DOCUMENT RESUME

ED 388 296 IR 017 445

AUTHOR	Soclof, Michal S.; Pao, Yoh-Han
TITLE	Combining Associative Memory and Multimedia Technology for Training Patternmakers.
PUB DATE	94
NOTE	8p.; In: Educational Multimedia and Hypermedia, 1994. Proceedings of ED-MEDIA 94--World Conference on Educational Multimedia and Hypermedia (Vancouver, British Columbia, Canada, June 25-30, 1994); see IR 017 359.
PUB TYPE	Reports - Descriptive (141) -- Speeches/Conference Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Apprenticeships; *Associative Learning; *Computer Assisted Instruction; Computer System Design; Geometric Concepts; Metal Working; Multimedia Materials; *Patternmaking; *Skill Development; Skilled Occupations; *Trade and Industrial Education; Troubleshooting
IDENTIFIERS	*Multimedia Technology

ABSTRACT

In the manufacturing industry, many complex tasks are taught through an apprenticeship program; the experience and expertise gained through years of practice is invaluable to the industry and can be lost if not properly captured and transferred. This paper reports on the design of a training system that combines the use of computer-based associative memory and multimedia functionality, with a focus on patternmaking for the metalcasting industry. The goal of the system is to provide means for helping the student learn the facts and fundamentals of the topic area, as well as to provide support in his practice of the art. The system facilitates associative recall of similar designs encountered in the past and supports troubleshooting and preemptive troubleshooting. Students are taught an important basic skill: the ability to describe designs in terms of meaningful geometric and descriptive features, and to describe the imperfections in terms of standard defect classes and causal features. These linguistically expressed features serve as the interface between the multimedia training system and the student/practitioner. (Author/AEF)

Combining Associative Memory and Multimedia Technology for Training Patternmakers

MICHAL S. SOCLOF and YOH-HAN PAO
Department of Electrical Engineering and Applied Physics
Case Western Reserve University, Cleveland, Ohio 44106, U.S.A.

Abstract: We report on ongoing research in the design of a training system that combines the use of computer-based associative memory and multimedia functionality. The goal of the system is to provide means for helping the student learn the facts and fundamentals of the topic area, as well as to provide support in his practice of the art. The system facilitates associative recall of similar designs encountered in the past and supports troubleshooting and preemptive troubleshooting. Students are taught an important basic skill: the ability to describe designs in terms of meaningful geometric and descriptive features, and to describe the imperfections in terms of standard defect classes and causal features. These linguistically expressed features serve as the interface between the multimedia training system and the student/practitioner.

Introduction

In this paper, we report on ongoing research in the combined use of computer-based associative memory and multimedia functionality, in the teaching of complex tasks. We find that of critical importance is the matter of teaching interpretive and judgemental skills. With those abilities in hand, the learner can access computer-based associative memories as well as his own memory to recall previous experiences, to enhance efficiency and to anticipate problems. Multimedia capabilities and appropriately structured computer associative memories are useful not only for the teaching of such skills but also in the practice of the art.

In the manufacturing industry, many complex tasks are currently taught through an apprenticeship program. Through examples and instructions, the expert craftsman relays to his charge the expertise gained through the years. It is this experience that sets apart the master craftsman from the novice, allowing the master craftsman to draw upon past mistakes and achievements to produce new products correctly and efficiently. The experience and expertise gained through years of practice is invaluable to the industry and can be lost if not properly captured and transferred. Our work addresses the question of how this information might be captured and transferred with the help of computer-based associative memory and multimedia technology.

Our goal is to help the student develop the judgment, skills, and experience required to become an expert in a topic. We teach not only the facts but, more importantly, the ability to form interpretations and make useful associations. The approach is to augment the apprenticeship program with the use of a computer-based memory system that gives the student freedom to explore the use of the associations built into the memory. Furthermore, we add the use of different forms of media for interaction and presentation, in order to provide a descriptive mechanism that may help shorten the learning cycle and teach the necessary interpretive skills. The interaction between the associative memory and the multimedia techniques provides a powerful and flexible tool to help the user build his own skills and concepts.

In the next section, we describe the topic that we selected for exploration purposes, namely patternmaking for the metalcasting industry. We then describe our early achievements for teaching facts and fundamentals. In the final section, we discuss ongoing research and design of the overall system, including associative memory, troubleshooting and the teaching of interpretive skills.

