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ANALYSIS OF CUSTOMIZED AND COMMERCIAL SOLUTIONS FOR REMOTE MONITORING OF MANUFACTURING PROCESS

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Abstract. *Remote monitoring can be understood as a data acquisition process from a system and its live transmission through a net, to geographically distinct places, generally at great distances. Among the several applications of remote monitoring, there is the manufacturing process monitoring. The CCM-ITA ("Centro de Competência em Manufatura"- Manufacturing Competence Center), has been developing a number of projects in the area. The purpose of this work is to summarize and annalyze these projects, comparing diferent solutions for remote monitoring. Three case studies are presented in this paper: the development of a customized software for CNC machine certer monitoring, a web applicative and the analyses of a commercial solution for remote monitoring.*

Keywords*: remote monitoring, data acquisition, video, manufacturing process, numeric control*

1. INTRODUCTION

Today, the manufacturing industry faces new challenges, which are the result of an increasingly competitive global scenario. The Internet and the so-called "e-business" has added ''velocity'' to everything in industry. It accelerates product realization, manufacturing, delivery, and customer services. In addition, manufacturing outsourcing provided many opportunities but also added challenges to produce and deliver products with improved productivity, quality, and costs. Lead times must be cut short to their extreme extend to meet need the changing demands of customers in different regions of the world. Products are required to be make-to-order, which requires a tight control and near-zero downtime of the plant floor, equipment and devices. It necessitates suppliers to guarantee near-zero-downtime performance on factory equipment (Lee, 2003).

Furthermore, global markets are, more and more, demanding the organization evolution into decentralized units, spread all over the world. In order to serve customers' demands to their best, the different industry units should collaborate and coordinate efforts, coping with distributed customers, operations, and suppliers. Zhan et al. (2003) named this new pattern of relationships as Dispersed Network Manufacturing (DNM). It consists of enterprises that are geographically dispersed but need to communicate and work concurrently with large amount of data of their factories, sub-contractors and suppliers across the border.

As a result, a new production paradigm has emerged. The traditional local factory philosophy of integrating the shop floor equipment has been abandoned and a new global approach takes place, integrating all elements of the supply chain in an e-factory philosophy (Lee, 2003). This integration is both vertical and horizontal, and becomes more and more significant. Vertical cooperation occurs along a supply chain (i.e., among suppliers, manufacturers, warehouses, distributed centers, and retailers), while horizontal cooperation is performed among peers (even competitors) (Hao et al, 2004).

The new structure of manufacturing systems motivates the use of Internet based tools for information interchanging with high flexibility and rapid response, resulting in the concept of *e-manufacturing*. E-manufacturing has emerged during the last years as a consequence of the popularization of Internet applications. It is a broad field of research. A number of examples of successful applications and researches can be found in literature and in industry.

In (Hao et al, 2005), the problem of factory integration is approached by proposing a framework based on Web Services and agents that actuates in all levels of the organization – from the virtual enterprise (inter-enterprise), to the enterprise (intra-enterprise) and shop floor levels. (Wang et al, 2001) explores the Internet for product data management. It proposes an integrated data model to the information integration for remote robot manufacturing. The data model is exchanged among geographically spread customers, suppliers, design and manufacturing companies, through the lifecycle stages of the product, from requirement specification and conception design, detailed design, fabrication and assembly, installation and operation.

Other Internet-based solutions focus on Supply-Chain Management (SCM) and Enterprise Resource Planning (ERP) systems. In (Frohlich, Westbrook, 2002) different strategies for demand and supply integration are discussed. Customers and suppliers are linked together into tightly integrated networks where real-time information travels immediately backwards through demand-driven supply chains while inventory flows swiftly forwards.

Another area of research is the development of a collaborative design environment by interconnecting CAD/CAE/CAPP/CAM systems. Some examples are (Li et al, 2004; Zhan et al, 2003). These works provide an Internet based computational architecture that supports the sharing and transferring of knowledge and information amongst geographically distributed and disperse centers. These works are motivated by the need of collaborative design, i.e., to co-develop parts by designers at different locations. Particularly, (Fu, Li, 2005) discuss the problems related to Web-based visualization and 3D concise representations using formats such as VRML, X3D, W3D, MPEG-4. In (Adamczyk et al, 2002) a web-based applicative supports interactive NC programming based on a shared CAM database. In the CAAP context, (Chung, Peng, 2004) presents an interactive web-environment for the selection of tools and machines.

