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Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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CAD/CAM TECHNOLOGY IN COUNTRIES OF THE ECWA REGION

by

Stanislaw ZIETARSKI
UNIDO consultant *

* Technological University of Warsaw /Politechnika Warszawska/
Warsaw, Poland

CONTENTS

1. INTRODUCTION

Computers are playing an increasingly important role in all stages of product design and manufacture. The development of the CAD/CAM technology is already influencing design philosophies, factory techniques and management attitudes to enterprise organization and staffing. CAD/CAM incorporates substantial elements of the so-called "micro-processor revolution" and "robot revolution", which are taking place in industry of the most developed countries.

The terms "Computer-Aided Manufacturing" /CAM/ and " Computer-Aided Design" /CAD/, in a broad sense, denote all the relevant activities in the manufacturing environment divided in four principal areas:

- collection of data ;
- control of machinery ;
- control of processes ;
- computer-aided design and drafting, and production control.

By the end of the 1970s, CAD/CAM methods had been profoundly established in the aerospace and aircraft industry, shipbuilding, civil engineering, electrical and electronics industry. There had been a growing number of integrated computer-aided design and manufacture systems in these industries invariably connected with application of highly sophisticated software implemented on mainframe and/or minicomputers. The integrated systems included: computer-aided design and graphics, customer order handling, production control, numerical control of machine tools, robotics, inspection and testing, automated packaging, and automated warehousing. Underlying most of integretion efforts is the development of common data bases as links between the design and manufacturing functions, and it makes comprehensive CAD/CAM systems very expensive.

In the early 1980s new microelectronics developments, particularly the development of standard software packages and the emergence of proven microprocessor-based hardware, have opened up a new range of possibilities for CAD/CAM technology. Fourfold increase in number of CAD/CAM systems, between 1980 and 1984, illustrates the worldwide impact of microprocessors. This dramatic growth of CAD/CAM applications has been coupled with a new approach of small and medium-sized enterprises to computer-aided techniques. It must be noted that the major users of CAD/CAM are the large companies in high technology, but the situation has begun to change with the introduction of less expensive microcomputer hardware and flexible modular systems. Adopting a step-at-a-time, modular approach even small enterprises can benefit from CAD/CAM. According to estimates, between 1980 and 1984, more than three million new microprocessor systems were installed in the industrial application field,and these systems can be viewed as CAD/CAM components.The microprocessor applications in the industrial fields are distributed as follows: production equipment/ 30 per cent/, production monitoring / 25 per cent/,test and inspection /10 per cent/,factory data collection/8 per cent/,electrical test and measurement/5 per cent/,process control/3 per cent/,and others.

As a result ,there is increasing pressure to automate production functions as the most cost-effective first stage in factory automation.The past three years in manufacturing have been characterized by the maturing of technologies for factory automation/ including cost falls and performance improvements/and the growing trend towards convergence with the CAD/CAM technology into the so-called computer-integrated manufacturing/CIM/.

Application of mini-and micro-computers to manufacturing processes has made economically feasible and justified the following trends in factory automation:

- a growing number of flexible manufacturing systems/FMS/.Unmanned operation of small batch production,increasing flexibility of mass production;
- development of automatic assembly systems.Introduction of industrial robots,increasing flexibility of automatic assembly lines;
- automation of materials handling systems.Introduction of automated warehouses and automatic quided vehicles;

The vlue of computer-integrated manufacturing is that it brings all manufacturing industry,even the traditionally batch-oriented industries,close to the process industry like petrochemicals. Important characteristics include continuous or near continuous operation/high plant utilization,high levels of control toproduce high and reproduceable quality and tailor production to specific customer needs/,high reliability,improved utilization of inputs of labour,energy,and materials.

Whilst the development of CIM is well advanced,there are major problems involved in linking up the various components of CAD/CAM and flexible manufacturing systems,including software and hardware compatibility and organizational problems associated with the need to move to a radically different philosophy of production.

Nevertheless, in the last two years several thousands of CAD/CAM systems and flexible manufacturing systems has been installed in the United States,Japan and Europe.

In the decade of 1970s,the CAD/CAM technology was economically justified only in design and manufacture of highly sophisticated, complex products like spaceships,airplanes,computers,vehicles, ships,colour TV sets,etc.,therefore it could be viable in developed countries.

