Adding a Sense of Touch to Online Shopping: Does it Really Help?

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ABSTRACT

Haptic feedback has always been a missing link in online shopping. In this project, we study whether a commonly-used haptic device with only one Haptic Interface Point (HIP) can be used in online shopping for compensating lack of physical touch. A user study was conducted in which data-driven haptic weight, shape and texture information was simulated and provided to the users. Despite the limitations of the device, the results have shown positive effects of providing haptic feedback in enhancing users' understanding of physical properties of a product.[1]

CCS CONCEPTS

• Human-centered computing~User studies • Human-centered computing~Pointing

KEYWORDS

Haptic responses, physical properties, online shopping

1 INTRODUCTION

With the increasing popularity of online shopping in the last decade, there has been a trend towards creating a more immersive life-like shopping environment for online shoppers. Currently, most of the cutting-edge interactive technologies are focused on visual enhancing of online shopping experience, such as enabling 3D virtual dressing [1-2] and establishing immersive virtual shops [13]. However, touching a product also plays an important role in the evaluation of products [3] and lack of touch has always been an issue in online shopping. For example, many people would still go to a real Apple Store before buying a phone or phone case online. Instead of seeing the texts, images or videos of the products in online shops, the shoppers prefer feeling the weight, texture, etc., of a product with their hands.

Haptic technologies have provided possibility of building a tangible link between online shops and the shoppers, yet most of the cost-effective haptic devices so far are desktop devices with only one HIP (e.g., Geomagic® Touch, Force Dimension® Omega.6, as well as recently available Geomagic® Touch 3D stylus and Novint® Falcon). Such devices can only simulate a feeling of touching with a pen, rather than touching with the whole hand. Therefore, the question is, "Can such haptic devices, if they were commonly available in every household, be used in online shopping for compensating lack of physical touch?"

In this paper, we used a medium-priced desktop haptic device, Geomagic® Touch, and a more affordable but discontinued haptic device, Novint® Falcon, as examples to study whether the haptic devices with one HIP can help to enhance the shoppers' understanding on the physical properties of a product. We chose these two devices because Geomagic® Touch can be found in many research labs while Novint® Falcon was designed to be a commonly-used game controller. Both of them can provide stable force feedback which is delivered through a handle. To investigate the possibility of using them in online shopping, we built a mock-up e-shop with tangible browsing interface where invisible haptic models are aligned with the product images to provide physical information of the given products — weight, shape and texture. The new iPhones and their cases were presented there with the corresponding haptic information so that the users could perform a real try-on and weighing, like in a real Apple Store.

2 RELATED WORKS

In real life, the feedback that one gets from exploring an object is basically a combination of tactile and kinesthetic information. Due to different generation principles of these two types of feedback, many haptic interfaces provide only either tactile feedback (e.g., vibration and texture perception) or kinesthetic feedback (e.g., sensations which reflects weight and inertia of an object). Thus the choice of devices imposes constraints on the roles of haptics in online shopping applications.

Research involving commercial desktop haptic devices generally aims at providing kinesthetic feeling of touching or operating an object, though some desktop devices can also generate vibrations. For example in [4], Novint® Falcon was used to simulate test-driving where the customers could feel the road condition and the virtual objects in the driving environment. The results of the experiment indicated positive impact of the simulated test-driving on the product evaluation

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for the customers with high *instrumental Need for Touch.* A more comprehensive study about the effect of providing haptic weight and friction to online shoppers using Sensable® Phantom Omni (currently Geomagic® Touch) was done in [5]. This paper emphasized on comparing users behavior and decision in textual-based and haptic-based shopping environment and concluded that the presence of haptic feedback increases confidence in the online shopping decision. However, despite the positive results presented in these papers, they failed to provide tactile feedback to the shoppers, and the kinesthetic feedback provided was not meaningful enough to represent the real physical properties of the products.

