ENGINEERING KNOWLEDGE MANAGEMENT RESEARCH AT THE NORTH CAROLINA STATE UNIVERSITY

by

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INTRODUCTION

This summary presents an overview of an ongoing research program designed to respond to the need for research in engineering and scientific knowledge acquisition, representation, management, use, and generation. Such a program is being jointly implemented by the Departments of Civil and Industrial Engineering at NCSU.

Engineering and scientific knowledge management, which combines concepts of artificial intelligence with information representation, requires increasing attention as the amount and complexity of information necessary to perform engineering operations increases, and the need to coordinate its acquisition and use increases. This area of research promises advantages for a wide variety of engineering applications, particularly those which seek to use knowledge in new and innovative ways. Such ways include graphics and computer-aided design which depend on the underlying database representation of geometric data, and expert systems which depend on the representation of information in the form of "expert" design knowledge.

THE REPRESENTATION OF DATA

Database Management System Research

A major trend now exists towards the integration of individual, stand-alone engineering analysis and design application programs into comprehensive, user-friendly, multi-component design systems. For example, traditional manufacturing tasks, which are performed by several semi-autonomous departments, must now be viewed as being components of an integrated and somewhat continuous process. This process produces data at each stage which must be readily accessible, in real time, to the next stage. Although product and process design teams were once separate entities, they must now work together using integrated computer-aided design facilities. Engineering databases are viewed as the primary integration mechanism between the various design and manufacturing processes. These, in combination with database management systems (DBMS) and executive controllers, are essential for achieving truly integrated, generative, computer-aided design systems. A multi-faceted DBMS research program can result in the developments necessary to enable these systems to emerge.

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Although databases originated as passive repositories of data, recent research efforts enhanced their capabilities by enabling them to rigorously perform integrity and consistency checking by establishing constraints that limit individual data item values. Subsequent research extended the role of the database further by using constraints to enable the database to automatically generate limited amounts of data. The presence of patterns of data in the database is used as a triggering mechanism for constraints which then determine and assign a value to a dependent data item as a function of its ingredient data items.

The research program described here seeks further extensions to obtain a DBMS environment that accurately represents an entity, design, or process, permits intelligent external interaction, ensures integrity and consistency through the evaluation and satisfaction of engineering constraints, and actively contributes to its own evolution by generatively increasing its data content. A research objective of immediate concern is communication between an internal data representation scheme and the external environment. Such communication must occur through the use of application program interfaces, graphic and alphanumeric problem-oriented query languages, and automated data acquisition mechanisms to obtain data from both designers and sensors. The influences of developments in this area are expected to be far-reaching; borrowing from and contributing to research efforts in constraint formulation, geometric modeling, codes and specifications, application program interfacing, and DBMS technology. Yet significant progress toward the achievement of these objectives is a realistic goal and one that is necessary to solve the current problems that are inhibiting industrial organizations from developing and most effectively using large-scale, broad-scope design systems.

THE REPRESENTATION OF HEURISTICS
Expert Systems Research

Knowledge-based expert systems (KBES), providing programmed problem-solving capabilities comparable to that of a human expert in a particular problem domain, have emerged. KBES's use expert knowledge and expert methods to conceptualize and reason for the purpose of deriving decisions and inferences from which problem solutions are obtained. A number of successful applications have been developed that demonstrate their feasibility and utility. The range of expert system applications extends from interpretive problems, where reasoning about the problem is required in light of the knowledge available in that problem's domain, to generative problems where potential solutions are generated and tested against candidate solutions defined by sets of constraints. Work at NCSU is focusing on prototype expert system development for machine-task matching and for the design of facilities, both in the areas of structural design and factory shop-floor design. The expert systems under development at NCSU address problems which are both interpretive and generative in nature.

Knowledge-based expert systems are presently moving from the research environment to production environments. One potential scenario for the transition is that they act as new stand-alone tools for engineering use. Another is that engineering capabilities be built into them. A more desirable transition, however, dictates that they possess the extensions necessary to enable them to successfully fit within the traditional engineering design and manufacturing environment. In particular, they must be incorporated as an integral component into a comprehensive engineering design and manufacturing computer-based system.

To achieve the greatest utility from KBESs, as components of a larger system, requires research on system component configurations as well as the problems inherent in building such a configured environment and using it as an automated engineering assistant. KBES interfaces are of particular concern. The interfaces must tie KBES's to existing external engineering software, database management systems, graphical displays and graphics software, sensors, and knowledge and data acquisition modules. One direction in which research is proceeding is to build these capabilities directly into expert systems. However, such efforts have limited utility from the perspective of an integrated engineering computing environment that is already largely in place. One aspect of the research at NCSU seeks to investigate external KBES interfaces to determine ways to successfully integrate KBESs into an environment supporting engineering design, manufacturing, planning, control, and production. For example, one research project focuses on the development of a multi-modal communications interface between the designer and the expert system, enabling communication via graphics, touch, or voice depending on the problem characteristics.

The flow of engineering and scientific analytical data among CAE system components has been investigated and is well understood. But to achieve the objectives proposed here will require a new form of flow analysis. It will require an investigation of the analytical problem solving process as a collection of subprocesses at a "quanta" level for common use in databases, expert systems, and multicomputer architectures. In addition, the imposition of a myriad of engineering constraints on analytical data and constraint handling capabilities is also of concern. On the other hand, the form, content, and characteristics of heuristic and logical data also mandate new thinking with regard to information flow. In both cases, efforts designed to improve the information flow, the interface pipeline through which information will pass, and the configuration of an engineering system supporting KBES's are currently underway at NCSU.

SUMMARY

The developments outlined in these areas of investigation make a significant contribution to the formulation of a program of research in the representation, management, and use of information and knowledge in an expert context in engineering processes. The results of these research programs will directly contribute to our understanding of the use of

information analysis methodology, decision logic theory, and database theory for representing engineering data and to the development of an environment enhance monitoring and control of the engineering process and improve data management efficiency while providing up-to-date information in a variety of forms to those who need it, allowing them to respond quickly to changes in anticipated patterns. As a result, these research programs will be of particular interest to those individuals and organizations who develop comprehensive integrated application software and databases.

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