REMOTE CONTROL OF A ROBOTIZED FLEXIBLE WORKCELL USING A WEB INTERFACE

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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. 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, either located in a local network or via Internet. Additionally the platform allows users to run remote robot vision sessions and to develop and execute robot-vision programs.

Keywords: remote control, flexible manufacturing systems, interface, robot vision, robot control.

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 paper describes a system which can be used to unify, control and observe the cell's devices (in particular each robot-vision system) from a remote location for control and learning purposes, using an advanced web interface.

The system has multiple functions:
Observing *locally* the *foreground* of robot workplaces (processing area, storage, conveyor belt, part buffer, pallet) using multiple area cameras – stationary or mobile, arm mounted, and *globally* the robot *workstation*;

Set up of the *operating environment* (lighting pattern, virtual camera configuration, feature selection for material flow description) and learning the *model parameters* for scene description, part recognition and measuring, part grasping and gripper fingerprints for collision avoidance;

Editing, debugging and downloading application data and programs;
Remote shared control of multiple robot systems from a central point and event-driven supervision of robot actions including reaction and emergency routines launching;

Access via a Lotus Domino-based messaging and collaboration portal to a team workspace addressing hands-on team training and authenticated e-learning in the areas of computer aided design, planning, control and quality inspection for networked manufacturing workstations/cells.

2. THE SYSTEM ARCHITECTURE

The system is composed by the following applications (Fig 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. The robot training and control is interactive – menu-driven and acknowledged by image display in a VISION window. Some of the main functions available in this window are: choice of the physical and virtual cameras and of the image buffers; selecting the display mode and resolution; histogram and average curve contrast analysis; selection of switches and parameters for virtual camera construction; display of vision system status; training and planning multiple ObjectFinder models for recognition and locating (AVI & GVR); learning fingerprint models for collision-free grasping; editing, saving, loading and running V+ programs.
- *Monitoring*: a Monitoring/Treatment scheme can be defined for each Client/Station (the latter can be selected from a drop-down list of robot controllers connected to the server, by adding/removing them from the Client window). 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 the observation 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 via its controller. Finally, the SA outputs commands which are received from the eClients or acknowledges task execution.

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:

- one application which has the function of retrieving the images from the observation cameras (AXIS 214 PTZ) 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 (Java client) 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

