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Development of a Web-Service e-Diagnostic and e-Maintenance Framework for Industrial Monitoring

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Abstract- An integration in a framework of e-diagnostic and e-maintenance components based on web-services has been developed for industrial monitoring systems. The aim is to perform tele-monitoring, diagnostic and maintenance tasks for industrial monitoring systems working in dynamic conditions of commitments, suppliers, and customers. The framework has been customized initially for an elevator machine system for improving service performance in companies of installation and maintenance. The experimental case study, reported in the present paper, shows encouraging results and fosters industrial technology transfer.

I. Introduction

The actions to guarantee a correct and high-quality operation in an industrial plant exploiting a remote monitoring systems are essentially the fault diagnosis and the maintenance. When a fault occurs in the system, engineers can repair the system from information based on their own experience or by looking for documents provided by suppliers. Almost always, when the problem is too complicated, the suppliers send their technicians to resolve the problem with consequent increase in costs associated to fault repair.
To override these problems, in the last years more remote diagnostic systems have been proposed such as in the cement industry [1], manufacturing industry [2], and international space station [3]. At same time, *diagnosis* is almost always accompanied by *maintenance.* More recent efforts, for the modern industry, lead to the concept of *correct maintenance,* to achieve the objective of *near-zero downtime* [4].
During last years, the concept of e-diagnostic applied to process industry has been introduced [5-8]. Through e-diagnostic, companies can remotely link supplier's expert through internet to take quickly actions, such as diagnosis, configuration, debugging and performance monitoring of the system to be repaired, in order to reduce service loss.
Recently, International SEMATECH (ISTM) has proposed generic guidelines for the capability requirements of an e-diagnostic system applied to some manufacturing industry [9]. ISTM divides the features of an e-diagnostic system in four level: (1) Level 0 - Access and Remote Collaboration: remote connectivity to the equipment and remote collaboration capabilities; (2) Level 1 - Collection and Control: remote equipment operations, remote performance monitoring, data collection and storage; (3) Level 2 – Analysis: automated reporting and advanced analysis with SPC capabilities and (4) Level 3: Prediction: predictive maintenance, self-diagnostic and automated notification.
However, the aforementioned systems, as well as the ISTM guidelines, are referred in principle to manufacturing industry (or complex processes such as space industry and health-monitoring). These solutions does not take in account always variability of the environment where a *service industry* can operate. Most of the proposed architectures for survey are based on the concept of remote control of the system (or machine) to be diagnosed, working in homogeneous environment and needing for additional resources. Indeed, a service company performs a *service* (maintenance, installation and diagnosis) on a plenty of systems. It can be have more suppliers and can decide to change some of them. Moreover, a service company can achieve or loss commitments. It works in an actual and dynamic environment where implement the aforementioned architecture in a stable way can turn out to be really difficult.
To override this shortcoming of the existing systems, an e-diagnostic/e-maintenance system needs to integrate various heterogeneous data and subsystems on Internet and Intranet, (i) by avoiding additional resources to accomplish diagnosis and maintenance, and (ii) in a way more dynamical than in current state-of-the-art solutions. Different equipment data, local self-diagnostic and maintenance subsystems have to be lined, messages have to be sent, and information have to be delivered/found to/from the suppliers.
In this paper, an e-diagnostic and e-maintenance framework based on web-service (EDMWS) for industrial applications is proposed. EDMWS possesses the mechanism of automatically integrating diagnostic and maintenance information over internet to the local self-diagnostic/maintenance subsystems, collecting and

storage the related data and send messages to the technicians. Experimental tests on EDMWS are currently on going for an elevator systems under the research project EVODIALIFT, in cooperation with the company Del Bo Group (Naples, Italy), supported by the Italian Local Government of Regione Campania [10].

