Hybrid Modeling
Manual and digital media in the first steps of the design process

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Abstract. *This paper proposes a new paradigm in computer-aided design: hybrid modeling. Considering, on one hand the traditional sketches and mock-ups, and digital techniques on the other, this paradigm fuses the two and proposes a new technique that uses the performance of the digital with the capacities of the analog without replacing or imitating one or the other. In the development of design computer solutions, it is important to know the user well. However, most researchers propose systems that do not consider how designers actually work. Furthermore, two principal elements must be considered in the design process: shape and space. These aspects need to be approached with convenient tools that are adapted to the designers. This new paradigm is presented through two new innovative techniques: the hybrid mock-up (for shape) and drafted virtual reality (for space).*
A review of the implications of this paradigm on the design process is presented. Not only are the techniques fast and easy to learn and execute, but the results demonstrate that the designers can express both their individuality and the idiosyncrasies of their personal representations; important elements that are difficult to achieve with conventional 3D modeling techniques, especially during the primary stages of the design process.

Keywords. *manual media, design process, rapid prototyping, sketches, 3D modeling.*

Introduction

The aim of this study is to question the actual use of the computer in design and at the same time to propose a new approach. It targets principally the use of CAD systems during the first steps of the design process while creative activity is most important and the computer brings more limitations. Nowadays, the computer is used as a presentation tool rather than a design one. Even if computer visualization improves the communication of complex forms for designers and design teamwork, most of the design tasks and decisions are carried out through traditional analogs tools like sketches and models. It is thus essential to propose new approaches which would bring forth the advantages of the computer in design.

Besides, a new type of designer, specialized in computers, seems to distinguish himself in the practice. Are computer solutions intended for de-

signers? Do the complexity of the tool and the approach chosen to integrate it in design function well? The majority of suggested computing solutions come from other disciplines and are effective for other tasks. By using the computer in this way, are results affected? Before, traditional manual tools had their own limits: do new CAD tools also limit the current design? This paper will try to address these questions.

This new approach is presented through two techniques one focuses on the design of spaces, and the other on the form: the Drafted Virtual Reality (DVR) (Dorta, 2004) and the Hybrid model (HM).

Today's computing = accuracy

Current computing requests precision and set ideas from the designer, both of which can limit creativity. The principles of several 3D software programs require detailed forms and dimensions which can challenge the designer's initial mental images, and this, from the very start of the design process. Given the way CAD interfaces are conceived, they seem to block the designer in his process because he has to concentrate on the tool, rather than on the design task (McCullough, 1996). Through structured actions of the mouse with menus, the designer is forced to make premature decisions, requiring an inappropriate precision, in comparison to sketching on paper techniques (Gross, et al., 1996).

In the guiding principles of graphic computing, one of the most important principles was to know the user well (Hansen, 1971). However, computing development is carried out without taking into account the designer's specific needs. Designers are then playing a passive role, adapting solutions to their requests. The result is that the interfaces used are inappropriate to design. The focus is not on creating but on reacting to the requirements and whims of commands (Raskin, 2000). All advances in terms of interactivity and 3D visualization are diluted by the complexity of these commands (parameters, default values, attributes, etc.). Moreover, designers are currently proposing new software solutions but still interact with mouse and keyboard. Furthermore, the geometrical requirements for 3D forms in these systems seem to be premature, especially at the beginning of the process. Since these programs are being elaborated on Euclidean geometry, several elements of visualization (orthogonal views and wireframe presentations) must be decoded, limiting the facility to comprehend the suggested form.

Specialized Designer vs. Common Designer

There are specialists in various tools, like professional model makers and illustrators. However, in the language of design, the creation of mockups and sketches is common and necessary, and the computer representation must be added. But because of its complexity, a particular computer expertise is needed. Do design tools require specialization? Should they be acquired and mastered as vehicles of the designer's language to find solutions?

The designer should be an expert in the design task, in the search of appropriate propositions, and not in the representation tool. The tool must be adapted to his process, nourish and facilitate it without affecting it. It is as if the computer had become the rhetoric of the object of design and not its creator. It is a tool for the discourse of the designer, but not necessarily the ideation ground. Several design solutions seem limited by control of the software used to represent them. Are we facing the same problem as with the traditional tools?

