Intelligent Design for X

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Abstract: - Intelligent "design for X" systems aim to capture the expertise of an expert in some aspect of manufacture or use of a design, and to make this expertise available to designers to assist in optimising the design in the area of expertise. Two examples of such expert computer aids are discussed in this paper. The first system is related to ergonomic and aesthetic design, while the second system is meant to provide advice and design strategies in product development from plastic materials.

Key-Words: - knowledge based systems, engineering design, product development, ergonomics, aesthetics, plastics

1 Introduction

The use of computers in the modern design process is almost inevitable. Computer aided design (CAD) is extensively applied in every company that wants to stay competitive on the market. Yet, the existing CAD systems concentrate rather too much on graphic presentation of the design, but have the limitations in providing design information and advice.

Even though CAD systems concentrate mainly on the modelling of designs, the range of properties that are well represented in CAD is quite limited. Only the geometric form and dimensions are covered satisfactory, whereas the other properties like tolerances, material, surface condition, etc. are generally covered by annotation of a drawing, or by attaching attributes to a three–dimensional model. Moreover, even the geometric aspects of a design could be modelled much more in a way that designers think of them, for example in terms of manufacturing features like a drilled and taped hole. In fact, a route that is currently being explored in CAD research is to represent components in terms of higher–level entities, called “features”, which do have some engineering meaning.

Design projects normally originate in form of problem statement provided to the designer by someone else – the client or the company management. These problem statements set a *goal*, some *constraints* within which the goal must be archived, and some *criteria* by which a successful solution might be recognised. It is usually possible to improve the initial definition of the problem. Yet, many design constraints and criteria still remain unknown and the existing CAD approaches are not able to help designer in dealing with uncertainty and inconsistencies. Thus, the quality of design solution depends mostly on the designer's skill and experience.

Specific design areas have their specific constraints and criteria and therefore require specific approach in design process. Some ideas and development strategies to build intelligent modules in terms of knowledge based (KB) computer systems for supporting specific goal-oriented design processes are presented in this paper. Two examples of such intelligent modules, first for KB support to ergonomic and aesthetic design and second for KB design of plastics products, are discussed in detail.

2 Design for X

Customer needs and product specifications are the basic guidelines in the concept phase of product development. However, during the later design activities, development teams often have difficulty to link specifications and needs to specific design issues they face. For this reason, many design engineers practice so called "*design for X*" (DFX) methodologies, where X may correspond to one of many quality criteria, from more general, such as reliability, appropriateness for assembly, robustness, and maintainability, to more specific, like environmental impact, ergonomic and aesthetic value, etc. [1]

The most common of these methodologies is design for manufacturing (DFM), which is of universal importance, because it directly addresses manufacturing process and its costs. Effective DFM practice leads to low manufacturing costs without sacrificing product quality. DFM is one of the most integrative practices involved in product development. All members of the development team as well as outside experts need to contribute their part of expertise. However, the other specific design issues are also of crucial importance.

3 Intelligent computer support to design

The application of artificial intelligence (AI) to design is generally concerned with studying how designers apply human intelligence to design, and with trying to make computer aids to design more knowledgeable. The AI applications in design are specially interesting for the representation of heuristic knowledge that is less easy to express by using traditional mathematical approaches. The part of AI that is particularly concerned with the development of such representations is known as expert systems, or more generally knowledge–based systems, often also intelligent computer systems [2].

Although the AI technology is still a subject of extensive research, many successful AI applications in real–life domains already proved the usefulness of these technologies when dealing with nondeterministic problems that cannot be treated adequately by using conventional approaches, unless the user is possessed of special skills and experience.

It is becoming increasingly evident that adding the intelligence to the existing computer aids, such as CAD systems, leads to significant improvements of the effectiveness and reliability in performing various engineering tasks, including design. Actually, AI applications to design are reality and subject of intensive development and implementations. Proceedings of the international scientific conferences “AI in Design”, edited by J.S. Gero, constitute a good collection of papers related to this area [3].

Intelligent computer support to design may be classified into four broad groups, as follows:

(1) Intelligent consultative systems for guiding inexperienced users;
(2) Intelligent systems for ‘automated’ design of particular type of products;
(3) Intelligent analytical aids;
(4) Intelligent systems for product design optimisation considering specific manufacturing or application aspects.

In continuation of this paper, intelligent systems that belong to the last group listed above are discussed by addressing two different areas of possible application, i.e. design of products with the appropriate ergonomic and aesthetic value, and design of plastics products.