At the present stage of the CAD/CAM development ,there is deep conviction about the ubiquitous impact of computers on all industry sectors.In whatever industry sector ,it is understood that enter--prises are unlikely to survive,in an increasingly competitive market,unless they understand how the computers can aid their product design and manufacture. With all of the attention being paid to the computer-integrated manufacturing technology in developed countries and the resultant dramatic successes in an ever-increasing range of applications,it is little wonder that developing countries want to exploit the full potential of this technology to reap the full benefits. The question is no longer "should" the developing countries become involved in advancement of computer applications in domestic industry,but rather "how" to best utilize available resources/such as manpower,capital,and equipment/,to most effectively enter the field of CAD/CAM and FMS technologies,and gain control of the direction the technology takes in the country.

The importance attached by each country to being self-reliant in the use of the technology will determine whether or not adequate and timely support of this new field will be given. As a rule,the main point of interest for developing countries are mini-and microcomputer-based components of CAD/CAM systems.

In countries of the ECWA region,the efforts are being made to accomodate advances in microelectronics and computer applications with national development programmes.Recently,a number of countries in the region/Egypt,Iraq/have initiated the applications of CAD/CAM technologies.

The paper is a result of a UNIDO sponsored mission in the Republic of Iraq,which was conducted in December 1984 / 10 days / in order to assess the experience gained in the ECWA region so far and to propose ways and means to develop technical capabilities in regard to applications of the CAD/CAM technology.

2.OBJECTIVES

The UNIDO mission on the CAD/CAM technology in countries of the ECWA region was formed to identify technical problem areas which are essential for CAD/CAM applications.In addition,the mission was to recommend possible actions at the national and regional levels,including actinns by ECWA/UNIDO and other institutions.
To this goal,the mission had two primary objectives:

- to evaluate the diffusion and advancement of computer-aided design and manufacture in the region;
- to establish a framework and propose necessary steps for the UNIDO/ECWA plan of action related to the development of CAD/CAM technology in the region.

3. CAD/CAM TECHNOLOGY

Despite the relatively hesitant approach in the region,as in other developing countries,to CAD/CAM possibilities,there are abundant signs that both governments and industry are becoming aware of the latest computer hardware and software potential in this field. The development of CAD/CAM technology in the region can be described against an overall background of CAD/CAM applica--tions in manufacturing. Manufacturing can be broadly grouped into three activities: preparation,production and management.
In the first group are those activities like design and pre--paration work /mouldmaking,toolmaking,etc./. In the second are the actual production operations:machining,moulding,heating,etc.
In the management group are the operations necessary to manage the process: stock control,production control,planning and scheduling,etc.

Much of the early effort in automation has gone into these areas to produce a wide range of automation technologies for discrete elements,eg.computer-aided design /CAD/,process controllers, handling robots,etc. The trend to computer-integrated manufacturing /CIM/ essentially involves integrating these discrete automation technologies into complete production systems.

A good example of this can be seen in the metalworking sector of the engineering industry. Here the changes have been from discrete manual machining,to automated machining on NC and CNC machine tools,to multiple machining on CNC machining centres

/ie.able to carry out several different operations on one machine instead of passing the workpiece amongst several different machines/,to direct numerical control /DNC/ with a supervisory shopfloor computer running several different machining centres, through to flexible manufacturing systems /FMS/,comprising of machining centres with handling systems /robots,automatic quided vehicles,programmable conveyors,etc./ and warehousing systems. The whole is under hierarchical computer control and is linked to the computer-based management systems for stock control, purchasing,production planning and control,etc. CAD/CAM system adds to it the preparation stage and integrates all elements into computer-integrated manufacturing.

The broad CAD/CAM categories of activity are shown in Fig.1.

The latest developments in linking up the various,factory shop--floor elements into flexible manufacturing systems are leading toward fully automated factory. So far,there are around 300 FMS in operation worldwide,mainly in the metalworking and other industries including aerospace,automobiles,electronics,and food processing.

It will be usefull to look at chronological development of the flexible manufacturing systems,as a new,rapidly expanding part of CAD/CAM tecnology. It is shown in Fig.2.

A common approach to implementation of CAD/CAM is that at first installed are some elements of the whole system. As a starting point,computer facilities are exploited in selected areas of design and manufacturing activities. Hence,practical CAD/CAM systems never include all elements given in Fig.1. In addition,it must be pointed out that in most cases elements of CAD/CAM systems can be run as a stand-alone subsystem.

