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A Remote Maintenance System with the use of Virtual Reality.

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Abstract

The use of robots for fault diagnosis and maintenance operations is going more and more widely used, these robots' controls is generally done by teleoperation. This still has many weak points. To remove these problems, we use the virtual reality techniques. We conceive a system for collecting vibration data with the use of a remote robot control controlled by a virtual designed model. With our model we can manipulate both of the machine, to be checked, and the robot. In our 3D model the data collecting points are very well known. This will assure a good exactitude in the data collection.

Our system will assure a good remote maintenance and fault diagnosis not only in dangerous places, but also in the ordinary cases.

Key Words: *remote maintenance, robotics, telerobotics, computer graphics, virtual reality.*

1. Introduction

A lot of researches are being done on the field of the remote diagnosis and maintenance, but until now these research doesn't succeeded in getting good diagnostic results such as the Inspection and Diagnosis Robot (I.D.R.) described by CHEN, and Toyota(1), where they use the sound diagnosis method.

The use of sounds diagnosis methods to detect failures is generally difficult to apply in the working environments. This is due to that the failure's sounds (signals) radiations from a machine are generally contaminated by noise and echo.

The vibration diagnosis method attributes to a better determination of defected parts. The use of the vibration diagnosis method by the mean of a robot faces a lot of problems:

The vibration sensor must be placed in a specific data collecting points, this points are some times hard to attend with just teleopertation systems.

The sensor must be in contact with the machine at the measure point and according to the sensor the pressure force must be must be adjusted.

When moving the robot arm, it is necessary to check the safety, and assure obstacle avoidance with the space around the machines.

We must consider the vibration noises generated by the robot.

These difficulties make the use of inspection and diagnosis by robots very limited to a few diagnosis methods such as sound diagnosis method where no precise point is needed to be reach and no contact with the machine is needed. But the fault diagnosis results are also very limited compared with that given by the vibration method.

Furthermore a remote maintenance system must be appropriate for unstructured environments.

Unstructured environments are often subject to unpredictable changes, which therefore inhibits the ability to initiate repetitive programmed procedures. A high flexible operational system is needed.

Virtual Reality offers the possibility for humans to interact in a more natural way with the computer and its applications. Currently, Virtual Reality is used mainly in the field of visualization where 3D-graphics allow users to more easily view complex sets of data or structures. The use of virtual reality in the maintenance field is still in an embryonic phase. Many research has aimed to overcome this lack, but almost all of them stopped in the simulation phase based on a three dimensional interface.

This research aims to overcome the above-indicated problems, thereby creating a usable interaction platform for diagnosis and maintenance by using Virtual Reality techniques. We propose a method to use the vibration sensors with the Inspection and Diagnosis Robot (I.D.R). This presents a background into the field of Virtual Reality and its application on the industrial field on general and on the maintenance field on particular. It goes on to propose an application of using the virtual reality techniques to collect the vibration data for fault diagnosis and machine state prediction.

Furthermore, the paper describes an implementation of this vibration data collection application. The implementation was completed using a Mitsubishi 6 degree of freedom robot hand, a Nittetsu Rotating Machine Simulator, a Sony CCD camera, OpenGL as graphical library, LightWave as a modeler and C++ Builder for the graphical user interface and the programming units.

This case study demonstrates the particular use of virtual reality techniques in the fault diagnosis phase and its efficiency in unstructured environments, as well as demonstrating the generic nature of the system and its extensibility to be used in more specific maintenance tasks.

The structure of the proposed system, the 3D model and the processing algorithm used for data collecting, are explained.

Finally, the generic nature of the framework is further demonstrated by moving the machine in different position and collecting the vibration data, by changing the machine to be controlled, and the operating tasks.

The system is also extendible to be controlled and manipulated through Internet. We conclude by showing the importance to implement Virtual Reality techniques in the maintence filed. This has promises, to limit danger for operators, to ameliorate the data access, to reduce costs and to assure a better remote preventive maintenance.

We have shown that our system is implementable and useful in the field of maintence, making it easier for experts to control and diagnosis their machines from distant places.

2. Objectives:

The basic idea of our system is to supply maintenance teams with a system, which allows them to explore and diagnosis a modern industrial enterprise, from distant places (Fig. N1).