As for the simulation of tactile feedback, two types of haptic interfaces are commonly used: touchscreen devices and wearable haptic devices. Most works on simulation of tactile feedback on touchscreen devices utilize extrinsic actuators to create screen/tool motion or vibration. In contrast, TeslaTouch proposed by Bau et al. [6] presents an actuator-free approach for producing tactile feedback based on electrovibration principle. This approach is enhanced by Tanvas [7] for creating commercially-ready tablets, which allow the users to feel dynamic textures by scrolling the finger on the screen. These touchscreen-based techniques could serve as a promising way for generating meaningful vibration and haptic texture for online shopping, however, such physical properties as weight and stiffness would still be missing in the interaction.

To better simulate interaction with hands, some researchers experiment with wearable haptic devices capable of providing both types of haptic feedback at the same time, but this kind of device is normally heavy and big because of its actuators, even if it is designed just for one finger [8]. The emerging techniques, which use air pressure to generate forces [9, 10], may create new opportunities for wearable devices. Although not matured yet, the existing prototype already shows great potential.

Other than wearable devices, the release of Penn Haptic Texture Toolkit (HaTT) [11] provides an alternative solution by transforming texture force into a kinesthetic force, which can be directly rendered by Geomagic® Touch. Haptic texture and friction model of the real objects is pre-recorded and then applied to the users based on the current normal force and speed. Since this toolkit enables us to deliver data-driven tactile feedback with Geomagic® Touch, what remains to be solved is how to create meaningful kinesthetic feedback which can resemble the feeling of touching and weighing in real life.

The goal of our project is to simulate a reference feeling similar to touching and weighing the products in real life as well as to investigate whether these feedback enhances the shoppers' understanding of physical properties of products. The real characteristics of the products are referred when generating haptic weight, geometry and texture information. In this way, the online shoppers are able to collect meaningful information from both kinesthetic and tactile feedback.

3 METHODS USED IN THE STUDY

Here we describe how to simulate force feedback of weighing an object with Geomagic® Touch as well as to obtain perception of feeling its shape and texture.

3.1 Weight Simulation

When using desktop haptic devices, it is assumed that the force output is equal to the force sent to the device. Based on this assumption, the haptic weight feedback can be calculated as:

$$F_w = mg \tag{1}$$

where m is the mass and g is the local gravitational acceleration. Most haptic devices with one HIP, such as Geomagic® Touch, are built as linkage-based structures similar to robotic arms. The users feel the force feedback by holding the device handle attached to the mechanical linkage. If such devices are used for delivering weight information to the users, the linear relationship described in Eq. (1) cannot be used to define the haptic weight model considering the effect of the linkage and the weight of the handle. Then, the question is whether there is a correlation function describing the relationship between the haptic weight output and the mass input for any given haptic device.

To answer this question, we measured the weight generated by Geomagic® Touch and Novint® Falcon using a kitchen digital scale (5kg Max/1g Resolution). The force output was set according to Eq. (1), and the device handle was weighed to show the actual mass that the device delivered. For each measurement, the handle was placed on the scale after it was returned back to zero to avoid the influence of the previous measurements. After a few trials, it was found out that the position of the scale and the placement of the handle largely affect the measurement results for both devices, but nevertheless, if the positions of the scale and the handle were kept still during the measurements, the results of Geomagic® Touch showed a certain regularity with the input mass while Novint® Falcon failed to do it. This observation suggests a possibility to use Geomagic® Touch to approximate haptic weight feedback.

Figure 1: Scale position and handle placement setup during the measurement.

To validate it, we measured and recorded the weight of the handle for different inputs with the scale placed right in front of Geomagic® Touch. During the measurement, the handle tip was always pointing to the inkwell of the device – its docking socket (Fig. 1). The measurement results (i.e. the handle's measured mass) were closest to the input masses in this setting.

The input mass ranged from 0g to 300g with an increment in 20g. The weight of the handle was measured five times with each input, of which the average was used as the final result. To minimize the influence of the placement and the previous measurements, we lifted the handle up until the scale went back to zero and put it carefully back at the same place every time.

The raw mass/measurement data points are plotted and connected as the red curve in Fig. 2. We can see that it shows a nearly linear relationship between the input masses and the raw measurement results, although the raw measurement results and the expected mass output do not overlap. If the input mass is x, the red curve of the raw measurement result can be approximately fitted by a linear function $f(x) = kx + b$. To adjust $f(x)$ so that it approaches the expected output, which is $f'(x) = x$, the input mass x should be set to $(cx + d)$, where $c = 1/k$ and $d = -b/k$.

