Evaluating a Haptic Modelling System with Industrial Designers

Bahar Sener, Paul Wormald, Ian Campbell
Loughborough University, Department of Design and Technology
Leicestershire LE11 3TU, United Kingdom
{B.Sener | P.W.Wormald | I.R.Campbell@lboro.ac.uk}

Abstract

Haptics research has become a significant issue in industrial design recently by offering a revolutionary approach for combining physical and digital modelling. Despite the progress made in the past two decades, haptic devices have not yet become commonplace in industrial design. SensAble's FreeForm haptic modelling system, combined with the PHANToM device, is the first CAID tool which lets designers sculpt and form virtual clay and foam using similar tools and techniques that are employed in the physical world. This paper reports the design and modelling experiment using the FreeForm system which aimed at examining a potential strengths and weaknesses of the system according to industrial designers, and exploring the level of usability that the haptic system would provide in 3D form-giving. The results show that the concept is very promising, especially for the early stages of design. However, the system has some drawbacks at the moment. In order to be able to use the system at the later stages of design, it is important to identify how industrial designers work, and what tools and techniques they commonly use in 3D form-giving.
s

Keywords: FreeForm, haptic modelling, computer-aided industrial design, industrial design

1. Introduction

Haptics research has become a significant issue in industrial design recently by offering a revolutionary approach for combining physical and digital modelling. In industrial design, there are broad areas of potential research into this technology, using different kinds of haptic devices in different applications, from a simple painting application to a more complex application like three-dimensional (3D) computer-aided design (CAD) modelling for virtual prototyping [1]. Until recently, none of the computer-aided industrial design (CAID) tools available have allowed industrial designers to physically get in touch with the design while working on a computer. However, research, with input from both academic and commercial groups, is continuing to provide industrial designers with computer-aided 3D-form generation tools combining the interaction techniques being used in physical 3D modelling. Although the progress has been made in the past two decades, haptic devices have not yet become commonplace in industrial design. Given the continued rapid development of 3D modelling and visualisation with computers, the challenges for the future are likely to be the integration of haptic devices in industrial design [2].

This paper reports a design and modelling experiment with the FreeForm system. This experiment is embedded in a larger research project which investigates modelling and design with particular reference to industrial design and the use of tools and media for 3D form-giving. The preliminary results of this study have shown that [3] neither of the manual or CAD modelling techniques was totally satisfactory but both had particular benefits to offer the designer. This suggested that current CAD tools were a long way from completely replacing conventional modelling skills and that manual methods were not ideal.

SensAble's FreeForm haptic modelling system, combined with the PHANToM device, is the first CAID tool which lets designers sculpt and form virtual clay and foam using similar tools and techniques that are employed in the physical world [4]. Despite what these technological changes offer in terms of modelling, their impact on 3D modelling in industrial design has not been fully investigated through active research experimentation using haptic modelling tools. Therefore, a further study was conducted aimed at examining the potential strengths and weaknesses of the haptic modelling system according to industrial designers, and exploring the level of usability that the haptic system would provide in 3D form-giving.

2. Background to the PHANToM Haptic Modelling System

Today, the commercial viability of haptics is established in several areas [5] and the haptic systems have a wide range of application fields, such as assistance of disabled individuals, entertainment, medical, educational and military training applications. Haptics can be applied in many areas to create touch-enabled solutions that improve learning, understanding, creativity and communication [6]. For example, training of medical procedures and the use of medical devices (medical), preparation and interpretation of seismic data (oil & gas); exploring and learning by feeling (education). Design and engineering related examples can be as rich as exploration of product form, feel and functionality conceptual design, new design and surface styling tools, digital prototyping, touch-enabled digital mock-ups, assembly and maintenance training, test and evaluation of product functionality.