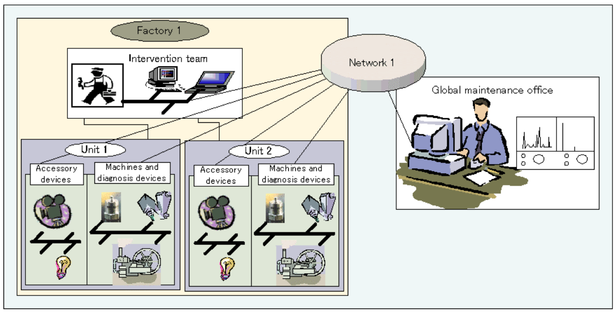


Fig.N1: Structure of the System.

An appropriate system should give the user the impression of being there, and should assure a maximum safety for both people and equipments.

The system must be appropriate for unstructured environments, where unpredictable changes often occur. Unstructured environments are often subject to unpredictable changes in the environment, which therefore inhibits the ability to initiate repetitive programmed procedures. A high flexible operational system is needed.

Because it is impossible to perform any sort of prediction without some knowledge of the system, it is necessary to have an adequate model of the controlled system. The operator simulates the robot operations within the graphical simulation model, assisted by the camera image of the remote side, and then he can transmit the instructions to the remote side.

The clearest solution to this requirements is to design the core of the system as a Virtual Environment based on realistic looking 3-D models representing all the machines to be diagnosed, the diagnosing tools, the surrounding environment and also a real video camera's image of the distant environment, which allows a real-time visualization of the real environment. The online control of the real environment is needed especially in unstructured environments.

A typical industrial enterprise consists of the plant building and the various departments, such as the production and the maintenance departments. The production department is also divided to various departments with its respective machines, robots, and transportation systems. The system will allow the maintenance teams to simulate and execute the different diagnosis steps from a distant place. This will be true for any machine in the different departments.

The Challenge is to implement not only a virtual maintenance system but also a realistic diagnostic data collection system and maintenance system for distant machines.

Graphic rendering complex 3-D models, simulation of machines, robots, diagnosis steps, the real-time visualization of the real environment and the remote data collection by the robot have to be assured by the system.

3. General Approach:

Our system allows to download 3D model of the desired machine to be checked, match that model with the respective camera's image and perform the desired checking steps and operations.

This project was designed from scratch, starting by over viewing and studying the different diagnosis techniques, their use, their efficiency, and their ability to be used in order to assure an appropriate remote maintenance. The existing research and proposed solutions remote diagnosis are also consulted. Deciding the diagnosis technique that will be used concludes this step.

The design of the machines and robot's models were studied and designed by the use of modeling softwares and the basic graphical library OpenGL.

The use of modelers was in order to realize representative models; in our case we used LightWave as a modeler. In order to assure the scalability of our system and its use in different platforms on many hardwares, all the graphical unites were done with the OpenGL graphic library.

We establish the system, experiment it, we finish this study by evaluating the system. We evaluate the system by comparing the vibration data collected by using the system and those colleted by the ordinary way. We finish by studying its implementability in a real enterprise and the possible future improvements.

4. Structure of the system:

We proposed a vibration data acquisition system; the conceptual model of our system is shown in fig. N2.

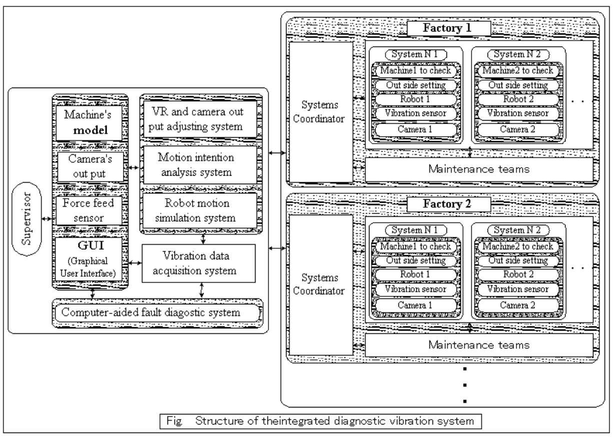


Fig.N2: Conceptual model of the system.

The system consists of a VR system and a real system. Our virtual space consists of the 3D graphical models (of the machine to be controled, the sensor, and the robot) and the image collected by the CCD camera that is exploited as shown below. In this model the space coordinates are very well known, we use this fact to assure the exact control of the real robot in the real environment where space coordinate are immeasurable with the only use of teleoperation. This is done by matching the real environment CCD camera's image with our virtual model. The model of the machine can be manipulated (translated, rotated, zoomed…) by the use of a graphical user interface to be adjusted on the background image.

