REMOTE MONITORING AND AUTOMATIC ADJUSTMENT OF A FLEXIBLE MANUFACTURING CELL

Francisco J. Barrientos García* - Isaac García Incertis*
Félix Miguel Trespaderne - Eusebio de la Fuente López** - José R. Perán González***

**CARTIF – Centro de Automatización, Robótica y Tecnologías de la Información y la Fabricación.*
Parque Tecnológico de Boecillo, parcela 205 – 47151 Boecillo (Valladolid) SPAIN
***ITAP – Instituto Tecnologías Avanzadas de la Producción. Universidad de Valladolid*
Paseo del Caude s/n – 47011 Valladolid SPAIN

Abstract: This paper describes the functioning of a manufacturing cell, in which several complex systems have been joined, such as: a robot, a computer vision system, and a lathe. To allow communication between these systems, diverse technologies have been used, varying from a field bus to the intranet of the company. The robot takes the role of master, coordinating the functioning of the rest of subsystems. The cell is endowed with the possibility of remote adjustment and monitoring across the company's Intranet. The cell's functioning conditions can be modified from the laboratory, to assure that the pieces made are within the quality limits specified by the clients. *Copyright CARTIF 2005.*

Keywords: Fieldbus, communications, computer vision, architecture.

1. INTRODUCTION

The automatic system for the control of the production and packaging has been established in a plastic factory. The pieces are made injecting high temperature fused plastic in a mould. The system has been designed to work with the piece named air sleeve guide. This piece forms part of the components of semi-pneumatic suspensions, and serves as a guide and seal with regard to the sock absorber, allowing the connection of the pressurised air ducts, as well as the mounting of the elastic bladder.

The current increase in the requirements of productivity and the desire to improve the quality of the product are causing the transformation of the traditional, relatively rigid lines of production, into automated and flexible systems that can be adapted to changes in market trends, minimizing costs in the production process modifications. The gradual incorporation of information technologies in all the productive process stages, has been a decisive factor in the transformation of the traditional environments of production into more flexible and efficient systems.

An automated manufacturing system is characterized by a high degree of automation, integration and flexibility (Bennet, 1994). The system here described includes a lathe, several conveyor belts and a packaging system that work in an automatic form. The use of computer vision awards the set the high degree of flexibility required. The different technologies used for the communication of the different elements contribute a high degree of integration, and make possible the on-line access to the functioning parameters of the whole system.

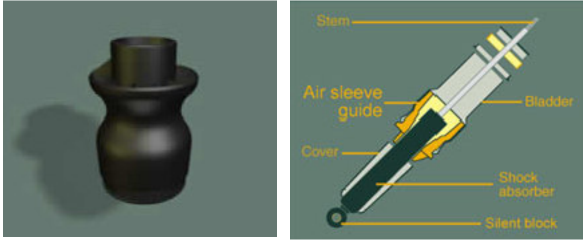


Fig. 1. Air sleeve guide.

The following sections explain the system functioning. Section 2 gives a brief description of system components and its relationships. Next, we summarizes the way the communications have been established and why. Section 4 explains the developed programs and the form the system can be remotely controlled. Finally, the conclusions explain the results, insight comings and lessons learned. A critical review points the possible improvements that can be made to the system.

2. BRIEF SYSTEM DESCRIPTION

The process object of the automation includes all the operations that are performed on the pieces of plastic once shaped. The first step is the cooling, for it, pieces are submerged in a basin with cold water for a certain period of time. The belt conveyors for water duty are designed for conveying parts requiring rapid cooling to avoid their deformation. After the cooling, the piece is introduced into a lathe, where is mechanized. After that, the air sleeve guide is packaged. Prior to the introduction of this automated system, a human operator was taking charge of the transference of the pieces from one position to the following one: from the cooling basin to the lathe, and from there to the packaging bags, which meant a tedious and repetitive work.

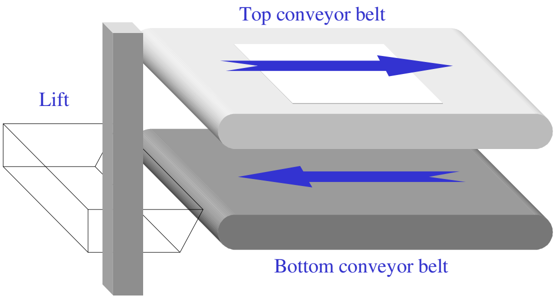


Fig. 2. Conveyor belts configuration. Top conveyor belt is translucent to allow the computer visión process. Bottom conveyor belt circulates in opposite direction.