The force of the analogue: the craftsman

Designers are competent to work with three-dimensional objects and space. Like craftsmen,

they handle certain materials and, with their hands and stereoscopic vision, can correctly control the form. During their education and practice, several techniques of graphic expression are also added to sketch ideas.

As a whole, manual work is where abstractions of images on the screen are validated by direct manipulation, haptic sensations and psychomotor interactive work. The visual image becomes stronger when results of psychomotor activity are integrated with those of visual observation (Furness, 1987). The connection of the mental image with the psychomotor operation produces a physical image: the drawing. This is possible through a closed network composed of the drawing, sight, the mental image and the hand (Lasseau, 1980). According to Furness, the creative process is improved when the three processes (visual, mental and psychomotor) are active.

The interface of the pencil on paper and the construction of models are more direct and easier than the computer for a creative work. It is often said that computer images and 3D modeling are slower than human imagination. Creativity depends on system speed and facility of use (Klercker, 1995).

The model

The scale model is a very effective tool to try out forms that will be presented in real size. It can be built on any scale, even in full-scale as in industrial design, which implies the possibility of direct work on the mock-up; that means that the decision-making and the form validation, the details and textures are made directly on the object. Being able to touch the object and to feel its forms through malleable materials improve creative work.

Moreover, the scale model is a 3D form that is handled and studied in the real 3D world, allowing research on the form and proportions without the intermediary of computer screen images. In addition, the model being malleable facilitates free exploring of geometries with ambiguities and inaccuracies, but without premature limitation of ideas. The model also ensures that certain questions remain unanswered, leaving a margin of flexibility and giving an explicit visual place for the decisions that remain to be taken.

On the one hand, the sense of touch is very important for human perception. It allows one to truly understand a 3D geometry. Even by proposing a large variety of graphic interactive methods, very few modeling computer based techniques enable the designers to conceive directly with their best toolkit: their bare hands (Dachille, et al., 1999). On the other hand, the sense of vision obviously takes much place in our perception, and almost any task can be carried out only with vision. However, the use of another intuitively and naturally sense like touch will give more interesting results (Tan, 2000). To illustrate this, let us look at the importance of the hand to eye coordination in sculpting: the visual continuity of a digital pen on the screen is surpassed by the expression of a 3D model with a visual and tactile continuity, this time without commands, but by touch.

Lastly, among the most important problems of models, we find the Gulliver effect that is felt when the scale is too small (Porter, 1979), and problems related to the transformations of the form and the proportions. They are more difficult to manage than the sketch.

The Sketch

The general characteristics of freehand sketches are that they are abstract, ambiguous and inaccurate (Gross, et al., 1996). By using abstracted elements, the specification of the details can be pushed back. Ambiguity allows to maintain several possibilities open for later selection or identification. It also helps the designer to discover new ideas because these can often be misinterpreted, thus offering incomplete information (Park, 1996). Inaccuracy prolongs the decision-making regard-

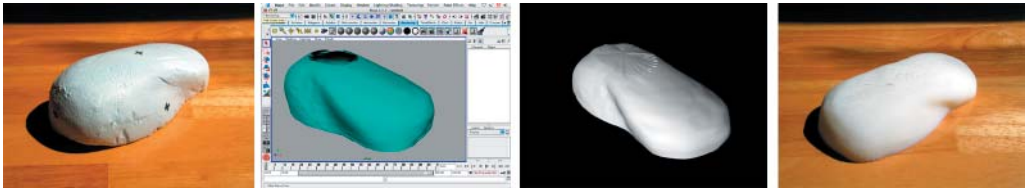

Figure 1. Foam model, 3D scanning, 3D modeling modifications (scale and proportions) and RP mode.

ing the position and dimensions of the elements.

The sketch is a fast visualization and intuitive graphic simulation tool that hasn't been replaced yet. Goel (1994) argues that sketch representations support the designer's cognition better than more precise and finished forms. One easily obtains changes, and precision is not necessary for the expression of an idea (Zeleznik, et al., 1996).

