Expert system for thermal diagnosis for main equipment in a fossil power plant

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Abstract: - This paper shows the integration process of a case based reasoning expert system into a real-time information system for supervision and diagnosis of the operative conditions for the main equipment in a fossil power plant (thermal power station). The stages of analysis, development, integration and tests are described. Settles down the architecture used to integrate an expert system that based on behavior indicators (calculated in real-time), is able to identify low performance situations in the main processes equipment in a fossil power plant, as well as to emit a diagnosis of the current state for the equipment and the recommendations for maintenance.

Key-Words: - Case Based Reasoning (CBR), Expert System, Real-Time System, Diagnosis System, Induce-It

1 Introduction

In the Processes Supervision Department, inside of the Electrical Research Institute in Mexico, are in the tests stage a **real-time information system** (**RTSys**) in charge of the supervision and diagnosis of the main equipments for a fossil power plant. As part of this system it is necessary to integrate an **Expert System** (**ExSys**) in charge of to execute algorithms to carry out the diagnosis of the operative state for the main processes equipment in the thermal power station [Espinosa, et. al.].

The main function of the ExSys is calculate and shows a diagnosis about the current state of the main equipment (monitored continuously using a real-time data acquisition system), as well as the correspondent recommendations of maintenance. The ExSys receives and processes the results of a calculation module of behavior indicators of the RTSys. Also is included a validation module where are evaluated the conditions of the process and reviewed the restrictions defined by international standards for equipment diagnosis.

The ExSys is based on the methodology for cases based reasoning (CBR) and implemented by means of *Induce-It* (a commercial software tool for Expert Systems configuration and integration), both, the methodology of CBR and the *Induce-It* software tool were selected using a depth evaluation of diverse methodologies for expert systems implementation.

2 Problem Formulation

The RTSys was developed completely using the LabVIEW 8.20 platform (National Instruments Company) for the real-time data acquisition and data processing. In this version, this platform does not include native functions or schemes that facilitate the development of an expert system, reason why arises the necessity to develop and to validate in an independent way an expert system for the diagnosis task, so that their architecture and technology allows easily integrate it in the RTSys and that in addition it must be completely compatible with LabVIEW platform.

3 Reasoning Definition

The expert systems belong to a branch of the artificial intelligence (AI) that imitates the human activities to solve problems, that can store experts knowledge for a certain field and to solve a problem by logical deduction of conclusions [Canca].

Different methodologies allow the expert systems development. For the ExSys, the most suitable selection was carried out using a formal evaluation [Islas, et. al.].

Some of the AI methodologies that better perform the required reasoning for the equipment diagnosis are (proposed by experts in AI):

- Fuzzy Logic
- Case Based Reasoning (CBR)
- Rules Based Reasoning (RBR)
- Bayesian Nets
- Hybrid System

The evaluation process considered the following characteristics:

- Development facility
- Maintenance facility
- Heuristic ability
- Modularity
- Learning curve
- Integration with others technologies
- Commercial cost
- Autonomous learning ability for no considered cases

The result obtained in the evaluation process, establishes that the Case Based Reasoning (CBR) is the most adequate methodology to implement the expert system for equipment diagnosis. Also it was identified that the Rules Based Reasoning (RBR) allow to integrate in an easy way the evaluation algorithms of the calculation conditions or calculation restrictions, therefore the ExSys finally is an hybrid system

4 Software Tool Selection

In a similar way to the evaluation of methodologies, for the ExSys implementation was made a revision of commercial tools that implement CRB and/or RBR; then was applied a qualification in a global way, considering the methodology and the software tool as one.

Some of the tools that were considered in the evaluation are the following ones:

- MATLAB (Math works Inc.)
- INDUCE-IT (Inductive Solutions).
- CLIPS (Software Technology Branch, NASA/ Lyndon B. Johnson Space Center).
- FuzzyCLIPS (NRC Institute for Information Technology).
- ELVIRA (Granada University).
- HUGUIN (Hugin Expert A/S).

The next figure shows a comparative of some of the tools evaluated using the formal methodology proposed by [Islas, et. al.]. In this graph, *Induce-It* is the best software tool for this system.

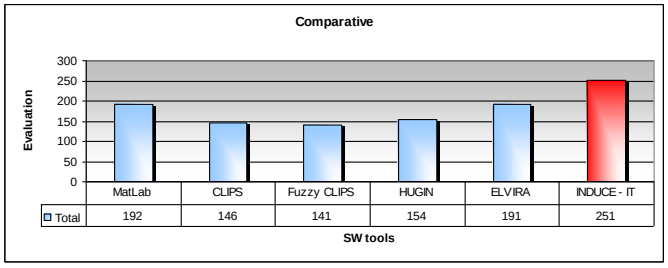

Figure 1: Comparative for software tool selection.

In this way, *Induce-it* (Inductive Solutions) was selected. *Induce-it* is a commercial tool that offers the implementation of Expert Systems using CBR, was developed into Microsoft Excel, where the rows and the columns of the spreadsheets are used to define the cases and their qualities. Additionally, the use of tools built into Microsoft Excel like graphs, formulas, functions and macros is allowed. It accepts integrate diverse operation schemes like hierarchies, weights, functions of proximity or similarity, boolean logic, fuzzy logic and combinations between these.

5 Case Based Reasoning

Case Based Reasoning (CBR) is a problem-solving technique that is similar to the decision-making process used in medicine, law, and business.

