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OVERVIEW OF THE INITIATIVES ON THE DEVELOPMENT OF DESIGNER'S TOOLKITS

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1. Introduction and problem definition

Since the introduction of the computer in design processes there has been a development of a range of computer products for designing with computers. Several research programs started to integrate computer aided design programs to create a design environment that could be used in all phases of the design process [Hennessey, 1987]. Now, after fifteen years we started a literature search to investigate the goals and results of the initiatives. The question to be answered in this paper is: "What were the initiatives and goals for developing an integrated computer design environment, and what has been achieved?"

To gain a clear view of what has happened and what has been achieved in the development of computer tools in the design process we will give an historical overview as well as an overview of the developed tools categorized in phases of the design process. These overviews are based on the 94 articles we found related to designer's toolboxes and therefore cannot be considered as unabbreviated. The goals and initiatives are mapped and the results and reasons for failure are investigated.

2. Description of the design process model

To categorize the researched initiatives, a design process model is presented, which is based on our own design experiences and on the models we found while studying the literature [Roozenburg e.a., 1995]. Because of the iterative character of a design process the model cannot be seen as strictly linear.

We identified the following seven phases:

1. Analysis

The first phase in a design process consists of analyzing the assignment and investigating the requirements that will lead to a problem definition. Also the investigation of standards and market information belongs to this phase.

2. Product idea generation

During the product idea generation phase, the first sketches are made; this phase is also known as synthesis. It is hard to get grasp of the synthesis phase, because the human creativity plays an important role in it.

3. Conceptual design

During the conceptual design stage of the process, the ideas and the problem definition will lead to the establishment of one or more defined concepts. These concepts are compared with the requirements and one concept is chosen.

4. Detailed design

Detailed design concerns the materializing of the final concept derived from the conceptual design phase. In this phase materials and production technologies are chosen and constructions are detailed.

5. *Evaluation phase*

   During design evaluation, the analysis results are derived and compared against the predefined requirements and objectives. If necessary, the design is modified again and the process repeats itself until a satisfactory design solution is obtained.

6. *Manufacturing planning*

   During the sixth phase preparation of the design for fabrication, assembly and transport, and the development of the production process are carried out.

7. *Production*

   In the production phase the actual production of the design takes place, resulting in a ready-for-market 3D-product.

These last two phases will not be considered further in this paper, because we focused our literature study on the first five phases.

3. Overview of tools for the design process

The articles we have studied describe many tools, which we tried to categorize in the phases of the above described design process model. Some tools can be used in more than one phase.

Analysis

In our literature we did not find many specific tools developed for the analysis phase, but that does not mean the computer plays no part in this phase. As a matter of fact: the computer has a very important role, shaped in complex electronic databases and the use of internet, which has lead to a global spread of information. Therefore, the computer cannot be excluded from the modern way of retrieving data (e.g. digital knowledge bases and the internet). There is such a vast amount of electronic data retained in databases, that it requires some expertise to manage the search for specific files. There exist several programs for analyzing ergonomic and marketing data (e.g. ADAPS, SPSS).

Product idea generation

In our experience it is hard to draw a sharp line between the product idea generation phase and the conceptual design phase. The tools developed for product idea generation must combine the ability to search for structures, generate ideas by sketching and find different solutions to one idea (e.g. Fast shape designer, Teddy sketch, Sketch up, Gesture VR, Quick sketch and GEMCON).

Conceptual design

In the past years the academia have done much research on the requirements and developments of conceptual design. Besides developing new tools, research has been done on using existing CAD/CAM tools for conceptual design. According to [Vergeest, 1996] the main reason for the lack of computer support during conceptual design is the apparent chaotic nature of the activities. (Tools: e.g. Schemebuilder, HI RISE, CANDLE, DMPShape Sipsurf and CONMOTO).

Detailed design

The detailed design phase is equipped with a lot of research and literature. In our research the greater part of the literature consists of literature on detailed design. A few remarks can be made: the literature found is often about the benefits and drawbacks of the latest CAD-programs. Much literature is based on adjusting databases to CAD-programs. The development of databases has been put into action by the adaptation of the CAD-software of those days to the engineer users. In 1985 according to the literature engineers need more expressive power within database management systems than is currently available commercially. Also a lot of literature is based on the requirements for CAD-software and the improved complexity of the software (e.g. Strim 100, Autocad, Raymo, Rhino, Geonode, Pro Engineer, Medusa, SDRC, Geodat/campus, Solidworks and Didacoe, CADAMP, Sculpturing robot system).

Evaluation

The evaluation phase is to be considered as a time for analyzing, simulating and testing the designed object. The ability to test products provides the designer with knowledge about the product's usefulness and its strengths. The simulation and testing tools are developed on several aspects of the design: material and construction strength etc. (e.g. Moldflow, Tutsim, Procop, Ansys, Marc, Simapro, C-mold and Eco-scan.)