The Arab countries follow this pattern and enter into computer assisted technology by applying microcomputers and computers in separated areas of manufacturing.

Therefore,it is worthwhile to profile the current spectrum of CAD/CAM applications on worldwide scale and in the region.

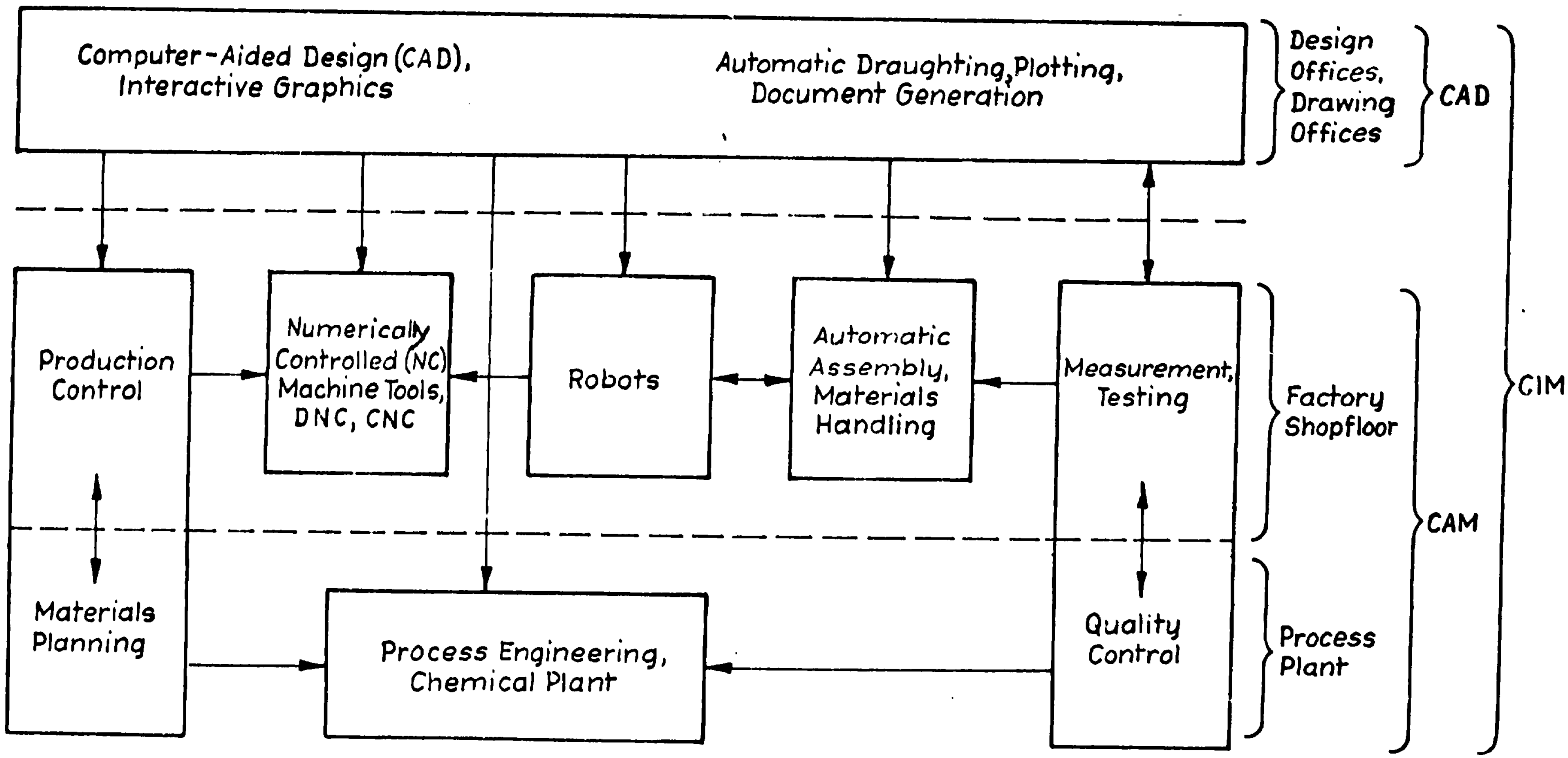

Figure 1. Broad Categories of CAD/CAM Activity.