Finally, some works focus on the development of remote monitoring and control of manufacturing process. Among them, (Muto, 2003) presents a XML system called @factory that provides remote surveillance, video camera monitoring, schedule management and data analysis for CNC machines. (Garcia et al, 2003) proposes a robotic teleoperation system, discussing the problems related to what happens when the connection is interrupted. (Kimura, Kanda, 2005) discusses the development of a platform to support monitoring functions which include notification of problems using cell phones and re-allocation of jobs. In the educational area, (Yeung, Huang, 2003) presents a remote-access laboratory that provides the remote control of a dc motor, and (Yen, Li, 2003) presents web-based support system for learning pneumatics.

In the context, the purpose of the paper is to present and discuss some case studies developed at CCM (*Centro de Competência em Manufatura* - Manufacturing Competence Center) at ITA (*Instituto Tecnológico de Aeronáutica* – Aeronautics Technological Institute). The case studies focus on remote monitoring of manufacturing processes.

This work is been developed as part of the Brazilian Government Program TIDIA/KyaTera (TIDIA-KyaTera, 2007), which connects a number of research laboratories through an advanced high-speed optical network. The TIDIA/Kyatera network is been used as a testbed for research in different areas including the remote control of manufacturing systems.

The paper is organized as follows. Section 2 describes the first case study: the development of a remote monitoring system for a CNC machine. Section 3 describes the second case study: the analysis of a commercial platform for remote monitoring of manufacturing cells. Section 4 presents the last case study: a web-based environment for remote monitoring. Finally, Section 5 presents some conclusions and discusses future works.

2. CASE STUDY A: DEVELOPMENT OF A REMOTE MONITORING SYSTEM

The Case Study A refers to the remote system developed to monitor the CNC machine Hermle C600U (Figure 1), installed at CCM. The CNC center uses HSM (High Speed Machine) technology, processed by Siemens controller Sinumerik 840D. The controller must move the 5 axes (X, Y, Z, A and C - Figure 2) of the milling machine, and also controls the tool magazine.

Figure 1. Hermle C600U Machine.

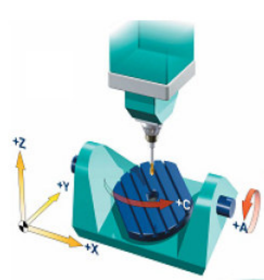

Figure 2. Hermle C600U machine axes.

The purpose of the remote monitoring system is to collect data about milling processes under execution and make it available for users geographically dispersed in remote locations. The remote system is divided in two main blocks: (1) the data acquisition, which collects the data from the machine and makes it available to a local computer; (2) the data transmission through Internet to a remote computer.

In order to perform the data acquisition it is necessary to understand how and where data is processed and transmitted in the Hermle machine. The Hermle machine uses a serial communication protocol, the MPI (Multiple Protocol Interface, a simple version of Profibus) to connect in a single network the processing components, such as the HMI (Human-Machine Interface) and the PLC (Programmable Logic Controller). The acquisition system must, therefore, interface with the machine system using the same protocol. It must also be connected to the local computer, which makes the data available on the Internet. The local computer is a common PC. One of the most used connections on PC is the PCI (Peripheral Component Interconnect) Standard. Considering this two restrictions, the solution adopted for the hardware of the data acquisition system is the Siemens PCI board CP5611.

The data monitored by the system are: position of the machine axes, speed of the machine axes, video and audio of the undergoing process. The first two set of data are collected by the CP5611 board, connected to the MPI net. For the video and audio a webcam and microphone are installed inside the machine.

Figure 3 presents the solution adopted for the data acquisition architecture. The user programs the machine using the HMI module. The PLC controls the milling process sending the appropriate commands to the machine motors. The PLC also monitors the milling process, collecting data and sending it to the CP5611 board. The CP5611 board makes the data available to the local computer.

