Biometric Perception Interface

Mengyu Chen, Jing Yan, Yin Yu

To cite this version:

Mengyu Chen, Jing Yan, Yin Yu. Biometric Perception Interface. International Workshop on Haptic and Audio Interaction Design - HAID2019, Mar 2019, Lille, France. hal-02048239

HAL Id: hal-02048239

https://hal.archives-ouvertes.fr/hal-02048239

Submitted on 25 Feb 2019

Biometric Perception Interface: A Multisensory Soft Robotic Agent for Affective Social Interaction

MENGYU CHEN*1, JING YAN†2, YIN YU‡1

[1]**MEDIA ARTS AND TECHNOLOGY, UNIVERSITY OF CALIFORNIA SANTA BARBARA**
[2]**D2 NOVA CORP.**

Soft robotics are primarily composed of soft materials with low moduli which are close to that of biological materials [1]. This unique feature leads to its potential of being utilized on human body as wearable devices that can directly stay and interact with the user's skin, further expanding the application scenario of robot as a haptic agent of interpersonal communication. With the possibility of conveying intimate messages while maintaining a desired physical distance, a skin-contact based remote communication can create a new form of intimate relationship for people. We present Biometric Perception Interface, a wearable perception extension interface that measures and converts pulse into haptic actuation, and allows users to record and playback pulse data from and to their bodies. We demonstrate three inter-connected components of Biometric Perception Interface: Memorizer, Choker, and Antenna. Additionally, Biometric Perception Interface challenges the common practices of visual memory and quantified abstraction of biological phenomena, and proposes an alternative interpersonal intimate communication mediated by soft-robotics.

INTRODUCTION

The effectiveness of visual communication can reach certain limit when an intimate relationship is involved. As visual information is conveyed by human eyes without direct physical touch, intimate and emotional contents can be lost because of the distance. Research has shown that touch stimulation can make infants behave more actively with the environment and emit more smiles and vocalizations [2]. It is also proven that touch is often associated with enhanced affect and can convey a stronger sense of bond between people [3].

Data visualization often is challenged by the same limits its lack of affect. Conventional information display with graphs and numbers can describe the objective state of events in rich details, but can insufficiently express affection and emotion [4[5]. Various devices have been made with an attempt to convey such complex information via haptic links of users [6][7]. Simulating or recreating direct human touch, such as hugging, appears to be the most common form of communicating with affect. Prior works has focused on translation of audio or visual data into tactile stimulation, but they are mostly made as sensory assistance for blind communities [8][9]. Haptic displays were also investigated as new ways of information representation, such as position sensing and movement coordinating. They are commonly used for emerging media such as virtual reality (VR), but not for an affective interpersonal communication [10].

We foresee a need for exploration and experimentation in haptic data representation in the context of affective interpersonal communication. In this paper, we are proposing a set of biomorphic designs of soft robotic prosthetic devices that provide users a unique haptic experience dissimilar to the conventional optical reception of biometric data representation. We fabricate pneumatic soft device as wearable interface that can fit on human body, using commodity materials and electronics, such as pulse sensor and low-pressure air pump. Extend a user's exteroceptive field like artificial organs, the devices we are showing and their capacity to physically link two human bodies at the same time open up a new way of intimate but distant communication without direct skin contact of the users. We name this mode of communication *Biometric Perception*, associated with a hardware interface of interconnected components. The devices shown in Figure 1 (b) and (c) actuate inflation on the neck, detect and output pulse signals to external data apparatus. Figure 1 (a) shows an example of a user experiencing pulses and perceiving another user's body movement via our devices.