Patternmaking and Metalcasting

We chose to concentrate on the metalcasting industry, specifically in the area of patternmaking. A metal casting is an object that is produced by pouring molten metal into a mold cavity and then allowing the metal to harden. The process of metalcasting involves several steps and is staffed by highly trained individuals.

After the design engineer creates the design and sets the specifications for the part to be cast, it is the job of the patternmaker to translate the engineer's blueprint to a solid three-dimensional form called the pattern. In part, the pattern is a duplicate, in shape, of the final casting. However, in addition, incorporated in the pattern is a system of channels, called the gating system. The gating system is necessary to properly feed the molten metal to the cavity. The geometry of the part may also need to be adjusted in order to be able to properly remove the pattern from the mold, while leaving the mold intact. This means for example, that draft is required. Draft is the taper on the vertical sides of the pattern.

The pattern can be made from different types of materials: wood, plastic, or metal. The mold can also be made in different ways using a variety of materials. A common process is the green (meaning moist) sand molding process. The mold must be made while the sand mixture is still damp.

The simplest way to make a pattern is to make it in one piece. This is not always possible because certain shapes cannot be withdrawn from the mold while leaving the sand intact. For example, there are many castings that have hollow parts or internal protuberances. Patterns that provide for these features cannot be withdrawn in one piece. Cores and loose pieces, however, allow these types of castings to be poured. The core limits the flow of metal in the mold. The core is put into the mold right before the molten metal is poured. Keying devices, called coreprints, are used to help hold the core in place, in the mold, during pouring.

A mold is made in a hollow rectangular box, called a flask. The mold is divided into two parts: the cope, which is the top half, and the drag, which is the bottom half. The line on the casting corresponding to the separation between the cope and the drag is called the parting line.

The issue of draft is directly related to the parting line. The placement of the parting line impacts the amount of draft required as well as which surfaces should be drafted. Another concern associated with both parting line and core design is the tradeoff between designing the pattern with cores versus using the technique called "cope-down." Under certain circumstances, the patternmaker can choose whether to "cope-down," that is to design the cope to be extended into the cavity, or whether to have a flat cope with a core placed in the cavity. This decision is up to the patternmaker since usually, the quality of the pattern and casting will be equivalent regardless of the decision. This issue is very difficult to explain with text alone and is an example of why multimedia technology is helpful.

The concepts described in this section are illustrated in Figure 1. In this figure, we see a hollow cylindrical part to be molded and the drag of the mold, with cores in place. The mold is for fabricating two castings at the same time and shows two cavities side by side. The cope is not shown.

Early Achievements

We designed a system with the intent to teach the facts and fundamentals of a specific subtask of the general practice of patternmaking as we'l as to illustrate how the associative recall of similar previous designs could be used in the training system. In designing the prototype system, we want to lay the groundwork to visually display different pattern designs in order to explain the process of patternmaking. This prototype would also let us design the framework for a more complete training system. Furthermore, it would establish the structure that would allow us to show and discuss different parts, view different designs, as well as provide the tools to teach difficult concepts.

