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KNOWLEDGE BASED SYSTEMS: FROM PROCESS CONTROL TO POLICY ANALYSIS

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Abstract

Los Alamos has been pursuing the use of Knowledge Based Systems for many years. These systems are currently being used to support projects that range across many production and operations areas. By investing time and money in people and equipment, Los Alamos has developed one of the strongest knowledge based systems capabilities within the DOE.

Staff of Los Alamos' Mechanical & Electronic Engineering Division are using these knowledge systems to increase capability, productivity and competitiveness in areas of manufacturing quality control, robotics, process control, plant design and management decision support. This paper describes some of these projects and associated technical program approaches, accomplishments, benefits and future goals.

INTRODUCTION

For over a decade Los Alamos has been pursuing the use of Knowledge Based Systems (Artificial Intelligence / Expert Systems) in modeling, analyzing, and supporting a wide variety of projects. Los Alamos has invested many years and millions of dollars in developing one of the strongest knowledge based systems capabilities within the Department Of Energy. In the Sensors, Systems and Robotics Group of Los Alamos' Mechanical and Electronic Engineering Division, we are using this technology to support many diverse projects.

In recent years, the field of Artificial Intelligence/Expert Systems has become quite commercial. Driven by the maturation of powerful, commercially supported tools and the universality of the technology, many applications are appearing as manufacturing and business solutions. Only now, it is more politically correct to refer to applications as Knowledge Based Systems (KBS) or "applied intelligence". Furthermore, as these KBS are often deployed as imbedded in or part of other systems (such as CASE and GUI), their identity is further blurred. Whatever the name, KBS applications can significantly enhance business operations in many areas ranging from process control to policy analysis. I will discuss some of

Los Alamos' applications of KBS in this paper.

KBS, CONVENTIONAL COMPUTING, AND BUSINESS SOLUTIONS

KBS computing is firmly based upon mainstream computing and uses every conventional capability available. KBS computing is different in that it emphasizes the development of specific elements of computing to meet the challenge of modeling and capturing knowledge and intelligence. For example, because human intelligence tends to deal with natural language and fuzzy, contradictory and incomplete knowledge, KBS computing emphasizes symbolic computing based upon natural language as opposed to numeric computing. It also emphasizes methods and tools that allow for inexact inference, incremental definition and test of models, rapid prototyping and easy maintenance of programs. Object Oriented Programming, rule based inferencing, CASE and natural language-like interfaces are examples of such tools which were heavily emphasized by the KBS community in the seventies and eighties. These tools are now finding their way into the commercial mainstream.

The bottom line for business is that it is possible to develop powerful and dynamic models, simulations, and process control systems across a wide range of business activities. These systems can capture complex business policies, operating procedures, regulations and economics as well as technical and production operations. Using these tools, a business is better able to understand, analyze, plan and control its activities. Examples of some ongoing projects at Los Alamos will help illustrate the elements of KBS and their uses.

MANUFACTURING QUALITY CONTROL WITH NEURAL NETWORKS

Neural networks are technically not KBS. I mention them because we use them as inputs and parts of knowledge systems. Neural networks are hardware and software systems that can be trained to recognize patterns and images. You do not program them. You repeatedly expose them (train) to input patterns until the network reorganizes itself to recognize or classify the pattern. For example, using a video camera we could repeatedly expose a neural network to many different human faces and it would learn to identify and associate the faces with their owners.

We have developed neural network systems that we believe will outperform available commercial imaging systems in some tasks involving product inspection and quality control. The objective is to have an inspection system that is accurate, fast and quickly trainable to work with new products. Once trained on an acceptable product, the system will reject any product not meeting standards. We are now developing a PC version of this system which we

believe will be inexpensive and relatively simple to use.

