86CH2300-2

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CONFERENCE RECORD OF 1986 THIRTY-EIGHTH ANNUAL CONFERENCE OF ELECTRICAL ENGINEERING PROBLEMS IN THE RUBBER AND PLASTICS INDUSTRIES

APRIL 7 & 8, 1986

Sponsored by the

Rubber and Plastics Industries Committee
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Papers presented at the Thirty-Eighth Annual Conference
Akron, Ohio
April 7 & 8, 1986

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PRICE: $40.00

Available from
IEEE Service Center
445 Hoes Lane
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IEEE Catalog No.: 86CH2300-2
Library of Congress No.: 84-644754

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USE OF ARTIFICIAL INTELLIGENCE IN ENGINEERING

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Abstract

Artificial intelligence concepts can now be applied to engineering practice through the discipline of knowledge engineering and an emerging expert systems technology. Terminology related to these fields is reviewed, and several projects are described. These illustrate how engineering practice can benefit in the near future from AI research. A new expert system tool is introduced for immediate applications. This system enables a knowledge engineer to implement a large capacity expert system on a personal computer.

Introduction

There is a lot of competitive pressure on all corporations (which is transmitted to engineering staffs in quite clear terms) to get results --

- in greater quantity,
- of higher quality,
- much faster,
- at lower cost, and
- with fewer engineers.

An obvious way to meet these demands is to automate engineering tasks insofar as practical and to furnish engineers with more tools to do their work.

Recent interest in AI for engineering applications to meet this need focuses on expert systems due to inherent practicality even though there are other fields under the AI umbrella that are also very promising.

Knowledge Engineering

Using expert systems methodology involves first understanding a new discipline, knowledge engineering, its viewpoints and its terminology.

However, no one is saying that the expert system is an exact replacement for the domain expert.

Domain Experts

Expert systems are really attempts to capture human expertise and somehow get it into a computer so that other less expert people can use it whenever they need it. The domain expert is the human expert whose expertise is to be captured and you must have at least one of these people before you can get started.

There are certain problems in debriefing domain experts. Although such an expert may be widely recognized for his adeptness at solving tough problems in his domain, he may not be able to explain what it is that he does or why he does it. Then too, it is necessary to win his cooperation. He may not feel his own interests will be well served by the proposed expert system; or he may think the individual asking the questions is stupid and can't possibly understand the answers. He may also get bored if there is too little progress.

These problems tend to be less as acceptance of the individual who does the debriefing becomes greater. Winning acceptance is a definite talent. Everyone who is involved in a project should feel good about it.

Knowledge Engineers

Knowledge engineers are the people who debrief domain experts and somehow manage to actually capture the experience and techniques of the domain experts. Knowledge engineers may know a great deal about programming and/or a great deal about computer hardware; then again, they may not. They must, however, be able to understand what the domain expert is saying and this usually means learning a lot about the domain quickly. Furthermore, they must be able to manage good interviews that ferret out the facts. They also need to keep the domain expert interested in the project. They are problem solvers and they are people-oriented.

Once the expertise has been put in the "can", it still must be tested, evaluated, and made ready for delivery to users. This "canned" expertise constitutes an expert system which substitutes for the consultant by delivering "consultation" to users when the consultant is not present.

Users

Users of expert systems are generally considered to be anyone who would ordinarily be a client for the domain expert were the expert readily available.

This is only partially true. Expert systems have been devised which are intended to be used by the experts themselves so that they may increase their productivity and/or sharpen their skills and/or make certain they miss nothing in offering a consultation.

Medical diagnostic systems are a good example of expert systems designed to be useful to experts. Every doctor who practices is thoroughly trained in diagnosis and may specialize in some field for which he has a complete and thorough knowledge. Then why did Dr. J. Meyers, of the University of Pittsburgh, obligate himself to a twelve to fourteen-year project to build a good general diagnostics system? As a teaching doctor, he was worried about the increasing specialization in the medical profession and the resulting decrease in general diagnostics capability of specialists. He and H. Pople, also on the Pittsburgh faculty, created Caduceus with these new specialists in mind. Caduceus can diagnose 600 diseases even with multiple diseases present. The creators of Caduceus readily admit it can't recognize a new disease for which it isn't coded, but it never misses prescribing a lab test either.

Tools

The tools of the trade for knowledge

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engineering include but are not limited to the following types of computer programs:

1. Knowledge representation: the form used for storing knowledge in computer memory for recall

2. Knowledge acquisition: getting the knowledge from the domain expert into the computer in a form that can be used; includes procedures and data.

3. Knowledge base: knowledge stored in the computer ready for use.

4. Inference engine: the computer program that processes the knowledge base in order to deliver answers relevant to questions asked.

5. Shell: expert system from which the knowledge base has been removed so that a new knowledge base may be inserted to create a new expert system using all else from the original expert system.

Even these early AI tools represent a change in the way engineers may expect to do their work in order to meet the time, quality, and cost needs of their managements.

Expert Systems

Early expert systems were conceived mainly as stand-ins for domain experts, systems that could provide advice when consulted and given a description of a problem. More recently, the application of expert systems has been extended to serve within instrumentation systems with the result that instrument and control systems can behave a great deal "smarter".