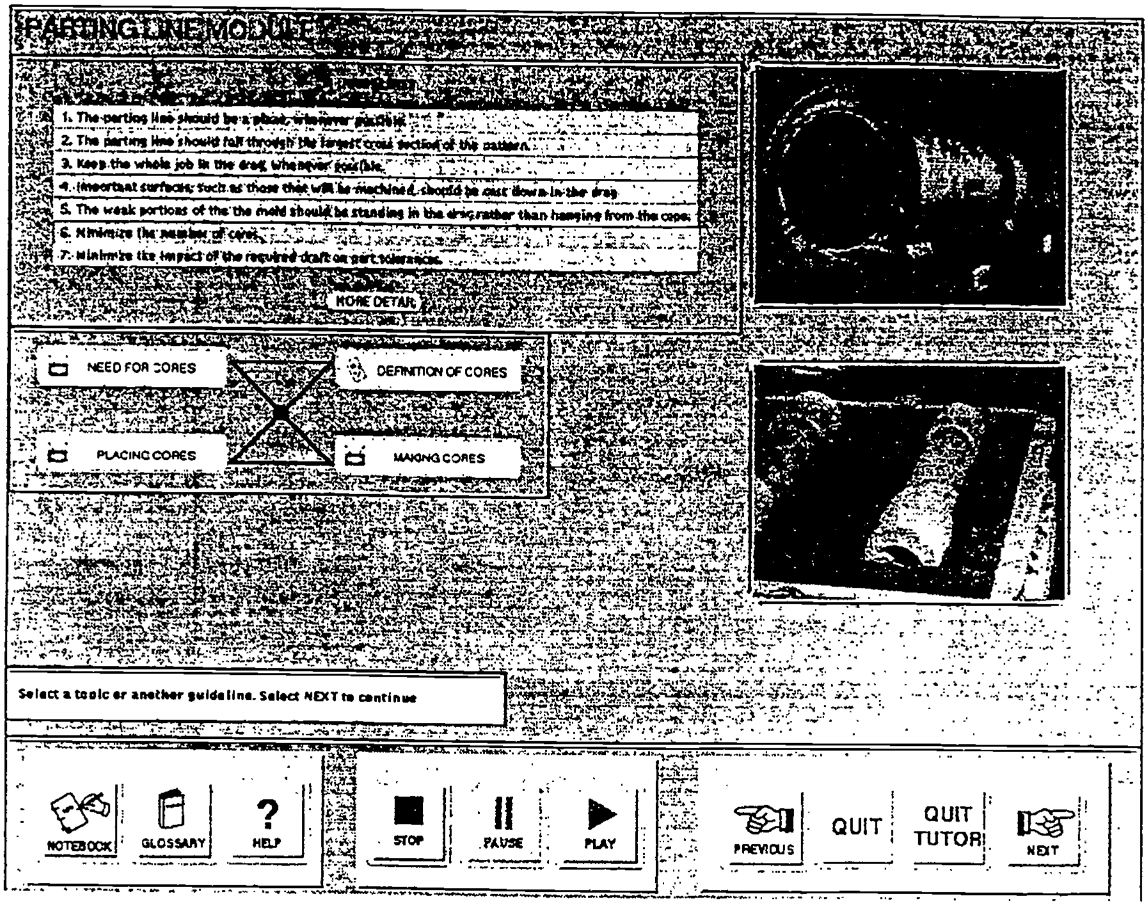

Figure 1: Prototype System Screen for Guidelines to Location of Parting Line

For the prototype, we chose to concentrate on an important aspect of patternmaking: the location of the parting line. As mentioned previously, the parting line is the line on a casting that corresponds to the separation between the cope and the drag. The placement of the parting line is one of the first and most important decisions that a patternmaker must make when designing a pattern. It is important because it will affect other design decisions for that pattern. For example, the amount of draft required as well as which sides of the pattern must have draft is directly affected by the parting line location. Furthermore, the decision whether to "cope-down" or make cores is also bound to the location of the parting line. There is no body of general hard-and-fast rules that can be used to decide where to place the parting line. Each decision must be made individually, based on the geometry of the part and other considerations. What complicates the matter even further is that there may be several correct parting line decisions for each design. The patternmaker chooses the placement of the parting line based on his knowledge, past experiences, and personal preferences.

In order to teach parting line decisions, we have to present the information at a conceptual level. Furthermore, we want to be able to provide knowledge both in the form of meaningful guidelines and related experiences. The guidelines will present the fundamentals and the experiences will provide the means for the novice to gain expertise based on the successes and failures of other patternmakers.

Upon entering the system, the student is presented with a brief definition of a parting line using a live video image, a still and an audio description. Seven short guidelines on the placement of the parting line are then presented. The student can request more information on any of the guidelines by selecting that specific guideline. Based on his choice, a detailed explanation of the guideline and several examples are presented to the student. These examples may be shown in the form of graphical images with audio explanations or videos.