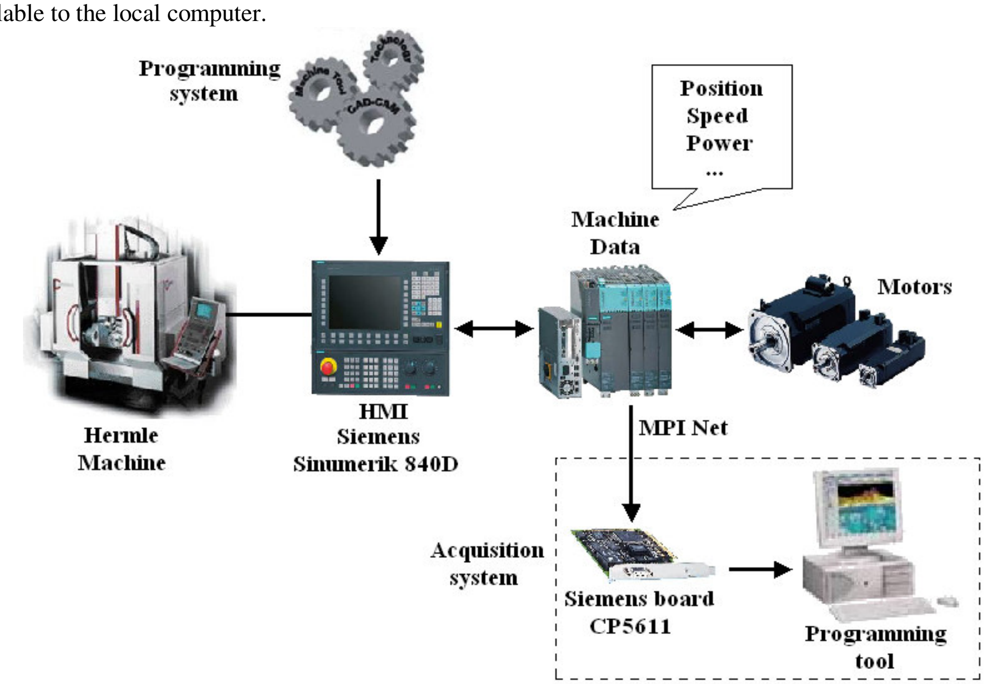

Figure 3. Data acquisition system architecture.

The machine data acquisition is possible only because the CNC uses an open architecture that allows the data of the CNC and PLC to be accessed and even modified (with some security and safety restrictions) by external programs using DLLs (Dynamic Link Libraries, the Microsoft standard for sharing libraries in the Microsoft Windows operating systems). This procedure is illustrated in Figure 4.

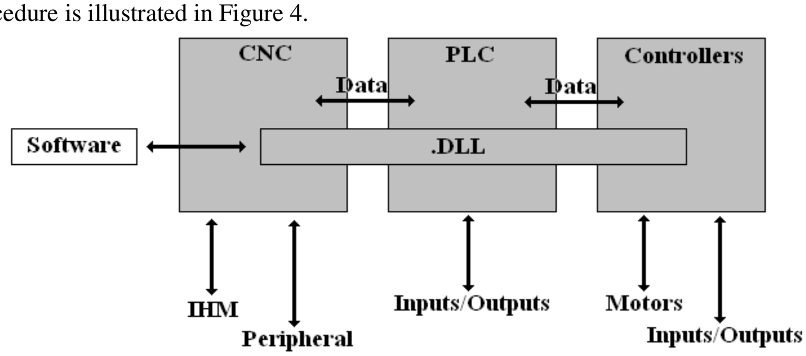

Figure 4. Data sharing in the machine.

An applicative is proposed in this paper to make the data in the local computer available to remote users. According to this architecture, the local computer is called Server and hosts the Server Program, which receives the machine data, organizes it and sends it to Internet. For this purpose, the Server uses the local Internet Server and the World Wide Web. The remote computer that receives the data is called Client and hosts the Client Program, which processes the data and shows it to users in the appropriate way. This system is illustrated in Figure 5.