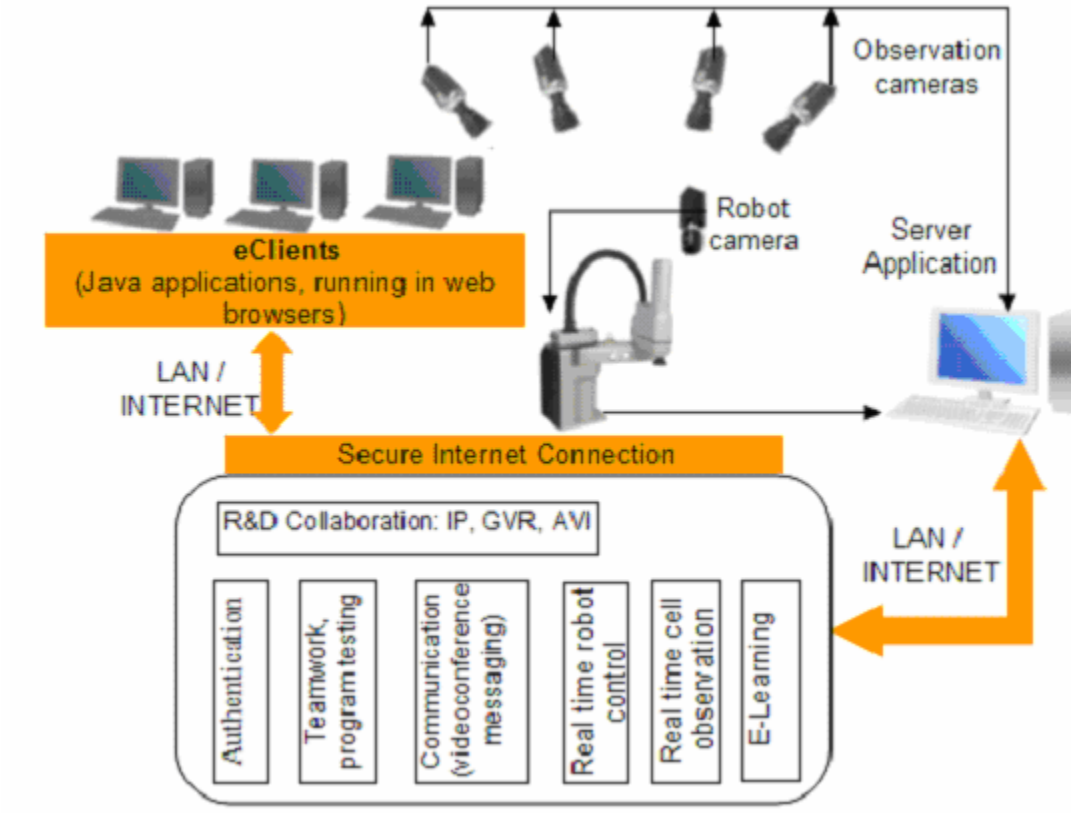

Fig. 1. The System Architecture.

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 (see Fig 2). 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.

For team training and application development, the system allows accessing related documents, presentations and multimedia materials, Web conferencing, instant messaging and teamwork support for efficient and security-oriented creation and use of group workspaces (students / trainers, researchers).

The Server and eClients Applications run on IBM PC workstations on which IBM Lotus software offerings are customized and integrated with other applications (error-free data and

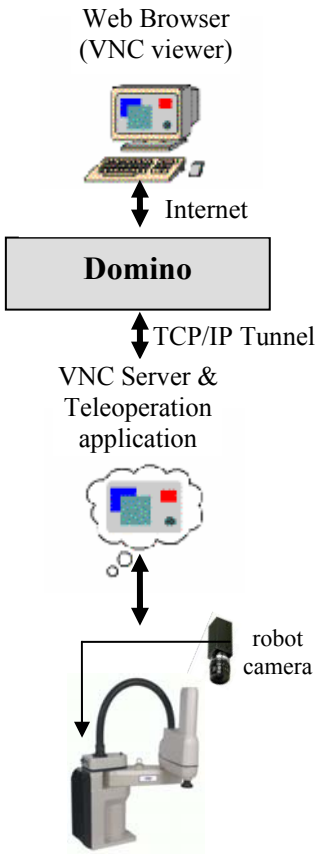

Fig. 2. The VNC communication.

command transfer, V+ program editing, real time image display and refresh in multiple Client windows, replication functions, Client authentication, etc) in a virtual training and research laboratory across geographical boundaries.

Lotus-oriented solutions have been considered for transferring messages, status reports, data and video camera images, interpreting them and accessing databases created by all partners. The final objective of the platform is to develop an E-Learning component allowing students to access and download technical documentation, create, test, debug and run RV and AVI programs, attend real-time laboratory demonstrations, and check their skills in proposed exercises.

Thus, IBM Lotus software unifies all three Application modules, providing the necessary management and interconnecting tools for distributed industrial controllers, and the collaborative tools with back-end relational databases for team training and research.

3. USING 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 (Fig 3):

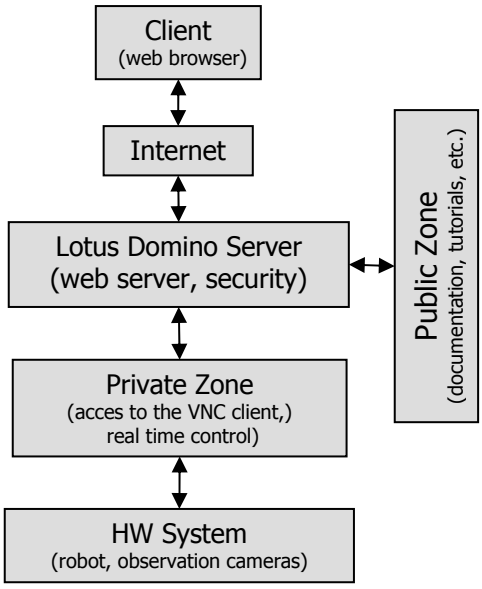

Fig. 3. The portal structure.

- 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 Fig 4).