A literature search on 'haptics' produced a large number of papers that deal with various aspects of haptics and haptic devices. However, the foundation for this research area was laid down by Thomas Massie and Kenneth Salisbury, the developers of the pioneering haptic device from Massachusetts Institute of Technology's Artificial Intelligence Laboratory. Later on this device was named "PHANToM Haptic Interface". The following is a brief description of this device. However, in Sener's recent study of haptics literature [2] the interested readers can find more about it as well as some other haptic devices that are in use today.

With the PHANToM, the designer uses a stylus (i.e. puts one finger on a stylus connected to a metal arm) to control a virtual modelling tool on the screen. By moving his hand around, the designer can feel virtual 3D objects that are programmed into a computer (figure 1). This virtual carving device is used to model the digital object, which appears via the accompanying on-screen interface software called FreeForm. The virtual material can be modified to feel as hard as wood or as soft as butter, and materials can be added to or subtracted from the digital object. The FreeForm system uses voxels (similar to pixels but with the addition of 3D volume data) to create volumetric modelling and rendering [7] [8].

3. Haptic Modelling Experiment with Industrial Designers

In this experiment, FreeForm virtual clay software Version 4 and a PHANToM force-feedback input device (both from SensAble Technologies) were used as the 3D haptic modelling system.

3.1. Participants and Timescale

The experiment was carried out with both industrial design undergraduates and design professionals. The participants had previously been involved in a study of design and modelling with CAD and blue foam [3]. At the beginning of the experiment, all participants were given a fifteen minutes demonstration on how to use the PHANToM haptic device and how to model on the FreeForm system (e.g. ways of form creation). Then, they were given half-an hour for exploring the system, getting used to a new modelling medium, and getting familiar with the interface (e.g. icons, pull-down menus).

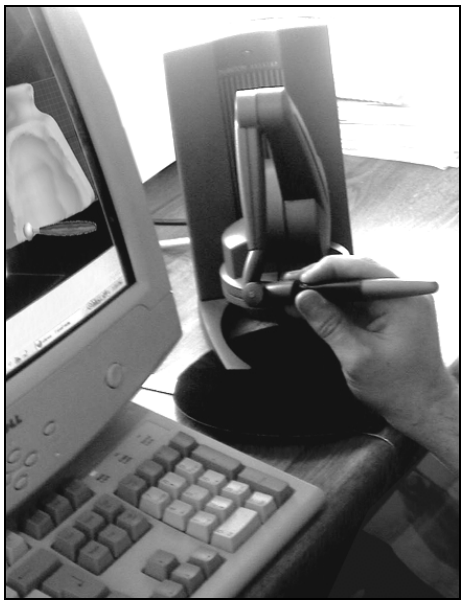

Figure 1. The PHANToM haptic device in use

3.2. Design Task

It was important to set a design task for the participants in order to monitor the difficulties that they would have experienced whilst modelling on the haptic system. Therefore, each participant was asked to design a perfume container. Accordingly, the participants spent the rest of their time (two hours) on the design task. Considering the fact that none of the participants had any experience in haptic modelling before, they were not expected to come up with refined designs at the end of the session. Instead, they were expected to model only the 3D form which did not indicate any other details, such as texture and decoration.

3.3. Data Collection

During the experiment participants were asked questions to review what they had planned and achieved,

and the difficulties they had faced. However, they were also free to ask the researcher for further help. The reason for working with inexperienced FreeForm users was to observe how easily they could adapt to (learn to use) the system. The authors thought that it would have also been very useful feedback to hear about the participants' first reactions before they became more used to the system. At the end of the sessions they were asked additional questions with the aim of discovering their personal opinions and ideas about the drawbacks and potentials of the software, the input device and modelling with haptic system in general. Consequently, the participants responded to several aspects of modelling with FreeForm system during and at the end of the experiment. The qualitative data obtained from photographs, questionnaire answers and observation notes were then evaluated.

4. Results of the Experiment

Nine participants completed the experiment and a number of issues were revealed. This section presents the results of the experiment. The results justify the use of PHANToM input device, further research, testing, and refinement on its design and functionality, on-screen interface in relation to modelling tools and functions.

