Medrac, an innovating tool for planning based on cases

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Resumen: *Este artículo describe el módulo generador de planes (Medrac) el cuál es parte del proyecto "Planificación Inteligente de Procesos Dinámicos". Una importante característica de Medrac es la utilización de Razonamiento Basado en Casos (RBC). El caso de estudio corresponde a la elaboración de planes para asistir a los operadores de centrales eléctricas de Ciclo Combinado (CCPP) en la tarea de llevar la planta a un estado estable de operación. La arquitectura del módulo de generación de planes es presentado y el uso de planificación basada en casos es descrito. Este incluye la adaptación de un plan seleccionado desde una Librería de Planes, de acuerdo a la nueva situación en el proceso. También los aspectos técnicos de la generación de planes son caracterizados, al igual que los beneficios y expectativas de su uso en cualquier CCPP son mencionados.*

Abstract: *This paper describes the plans generator module (Medrac) which is part of the project "Intelligent Planning of Dynamic Processes". An important feature of Medrac is the utilization of case based reasoning (CBR). The case of study corresponds to the elaboration of plans to assist the operators of combined cycle power plants (CCPP)in the task of taking the plant to a stable state of operation. The architecture of the generating module of plans is presented and the use of case based planning is described. This includes the adaptation of a chosen plan from of plans base, according to a new situation in the process. Also the technical aspects of the generator of plans, as well as the benefits and expectations of their use in any CCPP are mentioned.*

1 Introduction

In the last decade an increasing interest has awaked to use modern technologies of Artificial intelligence in domains of real world. Successful applications of Artificial Intelligence in fields like industrial, medicine, businesses, manufacture and processes exist. The electrical sector has not been the exception, since applications of this one in tasks are reported such as control, monitoring and diagnosis, prognosis of load, planning, and security among others.

The use of the Artificial intelligence is boarded different problems using diverse techniques. For example, system SPAR (Expert for System Incident Analysis and Power Restoration Assistance) supports to the operator in the handling of alarms in real time by means of a rule-based expert system. Another example is the system of supervision of gas turbines TIGER, that establish the necessities of maintenance of a turbine based on the present conditions of the same one. This project uses reasoning based on models to make its diagnosis.

One Combined Cycle Central (CCC) is a complex system within which it takes place a serie of transformation processes and interchange of matter and energy. In order that those processes are safe and efficient, the variables characteristic of each one of them must stay within certain ranks of operation, for it is counted on different tools from control to manipulate the most important variables. Nevertheless, by its complexity, a unit of combined cycle only can be automated partially, this means that all the processes cannot be controlled automatically and those that are it have protection or control systems that only operate within certain limits. By the previous thing, the behavior and the evolution of the process of electrical generation of a unit of always combined cycle are supervised by a group of human operators.

Taking like reference academic works from other institutions like Stanford Research Institute (SRI) [Wilkins, 1988] and the National Aeronautics and Space Administration (NASA)[Fisher, 2000] related to the implementation from systems of aid in line based on intelligent planning, the IIE develops to an own architecture, whose main axis is an intelligent system, which processes the representative information of the present state of the plant. The system is provided with two knowledge bases: one with the applicable actions (ACT) and another one with the resulting facts of a process of association between the data contained in the data base and the knowledge on plant states. All these elements interact of an intelligent form and generate a sequence of actions that the operator must execute to take the plant to a stable state of operation. Modes of Operation.

The CCC can generate, under several configurations of equipment, through four basic modes of operation:

- ❖ Power Station in cold.
- ❖ Power Station endorsed.
- ❖ Power Station in emptiness.
- ❖ Power Station generating.

In the state of the power station in cold, this one is sudden flight and all the equipment must be available and ready to start.

In the state of power station endorsed or hot endorsement, the heat recovering generates an amount sufficient of steam to maintain pressurized and to warm up the lines of main steam, besides to provide steam to turbine seals. Starting off of the endorsement mode, the total capacity of the power station can be obtained, in an approximated time of one hour.

In the mode of power station in emptiness the gas turbines operate to 3600 RPM, lists to synchronize itself. The heat recovering generates the steam necessary to maintain the speed of synchronism of the turbines, turning aside to the condenser any generation in excess.

In the mode of power station generating, all the greater loads are included or equal to the minimum, this is:

- ❖ Power station in lowest charge.
- ❖ Power station in primary cartridge.
- ❖ Power station in load tip.

in addition to these, the power station can operate with intermediate loads between the minimum and the base and the load base and the load tip.

