The PSYONIC-ROMP Collaboration: Providing Affordable, Advanced Prosthetic Hands in Quito, Ecuador

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***Abstract*— In this project, we ran the first home trial of the PSYONIC's compliant, sensorized prosthetic hand in Quito, Ecuador through the Range of Motion Project (ROMP). This RAS-SIGHT project contributes to a more equitable distribution of prosthetic care by providing a highly functional and low-cost prosthetic hand to people with below-elbow amputations in Quito (where access to affordable prosthetic care has been limited) and by training prosthetists in Quito to train patients and maintain this prosthetic hand themselves, in their own community (Fig. 1).**

I. The Problem

There are over 11.4 million people in the world with hand amputations. According to the World Health Organization, 80% of people with amputations are from developing nations, and less than 3% have access to affordable rehabilitative care [1]–[3]. People with transradial amputations who live in economically disadvantaged communities need a prosthetic hand that is not only functional, but also affordable, easy to manufacture, and simple to maintain [4].

The most common reasons for upper limb loss include traumatic injuries due to war and diseases like diabetes [5]. State-of-the-art commercially available prosthetic hands that can be controlled neurally from residual muscles (myoelectric control) are priced between \$15,000-30,000 and are manufactured between \$3000-\$5000, making them unaffordable for most people with upper limb amputations. In addition, commercially available prosthetic hands are made of rigid materials and that are damaged often and make handling delicate objects difficult. These prostheses make use of injected molded plastics along with heavy steel and metals that drive up costs. Alternatively, there are many 3D-printed prosthetic hand projects made of cheap plastics that break easily.

Also, no commercially-available prosthetic device can provide useful sensory feedback. Prostheses and their users are unable to determine how much force is being applied to objects that they are grasping. Poor manipulability due to the lack of sensory feedback is a leading cause of prosthesis abandonment [6], [7].

II. The Solution

PSYONIC is developing an affordable, highly-functional myoelectric prosthesis (Fig. 2). This RAS-SIGHT project contributes to a more equitable distribution of prosthetic care by providing a highly functional and low-cost prosthetic hand to people with below-elbow amputations in Quito (where access to affordable prosthetic care has been limited) and by training prosthetists in Quito to train patients and maintain this prosthetic hand themselves, in their own community.

In the past 3 years, we have conducted over 100 in-

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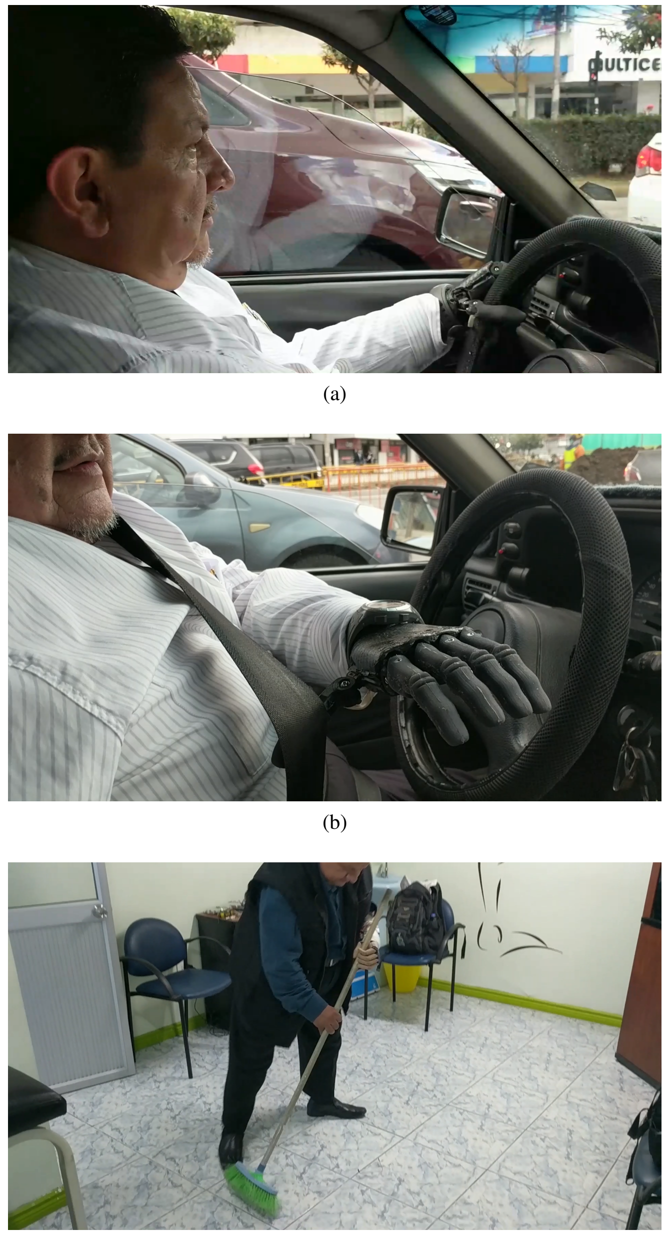