4 Ergonomic and aesthetic design

4.1 Currently used design procedures

In order to deliver suitable design solutions, designers have to consider a wide range of influential factors. Ergonomics and aesthetics certainly belong to the most complex ones. Less experienced designer could meet several problems in this design stage.

Ergonomics is interdisciplinary science that provides information about potential users of the products. Designer needs information/knowledge about human anatomical, anthropometric, physiological, and biomechanical characteristics, as well as their relation to physical activity in terms of working postures, materials handling, repetitive movements, work related musculoskeletal disorders, workplace layout, safety, and health. Therefore, it is understandable that ergonomic studies belong to important phases of product design process, and make designer responsible for the ergonomic value of the product.

There are some computer tools available to be used for evaluation of the ergonomic condition of the product [4]. However, a lot of experience and knowledge in field of ergonomics is required to choose and carry out the appropriate redesign actions that will lead to better ergonomic value of the product in reasonable time.

On the other hand, the aesthetic design phase still depends mostly on the designers’ skill and experience. It is not supported by any computer tool of practical value at all. In fact, it is very hard to define a procedure that would assure acceptable results of the aesthetic design process. The aim is to build innovative CAD tools that adhere to the creative user mentality and to improve cooperation between the main players involved in the product development process, by identifying shape properties directly affecting the aesthetic character, and by providing modelling tools for their evaluation and modification [5].

4.2 KB design procedures

It is obvious that KB support to ergonomic and aesthetic design could be useful. In this context, we decided to develop the intelligent consultative system that will be able to support designer trough the decision making process when defining the ergonomic and aesthetic parameters of the product.

Since the aesthetic and ergonomic properties of the product are established at the early phases of the product development, the intelligent advisory system should be able to support the initial design process with minimum data requirements.

The ergonomic analysis and aesthetic evaluation should be performed on the initial CAD model. After that, the intelligent system could be used again to advice the user which design changes are possible or even necessary to improve the ergonomic and/or aesthetic value of the product if applicable.

In order to improve ergonomic and aesthetic value of the product, design recommendations will be proposed to the user by using expert knowledge collected in the knowledge base of the system and case-specific data provided by the user.

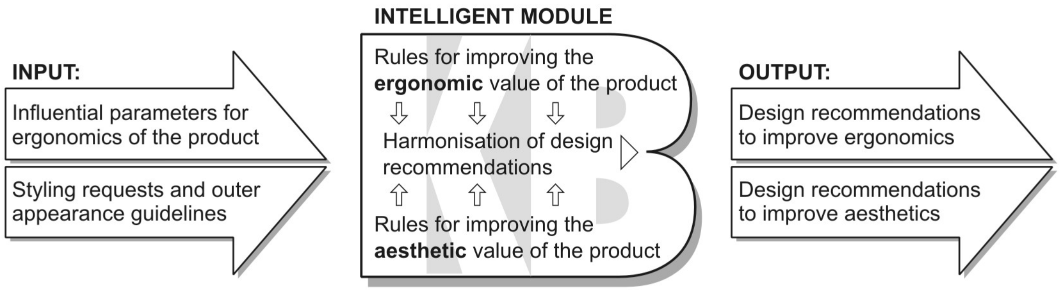

Fig.1. Knowledge based ergonomic and aesthetic design.

For a proper control over each part of the system, we decided to build two separate knowledge bases, containing theoretical and practical knowledge about design and redesign actions, one for the ergonomic and the other for aesthetic part of the system. In case the user would apply only one part of the system, the inference engine will be able to use separate knowledge base that belongs to that part. On the other hand, when the complete system with both knowledge bases will be used, some special rules will be applied to harmonise ergonomic and aesthetic design recommendations when needed.

Figure 1 shows the expected data flow and inference procedure for KB support to the ergonomic and aesthetic design, including the harmonisation between ergonomic and aesthetic recommendations that in some cases might be contradictive.

5 Design of plastics products

5.1 Currently used design procedures

There are many design issues to consider for good product development. Determination of the material to be selected for an application is certainly one of these issues. Today product designers have a vast menu of something over 120 thousands materials at their disposal to select from. Most of these materials belong to one of various plastics generic families. Each generic family of resins is unique and fulfils specific product and user applications. Plastics can replace existing materials such as metals, wood, and ceramics, to create new products. Moreover, basic resins properties can be enhanced when they are mixed or alloyed with other plastics, fillers, reinforcements and other modifiers including colour to develop more unique and distinctive materials for special products.

