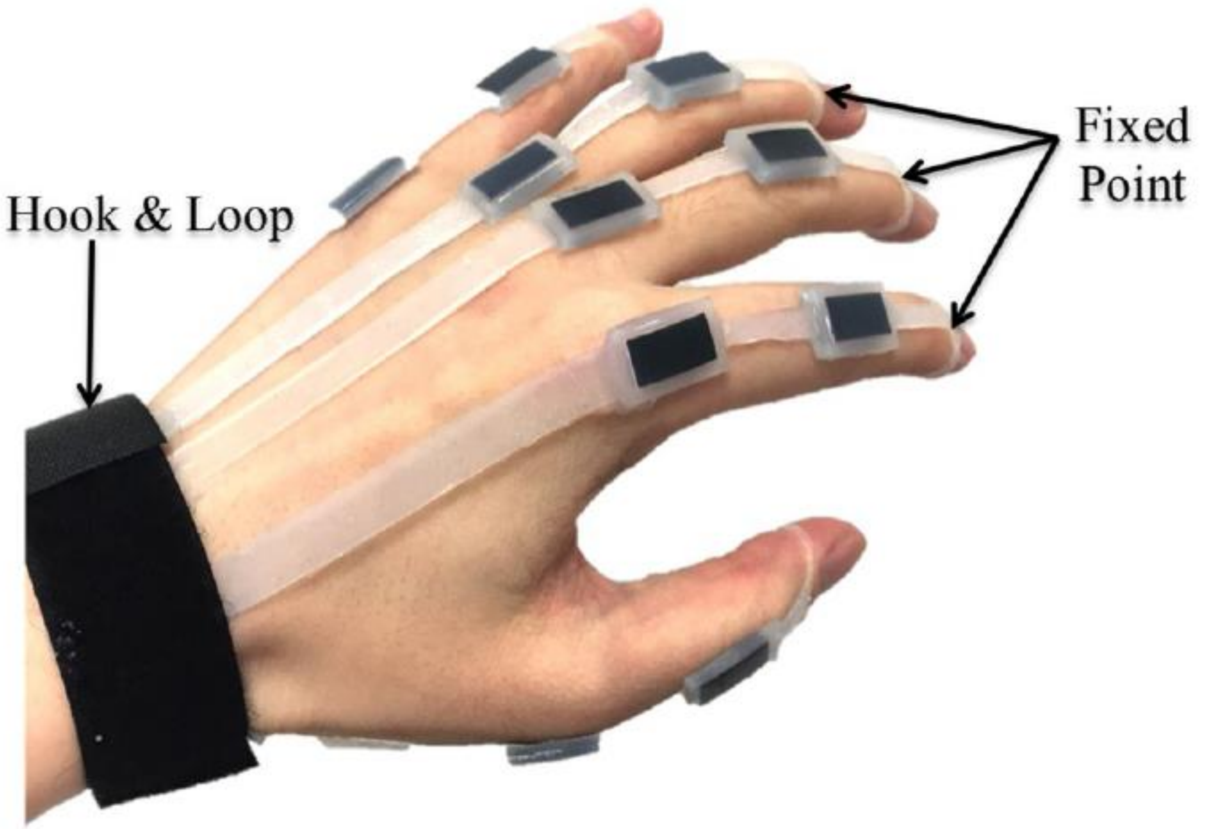


Fig. 5 Soft rubber data-collecting glove. The top of each part of the glove is a ring-shaped structure, and it is used to locate one end of the glove on the fingertips. The bottom of the five parts fixed inside the hook&loop to locate the other end of the glove on the wrist. There is a preload in each part of the glove to keep the sensing zones on the corresponding joints

[10]

FIGURE 1. The hybrid exoskeleton glove is equipped with a tendon-driven system for finger flexion, pneumatic actuators for finger abduction, and an inflatable, telescopic extra thumb for grasp quality enhancement. The soft glove is connected to the control box that houses the actuators.

[11]

FIGURE 3. The soft glove system of the device consists of a glove, a tendon-driven system, and a pneumatic system that is composed of four soft actuators and five laminar jamming structures. Five plastic tendon termination structures are stitched onto the fingertip regions of the glove. The tendon-driven system has a tendon connected to each of the tendon termination structures and an extra tendon that is connected to the thumb's interphalangeal joint region, facilitating the execution of the opposition motion. The soft structures are used for three different purposes: to perform abduction/adduction of the fingers, to increase grasp stability by implementing an extra thumb structure, and to change the bending profile of the fingers. Three of the pneumatic chambers are connected to the region in between the fingers allowing for the execution of the abduction/adduction motion of the fingers. Another soft actuator was designed to act as a telescopic extra thumb that participates in grasping tasks, increasing the area of the contact patches between the hand and the object and increasing both grasp efficiency and stability. At the back of the glove, five laminar jamming structures were added to adjust the stiffness of the joints and to perform a passive extension of each finger and keep the hand in its natural, zero effort position. A flex sensor is located at the index finger and can be used to control the motion of the exoskeleton glove.