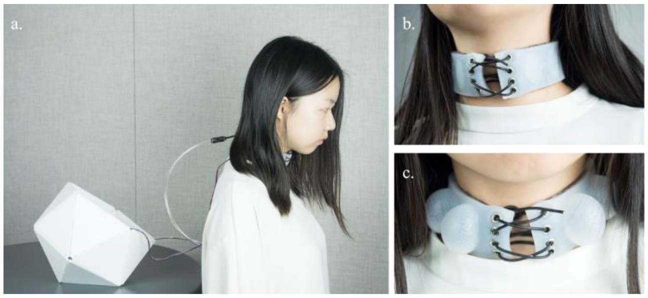

Figure 1 (a) A user experiencing pulses and perceiving another user's body status. (b) Choker is deflated (c) Choker is inflated.

Biometric Perception Interface serves as a conceptual design for exploring potential application of soft-robotic wearables that it would facilitate interpersonal intimate communication, such as augmented telecommunication, multi-sensory immersive movie theater, social VR, remote infant caring and soothing, and touch-based psychotherapy. Our system extends the concepts proposed in prior works on robotic design for intimate communication [8] and remote haptic communication [7], and appropriates soft robotics and biomorphic design into the process. Having the benefits of soft materials that can easily adapt to the human body, our devices also accommodate wearable fashion. User can detach themselves from the physical interface and simply wear the adjustable soft actuating component as decorative chokers on their necks. Our evaluation suggests that the low-moduli materials we are using in the actuator can provide sufficient physiological comfort for users even after a long time usage. We also observed how users feel comfortable about wearing the devices while performing other tasks.

---

* mengyuchen@ucsb.edu
† jyan@d2nova.com
‡ yin_yu@ucsb.edu

DESIGN

During the design phase for this research, we identified the following major design requirements: a) accurate and immediate biometric data collection from users, b) on-body pulse simulation and actuation, c) human machine interface with data communication, d) modularity that users can easily detach themselves from the data exchanging network with other users, e) portability that allows a quick setup in a wide variety of social and private space. Given these design constraints, many large-scale technologies and skin unfriendly materials were ruled out. For example, electro-active polymer (EAPs) could not be used because of the potential electric injury on skin that may come from the high-voltage it requires for an effective shape shifting. Large air compressor was also ruled out because extra calibration and safe operation would be required to be handled by a professional. After testing upon human skin sensitivity on different body areas and the air pressure required to actuate simulated pulse behaviors, we settled on a portable air pneumatic system of interconnected detachable components with low-power electronics and cast silicone.

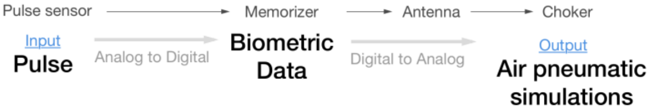

Figure 2 (a) Biometric perception interface system diagram.

SYSTEM

A single set of Biometric Perception Interface consists of three components: Memorizer, Choker, and Antenna. A memorizer, functioning as the central data apparatus and control unit, can have up to two chokers and two antennae connected onto it. Each Antenna links to a choker that is directly worn and attached to a user's neck. Users can choose between Input and Output Mode during their usage of the device.

Input Mode (data record): the antenna senses the pulse rate of the user and send the data to the memorizer. The biometric data is then stored inside the memorizer for future retrieval.

Output Mode (pulse playback): the memorizer retrieves the stored pulse data and converts the data to control the frequency and volume of the airflow that is generated from its integrated air pump and valve system. The air flow is then transmitted via antenna to inflate and deflate the choker to simulate a set of pulse movements that belongs to the previous user who committed a data input.

COMPONENTS

Memorizer – we design memorizer as a central data apparatus together with embedded air pump and valve system. A microcontroller inside connects and controls all the electronic peripherals, which include a 12V DC air pump, two solenoid valves, and a pulse sensor. A memorizer is designed to be a desktop object instead of a wearable component so that two users can share and be linked to it together at the same time.