Consultation

Expert systems are still much used for creation of "electronic consultants", packages which provide expert advice when and where domain experts are not available. This form has proven to be valuable in diagnostics, trouble-shooting, and maintenance where a large need exists.

Insofar as the dialogue between the user and the expert system used in consultation mode is likely to be very specific to a particular problem, the user must be able to understand the language of the problem and give accurate, pertinent answers. In other words, a user is likely to be something of an expert himself -- and he may even be the human expert who contributed the knowledge in the first place. This is very true for expert systems used in engineering domains. And the need for these systems has hardly begun to be served.

Instrumentation & Control Expert Systems

"Intelligent" instrumentation and control systems are becoming available which provide expert advice in open loop or expert inference in closed loop systems.

Laboratory Instruments

A project executed by Rutgers University (5) is a good example of the methodology applicable to expert systems. It led to a prototype expert system captured in ROM for a M-6809 microprocessor embedded in a small, widely used clinical medical laboratory instrument. Rutgers collaborated with the Helena Laboratories to add expert system capability to the existing Clini-Scan blood protein analysis instrument.

Steps taken to accomplish the project were:

1. Specification of the knowledge base using EXPERT (an expert system shell, the property of Rutgers) on a mainframe computer.

2. Empirical testing with several hundred cases.

3. Refinement of the knowledge base by the domain expert.

4. Further cycle testing with additional cases and review by independent experts in this domain.

5. Test of the final model on the mainframe development machine.

6. Automatic translation of the EXPERT model to a specialized program in the assembler language of the M-6809 microprocessor.

7. Installation of the assembly language model into the clinical instrument.

The first six steps were carried out by Rutgers; the last step was carried out by Helena Laboratories.

The actual output of the machine is a strip chart recording of the five protein components of a blood albumin sample measurable as five peaks. The additional output, coming from the expert system, is in the form of several lines of printed text which constitutes an analysis of the specimen from the instrument output and given data. The whole (chart plus printed analysis) is submitted for approval by an MD who will indicate acceptance and approval by signing the record.

This particular expert system is successful insofar as it bypasses several hang-ups in the medical profession. Manual entry of data is kept to a minimum; the expert system is embedded within the instrument and is perceived to be a feature of the instrument; no human functions are preempted.

Fuzzy Logic in Control Applications

The Smidth Cement Kiln Controller (6) from F. L. Smidth & Co., Copenhagen, uses production rules and "fuzzy logic" to determine what adjustments must be made in the flow of air, fuel gas, and raw materials or rotation speed of the kiln in order to nudge kiln performance to a more economical or high quality level.

Cement is made in the same manner as it was in ancient Rome: clay and limestone are crushed and mixed, heated to drive off CO_2 and water, then cooled and ground into powder. A modern cement kiln is a huge rotating tube (perhaps 500 ft. long, 12 ft. diameter) on its side and tilted so that clay and limestone may be fed at the high end and cement clinker recovered at the low end. Air and fuel gas are mixed and burned at the low end with stack gases leaving at the high end; temperatures are 1000-1400 C. As the kiln rotates, the solid feed tumbles and moves toward the low end. Control is maintained on clay, limestone, air, and fuel gas feed rates plus the kiln-drive torque.

Chemical lab analysis of the product is

performed periodically to determine quality, primarily the free lime content of the cement clinker. Adjustments are made on the basis of this analysis to trim costs and increase cement quality.

Production rules are used to capture the 40 to 50 heuristics which experienced kiln operators learn over time; e.g.

IF THE OXYGEN PERCENTAGE IS RATHER HIGH AND THE FREE-LIME AND THE KILN-DRIVE TORQUE ARE NORMAL, THEN DECREASE THE AIR FLOW AND SLIGHTLY REDUCE THE FUEL RATE.

There are problems in automating kiln control with such rules:

1. several rules may apply in varying degree at once and may be in conflict;

2. rules may vary in force depending upon applicability;

3. rules are expressed in "fuzzy" terms: "rather high", "normal", "decrease", "slightly reduce".

4. there are few internal kiln condition measurements possible;

5. chemical reactions involved are complicated.

How does the Smidth controller work?

For each rule that applies to a given situation, control adjustments are computed and the condition which is satisfied to the least degree determines the degree to which the entire rule will be satisfied. Then the actions recommended by each rule are weighted and "averaged" to obtain the appropriate control change.

"Fuzzy logic" is also the basis for a new chip created by AT&T which is intended for use in factory automation. Last December, Togai and Watanabe (4) of AT&T's Computer & Robotics Systems Research Laboratory presented a paper at an IEEE Computer Society conference which described a chip using fuzzy logic with up to 64 rules.

The AT&T chip is claimed to be amenable to parallelism; more rules can be added by cascading more parallel chips. Also, with this chip, the use of fuzzy logic apparently permits six rules to do the work of forty-eight rules based on traditional probabilistic confidence levels. If these claims are really true as stated here, then a great step forward has been achieved.

Process Control

The PICON (Process Intelligent CONtrol) instrument from Lisp Machines, Inc., is a general purpose process control machine that uses two Motorola 68000 microprocessors to monitor a very large (up to 20,000 points) sensor network and find those points which need attention (2).

