Soft Social Haptics: Recreating Human Touch Sensations using Soft Materials and Pneumatics

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Abstract— *Social interaction over long distances is primarily dictated using visual and audio devices. However, touch is an essential method for communicating emotions between individuals. We present a device that can replicate common human touch sensations (i.e. patting, stroking, and poking) using soft materials and pneumatics. Our haptic device contains multiple silicone-based chambers capable of deforming based on the air pressure applied. A user study was conducted to determine the continuity and pleasantness of our device. It was concluded that the pneumatic actuators should be controlled using a combination long durations of air pressure as well as short delays in between air chambers.*

Keywords—*social haptics, human sensations, soft materials, pneumatics*

Introduction

Social interaction over long distances is primarily dictated using visual and audio devices. However, the most powerful non-verbal communication is through human social touch. The psychological and neurological effects of social touch have been heavily researched upon. Social touch affects areas including physical and emotional well-being, attachment and bonding, behavior change, and communication of affect [1]. Therefore, we want to replicate common human touch sensations (i.e. patting, stroking) using haptic technology to induce feelings and reconnect separated individuals.

Social haptic device has been done by many researchers before. One example was a group from Stanford that focused on using motor actuators to recreate the human stroking sensation on the skin [2]. They designed an array of linear coil motors to present sequential indentation to perform lateral motion. However, one potential drawback is that the users of the experiment might have felt a stiffer and more vibratory sensations while the skin was in contact with the actuators. The human finger is usually softer and more deformable when in contact with solid objects.

There has been a recent surge in the interest of soft robotics, due to its properties of safer human interactions, adaptability to new task settings, and resilience to instable systems [3]. Soft pneumatics actuators take advantage of a sealed chamber and air pressure to produce inflation and deflation. They also provide normal indentation forces that actuate and deform the skin at different time points. Therefore, we present a novel soft haptic device to simulate the human touch sensation by using the soft materials and pneumatic actuators.

Design

<u>Materials</u>

To mimic the skin of the human finger, we chose silicone polymer as our primary actuator material. Silicone polymer is widely used in robotics and the medical industry due to its physical properties and flexibility. Additionally, these materials have been chosen by previous studies for the application for soft robotics [4], [5]. We chose three types of silicone from Smooth On Inc., including Dragon Skin-10, Dragon-Skin 20, and Ecoflex-30, for prototyping and testing.

Our first iteration of prototypes aimed to decide the optimal sizes of the soft actuators and the type of material which best fit our application. To mold our prototypes, we first molded a bottom layer. Next, we put a stencil on the bottom layer and used a mold release spray to spray a thin layer on it. Mold release spray was used to produce an air chamber between the bottom layer and the top layer. The last step was to simply fill in the top layer. As a result, air can be pumped between these two layers and inflate the soft actuators to perform single indentation.

After our first few prototypes, we discovered that Dragon Skin 10 was the optimal material. It had enough flexibility to be inflated while being stiff enough to maintain its shape. To make the user feel a realistic stroking sensation, we needed to minimize the size of the chamber and the distance between adjacent actuators. We discovered that individual actuators produced a less continuous stroking feeling. As a result, we decided to use one long, continuous actuator with four separate chambers that are 20mm x 20mm in area.

Hardware

Our hardware system is based on a fluid control board. Our board consists of one Arduino Mega board, four control valves, and one air pump with a maximum air pressure of 30 psi. As a result, we were able control a maximum of four individual chambers at the same time.

There are three actuation parameters that can be controlled. These include the pulse width of each actuator, the time of delay between each actuator, and the pressure of the air. Pulse width modulation (PWM) signals can be utilized to modify the amount of air pressure applied to each actuator, but we found that they caused significant vibration and would affect the overall sensation. Therefore, we decided to use digital input and output to control the air pressure (e.g. 1 representing 30 psi while 0 representing 0 psi).

Some additional considerations of our haptic design were how we mounted it. We used Ecoflex 10 for our mount designs to strap around the arm since it was flexible and able to compensate for the different sizes of arms. Furthermore, since we wanted to maintain a uniform distance between the contact surface of the device and the user's arm, we attached a rigid spine directly on top of the device.

User Study

The purpose of our user study aims was to find the best combination of actuation parameters and determine whether Dragon Skin 10 silicone based actuators can replicate human touch sensations. A total of five individuals participated in our study.