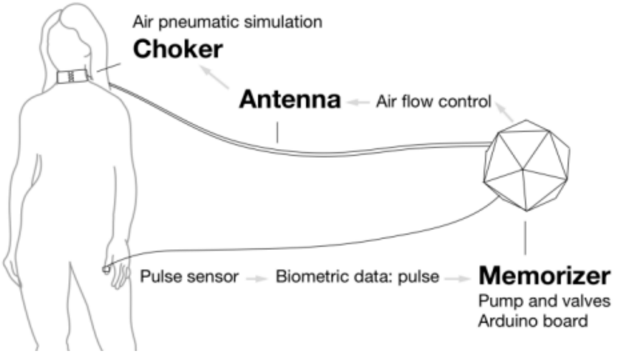

Figure 2 (b) Biometric perception interface installation diagram.

Choker – we use silicon based high performance rubbers Dragon Skin to cast a soft but stretchable skin-safe pneumatic structure of varying degrees of elasticity. Designed to be worn on user's neck as both a haptic actuator and a wearable object of fashion, a choker has eight eyelets with laces at the front that user can adjust its size for a more comfortable wearing. Leathers are used as decorative padding layers for a smooth skin contact and also as functional strain-limiting layers that enhance the pneumatic actuation for either visual or haptic purpose. When actuated by compressed air from the pump inside the memorizer, an array of protruding air bubbles on the choker's surface constantly change their shape and volume back and forth in a state between flat and slight convex, morphologically simulating respiratory motions on user's neck. Connection ports for air tubing and electrical wires are also designed on the back with push-pull connectors for quick disconnection from the whole system.

Antenna – we design antenna as a cable-like two-section connecting agent between memorizer, choker, and user. An antenna provides the necessary air flow transmission and electrical data communication via the air tubings and electrical wires inside and has push-pull connectors on both ends that can easily link other components and the users together. The pulse sensor connected to the Memorizer is extended by antenna to sense another user's heart rate in multi-person mode, or to capture the user's own heart rate in single-person mode.

INTERACTION

Our system is designed with two different operation modes: 1) single-person mode 2) multi-person mode. The difference between the two modes depends on whether the data is recorded and played in real-time or not. In single-user mode, user interacts with a piece of biometric data recording in the past, retrieved from the memorizer's data storage. It allows the user to sense a particular biological body event of someone in history, no matter that one is present or not. The user can also record his or her own biometric data into the memorizer for others to sense in the future. In multi-user mode, two users simply connect to the same memorizer at the same time, and sense each other's pulse in real time without delay. The data is synchronized and exchanged immediately in the memorizer, and both of the users can haptically experience each other's pulse without actual skin-contact.

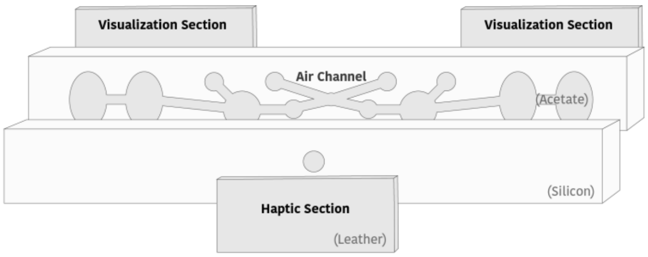

Figure 3 Structural design of choker with air channel

MODEL

Calculation was needed to determine the relationship between the supplied air pressure from the pump and the flow rate into the air cells on the choker. With a knowledge of an estimated range of the flow rate, we use Bernoulli's equation to calculate the maximum volume of the air cells:

$$p + \frac{1}{2}\rho v^2 + \rho g h$$

$$p_1 + \frac{1}{2}\rho {v_1}^2 + \rho g h_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Where v is the flow speed, g is the acceleration due to gravity, h is the hydraulic head, p is the pressure at the chosen point, and ρ is the density of the fluid at all points. Since Bernoulli's equation is applicable to compressible fluids up to approximately $Mach\ 0.3$, we start with an examination on the relationship between the speed of air from the pump and the speed of sound ($Mach\ 0.3$). The rated pump flow rate is 12 - 15 liter per minute (LPM). We calculate the linear velocity of the flow based on the volumetric flow rate we have with the equation,