PICON is unusual in several ways.

1. The development system (used to develop an application) is the same machine that is used for the delivery system (the product delivered to the user in the field).

2. In setting up and defining control action, two domain experts are used: a control engineer and a process operator.

3. Expertise is acquired automatically from the domain experts.

The first expert, a control systems engineer, uses a CAD style input technique at the PICON "work station" display to enter what he knows about the sensors, their locations, control algorithms, etc.

Then the second expert, a thoroughly experienced operator, enters his knowledge of how the system should be controlled by using IF...THEN... production rules in response to prompts by the computer; the operator also assigns probabilities.

Furthermore, the program that does all this and organizes the data it obtains is a very sophisticated knowledge acquisition and representation system on its own.

Of the two M-68000 microprocessors used, one does real-time interfacing to as many as 20,000 sensors on the process to be controlled while the other performs as an expert system to determine what must be controlled and how. This processor uses the "expert operator" paradigm: "don't pay any attention to instruments that are near their set-points; focus on instruments that are near or exceed process limits."

During operation, the system continually scans the sensor network for readings that are outside of limits. When it finds such readings, it determines what is wrong, what should be done, and initiates action based upon information in the knowledge base and logic of the inference engine.

Although none of the three examples has been presented as a closed loop system, the PICON system nevertheless has this capability.

Design

"Expert" engineering design systems are under study at the university level which promote integration of existing non-compatible, distributed CAE/CAD/CAM systems.

The Carnegie-Mellon University Design Research Center has an extremely ambitious program under way which is intended to use any program and any data base resident on any of several computers attached to their network and use them to do engineering design work (3).

This requires that the system be able to organize diverse data base queries getting information from wherever it might be and putting it into the form needed for the requesting terminal.

In a similar vein, calls can be made to programs based on the designer's commands to perform tasks.

This particular system off-loads all the various operator commands normally required to perform these tasks and puts the responsibility for correct formatting and call sequences on the system itself.

The CMU project uses an expert system at the center of its organization which uses a "blackboard" that all the programs (referred to as "knowledge sources" or KS) can read from and write to. This blackboard expert system also is able to compare the results on the blackboard and to select the next knowledge source (data base, computational program, or other expert system) to be activated. This capability involves a "focus of attention" and "opportunistic scheduler" program modules which can determine what KS offers the best opportunity of success, then execute it.

Applications under study (as of April 1985) were:

.Selection of Chemical catalysts;
.Mobile robot planner, sensor systems;
.Production scheduling;
.Design of metal alloys;
.Integrated circuit layout; and
.Structural design of buildings.

An integrated circuit layout package known as the Design Automation Assistant (1) has been developed and tested by CMU by going through redesign of first the MOS Technology MCS-6502 chip and a redesign of the IBM System/370 data path chip (used by IBM for its 370-board set that can be inserted into the IBM PC). Claud Davis, of IBM Poughkeepsie, evaluated the 370 data path design and said it "...exhibited the quality I would expect of one of our better designers..."

The NQ Expert System

In the Department of Electrical Engineering of The University of Akron, the importance of expert systems for engineering is well recognized. One response has been the addition of a special topics course in Expert Systems for senior and graduate level students. Student projects and contract research involving graduate students are providing additional opportunities in machine intelligence. And we have our own expert system. We call it NQ.

"NQ" stands for "No Questions". NQ is an expert system shell, a program that knows how to conduct an interactive consultation with a user, but does not itself contain the domain knowledge that is the basis for the consultation. Instead, a knowledge engineer prepares a "source" knowledge base and compiles it into the form that the consultation program uses. Also, the engineer may customize the consultation program for a particular application.

We call the system NQ because it largely avoids an objectionable behavior of expert systems, the tendency to ask a long series of questions which the user cannot effectively control. Every expert system must collect facts from which it makes inferences to establish conclusions. NQ asks no questions, but instead displays, in increasing detail, facts that can be set true or false, or left reset, as the user desires. By choosing which rules to look at in more detail, the NQ user explores the knowledge base, passing over facts that do not apply and bypassing entirely regions of expertise in which he has no current interest.

NQ gives the user rule displays, exploration paths, and structure maps that help with the exploration. A part of the compiler's function is to assemble text so that it can be made accessible for rule displays. What makes NQ an expert system, however, is its inference engine. NQ's inference engine is not allowed to control the fact gathering, but it has essential functions to perform. Whenever the user changes the true or false state of a fact the inference engine determines the effect on every AND or OR clause in which the fact appears and on every rule in which they occur. If the state of the rule changes, the effect on any rules containing this rule are computed. And so on. The user sees how many such inferences have occurred and may use structure maps of the rule base to locate quickly where entered facts are creating conclusions.

NQ was designed to handle large rule bases on a personal computer. Our IBM PC version supports 8000 symbols representing facts or rules. With a hard disk to make enough rule screens available, this version can run thousands of rules. It is implemented in FORTH, which offers execution speed compatible with interactive and real-time applications. The inference computation is fast, because the compiler has created a compact binary version of the rule base, with pockets for the truth state of facts, clauses, and rules, which the inference engine can traverse and update quickly.