The modes of operation before described are fundamental for the elaboration of the plan, since they show the mode to take the power station to a specific state of generation.

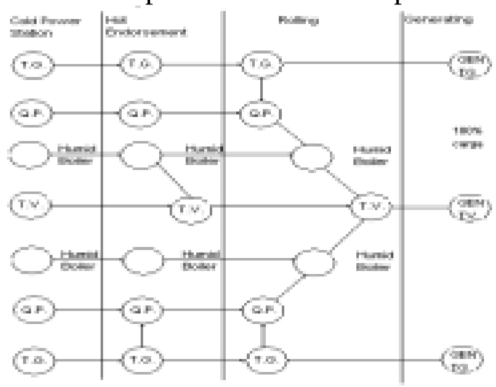

Figure 1. Modes of operation and equipment necessary to take the power station to 100% of generation.

The level of load of the power station is expressed in percentage of electrical generation (example 40%, 50%, 65%, 83%, 90% among others) this percentage represents a goal for the operator. With this goal, the equipment available and with the actions that can be made it is possible to generate a plan that, possibly, will take the power station to the wished state.

In Figure 1 are the minimum resources necessary to maintain the plant in each one of the four modes of operation and how these resources interact to reach the total load. It is important to make notice that to obtain this goal, it is necessary to pass through each mode of intermediate operation between the initial state and the final state (to see Figure 4).

II. - Architecture of the Plans' Generator.

To the date it is counted on a prototype of a planning system.

Figure 2 shows a first attempt to generate an abstract plan based on the architecture of the developed prototype in the IIE. The architecture of plan generator consists of two great parts: the modules of generation of plans and the reasoning based-cases named *Medrac*. These modules work of cooperative way to produce a plan represented by a ordered list of the ACT.

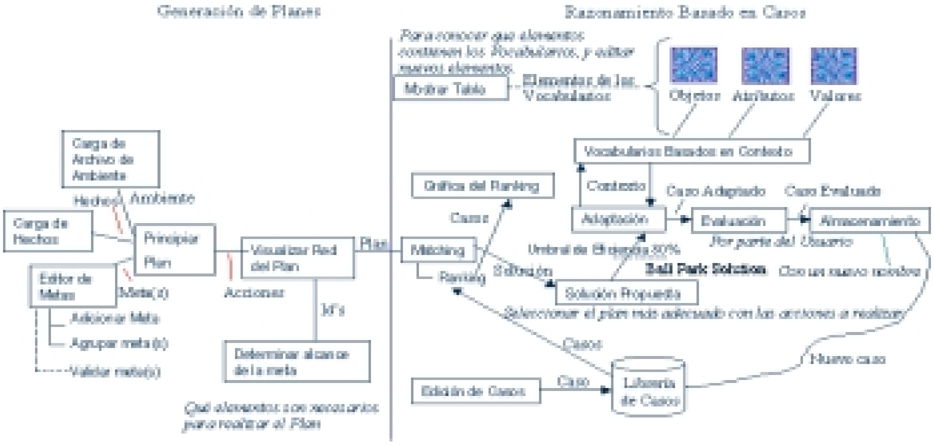

Figure 2 Architecture of the planning system, including *Medrac*.

These operational problems could be overcome by means of an intelligent system that shows recommendations to operators about how to make the best action on the process and correct the problem. The system should be able to find an optimal path according to the crisis dimension, take into account that actuators are not perfect and can produce non-desired effects.

The ACT: allowed actions.

A ACT describes the formalization of an abstract action very similar to the STRIPS operators (Stanford Research Institute Problem Solver). The advantage of this model of the actions is that it allows to lodge actions of greater detail by means of a graphical representation. For example, the passage of the turbine to mode generating starting off of the mode rolling is obtained when closing the switch of the field generator. In this case, the action is to close the field switch to manage the intention to take the turbine to mode generating, but before is due to fulfill the condition of turbine in mode rolling. Formally a plan has the form:

$Plan = (Act_1 \wedge Act_2 \wedge \ldots \wedge Act_n)$

The general form for the representation of the plant facts is the following one:

$W = \{S_1, S_2, S_3, S_4, S_5, \ldots , S_n\}$

Where $S_1, S_2, S_3, S_4, S_5, \ldots , S_n$ represents discreet states of plant or inferred modes of operation, each state is one as well tupla of the form: [attribute, value], for example:

fact(motor_de_arranque,fuera)
fact(bomba_combustible,dentro)
fact(tg1,generando)

fact(tv,planta_fría)

The set of facts that represents the real state of the plant allows that the production system initiates the inference, turning therefore the data a formalism that *Medrac* can understand. The result of this first stage of reasoning is a set of facts on the mode of operation in stable state of the plant. These facts indicate the resources available and the conditions of operation of the diverse equipment that contituyen the power station.

