AUTOMATION AND CONTROL IN PRODUCTION PROCESSES

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Summary

This chapter deals broadly with some modern approaches to the automation and control of industrial production processes, particularly in various fields of manufacturing and in

food and fish production industries. Automation today is a compulsory tool that helps survival on the competitive international market by improving the product quality, enhanced production flexibility and through innovation in production technology.

In manufacturing, computer-aided design, computer-integrated manufacturing, and flexible manufacturing concepts are essential for modern enterprises. In computer numeric control, of particular importance is the automation and control of machine tools as the responsible factors for product quality and machine availability. On the other side, welding is one of the most important operations in car and vehicle making industry that is a responsible factor for car and vehicle reliability and safety.

In electronic industry, again, automation has to solve the most crucial control problems created by rapidly increasing product complexity and operational speed, and by steadily decreasing internal structural size of the product. Especially in this industry, intelligent automation approaches are required for development of complex products , prototyping, simulation, test, manufacturing, and inspection.

Finally, in the food industry and fishery, the problems of food preparation, preservation, and food manufacturing have to be optimally solved. Particularly in aquaculture, additional problems that need computer-based automation are the demands on harvest prognostics, production input planning, and design and maintenance of aquaculture facilities.

1. Introduction

Industrial production processes are basically sequences of engineering operations through which *something*, i.e. some *products* are produced. This definition encompasses a majority of industrial processes. Depending on operations involved in the production process, the industries are classified as

- *process industries*, where the products are the results of mainly chemical processes based on some raw materials like in chemical and petrochemical industries, pharmaceutical industry, pulp and paper industry, cement industry, etc.
- *production industries*, where the products are the results of mechanical or other physical treatment of initial materials like in manufacturing, car making industry, aerospace industry, electrical and electronic industry, food and textile industry, etc.

In the following, a survey of some essential issues of automation and control in the production industries will be given.

Automation in the production industry has gone through a number of development phases, from the early phase in which individual control devices on the floor have been used up to the modern contemporary automation that could be *fixed* or *hard automation*, *programmable automation*, and *flexible automation.*

In the *fixed automation* the configuration of production facilities, as well as the sequence of processing operations is fixed. For instance, in the manufacturing the number of operating stations, interconnected by transportation links for material transfer between the stations is fixed. It is designed for running mass-production over a long period of time. Each station within the line in each production cycle performs its operation simultaneously with other stations, so that at the output of the production line the finished product leaves each production cycle. Such automation is typical for car producing industry.

The *programmable automation* is predominantly used in batch production processes consisting of a sequence of production steps. Each step is specially programmed and can easily be re-programmed if the production-plan changes. This is typically found in food industry, but also in the numerically controlled (NC) machine tools and in use of programmed industrial robots.

In the *flexible automation*, that is, an extended form of programmable automation, multi-computer systems, usually hierarchically organized and distributed, are used as shown in Fig. 1.

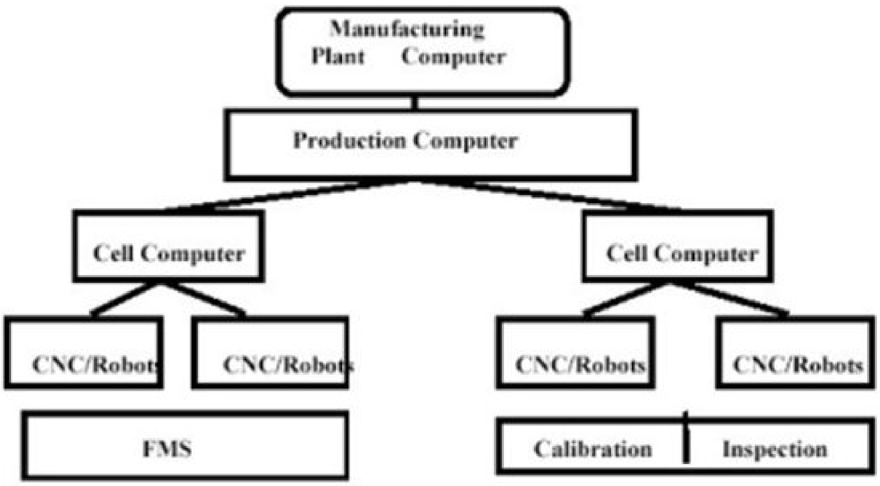

Figure 1: Multi-computer Based Manufacturing System

2. Manufacturing

Manufacturing is the industrial sector that mainly makes the products out of materials using machines and/or robots. It largely encompasses various heterogeneous industries, such as textile and clothing, food and beverages, tobacco and cigarettes, plastic and wood, glass and ceramic, paper making and other industries. In a restricted sense, manufacturing is defined as the process of mechanical assembly of components or sub-systems into a final product. Typical industries in this sense are the car and aircraft making industries, electrical and electronic industries, such as computer and consumer electronics, etc.