Drawing is a graphic simulation system (Lebahar, 1983). It makes it possible to represent ideas through graphic objects. While manipulating these objects, the designer will build, destroy and rebuild, place and move, and determine the dimensions of the object. This simulation gives him the possibility to transform his mental image before the object is built. As the search approaches completion, the knowledge of the designer increases in quantity and precision.

Also, compared to detailed plans, the sketch contains the designer's thoughts and deliberations during the first steps of the process (Dirk, et al., 1995). Lockard (1973) argues that freehand sketches allow our brain to see information, to understand it and answer it. The process is seen as a reflection in action (Schön, 1985).

The impossibility to feel the inside of a space and not being able to avoid the abstraction to understand three-dimensional forms and complex relationships are problems related to drawing (Lansdown, 1994). There are also unconscious proportion errors, due to the inaccuracy of the representation, the disrespect of the human scale and the observer's angle of vision.

Proposed techniques

We propose the use of traditional analog tools along with the advantages of the computer, thus avoiding computer related problems and concentrating on the user task: design. The idea is to take out the information from the computer when it reaches its limits, to treat it by hand and with acquired techniques, and then to return it to the system in order to take advantage of visualization and form processing.

Some exploratory research relating to the integration of the two modes (analogue and digital) initiated investigation within the framework of design workshops (Hebert, 1995; Burry, 1998; Bermúdez and King, 1998; Angulo and Vásquez de Velasco, 2003). However, it is important to offer structured techniques of integration that will support this exploration of form and space.

1) The Hybrid Model (form)

It consists in working with the two modes of representation (analog and digital) by modifying the 3D model through analog (clay modeling, etc.)

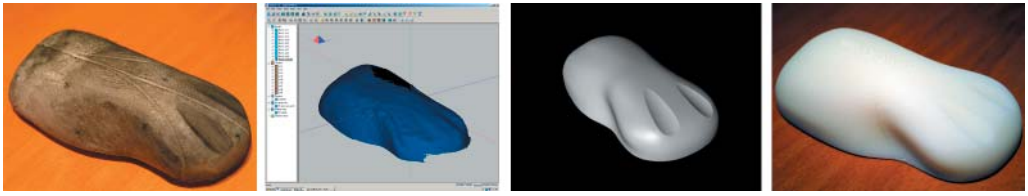

Figure 2. Modified RP model (foam), 3D scanning, 3D modifications (shape and details) and RP model.

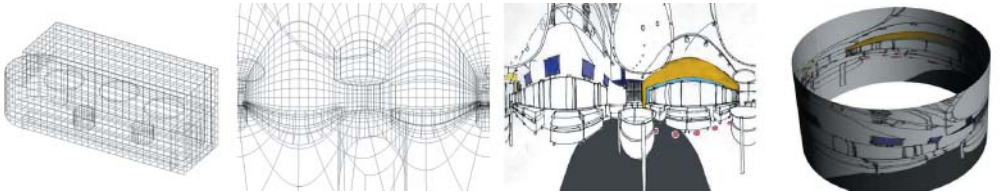

Figure 3. Meshed basic shapes, wire frame panoramic template, sketched template, and QTVR.

and digital (free transformations, Boolean operations, etc.) processes. It is a cycle of continuous back and forth iterations between the virtual and the real, through 3D scanning and rapid prototyping (PR), in order to benefit from the advantages of both modes.

To illustrate the approach, let us consider a designer that undertakes the formal modeling of an object. He could begin his research by handling a Styrofoam block, which he modifies manually to create his first idea. This concept is then digitalized and visualized, and consequently the designer uses techniques suitable to the digital mode to apply transformations and Boolean operations such as subtractions or additions. The return to the analog mode is done via rapid prototyping (Figure 1).

The object created is relatively malleable and can easily be modified, carved by subtraction (cutting, drilling, sandpapering, etc.) or addition (clay, paperboard, styromousse, etc.). The form evolves in this way and takes again the path towards the digital mode to be treated there by specific tools. The goal of this approach is to benefit from the advantages brought by digital and analog modes, in a repeated way, and by allowing the designer to chose the method that he considers most suitable for a particular action (Figure 2).