After matching the models on the camera's image, we manipulate our system in the virtual space, we put the sensor on the appropriate place for collecting the vibration data and if we are satisfied with that manipulation, we execute it in the real space. The real system consists of the machine to be checked; in our experiment it is a Rotating Machine Simulator (Nittetsu Electrical Engineering and Construction CO LTD), Robot hand RV-E2 (MitsubishiElectrical Engineering), CCD Camera (Sony), and the vibration apparatus.

These equipments are shown in more details in fig N.3.

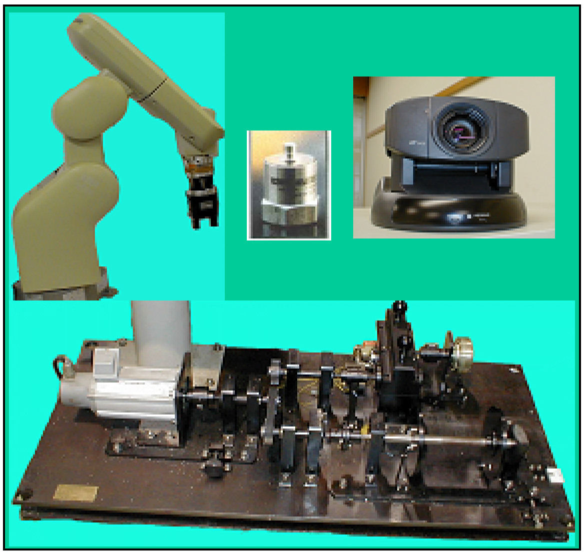


Fig.3: The instruments used for the experiment.

5. System Implementation:

5.1. Geometric Modeling:

All geometric modeling was done with 3-D CAD tools (Light Wave and AutoCAD). They were modeled in a precise way in order to assure a best matching. Colors and lights were chosen in order to give an attractive view of the models.

The constructed models are shown in the following images. (Fig N.4, 5)

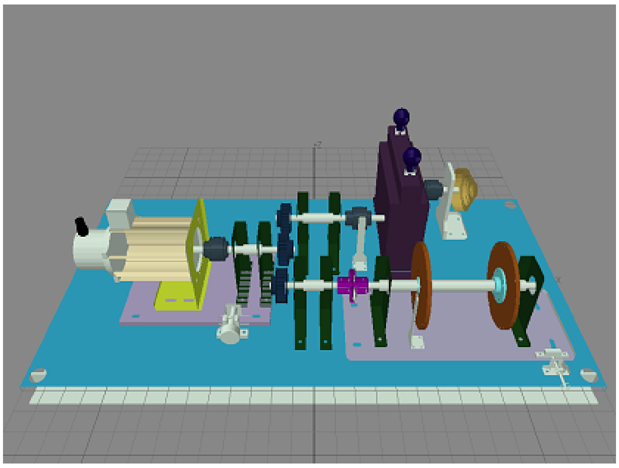


Fig.N4: 3D Model of the rotating simulator.

The robot's model is done in a way that by the use of the GUI and buttons, it can assure the same degree of freedom and motions as the real robot.

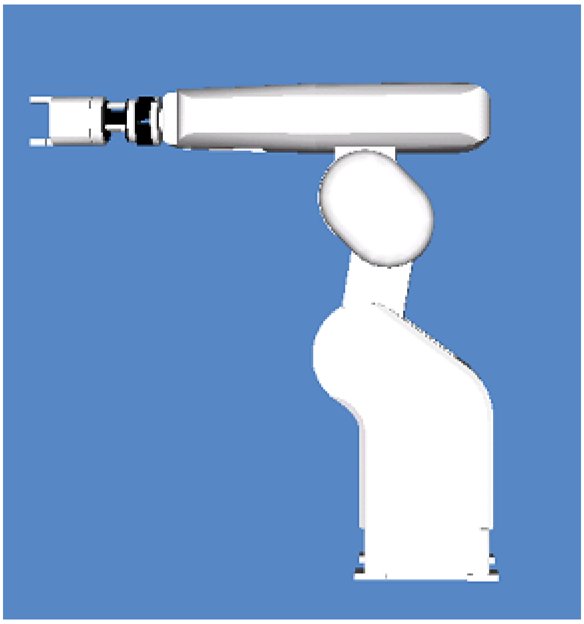


Fig.N5: 3D model of the robot.

5.2. Processing algorithm:

The processing phases are shown in fig .6.

