Morphology Extension Kit: A Modular Robotic Platform for Customizable and Physically Capable Wearables

Sang-won Leigh
MIT Media Lab
75 Amherst St
Cambridge, MA, USA
sangwon@media.mit.edu

Kush Parekh
Rhode Island School of Design
Two College Street
Providence, RI, USA
kparekh@risd.edu

Timothy Denton
MIT
77 Massachusetts Ave
Cambridge, MA, USA
twdenton@mit.edu

William S Peebles
MIT
77 Massachusetts Ave
Cambridge, MA, USA
wpeebles@mit.edu

Magnus H Johnson
MIT
77 Massachusetts Ave
Cambridge, MA, USA
magntron@mit.edu

Pattie Maes
MIT Media Lab
75 Amherst St
Cambridge, MA, USA
pattie@media.mit.edu

CHI'17 Extended Abstracts, May 06-11, 2017, Denver, CO, USA
ACM 978-1-4503-4656-6/17/05.
http://dx.doi.org/10.1145/3027063.3052969

Abstract
Robotic and shape-changing interfaces hint at a way to incorporate physical materials as extensions for human users, however, rapidly changing environments pose a diverse set of problems that are difficult to solve with a single interface. To address this, we propose a modular hardware platform that allows users or designers to build and customize physical augmentations. The process of building an augmentation is simply to connect actuator and sensor blocks and attach the resulting wearable to the body. The current design can be easily modified to incorporate additional electronics for desired sensing capabilities. Our universal connector designs can be extended to utilize any motors within afforded power, size, and weight constraints.

Author Keywords
Synergistic Interaction; Modular Robotic Platform;

ACM Classification Keywords
H.5.2 User Interfaces: Input devices and strategies (e.g., mouse, touchscreen)

Introduction
Research in the field of Augmented Human (AH) has focused on increasing human capabilities through

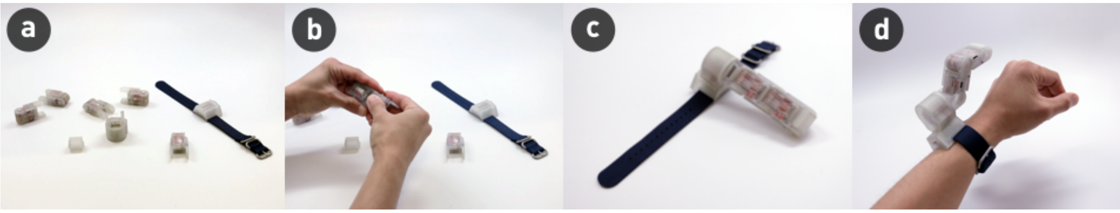

Figure 1. a) modules for robot assembly b) the modules are connected by a single clasp action c) an assembled robot connected to the wrist attachment module d) the robot in action, worn on a user's wrist

computation-driven augmentations. However, when it comes to an actual realization, there is only limited space on the human body for adding such robotic body parts. In addition to that, one specific-purpose body-integrated device may not be sufficient [2] for the variety of problems we encounter every day.

To address this, we propose a modular robotic assembly kit that allows for customizing and building motor augmentations on demand. The process of building one is straightforward – it is simply to connect robotic modules together and attach the resulting structure to a base on the body, for example the wrist. The modularity of our design accommodates augmentations of various kinds, not only including conventional robotics applications, but also ones in the scope of HCI.

To demonstrate the idea, we implemented two types of servomotor modules, and an interchangeable tip module that can be modified to serve different sensing or effector functionalities. The mechanical/electrical connector design of the modules can be incorporated in the design of new modules with any desired features, making them compatible with the rest of the modules in our system. Along with the early examples of modules, we present the underlying hardware and software design of our system and several applications. We also present examples of different tip module designs to highlight the customizability of our system.

Related Work

Supernumerary Robot

Supernumerary Robots (SR) [6] is a field of research exploring extra robotic fingers or limbs in addition to the human body, unlike exoskeletons and prostheses that are designed for offering amplified performance or artificial replacements for the loss of body parts. SRs are often designed in a wearable form and work in parallel with the human limbs.