II. The proposed method

The aim of EDMWS is to perform tele-monitoring, diagnostic and maintenance tasks for industrial monitoring systems working in dynamic conditions of commitments, suppliers, and customers.
EDMWS consists in four subsystems mainly (Fig.1): (i) *Diagnostic System* (DS) based on Diagnostic Manager, Artificial Intelligence (AI) Diagnostic and e-Diagnostic Server (EDS); (ii) *Maintenance System* (MS), based on Maintenance Manager and e-Maintenance Server (EMS); (iii) *Information Manager* (IM), based on Information Manager Diagnostic Server (IMDS), Information Manager Maintenance Server (IMMS), Local Diagnostic Database (LDD) and Local Maintenance Database (LMD); and (iv) *Web-Services* (WS).
In particular, EDMWS acquires signals and information by means of a sensor network installed on the plant to be supervised (e.g., an elevator system, Fig.1). Through a Control Unit based on microprocessor (CU) the information acquired are sent to a Central Monitoring Unit (CMU) with capability of monitoring the state of the system.
CMU can link the aforementioned subsystems, as described in the following, in order to accomplish e-diagnostic and e-maintenance task. The DBs for the DS, MS and IM have a cache memory to store the sent requests and the respective output, in order to minimize the waiting time for the requests already dispatched and avoid further request transmission to WSs.

A. Diagnostic System

Diagnostic System is a process inside CMU. DS is activated by means of some specific events. When some monitored parameters override the respective thresholds, the Diagnostic Manager is activated to perform the following operations: (i) the Diagnostic Manager launches the AI Diagnostic [11], a diagnostic tool based on artificial intelligence in order to perform a local diagnostic on the system. If AI Diagnostic does not find a coherent solution, then (ii) the Diagnostic Manager sends a message to the e-Diagnostic Server. It formats this request by means of XML standard language (eXtensible Markup Language) and sends the request to IM using SOAP protocol (Simple Object Access Protocol). Such as described in the following, IM elaborates this request in order to find a coherent diagnosis on remote Web-Services

B. Maintenance System

The Maintenance System also is a process inside CMU. MS can be activated by a timer or by an external call. Then, MS compares the monitored parameters with the corresponding nominal values reported in the tables inside the DB associated to MS. If there are same parameters that override the thresholds values, MS formats a request by means XML standard language and sends it to IM by SOAP protocol. The request contains information about the part number of the system that has to be replaced. IM processes this request in order to find the availability of the specific part of the system on remote Web-Services (first to companies performing maintenance service and then to external suppliers).

C. Information Manager

The Information Manager is the most important part of the EDMWS. When IM receives a request (formatted in XML language), from the EDS or the EMS, it verifies the request typology. Then, IM performs a search on local DB in order to find previous identical requests. If any exact matching with previous requests is not found, IM carries out different operations based on: (i) DS request typology and (ii) MS request typology.

C.1 DS request typology

IM performs a search on Diagnostic Web-Services. In particular, each Diagnostic Web-Service contains a troubleshooting reference of each single suppliers.

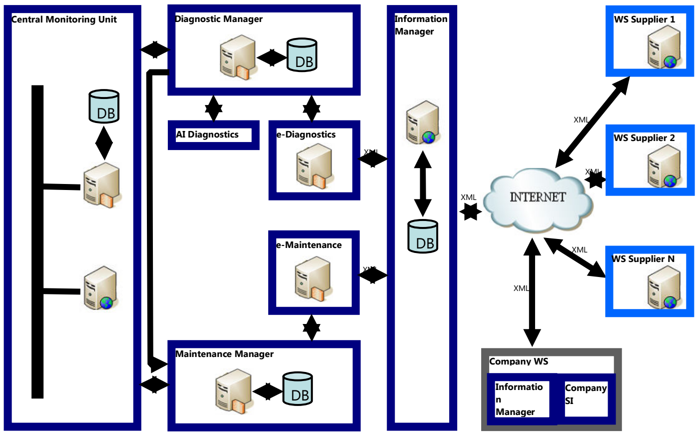

Figure 1: Architecture of EDMWS

The troubleshooting reference assigns an ID to each fault. Each ID is associated to same *keywords* denoting the anomalies occurred in the monitored system. In Fig.2, an information interactive process among different parts of the system in a fault diagnosis is pointed out. The specific steps are:

