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Diagnostic Expert System in the PF LINAC

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Abstract

A prototype diagnostic expert system (ES) was developed for the Photon Factory 2.5-GeV electron / positron LINAC injector system. The ES has been on-lined with the conventional linac computer network for receiving real data. This project was undertaken in an attempt to reduce the linac operator's mental workload, diagnosis duties, and to explore Artificial Intelligence (AI) technologies.

The outlook for ES and its problems, and what has been achieved are outlined in this presentation.

I. Introduction

Diagnostic problems are relatively well understood both empirically and theoretically. A variety of shells / tools are available on the market to facilitate the implementation of diagnostic systems. We have developed several diagnostic ES for the LINAC and some are now under operation. Having gained experience through previous projects, we built a new hybrid ES this time. The application described here is an ES for the injector system of the Photon Factory (PF) LINAC[1-4], which is being operated a total of 5000 hours per year, making injections to the PF storage ring and the TRISTAN e+/e- collider. Accelerators (LINAC) are complex devices, using many thousands of components. We have been looking for appropriate expert system shells and tools with which we can easily and rapidly establish an expert system. For several years, a small ES based on a personal computer was used for exploring applications of AI techniques. A prototype diagnostic system has been built in order to determine whether or not the various problems can generally be solved using an ES frame-work; a knowledge base (K/B) for the accelerator domain and task analysis were also investigated in this project.

II. Why we need ES for the accelerator

When any fault or trouble occurs in the LINAC, the operator is required to recover the system, even at midnight, even though, he may not be an expert regarding many of the fields required to diagnose the specific trouble.

Diagnosing faults in a complex process is a task that requires experience and considerable knowledge in many fields. Thus, any assistance given to the linac operator regarding diagnosis and operation is extremely desirable.

When human experts are scarce, and when problems must be solved for which there are no established solutions or exact theories for problem solving, an expert system seems to be appropriate. When there are several candidate procedures, or algorithms, involved in problem solving. Also, ES should be useful and more efficient than conventional programming.

Since most ES are flexible, if we change the physical structure of the accelerator, the K/B can be gradually extended by adding new knowledge while being refined. Programming costs will be minimized by using ES. This is the essential advantage of an expert system.

III. Definitions of AI

Some people think that "AI by itself can solve all of the problems." We must be very careful concerning this idea. AI is not magic, and its capability is still limited in solving practical problems . On the other hand, there are other people who believe that AI can do nothing worth while at all. We, thus, need to define AI before any discussion.

We have seen many definitions. People's dreams are big, and they could have answered that "Artificial Intelligence is the science of constructing a thinking machine."

Marvin Minsky gave a new definition: "Artificial Intelligence is the science of making machines do things that would require intelligence if done by men".

Today, the abbreviation "AI" is used with the meaning of "Advanced Information processing technology". From this perspective, AI will certainly become more and more important in the Accelerator domain.

We discuss here only knowledge-based systems which are a subset of AI technology. In most cases, ES is a rule-based production system which dispenses with specialized knowledge of a well-defined domain.

It is said that ES belongs to the most important developments of a new type of software generation.

IV. History of AI

It should be mentioned that AI is still very young. Fundamental AI researches are necessary for continuously defining and realizing AI's future.

The term "Artificial Intelligence" was invented at the Dartmouth Conference in 1956, where John McCathy (Stanford) and Marvin Minsky (from MIT) were participants. After that, a new field of research was born.

The feasibility of the first expert system was demonstrated in the 1970's under the leadership of Edward Feigenbaum. There have been many successful ES in the past. If we classify the

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generations[6], from the viewpoint of an ES tool, we can define three generations as follows:

In the 1st generation, until 1980, simple tools and languages were utilized;

In the 2nd generation, 1980 to 1985, hybrid tools were commonly used.

We are now in the 3rd generation, which is characterized by easy-to-use tools and task oriented; domain-specified tools are available now. We have established commercial systems, specialized languages, and tools for developing such systems.

Today, the development of the so-called knowledge based systems has started moving out of the research laboratories of pure informatics into other disciplines of science.

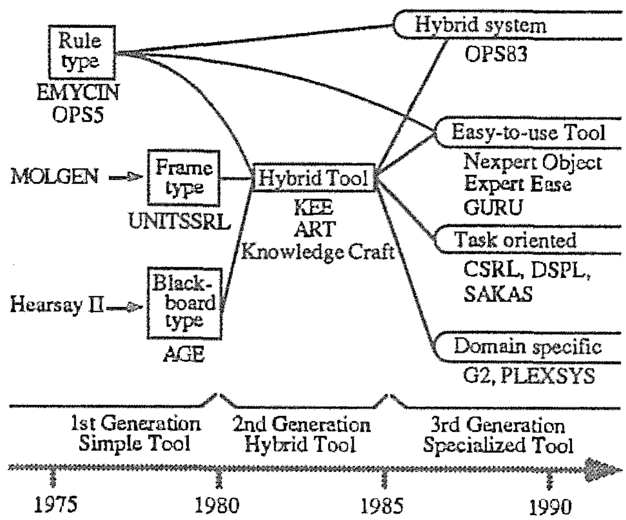

Fig. 1 History of Tool

V. Software tools

For the most part, the ES tool comprise an inference engine, knowledge-aquisition, a knowledge-base, a explanation system and a user interface.