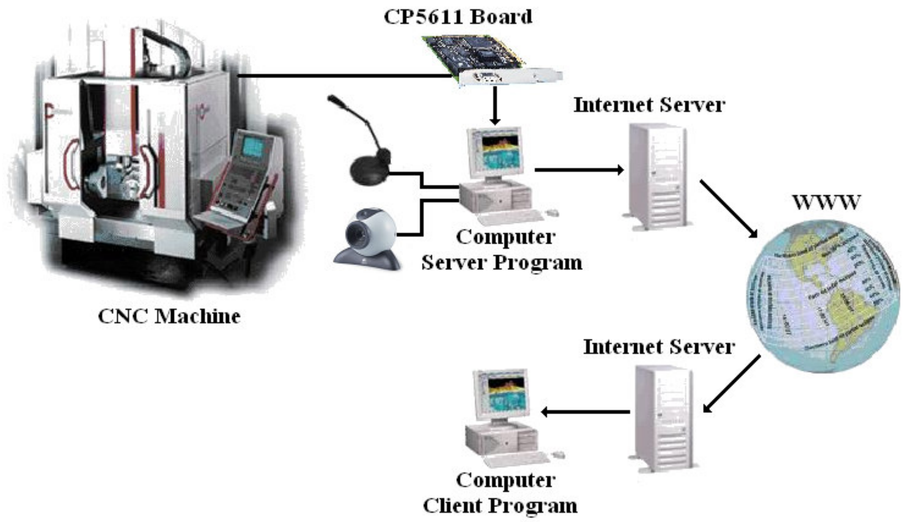

Figure 5. Remote monitoring system architecture.

The data transmitted by the CP5611 board to the Server must be formatted in order to be processed by the Server Program. For this purpose, the DDE protocol (Dynamic Data Exchange) is used. DDE is a standard protocol for communication and data sharing between multiple applications under Microsoft Windows. Although newer technologies have been proposed (such as OLE - Object Linking and Embedding and COM- Component Object Model) the DDE is still used in the Windows platform and is adopted in this work due to the availability of converters. In this context a NC-DDE converter is used to receive the data from the CP5611 board and send it to the Server Program using the DDE standard. The NC-DDE converter runs simultaneously to the Server Program. Figure 6 illustrates the data exchanging in the local computer.

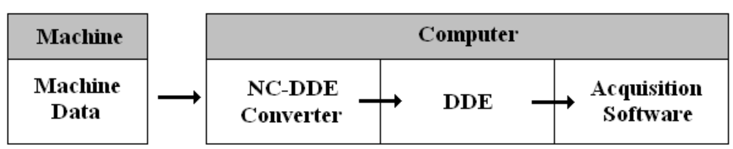

Figure 6. Data exchanging among programs in the local computer.

Once that the data are available, they are used by the Server and Client Programs.

The Server and Client Programs are mostly developed in the Borland C++ Builder 6 environment. An independent interface module is developed using Visual Basic 6. This module makes the communication with the NC-DDE program. The Visual Basic is used in this interface module due to the major availability of DDE functions in the Visual Basic environment. The remaining of the applicative is made on the Borland Builder, which has a number of facilities for building user-friendly interfaces, and has a number of components that helps the user to implement functionalities such as video and audio acquisition. When the Server Program is initialized, it starts two additional programs: the NC-DDE and the interface module.

The data transmission through Internet is made using socket technology and data streaming. Socket is a communication end-point unique to a computer interacting with others computers using Internet protocol such as the TCP/IP (Transmission Control Protocol/Internet Protocol). Sockets work on a Client-Server model. The program on the Client connects to the program on the Server to make a request for information. The client needs to know of the existence of and the address of the server, but the server does not need to know the address of (or even the existence of) the client prior to the connection being established. Once a connection is established, both sides can send and receive information.

The steps involved in establishing a socket on the client side are as follows (Sockets, 2007):

1. Create a socket with the socket() system call.
2. Connect the socket to the address of the server using the connect() system call. For a server socket on the Internet, an address consists of a port number on the host machine.
3. Send and receive data.

The steps involved in establishing a socket on the server side are as follows:

1. Create a socket with the socket() system call.
2. Bind the socket to an address using the bind() system call.
3. Listen for connections with the listen() system call.
4. Accept a connection with the accept() system call.
5. Send and receive data.

The Client Program is composed of a main window, which presents the video and data of the undergoing milling process (Figure 7). Auxiliary windows are used for the program configuration and customization. An Option Windows is used for specifying the camera hardware and the IP of the Server.

A number of functions are available, such as:

a) Functions for manipulating videos and images: the program allow the visualization of the remote milling processes and provides functions for recording video and capturing images.
b) Functions for manipulating audio: the program transmits the audio of the undergoing process and provides functions for analysing the sound.
c) Functions for real-time monitoring of the milling process variables: the program present in real-time the value of some variables of the milling process, such as the axes positions. It also provides functions for plotting graphics.
d) Functions for database creation and manipulation. The development of the database is made using the Database Desktop, also from Borland.
e) Functions for client-server communication: the program provides facilities for exchanging text messages, such as in a 'chat' environment.