4. Historical overview

Besides the overview in the different design phases, we also created an historical overview of the 94 articles we have studied. In this overview the changes in emphasis in the developments of design tools are presented alongside a time-axis. Thereto we have tried to describe for each year the main contents of the articles in one sentence. Figure 1 represents this overview in which the articles in a timeline from 1984 to the present are presented. Of each year we give a short description of the main topics of the articles and the total number of researched articles.

5. Discussion of the initiatives in the design process

In this discussion we will first explain the main difficulties described in the literature. Also we will discuss some initiatives.

Because of the vast amount of data available in knowledge bases in the *analysis phase*, one may have difficulty selecting the appropriate information. Besides that the conversion between the analysis phase and the product idea generation phase is not well implemented. The output of the analysis phase cannot serve as direct input for the idea generation phase. The transition is made by the designer, without the help of any computer-aid.

In the *product idea generation phase* are certain sketching-tools available. These tools have a disadvantage: there is a lot of specific form information needed to use the tools, while the idea generation phase is meant to be a creative process in which at any given time the shape is defined only partially. Besides it cannot be proved that using a sketching tool will give the designer any financial or time advantage. You might even say that the designer is not at all interested in a tool for product idea generation, because the designer does not have a problem in this phase, for which he needs computerized support.

In the *conceptual phase* the main problem is to constrain the complexity of choices. One of the main differences between the requirements for the conceptual phase and the abilities of CAD is that CAD has a very static design environment and conceptual design needs a dynamic system where there is the constant possibility of adjustment. Conceptual design by CAD is not anymore about the technical specifications and capacities of the computer as discussed in the 80s and 90s, but instead the attention is on the user interface and the control of a large complexity of choices. Ulrich Flemming (1997) says that the CAD tools are used inefficiently, because users compare the CAD-program with their past experience with traditional drawing media. This prevents them from discovering and using effectively powerful system commands that have no equivalent in manual techniques. These findings suggests that we should rethink the ways CAD users are trained and manuals are written, and introduce CAD users to a more strategic use of CAD.

In the 80s the emphasis of the developments of *detailed design* were on database management. The main problem then was the PDM within the CAD system. This can now be seen as a problem for the conceptual design.

The *evaluative tools* are used at the end of the design process, while the beginning of the design process is the most cost determinative. It would be very useful to use the evaluating tools earlier in the process to support the making of design decisions during the conceptual phase.

