A REAL TIME EXPERT SYSTEM FOR FAULTS IDENTIFICATION IN ROTARY RAILCAR DUMPERS

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Abstract: This paper describes the development of a real-time Expert System applied to the ore extraction Industrial branch, specifically used to assist the decision making and fault identification on rotary railcar dumpers of the operational productive system located at Ponta da Madeira Dock Terminal, built and operated by Companhia Vale do Rio Doce (now referred just as VALE) in São Luis-MA. The Expert System is built on JESS (Java Expert System Shell) platform and provides support to engineers and operators during the ore unloading as soon as supplying on-line information about faults triggered by device sensors of the rotary railcar. The system's conception involves the application of CommonKADS methodology, knowledge engineering and artificial intelligence techniques at the symbolic level for representing and organizing the knowledge domain in which the system is applied.

1 INTRODUCTION

In a great deal of industrial production mechanisms approaches able to turn automatic a wide range of processes have being used. Such applications demand from high control pattern to decision taking, where Artificial Intelligence (AI) presents wide applicability of those approaches implementing their concepts under the form of Expert Systems (Su et al., 2005). Applications with this architecture allow the machine to be structured into a model apt to behave in the most similar way a human specialist uses its reasoning when facing a decision taken problem (Feigenbaum, 1992).

The VALE production system comprehends several mining complexes, among which is notorious the Ponta da Madeira Dock Terminal (PMDT). In this complex, processes such as Unloading, Storing and Minerals Shipping are conducted, supervised by the Operational Control Center (OCC). This article discusses the development of a real time Expert System applied to decision making when facing faults occurred in the VV311-K01 rotary railcar dumper system used to unload minerals at the VALE's PMDT. Besides, we apply some information technologies such as: the JESS, the JAVA language and also XML (eXtensible Markup Language) aiming the real time running of the Expert System.

This paper is organized as follows: Section 2 describes the particularities and the operation of the rotary railcar dumper system. In Section 3 are detailed the Expert System Development steps, such as knowledge acquisition, representation and system's implementation. Section 5 summarizes some remarks and the conclusion.

2 THE ROTARY RAILCAR DUMPER SYSTEM

The minerals unloading mechanism initiates at the rotary railcar dumper with the arrival of the locomotive pulling behind it 102 to 104 rail-wagons that will be positioned in the dumper.
To attain the rotation a positioner car fixes the rail-wagons in the rotary and this, consequently, unloads

the material by performing a 160° rotation, in the conveyor belts (Fonseca Neto et al., 2003). The Operational Process is monitored by the Supervisory Control and Data Acquisition (SCADA). This supervision is also conducted by means of the programmable logic controllers (PLCs) which receive all the information from the dumper hardware through input cards.

Thus, the rail-wagons dumper's hardware is one important middleware for the communication between the Expert System and the VV311-K01 hydraulic and mechanical components at the operation time.

3 THE EXPERT SYSTEM DEVELOPMENT

In order to develop the Expert System we highlighted its stages based on JESS and CommonKADS methodologies.

The JESS architecture involves cognition components defined as: Inference Engine, Agenda and Execution Engine. All these structures catch assertions or domain facts and also create new assertions. The inference JESS engine (based on the Rete algorithm) is constituted by the Pattern-Matching mechanism that decides which rules will be activated. The Agenda programs the order in which the activated rules will be fired, and the Execution Engine is in charge of the triggering shot (Friedman-Hill, 2003). In JESS the reasoning formalism presents rules composed by *if...then* patterns, represented by the LHS (Left-Hand Side) and RHS (Right-Hand Side), respectively.

CommonKADS is a methodology for building knowledge based systems (Labidi, 1997). Products arisen from Expert Systems development that use this methodology are the result of the performed phases modelling activities, and characterize the input artefacts for the successive refinements undergone in the next steps of the CommonKADS life cycling.

The steps of the system with actions such as Acquisition and Knowledge representation are summarized– also including the Analysis phase– Rules representation– attending the Design phase – and the System's codification – satisfying the phase Implementation.

