

COMPUTER-SUPPORTED SHAPE CONCEPTUALIZATION - INTERFACING ENGINEERS WITH ACADEMIC RESEARCH

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1 Introduction

In spite of the advances of current Computer Aided Design (CAD) systems, the conceptual phases of design still suffer from a lack of appropriate software support tools. Contemporary research toward design support and automation puts substantial effort into the development of improved Computer Aided Conceptual Design (CACD) and Computer Aided Industrial Design (CAID) systems, both by industrial R&D and by science academia. However, there appears to be a severe issue concerning the interplay between academic research and the concrete needs of designers in industry [1]. A recent survey [2] in France of small and medium enterprises revealed that the majority of these companies declared that they do not use any academic method or procedure in the design stage, except in detailed design.

The proliferation of CAD in the conceptual design and styling departments is significant, but still far from what could be expected, considering the almost unlimited flexibility and freedom that recent modelers provide to the user. Gaining understanding of this apparent mismatch was our motivation to explore the user's requirements more deeply. This might help to increase the chance that the technical requirements for the tools are the ones that should actually be fulfilled. The following problems were addressed:

1. How should conceptual design tool requirements be obtained, and from whom?
2. How can these requirements be interpreted and be verified?
3. How can these requirements be met?

In scientific research, the latter problem should not form the starting point of a project, but a proven or tested condition. We report initial results of a research into new conceptual design tools, in which all three stages are comprised. However, the main emphasis of this paper is on the first stage, namely, the extraction of authentic requirements. The verification of requirements is also addressed.

2 Extraction of tool requirements from companies

The most direct way to identify the requirements of better design tools is the inquiry of the users working in the industry. They can be either the users of present systems, or designers and engineers that would potentially use a proposed, better, but not yet existing tool. Typically, the first group of users will 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 a right balance between those extremes [3].

In this section we report on an inquiry among professional engineers and product developers. We focused on one aspect of design, namely shape conceptualization. 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 conceptualization phase and during the entire lifetime of the design and the realized product. Nevertheless, this conjecture was explicitly evaluated during the inquiries.

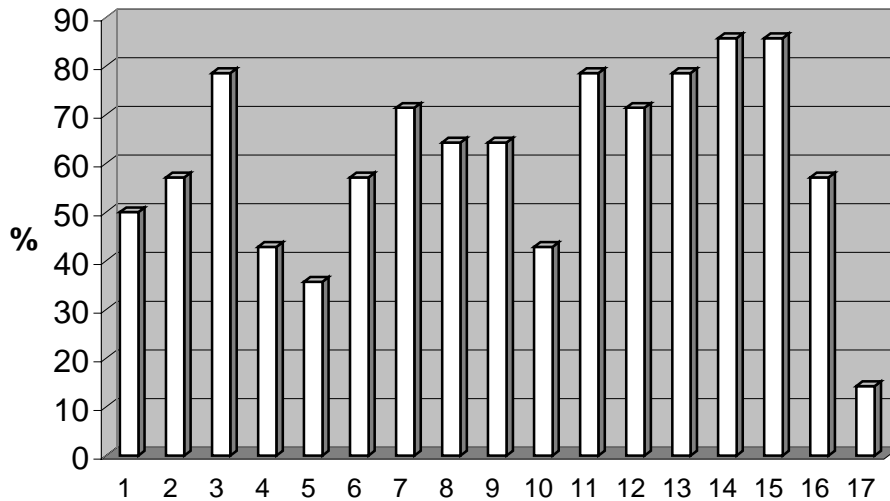
The aim of the inquiry was to obtain input to the research into new computer-based design tools, as presently conducted in the ICA project at the Delft University of Technology. One of the issues studied is concerned with the apparent shortcomings of even the most recent shape design tools. It is sometimes stated that the user should have unlimited freedom when manipulating the object's shape. This is seemingly what is offered to the user in the form of unlimited pick-and-drag of any point or region on the shape. However, we hypothesize that unlimited shape editing can be far from effective, and that constraints into these processes should be introduced, even in the earliest stage of shape conceptualization. The inquiry was meant to explicitly reveal these types of issues.

The inquiry does not provide a statistics-based account of any design/engineering factor in industry. We were looking for some typical, practical situations in a company that would pinpoint the issue of lacking computer support in conceptual shape design. The companies that we approached do not necessarily form a representative subset of any branch of industry.