(a)

(b)

(c)

Fig. 1. Our patient in Quito, Ecuador (a) driving his car, (b) putting on his seatbelt, and (c) sweeping with the PSYONIC hand.

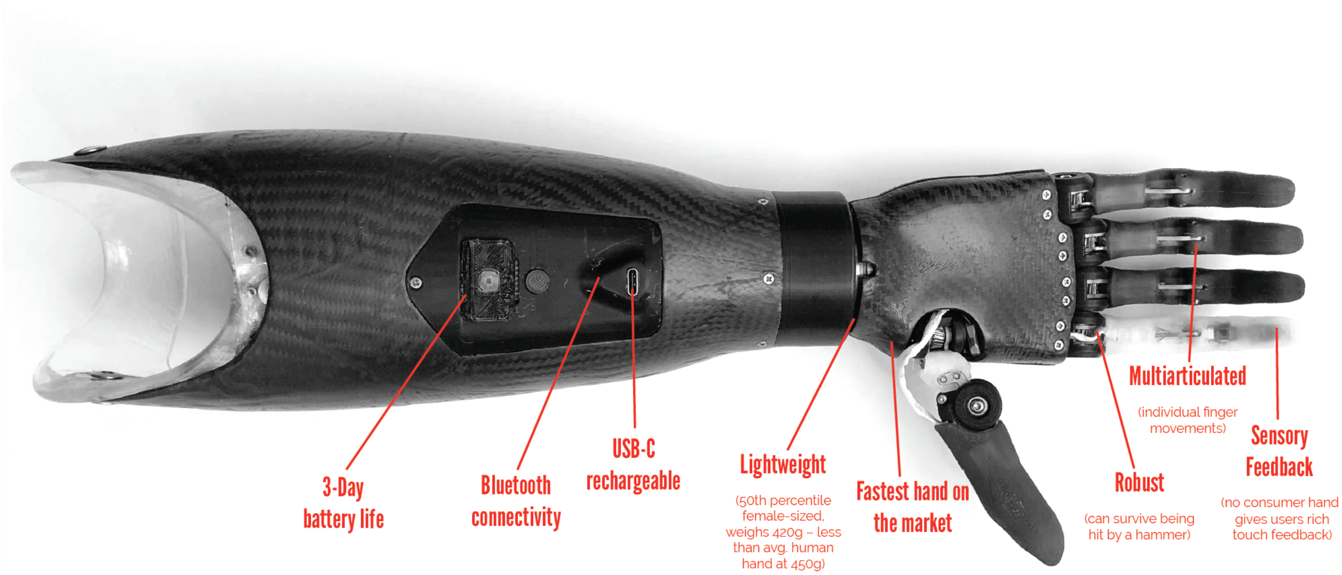

Fig. 2. PSYONIC's affordable, compliant, sensorized bionic hand.

terviews with leading prosthetists, researchers, prosthetics manufacturers, and people with upper limb amputations. From those interviews, we identified a clear market need: affordable, robust prosthetic hands that can grasp a variety of objects naturally and can also handle delicate objects without breaking them.

Our prosthetic hand addresses these issues by using compliant materials like silicone and polyurethane rubber to create hands that are both strong and resilient. Furthermore, by incorporating sensors in the fingertips, we can measure pressure applied to the fingers, enabling highly sensitive touch feedback. A block diagram of the hardware is given in Fig. 3. The hardware was compartmentalized into three subsystems: 1) the socket, 2) the hand, and 3) the sensory substitution system.

