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# NEW GENERATION COMPUTER-AIDED DESIGN TOOLS: TWO RELATED RESEARCH PROJECTS INVESTIGATING THE FUTURE EXPECTATIONS OF DESIGNERS

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## 1. Introduction

Recent improvements in applied information technologies provide advanced tools in the field of Computer Aided Design (CAD). In order to support different phases of the design process, contemporary research, both by industry and academia, focuses on the development of enhanced Computer Aided Conceptual Design (CACD) and Computer Aided Industrial Design (CAID) systems. The aim of this paper is to add to the debate through the findings of research following these common aims: to explore the capability of current CAD systems to support conceptual design activity; to identify user expectations of new generation CAID tools. The outcome of these studies will help researchers and software developers to better understand the needs of professions involved in the design process, such as industrial designers and design engineers, and will help to produce improved CAID tools that can be used from concept sketches to final product.
The paper begins with a review of the literature describing the role of sketching in design. This is followed by discussion of the results of two discrete ongoing research projects carried out in England and in the Netherlands involving CAD users in industry and academia. The implications of these findings for the future expectations of CAD users of new generation CAID tools complete the paper.

## 2. The role of sketching in design

The activity of 'sketching' in its widest sense is an essential tool employed in writing, music, science, mathematics, and in any creative enterprise as part of the conceptualising process involved in 'working up' ideas to a final and formal condition [Temple, 1994]. Temple suggests that the place of sketching within the design process, however, can be understood as a visual dialogue or argument between opposing points of view, changing in its details by small increments until a satisfactory outcome is reached [1994]. During the design process, particularly in conceptual design, sketching, where designers make their visual notes and use them to represent themselves, is of primary importance. Therefore, most designers consider sketching essential for their creative process and will report frustration if hindered whilst doing so. Sometimes, people find their way around this frustration and this is why concept sketches can be found on backs of envelopes, edges of newspapers, or napkins.
Designers constantly use sketches, not only during the conceptual stages, but often at every subsequent stage too. In contrast to presentation-sketches, which are made at the end of the design process to present the final design idea, idea or concept-sketches are made in the early phases of design. A concept sketch is 'a collection of visual cues sufficient to suggest a design to an informed observer.' It is possible to categorise concept sketches as 'free theme sketches' and 'package-constrained sketches'. A free theme sketch is "intended to convey the visual appearance of a design proposal." It is the initial

expression of how a design is expected to look [Tovey & Dekker, 1996:62]. In contrast to free theme sketches, the package-constrained sketch brings geometrical accuracy into the sketching activity. The package for a design contains the legislative, ergonomic, operational and mechanical dimensions and constraints.
According to Temple [1994], a sketch is likely to be made for one of three reasons; to make a quick visual representation of entities or environments exposed to the naked eye; to visually recall the physical nature of objects or environments from memory, or to communicate the physical nature of an entity conceived in the imagination of the sketcher. Nevertheless, whatever the type of sketch, as Tovey and Dekker say:

> *"...its function remains the same: to get the design concept out of one head and into another(...) Each of them represents the design concept in a way that makes it possible to make the right kind of design judgements at that points in the process." [1996:63]*

