A Collaborative System for Remote Diagnosis and Maintenance using CSCW and Virtual Reality

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Abstract

With the increasing of machineries technologies it becomes more and more difficult for ordinary technician to solve maintenance problems and take the write decision without collaboration with more experienced technicians and the machinery producers. Cooperative remote diagnosis and maintenance can be with big benefits for production industries. After an assessment of needs for an appropriate remote maintenance, the architecture of a new system for a distant cooperative machinery diagnostic and maintenance is designed. The method was applied to diagnosis rotating machinery using vibration data analysis. An online and offline diagnosis system based on condition monitoring is developed.

1. Introduction

The rapid evolution of information and the new potentials for communication between people have been of great importance to the success of most organizations. Assuring a successful meeting needs a lot of energy, time and money (traveling time and fees), especially in case of urgent interventions.
Finding a solution for these problems is the aim of many research in different fields. One of these research is the remote diagnosis and maintenance. In previous research we implemented a remote diagnosis system for rotating machinery using virtual reality (1,2,3,4).
Using one camera and by matching the camera image with the virtual reality environment the user can reach the desired machine checking point and collect the needed data such as the vibration data. The system structure is shown in figure 1. The system consists of a master and a slave side. On the master side, we have a VR system; the user manipulates the VR system, does the desired operation, and at the same time supervises the remote side with a tele-operated camera.

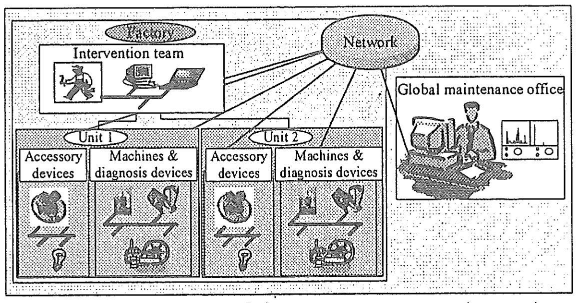

Figure 1: Structure of the one user remote system

The system is controlled through the local network. Our virtual space consists of the 3D graphical models (of the subject machine to control, the sensor, and the robot) and a real-time video image collected by the CCD camera. Video-images are displayed at the master side in order to check the behavior of the remote environment. From the master side, we can control the video camera at the slave side (zoom up/ down and pan/tilt). The image of the machine subject to check and the robot hand are captured by the video camera and sent to the application through the network in order to be displayed in the application software. The user interact with the system with a GUI shown in figure 2.
The actual system is one user system, only one user can access to the remote factory and collect the needed data and no cooperation can be done. In practical cases, in order to take the needed decision about machinery states or intervention, the observed state of the machine and the collected data are usually discussed within a group of experts taking in consideration the machine's history and other old cases. A multi user cooperative system seems to be very necessary for an appropriate maintenance and decision taking.

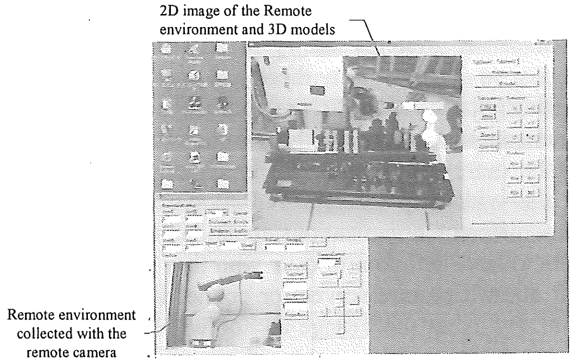

Figure 2: Graphical user interface for the one user remote diagnosis system

In order to build a useful remote cooperative diagnosis and maintenance system we started by taking out the needs and operations that must be assured by the new system. Much discussion with different maintenances, production and industrial experts was done. Furthermore a review of other research and the use of cooperation system in other fields are also done. If some works show good perspective results, this research can't be applied in many real cooperative tasks such as the remote diagnosis and maintenance fields.

The use of Computer Supported Co-operative Work (CSCW) combined with virtual reality can make collaborative work and tasks more effective. In this paper in a first part, we show the needed requirements for a remote diagnosis and maintenance system. Then we introduce our new designed system for a cooperative muti-users remote diagnosis and maintenance.