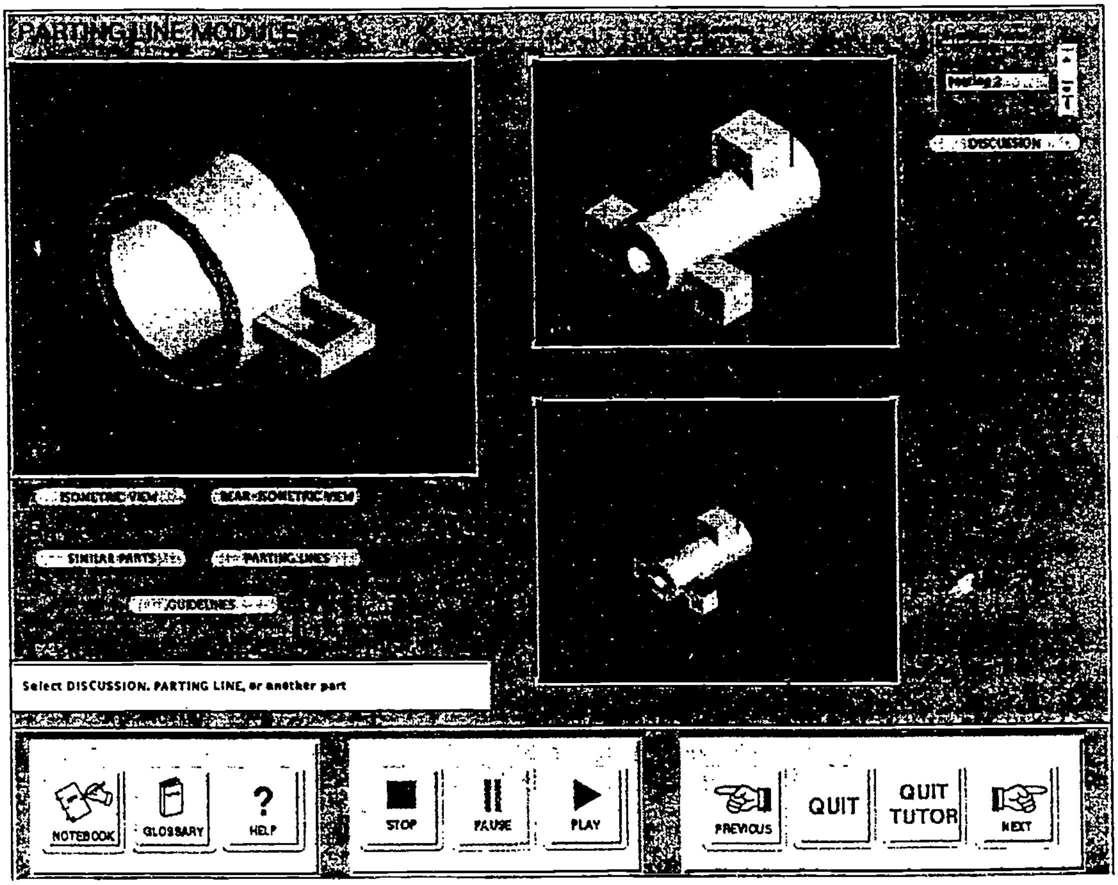

Figure 2: Retrieval of Similar Previous Part and Its Solution

Whenever any piece of information or instruction is presented, the student may choose to have it repeated as many times as he would like. Furthermore, additional topics that are related to his query and the interconnection between them are shown. The student can then choose to study any of the associated topics. When ready, he can proceed. Figure 1 shows a prototype system screen during this interaction.

Next, the student is shown a new part and different choices of parting lines for that design. He can view the part from different perspectives. If he is ready to make a selection, he can choose the parting line that he thinks is best. He will then get a discussion about the part and the solution, including which guidelines were followed, how the other solutions compare, and references to associated designs. If the student is not ready to make a decision, he can explore the related experiences of other patternmakers that are stored in the memory. If he chooses that option, he will then have a choice of several associated parts. In viewing each associated part and the correct solution, the student can learn from past experiences of other patternmakers and learn why the parting line decision was made for each case. The student may then be able to infer the solution for the part that he is currently studying. Figure 2 shows a prototype system screen during this interaction. In this figure, for example, the hollow cylindrical section in the associated design would teach the student how the parting line placement affects the need and design for a core, which could then be applied to the hollow cylindrical section of the part in question. When the student feels comfortable with making a decision for the part in question, he can return and make the choice. At any time, the student can explore the information contained in the memory and the associations presented to him. He can study the topic of interest, viewing more examples, videos and instructions.

Ongoing Research and Design

After using the system for training in learning the facts and fundamentals of the patternmaking task, we would like the student to be able to use the system and its multimedia capabilities for guidance during the practice of the art. Using the system as a guide would enable the practicing patternmaker to effectively apply the associated experiences of previous patternmakers as well as allow him to troubleshoot defective parts and patterns. Given the complex nature of these goals, we would also like to incorporate into the training system the lessons necessary to teach the trainee how to effectively use the system as a guide.