## 3. Sketching on the computer

In the early stages of design, the free-flowing production of sketches plays a role as a kind of visual stream of consciousness which depends for its effectiveness on complete freedom and the ability to modify instantly. For that reason, computer based initial design development is often found to impede the rapid flow and fluidity of ideas [Temple, 1994]. Until now, paper and pencil sketching has been the predominant tool among those who are actively engaged in sketching, such as industrial designers. According to Tovey & Street [1997], there is a little point in computerising sketch design unless something is gained over the traditional method. Sketching by conventional means is extremely quick and effective, nevertheless, one of the disadvantages of the use of sketches is that they are two-dimensional (2D) and a 2D representation of a three-dimensional (3D) object has inherent limitations as it nearly always involves a loss of dimensionality.
Although, today, the manufacturing industry is aware of several CAD systems that are aimed at providing a support role in the early stages of design [Sener & Wormald, 2001], there is still a significant lack of appropriate software support tools for the conceptual phase. Hand sketches are still quicker and easier to produce. Therefore, designers who are skilled and fluent in the use of paper-based sketching techniques and materials seem to be reluctant to contemplate moving to computer-based systems [Tovey & Dekker, 1996]. In addition, electronic sketch tablets, like paper and pencil, support unspecified input and leave the combining and structuring to the sketchers, appear to be, for now, more appropriate electronic ideation tools. However, they still need to be improved to fulfil the user requirements. As a result, in most cases hand sketches are typically created at the initial concept stages.
Nevertheless, there are at least two important reasons for applying digital tools and models in the early design phases. First, since the decisions made in conceptual design have a very large impact on the overall product success, all methods and tools that would enhance the conceptual design stage should be employed. Second, since in the later stages of product development such as engineering, analysis and manufacturing planning, the product model should be available in electronic form, it would be advantageous to derive those electronic models from CAID systems rather than to convert from traditional media into digital forms. As Hughes & Cunningham mention [1996], using CAD from the early stages of design helps provide visual representations of the product very easily and the computer model can be used to check fits of internal component packages into the space volume. Computerised data can also fed to machining processes to produce further physical models very quickly.

## 4. Research involving CAD users in industry and academia

As it was the most direct way to identify the requirements of users of CAID tools it was decided to talk to current CAD users both in the industry and academia. The users are either of present systems, or designers and engineers that would potentially use a proposed, better tool that does not yet exist. Typically, the first group of users put forward gradual improvements of the systems they already use, whereas the second group may come up with extravagant speculations about what a conceptual design system should be capable of. To obtain data that is useful as an input to developers and researchers of

new tools, it is important to find the right balance between those extremes. This section reports the interviews carried out both in industry and academia through research involving CAD users in England and in the Netherlands.

### 4.1 Interviews in academia in England

It was decided that in order to gather more up-to-date and focused information about the needs of CAD users, current CAD users would be interviewed. A series of research questions was drawn up in order to provide direction to the brief. These questions concerned the strengths and weaknesses of the computer hardware and software as experienced by users, the expectations of those users with regard to functionality and input/output options, and the identification of user expectations over the next five years. A questionnaire was designed which would generate the information required to answer these questions.

Then, face-to-face interviews with nineteen postgraduate design students were carried out. In order to be able to generalise the findings, the interviewees were chosen from a group of students using the same software application during the design process, that is Wavefront from Alias. The aims of the interviews were to investigate creativity and the use of CAD; to explore the capability of current CAD systems to support design activity; and to identify user expectations in the near future. The interview questionnaire was structured under four main sections: (1) Personal and company details, (2) The design process, (3) Computers, and (4) Future expectations, each with relevant questions reflecting the main themes of the investigation. The questionnaire was the same for all participants.

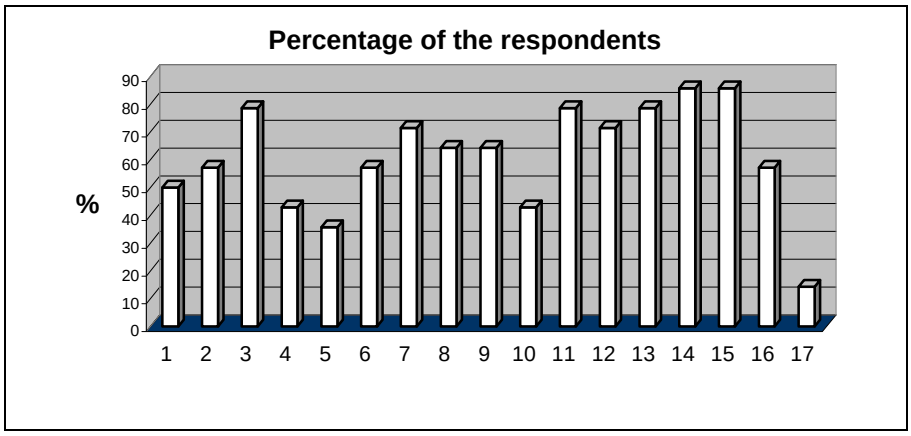
In this study qualitative research methods were selected in order to generate data rich in detail and embedded in a research context. The qualitative data was obtained by tape recordings during the interviews, and they were then analysed.