The constructed manufacturing cell consists of the following elements. A conveyor belt endowed with a basin designed to lead the pieces across the water for their refrigeration. As soon as the pieces have the suitable temperature, they are led up to another conveyor belt. On this second belt a computer vision system is placed. A zenital camera captures the images of the pieces that are circulating along the belt and, applying computer vision algorithms (González, 2000), calculates the position and orientation of the pieces in the space. This information is transmitted to the robot, which takes charge gathering the pieces in the coordinates indicated by the vision system (Yi *et al.*, 1995).

The robot tool needs a free space around the piece to be able to gather it. Provided that the fall of pieces onto the conveyor belt is a stochastic process, it means that, the pieces will appear in random positions on the belt, some capable of being gathered by the robot tool. For the case in which the piece is not accessible for the robot, another conveyor belt has been placed below the principal belt, which circulates in the opposite direction. With this, the pieces re-circulate and return to pass for the vision stage with a different placement.

As soon as the robot has gathered the piece from the conveyor belt, it carries the air sleeve guide to the lathe. The robot reports to the lathe of the reference that it has to mechanize, as well as the mechanized size. Once finished the process, the robot gathers the piece.

The robot carries the piece up to the packaging post, where it is deposited. The robot takes the control of the number of packaged pieces and, when it is necessary, send the command to the packaging subsystem in order that it removes the bag full of pieces and introduces an empty one.

3. COMMUNICATIONS SQUEMA

The variety of the components that integrate the developed system, forces the use of very diverse communication technologies. The purpose is, to achieve that the different elements communicate between each other, in order that they should work in a synchronized manner as a whole. In the development of this machine there has been included the whole industrial communication pyramid, from the field buses up to the factory network.

DeviceNET has been used as field bus for the communication of the sensors with the PLC. The robot centralizes the control of the installation, provided that it can acts as a PLC. Its DeviceNet module takes the net master role, and the slave modules take charge of the connection with the sensors. By this manner, the robot has the control of the conveyor belts, the lathe and the packaging system.

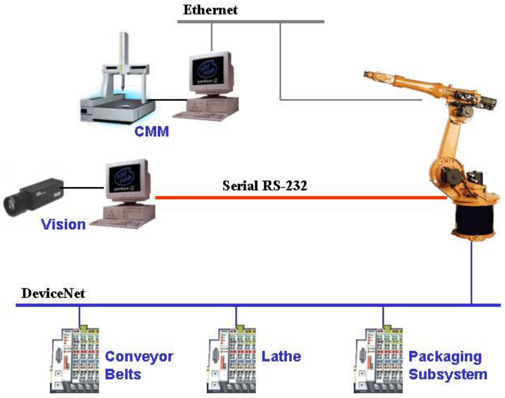


Fig. 3. Communications diagram.

Serial RS-232 communication is used for connecting the robot and the computer vision system. This cell net uses the Siemens 3964R protocol, provided that the robot already has it implemented between its control routines, and executes it in Real Time mode (Kuka, 2001). Depending on the production, the robot takes charge of the start/stop of the vision system, as necessary. The vision system reports to the robot when it must start and stop the conveyor belts, as well as the coordinates and orientation of the pieces that it must gather.

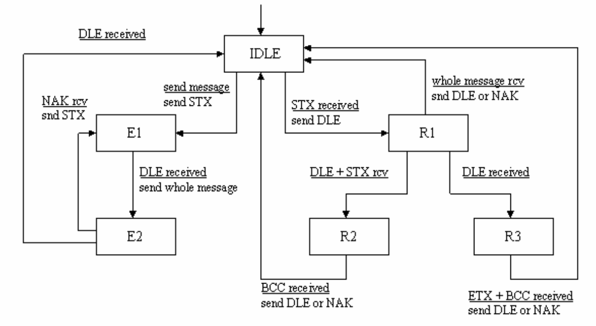


Fig. 4. Serial communication state machine.

In the top level the communication is across the factory network. In this case, it is switched Ethernet 10/100, that communicates, amongst others, the robot with the computer of the measuring laboratory. Client/server architecture has been chosen, because it is the one that better fits the raised needs. The Server program runs in the robot and the Client in the computer of the laboratory, this way the robot remains listening to the possible orders sent by the Client from the laboratory for the remote adjustment of the manufacturing parameters (Simon, 1997).

