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A promising OPC-based computer system applied to fault diagnosis

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Abstract

Fault detection and diagnosis is a challenging problem for plant economics and safety. In this context, a promising OPC-based modular architecture for a Fault Diagnosis System (FDS) is designed and implemented. This FDS has been validated by performing on-line real-time diagnosis on a simulated process. The modular architecture allows openly connecting a simulator or a real process via OPC. The Tennessee Eastman Process (TEP) is used as data generator and case study, so that several abnormal operation conditions can be diagnosed by the system. The proposed architecture is discussed regarding the integration of future modules for the timely adoption of appropriate corrective actions.
Keywords: Fault Diagnosis, Supervisory Control, Software Architecture, OPC, Tennesse-Eastman.

1. Introduction

CAPE tools are software applications used to increase process productivity by reducing costs and time (Sequeira et al., 2001; Charpenter et al., 2007). This kind of tools is used in project design, process synthesis, process economy and other applications such as process control and diagnosis. In the CAPE framework, fault detection and diagnosis is a challenging problem for plant economics and safety. Fault Detection and Diagnosis (FDD) has been addressed with different approaches that consider both knowledge-based and data-based models (Venkatasubramanian et al., 2003; Wang, 2009; Monroy et al., 2010). However, not much attention has been paid to the actual implementation of these approaches. In addition, less effort has been dedicated to the architecture of a computer information system that allows the on-line diagnosis of chemical processes.

Presently, many control and instrumentation systems, among others process systems, include the OPC standard maintained by the OPC Foundation. OPC is an open and flexible communication standard in the process supervision field that allows individual software or process modules to interact and share data. In this sense, OPC defines a standard set of objects, interfaces and methods to be used in process control and automated process applications in order to facilitate interoperability between them.

In this work, a promising modular OPC-based computer architecture is proposed and applied to the fault diagnosis field. Each component is next explained in detail.

2. Methodology

In order to develop a standard information system that allows the on-line diagnosis of chemical plants, an open architecture has been proposed and implemented. This system consists of the next components: a data generator, which can be either a real plant or a simulator; a diagnosis system as a decision-making support tool; a standard specification based on OPC; an information repository; a customer interface to the supervisory system. Fig 1a shows the general scheme of the proposed architecture and Fig 1b shows the particular implementation in this work.

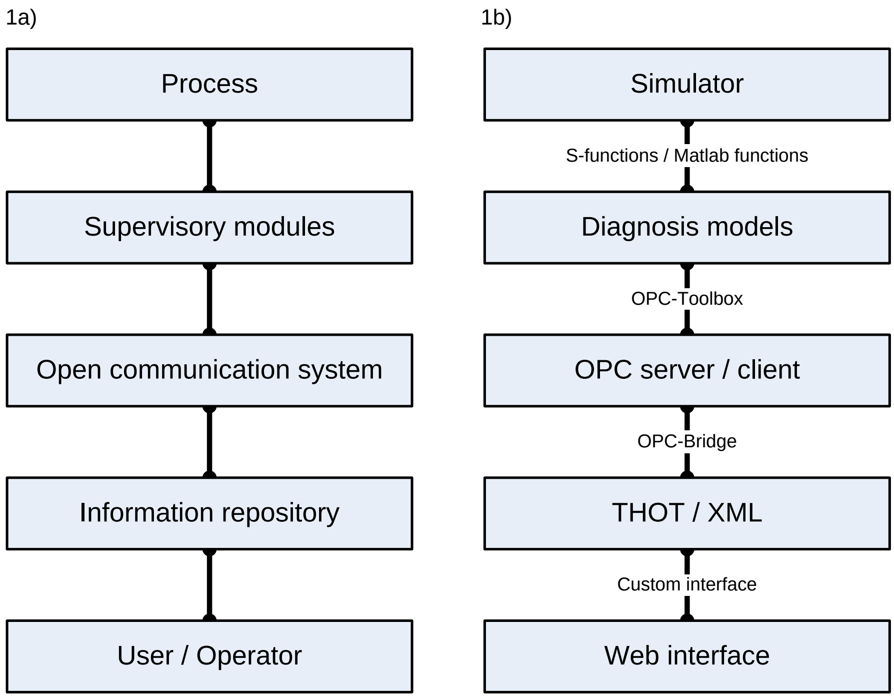

Fig. 1. a) General structure of the proposed architecture and b) particular implementation