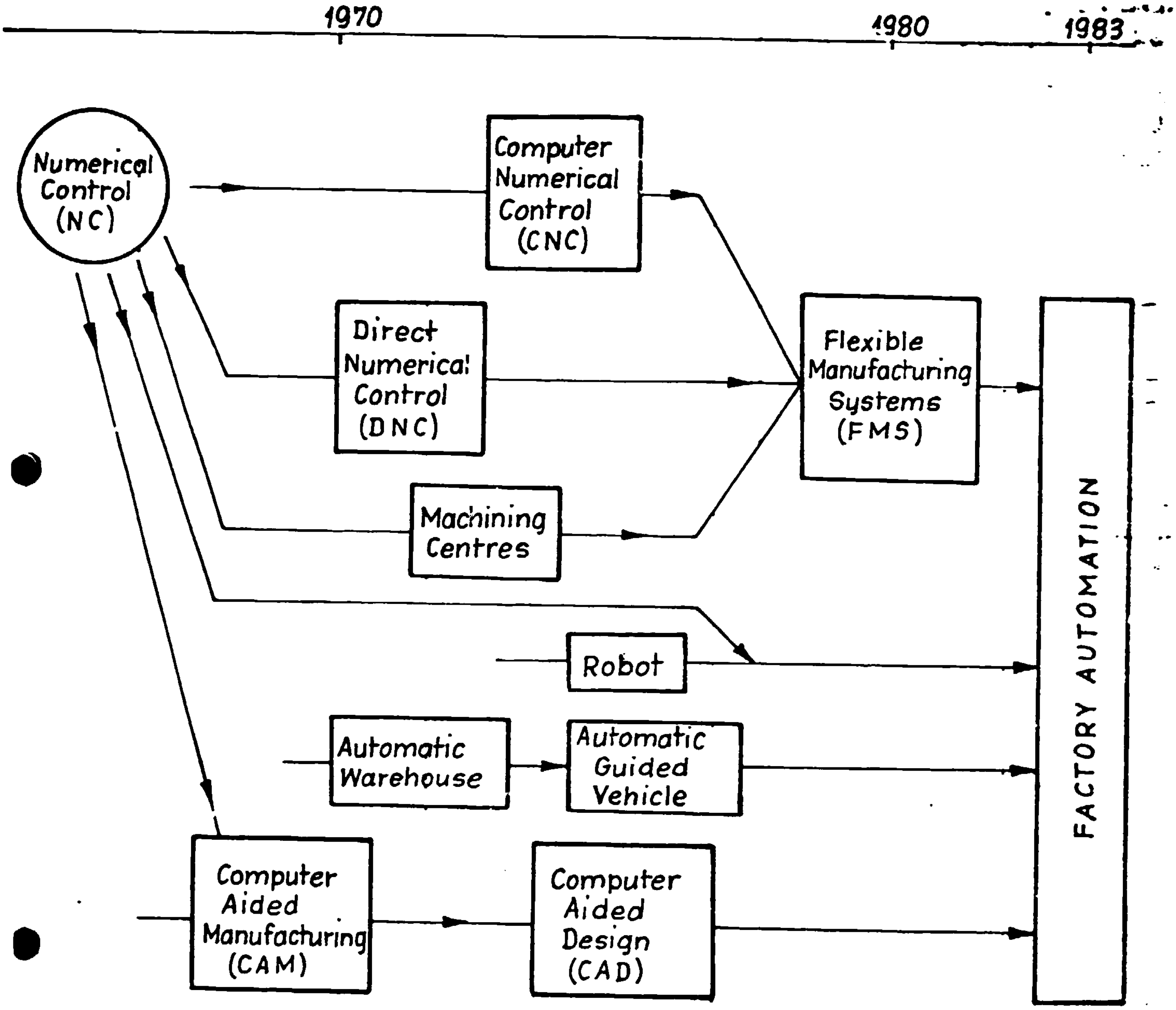

Figure 2. Development of manufacturing automation.

3.1. PRODUCTION CONTROL

The aim of effective production control is to optimize production efficiency, cutting out bottlenecks, wastefull investment and any other inefficient use of material and resources. To this end a wide range of software is now available and individual packages can be implemented as modules in comprehensive systems. Computerized production control represents a heavy investment in the manufactu--ring environment. It is worthwhile only when due attention is given to all the relevant factors.