Since the truth state of the knowledge base is integrated with the binary rule structure, it can be saved with the structure on a diskette at the end of a session. Even in a hard disk system, the state of a consultation is saved on a diskette. That particular consultation is resumed, at the point of the save, when the diskette is reloaded. Of course, the truth state can be reset at any time to "all facts reset and on the main rule", to start another problem.

The features we have described make NQ a potentially useful tool in many areas of engineering. Of particular significance here is that the consultation based on propositional logic can be supplemented by the addition of FORTH functions that can prompt for numerical data, do calculations in real or integer arithmetic, present graphics, or drive external interfaces memory mapped into the computer. So our research is turning now from development of the NQ shell to applications that utilize specialized function libraries to bring NQ advantages into new environments.

We plan to have demonstration NQ consultations on a manufacturing control system, your income taxes and motor diagnostics for you to see at the conference. We'll also have an NQ authoring kit. With this, you can design your own NQ consultation.

Conclusion

This quick overview of important aspects of expert systems usage in engineering is a brief introduction to the subject. It comes nowhere close to being exhaustive. The status of the most meaningful projects in this field at this time is still mainly R&D with significant products coming to commercial realization.

Expert systems research in the Department of Electrical Engineering, at the University of Akron, has produced the NQ shell. NQ provides a way of creating expert systems for a wide range of engineering applications and promises to be a useful tool in the Rubber and Plastics industry.

The AI contribution to engineering will be towards automation of manual methods, increasing reliance upon computer-aided analytical work, increasing aid from expert systems, and more sophisticated problem solving by engineers. The result is certain to be the higher productivity of engineers needed to meet the economics-driven requirements of higher quality, lower cost engineering on shorter schedules. That's what succeeds in a competitive, global economy.

References

(1) Kowalski, T. J., Thomas, D. E., "The VLSI Design Automation Assistant: An IBM System/370 Design", IEEE Design & Test of Computers, v. 1, n. 1, February 1984, IEEE Computer Society, Piscataway, NJ, p. 60-69.

(2) Moore, R. L., Hawkinson, L. B., Knickerbocker, C. G., Churchman, L. M., "A Real-Time Expert System for Process Control", First Conference on Artificial Intelligence Applications", IEEE Computer Society Press, Silver Springs, MD, 1984, p. 569-576.

(3) Rychener, M. D., Banares-Alcantara, R., Subrahmanian, E., "A Rule-Based Blackboard Kernel System: Some Principles of Design", IEEE Workshop on Principles of Knowledge-Based Systems, IEEE Computer Society Press, Silver Springs, MD, 1984, p. 59-64.

(4) Togai, M., Watanabe, H., "A VLSI Implementation of Fuzzy Inference Engine Toward an Expert System on a Chip", Second Conference on Artificial Intelligence Applications, December 1985, IEEE Computer Society, In Press.

(5) Weiss, S. M., and Kulikowski, C. A., "A Practical Guide to Designing Expert Systems", Bowman & Allenheld, Totowa, NJ, 1984, p. 107-116

(6) Zadeh, L. A., "Making Computers Think Like People", IEEE Spectrum, August 1984, New York, NY, p. 26-32.

MAP - MANUFACTURING AUTOMATION PROTOCOL, INDUSTRIAL LOCAL AREA NETWORKS FOR DATA COMMUNICATIONS BASED UPON INTERNATIONAL STANDARDS

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ABSTRACT

Local area networks (LAN's) are being developed to reduce the cost of interconnecting programmable devices in a multi-vendor environment. The current cost of integrating these devices into a cohesive whole, has been negatively impacted by the lack of compatible protocols. The Manufacturing Automation Protocol (MAP) specification development work was started by the General Motors MAP Task Force in the early 1980's to address this recurring connectivity cost. The continuing MAP LAN development activity has been supported by the standards organizations, the SME/MAP Users Group, and the vendor community.

BACKGROUND

In 1980, General Motors (GM) formed a task force from the ranks of its computer and manufacturing organizations, to develop a communications standard that would enable programmable devices from multiple vendors to communicate with each other. At that time, almost half of the investment in automation was spent developing customized software to achieve machine-to-machine communications. The MAP Task Force determined that the only way to achieve a low cost and widely supported communications utility, would be to utilize international industry standards in the MAP specification. The required standards not currently available would have to be developed in conjunction with the standards organizations, communications vendors, and other potential user companies.

Since the formation of the GM MAP Task Force, other manufacturing companies have recognized that their survival against worldwide, lower cost competition depends upon their ability to create and manage an efficient, electronic information flow system within their organizations. The factory of the future concept requires the integration of separate automated processes into a cohesive whole. Timely information must be available for exchange between and within the functional organizations and for presentation to management in a usable form. This information capability can provide on-line status.

A simplified answer to the question of "What is MAP?" is that MAP is a specification for an industrial LAN and the data communications interface used between an intelligent (computer based) device and the LAN. The complexity of the communications task demands a structured development approach. The model described in this tutorial about MAP, is a seven layer model based upon international standards.

