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RESEARCH IN PROGRESS

AI Research in Engineering at North Carolina State University

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Abstract

This article presents a summary of ongoing, funded artificial intelligence research at North Carolina State University. The primary focus of the research is engineering aspects of artificial intelligence. These research efforts can be categorized into four main areas: engineering expert systems, generative database management systems, human-machine communication, and robotics and vision Involved in the research are investigators from both the School of Engineering and the Department of Computer Science The research programs are currently being sponsored by the Center for Communications and Signal Processing (CCSP), the Integrated Manufacturing Systems Engineering Institute (IMSEI), the National Aeronautics and Space Administration (NASA), the National Science Foundation (NSF), and the United States Department of Agriculture (USDA)

Expert Systems

Knowledge-based expert systems (KBES) use expert knowledge and expert methods to conceptualize and reason for the purpose of deriving decisions and inferences from which problem solutions are obtained. The range of expert system applications in engineering 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 applicable constraints.

From an engineering perspective, expert systems can be viewed as new tools that will enable current computer-aided engineering (CAE) systems to be enhanced or, in appropriate situations, as replacements for these systems and their human users. Certainly the future offers a sampling of both. Work at NCSU is focusing on prototype expert system development in such areas as machine-task matching and the design of facilities, both in the areas of structural design and factory shop-floor design. The machine-task matching work focuses on the selection of production equipment for a given set of working conditions. Specifically, forest harvesting equipment is chosen for various existing topographical, silvicultural, and operational scenarios. The structural design research addresses the analysis of loading conditions in the building design process, determining load parameters for various structural components. Work in factory design involves examination of such problem components as equipment selection, capacity planning, conflict identification, and layout

An important aspect of the work at NCSU is the integration of expert systems into the computer-aided engineering environment. These systems must possess the extensions necessary to enable them to be incorporated as an integral component into a comprehensive computer-aided engineering system that supports planning, design, manufacture, and control. Expert system interfaces are of particular concern. The interfaces must tie expert systems to existing engineering software, database management systems (DBMS), graphic displays and graphics software, sensors, knowledge and data acquisition modules, and system users. One emphasis area of the research at NCSU seeks to determine the components and architecture of the communications environment between database management and expert systems. Specific work in progress is concentrating on the development of interfaces between an expert system that requires data to solve a problem and one or more database management systems (of different types) that act as data sources.

Program participants: Edward L. Fisher, William J. Rasdorf

Generative Database Systems

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 be viewed as being components of an integrated and somewhat continuous process. This process produces data at each stage that 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 engineering processes. Such databases are essential for achieving truly integrated, generative, computer-aided engineering systems. A multi-faceted database management system research program can result in the developments necessary to enable these systems to emerge.

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

The research program at NCSU seeks further extensions to obtain a database management system environment that accurately represents an entity, design, or process; permits intelligent external interaction with expert and autonomous systems; 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 users and sensors. Significant progress toward the achievement of these extensions and objectives is necessary to solve the problems that are currently inhibiting industrial organizations from developing and most effectively using the large-scale, broad-scope systems.

Program participant: William J. Rasdorf

Human-Machine Communication

Two areas of emphasis at NCSU with regard to human-machine communication are those of 1) user interfaces with engineering tools and 2) error detection and control in voice input and output. The objectives of the research programs in these areas are described below.

User Interface

Enhanced intelligence of engineering tools, particularly in the case of expert systems, demands a faster and more effective means of communicating knowledge between the user and the tool. Although a great deal of information must be obtained from, among other sources, electronic sensors and database management systems, a significant amount of information must be solicited from, and communicated to, the user. This research investigates the development of a multi-modal communication interface which would allow knowledge transfer between the users and their tools to take place by means of graphics, touch, and voice, in addition to keyboard interaction. The research currently focuses on engineering design tasks

Methods of improving the communication links between the designer and design programs are needed so that information can quickly be transferred between the two in ways which are understandable to both. This requires the communications interface to have a model of the real world (as currently is provided) and also to have a model of the user's view of the world. Applications exist in such areas as product design, where the user can construct solid models from geometric primitives, and in facilities design, where the user must communicate problem descriptions and objectives, equipment and location preferences, and changes to alternative designs generated by computer analysis. By allowing communication to take place in a user-preferred mode (*e.g.*, touch as opposed to keyboard entry), errors in translation can be reduced, and the user's creativity can be supported more effectively.