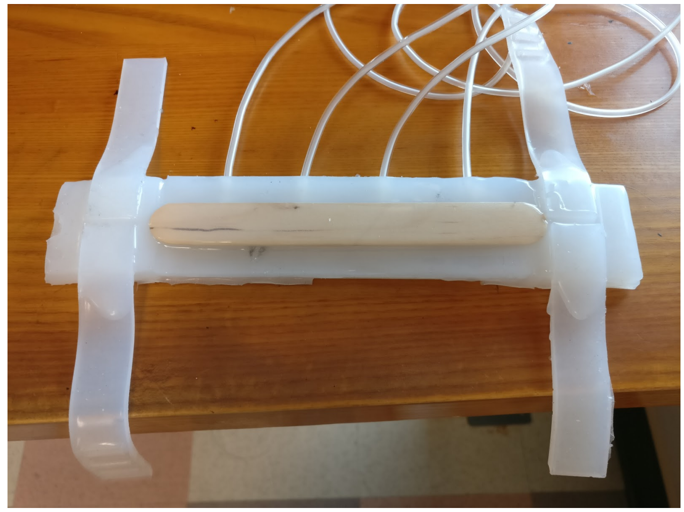

Fig. 1. Our haptic device consisting of two elastic straps, one single actuator with four independent air chambers connected to the control board, and a spine.

To conduct our user study, we first defined three different pulse widths (50 ms, 175 ms, and 300 ms) and three different delays (25%, 50%, and 75%). As a result, we came up with nine unique combinations of pulse width and delay. Each participant was tested for all nine cases and each case lasted fifteen seconds long.

The participants were then asked to rate the continuity and pleasantness after each case. Individuals rated the continuity based on a 1 to 7 scale, where 1 represents very discrete and 7 represents very continuous. Similarly, they were asked to rate the pleasantness on a 1 to 7 scale, where 1 represents very unpleasant while 7 represents very pleasant. In our study, continuity refers to whether individual actuation points can be distinguished, while pleasantness refers to the "real-ness" of the sensation and how comfortable the user feels.

Results

Table 1: Average Pleasantness Rating

Delay	*50 ms*	*175 ms*	*300 ms*
25%	3.33	4.11	4.78
50%	3.89	3.78	4.44
75%	3.78	4.44	4.22

Table 2: Average Continuity Rating

Delay	*50 ms*	*175 ms*	*300 ms*
25%	3.22	4.33	4.56
50%	4.22	4.22	4.89
75%	4.33	4.56	4.56

