Proceedings of the 4th WSEAS/IASME Int. Conf. on System Science and Simulation in Engineering, Tenerife, Spain, December 16-18, 2005 (pp17-20)

Intelligent Support to Post-processing Phase of Engineering Analysis

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Abstract: - The results of engineering analysis are often used as basic parameters for design optimisation process. However, the existing commercial software for engineering analyses still fails to provide adequate expert advice in post-processing phase of the analysis. Thus, the selection of appropriate design steps to improve the structure still depends mostly on the designer's knowledge and experience. A prototype of intelligent consultative system for supporting design decisions considering the results of a prior stress/strain or thermal analysis is presented in this paper. Intelligent system provides a list of redesign recommendations which should be considered to optimise a certain critical area within the structure.

Key-Words: - computer aided design**,** engineering analysis, design optimisation**,** redesign, decision support, knowledge-based systems, PROPOSE

1 Introduction

For many years various Computer Aided Design (CAD) applications are indispensable in design process. The skilled usage of CAD tools increases the designers' effectiveness and their capability to solve complex design problems. CAD systems cover different design activities, like modelling, kinematics, simulations, structural analysis or just drawing technical documentation. In spite of all that, they do not support designer in more creative parts of design process that involve complex reasoning [1], as for example when possible design solutions need to be evaluated.

To overcome this bottleneck, "intelligent behaviour" needs to be added to existing CAD systems. Knowledge-based Engineering (KBE), or Knowledge Aided Engineering (KAE), presents the link between Computer Aided Engineering (CAE) tools and methods of Artificial Intelligence (AI). KAE was born in the aircraft [2] and automotive industries [3] and has been applied over several years, but mostly for specific products.

Despite all this, designer lacking in experience still needs advice to be able to make the right decisions within design process and consequently to design optimal structures. The idea behind present research in this field is to apply intelligent advisory computer systems to provide decision support to design activity. In the paper, a prototype of the intelligent consultative computer system to support one of the crucial steps in design is presented.

2 Engineering Analysis

Optimal design performed at the first attempt is rare in engineering. The purpose of engineering analysis using, for example, Finite Element Analysis (FEA), in the design process is to simulate and verify the conditions in the structure, as they will appear during its operational life. If the structure does not satisfy given criteria, it needs to be improved by applying certain optimisation steps, such as design changes, use of another material, etc. A lot of knowledge and experience is needed to be able to understand the results of the analysis and to choose the appropriate optimisation measures. In spite of rapid progress in the field of graphics, workstations and corresponding software, the existing computer tools for post-processing fail to provide advice about further optimisation steps.

KBE techniques linked to FEA have been available over twenty years to teach, advice and automate the pre-processing stage, mainly involving automatic mesh generation. On the other hand, there are not so many reports about AI applications to the post-processing phase and to the consequent design modification and optimisation [4-7].

In practice, young engineers are capable to make a model of a design using a CAD system. When they want to verify their design, they usually manage to perform the analysis and obtain useful graphical presentations of the results from which critical areas can be located. However, they know neither how to perform design changes nor what to change to improve the design.

The list of possible redesign actions is a case-by-case solution of some quite complicated problems that require knowledge about the principles of mechanics, structures and materials technology. The experiences gained by many design iterations are of crucial importance. As a rule, there are several redesign steps possible for design improvement. The selection of one or more redesign steps that should be performed in a given case depends on the individual requirements of the certain problem.

Different software and hardware components are frequently required for the modelling and engineering analysis. Therefore, we decided to develop an independent self-standing intelligent advisory system for redesign recommendations. This decision implies that some kind of qualitative description of engineering analysis results will need to be presented to the intelligent system manually. For the first prototype, we were concentrated to the FEA and in particular to stress-strain and thermal analyses, which are the most widely used analysis aspects in engineering practice.

3 Development of the Intelligent System

AI methods are accepted in many fields of engineering. Analysis-based design optimisation is certainly one of those engineering tasks, with a great potential for intelligent systems application. It was already mentioned that KBE applications to the FE post-processing and design modification are quite scarce. The link of intelligent programs to the structural analysis is discussed in many research works. More recent works are concerned with the integration of different software systems in a way that the whole design process, including analysis, can be automated, mostly for specific products [8-10].