PROCESS MONITORING, ALARM AND AUTOMATIC CONTROL SYSTEM

For many years, Los Alamos has operated a low level radioactive waste collection system that is spread out over many miles. Double walled pipes, pumps, valves, tanks, and monitoring and alarm systems collectively move waste materials to central treatment facilities. Recently, we started a project to update equipment and the operations of this collection system. At the heart of this project is a knowledge based computer monitoring, diagnostic and control system.

Currently the KBS includes an interactive model of all existing equipment types, functions, layouts and operation capabilities. Also built into the system are basic operation procedures and safety requirements as well as interactive, graphical interfaces for the system operators. Later this year, when the KBS is physically connected to existing and new pump, valve and alarm hardware, it will monitor in real-time the complete status of the collection system and provide remote control capability for most of the equipment. Status includes elements such as valve positions, tank levels, pump operations and material inventory. When this initial hookup is completed, the new system will exceed the capabilities of the existing system. However, we intend to go much further with this KBS control system.

We have already started on future additions to the KBS. These knowledge additions will allow for automatic "intelligent" diagnosis of operation problems, "reasoning" as to what best corrective actions should be taken and actions such as reconfiguring or adjusting the collection system, stopping operations or alarming and advising human operators. The KBS will also keep a continuous record of all control operations for administrative, legal and regulatory use. Finally the KBS will be used as a "what if" simulation system for trade-off analysis involving new equipment designs, new operation procedures and continued development of the overall collection system.

INTELLIGENT ROBOT CONTROL

Environmental programs have become the fastest growing segment of the Department Of Energy (DOE). About 25 percent of the 1993 DOE budget of $19 billion is earmarked for environmental work. Some of this work is directed toward the development of environmental technologies that are currently unavailable. These technologies are to make the remediation effort proceed more quickly, more safely, and at a lower cost.

Working within DOE's National Robotics Technology Development Program, Los Alamos and other National Laboratories are developing an automated system for characterization of contaminated sites. The mission of this Contaminant

Analysis Automation (CAA) program is to develop a robotic characterization system that is intelligent enough to function continuously without human intervention. Characterization here refers to the chemical tests a chemist might perform to determine what contaminants exist in an environmental sample. A robot chemist might perform tasks such as "weigh sample," "dissolve," "extract," separate," "measure," and "interpret results".

The CAA technology program is focused on the development of a series of Standard Laboratory Modules (SLM) that can perform each of the above tasks and be assembled into many different chemical-processing configurations. Each new configuration results in a unique set of complete chemical characterizations. That is, the SLM modules are the fundamental building blocks of complex laboratory automation. Key to this approach is defining a set of SLM hardware and software interface specifications that will allow individual SLMs acquired from multiple vendors to become building blocks for automated systems of higher complexity.

As we develop these SLM systems we are using a knowledge based system to integrate and control the overall robotic workbench. This KBS must seamlessly integrate many different sources of hardware and software. It must provide a rapidly evolving environment to keep up with ongoing technical developments and it must allow for unforeseen change. The KBS is built at a very high, generic level of knowledge and operation to allow it to control existing and future SLMs.

ENVIRONMENTAL WASTE MANAGEMENT OPERATIONS

Department Of Energy (DOE) facilities generate significant quantities of mixed wastes, consisting of radioactive materials mixed with other hazardous substances. Over the years more than 49 DOE sites around the country have generated substantial inventories of such wastes, and more are accumulating. The DOE is required to manage these radioactive wastes in compliance with US Environmental Protection Agency (EPA) regulations. At present, DOE lacks the technologies and the needed treatment capacities for managing some of the EPA regulated wastes. DOE has established a Mixed Low Level Waste program to lay the foundation for management of waste operations in compliance with DOE and EPA regulations.

The knowledge underlying national and state waste management issues is extremely complex, constantly evolving and in need of continued updating and analysis. These issues deal with: existing and future waste types, inventories, generation rates, storage-treatment-disposal capability and needs, transportation needs, technology definition and construction needs, regulations, costs, and schedules. Include the needs of other agencies like the EPA and Department of Transportation as well as State and

local interests and you have a very difficult management task. Add changing and evolving national policy and budgets to all this and you have a severe case of information overload.

