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An investigation into the use of haptic modelling during industrial design activity

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Abstract
Physical models continue to form an essential outcome from industrial design practice for both student and professional. Whist the professional may be removed from the "hands-on" model build by employing the services of a modelmaker, students rarely have such resources. Indeed it was (and in many institutions still is) considered an essential part of the education programme for students to develop modelmaking skills and experience the physical interaction with form and material. However, the advent of remote model building technologies via rapid prototyping and computer controlled machining, has given students an alternative, enabling them to become increasingly removed from such interaction.

As increasing numbers of industrial design courses utilise remote model build technologies, the emergence of three dimensional (3D) digital modelling via a haptic feedback device may offer a route whereby students can continue to be involved with tactile design modelling. Acknowledging the need to utilise digital design techniques, this paper investigates the capabilities of haptic modelling for use within industrial design practice, with the aim of discussing its suitability for student use. The research is based on an industrial design case study for a communication device that was undertaken by the authors.

Keywords: haptic modelling, industrial design education

Introduction

As a profession involved in the definition of product form, industrial design makes extensive use of three dimensional (3D) models. These may vary in sophistication from relatively simple study models to full prototypes (Knoblaugh, 1958:15; Kojima, 1991:38). The type of model most associated with industrial design practice is the appearance model, which embodies the form of the production item but none of the functionality (Powell, 1990:11).

Prior to the advent of remote model building technologies such as rapid prototyping and computer controlled machining, models would be produced by manual working and craft-based techniques. Some designers take design decisions as they manually manipulate the material, modifying it accordingly.

As professional practice makes increasing use of remote model building technologies, the opportunity for the designer to be directly involved in the shaping of material decreases.

This has been shown to be the case with the full range of models, from study models to prototypes (Sharbaugh in Carrabine 1999:24). However, one must acknowledge that this takes place at a time when virtual evaluation has increased, and 3D computer aided design (CAD) and computer aided industrial design (CAID) systems allow photorealistic visualisation and real-time animation.

One could argue that the experienced practitioner might have sufficient levels of skill and judgement to bypass the direct interaction with form. Indeed, personal experience has shown that such practice often takes place when deadlines are tight or resources are limited. Students, however, need to actively develop their abilities in the manipulation of form, but this is of course happening at a time of increasing access and requirements to employ CAD and CAID, along with the potential to build physical models using remote model building. In response to these conflicting pressures, the emerging technology of digital modelling using a haptic

feedback device may have the potential to develop and encourage the physical manipulation of form, albeit on a virtual level. Haptic feedback devices give the operator the "feel" of the virtual object. If the operator moves a cursor onto an object on seen via the monitor, they actually feel its presence via an electro-mechanical system attached to the pointing device.

The authors, having backgrounds as both design practitioners and educators, have explored the nature of haptic modelling, considering its potential for integration into industrial design practice and design education. It follows a programme of action research that involved the industrial design of a highly conceptual communication device that was produced as an entry for the Nagoya International Design Competition in May 2000. The structure of the case study follows the three phases of professional practice as identified by Pipes (1990), involving concept generation, design development, and specification. These are now explored in some detail.

Concept Generation

The brief for the communication device specified that its form should cross the boundaries between what we consider to be jewellery and consumer product. The design was to have some of the functionality of a mobile telephone, without the transient feel of a polymer consumer product. Concept generation was undertaken using paper-based sketching, examples of which can be seen in Figure 1.
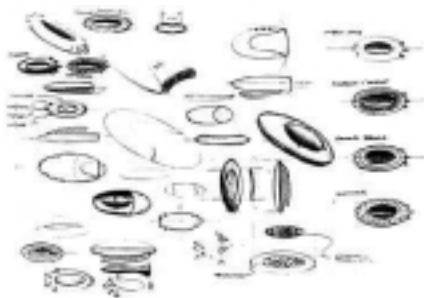
Whilst CAID was available throughout the project, the industrial designer felt that the application of this technology was inappropriate at the concept generation stage due to the lack of spontaneity afforded by its modelling methods. This is identified by Pipes when he states that "Conventional CAD at an early stage can stifle creativity by its insistence that the designer provides the system with exact dimensional and geometric information right from the start". (1990:88)

A small brooch-like product emerged from the concept generation phase, its form based around an elliptical body with a large answer button. Other functionality was accessed via three smaller buttons positioned on one end. The speaker/microphone was located on the opposite edge.

The paper-based sketches provided the industrial designer with sufficient detail on form and size to progress to the second phase of design development. If operating to a more traditional design methodology, this phase may involve some modelling in "soft" materials such as Styrofoam, or even the manipulation of more resistant materials. For the purpose of the case study, haptic modelling was to be introduced as an alternative.