After obtaining the adjustment parameters c and d, the same measurement was carried out again, where we replaced x with $(cx + d)$. As shown in Fig. 2, the difference between the expected output and the measurement results is largely decreased after the adjustment. It is under the 10 percent Just Noticeable Difference (JND) threshold [7] at most times except the case where the mass is within the range of 0g to 20g and 40g to 80g. We have also found out that the difference can be further reduced if the adjustment is applied one more time. Here we should note that the graphical interface has an influence on the haptic device output. Therefore, if the interface has been changed, new measurements would be required.

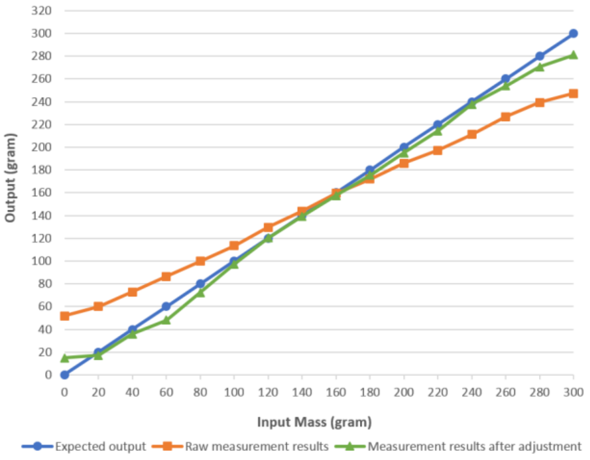

Figure 2: Line charts of expected output, raw measurements and measurements after adjustment.

3.2 Feeling the Shape Haptically

In many online shopping applications, shape information of a product is mostly presented in the form of images. In this project, to make images tangible, we augment them with invisible haptic models. These models, defined as FRep solid geometric shapes [12] using functions $f(x, y, z) \geq 0$, are aligned with the respective parts of the image to provide haptic shape information of the product (Fig. 3). When touching the image, the underlying haptic model is rendered as a feedback force $\overrightarrow{\boldsymbol{F_n}}$, which is oriented perpendicular to the model surface. Adding a tangential friction force $\vec{\boldsymbol{f}}$ will add more realistic perception of the shape.

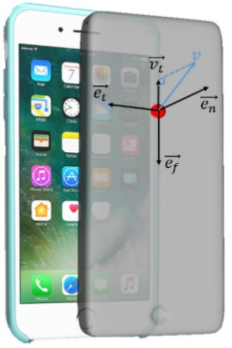

Figure 3: Directions of normal force, texture force and friction force.

3.3 Feeling the Texture

The release of HaTT [11] has made it possible to use an impedance-type haptic interface, such as Geomagic® Touch, to render data-driven texture force. With the pre-built measurement-based texture models provided by HaTT, we are able to synthesize texture vibrations in real time and transform these vibrations into a texture force that can be rendered by Geomagic® Touch. Therefore, if the texture of a surface has its model in HaTT, the texture force resulting from sliding the handle tip on this surface can be represented as $\overrightarrow{\boldsymbol{F_t}} = (ma)\overrightarrow{\boldsymbol{e_t}}$, where m is the mass of the Geomagic® Touch handle and the user's hand, which is approximated at 50 gram in our project, and a is the acceleration value obtained from the texture model based on the current normal force and tangential speed. As to the direction vector of texture force $\overrightarrow{\boldsymbol{e_t}}$, it is chosen perpendicular to both the normal force direction vector $\overrightarrow{\boldsymbol{e_n}}$ and the friction force direction vector $\overrightarrow{\boldsymbol{e_f}}$ (Fig. 3). Note that all the direction vectors here are unit vectors.

For each texture, HaTT also provides corresponding measurement-based friction coefficient along with the texture model. The friction force is simulated using Coulomb friction model: $\vec{\boldsymbol{f}} = -(\mu N)\overrightarrow{\boldsymbol{v_t}}$, where μ denotes the friction coefficient, N denotes the magnitude of the normal force and $\overrightarrow{\boldsymbol{v_t}}$ denotes the direction vector of velocity in the tangential direction.