Many manufacturing organizations have decided to computerize production control in a piecemeal way: for example, facilities for shopfloor data capture may be introduced before further investment is authorized for such functions as estimating, inventory control, and comprehensive manufacturing resource planning.

A piecemeal approach has the advantage that individual system modules can be tried out in workshop conditions before management makes an irrevocable commitment to a completely computerized production control configuration.

Again it is worth emphasizing the growing role of microcomputers. The diminishing cost of computer hardware has put computerized production control within the reach of many small enterprises. The microprocessors have opened up a new range of possibilities for the production engineer to monitor and control processes, machines, sections and departments-on an hour-by-hour cycle; if required. The monitoring of shopfloor activity is one area where micro-based data acquisition systems are facilitating production control. It is in the areas of production scheduling and capacity forecasting that computers have a particularly important contribution to make: it is very expensive, and often inefficient, to carry out manually the necessary mathematical procedures. Today, even a small enterprise can benefit from using a microcomputer for these tasks. A minimum-cost strategy could involve a relatively small system with the capacity to store, for example, 1 million characters of information on a floppy disk, a visual display unit, and a printer capable of operating at speeds of around 40 characters/second. Such hardware is likely to cost about 3000 dollars.

It is increasingly clear that efficient production control depends upon collecting and organizing data. Monitoring systems, often based on microprocessors, are finding increasing uses in the production control, The inputs to a data acquisition unit may comprise hundreds of channels of production signals,its outputs ranging from a simple strip printer listing to a long-line interconnections of data summarizing activities over preselected time intervals.

The development of new software ,much of it packaged and offered on a commercial basis,has helped to make the application of computers to production control a practical and cost-effective solutiom ,even on mainframes. COPICS of IBM is a modular system: each of the modules has standard programs that meet 80 per cent of requirements, allowing the customer the flexibility to introduee specific instructions for exceptional tasks. COPICS is introduced to around 80 medium to large companies,including a small car builder,a maker of motor accessories,a chemicals manufacturer,and an aerospace company. A typical installatiom has four software modules and about 20 terminals.

Hewlett-Packard has introduced system /MM-3000/,suitable for assemblers of electronic components,fabricators of light engineering products,and for the management of larger projects.

To implement a comprehensive,closed-loop production control system it is necessary to pay attention to technical aspects /hardware and software/,provision of data files /master production schedule,bill of material,inventory,etc./ and trained staff. It has been observed that a 15 to 18 months is needed for implementation. Implementation of large systems on mainframes usually involves a fundamental change in the way manufacturing activity is organized.

The production control systems are,according to estimations, the most cost-effective first stage in factory automation. In the USA, Europe and Japan computerized production control systems are implemented in enterprises,as follows:

Inventory control	in 75	per cent of all enterprises,
Bill of materials	65	- " - ,
Material requirements planning	61	- " - ,
Production cost estimation	53	- " - ,
Production scheduling	49	- " - ,
Shopfloor reporting	33	- " - ,
Process control	26	- " - .

/Source: IDC /

These different tasks may be carried out as separate functions, thus computers can be used to cover the separate functions only. This is also a prevailing pattern for the Arab countries. Many separate, but not interconnected yet,aspects of production control systems are initiated in several countries in the region,eg.cable,steel and electronic industries in Syria, engineering industries in Iraq,steel and iron industry in Egypt,refinaries in Kuweit,etc. So far,there is no fully computerized production control system implemented on a mainframe,

3.2. COMPUTER AIDED DESIGN AND GRAPHICS

Current integrated CAD/CAM systems tend to be specialized, developed by large companies that invested early in computerized design and manufacturing and developed their own applications, eg.McDonnel Aircraft,Northrop,Lockheed,etc. Significant productivity gains have been achieved using the computerized systems. For instance Northrop estimated an 800 per cent increase in productivity for the process of designing,manufacturing and testing the main structural box skin for the vertical tail of the F-18 aircraft. Stand-alone,not integrated CAD systems are capable of reducing design and drafting time at least 75 per cent.