Design Development

The Phantom Desktop input device and Freeform 2 software were made available by Sensible Technologies based in Boston Massachusetts. Twin 450Mhz processors with 512MB of RAM were used to run the software, and support was provided by the Sensible Technologies UK consultant. The Phantom Desktop input device can be seen in Figure 2.

Figure 1 Concept generation using paper-based techniques

Figure 2 Phantom Desktop input device with Freeform 2 software
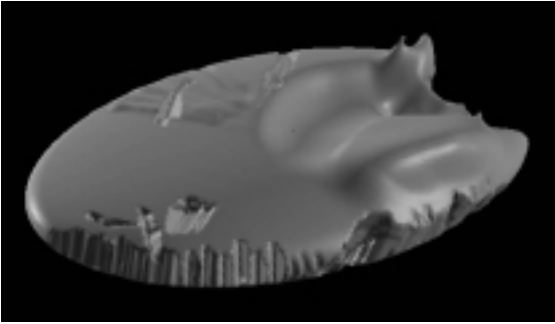
Figure 3 Model produced for evaluation of modelling capabilities

As a precursor to the product being modelled, an exploratory use of the technology was undertaken. This involved an evaluation of the additive and subtractive modelling techniques, along with smoothing operations and manipulation of material density. The move from interacting with a physical object, to a virtual model, was initially found to be an unusual experience. However, as familiarity with the software and system developed, the modelling capabilities of the media emerged. Indeed it soon became apparent that the haptic modelling system was capable of producing forms that could not be generated using CAID, although the value of these relatively abstract surfaces represents a separate issue. Figure 3 shows one of the models produced during the exploration of the media.

After a period of familiarisation, it became evident that the hardware and software could be used on two levels. The first involved techniques closely associated with CAD and CAID modelling, whereby forms could be generated by non-haptic input e.g. creating a sphere and numerically lengthening it in one or more planes. The second technique of haptic modelling was not possible within a CAD or CAID system, and had the potential to produce forms via various shaping operations whilst receiving physical feedback i.e. the operator could "feel" the virtual material.

Following the evaluation of the haptic modeller, a decision was made to model the communication device using the functionality of the Freeform 2 software. This was particularly appropriate for the

communication device, as the body shape had the potential to be formed from a scaled sphere. The basic outer form of the product was therefore modelled using the Freeform 2 software without any haptic input. It was generated from a sphere and distorted to produce the required flat, curved form. The speaker/microphone notches were to be modelled with the Phantom 2 haptic feedback device, but it was not possible to generate the smooth surfaces required. When the operator performed a haptic scooping operation, the surfaces were excessively rippled as there was no tight control of the motion. The designer was attempting to create the effect one would achieve by taking a scoop of soft ice cream, leaving a cavity with smooth sides.

It would have been possible to use more controlled modelling techniques within Freeform 2 (using a guide to control the path of the cut), but this was considered a significant move away from haptic modelling and more related to CAID techniques. It was therefore considered more appropriate to use CAID for the modelling of the basic form, and the Phantom Desktop for specific surface finishes. The communication device was modelled as a surface using the DeskArtes CAID software in less than one hour.

As the surface finish for the body of the product was to be modified using haptic modelling, the CAID model was imported into Freeform 2 as a .stl file. The imported surface can be seen in Figure 4.
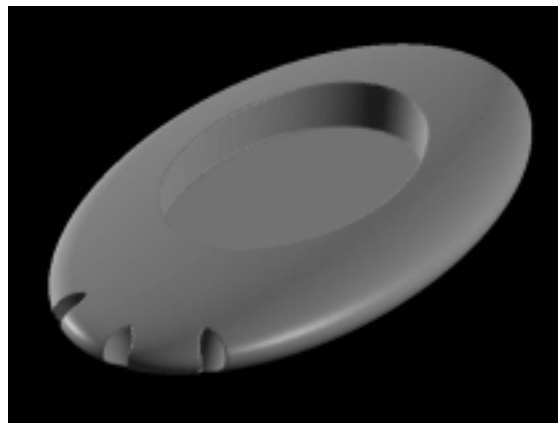