Shape Changing Interfaces

Shape-changing interfaces are utilized to create reconfigurable physical shapes for a broad range of applications. Other shape changing mechanisms such as actuator chains [3, 4] can offer 3D shapes and portability. Such a configuration has been used for a wearable robot [2] and demonstrated versatile usages.

Other researchers realized construction kits in which components are assembled to constitute a functional system. *Topobo* [5] is a tangible construction kit with which one can create animated assemblies. *IKO Creative Prosthetic System* [1] allows for building one's own prosthetic extensions using LEGO parts.

System

Our platform design emphasizes the combination of three interchangeable types of modules: actuator modules, sensor modules, and shape modules. Key elements to the design of this system are rigidity and universality of the physical connector design. In addition to those, real-time update of the structure

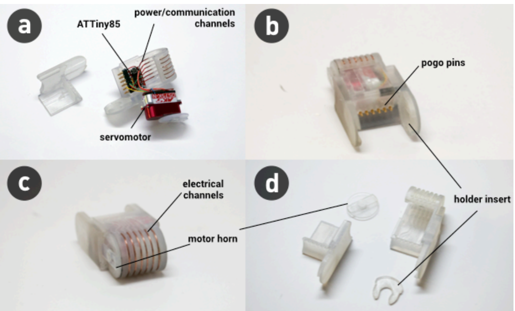

Figure 2. a) the internal view of the pitch module, the wires for the connector are embedded in channel structures b) front view: female connectors have pogo pins c) rear view: mail connectors have annular copper channels that get in contact with the pogo pins d) 3D printed parts for the module. The motor horn and the insert have clasp structures that hold connected modules together

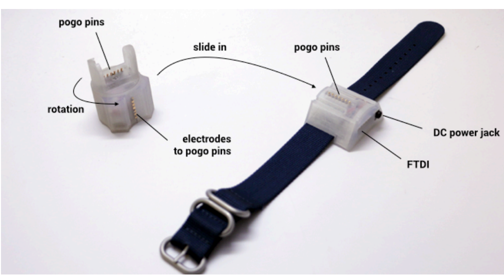

Figure 3. the wristband attachment module (right), and the rotational modules (left) that connects to the attachment module

Figure 4. different tip module designs - trigger, pick holder, sensor tip, knob tip, LEGO connector

during assembly and single clasp assembly are what differentiate this system from other modular hardware kits such as [3].

Actuator modules can be chained in series (figure 1b) (and possibly in a more complex network structure with branching modules designed), and constitute the main body of the final assembly. We demonstrate an implementation of a pitch angle module (figure 2), that offers a 1D rotational motion and an encoder that streams the motor's position to a base microcontroller. Sensor (tip) modules can accommodate up to two sensors and stream sensor data back to the base microcontroller. Shape modules can take passive forms that act as effector affordances (figure 4). A module can also act as both as a sensor and a shape at the same time.

Connector Design

A critical design requirement is to implement the same mechanical and electrical connectors across all different modules, so that users are not restricted to a specific order of assembly. For modules that involve motions, the male connectors have annular electrical channels (figure 2c) on which pins on the female connectors (figure 2b) can slide along. In this way, moving parts can be utilized without taking up extra space for embedding those inside. The connector design can also be utilized in designs of new modules, by simply importing the connectors into the new model. Therefore, different actuators or modules with alternative shapes can be easily created. The CAD files for the connectors will be released as open-source along with our electronics/software designs.

Ease of Assembly

The modules are attached to each other through a single clasp action (figure 1b), where electrical channels embedded in the mechanical connectors (figure 2b-c) get into contact once the modules are connected. After the electrical connection is made, our software automatically detects the change through an I2C bus in the overall structure and update the connection map. Hence, there is no effort required from the user other than simply plugging the modules together.

Exertion Capability

The motor we used has a torque density of 5N·cm/cm^3 (2.0 kg-cm stall torque at 4.8V power supply). The amount of force it can exert depends on the details of the configuration - a setup of four pitch modules will provide about 0.4kg of force pulling or pinching. Human fingers have 5kg to 7.7kg of tip pinching force, and given that four-modules setup is much longer than a finger, the amount of force the robot exerts is well within an order of magnitude from the human fingers.

Application

This section showcases how our platform can be deployed in practical applications. The robotic system can be mounted on different locations of the human body (such as on a belt) based on intended applications. A user can also wear more than one robot through the use of multiple attachment modules.

