REMOTE ROBOT CONTROL AND HIGH AVAILABILITY

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Abstract: Nowadays production flows are modular, each module in the enterprise being specialized and used to achieve a particular task. In many cases the modules are connected and materials are sequentially processed in each module resulting a final, unique product or assembly. One typical such production module is a flexible cell/system using multiple robots. In this structure, providing continuous service for applications is a key component of a successful robotized implementing of manufacturing. High availability (HA) is one of the components contributing to continuous service provision for applications, by masking or eliminating both planned and unplanned systems and application downtime. A high availability solution in robotized manufacturing provides automated failure detection, diagnosis, application recovery, and node (robot controller) re integration. The paper describes a platform which is a software product designed to control and supervise multiple robot-vision controllers using remote connections with a number of Adept Technology V+ controllers configured to use a high availability implementation, either located in a local network or via Internet.

1 INTRODUCTION

In a robotized flexible manufacturing cell, robot (-vision) controllers are masters over local workstations or cells, because robot manipulators connect two important material flows: the *processing* flow and the *transportation* flow. One solution to integrate these two flows with on-line *quality control* in the manufacturing module, further networked with the design and planning modules, is to adopt a unified feature-based description of parts and assemblies, technological operations, geometric & surface quality control, grasping and manipulating (Tomas Balibrea, *et al*., 1997).

The system is configured for *high availability* . HA systems are a combination of hardware and software components configured to work together to ensure automated recovery in case of failure with a minimal acceptable downtime (Harris et. al., 2004).

2 THE STRUCTURE OF THE SYSTEM

The system is composed by the following applications (Figure 1):

The **Server Application (SA)**: Remote visual control and monitoring of multiple robot controllers from mobile and stationary matrix cameras.

- *Visual control*: the Server Application supports almost all V+ and AdeptVision program instructions and monitor commands.
- *Monitoring*: a Monitoring/Treatment scheme can be defined for each Client/Station. For each client a list of events and controller variables to be monitored according to a user-definable timing and precedence, and reacted at by user-definable actions/sequences can be specified in an Automatic Treatment Window.
- *Communication management*: the Server Application manages the communication with the robot controllers and cameras, transfers real-time images from the cameras observing the robot workplace and production environment, reports status information, stores in a database and displays images taken by the robot camera.

The **eClients Applications (eCA)**: Java applications running in web browsers. They provide portal services and the connection of networked production agents: image data and RV program / report management; real-time robot control and cell / workplace observation. The eCA are composed by two applications:

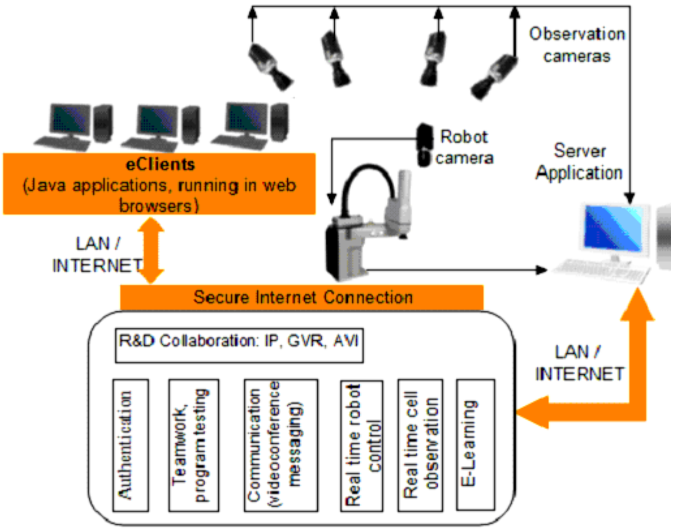

Figure 1: The System Structure.

- one application which has the function of retrieving the images from the observation cameras and display them in real-time and also gives the user the possibility to change the orientation and zoom factor of the cameras.
- the second application is a VNC client.

The VNC viewer is a web teleoperation application which can be executed into a web browser. The application connects to the Domino web server which makes a secure connection using a TCP/IP tunnel with a server having a private IP address, which cannot be accessed from internet but only using the Domino server.