$$Q = v \cdot A$$

where Q is the flow rate and A is the surface area. So the flow speed with an air tubing of 4mm inner diameter can be estimated at 15.9 m/s ~ 19.8 m/s, which is much less than the speed of sound. In such case, the density of air remains constant and only flow rate increases in Bernoulli's equation. We assume that the elevational change is small enough to be neglected, then, as the density of air does not change, its potential energy per unit volume pgh also remains the same. The equation can be simplified and we get

$$p_1 + \frac{1}{2}\rho v_1^2 = p_1 + \frac{1}{2}\rho v_2^2$$

After testing the maximum pressure that a 12V DC air pump we use can generate, we get the range of source pressure at 101.325 kPa ~ 151.988 kPa, which is 1~1.5 $Atmosphere$. Knowing the value range of pressure energy, fluid density and initial flow speed, we express the target flow speed v_2 as

$$v_2 = \sqrt{\frac{2 \cdot (p_1 - p_2)}{\rho} + v_1^2}$$

and can get an estimated range of v_2 at 15.9 m/s ~ 93.0 m/s. With the same tubing size, the volumetric flow rate is estimated to range at 200 ml/s ~ 1172 ml/s.

The air cells of our design have a total flat area of 50 cm^2, with an expected 2 cm height after inflation. The estimated volume of inflated air chambers in total should be less than 100 ml, given the shape of these chambers is semi-spherically extruded from the surface. Therefore, even if the pump is running at the minimum flow rate at 200 ml/s, our device can still actuate a pulse behavior up to 120 beats per minute (BPM). Certainly, with a higher number of flow rate, a higher BPM can also be achieved.

FABRICATION

CHOKER DESIGN AND FABRICATION

We start with designing the dimension of a choker and it's inner air channel. The total size of the choker is 32 cm (width) x 4 cm (length) x 0.6 cm (height). According to the previous air pneumatic model, we compute the approximate maximum air volume, and specify the total area of air cells. With that in mind, we design a basic unified air bubble structure and test the tactual sensation of the choker on users' neck. We find out that the back of the neck turns out to be more sensitive to haptic sensations, and conversely suppressing the front and side part of the neck would cause discomfort to user such as suffocation. Figure 3 shows an improved version of the air channel pattern and choker layers. The choker is fabricated with two visualization sections on the front and side of the neck with leather layer attached inside facing outward and a haptic section on the back of the neck with leather layer attached outside facing inward. Inside the haptic section, the air cells are made smaller compared to those of the visualization sections, and are located upon the acupuncture points of human neck to increase the comfort level and sensitivity of pressure.

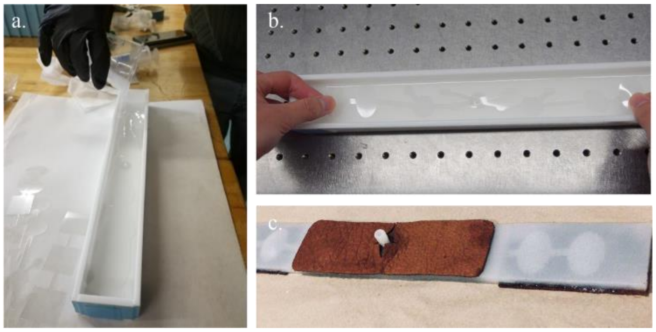

Figure 4 (a) Laser cut an acrylic mold and place first layer of silicone elastomer for actuator casting. (b) Place the acetate sheet after the first layer dry. (c) Attach leather onto the silicone

The air pneumatic choker use silicon as it's main body material. Inside the silicon, a sheet of acetate was placed to create an inner air channel. The overall fabrication of a choker consists of five steps. First, we laser cut acrylic boards and assemble the pieces to build the mold. Then laser cut a sheet of acetate according to the designed inner air channel structure (Fig 4. a). Once the mold and acetate are prepared, we then cast the elastomer. We mix a total of 48 ml of two component elastomer (Smooth-On) in a 1:1 ratio (24 ml each) and pour the mix into the mold as the first layer of the choker. After the elastomer layer was cured, we place the inner channel acetate on the top (Fig 4. b). Then we mix another same portion of elastomer and pour into the mold as the second layer. Once the silicone was cured, we peel it out from the mold and attach a layer of leather onto its outside surface to enhance the inner side inflation and create a wearable aesthetic (Fig 4. c).