Figure 4 Imported CAID surface

The surface finish to be produced via haptic modelling was not rigorously defined at the concept generation stage as it was intended to explore the possibilities of forming the virtual material using techniques closely related to craft-based interaction. Adjustments to the density of the virtual modelling material and shape of tool resulted in the development of a hammered effect. The desired result was achieved by using a rounded tool to "hammer" a relatively hard surface. The progression of the hammering can be seen in Figure 5.
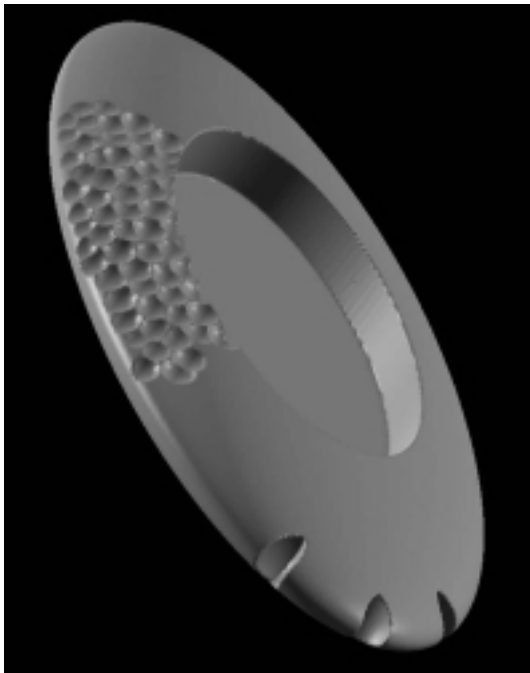

Figure 6 Final hammered effect

Figure 5 Haptic modelling of hammered effect

When completely hammered, the surface was smoothed-out to soften corners. A second series of hammer blows were then applied to give a more irregular effect. This was again smoothed-out on completion. The final finish can be seen in Figure 6.

Figure 7 Rendered hammer finish

The hammered surface was saved as a .stl file and exported to the CAID system for the addition of the remaining components and rendering. The rendered product can be seen in Figure 7, and as a photomontage with user in Figure 8.

A second proposal was produced to exploit the capability of the Freeform 2 software to mask surfaces to avoid deformation by subsequent operations. This not only creates
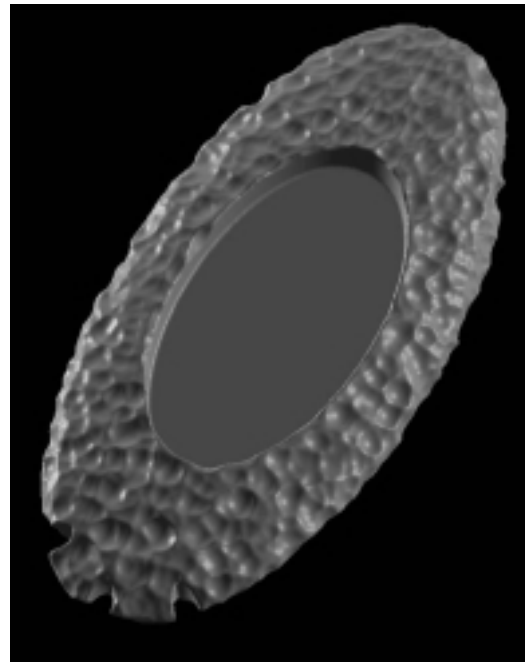

Figure 8 Photomontage of hammer finish product with user

mask, but it can also be used to define a cut on a surface and allow material removal. Whilst exploring the use of this functionality to produce a rim around a scored section of the surface, the potential to create a distinctive random transition between two surfaces became apparent. Figure 9 shows the definition of the masked area that was applied using a rounded tool with a haptic painting technique.
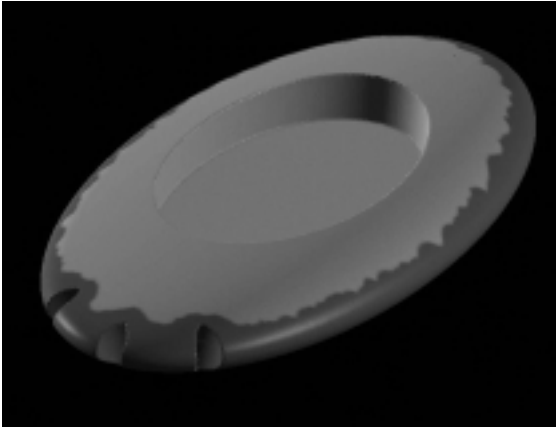