OSI REFERENCE MODEL

GM determined that any factory automation solution would require equipment from multiple vendors communicating with each other. This could only be accomplished on the basis of a widely supported nonproprietary factory communication standard. The economic reality of this is now widely supported by other companies in their automation planning and programs. GM selected the International Standards Organization's Open system Interconnection (OSI) Reference Model as the basis for the MAP specification because of the worldwide acceptance that this architecture has developed. This international nonproprietary basis could lead to broad based usage of these standards and cost effective communication solutions for the user community.

The OSI Reference Model, shown in Figure 1, divides the communication function in seven layers. Layers 1 through 4 provide the connection services, while layers 5 through 7 provide the communication services. As a result of the modular design, the various standards committees can more easily divide and coordinate the work required to specify the standards and protocols for the communication architecture in a timely fashion.

APPLICATION	LAYER 7
PRESENTATION	LAYER 6
SESSION	LAYER 5
TRANSPORT	LAYER 4
NETWORK	LAYER 3
DATA LINK	LAYER 2
PHYSICAL	LAYER 1

Figure 1. OSI Reference Model

The functions of the layers in the OSI Reference Model are defined below.

LAYER 1 - PHYSICAL: This layer accepts and sends streams of bits without regard for their meaning via the communication medium (wire, coaxial cable, or fiber optics). It encodes 1's and 0's, performs the necessary physical functions required for connecting/disconnecting/interacting with the communication medium, and provides the drive and isolation needed to send the signal out on the transmission medium.

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This layer is analogous to the physical telephone instrument and its connection to the telephone network.

LAYER 2 - DATA LINK: This layer is largely independent of the medium used in the Physical layer and is primarily concerned with message packaging and link management. This layer frames the data string; i.e., identifies the beginning and end of a message, controls medium connection/disconnection and performs error checking which also includes error correction or the performance of retries within the network.

LAYER 3 - NETWORK: This layers knows the network topology (configuration) and the capabilities of network resources. It takes outgoing messages from higher layers in the transmitting computer and combines them into packets by adding a packet header or routing information. The Network layer ensures that those packets are effectively directed toward the proper destinations. The Network layer is responsible for global addressing similar to the fully qualified telephone number for telephone systems. If one dials a seven-digit local telephone number, one reaches some receiving phone in one's local area. However, in a world-wide sense, there is a much longer number that must be dialed to reach an overseas destination. In a data sense, this longer world number is the fully qualified address.

LAYER 4 - TRANSPORT: Only messages destined for higher layers in a particular computing device ever reach the Transport layer. This is the first layer concerned with the end-to-end integrity of a message. This layer also provides message segmenting and reassembly. Segmenting is used to eliminate restrictions on the size of a message. In operation, this layer breaks the message into segments and then assigns a unique number to each segment. In the telephone scenario, one can think of someone picking up the telephone and saying, "hello". Note that two things happened here; first, a connection is established, and by saying "hello" the other end is verifying that the connection has been established.

LAYER 5 - SESSION: This layer establishes and maintains connections, called sessions or dialogue management, between specific pairs of communicating programs on separate computer systems. One can think of this as who talks first in the telephone example. The session layer negotiates the dialogue between the two computers and synchronizes or keeps track of requests/responses between them.

LAYER 6 - PRESENTATION: This layer deals with data representation and the format of data. A host computer may use a set of universal codes that are sent to many different types of computing devices. When the message arrives at the Presentation layer of a device, the universal code must be translated into a form that is coherent to the receiving computer. If two people on the telephone both speak English, then a common presentation layer is used by both. However, if one speaks English and the other speaks French, a Presentation layer translation is required in each end system.

LAYER 7 - APPLICATION: This layer provides the access point for user entry into the network. This layer establishes the context for what type of information will be transferred over the network. For the telephone example, if you were to go into a retail store and use a credit card, the clerk will make a call for a credit check. When the proper number is dialed, the person answering the telephone call knows that the clerk is going to be asking for a credit check.

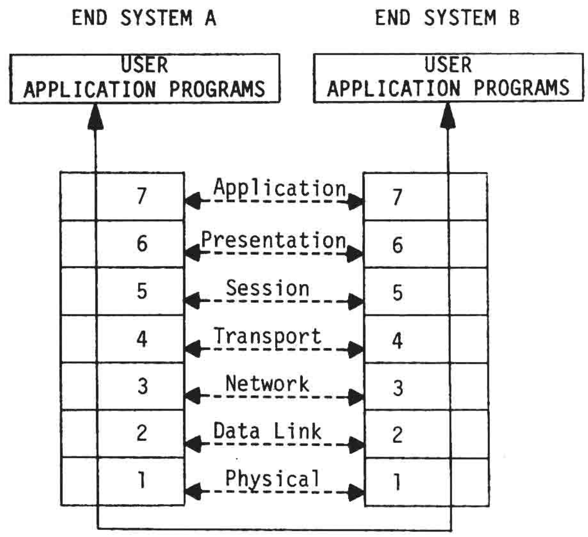

Figure 2. Application with Two End Systems

In a typical application shown in Figure 2, it is necessary that A and B end systems communicate with each other, since information in a data base located in A is required by an application program running on B. This would be typical of the communications required to download a new machined part program from a direct numerical control system host computer to the computer numerical control located on the machine tool. The only way to accomplish this exchange is for each user to agree on the meanings of the protocols used to establish the communication link and exchange data.