MEMORIZER DESIGN AND FABRICATION

As the central data apparatus, a memorizer is able to hold the air pump and valve system, and a microcontroller. The design of the memorizer reflects the idea of neuro-bio-data centralization that it serves as a central connection for user interaction as well as a storage center for the biometric data. A standard icosahedron with 20 equilateral triangular faces with each joint vertex formulating holes where the antenna and data cable can also go through.

The fabrication of the memorizor consists of 5 steps. We first laser cut the equilateral triangular acrylic pieces, each of which has an edge of 20 cm long and has three holes on each side (Fig 5. c). We assembled them together by tying with fishing wire through the holes in this prototype. After assembling, we place the microcontroller, valve, and air pump inside the icosahedron memorizer （Fig 5. a). Before attaching the last piece of the panels, we thread all the cables and tubes through the vertices of the memorizor. The last step is connecting the memorizer and the choker with the antenna.

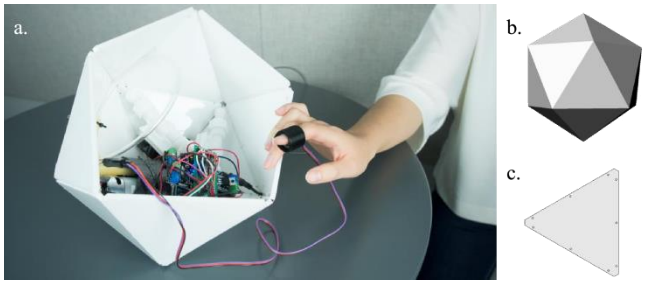

Figure 5 (a) Memorizer physical model (b) memorizer digital model (c) flat view of one panel of the memorizer

RESULTS

Our current system is capable of reading user's pulse and of playing back the data with pneumatic actuation on the neck. Users can wear the choker by attaching the silicon piece around their necks and adjust the size with the front tie, as shown in Figure 6 (b). We also tested that the leather padding at the inside layer is comfortable to let user wear the choker over a long period of time (over 6 hours).

During our experimentation of the system, we found that different areas on the neck have different sensitivity of external pressure. After testing different actuating patterns with different positions and sizes of air cells, we moved most of the air cells to the back side of the neck and decreased the size of air cells to maximize the haptic experience of air inflation. Figure 1 (c) shows the moment when the choker is inflated. Only indicative bubbles inflating outwards are visible at the front, and the actual functional bubbles that give user haptic sense of pulsing are all hidden at the back inner area of choker and are inflating inwards.

Figure 6 (a) shows the connection between a memorizer and a user wearing a choker. The memorizer fully enclose all the electronics including the control and pumping system. The pump inside can provide enough air pressure to actuate the air cells on the choker, and the amount of pressure produced by this soft robotic design can be adjusted by changing the opening time of the exhaust valve to achieve different levels of haptic sensitivity.

CONCLUSION

Our design of a haptic data representation on the neck not only gives the user a sense of touch of the biological state of a person, but also produces a deeper intimate situation of sensing others by touching body parts that are not socially accessible. Previous works were mainly focused on a distant simulation of common social gestures, such as hugging or hand stroking. For example, HaptiHug is a haptic display for communication of hug that simulates real-life interpersonal hug over distance with 3D avatars [9]. Other earlier works such as The Hug and HugMe are also similar that they all aimed at an enhanced distant social interaction that allows people to communicate with emotion and affection via haptic devices [7][8].

Our work continues with these ideas with a more intimate approach and adopts a soft robotic method using soft materials that is highly skin friendly, an effective communication of affect can be achieved. By translating biometric data into haptic stimulation, our device allows users to experience biological events from pulse which is another form of intimate communication. The metaphor here is the stethoscope that is used for auscultation or listening to the internal sounds of human body. This type of communication potentially can go beyond conventional social interaction and can possibly be an effective method of building effective relationships among people.