3.1 Acquisition and Knowledge Representation

All the knowledge acquisition was done by means of interviews with the expert through information kept in the operational reports. The knowledge representation was built based upon production rules that map the knowledge of the VV311-K01 operation expert.

There were observed the main concepts related with the dumper's positioner car along activities in the operational productive system, aiming at getting knowledge elements description to elaborate the organizational model that complements the CommonKADS.

The domain facts deal with the equipment situation and the potential causes that promote the main system stopping or the reduction of its productivity. Thus, by correlating problems and opportunities that can be solved or enhanced by the Expert System from which there were extracted the identified slots for building the VV311-K01 templates, it was elaborated the organizational model presented in Table 1.

Table 1: Organization Model.

SLOT	OPPORTUNITIES	PROBLEMS
Situation	Spin	Vibration
		Broken Rollers
		Lack of voltage
	Positioner car	Short-circuit
		Broken fixing screws
		Broken Counter-bolts

The slot called 'Situation' is one of the units for representing the knowledge in the JESS inference engine. The causes that lead the dumper to reach certain circumstances are pointers for guiding what must be done as to specify derivations that constitute a method for the positioner car problem resolution, and the strategies to attain this solution. These efforts are described through the knowledge model shown in Table 2.

Table 2: Knowledge Model.

SLOT	INFERENCE LEVEL	TASK LEVEL
Cause	Vibration	Motor basement snap
		Resonance
		Bend axle
	Short-circuit	Terminal out of order
		Low isolation
		Falling's wire material

According to Labidi (1997), the inference and task levels are layers that describe the expert Knowledge; thus, the model in Table 2 constitutes a set of knowledge instances on the VV311-K01 positioner car component. In Table 2, in order to better characterize the system's knowledge mechanism in agreement with the CommonKADS methodology, the activities organized in the inference model presented in Figures 1, were decomposed.

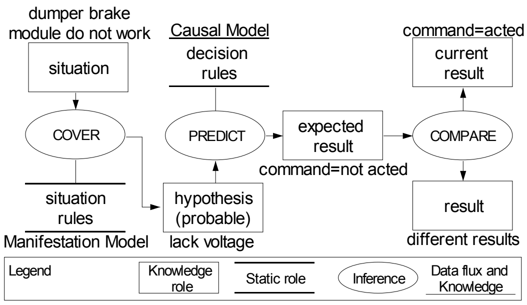

Figure 1: Inference Model.

The knowledge's roles, described in Figure 1, are functional names that capture the elements participant in the reasoning process. Inference actions assume as inputs static roles, represented by the manifestation and causal models. Within the causal model, the rules relate the positioner car fault modes taking into account their attribute's values, while in the manifestation model are reunited the production rules that express their responsibilities through the attributes' values, which satisfy some given conditions. The inference concepts represent reasoning axioms that will be mapped by the JESS inference engine used in the Expert System.

3.2 System Implementation

The Expert System decision module performs a scanning on the faults detected by the sensors present in the VV311-K01 instrumentation.

Through the checking of these faults addresses, which are generated by the PLCs and mapped into faults tagnames stored in the relational database, the Expert System rules are activated or not in the working memory of the JESS inference engine.

Tagnames (e.g. `AFF_CEP_F01@VV311K01`) are part of historical registry from PIMS (Plant Information Management System). In the Expert System they play the role of input data for the rules that deduce the situation the VV311-K01 components pass through, that is why they form the LHS rules pattern in the JESS language syntax, as can be seeing in the excerpt bellow:

```
(defrule rule198
(test(eq TRUE(actedTag
"AFF_CEP_F01@VV311K01")))
=>
(store RESULT198 "Loose-Wire-
Connection")
(assert (decision(decCausa Loose-Wire-
Connection))))
```

The 'actedTag' function returns true for 1 and false for 0, according to the result read in the XML file generated by the stored procedure into the PIMS oracle database server (see Figure 2). The function 'test' is a conditional JESS instruction responsible for determining that this pattern will only be unified if the result of the 'actedTag' function returns true. The part of XML document is shown as the following structure:

```
<?xml version="1.0" encoding="UTF-8" ?>
- <tags>
 - <tagname id="ASC_B11@VV311K01">
     <value>0</value>
   </tagname>
 - <tagname id="AIN_ALI_001@VV311K01">
     <value>1</value>
   </tagname>
```

Aiming at present the system's global solution, Figure 2 describes the Expert System architecture and the nodes distribution that form its structure in order to summarize the Expert System solution.