Some research work on the intelligent interpretation of analysis results was also done [7,11,12]. In this context, our idea was to encode the knowledge and experience about design and to create the rules for proposing correct actions for design changes. We have developed an intelligent advisory system to support design parameters modifications.

The proposed system was developed in a step-by-step manner. First and the most important step was knowledge acquisition. The theoretical and practical knowledge about design and redesign actions were investigated and collected. After that, the production rules were chosen as the most appropriate representation formalism for the acquired knowledge and the knowledge base of the system was encoded. Finally, we developed the shell of the system. The shell is named PROPOSE and is consisted of the user interface and inference engine suited to the existent knowledge base (Fig. 1). The knowledge base and the shell of the system are encoded in Prolog syntax.

3.1 Knowledge Base

The recommendations for analysis-based design optimisation are not collected and documented either in written or in any other well-ordered and comprehensible way. On the contrary, they are scarce and difficult to find in some design-related literature. In practice, the extensive knowledge and experience is possessed by individual design experts who have been dealing with design optimisation over many years.

It was not an easy task to take the advantage of all possible ways to acquire redesign knowledge, from a literature survey, including examination of previously-conducted engineering analyses, to interviews with some human experts. For example, many analysis reports contain confidential data and cannot be inspected. Additionally, interviews and examination of the existing redesigns are conditioned by the cooperativeness of the experts and can be time-consuming. Therefore, the scope of such results is very much limited by these individuals.

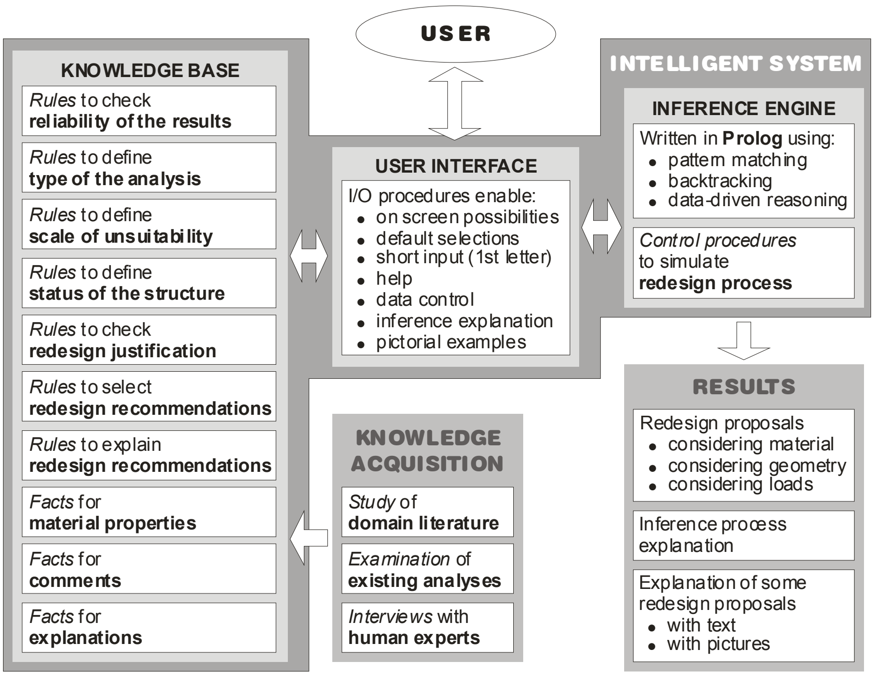

Fig. 1. PROPOSE – Intelligent advisory system for analysis-based design optimisation.

Unlike numerical problems, design problems do not have an exact and unique result. We believe that the designer should have a list of all possible solutions, from which he or she could choose those that are the most appropriate for the given design problem. In engineering practice, structural analyses are usually performed by expert analysts who define the possible redesign options. Designers are those who choose one or more design changes out of the list of proposals to improve design within given limits and criteria. The analysis of the redesigned structure can either confirm the correctness of the design changes or show the consequences of an inappropriate selection. In both cases, the designer can acquire some new knowledge during this iterative procedure.

