THE MOBILE ARM SUPPORT PROJECT: A TEST-BED FOR DESIGN RESEARCH AT THE CAMBRIDGE ENGINEERING DESIGN CENTRE

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Abstract--A host of methods and tools to support designing are being developed in Cambridge EDC. These range from tools for design management to those for the generation and selection of design ideas, layouts, materials and production processes. A project, to develop a device to improve arm mobility of muscular dystrophy sufferers, is undertaken as a test-bed to evaluate and improve these methods and tools as well as to observe and modify its design and management processes. This paper presents the difficulties and advantages of using design methods and tools within this rehabilitation design context, with special focus on the evolution of the designs, tools, and management processes.

I. INTRODUCTION

The objective of the Cambridge Engineering Design Centre (EDC) is to develop fundamental methods and tools which will support designers to develop better products. The core philosophy of the EDC is that a better process enhances the chance of developing better products. The term "process" as understood here includes that of designing as well as of managing the design process. The focus of the EDC has been specifically on supporting the earlier design phases such as those of task clarification and conceptual design. The earlier phases are vitally important for the design as most crucial commitments are made during these phases.

A number of methods and tools for supporting various activities during the design and management processes are being developed [1, 2]. In order to realistically evaluate these tools, a realistic design context is needed. Within this context, existing tools and methods can be evaluated for their potentials and scopes for improvement can be identified, leading to improvement of the existing tools and methods as well as to the development of new methods and tools.

In order to provide this design context, an in-house project was chosen. The objective of the project is to develop a means of supporting daily activities of muscular dystrophy and atrophy sufferers. Dystrophy and atrophy are disorders which lead to gradual deterioration of muscles [3]. The disorder proceeds from proximal to distal muscles, so the sufferers have some strength in their fingers while practically none in their arms. They soon become wheelchair-bound, and are dependent on carers for their daily activities which involve lifting and carrying of loads.

While it cannot provide an industrial context, an in-house project has the advantages of being easily observed and controlled. The project has run though two cycles: phase I and phase II, leading to the development of two mobile arm support (MAS) prototypes [4, 5, 6]. The usefulness of the tools under development were tested at various stages of this project, which led to identifying further avenues for their improvement. Some of the results of this evaluation and modifications will be highlighted below.

II. SOME RESULTS AND OBSERVATIONS

Three areas are discussed here: (i) the evolution of the MAS design over the two phases, (ii) the modification of the management style, and (iii) aspects of tool use and usefulness, with SpecBuilder as an example.

A. Design of the Mobile Arm Support (MAS)

In phase I, the goal was to develop a proof of concept for a device to improve arm mobility of a sufferer, so that they can independently perform activities (such as eating and drinking) for which they are currently dependent on their carers.

The design is essentially a four-bar linkage attached to the wheelchair and has powered vertical motion and a foot-switch control With the aid of this device, one sufferer, for instance, could manage to eat un-aided for the first time in twenty-five years. However, there are a number of tasks that the design could not support. Moreover, the design was not optimised in terms of cost and weight, and its aesthetics could be improved.

It was decided that the arm support in phase II would be an improvement on MAS I to provide improved functionality (e.g., to support a larger area of reach), weight and cost-effectiveness, and aesthetics. The result has been an arm support with sculptured surfaces, having a polar co-ordinate-like motion to allow for natural movements and with a bent fore-arm to provide access to a larger area. The number of standard parts have been increased to reduce the cost of the device.

B. Evolution of the Management Strategy and Style

The management process could be seen as a plan-implement-observe-modify cycle where human and other resources are utilised to meet the objectives of the design within a given deadline. The tools under development at the EDC are intended to support a design in an industrial context. However, the goals of this in-house project were different from an industrial design project. Besides developing a prototype, it was necessary to use and test the tools and methods, and also record the process for further research. Two aspects of the management process were observed and modified: the strategy

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(resource management), and the style (human aspects).

With the emphasis on simulating an industrial context, the management strategy in MAS I consisted of a chief designer responsible for all the deliverables (i.e. management, design, tool use and recording/documentation of the process, with the rest of the EDC members in consultant capacity. The style was authoritative. The management process led to the development of a sound proof of concept; however, use of resources, tool use and process documentation were less than satisfactory. The single strategic cause identified was the overloading of responsibilities on a single person. It was also suspected that the authoritative style led to low motivation. In the cases of documentation, it was found that designers have problems in simultaneously putting on designer's and observer's hats. The reason for the lack of tool use was identified to be the lack of sufficient awareness of the tools to know where in the design process they should be applicable.