We asked engineers and designers from 22 enterprises to provide a realistic description of a shape conceptualization process in their opinion as it typically occurs in the company. For each case we inquired how relevant shape conceptualization was, for the company in general and for the specific design process that was mentioned. Then the respondent was asked to supply detail about the depicted shape conceptualization process. A questionnaire was used to enter data about these processes. We also asked to which 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. Also the perceived shortcomings of the shape design process and/or actions associated to it were investigated.

2.1 Results from the inquiry

The response rate to the questionnaire was 68% (15 out of 22). Compared to other written inquiries this is a very high response rate. Rather than approaching companies using bulk mailing we contacted responsible engineers by telephone or e-mail first and asked for their agreement to accepting the questionnaire. The questionnaires were sent only to those companies that reacted positively. The respondents were either practicing stylists, design engineers, or were directly responsible for a design department. All respondents were involved in a multitude of tasks (see figure 1), but invariably, each of them was directly connected to the design of shape of new products. The companies were all located in the Netherlands and ranged in size from one-man's offices till multinational enterprises.



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

Figure 1. Fraction (%) of the respondents that were involved in the different tasks.

For a full analysis of the returned questionnaires we refer to [4]. In this paper we only highlight the findings that are most relevant to the extraction of tool requirements.

As mentioned, each respondent gave a description of a typical product design process in his/her company. The respondent was 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 the 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 or contractor that gave the assignment. The subsequent questions were referring to the shape design process description provided. In this way, we tried to avoid receiving merely general statements about shape design processes and their possible improvement; now the respondents were encouraged to formulate the answers in a more concrete way.

It was found that only 27% of the initial shapes were obtained from numerical data. In the remaining 73% of the described projects, some form of pencil sketching or physical clay modeling occurred first. However, in 93% of the cases, a computer-based model was required as output from the design department. Therefore, in the majority of the conceptual shape design processes, a transition from traditional to electronic representation form took place.

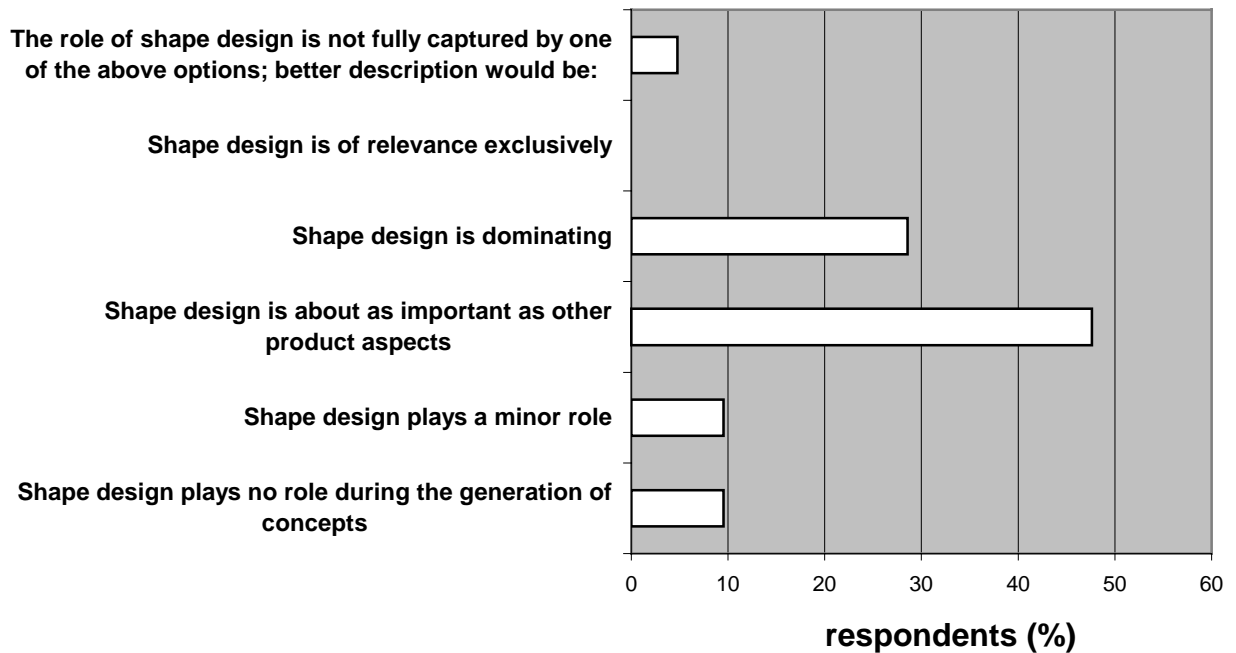


Figure 2. The relevance of shape in product design.