The data generator consists of the process itself. Thus, a real plant represents this component. However, a process simulator can perfectly work as data generator for validating the information architecture. Then, process samples from all the measured and controlled variables are the input of the diagnosis module. The module is developed in Matlab and incorporated in Simulink with an S-function in order to generate the diagnosis results on-line at real time.

An OPC server is incorporated into the architecture to set up the communication of the real-time process data from the process or from diagnosis module (as in this case) to the customer. Indeed, supervision engineers can play this role in real industrial applications.

An intelligent platform for real-time management of decisions at different levels of production, called THOT, is an important element in the architecture. This platform was designed by CEPIMA research group and works as a repository of all the stored and available information obtained from different processes and data-bases, in a transparent XML format. It plays an important role in the computer architecture by receiving the diagnosis information from OPC through an OPC-bridge and sending it to the operator through a custom interface. The platform is designed to be as open and flexible as possible. Thus, a flexible platform would allow sending information in the reverse sense to the plant and receiving and sending information from and to other decision-making support tools.

Finally, the custom interface of the computer architecture has been implemented as a Web application that uses an applet to render information coming from the process and the diagnosis module and passing through the platform. The real-time values of each variable are presented with visual aids allowing their reading and comprehension. Furthermore, the corresponding diagnosis values to each modelled fault will be provided in the same manner, allowing the diagnosis of the process as an application of the computer architecture. In this way, the appropriate corrective actions can be taken subsequently by the user.

2.1. Case study

The Tennessee Eastman Process (TEP) benchmark (Downs et al., 1993) is simulated in Simulink/Matlab and works as the data generator of the architecture. TEP is a complex industrial chemical process that consists of a reactor (where two simultaneous gas-liquid exothermic reactions occur), a separator, and a recycle. It consists of 52 process variables (41 measured variables and 11 manipulated valves) and allows simulating and diagnosing 20 faults. The TEP simulator provides real-time measurements that should be read and displayed through the user interface.

2.2. Fault diagnosis system as decision-making model

A fault diagnosis system represents the decision-making model in the proposed architecture. The diagnosis models and the TEP process are loaded in Simulink using their respective S-functions. This step is essential in order to communicate data from the simulator through the OPC server. The diagnosis models are data-driven models and are constructed in the next way: A training data set is built with data from the 21 process scenarios (normal and the 20 faults), where the data under Abnormal Operation Conditions (AOC) are obtained from the transient period of the fault. It has been observed that transient-data models for continuous processes are capable to diagnose faults not only during transient stages but also during steady-state (although with lower performance).

On the other hand, Data under Normal Operation Conditions (NOC) is taken from the process in steady-state. In this sense, NOC data is used to construct a projection model with Principal Component Analysis (PCA). Data is previously mean-centered and auto-scaled as a pre-processing step. Centering and scaling allows standardizing units in the process variables and extract the highest variance in the components when applying PCA. NOC and AOC data is then projected onto the PCA model in order to obtain the projections or scores, which are the real input to the classification or diagnosis algorithm.

Support Vector Machines (SVM) method is a classification algorithm exported from Machine Learning to the Chemical Engineering area that is applied in this work as fault diagnosis method. SVM work developing classifiers or diagnosis models by using kernel functions. A polynomial function of second degree fits better the TEP data used to construct the models. SVM use the PCA scores and the corresponding labels (assignation of the scores to the corresponding process scenario, either normal or

abnormal) as inputs. Then, the diagnosis models are constructed based on the calculation of the support vectors per each scenario.
The diagnosis models are validated on test data and finally applied to real-time measurements. As result, diagnosis values or predictions to the corresponding scenarios are obtained and read. In more detail, the whole diagnosis system receives the on-line data by the simulator and generates the diagnosis, interpreted from the predictions to each faulty scenario. If the diagnosis value of a fault changes from a negative to a positive value, such fault is being diagnosed as occurring, otherwise the process remains under NOC.