A. Mechanical Design

Compared to our previous work [3], the entire hand has been mechanically redesigned to be smaller, more robust through the use of compliant materials, and energy efficient through the use of non-backdrivable worm gears. The dimensions of the hand are at 50th percentile female anthropometry. Both PLA and ABS were used for 3D printing molds for silicone casting along with all structural components. The fingers are cast out of silicone to achieve compliance in the finger joints, providing human-skin like texture to the prosthesis. The compliant joints were developed by building a composite structure made of silicone (Dragon Skin 20, Smooth-On, Macungie, PA), 3D-printed flexible material (Cheetah, NinjaTek, Mannheim, PA) and nylon (Taulman 910, taulman3D, St. Peters, MO). By using a flexible bone inside of a silicone outer structure, compliance in the proximal interphalangeal joint was achieved. The joint compliance allows shock absorption from either flexion or extension directions. The nylon kept the distal interphalangeal joint fixed so that objects could not easily slip out of the hand when grasping large loads. Non-backdrivable worm gears decrease power consumption when gripping objects with constant high torque.

B. Motor Control

Electromyography (EMG) was used to control actuation in the hand. A pair of standard EMG sensors made by RSL Steeper was used to control various hand grasps. The EMG electrodes were placed over the wrist flexor and extensor muscles. The flexor electrode mapped to a power/key grasp (depending on the thumb position), the extensor electrode mapped to hand open, and co-contraction mapped to an index finger point.

C. Sensory Feedback

The hand microcontroller polls three MPL115A2 barometric pressure sensors (Freescale, Austin, TX) located in the finger tip and finger pad of the distal phalanges of digits 1, 2, and 5. Using the low-cost method described by Tenzer, et al. [8], we cast the sensors in silicone (Dragon Skin 20, Smooth-On, Macungie, PA) to turn them into highly sensitive touch sensors when depressing the silicone. The pressure readings from each sensor are scaled to a value between 0 and 1, and we detect contact when the pressure value exceeds a threshold of 0.2. If contact is detected in any of the six pressure sensors, a contact reflex takes place in which the speed of the hand is reduced to 30% of its current speed in order to provide the user with finer control in manipulating the contacted object without damaging it [9].

In addition to providing contact reflexes, information from the pressure sensors can be delivered to the user via sensory substitution. In particular, we use a vibration motor to provide this feedback, though any sensory substitution system, such as electrotactile stimulation or skin stretch, can

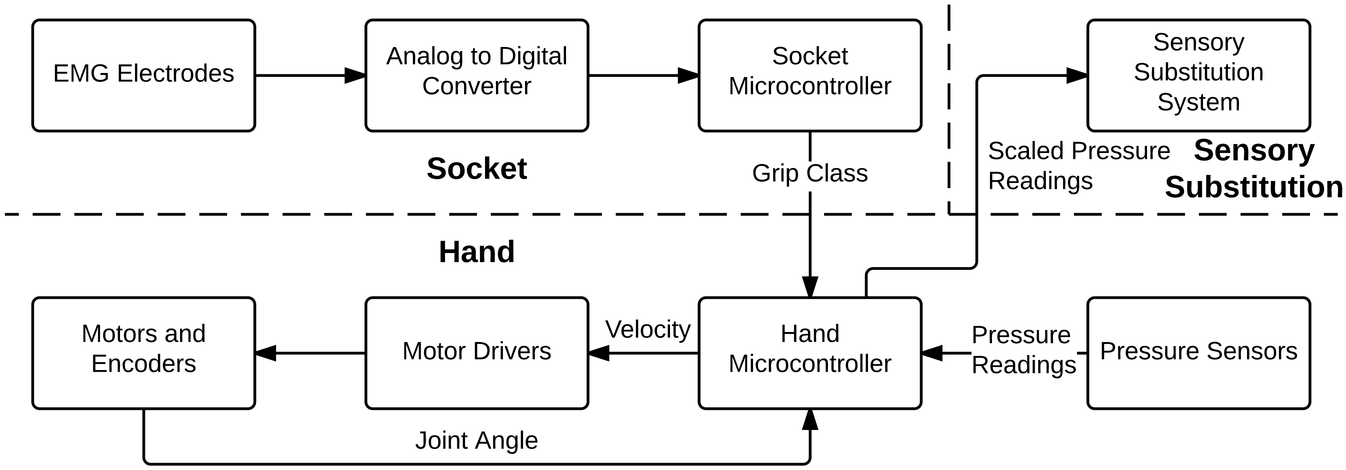

Fig. 3. Hardware Block Diagram

be used. The vibration strength is proportional to the pressure measured from the finger, and is housed completely inside the socket.

