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A Study on Controlling the Mobile Robot in an Automatic Manufacturing Processes

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ABSTRACT: In today's industry it is of major concern to keep the manufacturing processes as effective and flexible as possible. The usage of robots and automatic technology is a much known way to achieve the goals of rationalization. The disadvantage lays in the fact that implementation of robots is usually a very resource consuming task. However, in some circumstances a solution to this matter may be to simply implement mobile robots instead of fixed robots.

I. INTRODUCTION

1.1 Friction stir welding

Today's necessities in the competition of the manufacturing industry are to be flexible to the always changing market conditions. In the field of automation technology it can at times seem like it is almost impossible to keep up to date with all the latest development, and if a company would allow them self to fall back its application of new technology will be sure to soon find itself incapable of meeting its clients demands. As of result of this many companies will today show great interest in investing in the modern advanced systems, very often together with a flexible solution to produce different types of products all in the same production line. In the flexible systems, often referred as Flexible Manufacturing Systems (FMS), there are a lot of advantages such as faster production rate, lower cost/unit, and greater labor productivity. Another important matter today is the level of automation, the higher level of automation will result in also a higher level of rationalization the production may reach, and even some applications such as the Automatic Manufacturing Process (AMP) are not far from completely automated.

In these systems implementing industrial robots is of great importance, however rather than implementing many robots, in some cases just one mobile robot can successfully do the job of many fixed robots.

An automated manufacturing process located at the laboratory of Shanghai University of Engineering Science (SUES) consists of high-technology systems which are to produce diversified products at an effective rate. One part of this system is a mobile robot located on a rail between two very essential positions in the production. The first position (often referred as the home position) is located within reach for a conveyor and a lathe machine, at this station the mobile robot is suppose to grab items from the conveyor belt and do some various operations and processing in the lathe machine. Further along the rail there is a second position, were a CMM (Coordinate-measuring machine) and a milling machine is reachable for the robot.

II. AUTOMATION AND ROBOTICS

The control of industrial and other processes, mentioned above, by automatic rather than manual means is often called automation. Automation has played an integral part, and a vital role not only in modern industrial processes, but also in traffic, robotis, and automotive systems. Typical examples where automation takes place include: chemical, steel, electric power, and automobile industries, among others. Automation is characterized by self-acting machines and devices with integrated control systems that are often arranged in complex industrial processes or systems.

Automation of such processes as tooling, handling, and assembling consists of measuring, controlling, monitoring, supervising, and so on, and is usually arranged in several hierarchically structured levels and co-ordinated by a supervisory control system. Automation provides a means for attaining optimal product qua;ity, increases productivity, and relieves humans of many monotonous, routine, and repetitive activities. Futhermore, automation can perform

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tasks, which are far beyond the physical abilities of humans, such as positioning accurately a large radio telescope at the predetermined location.

Nowadays, many automated industrial manufacturing processes are performed by multiple-link computer-controlled robots. Their links rotate in a co-ordinated manner corresponding to a variety of tasks, such as welding, spray-painting, or parts assembling in the automobile industry. The engineering discipline for developing and application of multi-link computer-controlled robots is relatively new and is denoted as "robotics". Control systems engineering, besides image processing and measurement techniques, represents essentially the background for robotics.

PURPOSE

The goal of this project is to successfully control and understand the system of a mobile robot in a given manufacturing process. The task includes both studies on software and hardware level. The hardware structure includes a two-layered control system, I/Os, Profibus (Process Field Bus) and Ethernet wiring. The software level consists of computer communication and the comprehensive Profibus system with an integrated script language which are to be used for controlling the processes.

LIMITATIONS

The mobile robot has its main objective in the manufacturing process, for the operations between the lathe and the milling machine, therefore the thesis is limited to this specific task and nothing else.

In fact, the robot has already been controlled successfully before in a number of operations. The process is fairly well documented. However there is another rather big limitation, it's within the fact that the script language and the documentation are both in Chinese. Therefore, the translation from Chinese to English is a necessary part of the whole projects research. See Appendix A for some of the translated documentation and samplecodes.