Manufacturing was originally practiced by small companies organized in a simple way. With the growing complexity of production processes also the size and the internal organization of the companies has grown. New, special groups and departments have been established, such as *material handling*, *machining*, *assembly*, *inspection* and *packaging*, and the activities like *product development*, *computer-aided design*, *production planning and scheduling*, *computer aided manufacturing*, *inventory control*, etc. This has converged to the new production concept known as *group technology*

On the other side, the technological progress in instrumentation, computer, and communication technology has strongly shaped the industrial plant automation concept and the structure of computer-based automation systems to better meet the user's plant automation requirements. This has led to the *integrated automation concept* (Fig. 2) that meets the automation requirements within the entire enterprise. The progress in communication technology has given impetus to building large automation systems in production engineering, such as *computer-aided design and manufacturing* (CAD/CAM), *computer-integrated manufacturing* (CIM), and *flexible manufacturing systems* (FMS) that entirely interconnect all production facilities and all decision making departments of the enterprise.

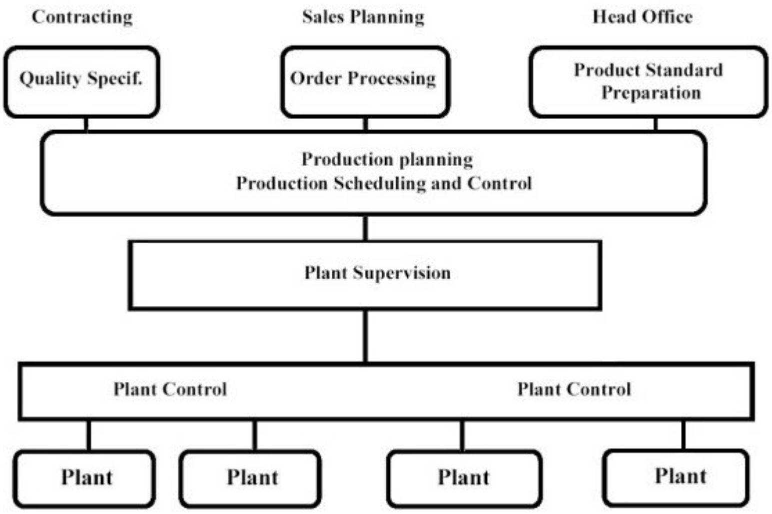

Figure 2: Integrated Automation Concept

Automation in computer-aided design is essential to the system and product designer in the development activities, and in prototyping and simulation. In computer integrated manufacturing the underlying automation concept generally supports all phases of manufacturing processes, from production planning and scheduling up to machining and quality control. As a rule, the systems are merged with the computer-aided design systems to result in CAD/CAM systems to encompass all product development and manufacturing activities. The most general automation concepts include also the highest organizational level of enterprises, i.e. the business data processing where the activities of material resources planning, inventory management, stock control and forecasting, plant and machine maintenance, market analysis, manufacturing costs estimation, billing and product shipping, etc.

With the introduction of working robots, new perspectives of automation problems in manufacturing have been opened through implementation of more complex automation tools through *robot path generation* and *robot motion control* (needed for servicing the NC machines and for material handling), *robots task scheduling* (for dynamic job scheduling in multi-robot environment), and *robots synchronization* (for just-in-time use of relevant robot actions planned for the actual task execution).

The remarkable development of automation concepts over the last decades was not solely a consequence of outstanding technical innovations, but to a considerable extent also a consequence of steadily increasing market demands for high-quality products. The manufacturer of such products, in order to compete successfully on the market, had to increase their efforts in achieving a possibly efficient production and product quality control. This, again, was only possible by improving the capabilities of automation systems to meet the automation requirements at all functional levels of a manufacturing plant, i.e. at

- *machinery level*, i.e., the instrumentation level of machine control
- *cell* or *group level*, i.e., automation level at which the operation of a group of machines within a manufacturing cell are coordinated
- *shop floor level*, i.e., the automation level where the supervision and coordination of several manufacturing cells is carried out
- *plant level*, i.e., the automation level at which the activities of production monitoring, scheduling, and control are placed
- *enterprise level* that includes the top management activities.

This is illustrated in Fig. 3.