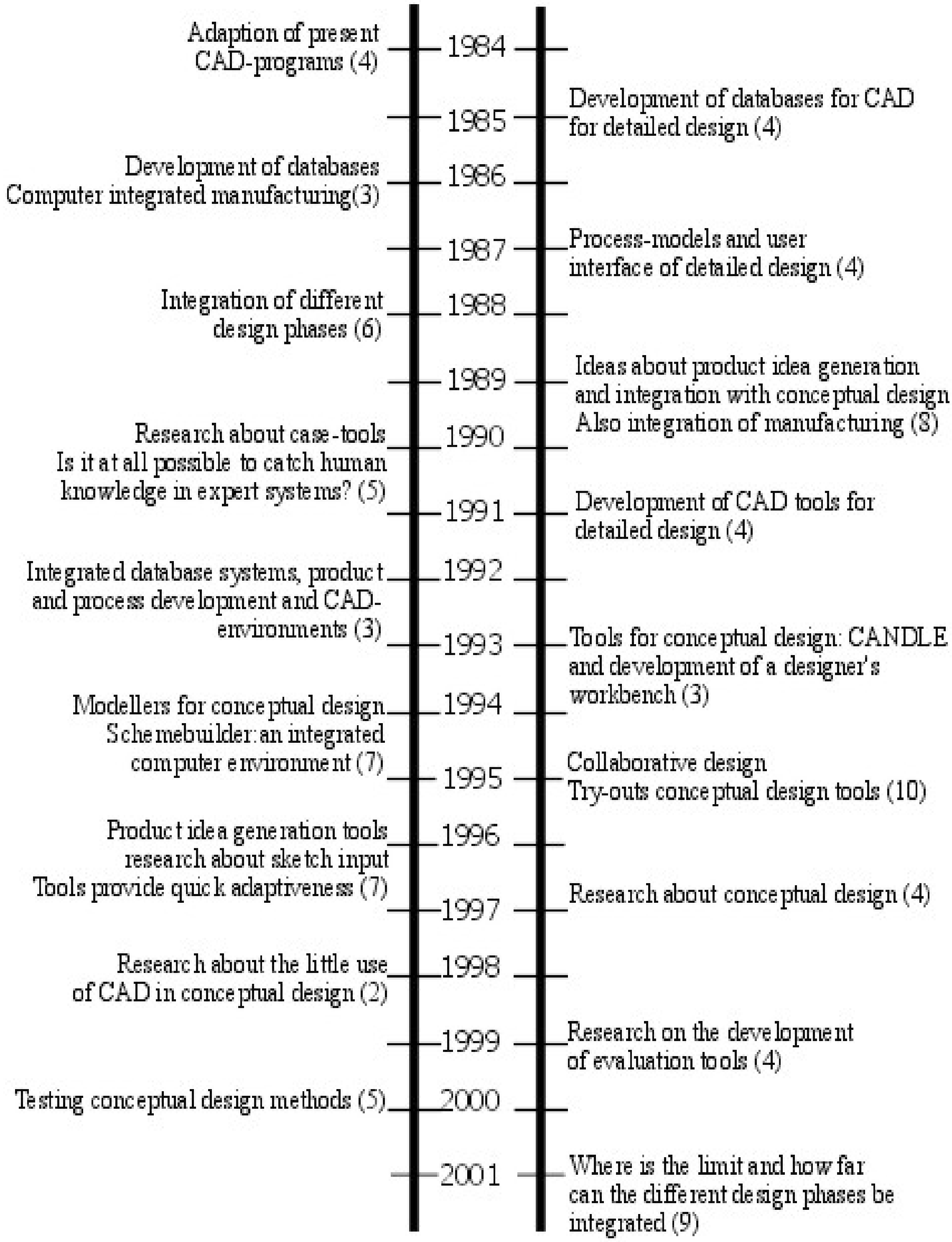

Figure 1. Timeline

6. Initiatives

The first initiatives for a product idea generation supporting tool started in the late 80s but continued in the mid 90s. An example of a few initiatives:

1. Mogens Myrup Andreasen: "Product modeling in a designer's workbench" [Mortensen, 1993]. The goal of the project was to develop elements for a designer's workbench based on the chromosome model. The project aims to answer the question of how products and product-

programs can be structured and if a modelling framework can be proposed for support of structuring to be implemented in design support systems

2. The IDEATE research projects: supporting design conceptualizing by J.M.Hennessey [Hennessey, 1994]. This research has been done, at the faculty of Design, Engineering and Production, on the use of computers during the conceptual design phase. The goal of the IDEATE project was to develop a designer's toolkit, which was able to bridge the gap between 2D representations and actual 3D objects. One of the important discoveries of the research is the need to have design tools on varying levels.
3. Desys (design environment system) project research group [Knoop e.a., 1995]: development of tools and methods to improve the output of product creation processes. Desys is part of a larger research structure, the TPI-programme, to develop support and optimize the product creation process and create a greater understanding of the role of information in product design. It focussed on the information aspects first before defining any requirements for a tool.
4. An Universal Design Theory [Grabowski, 1999] is a design theory containing findings and knowledge about design from different scientific and engineering disciplines in a consistent, coherent and compact form. The theory is part of a project named “ Design Theory-A new aproach for design”. A main assumption is every artifact which has been designed on earth is a combination of well known phenomena. One aim in the future is to make the design theory universal, which means to bring as many different domains as possible together, such as chemistry, chemical engineering, material science, technical biology etc.
5. The aim of H. Meerkamm et al. [Meerkamm,1999] is to develop a workbench which will help the mechatronic designer to integrate the design process, use adequate design languages for modeling and use the necessary components to support this process via a computer. Their conclusion was there is no appropriate universal design language, but instead a generalized description for engineering documents is available in form of bondgraphs. The components catalogue of generalized effects, component and model synthesis, component for model transformation and the simulation component are a profitable part of the workbench. Also Meerkamm was part of a program in which an assistance system was initially realized, with which the designer is supported during the selection of the best suited construction structure, based on product relevant analyses of mostly non-geometric data. Future work will be concerned with a further computer-support, which, through multi-criterial processing of the analysis results, recommends the best suited construction structure variant to the designer.

The first project is still continuing and has been implemented as a so-called Product Family Master Plan in 22 companies. The second and third initiatives were primarily ideas and confined themselves to research on the computer support of product idea generation and conceptual design, and aren’t actively continued.

7. Conclusions

Though there have been some initiatives to develop an integrated designer’s toolkit, the initiatives have not yet led to the development of an actual commercially usable designer’s toolkit for all phases of the design process. When one wishes to develop such a toolkit, research must be done on complex PDM-systems, the use of flexible constraints and conversion techniques.

Many tools are developed for the detailed design process. The first phases of the design process are, however the most cost determinative. The advantage of a new designer’s toolkit can be found in the analysis and product idea generation. The use of a tool there will be an improvement, as long as the tool leaves enough freedom for adaptation by the designer. This tool can be implemented as a structured knowledge base, which guides the designer in the retrieval of required information from knowledge bases and helps to structure the large amounts of data generated in these phases.

Because the articles described a reluctance to use newly introduced programs and users seem to be unwilling to give up their own ways of generating ideas, we believe the user must grow towards such a toolkit. The future generation of designers will be accustomed with the use of computers in the design process, which will make new developments easier to accept.

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