PneuHaptic: Delivering Haptic Cues with a Pneumatic Armband

Liang He, Cheng Xu*, Ding Xu, Ryan Brill

Carnegie Mellon University
5000 Forbes Ave, Pittsburgh, PA 15213
edigahe, xuding.bj, brill.ryan@gmail.com

*Capital One
201 Third St, San Francisco, CA 94110
chengx.cn@gmail.com

ABSTRACT

PneuHaptic is a pneumatically-actuated arm-worn haptic interface. The system triggers a range of tactile sensations on the arm by alternately pressurizing and depressurizing a series of custom molded silicone chambers. We detail the implementation of our functional prototype and explore the possibilities for interaction enabled by the system.

Author Keywords

Pneumatic; shape changing interface; haptic communication

ACM Classification Keywords

H.5.2. Information Interfaces and Presentation: User Interfaces—Haptic I/O

INTRODUCTION

Since Geldard suggested vibration as an information channel in 1960 [3], the Human-Computer Interaction community has been developing tactile interfaces. A common approach in creating haptic cues is moving the contact surface with electromechanical actuators such as vibrating electric motors, piezoelectric motors, or voicecoils [8]. While these actuators can be configured to effectively convey rich information, their high frequency movements could raise negative responses after lengthy exposure [4].

We built PneuHaptic to explore a new style of tactile stimulus. Our device is a wirelessly controlled armband composed of a series of compliant nodes (Figure 1). The node gently presses against the skin when swelling, and hangs loose when deflated. By actuating the nodes in different patterns several haptic cues are generated. In this paper, we focus on three sensations: tapping, holding, and tracing. We share our process in designing and fabricating the mechatronic system, and a preliminary user study.

On-arm vibration feedback has been effectively deployed for notifications [6], directions [1], and motion guidance [5]. We adopted a similar on body placement but avoided the high frequency stimulus. Previous research created shape changing alternatives to vibrations by turning servos [9] and inflating air pockets [7]. Fan *et al.* prototyped a tethered haptic band with inflating balloons to provide low-resolution force feedback [2]. Building on this work, our system explores different inflatable dynamics and builds a haptic vocabulary.

IMPLEMENTATION AND EVALUATION

PneuHaptic is composed of an array of pneumatically-actuated air chambers, a miniature air compressor, solenoid valves, and a control board. The system dynamically controls the inflation intensity and temporal pattern of each chamber which adds to the richness of the signal.

The pneumatic actuators are cast in silicone in a structure that encapsulates an air pocket with two holes for air valves The process is inspired by the Soft Robotics Toolkit[1]. A 3D-printed rigid box surround all faces of the chamber except for one, which both holds the chamber in place and constrains the expansion of the silicone structure.

A series of five air chambers are connected to two air compressors (KOGE, KPV 14A) via three micro solenoid valves which control the flow of air to make the actuators inflate and deflate. The pump and valves are controlled by a 5V Arduino Pro Mini connected to a mobile phone through Bluetooth Low Energy. The air chambers and control

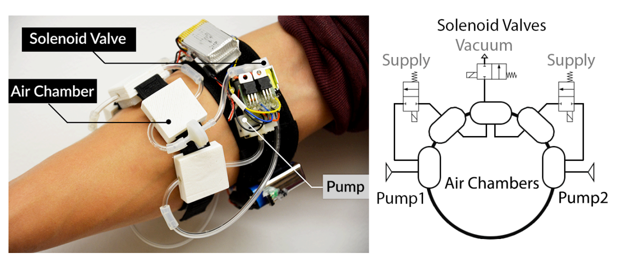

Figure 1. The overview of the PneuHaptic band

[1] http://softroboticstoolkit.com/

ISWC '15, September 7–11, 2015, Osaka, Japan.
ACM 978-1-4503-3578-4/15/09.
http://dx.doi.org/10.1145/2802083.2802091

