An Intelligent System for the Predictive Maintenance of a Hydroelectric Power Plant

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In this work we present aspects related to the elaboration and implementation of an intelligent kernel that works on the Predictive Maintenance System of the Hydroelectric Power Plant of Balbina in Amazonas, Brazil. The project was developed under the scope of a research and development contract involving many researchers from UNICAMP and UNB: the "Modernization Processes of Automation Area of the Hydroelectric Power Stations of Balbina and Samuel", with the support of EletroNorte. The system was elaborated to predict defects, failures or bad operational states of machines of the hydroelectric plant and suggest maintenance intervention and operational emergency actions.

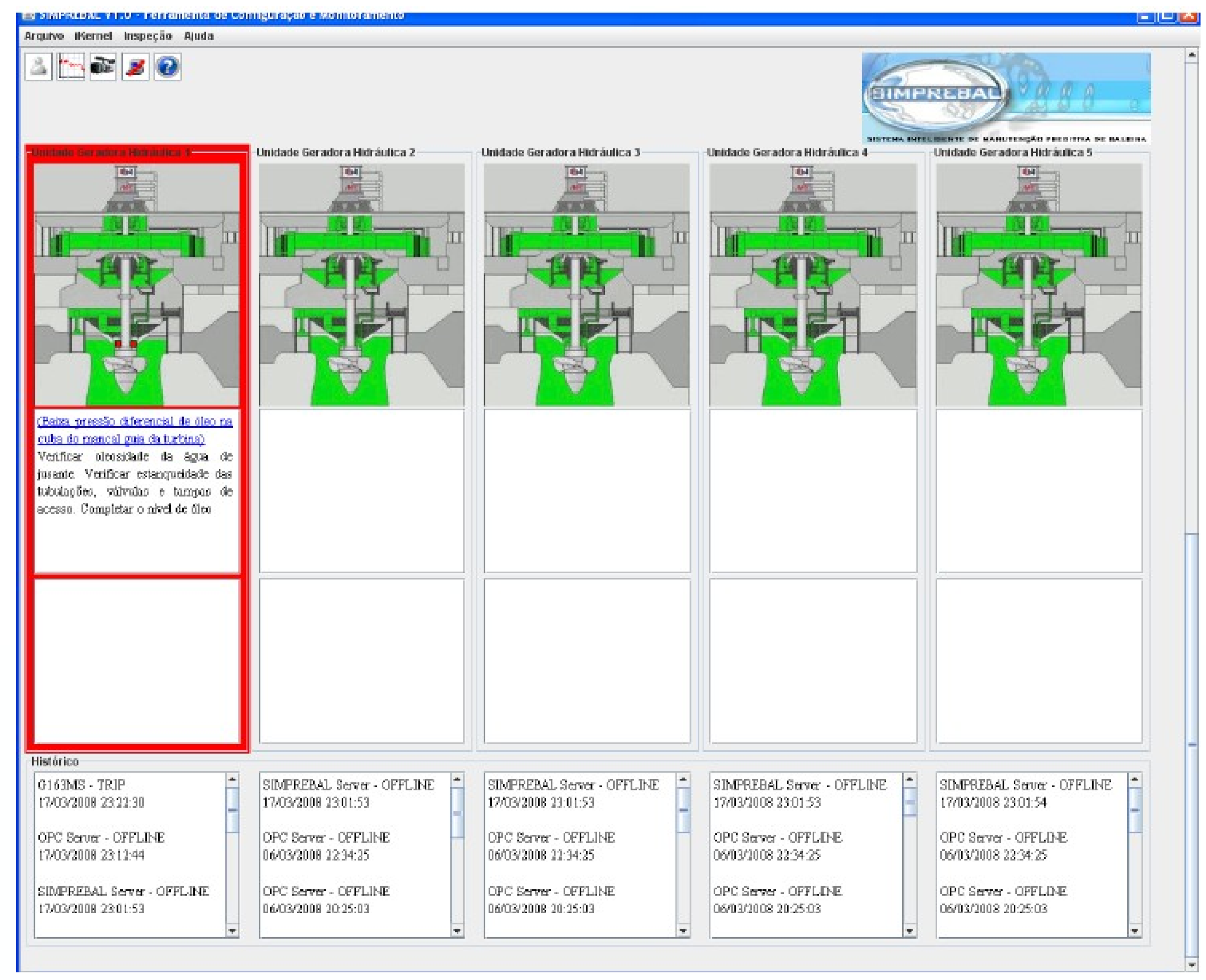
The system is split into two main parts – the intelligent kernel and the configuration and monitoring client. The intelligent kernel is a cyclic process which gets data from an OPC (OLE - *Object Linking and Embedding* – for Process Control) server and process it in an expert system using the JESS (Java Expert System Shell) tool in order to make diagnostics and prognostics regarding the plant conditions, which are stored in a database. The rules are derived using an FMEA (Failure Modes and Effects Analysis). The overall system is called SIMPREBAL (Predictive Maintenance System of Balbina) and is based on RCM (Reliability Centered Maintenance) concepts.