So that *Medrac* can reach the established goals, it must follow an order specific. This transference of states implies a high level of abstraction of the actions to be able to happen of an operation mode to another one. For example, in cases where it is had presented unemployment forced of power station after a period of prolonged maintenance, it is necessary to happen of the mode of hot endorsement to rolling, or cold plant to generating (to see Figure 3).

III.- Medrac, a system based on cases to improve the intelligent planning.

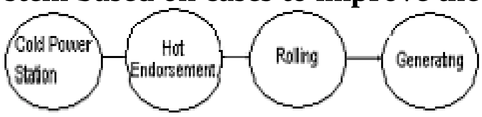

Figure 3. Transference of operation modes.

Medrac is a system based on cases that using informed search heuristically like inference mechanism. The system and its user interface was programming in Java2 of Sun MycroSystems on a Windows 98 platform, portable to other operating systems.

Previously the module of mapping data-knowledge is in charge to determine the facts that represent the operation mode in which is the power station. This module is formed by a base of rules and a production system (to see Figure 3). The registered variables are stored dynamically in a data base and turned clauses logics through the Mapper program. The set of these predicates the state of each one of the equipment of the power station conforms the facts base's representation.

The production system accepts the goal that the operator proposes through a goals editor and the facts base referred operation modes.

This version of *Medrac* generates a ordered list of actions to be made by the operator, in agreement with the current state of the power plant, and that later will evaluate the monitoreo module.

Medrac, is based on the system for based on cases planning [Kolodner, 1993], Figure 4.

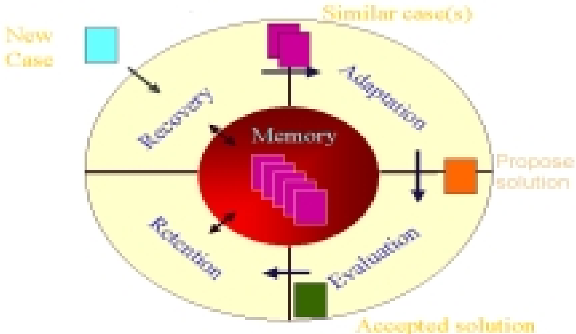

Figure 4 Conceptual model of the System for the based on cases planning.
The cycle of CBR is formed by the following elements:
1. Recovery of cases; 2.Adaptation; 3. Critic and justification.
4. Evaluation; 5. Storage.

A “Case”, is the complete and clear definition with precision of particular features of a problem that distinguish it of among other problems, and the actions that are due to take for their correction [Zezzatti et al., 2001], for this reason is similar to an operation guide (plan).

Agreed with the previous thing, a case is represented of the following way, to see Figure 5:

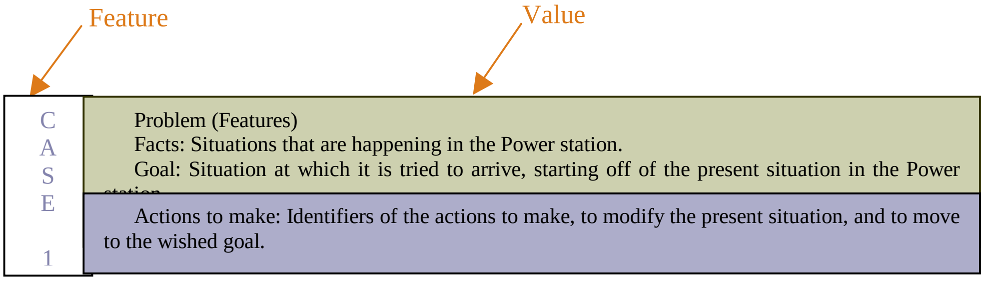

Figure 5: Representation of a Case, by MEDRAC

This example of documentation of the case, is not restrictive in its style, can be used greater or smaller information without losing of point of view, that between more clearer is, less possibility of confusion will have.

Once it is counted on the representation of a case, **matching** must be made, to determine which is the element of the Case library more adapted to the new case.