Figure 7. Interface of the Client Program.

A number of tests have and are being performed for evaluating the quality of the data, video and sound transmission.

It is important to highlight that this remote and monitoring system is partially independent from technologies. The communication with the CNC machine, performed by the CP5611 board, is an customized solution for the Siemens controller. The remaining of the system architecture and the Server and Client Program can be used in other systems. For this purposes, the NC-DDE converter must be developed in order to provide the data to the Server Program in the appropriate format.

3. CASE STUDY B: ANALYSIS OF A COMMERCIAL PLATFORM

The Case Study B refers to the installation and analyses of a commercial platform for remote monitoring of manufacturing systems. The platform is the MCIS (Motion Control Information System) from Siemens. It is based on the Ethernet and TCP/IP protocol for sharing data in a corporation network and over the Internet. It may connect a number of machines and workstations, making the data available for both local and remote users (Figure 8).

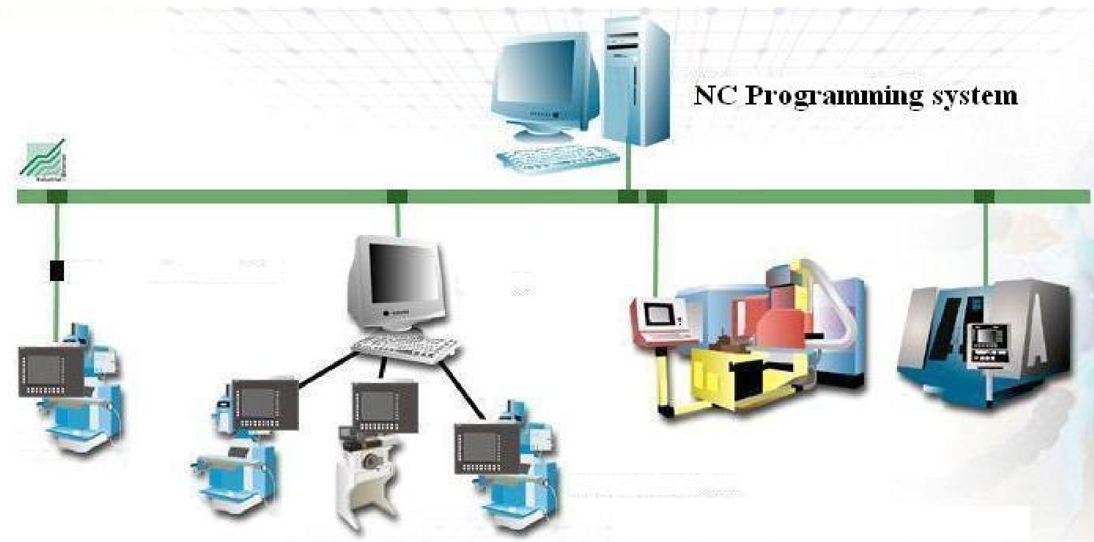

Figure 8. Example of MCIS network.

The MCIS environment is divided in five independent modules:

- DNC – Direct Numeric Control, which manages CNC programs.
- MDA – Machine Data Acquisition, which provides functions for monitoring CNC machine data and production data.
- TPM – Total Productive Maintenance, which manage the preventive maintenance of machines.
- TDI – Tool Data Information, which manage CNC tool data.

This work focuses on the MDA module. Most of MCIS platform and, particularly, the MDA module are relatively new in the national scenario. It has not yet been implemented in any company in Brazil. The purpose of this case study is therefore to evaluate its applicability in the Brazilian context. In order to analyse it, the software is installed and tested in a CNC controller, the Sinumerik 840D (Figure 9), and in a common PC connected to it through Internet.

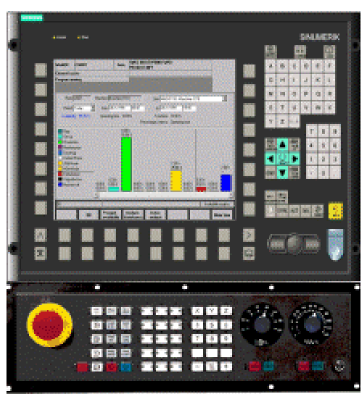

Figure 9. Sinumerik 840D CNC controller.