2) The Drafted Virtual Reality (space)

This technique uses the computer to build a panoramic grid (360º), which, once printed, becomes the graphic template where the designer makes his freehand sketch. This drawn panoramic image is then digitalized and visualized through the QuickTime Virtual Reality (QTVR) computer technique (Chen, 1995). Here the image is placed around the observer's point of view, which enables him to direct his sight in an interactive way while clicking on the image to move it in all directions. The panoramic view deforms the perspective to adapt it to a cylinder, which once closed by the QTVR technique, allows the user to observe multiple correct perspectives.

As a first step, the designer models the 3D basic forms in the software, which allows the panoramic view. These basic wire-frame forms will become the graphic references of the printed panoramic image. To add more lines to this graphic template, it is possible to mesh the objects. Once the template is printed, the designer uses the drawing technique that he controls most. The designer uses the reference lines of the basic forms on the template to guide and control the proportions and the projection of the drawing. Once the image is scanned, the QTVR software is used for visualization (Figure 3).

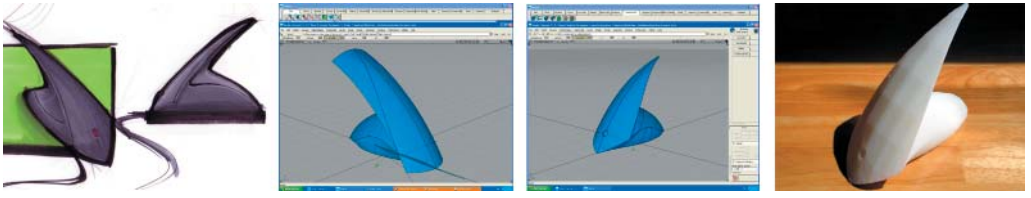

Figure 4. Sketches, 3D modeling and RP model.

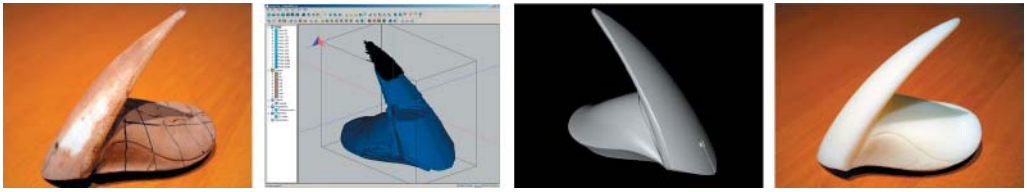

Figure 5. Modified RP model (clay), 3D scanning, 3D modifications (shape and details) and RP model.

Results

Using the hybrid model technique, two designers worked on developing shapes for a new computer mouse, one starting from sketches (Figure 4), the other from a Styrofoam model (Figure 1). On the one hand, for the initial iteration, after transforming the sketches into a 3D CAD file using Alias Studio and Cinema 4D, the first designer perceived this stage as leading prematurely to a quasi-finished result. This is because some aspects of the geometry were not sufficiently determined in the sketch to feed the CAD program with the needed accuracy. This premature intent was very obvious in the RP produced model. However, the sketches permitted the easy exploration of several solutions. On the other hand, the second designer's rough Styrofoam mock-up, despite its primitive nature, was a better portrayal of his comprehension of the object's shape, scale and proportion. Transformations were easily accomplished.

Once digitized and reproduced by RP, the designers found it sometimes easy, but other times more difficult to add material to the model. Subtracting was easily accomplished by both. At the end of the process, once the shapes were better defined and quickly completed by hand, both designers were dealing with more detailed, richer geometries (level 5 curves rather than 3), more difficult to represent in the software than those from sketches (Figures 2 and 5).

It was easier to visualize and feel with the mock-up than on the screen and to explore the asymmetry, which is hard to do by computer. Very small details were completed and the problems found on the muck-up where corrected by computer. The RP models were considered as 3D templates to achieve manual exploration. In the CAD software, instead of using sketches as background templates for 3D modeling, the rough scanned model was more reliable (Figure 6).