Figure 5. the robot can help the user to disengage from distraction through physical interventions

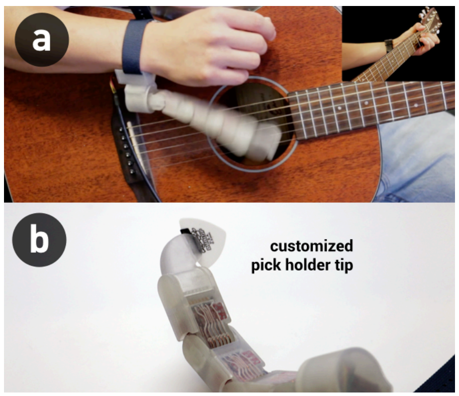

Figure 6. the tip module can be designed to perform a variety of operations, such as holding a pick (b), in turn allowing a remote user to help with a range of physical tasks such as teaching how to play the guitar

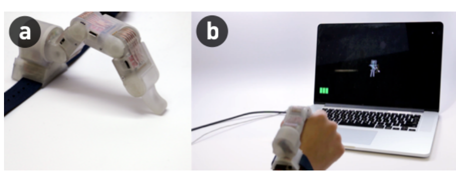

Figure 7. a) gun trigger tip mounted b) the robot used as a gaming interface c-d) running out of ammo triggers a shape change, notifying the user of a required action

Actuated Agent

In this category of applications, a body-worn robot is used as a semi-autonomous agent that assists the user with a task. Preprogrammed triggers initiate actions associated with the shape of the robotic construction. For example, the robot can notify the user about an unread text message from a close friend, by a gentle tap on the hand. The type of a notification can increase intimacy and can be an effective means in person-to-person communications. The robot can also help the user to focus more by creating a physical intervention when the user is distracted, such as when continuously opening web browsers while reading (figure 5).

Telepresence

Another category of applications enabled by our platform are various forms of telepresence. While a student user is resting his/her arm on a guitar, a remote guitar instructor can teach how to execute a certain rhythm pattern through the robot (figure 6a). The student user would need to swap the finger tip of the robot to a pick holding structure (figure 6b). Once the student picks up the rhythm, the instructor can move the robotic joints to another position and play percussion on the guitar body, therefore guiding the student like a metronome.

Always Available UI

The robot also affords an always-available, shape changing haptic interface. This feature is particularly useful for Virtual Reality (VR) applications, since it is not always straightforward to execute commands with hand gestures in a void or with a single type of controller. A reconfigurable robot can dynamically adjust physical affordances and behaviors on demand, as shown in our gun controller example (figure 7).

Conclusion

We presented a modular hardware platform for designing customizable and physically capable wearable devices. The constructed robot is connected an attachment module worn on a user's body, and act as a physical extension or an always-available agent to the user. We showcase our platform through demonstrating servomotor modules and a range of tip modules with sensing or effector functionalities. The potential of the system is not limited to what we have presented. The connectors and the electronic design can be embedded in new module designs offering alternative sensors, actuators, or physical forms.

References

1. Torres, C. IKO Creative Prosthetic System. https://vimeo.com/97877783
2. Leigh, S., and Maes, P. Body Integrated Programmable Joints Interface. In Proc. CHI '16. http://dx.doi.org/10.1145/2858036.2858538
3. Nakagaki, K., Dementyev, A., Follmer, S., Paradiso, J.A., Ishii, H. ChainFORM: A Linear Integrated Modular Hardware System for Shape Changing Interfaces. In Proc. UIST '16. https://doi.org/10.1145/2984511.2984587
4. Sekiguchi, D., Inami, M., Tachi, S. Robotphone: RUI for interpersonal communication. CHI EA '01. http://dx.doi.org/10.1145/634067.634231
5. Raffle, H. S., Parkes, A. J., Ishii, H. Topobo: a constructive assembly system with kinetic memory. In Proc. CHI '04. http://dx.doi.org/10.1145/985692.985774
6. Wu, F. Y. and Asada, H. "Hold-and-Manipulate" with a Single Hand Being Assisted by Wearable Extra Fingers. In Proc. ICRA '15. http://dx.doi.org/10.1109/ICRA.2015.7140070