In order for the patternmaker trainee to be able to effectively use the associative memory, it must be structured so that the trainee can interact with the memory in a natural and comfortable manner. The associative memory, described generally in Pao (1992), is structured so that designs with similar features, such as geometry, are associated together. It is not enough in this context, however, to just use geometric descriptions. In order for the memory to be useful for the patternmaker trainee, the part and the pattern should also be described in terms of part and pattern descriptive features that are appropriate for that field, for example, sharp corners or thin holes. These features are more natural and relevant for the student to use in describing parts and patterns for both design and troubleshooting purposes. Geometric features such as large section, long thin rod, flat plate and so on, in addition to the descriptive features, are useful for remembering parts on the basis of geometric designs. The student can be taught the skill of describing designs in terms of meaningful descriptive features by having the system show him several different designs, using various types of media, with their corresponding appropriate design features. Through practice, he can learn this interpretive skill.

The associative memory can also be very useful for troubleshooting defects and potential defects. Effective troubleshooting requires an additional skill that should be taught by the system. This skill is the ability to interpret or describe an observation of a problem on a part or pattern in terms of a named defect category commonly used in the field of patternmaking. In order to teach this skill, the system would show the student, through videos, pictures and graphics, examples of defective designs and patterns and then describe which features characterize certain defects and the actual name of each defect. This interpretive skill is the first step in a procedure to identify and correct defects, as shown in Figure 3. After the defect has been named, there are several contexts in which it can occur. For example, the defect may be due to inappropriate design or due to faulty pattern equipment. At present, we are concentrating on the pattern design context. For a given context, there are causal features that could have led to or *caused* these defects. At this step, another interpretive skill comes into play. The patternmaker trainee must now see if any of these causal features correspond to the pattern descriptive features for the given pattern. That is, he checks if his pattern contains any problematic features in the current context. If so, the student can then look up in the memory the cure associated with the problem. If not, he can check another context and its associated causal features. The student can also explore how the observed defect may be due to one of several different causes in different contexts. Using the examples stored in the memory, the student can ask for examples to learn the subtle signs that would be helpful in differentiating among several potential causes.

The memory and methodology used for troubleshooting can also be employed in identifying potential defects for a certain pattern design or a given part. This can be achieved by using the pattern descriptive features or the part descriptive features that the patternmaker trainee enters. The trainee, with the assistance of the system, can then check in the memory to see if a part with these features could correspond to a defect. The cure could then be incorporated into the design.

The methodology used to teach the design, troubleshooting and associative skills discussed is important in order for the student to truly benefit from the system. Several guidelines are used throughout the system. Specifically, during a learning session, the student is provided with a recommended learning path. He can, however, veer off and explore any area that sparks his interest, or that he would like to study further. He can continue in this manner until he is ready to proceed with the lesson. Therefore, the student is able to get help and information when he needs and wants. This type of system provides the student with a non-threatening