To accomplish this, each end system uses an interface based on the OSI Reference Model. The protocols utilized in each layer of the end system A interface must be the same as the protocols used in each corresponding layer in the end system B interface. Thus peer-to-peer communications is logically established between corresponding layers of each interface as indicated by the dashed arrows between the two interfaces. The data must physically flow from Layer 7 down through Layer 1 of the end system A interface, over the physical communication medium to Layer 1 of end system B, and up through each layer of the end system B interface. This flow is indicated by the solid arrow. The protocols and data are then available for use by the end system B application programs.

The MAP Specification

The MAP Users Group of the Society of Manufacturing Engineers (MAP/SME) has developed a document in the public domain called the MAP Reference Specification (2). The document is derived from and is consistent with the General Motors' MAP 2.1 specification which defines the seven layer, broadband interface (3). Also included in the MAP Reference Specification, is the definition of a MAP subnetwork based upon a carrierband physical layer and an Instrument Society of America (ISA) S72.01 link control layer (4). it is the intent of MAP/SME for this MAP Reference Specification to become the single, public, international MAP specification.

The specific set of protocols for each layer as defined by the MAP Reference Specification are shown below.

Layer 7:	ISO CASE (MAP subset)	
	MMFS	
	ISO FTAM	
	MAP Directory Services	
	MAP Network Mangement	
Layer 6:	Null	
Layer 5:	ISO Session kernel	
Layer 4:	ISO Transport, Class 4	
Layer 3:	ISO CLNS (Connectionless-Mode Network Service) inactive and subset	
Layer 2:	ISO/IEEE 802.2 type 1	(5)
	ISO/IEEE 802.4 Token Bus	(6)
Layer 1:	ISO/IEEE 802.4 10 Mb/s, Broadband	(6)

The reference to GM-specific protocols or subsets are interim steps and will be replaced with international standards when they become available.

BROADBAND PHYSICAL LAYER

The use of broadband technology for the physical layer of MAP applies to applications where a backbone network is required for a facility. The intent is not for every intelligent device found on the factory floor to connect to the backbone. The broadband modems employ rf technology and the connect cost per device is still quite high. Therefore, only those intelligent devices controlling or monitoring areas or workcells of the factory will connect directly onto the MAP backbone.

The broadband coaxial cable and accessories specified in the MAP specification are the same used in Community Access Television (CATV) systems (7). The CATV components are proven and rugged with mean time between failure of over twenty years. The type of cable specified has an extremely high outside noise rejection level on the order of 132 db. This is primarily due to the rigid outer aluminum sheath. Tests of noise rejection have been made by Inland Steel in conjunction with the MAP/SME Users Group.

The broadband cable system is multi-channel and can carry voice, video, and data concurrently over a distance of up to fifty miles. The multiple use of such a network implies that the network can be viewed as a facility communications utility, much as the wall outlets for electrical power. The MAP specification allows for six channels operating at 5 Mb/s on the same cable or three channels operating at 10 Mb/s.

The disadvantages of broadband cable systems are that they must be engineered and that broadband is expensive for single channel applications which are more cost effectively handled by single channel baseband or carrierband networks.

CARRIERBAND PHYSICAL LAYER

The flexibility of the OSI Reference Model is illustrated by the interchangeability of a broadband physical layer with a carrierband physical layer. The MAP/SME Reference Specification describes a carrierband IEEE 802.4 physical layer which uses a lower cost modem for the physical layer, but with the limitations of one channel per cable, a restricted number of nodes (drops), and reduced length of network cable. This configuration is designated as a MAP/PROWAY System and is one of the allowable systems that make up the MAP Cell Architecture for subnetworks within the factory workcell. Typically for subnetworks the response time requirement is shorter than the response time on the broadband backbone and a reduced 'cost to connect' is required. Commercial subnetworks currently available, are the proprietary networks from many vendors, which allow communication between vendor specific products within a workcell. The development of the MAP/PROWAY systems specification is currently underway by MAP/SME and the standards organizations.

NETWORK PERFORMANCE

The network performance of the broadband and carrierband networks is currently under study and demonstration in pilot projects by the user and vendor participants within the MAP/SME Users Group, along with the national Bureau of Standards.

DATA LINK - TOKEN BUS

The IEEE 802.4 Token Bus standard selected for the Data Link layer specifies that the node holding the 'token' (an OSI conceptual object) has control of the network and may broadcast on to it. The token is logically passed along the bus from node to node such that every node will have access to the network in a deterministic manner. This avoids collisions which could occur if nodes were allowed to transmit onto the network randomly as in a carrier-sense multiple access with collision detection (CSMA/CD) system such as an Ethernet network.