The actual rules used in the design process usually have a form: "IF there is a problem AND some limits THEN do action 1 or action 2 or action 3." The production rule has quite similar form. They were therefore selected as the most appropriate formalism for encoding redesign knowledge.

Each rule presents a list of recommended redesign actions that should be taken into consideration while dealing with a certain problem, subject to certain limits. The rules are generalised and do not refer exclusively to the examples that were used during the knowledge acquisition process. The designer should chose to apply one or more redesign actions that are possible, reasonable, and the most effective for each particular case. Some pictorial examples have been added to the system as an additional help to the user, to enhance understanding of the proposed redesign actions and to assist in making a suitable choice.

3.1 Shell of the System

Prolog was chosen to be used for developing our intelligent system because of its built-in features such as rule-based programming, pattern matching and backtracking, which enabled us to concentrate on declarative presentation of the knowledge, using data–driven reasoning, which is also very easy to encode in Prolog. However, some control procedures were also added to the inference engine of the system to adjust the performance to the real-life design process.

In developing the user interface, our goal was to simulate the communication between the designer–beginner and the designer–expert. The user interface enables the user to present the input data, informs the user about the results, offers help and presents the information about the inference process.

The system is still in development phase and is written as a console application. As such, it is more convenient for testing and rapid improvements. A future version of the system, with a graphical user interface, is being planned.

4 Application of the System

In order to use PROPOSE, the user/designer simply needs to run the executive version of the system. The execution starts with the system introduction, including some basic information on how to use the system. From that point the system leads the user from the initial specification of the problem to the final conclusions. At any time the list of possible choices and a default selection are presented to the user. Help is available through the whole data input process. The user needs to present a qualitative description of the critical areas that were determined by engineering analysis. For every problem area, the system searches for the improvement recommendations in the knowledge base. The user can also be reported with the information about the inference process. The system can present all the steps that led to the final conclusion together with the list of proposed design changes. In addition to this explanation, the user can also obtain more information about certain proposals. This kind of information is provided not only for the geometry changes, but also to support the selection of a more relevant material. The proposals are explained with text or/and with pictorial examples.

The abstract description should be as common as possible to cover the majority of the problem areas. For this reason, the number of predefined attributes is relatively small. However, by answering some additional questions, the problem can be defined in a more refined manner. In cases when the problem area can be described to the system in different ways, it is advisable to repeat the system for each such description. Thus, the system will be able to propose more suggestions, at the expense of only a few more minutes at the console. More proposals may confuse the user, who will probably need help in the form of explanation of the proposals. On the other hand, more proposals provide more possibilities for design improvements.

The PROPOSE system was evaluated in two ways. First, experts who were already involved in the knowledge acquisition process evaluated the system. After that, some real-life examples were used to test the performance of the system. The experts that participated in the evaluation process are practising designers and some academics. They individually evaluated the system from two points of view. First of all, they analysed the performance of the system using some real-life examples. In addition, they also evaluated the user interface by inspecting how well the system helps and guides the user, or even enables him or her to acquire some new knowledge. The suitability, clearness and sufficiency of the redesign proposals were also evaluated. All comments, critiques and suggestions presented by the experts were taken into consideration and resulted into numerous corrections and adjustments of the system.

5 Conclusions

The aim of our research work was to develop an intelligent system which would be able to support the user (designer or student) through the analysis based optimisation process, especially at the design verification and redesign phase. This paper presents PROPOSE, a prototype of such a computer system.

Development of the system has been presented, from knowledge acquisition and knowledge base construction, to encoding the shell of the system using programming language Prolog. The system was evaluated by several human experts, who all shared the opinion that the prototype of the system could already be applied as a useful supporting tool to the practical design of new products. Furthermore, it represents a solid basis for further developments that could result in commercial software.

The intelligent system presented in this paper offers help and advice on how to solve design problems in abstractly described critical areas of the structure after stress-strain or thermal analysis. The architecture of the system, based on production rules, enables the system to be relatively easily expanded with additional rules, for example for a more specific description of the problem, for other types of engineering analyses, and for a deeper, multi-physics understanding of redesign proposals.