III. PSYONIC-ROMP Partnership and Previous Experience

PSYONIC spun out of research at the University of Illinois at Urbana-Champaign during Dr. Aadeel Akhtar's graduate work. During his PhD, Akhtar developed the initial low-cost hand prototypes using 3D-printing, incorporating sensory feedback. Since then we have developed 6 hand prototypes. Throughout the development of PSYONIC's hand prototypes, we have established research and business partnerships with the Rehabilitation Institute of Chicago, Scheck & Siress Prosthetics & Orthotics, the Center for Wounded Veterans at the University of Illinois, and the Range of Motion Project, a non-profit organization whose mission is to provide the world with a more equitable distribution of prosthetics. We have successfully field-tested our prosthetic technology both locally in Illinois and in South America. PSYONIC's patients have included war veterans in the US and Ecuador. In Ecuador, PSYONIC and ROMP successfully applied the prosthesis to man who lost his arm 35 years prior in a war between Ecuador and Peru. After feeling from his prosthesis for the first time in over 30 years, he said he had felt as though a part of him had come back. This technology has enabled our patients to easily handle delicate objects, like eggshells and fruit, without crushing them.

IV. Patient Impact

There are several hundred people with upper limb amputations in the Quito, Ecuador area. We performed our first home trial with a 60 year-old male patient with a left wrist disarticulation (Fig. 1). The patient lost his left hand due to a traumatic injury from machine gunfire during his service in the Ecuadorian army 35 years ago. A standard transradial prosthesis socket was developed by ROMP prosthetists. PSYONIC's hand interfaced with this socket. We provided the patient with the option of two hands, one that matched his skin tone (Fig. 1c) and another with the carbon fiber visible (Figs. 1a-1b). He chose to carbon fiber appearance, as it had a more bionic look, which he appreciated.

After the initial fitting, the patient took the prosthesis home for 10 days. He used the prosthesis to drive his car, cut and eat his food, dress himself, sweep the floor, and greet people, among other activities of daily living (Fig. 1). On average, he wore the prosthesis for six hours a day. There were some minor mechanical issues with set screws becoming loose on the worm gears, which will be remedied in the future by epoxying the worm gears to the motor shafts. There were also issues with palm tolerances which made the fit poor at times, which can also be easily remedied in the future through a redesign. The patient reported to especially like the USB-C charging of the device, which allowed him to conveniently use his phone charger to charge the hand. Overall, the patient was pleased with the device and is excitedly awaiting the production model so that he can use the hand on a more permanent basis.

V. Project Members

Aadeel Akhtar, PhD (CEO, PSYONIC) - Dr. Akhtar received his PhD in Neuroscience and MS in Electrical & Computer Engineering from the University of Illinois at Urbana-Champaign in 2016, where he is currently a medical student. He holds an NIH National Research Service Award MD/PhD Fellowship. Dr. Akhtar also received his BS in Biology and MS in Computer Science at Loyola University Chicago in 2007 and 2008, respectively. In 2016, he won the $20000 Illinois Innovation Prize. His research interests include motor control and sensory feedback for upper limb prostheses, and he has collaborations with the Bretl Research Group at Illinois, the Center for Bionic Medicine at the Rehabilitation Institute of Chicago, the John Rogers Research Group at Northwestern University, and the Range of Motion Project in Guatemala and Ecuador.

Website: http://www.psyonic.co

David Krupa, Certified Prosthetist (CEO, Range of Motion Project) - As a prosthetist and the Founder and CEO of the Range of Motion Project, Mr. Krupa has provided custom-made prosthetic and orthotic devices to 5,394 of the western hemispheres most vulnerable individuals through a three-tiered delivery model emphasizing high quality clinical care; local investment; and advocacy. The majority of children and adults served need to return to work, care for young children, and support their families through physical labor. Through his volunteer commitment to ROMP, he is directly responsible for this replicable and scalable healthcare delivery system now serving amputees in Guatemala, Ecuador, Mexico and the U.S. An amputee himself, Mr. Krupa believes mobility can be critical in an individuals pursuit of lifes many aspirations family, community, work, active play and adventure. This fuels his continued drive to expand his impact on the healthcare of underserved populations.

Website: http://www.rompglobal.org

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