2. Multi-User Collaboration

The objective is to supply maintenance teams with a system that allows them to explore distant factories and diagnosis machinery from distant places, collect the needed data, discuss the alternative cases and take the needed decisions. As shown in figure 3, the system must allow monitoring the remote machines and collecting the needed data. In the case of trouble in the factory or in the need for decision talking such as the placement of a new machine in the factory, the discussion of collected data, the evaluation of an existing state etc. The user can call some specific technicians to cooperate with him or send a request to multiple technicians and ask them their opinions, or start a brainstorming about a specific situation. Any user from the called users can join, not all users will be in the same degree of accessibility to system. Technicians can also collect remotely data from the alternative machines. Only allowed technicians can operate remote instruments in the remote factory to collect data or change some machines setting. The machinery histories data will be saved not only in as a sensor collected data form but also in 3D model based system for a better understanding the past parts defections.

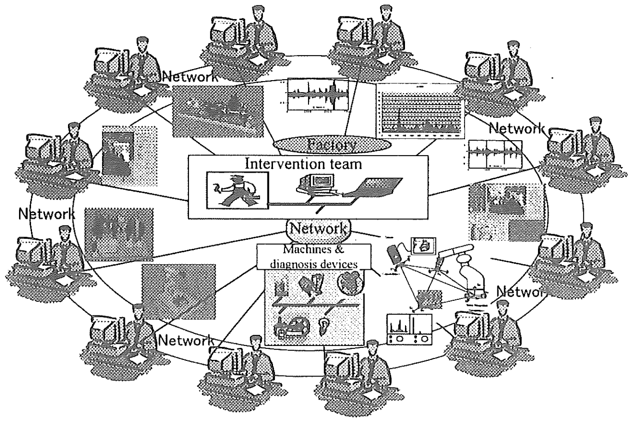

Figure 3: General structure of the maintenance cooperative system

In the case of a big factory many remotely exciting can collect different data from the different machines. In order to judge the hole system they can cooperate, present the different partly collected data, conclude about the hole machine and take the needed measurements or actions. A complete architecture for remote collaborative maintenance system should cover the range of functions from data collection through the recommendation of specific maintenance action. The key functions that facilitate remote collaborative maintenance systems include:

- Remote Sensing and data acquisition,
- Signal processing and feature extraction,
- Discussion about the different data and features,
- Production of alarms and alerts,
- Prognostics, prediction of the remaining useful life of the equipment in service,
- Decisions taking: maintenance recommendations or evaluation of asset readiness for a particular operational scenario,
- Management and control of data flows or test sequences,
- Management of historical data storage and historical data access,
- Machines configuration management,
- Human system interfaces,
- Description of the configuration of the system/equipment being monitored,
- A list of specific assets being tracked, and their detailed characteristics,

- Description of equipment functions, failure modes, and failure mode effects,
- Record of logged operational events,
- Description of the monitoring/ measurement system: sensors data acquisition, measurement locations, etc..,
- Characteristics of the monitoring components: history, model number, serial number,…,
- Record of sensor data (and its characteristics) whether acquired on-line, manually logged, or manually acquired using hand held roving instrumentation,
- Means of describing signal processing algorithms and resulting out data,
- Means of describing diagnoses of evolving equipment faults and projections of equipment health trends,
- Record of recommended actions and the basis of those recommendations,

Furthermore, a remote maintenance system must be appropriate for unstructured environments. These environments are often subject to unpredictable changes, which therefore inhibit the ability to initiate repetitive programmed procedures.

3. Proposed research plan

This research will induce the application of novel technologies for collaboration and visualization technologies (e.g. Tele-Immersion) to enable the development of wide area collaborative virtual environment with cooperating agents interacting in a dynamic environment, and to study the relation between the social and the technical group awareness, multi-user interfaces, concurrency control, communication and coordination within a group, shared information space and the support of a heterogeneous open environment which integrates existing single-user applications using the distinction between same time (synchronous) and different times (asynchronous), and between same place (face-to-face) and different places (distributed).

On-line and off-line analysis of simulation traces and results enable us to first understanding complex situations and than planning for responding to alternative situation. The design of the system will be specified in UML (or a similar standard notation) and, as far as possible, implemented in a variant of multi-agent technology.

There are many design decisions to be made in developing the architecture. One is whether it should be P2P, or a client/server system. After examining the existing CSCW architectures, we specify the key design decisions on new CSCW with virtual reality techniques systems such as whether a system should use a P2P or client/server deployment.