The important outcomes of the analysis are:

- 1) In 87% of the investigated companies, the product's shape was either of dominant importance (40%) or at least as important as other engineering aspects (47%). However, 100% of the respondents remarked that shape is not the exclusive concern (figure 2).
- 2) Only 15% of the respondents claimed that conceptual shape design does not pose a significant problem.
- 3) We asked the designers which activities of the process of shape development needs improved support most urgently. 40% of the respondent 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 most frequently indicated (24%) as the one that lacks computer support was manufacturability in conjunction with some sort of easy shape control or shape parameterization (see figure 3). 42% of the respondents mentioned shape evaluation and analysis of some type as the most important aspect that should be better supported. More general aspects including "better CAD/CAM systems" (18%) and "cost, speed, quality" (24%) were mentioned as well.

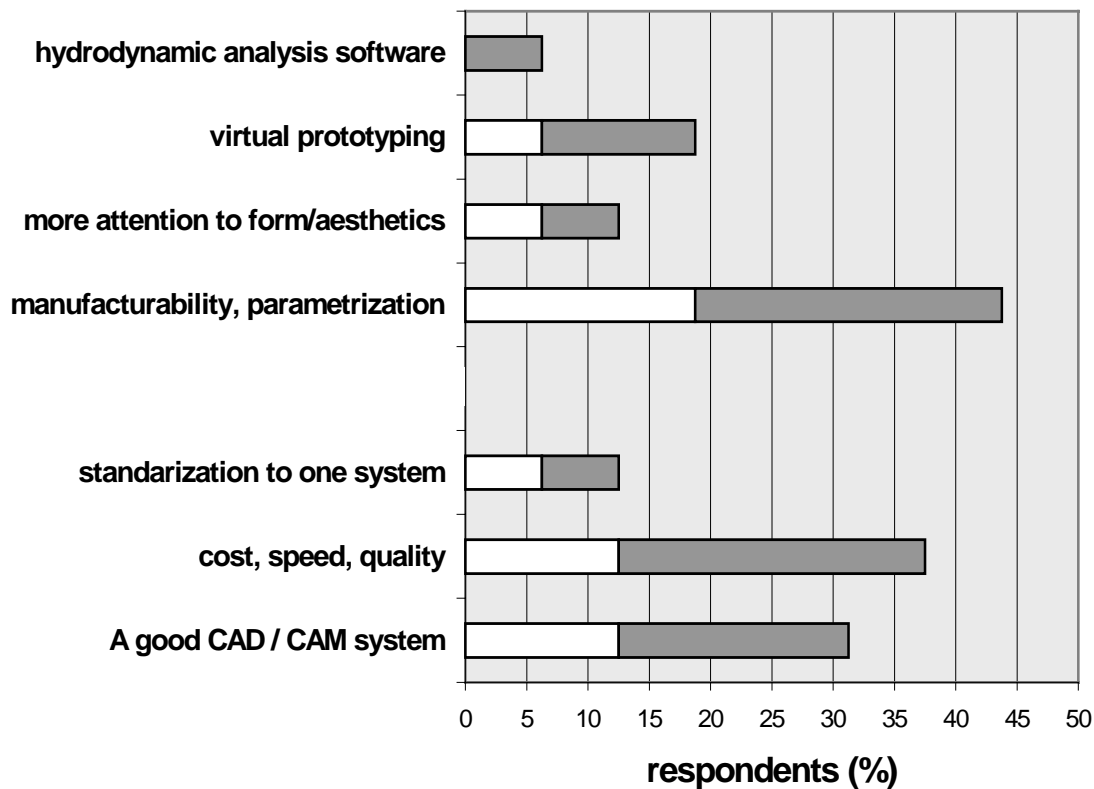


Figure 3. Issues in the shape conceptualization process which need improvement most urgently. The white portions represent those respondents who were explicitly involved in shape evaluation.

2.2 Conclusions from the inquiry

From the questionnaires a number of technical issues concerning CAD support for conceptual shape design could be clarified in an explicit way. Some of these issues are being addressed by research in the ICA group; voice control and behavioral shape modeling are example topics. 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.

3 Additional sources of tool requirements

Recently, we have investigated a number of different methods to increase the involvement of the end-user, *i.e.* the designer, in search for better design support tools. Some of the existing and emerging methods are described below.