The style was thus changed into a less hierarchical one, with a major division of responsibilities, along with a clearly laid out communication structure in terms of the strategy. For each major deliverable, there was a small group responsible, with others in consultant capacity. In order to improve tool use, one person was used as an intelligent interface who would quietly listen to the designers' discussions and suggest the use of tools when appropriate. The implementation of this management strategy and style resulted in the development of a design, having the promises of fulfilling the requirements, within the imposed deadlines. There was high motivation as the members felt more involved in the project. However, although more documentation was produced in phase II than in phase I, and more tools were used during the design process, these still were less than expected. Two main reasons are identified: one is the logistics of the environment, and the other is the mental block of the designers. The first is that it was impossible for the person acting as the tool interface to be around each time designers spontaneously met, which often extended to three times a day! The mental block that designers had was that they could do what the tools would in less time than the tools (with learning time included), and thus they felt it would not be useful to use the tools. However, more often than not this assumption was found untrue, and when they were forced to use the tools, they always found them very useful.

C. Evaluation and Modification of Design Support Tools

Two aspects of the tools were observed: whether they are/can be used, and whether they produced useful results.

SpecBuilder is a tool for helping designers to (i) clarify the design task with the use of a systematic checklist, and (ii) store the requirements in a structured way; this tool can be used in conjunction with evaluation methods to support structured evaluation of design alternatives [2]. In phase I of the project, this tool was used and was found simple and easy to use. However, there were two areas of weakness: it did not have a scope for distinction between customer and engineering requirements, and had little scope for relating these two requirement types. This is important if one must ensure that the requirements list reflects the wishes and aspirations of the user.

In phase II, quality function deployment (QFD) charts [2] were used to compliment SpecBuilder in the above two areas. These charts have rows where demands and wishes of the users are listed. The columns of the charts list the engineering requirements that translate user demands into engineering and economic quantities. The row-column junctions indicate the relationship between the corresponding user and engineering requirements. It has a number of advantages, including the identification of user requirements which are not translated into engineering requirements, and the identification of strong/weak points of other competitive products. However, it was found to be too complicated to use. Also, there was too much information to present to the designer. Moreover, determining engineering requirements, and relating them to engineering requirements, were difficult. Currently a tool is being developed at the EDC [2] which will combine the advantages of QFD and SpecBuilder.

III. CONCLUSIONS

This project is probably the only well-documented case of rehabilitation product design where design methods and tools have been explicitly used and tested for their applicability. On the whole, the experience was rewarding: apart from the fact that two satisfactory designs were produced, the project provided valuable insights into the importance of the management process, especially its human aspects. Notwithstanding all efforts, recording and documenting, as well as tool use, were found difficult to effect, indicating the human aspects of these problems. On the whole, tool use was found useful, and the experience highlighted the importance of easy and efficient user interfaces. It is interesting to note that the problems of documentation and tool use are similarly pronounced in industries, and the project gave some indications as to how these could be resolved.

REFERENCES

[1] N. R. Ball and F. Bauert, "The integrated design framework: supporting the design process using a blackboard system," in *Artificial Intelligence in Design '92*, J. S. Gero, ed., Dordrecht: Kluwer Academic, pp. 327-348, 1992.

[2] F. Bauert, C. A. Abel, K. L. Edwards, W-T. Chong, I. Evron, "The management assistant: tools to support managerial activities of engineering design projects," Tech. Report CUED/C -EDC/TR 15, Cambridge Univ., Dec. 1993.

[3] M. B. Wagner, P. J. Vignos, and C. Carlozzi, "Duchenne muscular dystrophy: a study of wrist and hand function," Muscle & Nerve, vol. 12, pp. 236-244, 1989.

[4] F. Bauert, "The mobile arm support phase I: design, manufacture, testing, software tools," Tech. Report CUED/C-EDC/TR 13, Cambridge Univ., Feb., 1993.

[5] A. Chakrabarti and C. Abel, "The mobile arm support project: a test-bed for design research at the Cambridge EDC," Tech. Report CUED/C-EDC/TR 17, Cambridge Univ., 1994.

[6] B. Wolf, "Systematic Design of the attachment for a mobile arm support,"Konstruktiver Entwurf, Technische Hochschule Darmstadt and Cambridge Univ., June 1994.