The private IP machine has a VNC server that exports the display, and also the teleoperation application. Using the exported display the user can view and use the application as when the application runs on his own computer. The access is made using a username and a password, process managed by the Domino server.

3 ACCESSING THE SYSTEM

To have access to the system, a user must have a username and a valid password to enter in the system. First the user must access the portal site using a java aware browser (like Internet Explorer, Opera, Firefox, with the JRE installed).

The portal is structured in two zones:

- one zone is a public zone which contains all the documentation, tutorials courses and so on..., needed by users to learn how to use the system this part of the portal can be accessed by anyone.
- and a private zone where the access is based on username and password. The private zone gives access to the eClients for teleoperation purposes.

After entering the correct username and password, the user is allowed in the system and has access to a the teleoperation application which is a menu driven interface which allows him to interact with the system (see Figure 2).

The teleoperation application is composed by two windows:

A command window where the user can select the robot system which he want to control and issue commands from the command line or activate the vision window.

The robot stations are commanded using the command line and the menus. When a client is connected, the IP address is checked and if the client is accepted, the name attached to the IP address is added to a drop down list from which the user can select what client he wishes to command. When a client who has a video camera attached the VISION button is enabled and if it is pressed the VISION Window will open.

From the VISION window, vision commands can be issued by selecting the wanted actions from the menus. The most important functions are:

- selecting the physical and virtual cameras, and the virtual image buffers;
- selecting the display mode and the resolution;
- image acquisition;
- issuing primary operations;
- displaying the vision system status; training models;
- switches and parameters configuration for virtual camera set-up.

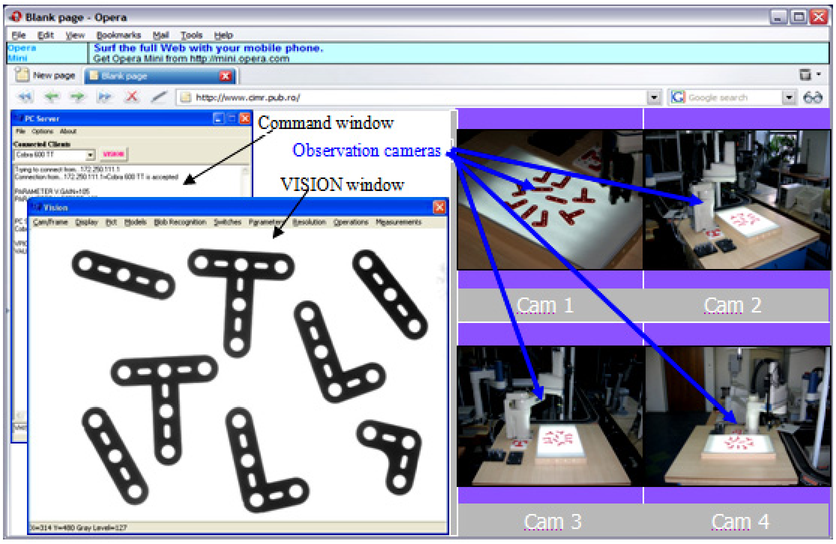

Figure 2: Accessing the system.

4 SOLUTION IMPLEMENTING FOR NETWORKED ROBOTS

In order to implement the solution on a network of robots, first a shared storage is needed, which must be reached by any robot controller from the cluster.

The file system from the storage is limited to NFS by the operating system of the robots. Five Adept robot manipulators were considered, each one having its own multitasking controller.

For the proposed architecture, there is no option to use a directly connected shared storage, because Adept robot controllers do not support a Fiber Channel Host Bus Adapter (HBA). Also the storage must be high available, because it is a single point of failure for the Fabrication Cluster (FC).

Due to these constraints, the solution was to use a High Availability cluster to provide the shared storage option (NFS Cluster), and another cluster composed by Adept Controllers which will use the NFS service provided by the NFS Cluster (Figure 3). The NFS cluster is composed by two identical IBM xSeries 345 servers, and a DS4100 storage.