Finally, it was easier to explore complex geometries on the analog mode than with the computer because of the complexity and heaviness of the software. Nevertheless, going from the physical to the digital mode was found wanting because of the difficulty and the shape's degradation using the 3D scanning technique (InSpeck). Furthermore, it would have been better to produce several copies of the model, as with the sketch, to explore more possibilities.

As for the Drafted Virtual Reality (DVR) technique, several interior design students felt that the representation retained a more personal touch than a computer generated rendering (Figure 7). Moreover, it was possible to have multiple correct perspectives in a single panorama. Just as for a digital pen, DVR takes advantage of previously ac-

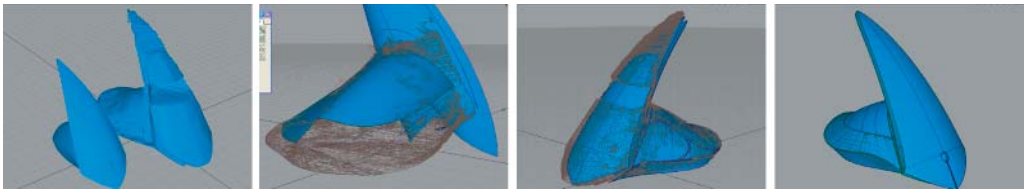

Figure 6. Rough scanned model as a 3D template for 3D modeling instead of sketches.

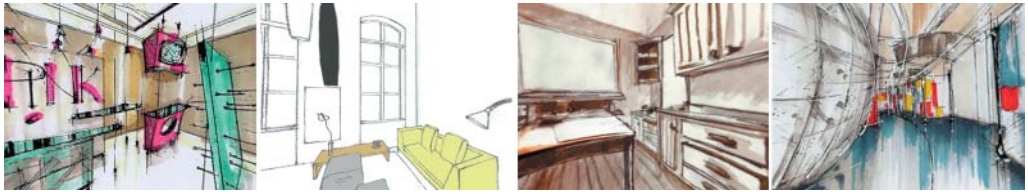

Figure 7. Sample perspectives of the DVR technique.

quired sketching skills. However, at the beginning, some found it difficult to sketch in a panoramic view.

The computer-assisted craftsman

The computer is integrated in the design process without understanding exactly where it is really effective. The 3D models and PR are part of the process to validate functional and technical aspects (precision and speed), but not for design reasons. These techniques were not created to support ideation or conceptualization tasks. In addition, these techniques are used mainly during the last steps of the process to communicate the idea to clients. Moreover, in spite of their advantages, traditional techniques like the sketch are reduced or badly integrated to new technologies. The designer should not see the two modes (digital and analog) as being distinct, and so, the limitations of each approach would be reduced: the interface or the complexity of modeling in the case of the digital, and the time consuming and dimensions errors in the case of analog. Thus, the 3D representation of the project would be carried out by design criteria and not by production criteria.

It would be necessary to stop making finished solutions from the very start of the process. We are aiming for a search of the form and space, just like sculpting or painting, through a series of empirical and successive stages of improvement, like the "New Modeling" proposed by Weinand (2004).

Controlled esthetics

Images and forms have become almost standardized since the advent of specialized software. One has the impression that all the representations are photo-realistic, perfect and precise, and this, even at beginning of the process. The quality of the proposed projects should be seen without the persuasion of a render without errors or even faked by software.

The designer's intentions should remain ambiguous until he is ready to move on to the next level. The tools and the techniques, which make it possible, must be adapted to the savoir-faire of designers. The frontier where virtual becomes accessible to explore concepts without limiting ideas and creativity must be built.

The designer himself, without fear of imperfection, should process the data. The computer should not thus be seen as an essential instrument used for the concepts: a revaluing of manual action and control of other tools is suggested.

Conclusions

In the new computer approach in design, the computer must be well integrated into the traditional basic tools in order to improve them. It is not a question of simulating these tools or replacing them by a digital equivalent. It is rather to use the advantages of the computer to process the data and to make more effective the current traditional tools (basic models and sketches), because manual work is important and easy at the beginning of the ideation. The designer must concentrate on his work of creation, and the tool must be centered on this task to fulfill the requirements of the designer, and be adapted to already acquired competences.

Acknowledgements

I acknowledge the help of the designers, students and of the formlab at Université de Montréal.

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