4.1. PHANToM input device

Initially, all participants found the PHANToM easy and straightforward to use. However, after a prolonged time, they experienced difficulties in using it in conjunction with the mouse and keyboard. All participants complained about their wrists getting tired, as they were unsupported. An example of a participant supporting his own wrist can be seen in Figure 2. The participants tried several ways to find the most comfortable method of using the stylus. Using the stylus as a carving tool also required them to rotate it freely in 3D space, as they would do with an actual carving tool. However, since the stylus had limited movement in its six degrees of freedom, they became frustrated.

The results showed that, the PHANToM requires more research on its design in order to develop it ergonomically. It should be provided with a hand/arm support and allow the users to manipulate it without getting tired quickly. There is also a need for improving its functions in relation to other input devices (i.e. keyboard and mouse) being used in the system. In fact, the designer can control the computer in the same way as if the PHANToM were a mouse. However, all participants still preferred to use the mouse so that they felt like the interaction with the computer was two-handed.

Figure 2. The participant is supporting his wrist

The mouse was also providing more precise control in some operations (e.g. zoom, rotate, pan). The keyboard, however, was mainly necessary for entering numerical data and for using the keyboard shortcuts (e.g. common Windows shortcuts). As the participants had need of three peripherals (mouse, PHANToM, keyboard), it caused them difficulty in finding the most comfortable way of manipulating them. Some participants preferred to control the mouse and the PHANToM with the same hand and they had to switch hands when necessary. This was a result of being left or right handed and feeling more comfortable to use them with the same hand. Several examples can be seen in Figure 3.

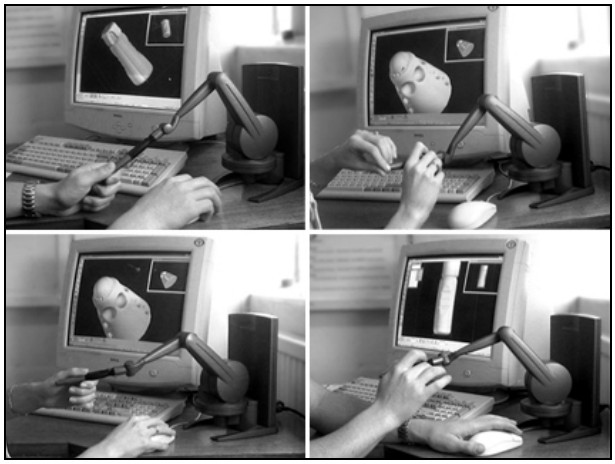

Figure 3. The participants are having difficulty in using the mouse and PHANToM at the same time

4.2. The On-Screen Interface

The interface was generally found to be simple and easy to use. However, the participants had difficulties in

finding the right tools and modification options from pull-down menus and/or icons. They also mentioned that some of the tools, such as the ruler and masking tool, were hidden in the menus and it was difficult to find them. Alternatively, the interface should be more flexible so that the users can choose their own modelling tools and arrange them as if they are working in their own workplaces. Providing the users with a customisable interface could be a solution for this.

4.3. Modelling Tools / Functions

One of the advantages of working with the system was being able to go several steps back after making a mistake, whilst still having the feel of working with clay or blue foam. The other advantage was to be able to work with this system anywhere (i.e. without needing to be in a workshop). However, model accuracy and being able to obtain engineering drawings, as from a CAD model, appeared as important issues which FreeForm was not able to deliver. It was also very difficult to get a smooth surface while working on larger surfaces.

5. Discussion

The FreeForm modelling system was mainly characterised as being useful for visualising quick design ideas. The participants liked to experience the physical feedback from the material as well as feeling texture qualities. Having haptic feedback was helpful for better understanding of the form. In contrast to this, the visual feedback was not sufficient. The system is described by SensAble as a clever and refreshing system that does not require accuracy. On the contrary, since it was not an accurate system, the participants stressed that they would not use it in the later stages of the design process. It was an insufficient system for making final design decisions.

