CAM

Developments in Computer-Integrated Manufacturing

Edited by
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Preface

"Developments in Computer-Integrated Manufacturing" arose from the joint work of members of the IFIP-Working Group 5.3 — Discrete Manufacturing, and other IFIP members.

Within the Technical Committee 5 of the International Federation of Information Processing (IFIP) the aim of this Working Group is the advancement of computers and their application to the field of discrete part manufacturing.

Capabilities will be expanded in the general areas of planning, selection, and control of manufacturing equipment and systems. Tools for problem solution include: mathematics, geometry, algorithms, computer techniques, and manufacturing technology. This technology will influence many industries — machine tool, automation, aircraft, appliance, and electronics, to name but a few.

The Working Group undertook the following specific tasks:

1. To maintain liaison with other national and international organizations working in the same field, cooperating with them whenever desirable to further the common goal
2. To be responsible for the IFIP's work in organizing and presenting the PROLAMAT Conferences
3. To conduct other working conferences and symposia as deemed appropriate in furthering its mission
4. To develop and sponsor research and industrial and social studies into the various aspects of its mission.

The book can be regarded as an attempt to underline the main aspects of technology from the point of view of its software and hardware realization. Because of limitations in size and the availability of literature, the problems of robotics and quality control are not described in detail.

Promoting the fundamental aim of sponsoring international cooperation, Working Group 5.3 essentially organized the three annual PROLAMAT conferences. Working conferences on special topics have recently been held, too. Past and planned activities are listed on p. 1.

The international scientific cooperation of the past few years has led to certain conclusions. In discussions of new results and trends in science it is sometimes difficult to reach a level of understanding conducive to agreement. This is true even with regard to apparently unambiguous terminology used in connection with new technical principles, methods, and solutions of advanced technological develop-

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ment. Senior members of IFIP Working Groups saw a need to produce a volume on the "state of the art — CAM", to characterize the highest level in total computer-aided manufacturing. Some other aims were:

1. To outline the range of advanced computer-aided manufacturing and the key problems of technical development
2. To trace and describe the main trends leading to computer-integrated manufacturing; as it was not possible to describe every aspect of the state of the art in depth, selected examples were chosen from developed industrial countries
3. To point out the need for cooperation between specialists in various fields, such as manufacturing and mechanical engineers, production and industrial engineers, economists, designers, software and system engineers, mathematicians, social scientists. Teamwork is necessary to characterize and classify the advanced knowledge and essential terminology in this scientific and technological development.

The starting points of relevant technical development are illustrated and the fundamental terms explained at the beginning of each chapter, especially NC techniques, which were the basis of these developments. The international authorship includes contributions from the major industrial countries. The extreme distances made it difficult to coordinate and integrate the authors' contributions; I am very interested in receiving critical comments from readers. It is anticipated that this book will give a survey of the advances made in computer-aided manufacturing toward the goal of computer-integrated manufacturing. The problems and challenges of manufacturing development should stimulate young scientists to participate in finding solutions and in the efficient application of computer techniques and automation.

I would like to thank all of the IFIP coauthors, especially those of IFIP-WG 5.3, for their creative and effective teamwork. In addition, I wish to thank the publishers of Springer-Verlag, represented by Mr. Rossbach, for their cooperation and for the excellent quality of the editorial and printing work.

Dresden, October 1985 D. Kochan

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1 Introduction

Computer-aided manufacturing (CAM) originated in the development of information processing, especially in connection with the control of machine tools. Parallel to this development, and to some extent independent of the automation of manufacturing processes in the 1950s, successful automation of intellectual routines by means of electronic data processing was also accomplished.

In addition to many single ideas, rules, and parameters, only a few methods of group technology were available for dealing with complex manufacturing processes in the metalworking industry.

The problems of production planning, supervision, and operational accounting were considered separately and independent of the direct manufacture.

The dynamic development of information processing in its different modifications for large computers, medium-sized computers, and minicomputers, and as programed logic or free programmable control, gave strong impetus to the entire field of manufacturing. In less than 20 years of development there have been four generations of numerical control systems for machine tools. Proceeding from the first programming languages and going on to NC programming and other technological programs for determining operations and stages of operation, the computer has become an indispensable aid to the engineer.

Information processing solves complex problems such as process elaboration, classification of single parts and group technology, recognizing of repetition parts, amendment service, and simulation of process run. The informational link to production planning, supervision, and operational accounting, and with different auxiliary manufacturing processes such as transport and storage — which are becoming increasingly automated — is becoming closer. Thus, the various items of informational feedback effectively contribute to the faster manufacture of industrial products which are better in quality.