Plastics today fulfil and satisfy the most rigorous customer requirements at reduced costs. However, plastics may not always work for all products, although there are now very few applications, except in high heat, high sustained load, or severe chemical situations, where plastic material is not suitable.

Many factors influence the selection of the material for the specific part. Beside basic demands and needs that are required for the application, the additional factors include material supplier recommendations, past experience, the choice of the competition, etc.

Design of new or redesign of the existing plastics product requires quite extensive list of basic steps and procedures to perform in order to compete in today's world-class markets [6]. This process is too complicated to be successfully completed by a single person, the designer. The design process requires a team approach utilising design specialists along with material, tooling, equipment, and services consultants. There are too many variables in terms of different design solutions, materials, moulding and processing procedures, for a single plastic expert to be able to make all the correct decisions.

Designing parts for today's polymers requires a more involved and upfront engineering approach than ever before. This is particularly true for components that are combined into more complex parts, especially when the challenge is to reduce or eliminate the use of fasteners required to assemble them. In this context, DFX principles play a special important role in design of plastics products.

5.2 KB design procedures

To consider the world today without plastics is almost too inconvincible to imagine. Yet, the majority of product designers are still better trained in the use of metals, and non plastics, for product design. Their selection of the material best suited to the purpose of the product is based on their experience, creativity and product performance requirements.

However, the choice of material cannot be made independently of the choice of process by which the material is to be formed, joined, finished and otherwise treated. The influence of the material on the environment is also becoming increasingly important.

Although DFX methodologies are of special importance for plastics product development, designers can expect very limited support in facing the challenge to design plastic parts and components at maximised quality and minimised costs.

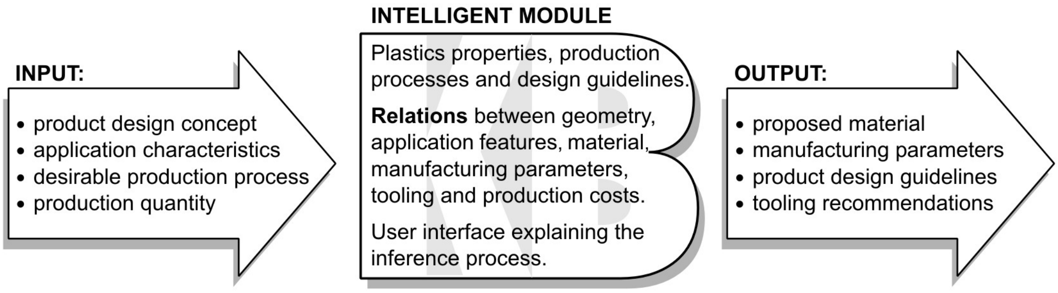

Fig.2. Knowledge based design of plastics products.

It is evident that expert support is decision making process is essential for almost every designer to perform design of plastics products successfully and efficiently. Thus, we decided to develop a KB system to support this important design issue.

Figure 2 shows the expected data flow, the content of the knowledge base and the most important input/output data for the proposed KB support to design of plastics products. The main objective of the proposed system is again, as in previous case, a consultancy with the designer in order to find, first, the most appropriate material for the product application, and in continuation, the related manufacturing parameters, product design guidelines and tooling recommendations, that will ensure high quality standards at low production costs.

6 Conclusion

It is hard to imagine a modern design process without using a computer. In fact, CAD is so extensively applied that in many companies all design work is done using CAD systems. Yet, there is a body of opinion that the benefits of applying CAD are bellow expectations. We believe the reason for this lies in the fact that the existing CAD systems are still not yet adequate as a proper aid to the designer in the process of designing a new product. They should provide a wider variety of a design's properties, in terms that are more familiar to engineers. Furthermore, the task of CAD systems of the future is to handle all aspects of engineering practice, company's organisation and equipment that influence design. The way in which it is hoped to archive this is to increase the intelligence of CAD systems.

Design data are not always well formulated, and almost never complete. Humans can deal with such data reasonably easily, while even the most "intelligent" programs have great difficulties. Designers are also reluctant to assign responsibility for decisions to computer programs, no matter how competent they may appear. One can also argue that encoded design knowledge does not allow designers to express their creative ideas. All these and many other factors constrain the application of intelligent systems in design.

Therefore, it is likely that no single technology will be adequate by itself. The designer will have at disposal a toolkit of techniques, including the intelligent modules for information and well–defined advice to make decisions and judgements.

In this context, the KB modules presented in this paper are being developed in our laboratory as relatively small stand-alone consultative intelligent DFX systems to be used together with the existing CAD tools in order to support specific design issues within product development process.

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