### 4.2 Interviews within industry in the Netherlands

An inquiry among professional engineers and product developers was performed which focusing on one aspect of design, namely shape conceptualisation. This choice was motivated by the supposition that the geometric shape of a product, although by no means the exclusive aspect of interest, plays a central role in the conceptualisation phase and during the entire lifetime of the design and the realised product. Nevertheless, this conjecture was explicitly evaluated during the inquiries. The interviews did not provide a statistically based account of any design/engineering factor in industry, but rather some typical and practical situations in a company that would pinpoint the issue of a lack of computer support for conceptual shape design investigated.

Engineers and designers from twentytwo Dutch enterprises were asked to provide a realistic description of a shape conceptualisation process as it typically occurs in the company. The respondents were either practising stylists, design engineers, or were directly responsible for a design department. All respondents were involved in a multitude of tasks (Figure 1, *overleaf*), but invariably, each of them was directly connected to the design of the shape of new products. For each case the interviewee was asked about how relevant shape conceptualisation was for the company. They were also asked to what extent computer support was applied and whether or not the introduction of existing or hypothetical tools might have made the process more efficient or more effective.

Each respondent gave a description of a typical, concrete, product design process in his/her company. They were asked to focus on a particular aspect, namely the creation of the product's shape. Information was explicitly requested about the following issues: 1) a concrete example of a project assignment for the design of the shape, 2) the way the shape concept was obtained in the company, which actions took place in which order, and 3) the form in which the designed shape was delivered or presented to the person that gave the assignment. It was found that only 27% of the initial shapes were obtained from numerical data. In the remaining 73% of the described projects, pencil sketching or physical clay modelling occurred first. However, in 93% of the cases, a computer-based model was required as the final output from the design department. Therefore, in the majority of the conceptual shape design processes, a transition from traditional to electronic representation took place.




***1.*** *Market research*
***2.*** *New product specification*
***3.*** *Generating product concepts*
***4.*** *Product aspects*
***5.*** *Product parts*
***6.*** *Global shape specification*
***7.*** *Generation of shape concepts*
***8.*** *Paper sketching*
***9.*** *2D CAD*
***10.*** *3D physical*
***11.*** *3D CAD*
***12.*** *Shape evaluation*
***13.*** *Shape modification*
***14.*** *Shape modification using cad*
***15.*** *CAD model exchange*
***16.*** *Providing feedback to design/styling*
***17.*** *Any other*

**Figure 1. Percentage of the respondents that were involved in the different tasks**

## 5. Discussion

The basis of this discussion is formed by the major points which arose from the investigations. Despite that fact that these were carried out in two different countries, it was still possible to achieve similar results. Although a number of arguments emerged after the inquiries with the CAD users in industry and academia, only the relevant issues are presented in this section.

### 5.1 The important outcomes of the analysis of the inquiries in England

From the findings of the interviews conducted in England, the main issues can be categorised as: problems with the computer graphical interface and usability, problems with data input devices, data compatibility with other software and hardware, and cost. The questionnaire provided interesting answers that would help identify the extent of future expectations of industrial designers of CAID systems. In this section only the results relevant to conceptual design are presented (Figure 2).