To help support DOE decision making, MEE-3 has built a prototype KBS that can deal with many of these problems. This KBS is an interactive, expert level information system that integrates much of the complex information mentioned above into an easily maintainable and usable, "intelligent", business decision support system. As a demonstration prototype, the KBS is limited in its knowledge and scope, but, it has already demonstrated many of the key functions needed in a larger operational system. The system is designed to be used by non-computer experts and will run on a PC computer.

The KBS is designed to help decision makers to integrate and understand the vast amount of knowledge and data being developed: including information on waste types, inventory, storage-treatment-disposal capability and needs, technology, transportation needs, costs, schedules and regulations. The system can maintain and extend this knowledge base as policy, budgets, waste operations and knowledge evolve and change. It can monitor current operations status of the DOE waste complex and produce up to-date program status reports, program projections and accountability documentation. The KBS also can perform thorough and complex "what if" analysis simulations to enable better program definition, understanding and evaluation of alternative operation strategies.

FACILITY DESIGN AND CONTROL

One of our most ambitious projects is to use a KBS to help define, design and eventually control a major $150 million dollar waste treatment facility. This Radioactive Liquid Waste Treatment Facility (RLWTF) is currently in its conceptual design stage. Initial facility sketches and layouts based upon preliminary technical studies have been completed. Further definition, design, construction and eventual operation of the proposed RLWTF involves the balancing of many complex technical and non-technical issues. Difficult trade-off decisions must be made as to capacity, performance, technology, costs and schedules. Moreover, these decisions must be made as regulations, policy, budgets, technology and the waste treatment mission of Los Alamos continues to evolve. To assure the success of the RLWTF Project, these decisions and the evolving knowledge underlying them, will have to be continually evaluated, analyzed and updated. We are building a robust, knowledge based, computer decision support system to aid decision makers in this task.

The KBS is being built to integrate technology, policy, regulatory and budget knowledge into a "living" technical and management decision support tool. We will be able to compare alternative plant designs as to

capability, performance and economics of construction and operation. We will also be able to project what will happen if equ pment and technology is limited or improved. As our knowledge of process options and costs improves, the system will help us to understand the effects on operations of shifts in budgets, policies and regulations. Of equal importance, as this tool helps us define and optimize the scope and feasibility of the waste treatment facility, the tool will also significantly help us to explain and justify our technical and program decision process.

INVESTMENT REQUIREMENTS

As the saying goes "there is no such thing as a free lunch". The capabilities , power and business leverage of using knowledge based systems do not come free. Required investment in industrial-strength hardware and software development tools starts at about $30,000. However, the most important investment must be in the training of capable people. An intelligent person will require about three to nine months of dedicated learning and practice to become productive in building knowledge systems. This time will vary with the computer abilities of the trainee. In addition, although KBS programming productivity is considerably higher than conventional programming methods, time is required to build powerful knowledge systems. The systems described above require about 1-3 person-years of development effort. Finally, the creative task of capturing knowledge is better done by small, synergistic teams of KBS developers then by individuals working alone.

CONCLUSION

Modern knowledge based systems are capable of very high levels of modeling, simulation and process control. Complex business problems, ranging from manufacturing quality control to policy analysis, can be addressed using these methods. These systems can deal with abstractions, complexity, and imprecise and evolving knowledge. They also can monitor, diagnose and control complex manufacturing processes at highly intelligent levels of operation.

Investment costs of building knowledge systems are not trivial. They include costs for hardware, software and the training of qualified developers. In addition, time is required to build capable knowledge systems. However, the significant increases in business capability, productivity and competitiveness can more than justify the investment.

Members of the MEE Division of Los Alamos National Laboratory are using knowledge based systems to solve a variety of DOE problems. Projects include, process control, facility design, waste management and policy analysis. Results have been encouraging and knowledge based systems activities are steadily expanding.