Both texture and friction forces contribute to the haptic material information of the product. In this project, we chose texture and friction models from HaTT based on the material type of the products. When the haptic cursor is in contact with the product surface, the force delivered to the user is the sum of normal force, texture force and friction force: $\vec{\boldsymbol{F}} = \overrightarrow{\boldsymbol{F_n}} + \overrightarrow{\boldsymbol{F_t}} + \vec{\boldsymbol{f}}$.

4 USER STUDY

4.1 Hypothesis

Peck and Childers [3] classify sensory information extracted from touching the products as: /1/ instrumental information obtained from the physical properties of the products and /2/ hedonic response related to the immediate sensation (i.e. without being processed by the brain) aroused by touching. A person's hedonic response for touching is a subjective element which is difficult to control. It can be influenced by many personal factors such as *Need for Touch*. Excluding the effect of hedonic response, the introduction of data-driven haptic feedback into online shopping is likely to present the shoppers more meaningful information about the physical properties of the products, compared to traditional online shopping environment. In this project, three types of haptic information—weight, shape and texture—are simulated, which leads to the following hypotheses:

> **H1:** The simulation of haptic weight feedback enhances online shopper's understanding of the weight information of the product.
> **H2:** The simulation of haptic geometric property enhances online shopper's understanding of the shape information of the product.
> **H3:** The simulation of haptic texture properties enhances online shopper's understanding of the texture information of the product.
> **H4:** Haptic feedback improves online shopper's satisfaction on the product browsing experience.

4.2 User Interface Design

To prove the above hypotheses, two mock-up e-shops with two graphical user interfaces—a traditional mouse-based interface and a haptic interface—were made to simulate online shopping product browsing context. Specifically, we chose the recent iPhones and iPhone cases as our target products. In both interfaces, weight, geometry and texture information of a phone with and without a case is provided as a reference to the user:

> **Mouse-based Interface:** Product information is given in the forms of texts and images. Mouse is used for navigation.
> **Haptic Interface:** Product information is given in the forms of texts, images and haptic responses. Geomagic® Touch is used for navigation, touching and weighing.

Both interfaces have two tabs, one for shape and texture information and the other one for weight information. Despite the difference in interaction tool, the two interfaces have similar layout and operational procedures except for the extra instructions and operations added for haptic interface users. These extra operations include feeling the shape and texture of the products with haptic cursor and weighing the products by holding the handle of Geomagic® Touch. The position of haptic cursor (displayed as a red ball in Fig. 4) corresponds to the handle tip position. Under the shape & texture tab, by moving the handle, the users can slide the haptic cursor by the product surface to feel its shape and texture. The illustrative video embedded into the interface, prompts the users how to use Geomagic® Touch properly. To minimize the influence of the interface, we deliberately simplified the design of the mock-up e-shop, limiting the provided information to the three types of information mentioned above only. More details about the interfaces can be found in the video at https://youtu.be/OJTd51WYsa4.

In the user study, the participants were randomly assigned to either mouse-based interface group (i.e. control group) or haptic interface group (i.e. experimental group) with no knowledge of existence of the other group. Both groups were asked to browse through the given interface to collect shape, weight and texture information of phone cases and answer the same questionnaire afterwards. In this way, we ensured the independence of two sample groups.

4.3 Experiment Environment Setup

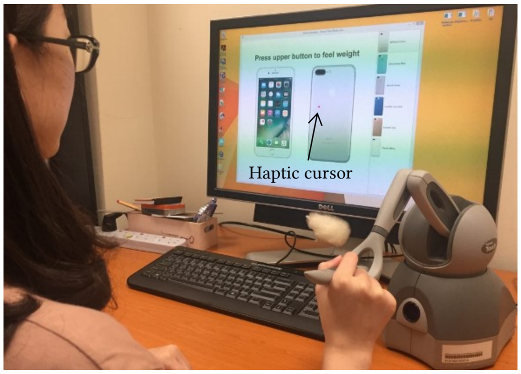

Figure 4: Environment setup for the experimental group.