In Case Based Reasoning, problems together with their answers are represented as cases. Cases are typically represented by a database of "basic" cases and "exceptional" cases. Given a new problem, the new answer is extrapolated from the answers of the most similar problems that were already solved and stored in the case database. Case Database records can be medical profiles of patients, company profiles, or time series records of monitored events.

Different cases are distinguished by different properties, attributes, or fields. Cases and case fields are conveniently represented in a table: the cases are in the rows, and the case fields are in the columns. In this representation, a Case Based Reasoning system shares many operations with a traditional (relational) database system. The "case database" operations include the traditional relational database operations (such as selection, projection, union, and deletion), non-relational "aggregate" operations (such as minimum, maximum, sum, average), and sorting operations (Freedman).

The CBR is a field of the artificial intelligence (AI) that is based in similar problems occurred in the past to find solutions to the existing or current problem.

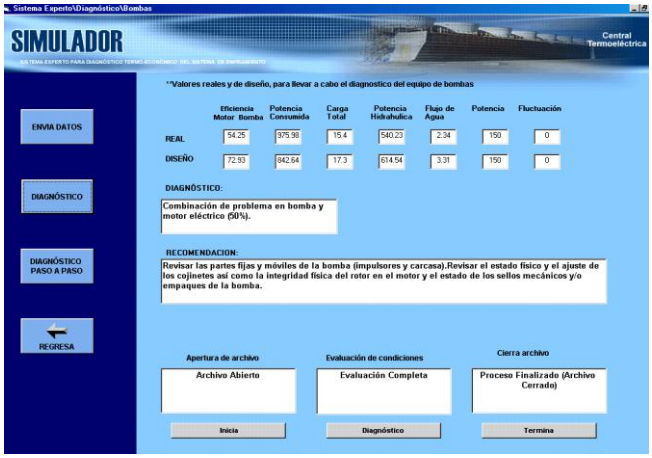

Figure 5: Main window of the off-line simulator for the Expert System (ExSys).

The DLL to drive the ExSys includes a wide error handling that maintains informed to the user in case that some unexpected situation appears and avoids that it happens an unexpected problem in the RTSys (for critical mission support).

8 Final Integration

The ExSys integration into the RTSys was carried out by means of DLL technology, using ActiveX controls. To do it, it is only necessary to define into the RTSys source code, a reference to the DLL of the ExSys and call its methods as if the ExSys was developed using LabVIEW, with the same structure and parameters defined into the DLL.

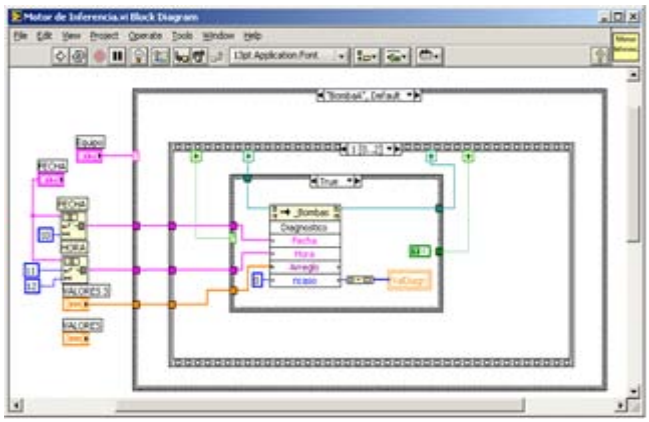

Figure 6: ExSys integrated into the RTSys using LabVIEW code like integration platform.

8.1 Routine for error catching

In order to avoid problems in the main process of the RTSys (for critical mission processing), a routine for catching errors was implemented into de DLL of the ExSys. In case of any kind of error, the DLL do not crash any process, instead of, returns an error code indicating a problem and the possible solution.

The next table shows some error codes.

Table 1: Error codes examples.

Error code	Description
-303	The Excel file can not be opened. Verify the path file.
-302	The evaluation is not possible. Close the Excel file manually.
-201	The Excel file can not be closed. Close the Excel file manually.
-219	*Induce-It* fails. Review the software installation using the simulator.

9 Conclusions

It was developed, validated and integrated an Expert System (ExSys) in independent way to the real-time information system (RTsys).

- A formal evaluation for Expert Systems implementation was carried out, selecting the most adequate technique to the RTSys. This is a combination of Rules Based Reasoning (RBR) and Case Based Reasoning (CBR).
- Specific software architecture was designed in order to integrate programs and techniques across many software platforms.
- A simulator was developed, that allows to make off-line and of independent way the validation tests and error handling.
- An Expert System (using the commercial tool *Induce-It*) was integrated into LabVIEW, demonstrating therefore the feasibility to use them all altogether of a very efficient and seamless way for the users.

10 Future Works

Nowadays, the real-time information system (RTsys), is in the final stage. In 2008, the RTSys will be installed in a 350 MW Fossil Power Plant in México. The cases database of the ExSys are considering knowledge for diagnosis of three equipments: Cooling towers, main condenser, and pumps of circulation water (cool water).

Ahead, is planned to increment the system abilities in order to integrate more equipments, something like heaters and motors. In this way, it is very important to have available the real-time information, so, it is necessary increment the data acquisition capacity in order to have the entrances to the Expert System.

A final consideration is important, the current knowledge in the ExSys is not generic; that means that it is necessary review and adapt to new installation, for example for a nuclear power plant. This is true due to the behavior of the equipment and its influence into a complete system and operative ambient. A tuning phase must be considered for the ExSys.

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