For it we will use the technique of nearest-neighbor retrieval (“vecinos cercanos”), shown in figure 6. This technique of closest neighbor, consists in determining the range that exists between the features of the new case and those of the already existing cases in our case other guides of operation, locating the case that is closest, using for it the function of similarity more adapted, *Medrac* uses one of the Cardasian type [Hammond, 1989], which specializes in determining similarity when the attributes are qualitative.

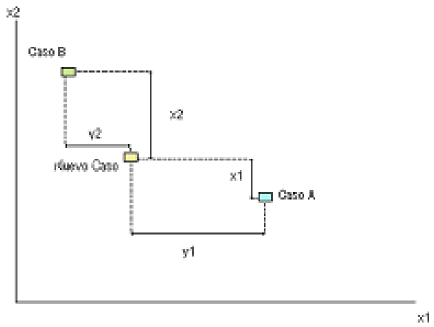

Figure 6. Diagram that show to the distance between the new case and the cases A and B, x1 and x2 are the features that define the cases.

The similarity of a case with respect to the elements of the Case Library, normally is made to emphasize a feature, weighs its distance, with a weight w_i to cause that it approaches or it seems more to one in individual, for it is used the applied function following:

$$\text{Cardasian Similarity}(T, S) = \sum_{i=1}^{n} f(T_i, S_i) \times W_i$$

T = Is the case to compare.
S = Is the case source.
n = Is the number of attributes in each case.
i = Is an individual attribute from i to n.
f = Is a function of similarity for attribute i in cases *T* and *S*.
W = Is the importance of the weight given to attribute i.

The **adaptation** consists in adapting the solution of the case most similar to the conditions of the new case. This is necessary, since normally the plans generated by *Medrac* to guide the operator are not identical to the happened ones in the previous cases. For it new actions to the plan will be adapted in order to obtain the specified goal.

The stage of **critic** and **justification**, consists of the validation of the propose solution. This validation is made resisting different solutions or simulating the solution to consider that so guessed right it is, for it *Medrac* counts on the knowledge provided by a group of experts.

In the **evaluation** stage the propose solution is applied and the result of its application is analyzed. If the results are the hoped ones confirms the solution, but if differences exist, it is due to find out why such differences happened and how they can be avoided. This information must serve to improve the definition of the case.

Finally, the **storage** consists of registering, in the Case Library, the information derived from the new case, or as a new case or an improved case.

Medrac, shows in its user interface to make a diagnosis, where in the window "Similar cases", they are due to list in order of occurrence probability, the nearest plans, after to have applied the function of similarity of the Cardasian type. This means that the plan that appears in the first place is most probable and in descendent order are the others (to see Figure 7).

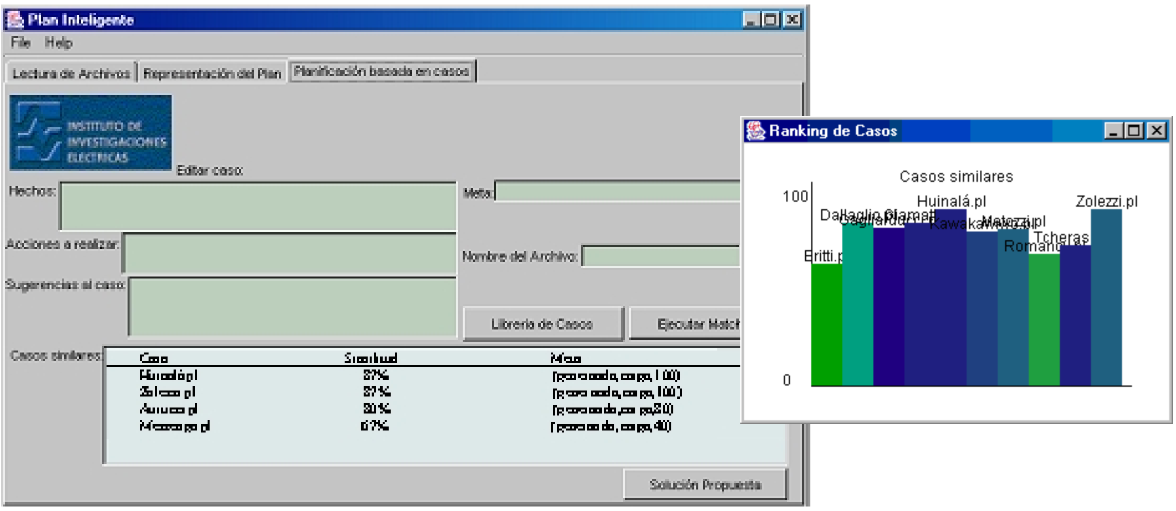

Figure 7. Module of Planning based on cases, showing the similar cases after applying matching, with a graphical comparison of similarity.