APPLICATION LAYER

Figure 3 illustrates the structure of the Application Layer as defined in the MAP 2.1 specification.

```
=================================
=               =               =
=     FTAM      =     MMFS      =
=               =               =
=-------------------------------=
=                               =
=             CASE              =
=                               =
=================================
```

Figure 3. MAP 2.1 Application Layer

The CASE (Common Application Services) protocols are are used to establish communication or associations between MAP applications riding above it in Layer 7. It is also used to manage and/or terminate data exchange. All protocols in the Application Layer utilize the CASE module.

FTAM (File Transfer, Access, and Management) allows for files to be transferred between end systems. Future enhancements of FTAM will allow applications to access files in remote file storage systems and will provide the services needed to create and delete remote files and read/update the remote file attributes.

The MMS (Manufacturing Message Service) protocol currently specified for MAP is MMFS (Manufacturing Message Format Standard). These protocols are for encoding messages and limited file transfers to programmable devices as CNC, programmable controllers, and robot controllers. MMFS, a GM-specific protocol, will be replaced with a rewrite of the current EIA Working Group 1393 document using an ISO notation and encoding standard, ISO Abstract Syntax Notation One, ASN1 (8). This rewrite, to be known as RS-511, should be available by the first quarter of 1987.

MAP INTERFACE IMPLEMENTATIONS

Currently, full seven layer MAP broadband interface products are available supporting a growing list of computer backplanes which include Intel Multibus, Motorola VME bus, and IBM PC bus from a list of companies that continues to grow in number. These single board solutions have the modem attached in a mother/daughter board configuration and therefore require two slots in the card cage.

Typically, Layer 2 has been implemented with custom gate arrays or VLSI designs, with Layers 3 and 4 implemented in Read Only Memory (ROM) of the on-board processor. The software developed to implement Layers 5 through 7 is typically downloaded from the network manager to the processor on the interface board. Not all vendors support all the protocols in Layer 7 due to the upgrading of MMFS to RS-511 during 1986 and 1987. This requires running the selected CASE and MMS protocols on the end system processor outside of the interface board until all Layer 7 protocols are supported by each vendor. For performance reasons, some vendors encourage users to only run Layers 1 through 4 (and maybe 5) on the interface card even after the upper layer protocols stabilize.

MAP DEMONSTRATIONS

The first MAP broadband multi-vendor demonstration was held at the National Computer Conference in 1984 (NCC 84). In that demonstration, seven vendors communicated with each other using interfaces which implemented Layers 1, 2, and 4 of a set of protocols which became the MAP 1.0 specification.

Alongside the GM demonstration was a Boeing demonstration of multi-vendor communications utilizing IEEE 802.3 (an Ethernet-type network) as the physical layer protocol (9). During 1985, the efforts of Boeing have contributed to the development of the Technical and Office Protocol (TOP) specification which selects the same layers used in the MAP 2.1 specification, with the physical layer being IEEE 802.3 instead of IEEE 802.4. The two demonstrations at NCC 84 were not networked together.

The second and most recent demonstration was AUTOFACT 1985. In the MAP/TOP booth sponsored by GM and Boeing, 22 vendors demonstrated multi-vendor communications utilizing networks and seven layer interfaces based upon international standards. The vendors were located on three interconnected networks within the MAP/TOP booth. These networks were an IEEE 802.4 - 5 Mb/s, an IEEE 802.4 - 10 Mb/s, and an IEEE 802.3 - 10 Mb/s. The MAP/TOP booth was connected to an IEEE 802.4 - 5 Mb/s network at the GM Technical Center over an X.25 (packet switching) link.

CONFORMANCE/INTEROPERABILITY TESTING

Conformance testing is intended to determine the degree to which the MAP protocols have been correctly implemented, both in normal and under error conditions. One of the positive aspects of conformance testing is that it is application independent. It can be applied once and as long as the results are available and the test administrator is unbiased, the testing need not be repeated by each end user. If, in an application of a tested MAP interface, the end user adds a protocol module, such as an implementation of the future RS-511 on top of Layer 7 CASE for example, only testing of the module on top of CASE would be required.

Interoperability testing ensures that devices will be able to communicate. This testing consists of interconnecting multiple implementations which have been previously conformance tested, and attempting communications among them. The fact that system A can communicate with system B and that system B can communicate with system C, does not imply that system A can communicate with system C. As such, interoperability testing is somewhat application dependent. Therefore, the testing must be applied to each application.

Currently, the Industrial Technology Institute (ITI) in Ann Arbor, MI is the only MAP conformance test center. It is using conformance testing algorithms developed by the National Bureau of Standards during 1984 and 1985. The current testing services of ITI provide MAP 2.1 conformance testing.

OPEN ISSUES

The open issues currently being addressed by the standards organizations, vendors, and users with respect to the broadband networks include:

1. Network performance
2. Network security
3. Network management
4. Conformance testing
5. Interoperability of the Physical Layer sourced from multiple vendors
6. Future interoperability of MAP 2.X and 3.Y
7. User education

SUMMARY

The development of industrial local area networks based upon non-proprietary, open, internationally recognized standard protocols has occurred in a compressed time frame as compared to standards developments in the past. This activity, even though initiated by GM, could not have progressed to where it is today without the support of the vendors, the users, and the standards organizations who are convinced that cost effective networking capability is an essential first step toward computer integration of our manufacturing operations as well as their total business.