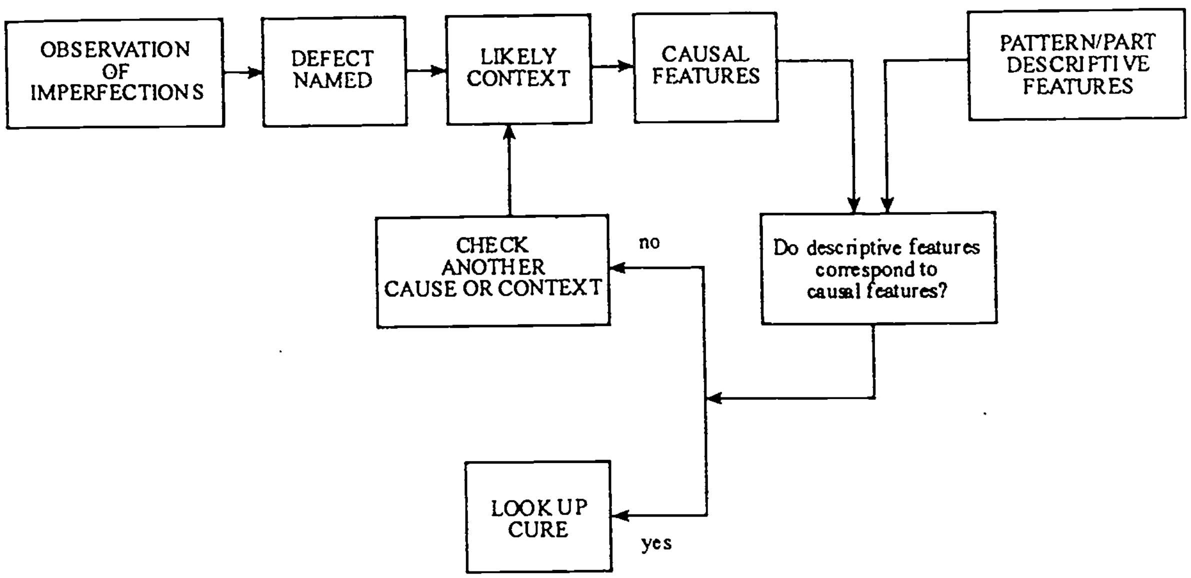

Figure 3: Procedure for Identifying and Correcting Defects

environment. He can continue to ask questions and explore areas of interest without frustration or fear of embarrassment. The learner can test himself to see if his interpretive skills are developing well or if he needs more examples and practice in a particular context or for a particular defect. He can test his skills by asking the system to provide him with more cases in a particular area.

The various types of media are important tools used in the design and implementation of this system. Given that patternmaking is both an art and a craft, a hands-on skill, it cannot be completely taught simply by classroom lecture instruction. The student must see different examples and be able to graphically try different techniques. Patternmaking is also a complex task. It is, therefore, important that the training and relaying of experience is presented appropriately for each given student. Various students may assimilate information differently. One person may find verbal instruction more useful, whereas another, may prefer a picture or diagram. Different techniques or combinations of techniques may be helpful in learning new material or reviewing information. Furthermore, certain information may be better transmitted in one form of media versus another. With multimedia technology, video, audio, text, graphics and pictures can be used to help a person learn new concepts or improve his knowledge in areas he has already studied. In this research, multimedia is used to ensure that all sensory channels available are being utilized, in text, in sound, in pictures and eventually, when possible, by feel. In order to be more effective, multiple forms of media are also sometimes used together.

These procedures and techniques illustrate the advantage and power of using the associative memory as well as the multimedia technology as tools to train and guide patternmakers. The memory and the different forms of media let the student benefit from the experience of seeing many different designs, patterns and problems without having to perform the design process himself. The trainee can benefit from the experience and expertise of many master craftsmen, both from their mistakes and their solutions.

Summarizing Remarks

We have carried out a conceptual design of a new type of multimedia supported, self-paced training system and have implemented our design in several aspects of the system. The goals of the system are to train a potential patternmaker in patternmaking and to provide guidance and support during the practice of the art. After training in the facts and fundamentals, the system can be used to support both the recall of associated designs encountered previously and troubleshooting. The student is also taught to describe a design in terms of meaningful descriptive features and to describe an observation of a problem in terms of a named defect category.

It is our belief that the storage of experiences and expertise of many trained individuals, when augmented with multimedia techniques, can provide a powerful tool and effective means of capturing and transferring the knowledge required to perform a complex task. Our approach entails storing the knowledge and experiences in an associative memory that gives the student freedom to explore the memory structure. Furthermore, given the difficulty of teaching patternmaking with text alone, we need to employ different forms of media. These include video recordings, audio instructions and explanations, graphical images and illustrations, as well as text.

In this paper we present a brief report on ongoing research. Given that we had to implement, at a very low level, many of the multimedia functionalities required by the system design, we look forward to improvements and innovations in multimedia technology. Also, we continue to explore and develop the associative memory structure. We feel that this prototype laid the foundation and framework necessary to continue and build on our research.

Acknowledgments

We acknowledge the considerable help we received from the staff of the American Foundrymen's Society and the Canadian Tooling Manufacturers' Association. Of the many helpful and instructive publications made available to us, we list three in the bibliography as suggestions for further reading and for reference. We also thank Stephen Gregory and Benny Carreon of Kelly Air Force Base for their assistance and guidance in this project. Alok Mathur of the University contributed significantly in the implementation of the prototype system. We also thank Ron Cass of AI Ware for his continued interest and never-failing readiness to provide helpful technical assistance, including providing example parts. Part of the funding for this project was provided by the Cleveland Advanced Manufacturing Program.

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