An ES tool should provide at least the following features:

- transparency and portability of the knowledge base,
- expert-like diagnosis (less questions, learning,)
- a graphical user interface for representation and a function of explanation

are very important in knowledge handling. Several operation modes are also necessary, such as a Run mode, Test modes and interactive debug modes.

Some useful knowledge-aquisition tools are available on the market which are helpful for simple surface knowledge.

VI. Hardware/software configuration

The LINAC injector control system has several microprocessor units (MPUs) which are connected to a local network (LOOP-2).

When a fault occurs in the injector part, the MPU picks up the first reason for the trip down and sends a message to a minicomputer, MELCOM 70, in the subcontrol room through LOOP-3, LOOP-2, and CAMAC. There are 50 interlocks and analog data displaying at the local pulser panel. Of course, ES requires more information for a complete diagnosis. Most of the same data which is available to checks locally is transfered to the main computer and as well as to the ES. The ES would be triggered to start diagnosis upon receiving a fault message through the network.

The ES has the following configuration: HP9000/370 (development station), 375 (LINAC operator's console), HP-UX, C, NEXPERT-OBJECT (hybrid-tool), Data-View (graphic tool), equipped with a 16MB RAM, 300MB(600MB) hard disk, and 3.5" floppy disks. There is a pre-process station (FMR-50 personal computer) which has a 600MB magnetic optical compact disk (CD), and is connected to the DSLink. There are about 30 personal computers (PC) under the DSLink network, and each PC has its own purposes or functions such as gateway, server, accelerator operator's console, monitors, development, expert system, and OS/2 stations.

The DSLink operator's console network of the LINAC is connected to the conventional LINAC networks through the gateway (FMR-70 HX3).

In addition to rule-like knowledge, waveform information is also highly important in carrying out diagnostic tasks. Pattern recognition using a neural network is thought to be helpful in this context.[6] A neural network is well suited for pattern-recognition problems, but has a disadvantage that the learned knowledge is hidden in the weights of the network's connections. We have thus developed what is called a hybrid ES by combining a neural network.

The injector ES has a debugging mode for diagnosis which makes it easy for users to carry out simulation at any time. The ES can operate in two modes (AUTO or MANUAL) at the operator's discretion. In the AUTO mode, when the ES receives serial shutdown data from a pre/post process station through the network, it automatically and periodically starts the diagnosis procedure. During a periodic analysis, ES starts a monitor programme to collect raw data for the error diagnosis process during the data-taking phase. The interactive debug mode can be invoked if an error in the run or one of the test modes occurs. Symptoms will be derived and possible repair actions will be proposed. In the debugging mode, the inference action is initiated, or fired, manually by the knowledge engineer or user. Each rule must be simulated step by step in this MANUAL mode both before and after running using empirical knowledge.

VII. Defining the task and application domain

In the accelerator domain, ES would be useful for operation support, fault diagnosis, and design work. We have investigated the task of diagnostic ES for the injector of the LINAC. The following tasks were important for ES:

1) On-line data processing.
2) Finding heuristic methods of diagnosis from human expert (surface knowledge).
3) Local checks using oscilloscopes, measurement tools, and visual checks.
4) Logbook, chart, and drawing checks.
5) Modeling, and calculations (deep knowledge).

These are the fields that an expert carries out during diagnosis; an expert system should thus duplicate them.