In the VR system, the operator carries out various tasks for the virtual elements. These tasks are classified as follows:

- From the image collected from the CCD camera, the factory's environment is well recognized. We can adjust our camera in order to collect the clearest image, most appropriate for the matching operations. Based on that processed image we superpose our 3D model. By using the mouse and the designed GUI, we can easily superpose the model onto the image.

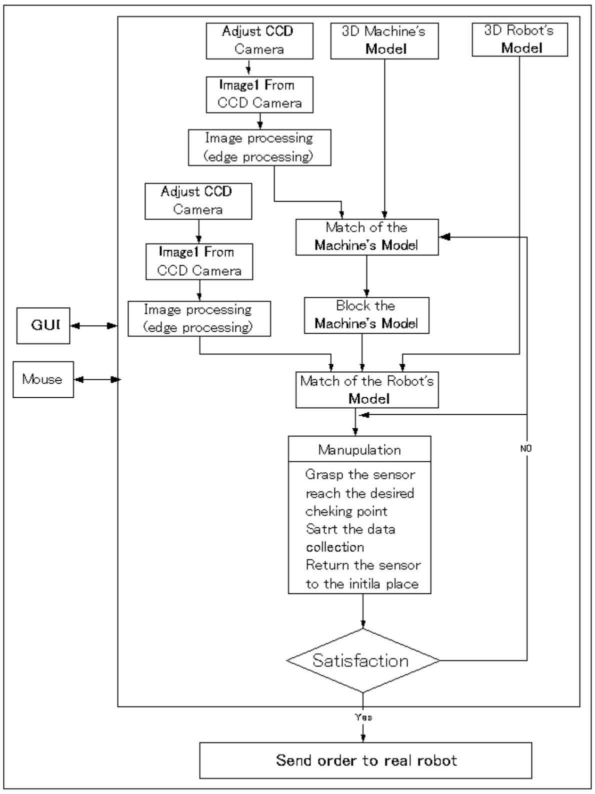


Fig.N6: Processing steps:

Our model consists of three main parts: The vibration simulator's model, the robot's model, and the vibration sensor that will be handled by the robot. In this superposition phase, next steps are followed:

- ✓ First, the user starts by matching the vibration simulator's model with the real one.
- ✓ Second he matches the robot's model with that of the processed image.
- ✓ After matching both models, we save this relative position.

- Depending on the checking point position and proposed testing sensor, the operator decides all the steps of the robot's virtual model. This model is controlled as follows:

  - ✧ Grasp the desired vibration sensor,
  - ✧ Adjust that sensor to the needed checking point, (This stage varies with the type of the sensor.)
  - ✧ Collect the vibration data,
  - ✧ Return the sensor to its initial place.

There are many kinds of vibration sensors, but the most frequently used ones are the acceleration vibration sensors, because that can assure good collection of the vibration signals. In our experiment, we use the acceleration sensors. In this class of sensors, there are two kinds:

- The first kind is mounted with a magnet, so we don't need to keep pressing the sensor on the checking point. We just touch the surface of the checking point, and we open the robot's fingers. After collecting the data we grasp once more the sensor.
- The second kind is a sensor that must be pressed on the checking point during the data collection time. This pressing force is adjusted by the use of the force feed back device PHANTOM.

We conceive our virtual environment in a way that it can be seen from different points of view.

After deciding the robot's steps the operator store them. The robot's commands are tested in the virtual system, if agreed, they are sent to the real robot, if not, we redo the manipulations. The robot adjusts the sensor on the designed place and we collect the vibration data.

5.3. Software Structure:

The software was designed in a way; it is easy to use by non-programmers, scalable, and of high performance. The software structure is as the follows. (Fig.N7):

The GUI component allows the user to manipulate the camera, the 3D model, the virtual robot's model and the real robot.

The camera unit is responsible for two actions: It assures the capture of the camera's feed back and a the its position control. After manipulating the camera, setting it in an appropriate position, we save that image. This is assured by the Image saving unit. The image is saved in the bit map format. The bit map image loader loads this image. In order to be used by OpenGL, to be represented in the background, we need to change its data format from BGR to RGB.

The vibration simulator's model is modeled by using LightWave modeler. This was done to assure the easy use of the system by an non programmers. Just model the machine by the modeler, save the data in the LightWave format and the system offer the possibility to download that model as well as the corresponding bit map image. This LightWave format file is downloaded to the space by the LightWave loader unit.