4. MANUFACTURING CELL REMOTE CONTROL

The robot includes two different operating systems. One is VxWorks (VxWorks), Real Time operating system that takes charge of the execution of the robot movement and control routines. On top of this one there is placed Windows 95, which takes over the user interface. Thanks to Windows 95, the connection of the robot to the Intranet is very simple. What does not turn out to be so immediate is the access to the internal variables and the program information of the robot, necessary to achieve the installation remote control. That is why it is necessary to execute low level routines in the robot that allow us, both the reading and writing of robot program variables.

There has been developed a program that is executed in the robot Windows 95 environment. This program is the one that has been called Server. It takes charge listening to a certain port and, when it receives some request, executes it. The typical requests are reading or writing of some robot program variables.

Another program exists, so called Program of Control of the Lathe and that does the Client's functions, which has been developed thinking about its execution in the measurement laboratory computer. This program shows to the user the state of the manufacturing cell, including the reference in production, the value of the measurement of the mechanized practised to the pieces by the lathe, the number of pieces that have been mechanized by the lathe from the last change of tool and the number of pieces packed in the current bag. The major usefulness of the Client program is that it allows changes in the depth of the mechanized practised by the lathe.

The technician of the measuring laboratory periodically gathers samples of the production and using a three-dimensional measurement machine (CMM, Coordinate Measuring Machine), he determines the quality of the pieces that are being produced. If any deviation in the measurements of the pieces is detected, the technician must return to the production plant and reset the machine functioning parameters to recover the quality of the production. Often, the proper workman is the one that controls, next to the machine, the quality of the pieces that are being produced and he takes charge ensuring they remain within the quality limits. The problem is that the workman possesses neither the knowledge nor the measurement tools that the laboratory technician has.

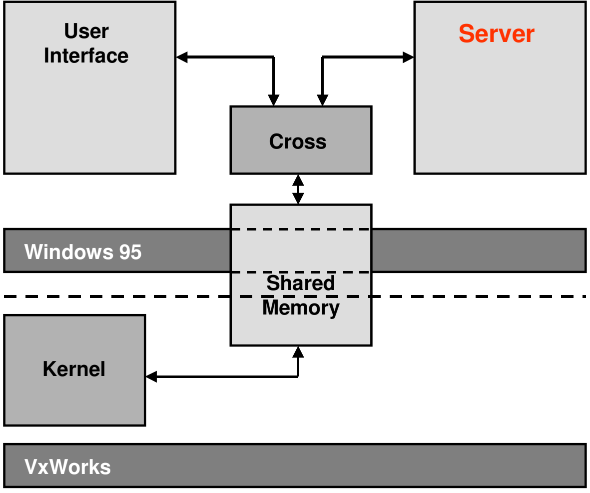
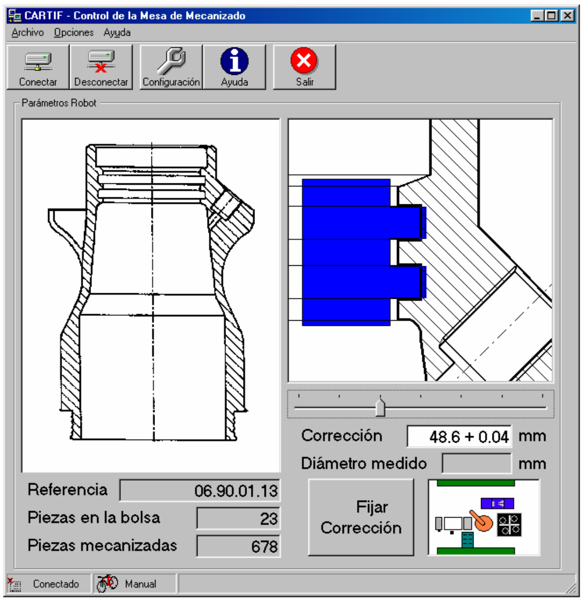


Fig. 5. Access to the robot program variables.

Using the Client program, the measurement technician, that possesses the knowledge and the suitable instruments, can modify the functioning of the machine from the laboratory. The CMM communicates to the Client program the measurements of the pieces that are been produced and this automatically calculates the modification that must apply to maintain the pieces within the quality limits. This modification is instantly transmitted to the robot Server in order that it modifies the functioning of the lathe.



Corrección 48.6 + 0.04 mm

Diámetro medido mm

Referencia 06.90.01.13

Piezas en la bolsa 23

Piezas mecanizadas 678

Fig. 6. Remote control aplication main window.