1) EDS sends request to IMDS;
2) IMDS search diagnostic solution on LDD;
3) LDD provides diagnostic solution;
4) IMDS sends diagnostic solution to EDS;
5) If no diagnostic solution of occurring anomalies is faund locally, or the fault cannot be remedied, IMDS sends a messagge based on "keywords", according to the occurring anomalies to RWS;
6) RWS sends an ID according to the "keywords" to IMDS;
7) IMDS stores the ID in LDD as "new case";
8) IMDS sends ID to RWS to find diagnostic solution;
9) RWS sends the diagnostic solution to IMDS, according to the ID;
10) IMDS saves the diagnostic solution on LDD as "new case";
11) IMDS sends the diagnostic solution to EDS.

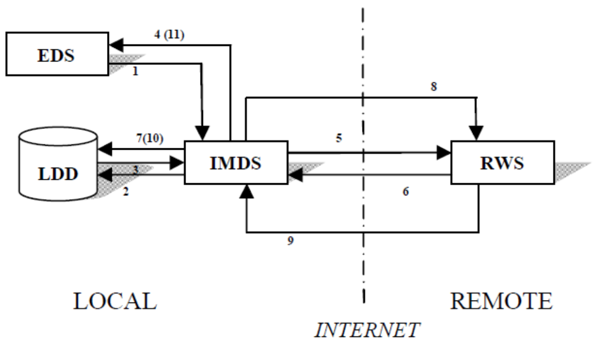

Figure 2: Example of e-diagnosis process

C.2 MS request typology

An MS request mainly consists of a list of parameters containing the part number to be replaced. When a MS request reaches IM, it firstly performs a search on local DB in order to satisfy the received request, from a stored previous one. If IM matches a previous request, it formats the output parameters (by means of XML language) and sends to CMU. The output parameters reports the presence of the component in the stock and its location.
Otherwise, IM formats the output parameters in XML language, and , through SOAP protocol, sends the request to a certain number of supplier's Web-Services, in order to verify the availability of the component/components

that has/have to be replaced. The output parameters from the WSs are successively formatted in XML and sends to CMU.
In Fig. 3, an information interactive process among different parts of the system in a fault diagnosis is shown. The specific steps are:

1) *EMS sends request to IMMS;*
2) *IMMS searches information on LDD in order to satisfy the received request ;*
3) *LMD provides the requested information;*
4) *IMMS sends the requested information to EMS;*
5) *If the requested information does not found on LMD, then IMDS sends the request to RWS;*
6) *RWS sends the requested information to IMMS;*
7) *IMMS sends a messagge concern the information achieved to EMS;*

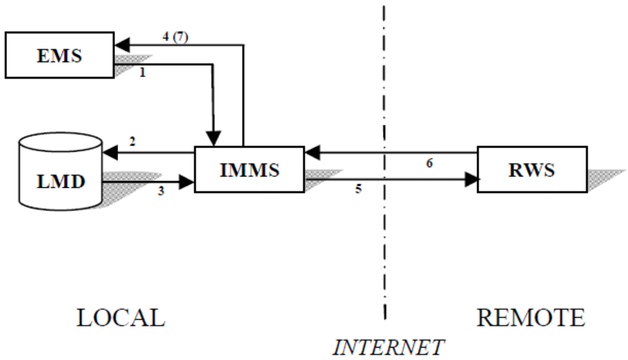

Figure 3: Example of e-maintenance process

D. Web-Services

The Web-Services are software systems supporting the interoperability between different systems of the EDMWS.
The interoperability is guaranteed by Web-Services based architecture called SOA (Service Oriented Architecture) allowing different software application on different hardware machine to exchange data and information and perform complex task.
Each request from IM is sent by means SOAP protocol and formatted by XML. WSs are connected to IM by HTTP communication protocol.
In the EDMWS WSs can be diagnostic WSs and maintenance WSs.
The former expose troubleshooting reference provided by suppliers. The troubleshooting reference is characterized by an ID to each fault and with the probable associated diagnosis.
The latter expose the availability of components to replace, by the suppliers, the associated cost and the delivery time