[11]

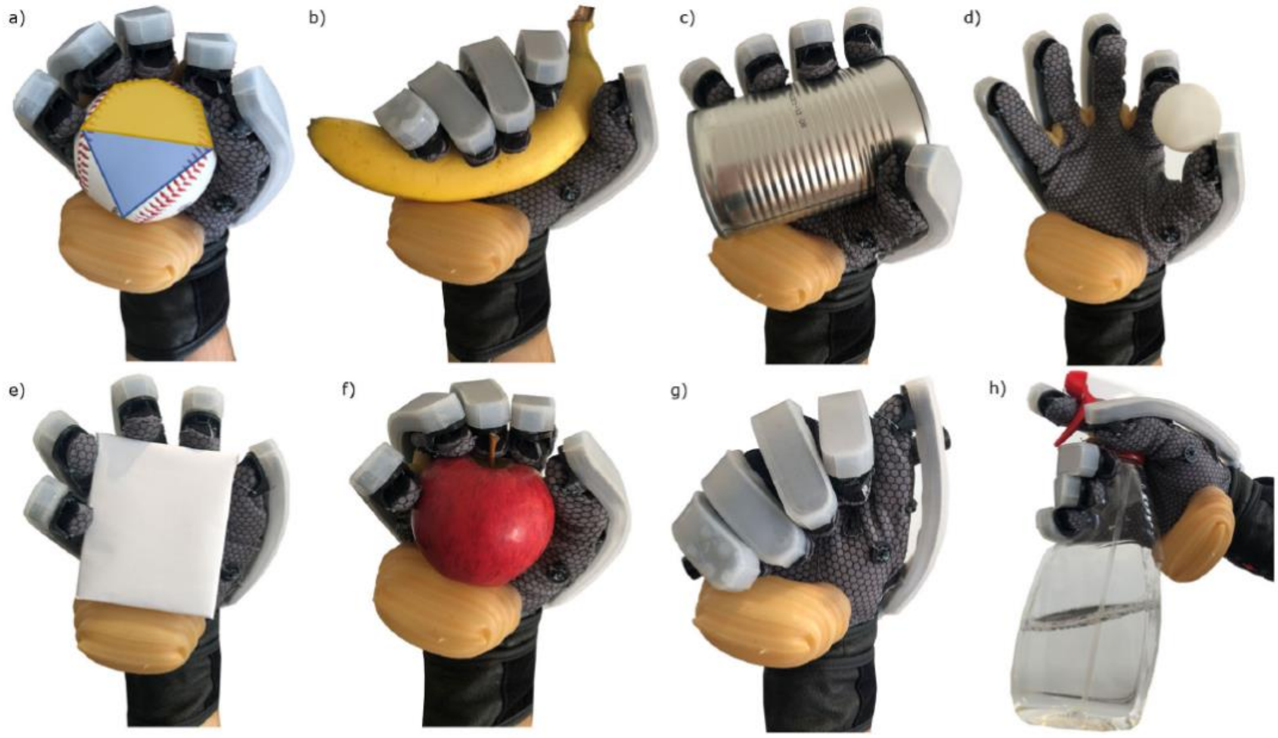


FIGURE 13. Grasping experiments executed with eight different everyday life objects: a) baseball ball, b) banana, c) can, d) table tennis ball, e) jelly box, f) apple, g) marker, and h) bottle, while the subject was wearing the proposed soft exoskeleton glove. The soft telescopic extra thumb module is employed in most cases, with the exception of the table tennis ball that is very small and requires a pinch grasp. The polygons in the baseball ball illustrate the grasp quality measure calculation for the objects: the yellow polygon represents the area generated by the center of the contact regions of the five fingers. The blue polygon represents the area generated by the center of the contact regions also considering the point of contact generated by the inflatable extra thumb.

[11]

文献：

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[3] Saad N. Yousaf,et al.， Design and Characterization of a Passive Instrumented Hand

[4] Stuart Biggar, et al., Design and Evaluation of a Soft and Wearable Robotic Glove for Hand Rehabilitation, IEEE Transactions on Neural Systems and Rehabilitation Engineering, Volume: 24, Issue: 10, October 2016

[5] Yuanyuan Wang, et al., Designing Soft Pneumatic Actuators forThumb Movements, IEEE ROBOTICS AND AUTOMATION LETTERS, VOL. 6, NO. 4, OCTOBER 2021

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