Among the functions provided by the MDA module are:

- *Machine monitoring and evaluation:* it includes machine status monitoring and analysis, disturbances and availability analysis, machine data acquisition, evaluation and comparison. An example is presented in Figure 10.
- *Part type evaluation*: it provides functions for part type production monitoring, comparison and analyses. For example, it is possible to evaluate the quality of the manufactured work pieces (good, scrap, rework) and also the required cycle times compared to the target cycle time. An example of MDA interface is presented in Figure . The user can see the number of pieces produced in each machine, their status and the corresponding time cycle.
- *Alarm evaluation:* carry out acquisitions of SINUMERIK alarms and messages, and performs statistic analyses of the alarm occurrence.

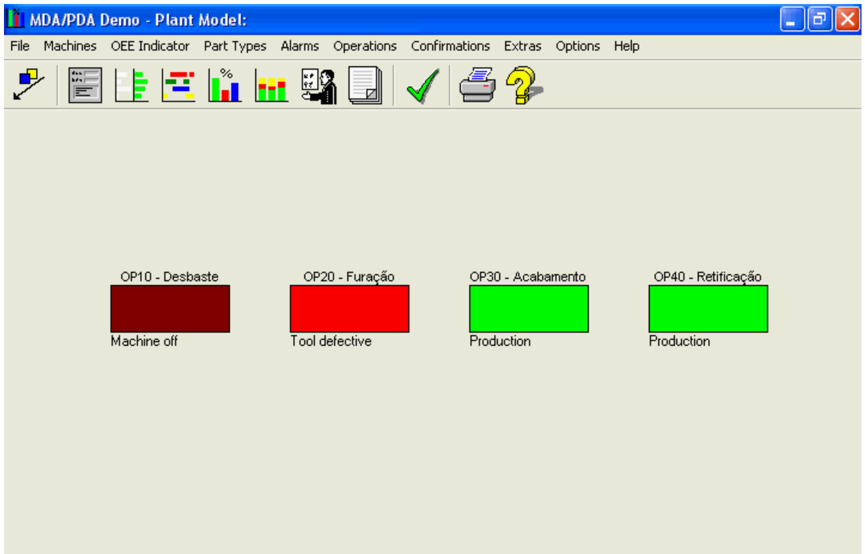

Figure 10. MDA interface for monitoring machine status.

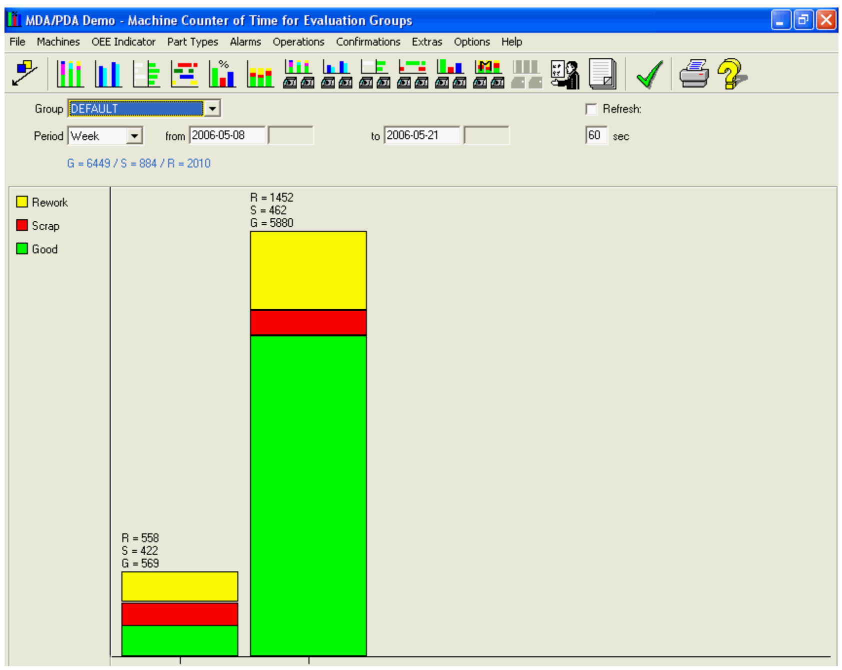

Figure 11. MDA interface for monitoring machine production.