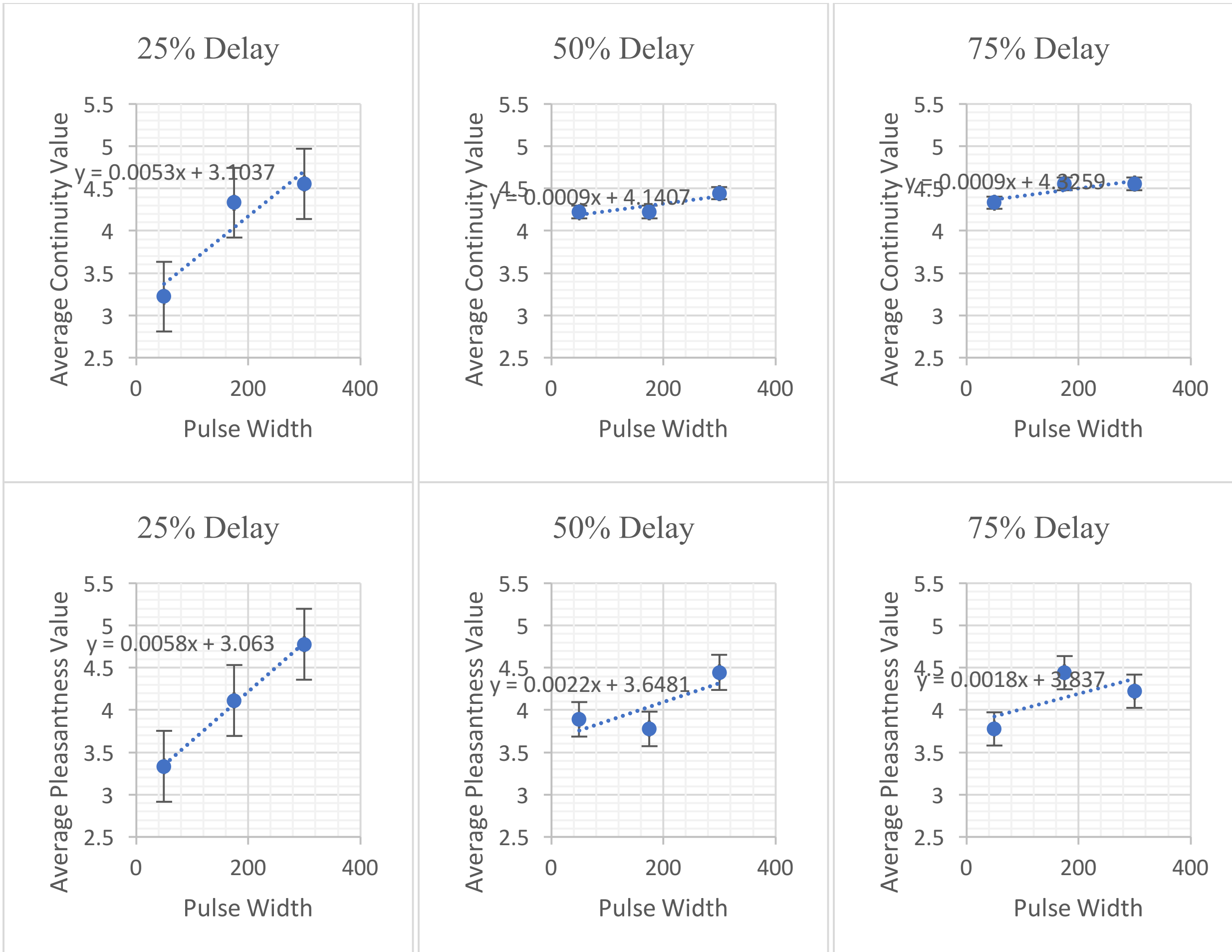

Fig. 2. Plots of the average continuity and pleasantness values for all participants with standard error bars and linear regression lines.

Through the linear trend-lines, we can observe a positive regression between the pulse width and the average continuity value across all three delay values. We can also observe a positive regression between the pulse width and the average pleasantness value across all three delay values. The magnitude of the slope of both curves decreases as the delay is increased.

We ran a single factor ANOVA analysis to determine the effects of different delay percentages and different pulse width values on continuity. Average continuity was significantly different for the different delay percentages (F(2) = 4.004, p = .0221), but was not significantly different for the different pulse width values (F(2) = .1688, p = .8449). Additionally, we ran another single factor ANOVA analysis to determine the effects of different delay percentages and different pulse width values on pleasantness. Average pleasantness was not significantly different for both the different delay percentages (F(2) = .034, p = .9665) and for the different pulse width values (F(2) =1.471 , p = .2361)

We proceed to run a one-tailed t-test to determine if the average continuity values for different pulse widths were significantly different from the neutral response (Continuity = 4). Of the three pulse width values, only the 300 ms was significantly above the neutral response, meaning on average 300 ms was rated continuous (tstat = 1.763, p = .0448). We then ran a second one-tailed t-test to determine if the average continuity values for different delays were significant different from the neutral response. Of the three delays, the 50% delay was significantly above than the neutral response, meaning on average 50% delay was rated continuous (tstat = 1.87, p = .041). 25% delay was also close to being significantly above the neutral response (tstat = 1.21, p = .123), but consisted of high variability.

We ran a one-tailed t-test to determine if the average pleasantness values for different delays were significantly different from the neutral response (Pleasantness = 4). Of the three pulse width values, none of them were significantly above or below the neutral response. The closest to being significant was pulse width of 175 ms (tstat =1.202, p = .1201). We then ran a second one-tailed t-test to determine if the average pleasantness values for different pulse widths were significantly different from the neutral response. Of the delays, none of them were significantly above or below the neutral response.

Discussion

From our graphs, we can see that increasing pulse width increases the average continuity and pleasantness due to the positive correlation. However, it is interesting that the magnitude of that correlation decreases as we increase the delay percentage. One possibility of this effect is that increasing delay can induces an overall slower response, since the timing of actuation between the pneumatic chambers is slower and less realistic as compared to a normal human stroke.

From our table of values, we can also conclude that the optimal pneumatic actuation parameters to achieve the best continuity and best pleasantness was a 300 ms pulse width and 25% delay. What is interesting is that the velocity of this speed is approximately 19 cm/s, which is much larger than the velocity at which mechanoreceptors in the lower arm respond to [6]. One possibility of this outcome is that people preferred a faster and quick stroking sensation compared to a slower stroke, which reinforces the fact that timing between actuation chambers should be short.

One conclusion we could make was that at least 50% delay was significantly above the neutral response, meaning it was continuous. In the future, we plan on proceeding with a delay range to 25% to 50% and narrow our range of pulse width values to be closer to 300 ms. Otherwise, we could not reach a conclusion whether certain actuation parameters yielded an average response of our device being pleasant. However, that also means that none of the parameters yielded unpleasant responses. We believe the main reason behind this is the fact that only nine individuals participated in our experiment, each with a unique perspective on what a pleasant stroking feeling was and thus an increased variability in our data. Future works should include a larger population size to produce a more robust study and conclusive results from data analysis.

Conclusion

In this paper, we presented a device that utilized soft materials and pneumatic actuators to mimic human touch sensations. The device consisted of one single actuator with four different air chambers, capable if inflating and deflating for different durations and at different timestamps. Using a user study, we concluded that 300 ms pulse width and 25% delay yielded the best continuity and best pleasantness. However, we could not provide enough statistical evidence to prove the significance and relationship between these parameters. We believe our work can be used in the future to induce stroking sensations using normal indentation. In the future, we plan to increase the robustness and consistency of our haptic device as well as increase our user study population.

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