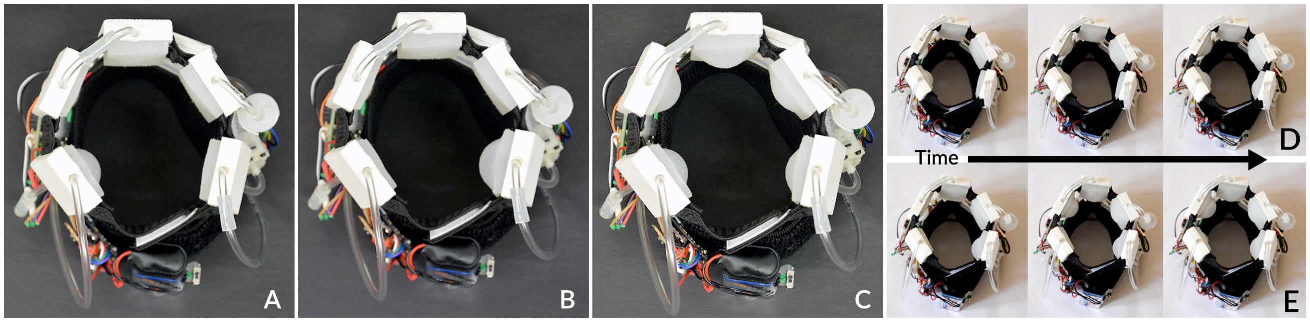

Figure 2: Basic interactions in our prototype: (A), left tapping (B), right tapping (C), holding (D), clockwise tracing (the deformation starts from the leftmost chamber) (E), counter clockwise tracing (the deformation starts from the rightmost one)

system are mounted on two elastically adjustable armbands. It takes approximately 4s to inflate one air chamber to its full extent and less than 1s to deflate.

The vocabulary for PneuHaptic is inspired by human-to-human interactions: tapping, holding, and tracing. Tapping is achieved by inflating and deflating one air chamber. Holding is mimicked when some or all of the chambers are inflated at the same time. The inner diameter of the band shrinks, putting pressure on the skin along the circumference of the band. If an array of chambers is inflated in sequence, a moving spot can be felt, simulating a sensation somewhat like a finger traced along the skin.

We conducted a preliminary study to understand the effectiveness of PneuHaptic. We tested five stimuli: clockwise and counterclockwise tracing, holding, and tapping on the left or right side (Figure 2). Four participants (3 male and 1 female, average age of 27) achieved an overall accuracy of 93% in identifying the stimulus (presented six times each in random order for two conditions: walking and sitting). Note, participants wore earplugs to minimize any auditory bias introduced by the air compressor.

Qualitatively, we found that errors occurred when the participants performed very active movements. Compared with tapping, tracing takes longer (about 5s) to recognize and is occasionally mistaken as tapping (about 2s), since both start similarly yet tracing takes longer to perform. Participants commented that PneuHaptic is ‘more versatile’ than phone vibrations.

FUTUTRE WORK AND CONCLUSIONS

Our spatial resolution is limited by the air conduits we can physically fit on a forearm. We are experimenting with a new topology of airflow and patterns of inflation to expand the touch vocabulary. We are also exploring interactive capabilities by embedding air pressure sensors.

In conclusion, we created a novel wearable haptic interface by gently pressing on the skin using compliant shape-changing nodes. By dynamically controlling the inflation and deflation of these nodes, we communicate several distinguishable haptic cues. Building on this vocabulary, we could enable wearable applications such as directional commands, rich alerts, and remote inter-person haptic communications.

REFERENCES

1. Bosman, S., Groenendaal, B., Findlater, J. W., Visser, T., de Graaf, M., & Markopoulos, P. Gentleguide: An exploration of haptic output for indoors pedestrian guidance. *Proc. MobileHCI 2003*, ACM Press (2003), 358-362.
2. Fan, R. E., Culjat, M. O., King, C. H., Franco, M. L., Boryk, R., Bisley, J. W., and Grundfest, W. S. A haptic feedback system for lower-limb prostheses. *Neural Systems and Rehabilitation Engineering*, IEEE Transactions on, 16(3) (2008), 270-277.
3. Geldard, F. A. Some neglected possibilities of communication. *Science* (1960).
4. Kaaresoja, T., & Linjama, J. Perception of short tactile pulses generated by a vibration motor in a mobile phone. *Proc.World Haptics 2005.* IEEE (2005). 471-472.
5. Kapur, P., Jensen, M., Buxbaum, L. J., Jax, S. A., and Kuchenbecker, K. J. Spatially distributed tactile feedback for kinesthetic motion guidance. *Haptics Symposium*, IEEE (2010). 519-526.
6. Lee, S. and Starner, T. BuzzWear: alert perception in wearable tactile displays on the wrist. *Proc. CHI 2010*, ACM Press (2010), 433-442.
7. Pohl, H., Becke, D., Wagner, E., Schrapel, M., and Rohs, M. Wrist Compression Feedback by Pneumatic Actuation. *Ext. Abstracts CHI 2015*, ACM Press (2015).
8. Poupyrev, I., Nashida, T., and Okabe, M.. Actuation and tangible user interfaces: the Vaucanson duck, robots, and shape displays. *Proc. TEI 2007*, ACM Press (2007), 205-212.
9. Stanley, A. A., and Kuchenbecker, K. J. Design of body-grounded tactile actuators for playback of human physical contact. *Proc. World Haptics 2011*, IEEE (2011), 563-568.