When using PROPOSE, designer has to answer some questions stated by the system to present the results of the engineering analysis qualitatively, with emphasise on the problem area that needs to be optimised. These answers are then compared with the rules in the knowledge base, and the most appropriate redesign changes that should be taken into account for the various cases are determined and recommended to the user.

The system provides constant support to the user's decisions in terms of explanations and advice. At the end, the user can obtain the explanation of how the proposed redesign changes were selected, and also some detailed information on how to implement a certain redesign proposal, including pictorial examples.

The PROPOSE could be very useful in design education process. The ability of the system to explain the inference process could enable the students to acquire some new knowledge. It may help them to learn more about the basic principles of the design process.

Acknowledgements

Development of the intelligent system presented in this paper was financially supported by the Ministry for Education, Science and Sport, Republic of Slovenia. We would like to thank the experts from the companies AVL-AST and RTI in Maribor, Slovenia, who were willing to act as a medium for transfer of their knowledge and experience. Thanks also to Dr. T.K. Hellen from UK for sharing with us his numerous ideas that were essential in building the first prototype of the system. Some part of the research work presented in this paper was performed during our visits to the Department of Engineering Design and CAD at the Faculty of Engineering Sciences, University of Bayreuth in Germany, headed by Professor Frank Rieg.

References:

[1] Mili, F., Shen, W., Martinez, I., Noel, Ph., Ram, M., & Zouras, E.: Knowledge Modeling for design Decisions. *Artificial Intelligence in Engineering, 15*, 2001, pp. 153-164.

[2] Liening, A., & Blount, G.N.: Influences of KBE on the Aircraft Brake Industry, *Aircraft Engineering and Aerospace Technology, 70(6)*, 1998, pp. 439-444.

[3] Kochan, A.: Jaguar uses Knowledge-based Tools to Reduce Model Development Times. *Assembly Automation, 19(2)*, 1999, pp. 114-117.

[4] Smith, L., & Midha, P.: A Knowledge-based System for Optimum and Concurrent Design and Manufacture by Powder Metallurgy Technology. *Int. Journal of Prod. Res., 37(1)*, 1999, pp. 125-137.

[5] Pilani, R., Narasimhan, K., Maiti, S., Singh, U., & Date, P.: A Hybrid Intelligent Systems Approach for Die Design in Sheet Metal Forming. *Int. Journal of Advanced Manufacturing Technology, 16*, 2000, pp. 370-375.

[6] Burczyski, T., Ku, W., Dlugosz, A., & Orantek, P.: Optimization and defect identification using distributed evolutionary algorithms. *Engineering Applications of Artificial Intelligence 17*, 2004, pp. 337-344.

[7] Sahu, K., & Grosse, I.: Concurrent Iterative Design and the Integration of Finite Element Analysis Results. *Engineering with Computers, 10*, 1994, pp. 245-257.

[8] Lambert, J.: Strategic Selling: Integrating ANSYS and Knowledge Based Engineering for Real Time Custom Product Engineering during the Sales Cycle. *ANSYS User Group Conference*, Pittsburgh, USA, 2000.

[9] Peak, R., Scholand, A., Tamburini, D., & Fulton, R.: Towards the Routinization of Engineering Analysis to Support Product Design. *Int. Journal of Computer Applications in Technology, 12(1)*, 1999, pp. 1-17.

[10] Blair, M., & Hartong, A.: Multidisciplinary design tools for affordability. American Institute of Aeronautics and Astronautics, AIAA-2000-1378, 2000.

[11] Armstrong, C., & Bradle B.: Design optimisation by incremental modification of model topology. *Proc. 8th Int. Meshing Roundtable,* pp. 293-298. South Lake Tahoe, California, USA, 2000.

[12] Koo, D., Peak, R., & Fulton, R.: An Object oriented Parser based Finite Element Analysis Tool Interface. Invited paper for Intelligent Systems in Design and Manufacturing II, *SPIE The International Society for Optical Engineering*, Photonics East, Sept 1999, Boston.