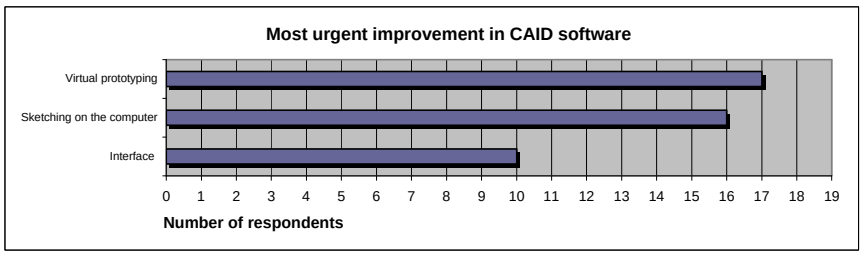



**Figure 2. Issues which require most urgent improvement in CAID software**

1. In spite of being promoted as 'easy-to-use' with improved interfaces, most interviewees (10 out of 19) had problems with the interface and usability of CAD systems. They would like to have less complicated CAD software that they can learn in a much shorter time without having difficulty becoming familiar with the interface. When using the software, it should be:
   *easy to find what tool to use for which purpose; easy to locate the tool; easy to create complex shapes; easy to remember which level of modelling is being used.*
2. All of the interviewees (19 out of 19) were convinced that the initial stages of concept design would always involve the production of sketches. Although the majority of the interviewees (16 out of 19) would like to sketch on the computer they stated that they had not come across any software that they can easily sketch with. Sketching on the computer should:

*complete the lines without any need to complete all the lines; be done as quickly as by hand; allow sketching in three-dimension; be using similar tools as in traditional sketching (such as pen); not limit but allow them to draw exactly what they want to draw; keep records of sketch work as layers that allow the designer to see previously created ones; allow designers to give drawings their own style (i.e. personal touch of designer).*

3. It was noted that nearly all interviewees (17 out of 19) imagined a CAD system which enables them to shape the object by hand, interact with the model by touching, feeling and holding it as in real life. With the advent of simulation technology some new systems, haptic systems, have been recently introduced which allow to joining of visual interaction with the simulation of physical interaction. Nevertheless, these tools have not yet been significantly introduced as a 3D modelling tool in industrial design [Sener & Wormald, 2001]. According to interviewees life-like modelling can be achieved by:
*shaping the object by hand; sculpting the model; touching/feeling/holding the model; interaction with the model/moving around the model.*

### 5.2 The important outcomes of the analysis of the investigation in the Netherlands

1. In 93% of the companies involved in the research, the product's shape was either of dominant importance (33%) or at least as important as other engineering aspects (60%). Furthermore, 100% of the respondents remarked that shape is neither the exclusive concern, nor totally irrelevant (Figure 3).