Experimental design projects. A quite drastic strategy was developed to discover priorities and requirements of design support explicitly from protocol data, and to measure the productivity change due to the implementation of the supporting tool [5]. The data was used to visualize and analyze activities, information requests and design performance as a function of time, and to statistically correlate the quantities. The value of a design process was rated based on an independent judgement by an expert, who determined which of the technical

requirements were addressed and met in the design concept. The rating was defined as the fraction of the engineering requirements met by the design as documented by the subject.

Research Cycle Methodology. This refers to a procedure that is suited when the focus is already on a particular type of tool. A panel consisting of practising designers is involved. This panel’s role is (a) to ensure the *a priori* relevance of the newly proposed tool and of its requirements and (b) to actually operate pilot implementations of the tool as part of the evaluation. This methodology is referred to as a Research Cycle, since its purpose is to enhance the understanding of the requirements on conceptual design tools [6]. The methodology was successfully applied for the investigation into a dedicated surface feature system [7].

Quick Evaluation. This method has been used to evaluate a new shape design tool when it was in the stage of pilot implementation [8]. The main steps in this method are (1) Preparation of a video recording of the usage of the design tool. (2) Preparation of a questionnaire, intended to be filled out by the evaluation panel members. (3) Selection of an adequate evaluation panel in industry and obtaining agreement from them to participate in the test program. (4) Sending the videotape, the questionnaire and instructions to the panel members. (5) Interpretation of the feedback obtained from the evaluation panel.

Abstract Prototyping. Abstract prototyping can be defined as the process of development and testing of abstract or in other words incomplete design support software implementations[9]

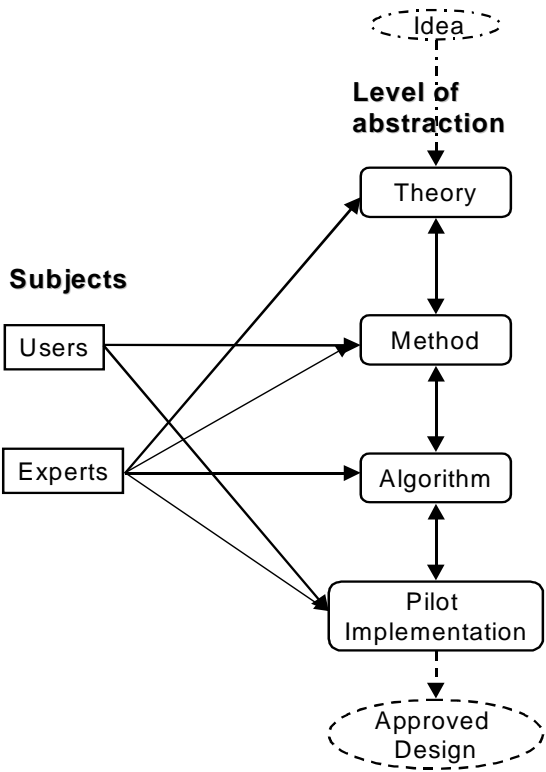


Figure 4. The users - experts involvement in abstract prototyping

Initially this method was successfully applied to test end-user requirements of new design tools, before any implementation form was available [3]. The method has been extended to

provide a systematic approach for involving the developers and various stakeholders in pre-implementation testing of design support software tools (Figure 4). Theories, methods, algorithms and pilot implementations are regarded as testable implementation of design support software. Requirements are clustered according to the levels of abstraction of the implementation and are used as evaluation criteria. Recent results of the research on abstract prototyping are published in [9]. The idea behind the abstract prototyping techniques at present is to introduce quality improvement cycles in the early stages of the design support tools development processes, and to provide a structured framework for defining requirements and testing of the incidental implementations of design support tools.

4 Conclusions

The inquiry learnt that context-sensitive shape editing was one of the most lacking functions of conceptual design tools. This touches a fundamental issue in design computation, the trade-off between the offering of tools for free and fast creation of shape alternatives on one hand, and on the other hand setting and maintaining constraints to the shapes. The challenge, obviously, is to dynamically ascertain which constraints should and which ones should not be applied to the designed shape. The ultimate shape design tool should have that capability. Some of the respondents even explicitly declared that they needed a tool to manipulate parameterizable shapes, where manufacturing constraints were implemented into the parameterization. This functionality is offered by feature-based CAD/CAM systems, but in the domain of regular shapes only, not for freeform shapes[10].

The various methodologies that we presented, contribute to a better interface between CAD tool developers and the stakeholders in industry. Such an improved interface is indispensable for the effective research into new design tools.

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