According to estimates,in the USA,Japan and Europe in 1983, stand-alone CAD systems were in operation in 9 per cent of all enterprises,and CAM systems in 14 per cent of all enterprises. Comprehensive,integrated CAD/CAM systems are seen to be still at the stage ,where the cost of hardware and software precludes using it in the developing countries. Nevertheless, it is worth mentioning that key objectives of newly developed and implemented CAD/CAM systems are to:

- define a CAD/CAM system framework that is as independent as possible of present or predicted computer hardware and software;
- establish a CAD/CAM system framework capable of orientation to an individual enterprise;
- provide a means whereby users may evolve at their own pace into CAD/CAM facilities;
- develop specifications for a generalized geometric modelling system through stepwise formulation of functional specifications;
- evaluate and disseminate related technology developments;
- develop and implement new automated tool path generating techniques, using three-dimensional geometry for the part description;
- create an advanced numerical control processor which will interface with other systems;
- improve reliability and accuracy of tool control;
- automate the fabrication process;
- expand processor applications to embrace such areas as,inspection, robotics and materials handling.

But even the most sophisticated systems have not achieved all of these objectives,eg. CADAM /Computer-graphics Augmented Design and Manufacturing/ used by most aerospace companies and distributed by IBM.

More attention must be devoted to stand-alone CAD systems and stand--alone CAM systems,because in this stage of development the Arab countries can follow the stepwise pattern.

Recently,CAD techniques have been developed to broaden the computer role in design activity in many different industry sectors /mechanical engineering,chemical plant,civil engineering,etc./.

CAD has been depicted as comprising two distinct disciplines: graphics and modelling.In electronics design,graphics facilities are exploited to allow the interactive display of the logic diagramm. Modelling techniques are exploited in the program that simulates the operation of the circuit. In mechanical engineering the same distinction can be made between the graphics display of component drawings ,and the use of a program accessing a data base to compute the indexes of mechanics and strength of materials.

The difficulties in using computer-based systems to aid design activity are related in part to the number of physical dimensions that are involved. For example,electronics has tended to deal with two-dimensional /2D / circuit layouts,whereas mechanical engineering is necessarily concerned with three-dimensional/3D/components. Some current computer-based systems have a 3D capability.

The growing interest in computer-based modelling and graphics derives in part from the successes of established CAD facilities. One such very successful application area is the design of blading for turbomachinery,a divers activity covering products ranging from ship propellers to multi-staged compressor blading for gas turbine engines. It is essential in each case to accurately define a surface which is generally curved in two orthogonal directions. It has been shown that computers are well suited to this sort of design activity.

In another area,that of integrated circuit design,computer-based systems are used to speed up the design of microelectronic devices.

In terms of hardware the most extensively used system for a LSI design by far is the VAX 11/780. The system has the great advantage that most of the software packages available for the LSI design can be directly implemented on it, without any modifications.

The design software can include a package for registrer level entry,a logic simulator /TEGAS,SPLICE,EPILOG/,a circuit simulator /SPICE/,preferrably a processor simulator/SUPREME/,an interactive graphics package /CALMA,GCI/, a cell or element extractor from the layout to verify or re-simulate the logic,software for mask fabrication and cell library with a data base containing the requisite design rules,ie. layout and electrical. Overall costs around $ 300,000.

It is very important to those Arab countries which will decide to go into "silicon foundry" for wafer fabrication,what is being considered.

Computer-aided graphics is sometimes regarded as synonymous with computer-aided design and the success of the overall CAD facility depends to a large extent upon the cost-effectiveness of the graphics system. The emergence of microprocessors made it possible to produce plotters with enlarged capabilities and enhanced software. Plotters are now able to cope with a large range of design requirements. Users need to choose between various plotter types /drum and flatbed pen plotters,electrostatic,etc./. Electrostatic machines offer very high speed output /eg. 1200 lines/min /,but may use more computer time than pen plotters. Flatbed pen systems allow overplotting but drum plotters usually allow faster throughput.It should be emphasized that any choice should follow a comprehensive assessment of needs.

Computer-aided design and other facilities rely upon software. A system necessarily includes a software element;developments in all the realated fields depend upon the formulation of appriopriate algorithms and the translation of these into software. To describe a computer-based design system in detail is,in large measure, to describe software.

A specific,important position among software elements of CAD systems have finite-element methods /FEM/. An increasing body of integrated FEM software is being made available for structural analysis and CAD applications. FEM programs can be used for data creation,a task that is usually carried out automatically by mesh generator. The value of interactive design is that there can be continuing communication between the designer and the computer-which,in FEM analysis,means that the topology of the structure as well as the geometry can be continuously modified.