BENEFITS OF USING ROBOTICS IN MANUFACTURING

- Using robotic machinery can help to increase profits because productivity is higher and faster.
- Using robotic machinery can help to reduce overhead expenses. However, this should be indicated that most of the saved overhead is in reduced payroll costs.
- Using robotic machinery can help give the manufacturing company a long term edge in the market place.
- Using robotic machinery can give you a higher output for a considerably lower cost.

III. METHODOLOGIES

The mobile robot is fundamentally contained of a robot arm fixed on a platform which is mounted to a horizontal rail. The robot model is a NX100 by Japanese robot manufacturer Motoman. The platform is controlled by a motion card by Chinese company GOOGOL Technology Limited. The mobile robot in all is controlled by the Profibus to move between the station of the lathe machine, milling machine, CMM and a conveyor belt.

The conveyor is connected to a chain of conveyors, which are all leading to a warehouse for storage. The last conveyor just before the warehouse is equipped with a vision system followed by an engraving laser and a carving laser. The vision system is for material identification, while the engraving laser is used for engraving different designs in the item and the carving laser is used for carving text on the items surface. For a graphical view of all the equipments see the sketch in appendix C and some snapshots

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Figure 1: The first figure is the upper computers, the figure to left from back is the warehouse followed by the conveyors, third one is a view of the client computers and the fourth figure is the original sketch of the system map.

SYSTEM MAP

The task includes both studies on software and hardware level. The hardware structure includes a two-layered control system, I/Os, Profibus (Process Field Bus) and Ethernet wiring. The software level consists of computer communication and the comprehensive Profibus system with an integrated script language which are to be used for controlling the processes.

Secondly, the project also includes related theory regarding different control systems and there flaws and faults.

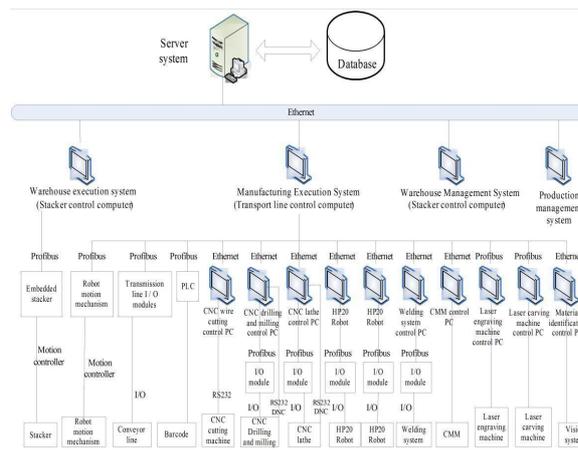


Figure 2: From the top, the server system and the upper computers, controlling the sub-systems and components through the bus net of Ethernet and Profibus.

PROFIBUS

From the outset, the field of automation has been subject to continuous change. Not so long ago, this change was limited to the production area of a company. In production, the implementation of fieldbus technology has meant considerable innovation, enabling the migration from centralized to decentralized automation systems. This has been the PROFIBUS objective for more than 10 years. In those 10 years PROFIBUS has become the world market leader in fieldbus technology. In spite of the outstanding success of recent years, PROFIBUS development continues with undiminished enthusiasm and energy. Initially the focus was on communication technology. Current activities center

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around system integration, engineering and, in particular, the application profiles. These profiles have made PROFIBUS the only fieldbus that provides comprehensive both factory and process automation. Additionally, Information Technology (IT) increasingly determines development in today's world of automation. Modern fieldbus systems have adopted IT principles and are achieving greater consistency with the corporate management level. In this respect, industrial automation is following the development trends of the office world, where IT has long since left its mark, radically transforming infrastructure, systems and processes. The integration of information technology in the world of automation opens up many new prospects for global data communication between automation systems. In pursuit of this objective, PROFIBUS is enhanced by the Ethernet-based communication standard PROFINet. The use of open standards rather than proprietary solutions ensures long-term compatibility and expandability - in other words - protection of existing investment. This is a matter of key importance to the PROFIBUS User Organization. The continuous development of PROFIBUS technology provides members with a long-term perspective.