Introduction

The search for optimization, speed and precision in production systems and processes, resulted in an increasingly number of automated system, e.g. in manufacturing, hospitals and in power generation plants. In parallel, waste and failure were proportionally less accepted and were synonyms of losses and insecurity.

Maintenance processes are a key issue in the quest for solving such kinds of problems. There are several types of maintenance, since the corrective up to the predictive: The corrective maintenance occurs when a problem with an equipment has already happened and it needs to be fixed. The predictive maintenance is related to the prevention of situations that can lead to failures and bad operation of a machine or device. Predictive maintenance can also be split into two different kinds. A Programmed Maintenance system occurs when maintenance actions are scheduled a priori, based on statistics of failures. Condition-based maintenance systems tries to estimate the condition of parts by performing an active monitoring of parts condition and performing a diagnostic of its health and a prognostic of future defects. Condition-based maintenance is at the heart of Reliability Centered Maintenance (RCM), a step-by-step instructional tool for how to analyze a system's overall failure modes and define how to prevent or find those failures early. Nevertheless, RCM does not fully specify in detail how to perform diagnostics and prognostics of malfunctioning. In this work, we present the SIMPREBAL system, a system which instantiates RCM using FMEA (Failure Modes and Effects Analysis) and expert systems in order to implement RCM in a Hydroelectric Power Plant.

SIMPREBAL is used to examine the condition of Hydraulic Generation Units and its parts, making a diagnostic of its health and a prognostic for its failure based on the active monitoring of many parameters, as temperatures and vibrations.



Proposition

One of the main goals of the SIMPREBAL System is to perform the diagnostic of conditions and predict failures in specific parts of a Hydroelectric Power Plant, and keep machines working in the way they were projected to.

To verify the operational status of the machines, SIMPREBAL gets information from sensors through an OPC (OLE - *Object Linking and Embedding* – for Process Control) server and determine a diagnostic of health and a prognostic of future failures using an expert system. Physically, data is collected from sensors and transmitted through a FieldBus Foundation network, an industrial network system for real-time distributed control.

Data is then passed through an expert system built using JESS – Java Expert System Shell, a tool conceived by Sandia in Java. An Expert System is a set of *rules* that can be repeatedly applied to a collection of *facts* about the world. Rules that apply are *fired,* or executed. Jess uses a special algorithm called *Rete* to match the rules to the facts. Rete makes JESS much faster than a simple set of cascading *if.. then* statements in a loop.