III. Preliminary experimental results

The proposed approach was implemented and tested experimentally under the framework of the research Project EVODIALIFT, supported by the Italian Local Government of Regione Campania [1], for the company Del Bo SpA, in Naples, Italy, committed to maintenance and installation of elevator systems.
Elevator systems are large used especially in modern cities, as they provide a quickly access to the building, in particular to the high one. However, long-time usage of the system increases fault-occurrence probability [12]. Every fault in the elevator system causes the interruption of service with obviously inconvenient to the workers and people that living in the building. For this reason, companies providing maintenance of elevator systems, are interested in tools that allow quickly diagnosis and correct maintenance of the system in order to improve and/or preserve their business.

Subsystems DS, MS and IM run on server machine under SO Windows Server 2008, while Microsoft Visual Studio .NET 2008 was the development environment; in particular, it has been used C# language (C-Sharp). The .NET framework has been choose as it naturally supports Web-Services application.
Preliminary tests on EDMWS are referred to the correct transmission of data packet sent from CU to: (i) IMDS and (ii) IMMS.
Data sent from CU are binary LOG file with following structure:

- *Header*
- *DataFile*

The Header part is a record with the structure as:

- *MN (2 byte): device identification*
- *SizeHeader (2 byte): header length*
- *SizeDati (4 byte): data length*
- *NumLet (2 byte): number of records in DataFile*
- *SN (6 byte): CU serial number*
- *SF (n byte): reserved for future tasks*

DataFile part is compound through a number of records specified in NumLet. Each record has a structure as:

- *NS (2 byte): signal identification*
- *Sizedata (4 byte): data length*
- *dataOra (4 byte): data time in seconds from 1/1/1970*
- *Data (n byte): data with length defined through "Sizedata"*

LOG file sent from CU are formatted in XML on CMU and send to server IMDS or IMMS. To verify the correct transmission of the packets, it has been used Trace Tool 11, of which in fig. 4 is reported a snapshot of the user interface.
This is a C#, C++, Delphi, ActiveX, JavaScript, and Java trace framework and a trace viewer. The tool has been installed on the servers (IMDS and IMMS) to monitoring the correct transmission and reception of the LOG file sent from CU equipment.
It should be noted that a more complete experimental phase following a complex test plan are currently ongoing. Hence the Authors believe that do not make sense report incomplete tests here. However preliminary experimental results did not show critical functional aspects.

Conclusions

In this paper, an e-diagnostic and e-maintenance system based on web-services for an elevator system is presented. The proposed system is aimed at extending the e-diagnostic and e-maintenance concept to service industry, where the existing methods are too complex to be applied. For these reasons EDMWS owns features to be applied in modern service companies.
The complete test on the proposed system is currently ongoing, though preliminary results are satisfying. A more comprehensive case study will be faced in next future.

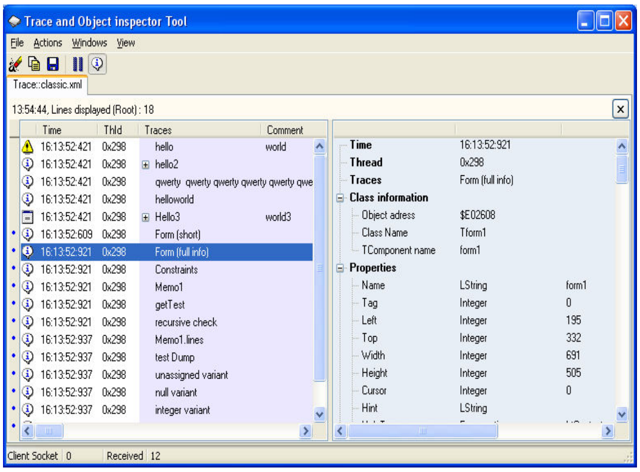

Figure 4: TraceTool 11 user interface

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