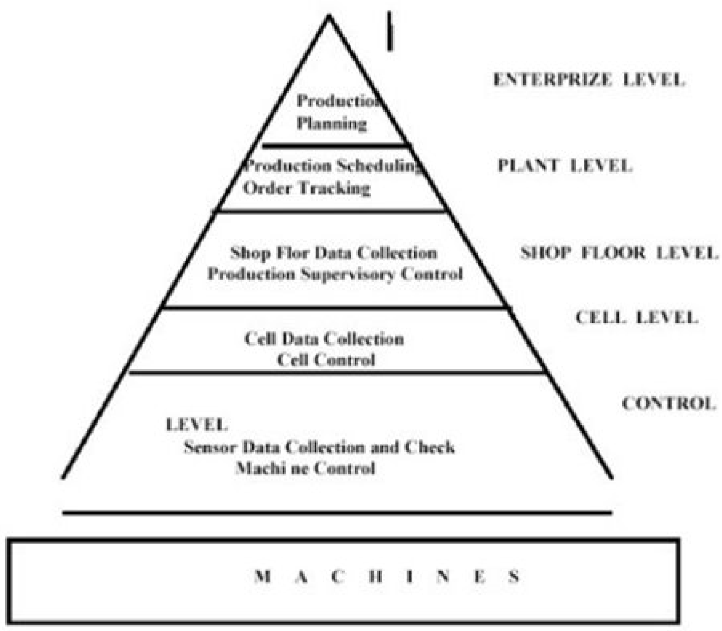

Figure 3: Functional Levels of Manufacturing Plant

Finally, the demands on more advanced automation technology have also motivated instrumentation, control, computer, and communication engineers to work out new concepts that improved the industrial automation. This has given an impetus to integration of a number of application-oriented engineering disciplines like signal processing, model building, adaptive, self-tuning, and intelligent control into a more advanced automation concept. Simultaneously, new software and hardware tools have been developed like modular and object-oriented software, expert, fuzzy, and neuro-software, intelligent sensors, and many others.

Computer-oriented technologies, such as networking and process and office automation, are seen by experts as a kind of *second industrial revolution*, that enables building intelligent manufacturing systems (IMS), *engineering data management systems* (EDMS), *product data management systems* (PDMS), and the like, that represent the building blocks of future production engineering systems.

Based on the past and the contemporary developments in instrumentation, computer, control, robot, and communication technologies, the coming automation features and system concepts are identifiable. For instance, it is to be expected that the integration of intelligent sensors, intelligent controllers, and intelligent man-machine interfaces will extend the hardware capability of the system. Besides, the system functions are expected to be extended to intelligent production plant monitoring and automated failure diagnosis in order to increase the plant safety and product quality. In addition, future distributed computer control systems will also be distributed intelligent systems capable of directly communicating with the Internet and similar remote information handling systems. This will help better meet the entire enterprise automation objectives.

Already now, the *neurocomputing* is successfully applied in machine-part family formation, process planning and scheduling, visual inspection and quality control, process monitoring and performance evaluation, and in adaptive and predictive control. In the future, *hybrid intelligent manufacturing* systems are expected to be in use in which the *soft computing* approaches like fuzzy, neuro-fuzzy, and evolutionary programming will be integrated and in process data pre-processing the *sensor integration* and *multisensor fusion* concepts will be used.

Particularly the *Kanban systems* as integrated *Just-in-Time systems* will get very popular in manufacturing for managing material flow on the assembly line, preferably in the car making industry because they are simple, easy understandable, low costs, quick, and because they avoid overproduction. Due to their modular structure, they are easy to re-engineer. Therefore in the future Kanban systems more intelligence will be integrated so that they will became a sort of *Kanbrain systems*. It is also expected that in the industry the population of intelligent autonomous moving robots, of intelligent autonomous vehicles, and of intelligent transportation systems will increase. For their navigational guidance the autonomous agents will be exploited.

It should finally be mentioned that the future automation systems will be more camera-oriented and will make more use of computer vision and pattern recognition.

2.1. Intelligent Manufacturing

From the very beginning, as the term *intelligent manufacturing* was coined, the difficulties arose in its definition because the computers have since long time been integrated into manufacturing systems as intelligent tools. The experts in this field therefore suggested that intelligent manufacturing should have human-like decision-making capabilities, implemented by imbedding the *intelligent technology*, preferably using expert systems and fuzzy logic systems, into the overall computer system. Of particular interest here are knowledge-based intelligent systems because much knowledge ranging from the product design up to the production and quality control is available. This knowledge is usually captured in disparate organizational modules and should be integrated to make up a *synergistic* knowledge-based manufacturing system. Besides, more intelligence should be put into improved monitoring and control of machines and of production process, as also some intelligent sensors and smart controllers should be added to enable self-control of manufacturing processes.

Initial trials to build intelligent manufacturing systems have been made at the University of Trondheim, where an interactive tool for short-term production scheduling was developed, and at Ohio University, where a case-oriented reasoning system was developed to interpret the values of parameters involved in material forming process. Furthermore, in a joint project between the Universities of Trieste and of Perugia an optimal assembly planning system based on genetic algorithm was developed. A step ahead was made at the Engineering Research Center of Purdue University where much research work has been done in process modeling, design tools, and integrated systems methodology. The final objective was to integrate the research results into a coherent system as the core part of an intelligent manufacturing system.