The teleoperation application is composed by two windows:

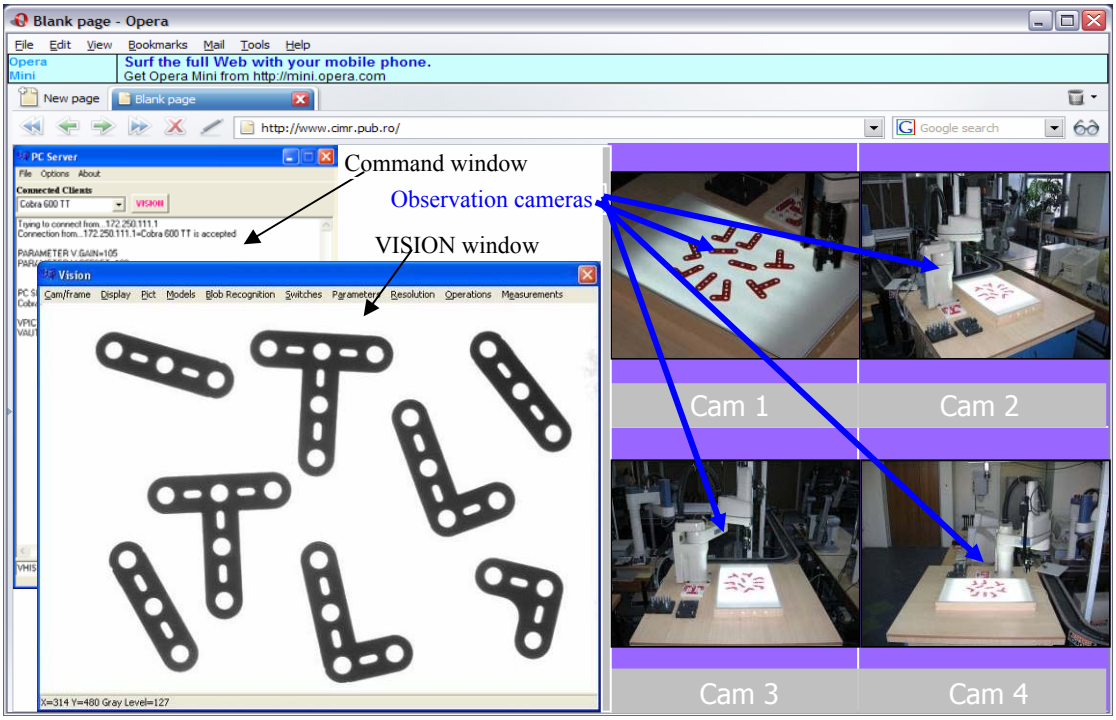

Fig. 4. Accessing the system.

A command window (Fig 5) 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.

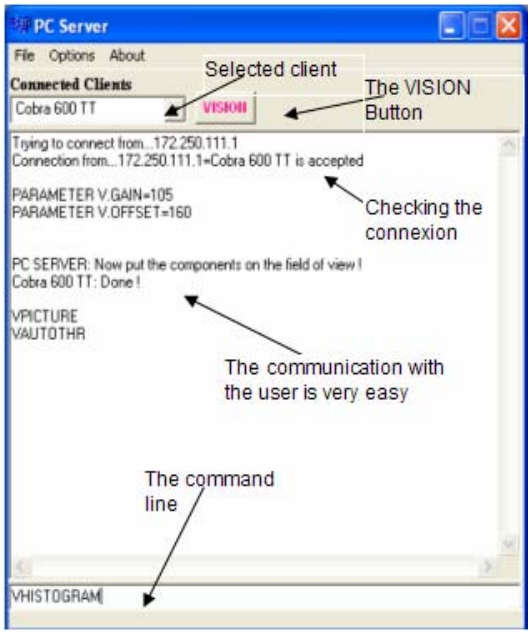

Fig. 5. The command window.

From the VISION window, vision commands can be issued by selecting the wanted actions from the menus (Fig 4). 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 (histogram, thresholding, etc.);
- displaying the vision system status;
- training models;
- switches and parameters configuration for virtual camera set-up.

The advantage of the Vision window is that all commands can be issued using menus, but also the fact that the image acquired by the camera and sent to the server can now be accessed at pixel level. Another major advantage is that the training of the part recognition and grasping models become a single-step process during which a unique window is used for parameters and constraints specification.
The client application can acquire full or partial images via the VGETPIC V+ operation and send them to the server (Adept Technology, 2001).

Captured image can be processed via the menus (filtering, binarization, convolution, morphing, etc.), saved into a common format and sent to a specialized image processing application. After processing, the image can be sent back to the client and integrated to the image processing board using the VPUTPIC operation, for further use (an application using this mechanism is in course to be developed, and consists in a new part identifying algorithm based on skeleton computation and matching.