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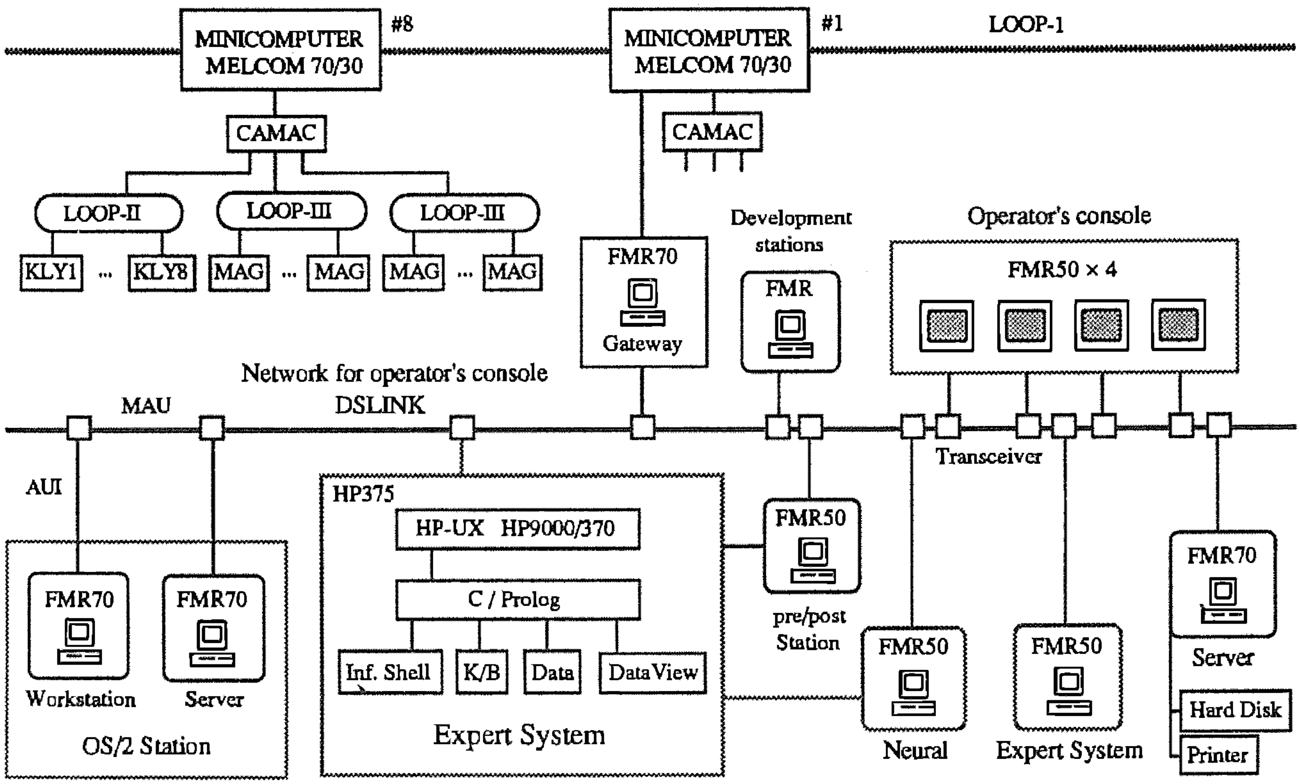

Fig. 2 Expert System and the PF Linac Control console network

VIII. Diagnostic ES and the Problems

The most difficult problems to be resolved have been the acquisition and representation of knowledge, as well as the selection of an inference strategy. When we develop an AI system, we must be clear about the following items regarding the planned applications:

1) The diagnostic resolution must be determined .
2) Necessary information must be available on-line; otherwise,the operator must supply a large amount of data to the expert system, which is quite unrealistic in practical situations.
3) The introduction of deep knowledge, such as model based diagnosis, is desirable.
Without deep knowledge, the number of required rules can be quite large.
Domain-specific knowledge can be represented in a logical programing system, in a frame-based system, in rule-based systems, or in hybrid systems.
4) The strategy for controlling the inference procedure is critically important.
This strategy should be made consistent with the content of rules in the knowledge base
5) Inference mechanisms: We must determine which direction of reasoning is appropriate, a forward-directed strategy from an initial to a goal state, or a backward. Inference method may be deductive,abductive, or inductive.
6) The handling of uncertainty in knowledge as well as in the observed data is also necessary.
7) Appropriate actions should be implemented.
If a new unknown problem occurs, the system should propose to contact a field expert.
The system must assist the expert in updating the related part of a knowledge.
8) Is a learning system or Case-Based Reasoning (CBR) important ?

IX. Knowledge Acquisition

Generally, knowledge acquisition can not be based on any model in this kind of diagnosis. Knowledge engineers or experts must build knowledge-base extracting rules and procedures using an empirical approach through interviewing experienced field experts regarding both operation and repairing.
Here, we have a bottleneck concerning knowledge taking.

For making the LINAC injector diagnostic knowledge-base, about one month during the first stage has been spent in interviewing and knowledge engineering for a shallow target. As the second stage, we are refining the knowledge base in order to obtain more knowledge. One hundred expressions concerning production rules, some frames, and object are being handled in the ES.

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X. Conclusions

The diagnostic capability is still limited; moreover, we have started with a shallow target. It was sufficiently faster than human (operators) diagnosis regarding execution.
A new K/B(Knowledge Base) is now being added and tested for expected phenomena in order to obtain more reliability.

It has become feasible now in the Accelerators field. We are sure that expert system technology will provide new possibilities for software systems, especially in future accelerators. Expert systems should be used more in our field, as in others.

As a final statement, the following will be the areas in which we must carry out research:

How to deal with a large domain,(many tasks).
How to model applications, such as task and domain analysis.
We need portability of K/B.
Learning systems and Case Based Reasoning.

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