New CAD and CAM software is announced in the journals almost every week /eg. CadCam International/. According to estimates of these journals the top manufacturers of CAD and CAM systems are: Computervision,IBM,Intergraph,Calma, Applicon,Gerber,etc.
In 1983 were installed around 10,000 turnkey CAD and CAM systems worldwide.

A typical,most widespread drafting system may be regarded as comprising:

- a minicomputer ranging in size from 64 K words to 512 K words;
- data storage peripherals such as disks,magnetic tape drives,etc.;

- graphics terminals,ie.display facilities with a range of input features /eg.keyboards,joy-stick,tablet digitisers,etc./. These are often referred to as workstations;
- a plotter.

Before a system is acquired it is necessary to investigate in detail the needs of the design and drawing office.A system with one workstation and peripherals /including plotter/ can cost in excess of $ 80,000 ,with additional workstations costing as much as $ 20,000 each. For this level of investment to be justified it has to be shown that the likely productivity gains are significant. For example,an increase in the productivity of the drafting process approaching 3:1 over traditional manual methods has been achieved for an average architectural and civil engineering practice.

These are various benefits from computer-aided drafting:

- once project data has been stored in the system,it is possible to produce drawings to any required scale with very little extra cost;
- when changes are necessary ,only one representation of the project need be altered.The computer can then replot all the drawings at the different scale required;
- a higher standard of drafting consistency can be achieved;
- skilled staff can be freed for specific design work.

It is worth to summarize some typical CAD applications to indicate the range of design activities to which computer-based systems can contribute.The particular stress is laid on this industry sectors which are important to the Arab countries.

3.2.1. Integrated circuit and printed circuit design.

An integrated circuit /LSI,VLSI/can have tens of thousands of circuit elements on a piece of silicon as small as 1 sq.centimetre,the elements all interconnected by microscopic circuit path. Various problems may be encountered at different stages of the design. For example, geometric problems may relate to circuit traces that cross or have breaks,whereas analytical problems may concern the calculation of element spacing to eliminate electrical disturbances,noise or static, which would cause the circuit to work badly or to fail altogether. The design process begins with the concept of the integrated circuit. Some systems allow checking of parameters before the design is finalized /eg. Sperry Univac/. Many efforts have been made to develop algorithms and software to achieve effective chip layouts and routeings /eg. IBM 370/. It has been claimed that an integrated circuit comprising more than two trillion gates could be designed accurately and easily, using the latest generation of CAD systems /eg.Computervision, Some systems are aimed to cut the time-consuming task of moving from VLSI circuit design to cutting rubyliths for making masks /eg.Calma, Hewlett-Packard/.

In designing printed circuit boards,an initial stage is the trans-lation of a conventional circuit diagram into a pencil layout diagram. After checking,the layout is ready for digitizing.The digitizer is a plotting board including a sensitized grid surface.Various subroutines enable the digitizer operator to delete and add track segments,full tracks,pads and group of pads.The layout drawing allows further tracks and components to be positioned,and the information can then be digitized and stored in the computer. It is possible to automatically generate outputs for PCB assembly drawings,drilling drawings,NC drill tapes,silk screen layers,component position drawings,solder resist patterns,instruction for component-insertion machines,and all the printed documents needed.

In many other branches of the electrical and electronics industries, CAD systems are aiding the production of efficient configurations /eg.electrical distribution switchboards,dc motors,and other designs in microelectronics and telecommunications/.

3.2.2. Steel industry

Design activity in the steel industry is being increasingly assisted by minicomputers and microcomputers.The data describing steel portal frame buildings /ie.shape and height of the building, wind speed,ground strength,types of roof and gutters,etc./ are input to the computer. The main portal frames are then automatically designed to minimize material and fabricating costs. CAD systems have also been used in the interactive optimal design of truss structures /eg.bridge trusses,transmission tower trusses,etc./.

Some computer-aided design and drafting systems are used in structural analysis and design /eg.Benson,which covers about 20 per cent of the world market in the computer graphics/. This can include the detailing and production of steel components and the design of reinforced concrete columns,beams and slabs for buildings,bridges and highways. Other uses relate to the oil, seismic and geophysical industries.

There is a significant interest in this area of applications among the Arab countries.

3.2.3. Tool design

The information generated during the computer-aided design of products can also be used to design the tools that will be involved in the manufacturing process /eg.computerized die design for zinc diecasters,thermal calculations for diecasting in brass,aluminium, zinc and magnesium,etc./.