In order to execute vision programs the user must setup the vision parameters in such way that the system will "see" the objects with the best image quality. The system have specialized functions to establish those parameters automatically or, manually if some special settings are required.
After setting the parameters and loading the calibration camera-robot, the user can measure objects, apply filters, apply morphological operators, train and recognize objects.

The measurements include signature analysis, polar and linear offset signatures are computed, and stored to be used in other applications, also the skeleton computation is included in the measurements category (Borangiu, *et al.*, 2005).

An important feature of the system is the mechanism of training object models and multiple grasping positions related to each model in order to accomplish a collision free grasping position on the runtime.
The training of object models can be done in two wais:

- first is the standard ObjectFinder model, which is computed by the vision board included in the system. The procedure to train such a model requires a set of steps which have been compacted in a single form in the application.
- the second way is to store a set of object features into a structure which characterize each model (Borangiu, 2004).

After the models are trained and stored the user can write applications using the trained models, and/or can learn also grasping positions in order to manipulate the objects.

4. LOTUS DOMINO PLATFORM AND E-LEARNING ASPECTS

The strong impact of the project is in stimulating the cooperation between different networked areas of an enterprise. The task was to build a system that provides access to public information for a wider audience and at the same time supports collaboration between registered members, provides safe access to protected contents and enables the publication and editing of contents. The system can be accessed from a great variety of places. Therefore great care was taken to also ensure optimal use in case of lower bandwidth and poorer quality hardware. The high level of security and availability are key components. This was ensured by the selection of high quality technical devices and the well-planned loading. As the portal must be prepared for a growing number of users, the tool must be highly scalable. It needs to integrate contents and services and provide access for document repositories. User groups must be able to access personalised contents.

High-level availability must be guaranteed. The system must be scalable according to loadness and requirements. The use of NLBS (Network Load Balancing System) provides a solution for an even load of the network. The portal user interface need to be customized, templates must be created and uploaded. The authorisations and user groups must be defined.

The eClient application Lotus Domino Server, and implements a security access policy to the virtual workspace. The access to the eClient application is granted based on the Domino defined ACL's (Access Control Lists), such that in order to connect to the application the user must specify a user name and a password. There were defined two classes of privileges:

A **user class** where the operator can observe images acquired from the observation web cameras and images from the VISION system taken by multiple area cameras; he can also view the commands issued by the trainer and watch the results of the commands;
A **trainer class** where the operator is authorized to issue commands for every connected robot system, upload, download and modify programs. The trainer can also take pictures from an individual camera and use the specific vision tools to process that image. The observation cameras can also be moved and positioned in the desired location by the trainer. The trainer can give full or partial permissions to users for program testing purposes.
The communication between the users is achieved by help of the integrated console (text mode) or using an Instant Messaging and Web Conferencing application (Sametime).
IBM Lotus Domino server software was used to combine enterprise-class messaging and calendar / scheduling capabilities with a robust platform for collaborative applications on a wide variety of operating systems. The design of the Lotus Domino Server made available three offerings: Domino Messaging Server (messaging only), Domino Utility Server (applications only), and Domino Enterprise Server (both messaging and applications) (Brooks, *et al.*, 2004).
The most important Lotus Domino features that were used are:

- Encryption, signing, and authentication using the RSA public-key technology, which allows to mark a document in such way that the recipient of the document can decisively determine that the document was unmodified during transmission.
- Access Control Lists (ACLs) determining who can access each database (application) and to what extent.
- Usage of Domino's new features to reduce network utilization. Network compression reduced the number of bytes sent during transactions by up to 50 percent. Connections across heavily loaded links such as WANs and XPCs will see the most benefit.
- Availability for the Windows NT and XP platforms, automatic fault recovery after shutdown

and server restart without administrator intervention after the occurrence of an exception. Fault recovery uses operating system resources, like message queues.

Because, the application eClient is accessed over the Internet, security represented a critical element. The access to different levels of the application is controlled by xACLs (extended ACLs) to allow or disallow access. The existing database Access Control Lists (ACLs) and the new ACL file feature ensure that application-private databases remain secure. In addition, file protection documents for the Domino Web server which is used to serve the eClient (Java application) provide additional access control for files accessed via HTTP.

5. CONCLUSIONS AND FUTURE WORK

The project was started at the end of 2005 as part of the PRIC research program (Shared Research and Training Resources) 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 (Bucharest, Craiova, Iasi and Galati). 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 final tests are made and at the fine of 2007 the project will be fully functional and will be accessed at: http://pric.cimr.pub.ro.

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