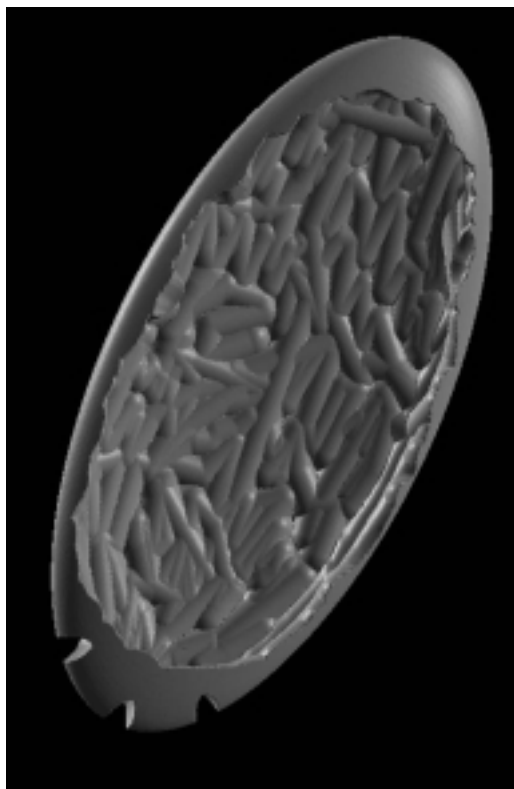Figure 9 Definition of masked area

Figure 10 Outer surface showing internal ridges

With the mask applied, it was possible to extract the inner surface and leave the outer section as a separate element. The inside
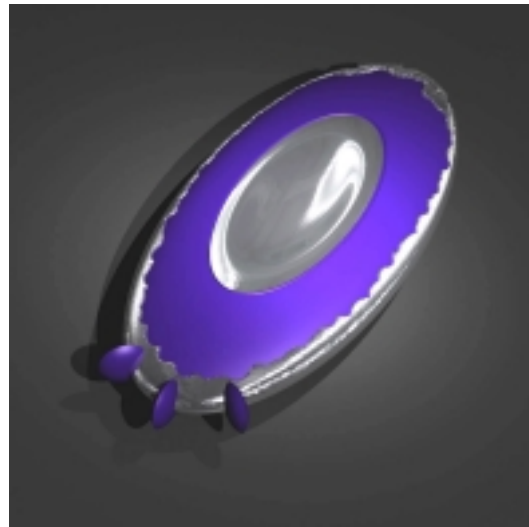

Figure 11 Rendered masked product

Figure 12 Photomontage of masked product with user

surface of the outer section was left with a series of ridges that were created by the rounded tool used to define the masked area. These appear as a series of ridges on the inner surfaces and can be seen in Figure 10.

The surfaces were exported back into the CAID system for rendering, where the outer section was specified as silver, and the inner as a gloss purple plastic. A rendering of the masked product can be seen in Figure 11, and photomontage with user in Figure 12.

Specification
The specification of product form to design engineers and manufacturers who are conversant with digital design techniques is relatively straightforward, requiring the transmission of digital geometry in a mutually compatible format e.g. IGES or .stl.

The proposition for the hammered product was for a low-volume, jewellery-like product. It would therefore be straightforward to convert the surface geometry of the body into a .stl file, thereby using the CAID data to produce the components in wax using a rapid prototyping system such as the Sanders machine. Investment casting could then be used to manufacture the components as a direct copy of the CAID model.

Conclusions

At the beginning of the project, the expectations of the haptic modelling system were high. In fact they were too high. Assumptions were made that the modelling techniques would be very close to those of conventional foam and clay concept modelling. Unfortunately, the functionality of the software and hardware made it difficult to obtain the surface quality needed for both rendering and production. This was highlighted by the attempts made to produce a clean scoop when modelling the speaker/ microphone detail. However, the responsiveness of the haptic modelling system to the generation of the hammered and masked effects was impressive. The production of the hammered effect was very closely associated with traditional hands-on modelling, whereby the designer controlled the manipulation of material whilst responding to tactile feedback. The capability to create the masked area was not expected, but the potential for this technique resulted in the emergence of a design opportunity that was quickly exploited.

For students of industrial design, the findings of the case study indicate that haptic modelling has its limitations. Whilst the stylistic trends within industrial design require smooth, crisp surfaces, the authors feel that every effort should be made to undertake physical modelling using traditional fabrication techniques as they cannot be reproduced by haptic modelling. However, one can only assume that future development in the hardware and software for haptic modelling will address the shortcomings identified in the case study. Further work will then be required to re-evaluate such capabilities.

In terms of the generation of random, almost craft effects, haptic modelling has much to offer. The authors feel that such a system may be of interest to both practitioners and students of jewellery design. This would be particularly relevant if the virtual material could emulate the characteristics of precious metals that may be too expensive to use. Indeed it may be possible to use haptic modelling to practice on a virtual material before working on the real (and expensive) precious metal.

At present, there appears to be nothing to reproduce the feedback and effects achieved when interacting with a physical material. The authors therefore feel that students should continue to be encouraged to experience the manipulation of a variety of materials as a means of developing their design skills. As the capabilities of haptic modelling systems develop, educators should be aware of their increasing capabilities as the boundary between the physical and virtual diminishes.

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