It is important to highlight that the scope of MDA is different from that of the software proposed in Case Study A. Although it can be configured to remotely show data about the axes position and speed in real time, MDA focus is on production data. In a hierarchical control architecture such as that usually adopted in many manufacturing systems (Silva, 1998) and illustrated in Figure , the MDA lies in a control level superior to that of the software of Case Study A.

While the software of Case Study A is used to the real-time monitoring a single milling process (local control layer), in Case Study B, the time horizon is usually larger, the user is interested in events such as the beginning and ending of a piece production. Therefore it can be considered a tool for the supervision control layer.

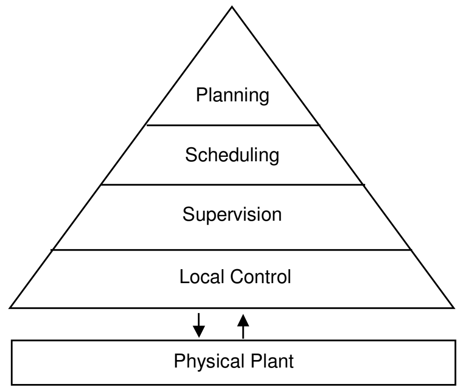

Figure 12. Control layers of a manufacturing system.

The following conclusions are obtained in the Case Study B:

- In order to answer to different needs and justify itself from a commercial point of view, the software includes a large number of functions and is highly flexible. As a consequence the installation and configuration process is complex and requires specific knowledge about Windows operating system. The documentation provided by the supplier is superficial and not enough detailed. However, once the system is installed and configured it is user friendly and does not require particular skills.
- Due to the large number of function provided by the software, the cost of the system is high and not easily justifiable in small and medium companies in Brazil.
- The program can easily interact with CNC controllers of the same supplier, i.e., Siemens controllers. It claims also to be able to interact with others controllers. However, the documentation provided for this purposes is almost null and it is believed that this is a difficult and hard process. The software is therefore appropriated to be installed in a brand new industrial park, where all the machines are up-to-date and from the same supplier. This may be a common scenario in Europe, while in Brazil most companies have industrial plants with machines from different vendors and with different ages.

Although these conclusions are obtained from the use of a single platform, the MDA module of MCIS, it is believed that they can be generalized to other commercial platforms for remote monitoring of manufacturing systems.

4. CASE STUDY C: WORLD WIDE WEB MANUFACTURING ENVIRONMENT

The web is one of the most popularly used Internet tools to provide a light-weight and an operation system-independent platform through a standard communication protocol, i.e., HTTP (HyperText Transfer Protocol). In this context, the purpose of Case Study C is to provide information about manufacturing systems in a webpage.

Differently from Case Studies A and B, in this case, the remote user does not need to have any particular program installed in its machine, just a web browser, such as Windows Internet Explorer or Mozilla Firefox. The information is simultaneously available in the webpage for many users and there is no interest in controlling the access to it. It is therefore a tool for *divulgating* the information collected from the manufacturing process.

The system of Case Study C uses a webcam and a microphone for transmitting manufacturing processes performed in the Hermle machine. It is developed in the Macromedia environment, using both “Dreamweaver MX 2004” and “Flash MX 2004”. The images captured by the webcam and the sound obtained by the microphone are transferred to a Flash Server and from there to an Internet Server, or transferred by Windows Media Encoder to an Internet Server directly, where can be set the best link parameters like tested in program, according to Figure 1. The webpage is presented in Figure , where a milling process under execution in CCM can be seen. The webpage address is <www.ita.br/ccm/Monitoramento_Remoto/monitoramento_remoto.htm>. Currently, facilities to transmit also process variables are under implementation.