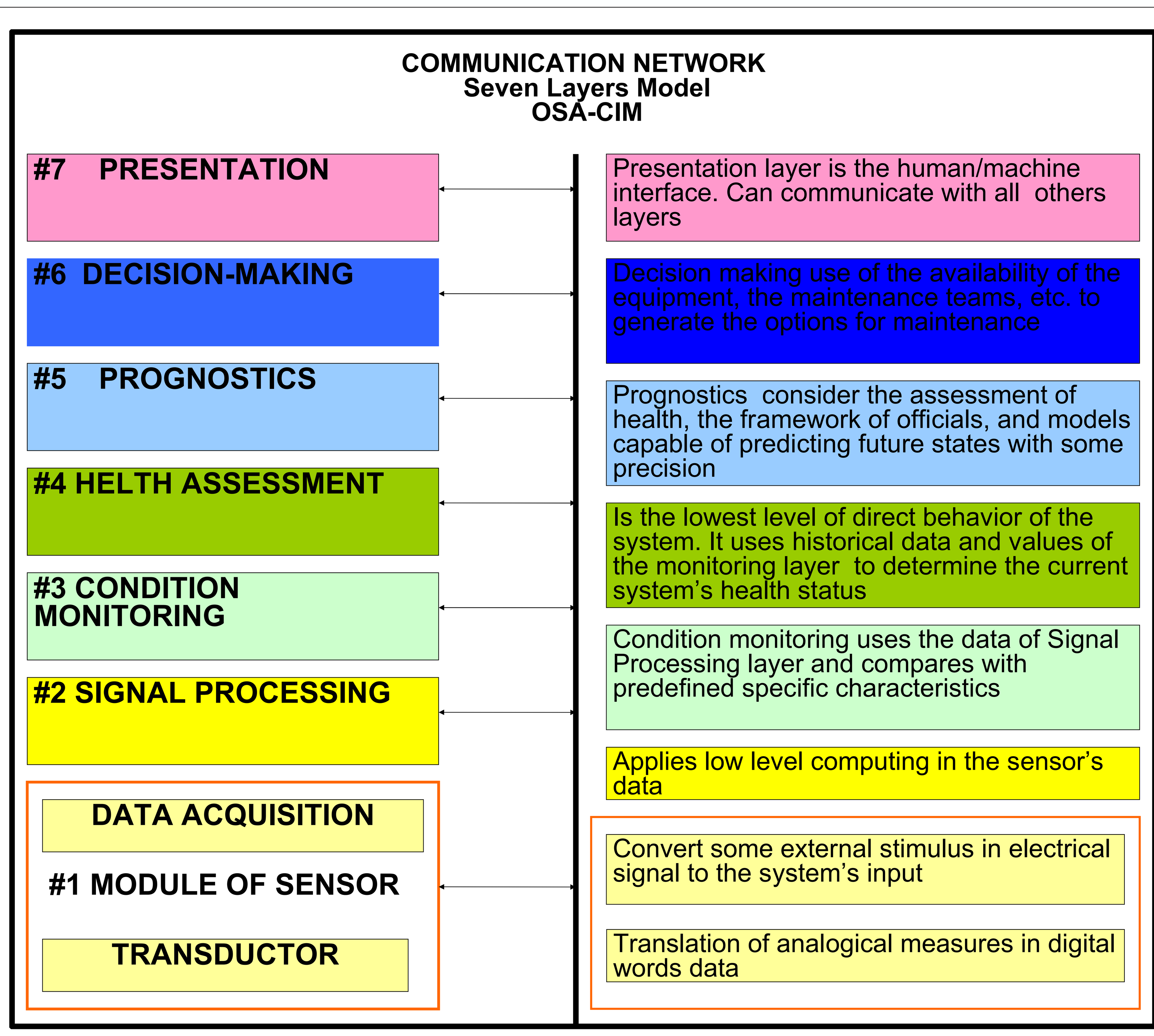
Its powerful scripting language gives access to all of Java's APIs (Application Programming Interface). Using FMEA and the Seven Layers Model of OSA-CIM architecture it was possible to create rules that could process all the information collected by the OPC Server from the sensors. The decisions and the sensors measuring are stored in a database for a future graphic and historical analysis.

There is a specific module of Simprebal that works with this information. The module I-KernelApp is a standalone Java application, responsible for data acquisition of equipments from Balbina, through the database and OPC server. Its intelligent processing was conceived in order to detect preventive maintenance situations, and eventually performing actuation in the system. The result of that process must be stored again in the database, and then can be used to generate alerts to the controllers of the power plant in the form of popup messages, e-mail or some other type of visual alert.

Similarly, they must be stored in the form of perennial records, to compose "logs" of diagnosed events by the system, acting as historical records of the different machines.

Beyond this module there is another one that completes the two main parts of Simprebal, the ConfMonitToolApp. It is a Java Applet, loaded from a Web page stored in Web server, and is responsible for the tasks of setting parameters and decision rules of the I-kernel, and the active monitoring of the variables considered important, displayed in a synoptic.

The I-KernelApp is installed in Balbina while ConfMonitToolApp is accessed through a Web Browser working in a Client/Server structure.



Conclusion

In this work we presented an Expert System called SIMPREBAL based on RCM (Reliability Centered Maintenance) concepts. This system is actually working in the hydroelectric power plant of Balbina in Amazonas and was created to act in the predictive maintenance scenery. It is divided in two main projects: the server and the client. The first is installed in the plant and collect data from sensors by an OPC server thought a modern network, the FieldBus Foundation. Inspired by the Seven Layers model of OSA-CBM (Open System Architecture for Condition Based Maintenance) and by FMEA (Failure Modes and Effects Analysis), we generated rules to perform diagnostics of health and prognostics of failures in specific parts of a hydroelectric power plant. Rules are controlled by JESS, an Expert Systems framework which was embedded into the system. The server also reads and writes information from the database witch is used for historical analysis.

The client runs in a Java Applet thought a Web Browser and is related to the last layer of the model mentioned above, and is responsible for the presentation of a synoptic of the system to the user. It contains graphics tools as well, showing the operational status of the different machines. The first can help the user to analyze a problem by plotting historic data in a graphic. The last tool alerts the user if there is something wrong with some of the five HGU by changing the defective part's color or by sending an automatic e-mail to the maintenance team.

Today SIMPREBAL is running at Balbina, resulting in a great benefit to the power plant.

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