3. Results and Discussions

A scheme of the diagnosis system incorporated to the TEP simulator in Simulink is shown in Fig. 2. As illustrated, the pred_sfunc block represents the diagnosis module (using Matlab) that receives the real time variable samples from TEP and generates the diagnosis values for the twenty modelled faults.

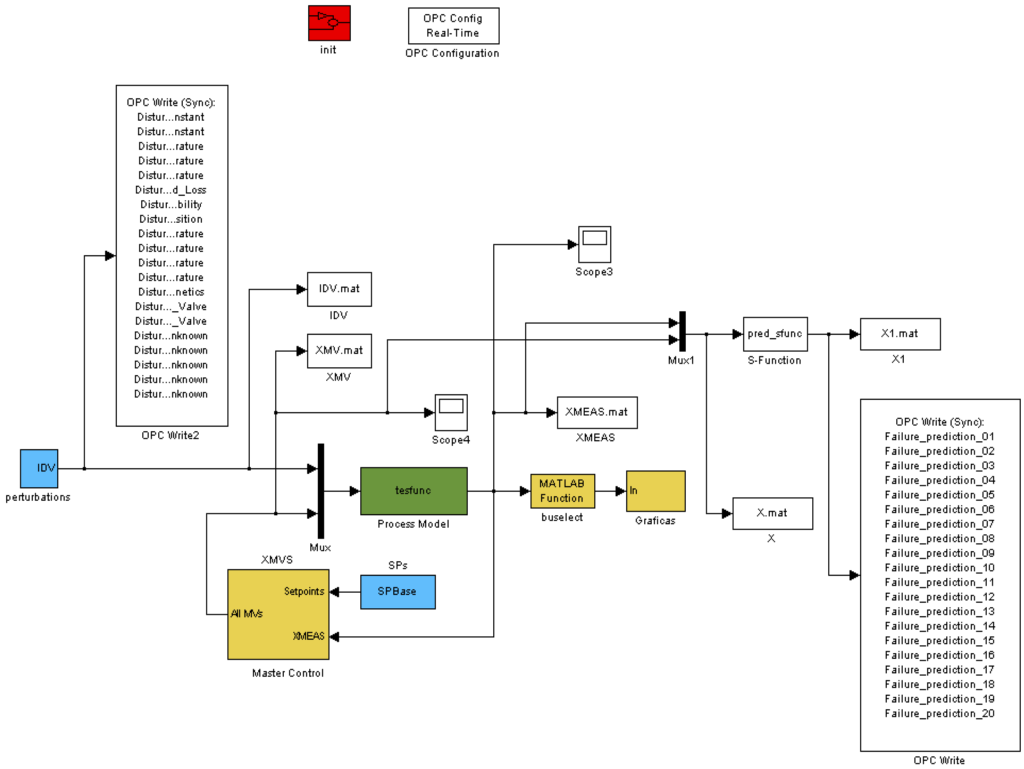

Fig. 2 Scheme of the diagnosis system in Simulink

The constructed models allow diagnosing successfully any of the twenty faults, as well as the fault-less process. In this case, the diagnosis values for the twenty faults are negative for each sampled time, indicating a process under normal operating conditions. However, some values for fault 15 are positive because such fault is almost imperceptible and with a regime similar to the fault-less operation.

The diagnosis values for each sampled time are then showed by the Web application. Therefore, the successful application of this architecture shows to be ready for its scale-up implementation in industrial scenarios.

4. Conclusions

This work has presented an open OPC-based architecture applied to fault diagnosis. This architecture connects several elements in order to provide real-time data to the plant operator. The diagnosis models are constructed with normal and abnormal regimes data, taken from transient stages. These models, previously validated, are used in the architecture and provide diagnosis values that can be interpreted as alarms in the process. Therefore, the architecture is successfully applied to diagnosis, by producing friendly results to the user.

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