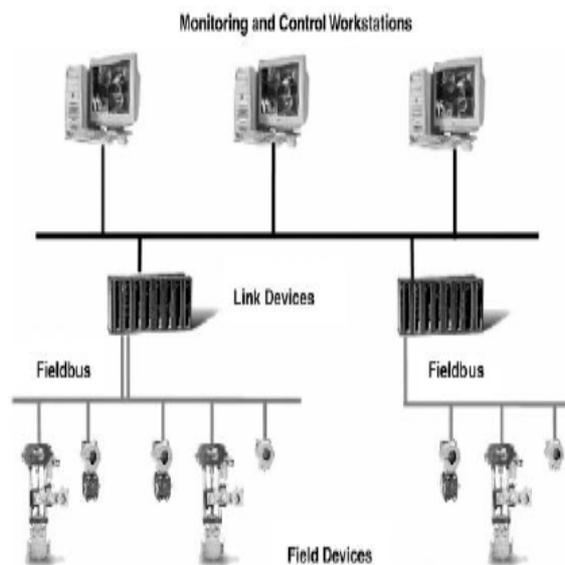


Figure 3: PROFIBUS Architecture

IV. COMMUNICATION IN AUTOMATION

The communication capability of devices and subsystems and consistent information methodology are indispensable components of future-oriented automation concepts. Communications are increasingly occurring horizontally at the field level as well as vertically through several hierarchical levels simultaneously. Layered and coordinated industrial communication systems, such as PROFIBUS with lower-level interfacing to ASInterface and upper level interfacing to Ethernet (over PROFINet) (see Figure 1), offer ideal preconditions for transparent networking in all areas of the production process. 1.1 Industrial Communication At the sensor-actuator level signals of binary sensors and actuators are transmitted over a sensor actuator bus. This provides a simple and cost-effective technology where data and power are transmitted over a shared medium. AS-Interface offers a suitable bus system for this field of application. At field level distributed devices such as I/O modules, transducers, drive units, analysis devices, valves or operator terminals, communicate with automation systems over a powerful, real-time communication system. Transmission of the process data is cyclic, while additional interrupts, configuration data and diagnosis data are transmitted acyclically as required. PROFIBUS fulfills these criteria and offers an universal solution for both factory and process automation. At the cell level programmable controllers such as PLCs and IPCs, communicate with each other and with IT systems of the office

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world using standards such as Ethernet, TCP/IP, Intranet and Internet. This information flow requires large data packets and a range of powerful communication functions. As well as PROFIBUS, Ethernetbased PROFINet offers a trendsetting solution for this purpose. Recently, Ethernet-based communication systems have emerged in industrial automation. They offer wide-ranging options for communications between the different levels of industrial automation and the office world. PROFINet is an example of one such Ethernet-based communication system.

INDUSTRIAL COMMUNICATION

At the sensor-actuator level signals of binary sensors and actuators are transmitted over a sensor actuator bus. This provides a simple and cost-effective technology where data and power are transmitted over a shared medium. AS-Interface offers a suitable bus system for this field of application. At field level distributed devices such as I/O modules, transducers, drive units, analysis devices, valves or operator terminals, communicate with automation systems over a powerful, real-time communication system. Transmission of the process data is cyclic, while additional interrupts, configuration data and diagnosis data are transmitted acyclically as required. PROFIBUS fulfills these criteria and offers an universal solution for both factory and process automation. At the cell level programmable controllers such as PLCs and IPCs, communicate with each other and with IT systems of the office world using standards such as Ethernet, TCP/IP, Intranet and Internet. This information flow requires large data packets and a range of powerful communication functions. As well as PROFIBUS, Ethernetbased PROFINet offers a trendsetting solution for this purpose. Fieldbuses are industrial communication systems that use a range of media such as copper cable, fiber optics or wireless, with bit-serial transmission for coupling distributed field devices (sensors, actuators, drives, transducers, etc.) to a central control or management system. Fieldbus technology was developed in the 80s with the aim of replacing the commonly used central parallel wiring and prevailing analog signal transmission (4-20 mA- or +/- 10V interface) with digital technology. Due, in parts, to the different industryspecific demands and preferred proprietary solutions of large manufacturers, several bus systems with varying properties were established in the market. The key technologies are now included in recently adopted standards IEC 61158 and IEC 61784. PROFIBUS is an integral part of these standards. Recently, Ethernet-based communication systems have emerged in industrial automation. They offer wide-ranging options for communications between the different levels of industrial automation and the office world. PROFINet is an example of one such Ethernet-based communication system. A need for the coordinated development and distribution of these fieldbus systems in the market has seen the emergence of a number of User Organizations comprising manufacturers, users and institutes, such as the PROFIBUS User Organization (PNO) and its parent organization PROFIBUS International (PI) for PROFIBUS and PROFINet technologies.