FreeForm was introduced as a tool that combines the tools and techniques similar to those employed in the physical world, yet with most of the advantages of a CAD tool. However, the participants expressed that since FreeForm was much like working with blue foam, it was still carrying on some of the disadvantages of blue foam. For example, it was very difficult to get a smooth surface or homogenous surface quality.

The experiment of how well the PHANToM haptic modelling system answers the needs of industrial designers in 3D form-giving showed that the concept is very promising, especially for the early stages of design. It was reassuring to be guided around a digital object by using the sense of touch and being able to run through many design iterations very quickly and experiment with several ideas to see if they work visually. In the commercial world, conceptual design is the first step in the long process from the designer to the consumer, whether the product is a manufactured item or an entertainment project. Therefore, seeing possibilities would help designers to think - not necessarily to show the client.

Nevertheless, the system has some drawbacks at the moment. It is very enjoyable to work with carving tools which provide a haptic feedback. As the tools are not constrained enough, accurate control of the form is not quite possible. Hence designers switch to CAD way of modelling rather than get the pleasure from a virtual hands-on activity. In addition to this, the modelling tools that are provided on the FreeForm system seem to be a collection of the tools used by artists which do not directly translate the shapes created in industrial design. Therefore, in order to be able to use the system at the later stages of design, it is important to identify how industrial designers work, and what tools and techniques they commonly use in 3D form-giving. The system should then make a more complete translation of these tools and how they are used. Combining the system with other CAID software, where it is possible to control things better, could be another solution. After exploring ideas on the FreeForm system, designers could detail and dimension them on other software packages.

6. Conclusions and Future Research

It is hoped that the design and modelling experiment using FreeForm system has, to some extent, established a framework within which the strength and weaknesses of the PHANToM haptic modelling system can be addressed. It is anticipated that the outcomes of this experiment will augment the previous results of the research project and comprise tangible recommendations for the FreeForm software and for the input hardware.

It is also important to identify the changes to the nature and structure of the design process that need to be made if the FreeForm system is to be used as a design tool. A further study with an industrial partner will be made in order to generate and analyse data on 3D-form creation using the PHANToM haptic device in real life design projects. Consideration will also be given to how Freeform can be better integrated into the product development process. The results of this experiment will also provide a clearer indication of how the FreeForm system may evolve in order to satisfy the needs of industrial designers. Along with the specific findings, this research is contributing to a more general understanding of three-dimensional modelling within the design activity.

Acknowledgements

The authors would like to thank Wil Schoenmakers and his group at Procter & Gamble for providing access to the FreeForm Modelling System that was used in the research experiment.

References

[1] Purnomo, E. “Haptic devices” http://www.cs.auckland.ac.nz [January 2002].
[2] Sener, B., Wormald, P., Campbell, I. (2002:a) “Towards ‘virtual clay’ modelling-challenges and recommendations: A brief summary of the literature” Proceedings of International Design Conference: Design 2002, Dubrovnik, May 14-17, 2002.
[3] Sener, B., Wormald, P., Campbell, I. (2002:b) “Three-dimensional design modelling: The strengths and weaknesses of alternative techniques” Proceedings of International Conference: Common Ground, London, September 5-8 2002. (in press)
[4] SeansAble Technologies, http://www.sensable.com [January 2002].
[5] Winkle (van), W. “Touch the future: Haptics is here”, Laptop Buyer’s Guide & Handbook, August 2000.
[6] Reachin Technology, http://www.reachin.se [May 2002].
[7] Sjöström, C. (1999) “The IT potential of haptics: Touch access for people with disabilities” http://www.certec.lth.se/doc/touchaccess [February 2002].
[8] Dransfield, B. (2000) “FreeForm: Synapse Modelmaking gives its verdict on this high-end modelling hardware” *3D World,* pp 80-83.