The user study was conducted on a computer with 8-core CPU working at 2.60GHz. For the experimental group, Geomagic® Touch was placed to the side of the participant's dominant hand. The distance between the device and the edge of desk was adjusted on a case-by-case basis so that the participants can rest their forearm on the desk while operating the device. For the control group, a mouse was used instead and placed at the same convenient position. All the participants were also instructed to adjust the chair to a comfortable position and height. The environment setup for the experimental group is shown in Fig. 4.

4.4 Experiment Design

The user study took 10 to 20 minutes for each participant and consisted of five steps:

1. Random assignment of the participant to the control/ experimental group.
2. Demonstration of how to use mouse/Geomagic® Touch with an example and introduction of the functionalities of the mouse-based/haptic interface.
3. User testing, where the participants were asked to browse the given interface freely to collect product information after they confirmed their familiarity with the use of the given device.
4. Filling in the questionnaire.
5. Collection of oral feedback.

Based on the proposed hypothesis, a questionnaire was designed in terms of weight, shape and texture information and overall satisfaction as in Table 1. To keep the independence for the two sample groups and to make the questionnaire universal, the users were asked to compare their browsing experience with the common real-life in-store shopping. Here, it was assumed that we can obtain the most information about a product in a physical shop. Therefore, for the first three questions, 7 means that the user can get as much product information through this interface as in a physical shop. Based on this, ratings 1 to 6 indicate the amount of information obtained from the interface compared to from a physical shop.

Table 1: Questionnaire for both two groups. All the questions are rated on a scale of 1 to 7 based on a comparison with in-store shopping experience.

Question	Factor
Compared to in-store shopping, my understanding of the weight information of the given products through this interface can be rated as: (1 – very poorly; 7 – as good as in-store shopping).	Weight information
Compared to in-store shopping, my understanding of the shape information of the given products through this interface can be rated as: (1 – very poorly; 7 – as good as in-store shopping).	Shape information
Compared to in-store shopping, my understanding of the texture of the given products through this interface can be rated as: (1 – very poorly; 7 – as good as in-store shopping).	texture information
Compared to in-store shopping, I find this browsing experience satisfying: (1 – totally disagree; 7 – totally agree)	Satisfaction

4.5 Results

Thirty-three users participated in this experiment, with sixteen of them in the control group and the other seventeen in the experimental group. The unpaired *one-tail Student's t-test* was utilized to compare the statistical difference between the average ratings of two sample groups for each question. It was one-tail because H1-H4 are all one-tailed hypotheses which will be accepted only when the rating of experimental group (i.e. haptic interface group) is significantly higher than that of the control group (i.e. mouse-based interface group). The results of the questionnaire is listed below.

Table 2: Average ratings of the two groups for the questionnaire and the t-test results.

	Weight	Geometry	Texture	Overall
Haptics	5.235	5.647	4.176	5.412
Mouse	4.000	4.750	3.938	4.000
t-value	2.376	1.753	0.459	3.563
p-value	0.012	0.045	0.325	0.001
Significance (p<0.05)	Significant	Significant	Insignificant	Significant
Effect Size (Cohen's d)	0.823 (Large)	0.608 (Medium)	N/A	1.235 (Very Large)

As to the ratings for weight, geometry and overall satisfaction, the *p*-values obtained by t-test indicate that the rating differences were significant at $\boldsymbol{p < 0.05}$. Thus we could accept hypotheses H1, H2, H4. In addition, Cohen's d was calculated to measure the effect size of the average rating difference for significant results. As to the texture information, although the result was not statistically significant at $\boldsymbol{p < 0.05}$, the average rating of the experimental group is still higher than that of the control group.

4.6 Evaluation and Discussion

4.6.1 Weight. Eight out of sixteen participants from the control group explicitly complained that they could not understand the weight difference based on mere textual description and that they wanted to weigh the products with their hands. As to the participants from the experimental group, they generally commented that the haptic feedback provided them with a better understanding of the weight information as a complement to numerical figures, while at the same time the following problems about the haptic weight simulation were reported.