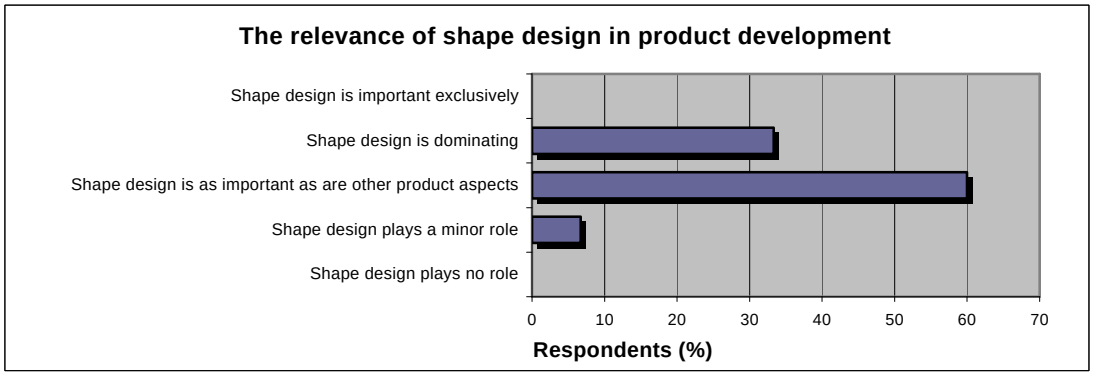



**Figure 3. The relevance of shape design in product development**

2. 15% claimed that conceptual shape design does not pose a significant problem.
3. The designers were asked which activities of the process of shape development needs improved support most urgently: 40% of the respondents mentioned the initial input of shape, and 45% shape modification with some form of feedback from manufacturing or other parties.
4. The aspect of shape development frequently indicated (28%) as the one that lacks computer support was manufacturability in conjunction with some sort of easy shape control or shape parameterisation (Figure 4, *overleaf*). 28% of the respondents mentioned shape evaluation, analysis and/or prototyping as the most important aspect that should be better supported. More general aspects mentioned included ‘better surface modellers’ (20%) and 'cost, speed, quality' (20%).

## 6. Conclusions

It can be concluded that professional users of CAD (CACD and CAID) systems still experience severe limitations and shortcomings from the currently available tools. By considering the role of sketching in the design process and the user feedback during the research carried out, the important requirements of CAID systems and the issues which will influence future research can be summarised below.

From the questionnaires a number of technical issues concerning CAD support for conceptual shape design needs to be clarified in an explicit way. One of the most salient outcomes from the investigation is the strong need for free and fast control of the shape, *however under certain constraints*. The character of these constraints differs among the different process descriptions; they originate from manufacturing, styling or functional requirements.

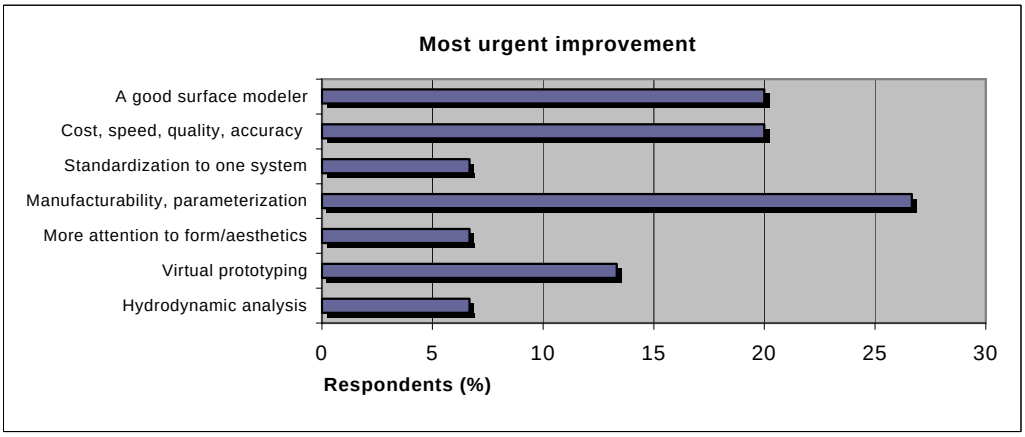



**Figure 4. Issues in the shape conceptualisation process which need most urgent improvement**

A dilemma becomes apparent in CAD research and presumably within the CAD software industry as well. On the one hand, users from styling design claim that they need (miss in CAD tools) the ease and fluency of 2D hand sketching [Goldschmidt, 1991] and claying [Tovey, 1998]. On the other hand, the imposing of explicit constraints on the shape model is mandatory in the later stages, and also in some situations during the early stages of design. In conceptual design, it could be concluded, there is a need of *partial* or *interim* design constraints and design parameters. A possible direction of future research is the use of freeform shape parameters. The primary motivation for the dedicated research is to determine which types of constraints and parameters would be the most effective for particular design tasks and design situations. The key to the successful integration of computers into the design process is not just having the technology available, but also ensuring it is used correctly within a well planned and managed development programme. Moreover, the increasing importance of vendors in supporting their software development as well as solving existing problems has to be acknowledged.

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