The storage contains a volume named Quorum which is used by the NFS cluster for communication between nodes, and a NFS volume which is exported by the NFS service which runs in the NFS cluster. The servers have each interface (network, serial, and HBA) duplicated to assure redundancy (Anton *et al.*, 2006; Borangiu *et al.*, 2006).

There are three communication routes: the first route is the Ethernet network, the second is the Quorum volume and the last communication route is the serial line. If the NFS cluster detects a malfunction of one of the nodes and if this node was the node which served the NFS service the cluster is reconfiguring as follows:

1. The server which is still running writes in the Quorum volume which is taking the functions of the NFS server, then
2. Mounts the NFS volume, then
3. Takes the IP of the other server and
4. Starts the NFS service.

The Fabrication Cluster can be composed by at least two robot controllers (nodes) – *group leader* (GL) and a common node. The nodes have resources like: robot manipulators (with attributes like: collision detection, current robot position, etc...), serial lines, Ethernet adapter, variables, programs, NFS file system. The NFS file system is used to store programs, log files and status files. The programs are stored on NFS to make them available to all controllers, the log files are used to discover the causes of failure and the status files are used to know the last state of a controller.

In the event of a node failure, the production flow is interrupted. In this case, if there is a connection between the affected node and the group leader, the leader will be informed and the GL takes the necessary actions to remove the node from the cluster. The GL also reconfigures the cluster so the fabrication process will continue.

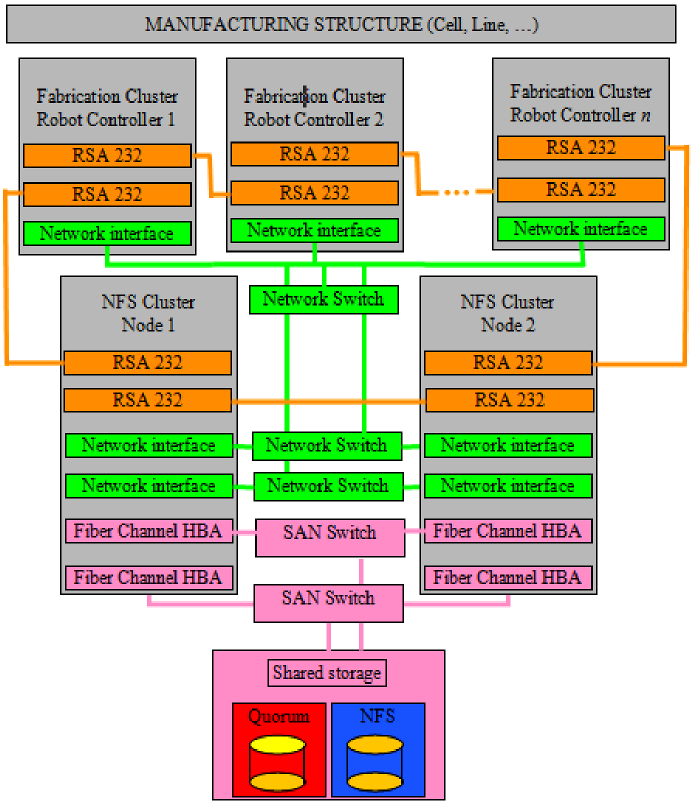

Figure 3: Implementing the high availability solution for the networked robotic system.

5 CONCLUSIONS

The project was started at the end of 2005 as part of the P.R.I.C. research program and is in the final stage of development.

The research project will provide a communication and collaboration portal solution for linking the existing pilot platform with multiple V+ industrial robot-vision controllers from Adept Technology located in four University Labs from Romania. This will allow teachers to train their student using robots and expensive devices which they do not dispose, and allow students to practice their skills using specialised labs without geographical barriers, and even from home. Also the portal will allow team training and research due to the messaging feature introduced by Domino.

The high availability solution presented in this paper is worth to be considered in environments where the production structure has the possibility to reconfigure, and where the manufacturing must assure a continuous production flow at batch level.

The advantages of the proposed solution are that the structure provides a high availability robotized work structure with a insignificant downtime.

The project is under development and can be accessed at: http://pric.cimr.pub.ro.

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