REFERENCES

1. H. Zimmermann, "OSI Reference Model-ISO Model of Architecture for Open Systems Interconnection." IEEE Trans. Communications, Vol COM-28, April 1980, pp. 425-432.

2. The MAP Users' Group of the Society of Manufacturing Engineers, "Manufacturing Automation Protocol (MAP) Reference Specification (September 10, 1985)." MAP Users Group of SME, Dearborn, MI.

3. General Motors Technical Center Advanced Product and Manufacturing Engineering Staff, "The MAP Specification." March 31, 1985, Warren, MI.

4. Instrument Society of America SP72 Committee, "ISA-dS72.01-1985 PROWAY LAN", ISA, 1985.

5. IEEE Std 802.2-1985 (ISO DIS 8802/2).

6. IEEE Std 802.4-1985 (ISO DIS 8802/4).

7. E. Cooper, Broadband Network Technology, Sytek Press, Inc., Mountain View, CA, 1984.

8. EIA IE-31 Project 1393 Working Group.

9. IEEE Std 802.3-1985 (ISO DIS 8802/3).

BUILDING A WINNING CADD-BASED ENGINEERING TEAM

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ABSTRACT - Over the past fifteen (15) years, the technology of Computer Graphics has been implemented in nearly as many ways as there are installed systems. This paper addresses the way in which the Manufacturing Services Division of The Goodyear Tire & Rubber Co. has implemented this leading-edge technology in-house, and how Goodyear has forged an assembly of its engineering consulting firms into a cohesive team, all benefiting from the resulting partnership.

INTRODUCTION

BACKGROUND - Goodyear Tire & Rubber Company, since its founding in 1898, has aggressively searched out new markets for its products and has constantly sought the latest technologies to produce those products. This has necessitated the constant upgrading of its manufacturing facilities and the regular addition of new facilities. This ongoing engineering effort has been handled by an internal engineering staff, supplemented by a number of outside consulting firms. The way in which the internal staff and the outside engineering firms interact with one another, and the way in which this interaction has been optimized through the use of computer graphics, is the subject of this paper.

A CASE HISTORY

NEW TECHNOLOGY INTRODUCED - Goodyear has used computer modeling for tire design since the early 1960's; graphic output from these mathematical models was added as the technology became available. We acquired our first turnkey Computer-Aided Drafting (CAD) system, for engineering work, in 1975. This system was acquired to support our construction efforts and was a three (3) station Auto-trol system. It included "electronic drafting boards" or digitizers for all (3) storage tube-type CRT stations, a magnetic tape unit for archival file storage, and a flat-bed plotter for final drawing output. As it was the sixteenth system that the vendor sold, there were few users to advise us. We set up the system, as most other firms did at the time, as a "closed shop" type of environment, with dedicated operators, in an enclosed room. Five (5) internal employees were selected for initial training, conducted at the vendor's headquarters. We began operations on the basis of a two-shift operation. The first year was spent with the emphasis on symbol/macro generation and simple drawing production.

INITIAL DISCIPLINES SELECTED - At the time of acquisition, we had 70+ designers and draftsmen working on drafting boards in-house. Roughly two-thirds were drafting Plant Layouts, at 1/8 inch to the foot, on six-size (36" high-variable length) roll mylar. Most of these drafters were contract personnel, placed in our offices as workload required it. Because this layout drafting process usually represented the "bottleneck" in the engineering cycle, we targeted Plant Layouts as the first application area to be moved to the new technology. Because of their straight-forward, repetitive nature, electrical and mechanical schematics were targeted as secondary candidates for transfer.

HARD LESSONS LEARNED - Procedures were initially developed for layering, scale, text, symbology, archival naming, etc. With considerable enthusiasm, we attacked the first plant to be moved from manually drafted to CAD. When you implement a new technology, and you are one of the "pioneers", you make a lot of mistakes. You look at a project from the standpoint of the "manual" environment that you are used to, rather than from the standpoint of the technology that you are trying to implement. For example, we maintained the scale of our layouts at 1/8" = 1'-0", even though we went from 36" high media to 26" high 4-size vellum frames. This increased the number of "frames" required to define the entire layout by roughly 40%, resulting in an increase in the number of layouts to be processed and filed, and amounted to a step backwards. After working with the technology, we found that because the "plots" (final inked output) could be scaled when they were drawn on paper by the computer, we could work on frames that were 33.3% oversized, and then by scaling the output to 75% of full-size, retain the same amount of data per sheet that we had on the "roll" drawings, over a proportional width. The data bases remained at 1/8" while the final drawings, when scaled, were 3/32" = 1'-0". This type of knowledge comes from experience; the vendors can't help you here and it costs you time and money. You make a lot of "false" starts and redo a lot of work. This is one reason for the often quoted statistic that the acquisition cost of the initial hardware and software components of a CAD system usually only represents 35% of the total cost of a computer graphics operation!

"AROUND-THE-CLOCK" OPERATIONS COMMENCED - After the system had been in place for a year, three (3) additional employees were trained by the vendor, and a three-shift operation was initiated. As our expertise grew and more plants were put onto the system, outside drafters were released back to their host firms. At this time, none of our

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