USER BENEFITS

User benefits are the motivation for the emergence and continual development of fieldbus technology. This ultimately manifests itself as a reduction of the total cost of ownership, as well as an increase in performance and quality improvement during the setup and operation of automation plants. The benefits are achieved during configuration, cabling, engineering, documentation, assembly and commissioning, as well as during production. An additional benefit is achieved by the reduction of the total life-cycle costs in the form of easy modification and continuous availability due to regular diagnosis information, preventive maintenance, simple parameter assignment, consistent data flow and asset management. Fieldbuses increase the productivity and flexibility of automated processes compared to conventional technology and they create the basic prerequisite for the configuration of distributed automation systems. Today PROFIBUS is used in virtually all areas of automation, in factory automation and process automation, but also in traffic engineering, power generation and power distribution.

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PROFIBUS I/O

Table 1 consists of all the mayor components of the automatic manufacturing process. Number 1-11 is the machines and robots used for processing, 12-16 is all conveyor related technology and 17-18 is the central control part for the mobile robot.

No	Component
1	CNC lathe machine
2	Automatic welding machine
3	Arc welding robot
4	Unloading robot
5	Mobile robot
6	CNC drilling and milling center
7	Laser carving machine
8	CNC cutting machine
9	Laser engraving machine
10	Robot motion mechanism
11	Coordinate measuring machine (CMM)
12	Automatic push stacking machine
13	Conveyor lines
14	I/O modules for control cabinet
15	Automatic stacker
16	Conveyor lines
17	Robot motion mechanism
18	Module control cabinet

Table 2: The following is the input/output of the Profibus system.

DISTRIBUTED CONTROL SYSTEM OF MOBILE ROBOTS

System configurations of self-contained robots can be divided broadly into two categories, that is, a centralized system and a distributed one as shown in Fig.1. A centralized system places a computer and an interface board which has A/D, D/A etc. At the center. Motors and sensors are all connected to the computer. A distributed system distributes I/O nodes all over the body which are connected by onbody network. Motors and sensors are connected to the nearest I/O node. From perspective of software, the centralized system can be controlled by simple software, because only one CPU controls all I/Os. On the other hand, software for the distributed system must be more complicated. Software on I/O nodes must communicate with a central computer while doing I/O. Also a software on the central computer needs to gather information from all nodes and distribute motion commands to them while doing an whole body motion control. From the perspective of hardware, wires between motors/ sensors and the interface board become long and gather to the board on the centralized system. Therefore they are susceptible to noise and wiring near the board becomes difficult. In the case of adding a motor or a sensor, a new wire must be added from the center. Wires between motors/sensors and I/O nodes are short on the distributed system and it is easy to add a motor or a sensor so long as the capacity of the network is sufficient. The number of wires between nodes is also constant(power and network). This distributed system configuration is effective especially on humanoid robots. Many humanoid robots have about 30 DOF. It is expected that the number of DOF increases by introducing multi fingered robot hands. The number of sensors can also increase dramatically by introducing sensor skin. Humanoid robots have wide movable ranges of joints and for that reason it is hard to provide spaces for wires. These issues are especially serious on a small-size humanoid robot, thus some of them adopted a distributed system from the start. We realize real-time

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communication on Ethernet and develop a distributed I/O system using it as an onbody network for a humanoid robot HRP-3P. This paper is organized as follows. Section 2 explains why Ethernet is selected as an onbody network. Section 3 describes how to realize real-time communication on Ethernet. Section 4 presents a small-size controller to distribute all over the body. Section 5 explains a real time CORBA which works on realtime Ethernet. Section 6 measures the performance of a realtime communication library. Section 7 describes a distributed I/O system for HRP 3P using the real-time CORBA. Section 8 concludes the paper.