- Fidelity: Seven out of seventeen participants from the experimental group doubted the fidelity of the haptic weight simulation. Three of them pointed out that the weight difference between the phone cases is too subtle too perceive. An explanation to this could be that the weight difference is below Haptic Just Noticeable Difference. For example, the weight difference between a plastic cover and a leather cover is only 3 gram. The other four participants felt that the simulated weight was heavier than the real weight. Although the haptic weight information used in the experiments was extracted from the real data of a product, the perception of weight could be influenced by many factors, such as the way of holding the handle and the handle's position.
- Unnatural gesture for feeling the weight: Four participants from the experimental group commented that the gesture for feeling the weight was unnatural. One of them tossed the handle into the air repeatedly to feel the weight, like how he does it in real life, but the feedback he obtained was not as he expected. The other three suggested to replace the pen-shaped handle of the haptic device with an object of which the shape resembles that of the real product so that the holding gesture would be more natural.

4.6.2 Shape. Most participants from the control group rated this question higher than neutral (4.0) because the shape of the given product (i.e. phone case) was familiar to them. Four of them wrote that front and back images were enough for simple geometry like that of the phone cases while for products with more complex geometry it would be better to have additional information such as 3D model or pictures taken from different angles. As to the experimental group, most of the positive feedback was related to the fact that the haptic interface enabled them to touch the parts of the product that could not be seen in the images. Other feedback from the experimental group was listed below.

- Functionality: An interesting finding was that some of the participants from the experimental group expected the buttons on the products to be functional. They clicked on the buttons in the image using the haptic cursor and got disappointed because they were not functional. This phenomenon implies that introduction of haptic feedback into online shopping could make the image of products more lifelike.
- Visual effect: Three participants from the experimental group found that the size of the product image was different from that of a real product while none of the participants in the control group mentioned about it. One explanation could be that with the haptic feedback the shoppers are more prone to expect seeing product images which matches the real size of the products. Besides, there were also participants from the experimental group suggesting to display 3D visual models of the products.

4.6.3 Texture. Statistically, the ratings of the control group for the texture question has the largest standard deviation among all the questions. For the participants in this group, those who thought that they could imagine the texture from the image rated this question higher than neutral (4.0) while those who complained about lack of touch gave very low scores. In contrast, the ratings of the experimental group were much less diversified, although many participants expressed concerns about the authenticity of the haptic texture feedback.

- Fidelity: Comments on haptic texture feedback were very subjective. For example, five participants commented that they were not able to feel the difference between some of the textures while other four participants reported that they were able to feel the difference but they could not tell what the texture was solely through touching with a pen tip. In terms of the roughness aspect, most of the users from the experimental group gave a positive feedback, however, four participants reported that the texture felt machine-generated.

4.6.4 Discussion. When we compared the behavior of the participants in both groups, it was found that adding a sense of touch made the products more real to them. The participants in the experimental group expected more realism in the shopping experience, such as that the size of the product image should match that of the real product and that the product image provides the same functionality as the real product. These were never requested in the control group.

The introduction of haptic weight feedback was also welcomed by the participants based on the statistical results of the user study. However, we must admit that given the available haptic technologies and their cost to the end-users, it appears to be unlikely to build a reliable, user-friendly and affordable haptic interface for online shopping in the near future. Besides, weighing and touching with a stylus is not a natural gesture for the users, while there are no affordable haptic devices of which the design is based on human ergonomics. Although the haptic texture provided in the user study was data-driven, the participants were not accustomed to touch with a stylus, which caused doubts about the fidelity of the feedback.

Based on the results of the user study, we conclude that the users expect and enjoy touching the product, despite the limitations of the device. They also value an ability to weigh the products physically. Although we proved that tangible images can help the users to gain a better understanding on the physical properties of the products, we cannot really expect that such device with only one HIP will be used in every household in the next few years, even if it is hypothetically distributed for free. A more user-friendly interface and convincing force feedback is expected and required.

5 CONCLUSIONS

We have presented an approach to simulate data-driven haptic weight, shape and texture information. To prove the feasibility and meaningfulness of incorporating haptic feedback into online shopping, a user study was conducted where the results of using two online shopping interfaces—a traditional mouse-based and a haptic interfaces—were compared and evaluated. The results have shown that the users expected to touch the products despite the limitations of the haptic device and that tangible images can serve as a promising way to add a new modality into online shopping. Nevertheless, given the undeveloped haptic technology, there is still a long way to go to have a user-friendly and reliable tangible interface for online shopping.

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