Once the architecture is formulated, in the following parcel of the system's decision rule, it is possible to observe that the cause 'Loose-Wire-Connection' deduces that the ultrasound on VV311-K01 must be made.

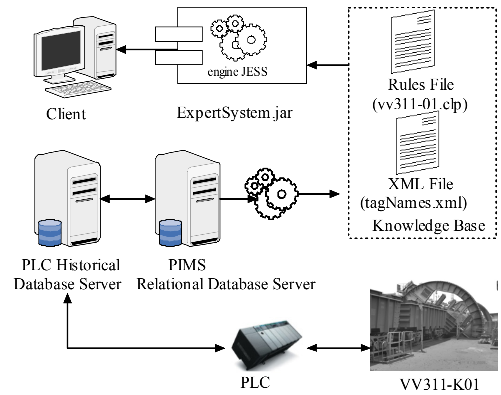

Figure 2: Expert System Architecture.

The RHS pattern of the rule's parcel below stores the result through the command store, and next inserts in the 'decision' template, the action to be done.

```
(defrule rule204
(decision (decCause Loose-Wire-
Connection))
 =>
(store RESULT204 "Do ultrasound on
VV311-K01")
(assert (decision
        (decDecision  Do-ultrasound-on-
VV311-K01))))
```

At the end of the performed deductions, in the shell JESS working memory is shown a window with the recommendations that were stored by the command store, based in the causes that led to the inference process pointed out by the system, along the responses given by the user. Figure 3 shows the decision taking delivered by the system.

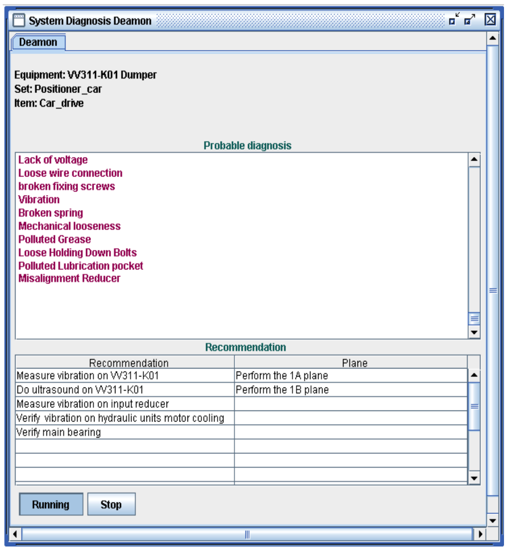

Figure 3: Expert System Recommendations.

The recommendations viewed in Figure 5, represent the rules that were activated in the working memory of the JESS engine and were triggered (shot) only because they got the unification of patterns present in its structure, deduced by the Rete algorithm. The control structure used for the Expert System rules chaining was based on backward chaining (Friedman-Hill, 2003).

4 CONCLUSIONS

The system developed in this work presented the conception and automation of the strategic knowledge required by VALE's mineral unloading system activities. The building of the Expert System in JESS, turned available the use of existing and well succeeded methods for the developing of systems based on knowledge, like the CommonKADS, and the direct handling of JAVA technology objects.

The system's performance while processing information in the JESS inference engine was considered satisfactory once the search frequency of such information elements was tested at 5 s. interval for the deduction of 250 rules, in order to update the expert system the events triggered by the PIMS server. The speed and proper timing obtained in terms of the updating processes of the expert system rules base was due to the use of the XML technology as to feed the system's knowledge base.

Finally, this system furnished enhancement and relative readiness to the knowledge processing, as a guide for the decision taking of the VALE's rail-wagon unloading system experts.

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