Figure 5: Mobile Robot

DISTRIBUTED ROBOT CONTROLLER

In order to make a distributed I/O system using the realtime communication library, a small-size CPU board and I/O boards are developed. Figure 6 shows four kinds of developed boards. The upper row shows a CPU board which has SH4 and it is used by stacking with an I/O board as shown in the middle row. The bottom row shows a link I/O board which controls up to five joints, a sensor I/O board which measures sensors with analog outputs and a serial I/O board which has four RS422 ports from left. I/O boards are connected with a CPU board by a connector which is mounted at the upper left corner of boards and power is supplied through the connector. Brief specifications of these boards. The CPU board has two Ethernet ports to construct ring topology as mentioned above. A kernel and a root filesystem of ARTLinux are placed in flash memory and their modification can be done while running OS. Therefore, if maintenance is required, a user can log on from a remote computer through network and modify them. The user needs not to connect a serial cable and download new files. This is possible by using Ethernet as network.

V. RESULTS AND CONCLUSIONS

To create a program from scratch to control a system of this magnitude and complexity requires tremendous amount of work and time. Therefore the value of a functioning program like Profibus values high. In the very beginning of the project there was an actual plan to try to do an exception from the Profibus software and create a standalone application to control the mobile robot. The idea was to create an application in C++ and then use Dynamic-link library (DLL) to call commands to the motion card through either Ethernet or Profibus communication. It is a possible way to control the mobile robot in this way of course; if there was time, right preparation and a more familiar setting to do such a project it could have been a good way. Unfortunately there wasn't much time, after arriving to Shanghai and later receiving the project the timetable didn't turn out to be suitable at all for the first plan. No harm done, the second plan took place and the work of learning and programming the Profibus started.

The task to successfully understand the system of the mobile robot ended up to taking a lot more time than the actual process of programming and testing it. There were a lot of recommended manuals to read, both about the motion card and the Motoman robot, manuals considering I/O, electrical wirings and software solutions. Reading the documentation was very enlightening and it helped a lot to understand the foundation of the system. However in the end, Profibus's own material turned out to be the most helpful tool for the actual programming of this project. Fortunately hardware configurations weren't necessary for this study, understanding the hardware was enough work

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already, the Profibus had already been configured up to handle the hardware aspects such as the data transmission and the network connectivity for example.

It took a fair amount of time getting started with the actual programming and the testing, partly because the need of a teachers assistances to get started and also sometimes simply lack of knowledge. There were some problems with e.g. which computer belonging to which sub-system and how to set up the systems different configurations. Even though I did document and translate a lot of the environment in the manufacturing process, both the hardware and the software aspects, translating everything would have been completely impossible considering the time schedule. With other words language problems were not an uncommon occurrence during the project.

Nevertheless, most of the problems were overcome fairly soon after they appeared. The result of planning and executing the project was overall a very constructive and instructive experience. Studying the different parts of the manufacturing process gave a very wide view of how the system works. But also, the study gave a lot of insight in specific sub-systems and components of the process such as the control system and the motion card.

Personally, I think staying in the laboratory of SUES gave me a good picture of modern research and development in the fields of robotics and mechatronics. The experimental research of an automatic manufacturing processes, included with robots, a distributed control system and other high-technology components, state as a good example for the fact that the industry is only heading for more and more intelligent systems and solution to improve the processes of manufacturing. This is what many manufacturers all over the world are working on to successfully accomplish, commonly with their main goal to reduce the need for human intervention and simply maximizing the profits. Although it is important to not forget that in many cases the use of humans is just far more cost-effective than implementing automatic technology, even when automation of industrial tasks is possible.

Even so, nothing can prevent the fact that automation plays a longtime important and increasing role in the world economy.

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