Client/server systems are generally considered to be simpler to design since there are more standards and existing tools. Client/server deployment allows an organization to more easily control interactions, and it can be more efficient for lower bandwidth connections such as wide area wireless. A P2P system allows people from different organizations to collaborate, and allows users to have full control over who they collaborate with. P2P doesn't require servers or connectivity to an access point. By using short range ad hoc wireless networks the system can be used anywhere. Since we need to support distant, intra, and inter-enterprise collaboration, the system will be designed to support both P2P and client/server communications.

The implementation will be accomplished using JADE (Java Agent DEvelopment Framework) for multi-agent interaction, VRML and OpenGL for 3D environments interaction, 3D modelers (lightwave, 3DMax, Virtools) for 3D objects modeling, Halcon for cameras calibrations and images processing.

JADE is software that simplifies the implementation of multi-agent systems through a middle-ware. The agent platform can be distributed across machines (which not even need to share the same OS) and the configuration can be controlled via a remote GUI. The configuration can be even changed at run-time

This research will progress as follows:

- Study the way people work in groups with the enabling technologies of computer networking, and associated hardware, software, services and techniques,
- Study of the existing CSCW systems, technologies and architectures,
- Study of the CSCW development: User-interfaces, programming languages, Computer hardware, distributed Systems, middleware (Java, CORBA), hypermedia, algorithms and abstractions for implementing collaborative applications: Consistency management techniques, distributed architectures, mobility, design patterns, Shared distributed repositories, Shared objects, shared user-interfaces
- Conception of the structure of the CSCW system through virtual environments
- Design, and the implementation of a collaborative virtual environment using computer-supported cooperative work (CSCW) systems for multi-user interaction,
- Evaluation and impact-study of this system in different fields such us the remote maintenance field and the disaster management and risk prevention fields.

In this space, users work in order to coordinate multiple activities. We proposed the user interface layout as shown in Figure 4. It is made with mainly 5 parts. Windows for the 3D environment, this 3D environment can be matched to a 2D collected image from the remote environment; this allows a secure intervention in the real factory by the interaction with the virtual environment. While interacting with the remote space the user supervise that space with the video feedback and can act in the case of any anomaly.

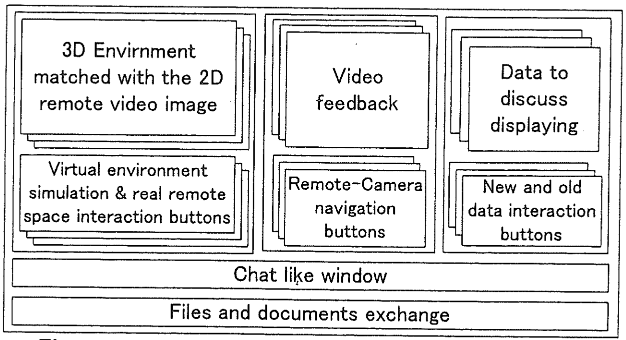

Figure 4: Multi-users diagnosis system Interface layout

The collected data or different parts defections can be discussed on the discussion display, using the mouse the user can write or circle a part of the image or chart for a better explanation. Furthermore the needed analysis function can be done on every terminal separately. The historical data can also be downloaded and discussion reports can be saved for future use. The users can talk to each others and exchange files. Many windows can be opened in the same time, this allow one user to cooperate with many other users about different cases. The use of robotics in the maintenance field for a remote diagnosis is a new field and our system presents a new approach for the remote diagnosis of rotating machines. The proposed system architecture is generic. The integration of virtual reality techniques and the CSCW systems will make these cooperative works more and more effective, it will be not limited to file exchanges, or chat systems like interactions systems, but by the integration of virtual reality we can create a cooperative work system, where we feel that we are in a 3D virtual environment. In this shared virtual space users can interact with each other and co-manipulate virtual objects, or control real machines through Internet.

4. Conclusion

Unexpected failures of critical machinery and frequent stops for disassembling, revision and repair can be an economic burden. For this reason, over the years increasing importance has been given to maintenance programs for industrial equipment. Cooperation and interaction between technicians in distant places is also a need to assure effectiveness of maintenance tasks. With new technologies there is no need for physical human meetings in order to cooperate and interact. Users can feel present in a shared virtual space in order to interact and manage multiple collaborative tasks and take the needed decisions without delay. With this study we started by defining the requirements for a good remote maintenance system and examining the different tasks of maintenance. We listed the requirements for a reliable machinery remote maintenance. We showed that a multi-user cooperative virtual reality and tele-operation based system can be with big advantages for this field to assure a good remote diagnosis and maintenance. Requirements are listed and the design of the new system is built. This research progress plan is also explained.

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