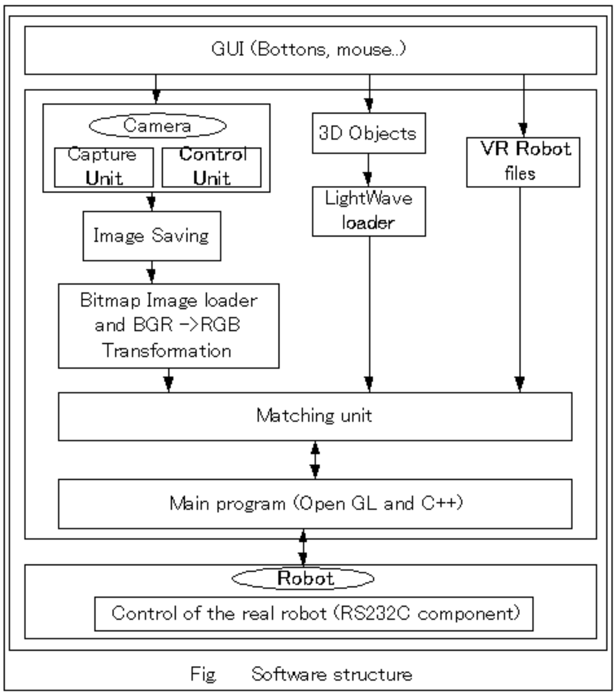
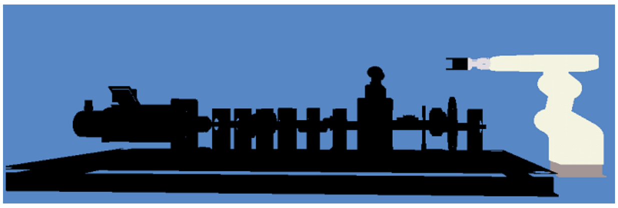


Fig.N.7 Software structure.

Our software contains also the unit for the matching; this unit relates the Graphical Users Interface Buttons with the operation that affect the 3D models. These operations are the translations, rotations, zooming, and Transparency adjusting (Blending) of the downloaded 3D model.

RS232 unit assures the control of the robot, and the cameras' position control. Our camera can assure rotations and zooming.

Our software is built in a way it assures a great ease for users. We have only to model the machine to be controlled with the modeler (LightWave in our case) and we can manipulate that model with our software and assure the matching and do the appropriate manipulation and diagnosis. This was in the aim to assure a easy use by the maintenance departments in any factory that present an interest in the remote diagnosis.



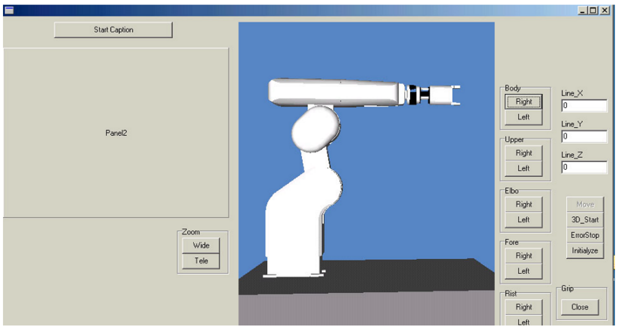


Fig.N.8 Graphical user Interface

6. Advantages of the proposed system and its implementability:

Our system has many advantages, this advantages:

1. It is not influenced with the delay time occurred in the real time control.
2. It is safe for both the operator and the equipments.
3. The operator can correct his operations in the case of mistakes without any bad effects.
4. The remote collection of vibration data is assured
5. The system can be implemented in even middle enterprise to assure remote diagnosis. The main cost is almost related to the cost of the robot.

Conclusion:

By this research we could implement a system that is very useful in unstructured environments, where we could assure a good remote diagnosis of machines.

The resultant accuracy given by this system depends on the accuracy of the matching step. A good matching assures an accurate manipulation of the system and as a result an accurate vibration data collection. In this research the matching operation was done with mouse by adjusting the 3D model on the image taken by the camera. This method gives acceptable results, but it has some disadvantages. It depends on the precision of the manipulation done by the operator, if he doesn't do a good matching the remote control will be done with a certain error. This method takes time and need some patience. The results depend from an operator to another. There are also some difficulties in adjusting the virtual cameras' parameters.

These drawbacks can be avoided if an algorithm that assures the matching operation automatically is realized, which is our future job.

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