This research promotes an understanding and supports the development of interfaces that allow effective human-machine interaction to take place. In addition, it facilitates the determination of the appropriate allocation of intelligence among the tool, the interface, and the user.

Program participants: Edward L. Fisher, Michael G. Joost

Error Control

The installation and acceptance of voice input and output devices in the engineering and manufacturing environment is not proceeding as fast as had been predicted. One reason for this is that people have unrealistically high expectations about voice communication, expecting to converse with the computer as if it were another human being. Due to a combination of error proneness and inflated user expectations, voice input and output systems must provide more robust error-handling capabilities than systems without voice require. Among these capabilities are:

- Detection of utterances which do not fit the input stream and, when possible, automatic correction of recognized errors to generate a meaningful command or entry.
- Provision of a system whereby the user can, after detecting a recognition error, correct the input stream

An objective of this research is to enable a host computer to detect and correct errors in recognition by applying grammatical and contextual knowledge to supplement phonetic input provided by a user through a natural language input system. The research into error control has identified two distinct approaches which can ultimately be combined for maximum performance: top-down and bottom-up.

In a top-down approach, the host computer, through a variety of complex "AI-like" techniques, gains some knowledge of the context in which the user is working and, based on this, is able to anticipate what the user is likely to say. In a bottom-up approach, each word, phrase, and sentence received from the user and reported by the recognizer is examined to see if it is a grammatical string of the input language and whether it makes sense.

Eventually a hybrid approach will prove the most efficacious. In the bottom-up approach, for example, if the host detects meaningless input, it may be difficult to pinpoint exactly where a recognition error occurred. But, if the host also has some top-down knowledge as to the context within which the user is working and some expectations of what the user intended to say, an intelligent interpretation of the input might be forthcoming

Program participants: Michael G. Joost, Robert D Rodman

Robotics and Vision

Artificial intelligence research as it is applied to machine vision at NCSU occurs primarily within the image analysis program of the Center for Communications and Signal Processing. Emphasis in the current program is on the analysis of three-dimensional images and on the development of intelligent visual robot control systems.

A three-dimensional image is an array of numbers in which each number represents the three-dimensional position of a point on the surface of an object. The objective of the analysis is to identify an object and determine its spatial position. Techniques currently employed include three-dimensional segmentation, surface analysis, object modeling using graph structures, and model matching, the latter of which is derived from AI knowledge representation work. The most immediate application of this research is in the industrial automation environment, particularly in robot vision.

Intelligent robot control systems based on dynamic sensing feedback using visual eye-in-hand systems have been determined to possess several advantages over systems using fixed external video cameras. One research project in this area makes use of a solid-state line scanner as the sensing element for a system that currently has the ability to determine the position and shape of objects and to define the proper hold location prior to grasping. In this research, an experimental model is used to simulate a fully opened parallel jaw gripper in which a photodiode array is embedded in one side of the finger. An interface between the linear array video scanning signals, a CPU, and video RAM is under development.

Another research project involves the combination of two-dimensional vision and taction for three-dimensional object recognition. A conventional video camera is used to obtain the top view of an object, and two tactile sensing arrays mounted on a robot gripper are used to measure information about the lateral surfaces of the object. Three-dimensional reference object models are established as a decision tree, and recognition of unknown objects is accomplished through measuring and comparing input object features hierarchically with those of the reference objects associated with the decision tree. Significant advantages are anticipated over systems using visual or tactile information alone

Program participants: Ren-Chyuan Luo, Wesley E. Snyder

Summary

The programs outlined here address problems in the areas of engineering expert systems, generative database management systems, human-machine communication for engineering applications, and robotics and vision. The results of these research programs are expected to contribute to our understanding of the use of information analysis methodology, decision logic theory, and database theory for representing engineering data; to the development of an environment of communication among a linkage of diverse computer-aided engineering system components including expert systems; and to visual and tactile sensing for robot control systems. In addition, the artificial intelligence research is contributing to the ongoing evolution of the artificial intelligence curriculum which includes courses in artificial intelligence, artificial intelligence languages, expert systems, computational linguistics and semantics, and related courses in the engineering disciplines.