If necessary, the remote control program allows the manual adjustment of the machine, so that the technician can specify the correction value that he considers appropriate, regardless of the measurements of the CMM. As a preventive measure against possible communication gaps or breakdowns in the factory network, there always remains the possibility of setting the correction values in a local way, through the robot console, using specifically programmed function keys.

5. CONCLUSIONS

The automation of the process of mechanized and packaging of the production of pieces of injected plastic, supposes an improvement in multiple aspects. The most important is the reduction in the fine-tune time of the lathe. Whenever there was changes to the reference that was going to be produced, it was necessary to do a series of adjustments in the lathe to adapt it to the measurements of the new piece. Once one believed that the lathe was tuned, it was necessary to mechanize a series of pieces to verify the measurements and, if it was necessary, return to fine-tune the lathe. This process was repeating itself up to the point of obtaining the suitable piece quality. With the automatic system, having selected the new reference in production, the lathe auto-adjusts to the new measurement. It is only necessary to mechanize some pieces to ensure the correct adjustment and it is possible to start the mass production.

With this system the company can optimise the use of its human resources. The person who takes charge supporting the production to the tolerances fixed by the clients is the same that measures the samples in the laboratory. This does not result in any additional work for the laboratory staff, since the adjustment can be made remotely, from the same measuring laboratory and in an automatic way, in combination with three-dimensional measurement machine. The laboratory staff has the suitable knowledge and the necessary instruments for correct adjustments of the production parameters. This way, the operator is getting rid of this task, and can be busy with supporting the conditions of functioning of the system: material supply, retirement and storage of the processed pieces; tasks less repetitive and weary than those of pieces mechanizing, counting and packing.

The application of Computer Vision provides the manufacturing cell with a great flexibility. It is not necessary to fine-tune the machine for every type of piece, so that its position is perfectly defined in order that the robot could gather it, the pieces can appear in any position and number. The vision system takes charge reporting to the robot the position and orientation of the pieces, in order that this one can gather them without colliding with any object.

In this application we have successfully achieved the integration of different communication technologies in order that they work in a joint and synchronized way. The serial communication between the robot and the vision system, determines the functioning of the conveyor belts. This way, it prohibits the arrival of pieces while the robot prepares to take those which are placed on the belt. The remote adjustment from the laboratory comes via the Ethernet to the robot Server, and this one takes charge modifying the necessary variables, which it transmits to the lathe across the field bus in order that it adapts immediately to the new measurements.

In small and medium companies it is not frequent to have robotized systems for the production. The complex systems, like the one described in this article, provoke certain rejection and distrust between the workmen, owed principally to its complexity. Therefore, in this case a special effort has been done to simplify the functioning of the machine and to involve the more highly qualified personnel of the company in its control and supervision.

5.1 Critical Review

This paper describes the functioning of a manufacturing cell, in which several complex systems have been joined. Some improvements can be made, mainly in two points. First, and most important one, include the computer vision into the robot program, but this is a hard task because the robot manufacturers does not provide enough information. The Real Time execution of the vision algorithms and the elimination of the serial communication could improve considerably the system performance.

The client/server programs for the cell's remote control could be replaced for a web server (for example, Apache, a well known web server) and

PHP pages. Instead of develop a specific client program, dealing with sockets, lets Apache, PHP and the web browser undertake the Ethernet communication. Only the robot program – web server interface need to be developed, maybe through a shared database. This way, the cell can be monitored from every computer on the plant, giving privileged access with passwords only to those in charge of the remote control of the cell.

Modifying the conveyor belts system, the robot could be feed with pieces from several machines, but always the same kind of pieces at a time. The vision system deal with any kind of piece, but the tools of the robot and the lathe need to be adjusted. The system's bottleneck is the lathe. The mechanizing time is considerably high (almost 80% of the cycle time) and it causes robot's idles. Another mechanizing post would resolve the problem, but the cost of a second lathe is a parameter to be consider.

REFERENCES

Bennet, Stuart (1994 second edition). *Real-Time Computer Control. An Introduction.* Prentice Hall.

VxWorks. *VxWorks Network Programmer's Guide.* Wind River Systems.

González Jiménez, Javier (2000). *Visión por Computador.* Paraninfo.

Yi, S., Haralick, R. M., Shapiro, L. G. (1995). *Optimal sensor and light source positioning for machine vision, computer vision and image understanding.* Addison-Wesley.

Simon, Richard J. (1997). *Win32 API Superbible.* White Group Press.

Kuka (2001). *Manual de instrucciones del Sistema Robot KR C1.* KUKA Roboter GmbH.