The field of computer-aided manufacturing has reached a considerably high level; therefore, for international understanding, it is imperative to give a systematic survey of important definitions and to explain them in detail.

2 Computer-Aided Manufacturing (CAM)

2.1 Fundamentals, Definitions, and Philosophy

This field of work includes those principal problems and complexes of activities which are carried out with the assistance of computers, i.e., which are automated, in the preparation for manufacturing and in manufacturing itself. These are problems prevailing in the manufacture of discrete parts in the metalworking industry; they are transferable, to a certain extent, to similar processes in the manufacture of piece goods.

CAM — discrete manufacturing is defined as computer-aided preparation of manufacturing including (see Fig. 1) decision-making, process and operational planning, software design techniques and artificial intelligence, and manufacturing

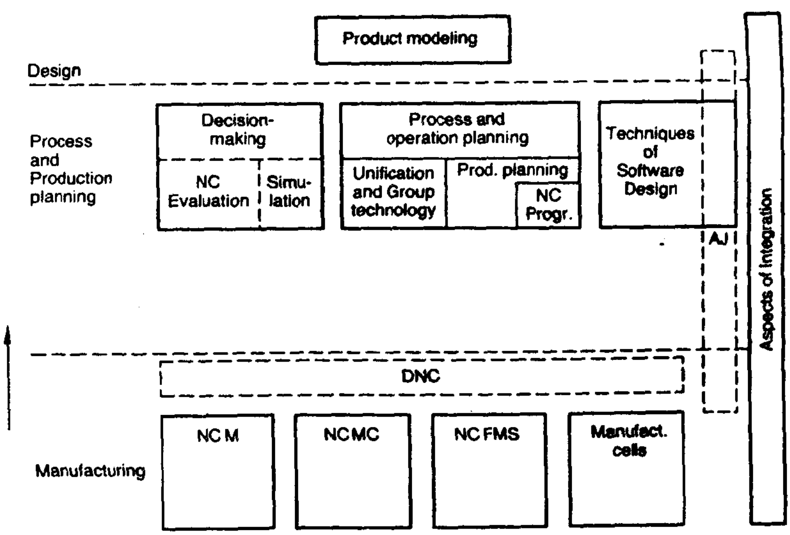

Fig. 1. The scope of computer-aided manufacturing

with different types of automation (NC-M, NC-MC, NC-FMS, NC machining cells), and different types of realization (CNC — single unit technology, DNC — group technology).
Proceeding from the fact that automation of manufacture decisively influenced computer-aided processes in the preceding stages of production, and that at present this influence prevails, this subject will be the center of interest. Very often, the concept of CAM is used only with respect to automated manufacturing but this is not the viewpoint of the IFIP-WG 5.3.

2.2 Main Historical Sources

In general, computer-aided manufacturing has three main sources:

1. The research in numerical control at the Massachusetts Institute of Technology in 1953 and the dynamic increase in the output of electronic data processing were fundamental prerequisites for this development. Thus, the necessity for computer-aided programming was caused by the progress in numerical control. The first programming language, APT, created at MIT, was the pattern for many further developments, especially in the western industrial countries.
2. The fundamental work carried out at the Soviet Academy of Sciences at the same time formed another substantial basis. The aim of these activities was to use electronic data processing to rationalize engineering projects and to plan the production of conventional machine tools for the first time. Outstanding results were achieved in rationalizing the delivery of working information for turret lathes with the aid of computers in the mid 1950s.
3. The work on unification and group technology originating in scientific activities in Leningrad in the 1930s were continued in the 1950s by means of modern technical aids. The activities and achievements of Professor Mitrofanov, and his worldwide influence on the progressive design of technological processes through his work on group technology, are recognized all over the world today.

3 Stages of Development in Flexible Manufacturing

3.1 General Remarks

For decades, in industrial-scale manufacture and mass manufacture the so-called rigid forms of automation prevailed, such as automated lines and transfer lines in the automobile and consumer goods industries, cam-controlled automatic machines in the mass production of standard components (screws, nuts, bolts), special machines or single-purpose machines for special manufacturing problems.

All these types of automation are characterized by the fact that, due to the high cost of setting up the manufacturing process the revision of production of a certain part or an entire product is profitable only after some weeks, or even after some years for special machines.

It is therefore imperative to develop more flexible forms of automation, adjustable to alternating requirements. The small and medium-sized pieces account for 75%-80% of the parts manufactured in all industrial countries for mechanical engineering. Following the Second World War the aeronautics, automobile, and consumer goods industries developed rapidly, increasing the demand for complicated geometric parts. And with increased demand for power and accuracy the manufacturing processes of turning, drilling, and milling have taken on added importance.