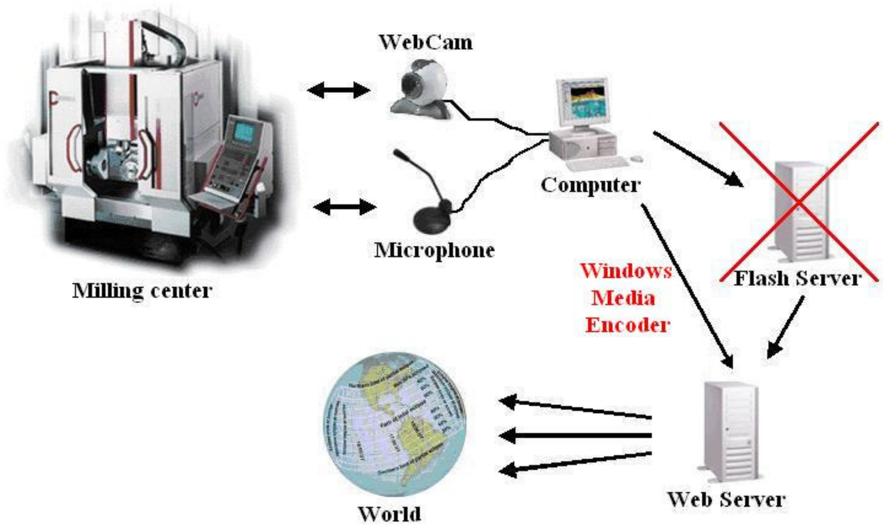

Figure 13. Information path in Case Study C.

Figure 14. Webpage for remote monitoring - Case Study C.

5. CONCLUSIONS

This paper presents and discusses three case studies developed at CCM-ITA related to the remote monitoring of manufacturing systems. By comparing the case studies the following conclusion are obtained.

The development of customized software is a good solution for the remote monitoring of single machines, when there is a need for specific data. From the computational point of view, they are lighter, ease to use and require lest computational power. The communication with the CNC machine is limited by the functions provided by the controller. Once the development cost is lower, they are adequate for small companies where the cost of a commercial solution makes it unavailable.

On the other hand, commercial solutions are robust and can integrate large manufacturing systems. The integration of machines from different vendors in a single remote monitoring system is still an open problem. The solution will be provided by the standardization of communication protocols in the factory environment. While a number of protocols are claimed to be open, there is not a consensus among the automation industries about a common standard.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

Adamczyk Z, Jonczyk D, Kociołek K (2003). A new approach to a CAD/CAM system as a part of distributed environment: Intranet database. Journal of Materials Processing Technology 133 (2003) 7–12.

Chung C, Peng Q (2004). The selection of tools and machines on web-based manufacturing environments. International Journal of Machine Tools & Manufacture 44 (2004) 317–326.

Frohlich MT, Westbrook R (2002). Demand chain management in manufacturing and services: web-based integration, drivers and performance. Journal of Operations Management 20 (2002) 729–745.

Fuh JYH, Li WD (2005). Advances in collaborative CAD: the-state-of-the art. Computer-Aided Design 37 (2005) 571–581.

Garcia CE, Carelli R, Postigo JF, Soria C (2003). Supervisory control for a telerobotic system: a hybrid control approach. Control Engineering Practice 11 (2003) 805–817.

Hao Q, et al (2005). Towards a cooperative distributed manufacturing management framework. Computers in Industry 56 (2005) 71–84.

Lee J (2003). E-manufacturing—fundamental, tools, and transformation. Robotics and Computer Integrated Manufacturing 19 (2003) 501–507.

Li WD, et al (2004). An Internet-enabled integrated system for co-design and concurrent engineering. Computers in Industry 55 (2004) 87–103.

Muto K (2003). Advanced technology for manufacturing engineering development. JSAE Review 24 (2003) 303–312.

Sockets (2007). Sockets Tutorial. http://www.cs.rpi.edu/courses/sysprog/sockets/sock.html (access in 04/2007).

TIDIA-KyaTera (2007). Advanced Internet Program, FAPESP, Brazil. http://www.kyatera.fapesp.br (access in 04/2007).

Yen C, Li W-J (2003). Web-based learning and instruction support system for pneumatics. Computers & Education 41 (2003) 107–120.

Yeung K, Huang J (2003). Development of a remote-access laboratory: a dc motor control experiment. Computers in Industry 52 (2003) 305–311.

Zhan HF, et al (2003). A web-based collaborative product design platform for dispersed network manufacturing. Journal of Materials Processing Technology 138 (2003) 600–604.

Wang, C, et al (2001). Implementation of remote robot manufacturing over Internet. Computers in Industry 45 (2001) 215–229.

7. RESPONSIBILITY NOTICE

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