2.2. Virtual Manufacturing

In the late 1990s intelligent approaches have been successfully applied in the creation of *virtual manufacturing software* underlying the visualization of product development process and the interactive product prototyping. This helps improve communication between various design groups of enterprise, reduces the product development time, and remarkably saves the overall product development costs. The strongest interest for development and use of *virtual prototyping* and of *virtual manufacturing* in general, has been demonstrated by automobile and airplane manufacturers, but considerable interest was also shown by various semiconductor companies, and by some food producers.

2.3. Internet Controlled Manufacturing

E-commerce has stimulated the interest to control the manufacturing through the Internet. This has demonstrated the benefits in and has shown its potential use in business improvement because through a direct "communication" between the manufacturer and the customer the middleman is excluded, and the execution of the customer order accelerated. For instance, the buyers of cars are able to send their orders via the Internet to the factory where their cars will be assembled and this can help provide a crucial edge against the competitors.

It is to be underlined that an Internet order does not contains only the financial component of the purchasing contract but also the technical details about the car to be produced. This tends to mass customization at the quality level and the costs demanded by ever-changing customer needs. In this way the customer will be able to specify the personal requirements before ordering and be sure that the specified requirements will be met. Toyota is one of the first car manufacturers operating in this way. A better application example is found at Berkeley University of California where the Internet-based experimental fabrication test bed for CNC machines, CyberCut has been installed for enabling the *client designers on the Internet* to style mechanical components and submit the created files to the related server for fabrication. This opens the perspectives of distributed and shared design environments in which the design concepts and the design tools are shared. In the CyberCut machining service, a set of Java-based design tools is available to facilitate the designers work.

In the recent years the trend that the business success of production industry increasingly depends on the degree of product and service customization became visible. In the time to come, more and more customers will prefer to tailor individually the product they would like to purchase by individual specification of their requirements and checking the deliverability of the specified product via the Internet. This is, for example, currently possible in computer systems ordering. In the mean time, however, a number of car producing industries are making serious efforts to introduce a similar product and service customization.

It was reported, that the car producers, General Motors and Ford, in cooperation with the electronic commerce companies Oracle and Commerce One, are elaborating on a customization project that *will* enable the customer to “assemble” and order his/her car via the *Internet*. Here, however, another problem arises, the problem of product fabrication in the order they have been ordered, and this is known as conversion of conventional *mass production* into *mass customization*. A solution of this problem was implemented in Toyota plant in Georgetown, Ky, where on the same production line at the same time the *minivan* and the was produced.

Use of Internet in manufacturing is a promising way of realization of new on-line services and new production capabilities. This particularly holds when the *intelligent agents* are used in interconnection of *intranets* with Internet, the feature of which should be exploited to improve the production system. Agents, as intelligent software, can travel along the intranets and the internet and - according to their programmed capabilities – collect the information related to the design, planning, production, purchasing, available resources, etc. They can subsequently analyze them in a common context, and distribute at the appropriate time within the production process. It was demonstrated, that the agent-based approaches could optimize the production in multiple ways. For instance, they can increase the production compliance to the market demands, improve resources allocation, etc.

2.4. Internet Controlled Robots

Another Internet-based initiative has captured the interest of developers to develop the *web robots,* i.e. the *teleoperable robots* over the *World Wide Web*. Such robots could serve as a distance manufacturing operational centers or can find application in hazardous environments, or for control of space and underwater vehicles.

The work on Internet controlled robots has been initiated by CERN in 1992 and in 1995 the first robot teleoperating via the Internet was implemented.

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Biographical Sketch

Prof. Popovic has received his M. Sc. (Dipl.-Ing.) from University of Belgrade and his Ph. D. (Dr.-Ing.) from Technical University of Berlin. He has been with the University of Bremen since 1972 as Chair of Process Control Computer Engineering. In 1982 he has established the Institute of Automation Technology and has headed it since the very beginning. Before coming to the University of Bremen he has been for more than ten years with the AEG-Telefunken in Berlin and with Bayer AG in Leverkusen, in charge of computer application to industrial plants automation.

Prof. Popovic is author and editor of several books, including the books on *Distributed Computer Control for Industrial Automation, Methods and Tools for Applied Artificial Intelligence,* and *Mechatronic Approach to Process and Product Design,* published by Marcel Dekker, Inc., New York. Besides, he has contributed 8 chapters to various Books in the areas of expert systems, neural networks in systems control, and in communication links for industrial automation His field of research includes, besides the process control, application of intelligent technology to texture analysis, video data compression, computer vision and intelligent robotics, where he has over 140 numerous publications.