3.2 Historical Development and Modifications in Flexible Manufacturing

3.2.1 Technical Advances

In the eighteenth century the first musical clocks and music boxes were developed, and certain programs were carried out by pinned rolls which were traced mechanically.

In the nineteenth century M. J. Jacquard elaborated punched cardboard patterns to automatically control certain functions of looms.

In the twentieth century the tendency moved to more flexible types of automation by the principle of cam control.
The term "cam control" must be understood as a general term for a great number of program controls, where either mechanical trip cams, slots or punched patterns, or film work as dimension storage or impulse machines.
On cam-controlled machine tools the path dimensions are represented by a limited number of cams which are variably mounted on a cam shaft (cam plate, drum). During the operation signal pulses are emitted with microswitches by the cam, which can be utilized to select the functions and to coordinate them according to the prescribed program.
The principle of cam control may offer a way to solve an automation problem seen in industry, where — based on the same fundamental principle — electronic components are increasingly used in place of mechanical components.

3.2.2 Origin of Data Processing and Numerical Control

Automated information processing and electronic control have the same origin.

1945 – 1946

The first digital electronic computer with practical application was developed by Drs. John W. Mauchly and J. Presper Eckert. It was called ENIAC (Electrical Numerical Integrator and Calculator). It was large and massive, utilized energy-consuming vacuum tubes, and was difficult to program. However, it was the basis of electronic data processing used to carry out scientific computations.
This project was first promoted by the US Air Force, and later received considerable support from the government.

1942 – 1952

The genesis of numerical control, which can be termed one of the most significant developments of our century in manufacturing is illustrated by some examples |65|. Numerical control, the first answer to new aerospace machining requirements, was developed by a small aircraft industry subcontractor, the Parsons Corporation, from northern Michigan, USA. Early in 1942, the Parsons organization, then a stamping company located in Detroit, was awarded a government contract to manufacture bombs for the war then being waged. John Parsons knew that bombs were strictly a wartime emergency product, and that other, long-range plans would have to be made. So the Parsons Corporation was created, to act as a contract facility for major airframe builders.
One of the first contracts called for the production of helicopter rotor blades. Along with the contract came patterns for checking the contours of the finished part. The technique used a punchcard to check the helicopter blade airfoil patterns by generating coordinate tables of the contours. The final results showed that the furnished patterns deviated considerably from a true airfoil curve.
Later, tabulating equipment was used to generate a set of tables so that no point was more than 0.5 % of the chord length from the precoding point. Working with

a tabulating machine, multiplier, collator, and card sorter was somewhat cumbersome, but the equipment served the purpose until a fully digital computer became commercially available in the early 1950s.

With the generated tables of coordinate information Parsons and Stulen proceeded to make checking patterns and to generate some two-axis airfoil machining-path data. A factor was even entered for the cutter diameter. The machining coordinate tables were taken to a simple milling machine and the X and Y points were called out to one operator who ran the X-axis handwheel and to another who controlled the Y-axis. The resultant machined curves were far more accurate than anything that had been achieved up to that time. They generated 200 points accurate to plus or minus 0.0015 inch.

With the necessity of generating three-axis-curve data — which was impossible to do with the early-generation tabulating equipment — came the birth of numerical control.

At MIT, numerical control was realized in 1952 as a vertical-spindle Cincinnati Hydrotel, with a lab-constructed control unit; programmed with machine instructions on a straight binary perforated tape, it successfully executed simultaneous three-axis cutting-tool movements.

Following further developmental work, Numerical Control was announced to the public in November 1954. Based on Parsons' patent, the first industrial numerically controlled machine tool was manufactured by the Bendix-Cooperation (USA).

1957

In manufacture, the US Air Force utilized the first numerically controlled milling machines.

1960

Other industrial countries — the Federal Republic of Germany was a forerunner in Europe — began to develop, produce, and use numerically controlled machine tools.

The steady increase in production of NC machines during the past two decades emphasizes the general importance of this type of flexible automation (see Fig. 2).

In the metalworking industry there has been a shift in production from the original milling machines to turning machines; this is because turning machines have a larger assortment of parts.

Numerical control is one of the most important basic innovations of our century; in the meantime it has gone far beyond the original cutting-machine tools and has revolutionized manufacturing and other areas of human productive activity (see also Fig. 3.)

With respect to the main application of NC to the production of machine tools, after 20 years of development nearly four generations of control systems have been applied in practice. Every year, on an international scale, more than one hundred different types of control systems are put on the market, together with different types of machine tools and numerous modifications in equipment.

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