USE OF AN EXPERT SYSTEM FOR BEAM DIAGNOSTICS

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Abstract

This paper treats the use of artificial intelligence methods, in particular expert systems, for beam diagnostics. Such an expert system is capable of solving the problems of analysis, choice and design of beam monitors for an accelerator control system according to their purposes, technical demands, working conditions and criteria for choice. This expert system provides intellectual support at all stages of design and development. This paper presents basic results and the structural scheme of the integrated expert system.

I. Introduction

Beam diagnostics involve a complex process of obtaining, transformating and representing various pieces of information about beam parameters using theoretical, technical and software tools. Successful decisions in these matters are necessary for effective management of accelerators; not only during the exploitation process, but also during construction and commissioning; for development of control systems, for increase of reliability, for improvement of measurement accuracy etc.

II. Background

The following pieces of information on beam parameters must be available:

I. Definitions of beam parameters and their common interpretations.

II. A classification of monitors according to different criteria.

III. A definition and standardization of measurement, exploitation-reliability and mechanical-technological characteristics of beam monitors, ranges of beam parameters, technical demands, working conditions and criteria for choice.

Analysis of modern trends in the development and the construction of monitors for beam diagnostics has revealed some problems. It is possible to use the methods and ideology of artificial intelligence for arriving at decisions concerning them. For instance, strong integration in the field of development, commissioning and exploitation of control systems for accelerators displayed evident contradictions with numerous existing commercial and industrial choices. These systems, having been created by different organizations and scientific centers, are incompatible with each other. Similarly the clients who wish to use and apply concrete expert systems for beam diagnostics may encounter some difficulties which are just part of this problem. Despite a large number of heterogeneous developments and a diversity of characteristics, parameters and demands, as well as a lack of competent independent experts, one can still address significant matters, especially when the results can lead to economic waste and unpredictible consequences.

Anothert problem is the exponential growth of information in specialized technical magazines, books, reports etc. This abundance of information makes it difficult for developers, managers and scientific workers who specialize in this field to keep up.

III. Analysis

Taking into account all these elements, it is felt that there are gains to be had in creating an integrative expert system (ES) for overall analysis and for choosing monitors to study beams according to their purposes, technical demands and abilities, working conditions and the choice of data handling criteria during the design process of the accelerator control system.

It is known that the development of an ES is not always well founded. However in this case the principal factors which encouraged this development are as follows:

1) The problems are extremely specialized. They serve definite purposes and require large numbers of criteria in the choice of solutions.

2) The problems require a great deal of experience in the field of diagnostics of charged particle beams.

3) It is possible to formalize the facts and heuristics of the knowledge base.

The development of such an ES is well founded economically because similar systems can reduce demands on experts and consultant services and save labor. Also the characteristics of the problems under consideration do not allow them to be solved with methods of traditional programming, i.e. the application of non-algorithmic heuristics is essential because it is necessary to manipulate both symbolic information and numerical data. There is a great problem complexity and a multitude of problem variables and connections.

IV. Integrated ES

This report considers a project of an integrated ES which examines the use of expert knowledge, as well as algorithms, procedures and models resulting from previous investigations regarding the nature of these problems, and a database of monitors and containing the information on measuring schemes [1].

The basic stages of choosing the monitors and the definition of parameters realized in the current ES are:

1) Evaluation of limitations of monitors according to their time characteristics and sensitivity;

2) Choice of those monitors which satisfy given technical demands and working conditions;

3) Choice of monitors according to their level of influence on beam particles, taking into account required measurement, exploitation, and reliability characteristics and any given constraints;

4) Comparison of selected types of monitors according to the informatation they examine, and choice of monitor type with appropriate mechanical and technological characteristics;

5) Calculation and definition of the parameters of a selected monitor type with the possibility of technical realization of a measurement scheme for charged particle beam parameters.

The structure of the ES scheme is shown in Figure 1. The integrated system GURU is selected as the most convenient and powerful tool of ES design automation and is run on an IBM-compatible PC/AT computer. GURU unites the ES design scheme, a relational database, spreadsheets, text editors, business graphics and the means of communication with other computers. The knowledge base volume of the current ES version consists of about 150 rules. The ES provides intelligent support of all design stages of a control system and its exploitation process as well as for diagnostics.

At present, the integrated expert system's knowledge base holds information about different types of beam parameter monitors (BPM), such as electromagnetic and electrostatic position monitors, current transformers, Faraday cups, secondary emmission monitors etc. This information includes basic descriptions of the monitors, such as sensitivity, bandwidth, resolution, precision, dimensions etc. In order to obtain this data over 400 papers, reports and lectures describing results of investigations of different BPMs were processed.

This knowledge base is being continually appended and extended as new information (conference proceedings, publications in different journals, ...) is received. The collection of related software is growing as well.

The possibilities for the integrated expert system are continually broadening, and the system is used in designing control and measuring systems not only when choosing a BPM and calculating its parameters but also to choose the structure and the modules of various subsystems (analog-to-digital converters, amplifiers, integrators, the means of processing, registering and displaying the information about beam parameters), concerning their working parameters, technical requirements and computation criteria.

V. Example

An example of a rule in the expert system is the following:

```
RULE : R1
        IF : 0.1 <= sm <= 10  &
           1 <=  pl <= 10  &
           50 <= pf <= 1000  &
           pc >= 1  &
           nopcf = "yes" &
           inf = "no",
        THEN :  type = "current transformer" &
                run  "ct.exe"
```

The following variables are used :

sm - sensitivity of monitor (V/A);
pl - pulse length (ms);
pf - pulse frequency (Hz);
pc - pulse current (mA);
nopcf - necessity of obtaining the pulse current form;
inf - influence on beam parameters;
type - type of beam monitors;
"ct.exe" - calculation program for a current transformer for satisfaction of technical demands.

VI. Conclusion

It should be noted that the demonstration prototype of an integrated expert system illustrating the basic principles was developed by means of the system GURU for PC 386/486. At present the building of a of research real-time prototype has been started. This new project is based on G2 by Gensym for Alpha AXP workstations.

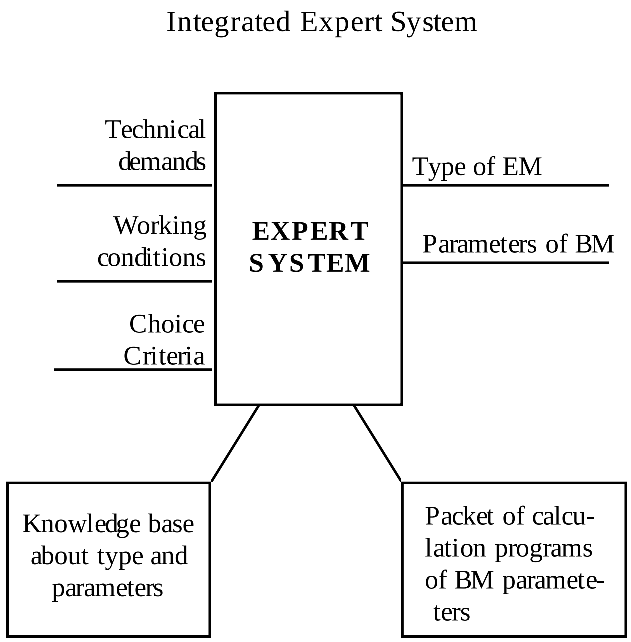

Figure 1: Structural scheme of the ES.

VI. References

[1] V.Rybin., G.Rybina., V.Safonenko. “An Expert System for Beam Diagnostics” 15th Intern. Conference on High Energy Accelerators, Hamburg, July 1992, pp. 237-238.