When two cases have a same value, example 87%, means that given the information of the plans the criteria are fulfilled that they induce to both plans. This indicates that greater information is required (on the part of the operator), to discriminate between both cases or that the plan is adapted for these. The final decision will take the user with base in its experience or consulting to somebody with more knowledge.

If the user selects a case, of the list of possible cases and is positioned in the option "Proposed Solution", it will observe or the suggested actions to adapt the plan and the documentation that the given solution bases.

How edit new cases in the case library.

Once the Case Library has been created, it is possible to edit the existing cases or to create new (see top fields in Figure 7).

IV. Case Study.

Due to the dynamics of the different carried out difficulty and processes in one CCC that presents the elaboration of plans of action for the reestablishment of the operation after an event nonanticipated, its continuous and nondeterminístico has been characterized atmosphere like.

Since the generation of plans for this type of processes is not trivial, it is necessary to have a generating agent of the plan and an agent monitor of execution of tasks, both coexisting in this dynamic and essential atmosphere. Under this scheme, the agent monitor verifies constantly that the execution of combat operations is made anteiormente according to the predicted situations. In case that the awaited conditions are not fulfilled, the monitor will ask for to the planning agent the representation of the present plan or the generation of an alternating or different plan:

V. Results

Until the moment it is counted on an intelligent system for the generation of abstract plans based on an intelligent system. This version of *Medrac* generates a list ordered of the actions to make, in agreement with the real state of the world, and that later the agent evaluated monitor. This list of all the actions to make has a high degree of abstraction but it determines the actions that the operator must follow to reach the propose goal.

Perhaps the most important contribution from the computacional point of view has been the development of an architecture able to adapt itself to the specific case of the power station from the case library, and its later use for the selection of action plans.

At the moment we are in the stage of learning and validation of *Medrac*, for which we have initiated, considering only cases that appear in operation guides of Power stations of Combined Cycle.

Related investigation.

A number of constructed systems exists to solve planning problems. Nevertheless, the applications of generation of plans in the electrical sector are rare. A few works of the SRI related to intelligent planning, like SIPE-2 (System Interactive Problem Execution-2) [Wilkins, 1988], with tendency towards the generation of plans for military strategies. SIPE-2 is a system of general purpouse for the generation and monitoreo of the execution of plans, whose nature is hierarchic and offers a formalism for the description of the actions like operators. Another system that uses planning is CLEaR (Closed Loop Execution and Recovery)[Fisher, 2000] developed by the NASA, is a planning system in real time constructed as an extension of REELS (Automated Scheduling and Planning Environment)[Fisher, 1999], both with applications towards the configuration of antennas towards the space.

In the field of the Technology, some CBR Tools has been developed successfully, so is the case of the produced one by the Parmalat company [Acquaviva et al., 2002], which allowed to increase its sales at world-wide level in a 27%, using for it the information of a some Italian communities, later took place new product ideas obtained with the use of this amazing CBR Tool.

Future investigation.

At the moment the planning algorithm is being fortified to incorporate a recoil mechanism of cases and its adjustment. Also this concluded a graphical editor of ACTs. Commercial tools will be used to integrate the intelligent system with the sources of real data of a power station.

Medrac will orient towards the prognosis of faults and situations of emergency, reason why it will be necessary to generate new knowledge bases. A new project of investigation denominated Development and Implementation of an Integral System for the monitoreo of a Turbogas Power Station, whose objective is the proposal of remedial actions through a reactive plan. The project will initiate, with funds of the federal government and the IIE, with sights to evaluate the intelligent system in a simulator of a CCC and its final integration in a real power station.

VII. Conclusions

Medrac, like part of the system of the System of Monitoreo Inteligente (SIMON), counts on all the elements to facilitate, the application of suitable plans that work as guides to the operator, as much as to increase the experience of the system, through the injection knowledge again derived from the deep analysis of new cases presented in the reality and which they do not adjust already to the existing ones in the Case Library.

At the moment, the system is in the phase of learning and validation. But he is safe that given the philosophy of the system, this one will be a invaluable tool for the plant operator.

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