In the future, we will conduct more user studies such as evaluate the system performance including analyzing the assess of user wearability, collecting the accurate data of pressure levels and the sensitivity of the neck, identifying users' emotional response during the haptic experience.

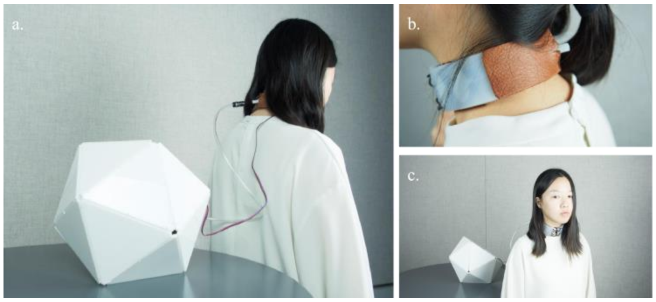

Figure 6 (a) Choker connecting memorizer - back view (b) Choker - side view (c) Choker connecting memorizer - front view

ACKNOWLEDGEMENTS

This work was performed in MAT594 - Soft Robotics, a MAT graduate course at the University of California, Santa Barbara, offered by Prof. Yon Visell. Lab space and equipment provided by the RE Touch Lab, Mechanical Engineering Design Lab, and Innovation Workshop at University of California Santa Barbara and California NanoSystem Institute.

REFERENCES

[1] D. Rus, and M. Tolley. Design, fabrication and control of soft robots. *Nature*, 521(7553), pp.467-475, 2015.

[2] M. Peláez-Nogueras, J. L. Gewirtz, T. Field, M.Cigales, J. Malphurs, S. Clasky, and A. Sanchez. Infants' preference for touch stimulation in face-to-face interactions. *Journal of Applied Developmental Psychology*, 17(2), pp.199-213, 1996.

[3] A. Debrot, D. Schoebi, M. Perrez and A. Horn. Touch as an Interpersonal Emotion Regulation Process in Couples' Daily Lives. *Personality and Social Psychology Bulletin*, 39(10), pp.1373-1385, 2013.

[4] J. Smith and K. MacLean. Communicating emotion through a haptic link: Design space and methodology. *International Journal of Human-Computer Studies*, 65(4), pp.376-387, 2007.

[5] J. Cha, M. Eid, L. Rahal, A. E. Saddik. HugMe: An interpersonal haptic communication system. In *Proceedings of IEEE Int. Workshop Haptic Audio Visual Environ. Games*, pp. 99-102, 2008.

[6] C. DiSalvo, F. Gemperle, J. Forlizzi, E. Montgomery. The hug: An exploration of robotic form for intimate communication. In *Proceedings of ROMAN 12th IEEE Int. Workshop Robot Human Interactive Commun.*, pp.403-408, 2003.

[7] Tsetserukou D. HaptiHug: A Novel Haptic Display for Communication of Hug over a Distance. In *EuroHaptics'10 Proceedings of the 2010 international conference on Haptics: generating and perceiving tangible sensations, Part I, pp.*340-347, 2010.

[8] T. McDaniel, S. Krishna, V. Balasubramanian, D. Colbry, and S. Panchanathan. Using a haptic belt to convey non-verbal communication cues during social interactions to individuals who are blind. In *proceedings of IEEE International Workshop on Haptic Audio visual Environments and Games,* pp.13-18, 2008.

[9] S. Ertan, C. Lee, A. Willets, H. Tan, A. Pentland. A wearable haptic navigation guidance system. In *Second International Symposium on Wearable Computers, pp.164-165,* 1998

[10] F. Gemperle, N. Ota, D. Siewiorek,. Design of a wearable tactile display. In *Proc. 5th Int. Symp. Wearable Comput.*, pp.5-12, 2001.