Electrochemical machining/ECM/ is another area that has derived benefits from computer-based design facilities /eg. metal removal calculations,gap calculations,etc./

In various engineering sectors it has proved possible to use computer-generated data to design metal-cutting tools,tooling templates,and other necessary items in the manufacturing process.

3.2.4. Automobile industry

Increasingly sophisticated CAD/CAM systems are being developed to aid the production of car components and car assembly.For instance, a mathematical definition of the complete skin of the car is stored in a mainframe data base,and then is used as a master for all follow-on operations. Structural design and analysis is carried out on the mainframe computers by means of interactive terminals located in design offices. Systems allow body design to be idealized into a framework of beams and shear panels joined at nodes. It enables the strength of a body shell to be predicted,a main design principle being to combine maximum strength with minimum weight. Computer-based systems are also assisting in component design. For example,computers have been used for some time to aid the design of gear transmissions to any specified requirements.

There is in principle no area of product design and manufacture which is not amenable to computer-based techniques. The applications cited are far from an exhaustive list. They are related to the applications ,initiated or planned in countries of the ECWA region.

The emergence of CAD facilities is influencing design,working practices and the character of new products. The new products are likely to be more reliable,more economically manufactured,and better suited to the user's needs.

3.3. NUMERICAL CONTROL AND AUTOMATION

To a large extent the computer is the most influential factor in the evolution of manufacturing systems occuring nowadays in developed countries. A key factor in this evolution is the progressive integration of computer-based facilities.This is evident in such areas as numerically controlled machine tools, microprocessor-based programmable controllers and industrial robots.

The impact of these developments is being seen also in the Arab countries,where hundreds of numerically controlled equipments were installed in the last few years. All new investments in manufacturing plants must be connected with NCs,irrespective of the industrial infrastructure of the country.It is easy to understand taking into account available sorts and types of machine tools manufactured in developed countries. For example,according to the Japan Machine Tool Builder's Association /JMTBA/,among 117 types of turning machines produced in Japan in 1982-1983, 76 per cent was numerically controlled,and 34 per cent of all milling machines types was numerically controlled. In addition,special-purpose machine tools used in conventional manufacture of some products are no longer available. In the Swedish industry in 1980-1982 computer-controlled machinery and computers composed 30 per cent of total investments in the engineering industry, 20 per cent in the process industry,and 23 per cent in the whole of the industry.

Numerical control must be seen as a starting point and substantial element of CAM in the industrial environment,therefore, the develping countries are usually exposed at first to this technique. The first commercially available NC machines included permanently connected control systems, with computer numerical control /CNC/ systems developing through the 1970s. In CNC easily modified stored programs provide machine versatility, In direct numerical control /DNC/ systems a number of machines are controlled by one computer. One variation of CNC is in incremental control where a minicomputer can control several machine tools on a time--sharing basis. Many commercial CNC systems are offered for use on a number of different machine tools. Computer and interface facilities are standardized as far as possible,with the different requirements of individual machines accommodated by software.

The microprocessor has widened the range of applications for which CNC is cost-effective. It is clear that computers will play an increasing role in manufacturing activity of all types and that a substantial proportion of this will relate to NC machine tools.

It is estimated that by the year 2000 at least 75 per cent of all mechanical parts, that are not mass-produced, will be manufactured using NC equipment. The most sophisticated CNC systems have already moved industrial activity towards the concept of the unmanned factory.

The use of computers in NC systems has enhanced the machine capability for manufacturing. Three types of computer control can be identified as parts of hierarchical control:

- machine control /level 1/, where the computer focuses on the metal-cutting process in individual machine tools. Here the conventional hard-wired logic is replaced by stored program logic for interpolation and machine functions. This is the basic CNC level;
- job control /level 2 /, where the computer is concerned, not only with the individual machine, but also with the loading of tool sets, part programs and workpieces;
- workshop control /level 3 /, where the computer controls various machine tools and peripheral work transfer devices so that a production schedule is followed. This represents a typical DNC facility.

These are various advantages of NC /CNC, DNC/ machine tools over conventional machines: increase in productivity, reduction in tooling costs, reduction of components in stock, reduction in lead time, reduction in inspection costs, improved accuracy, and improved management control.

It has been found that economic gains from NC machines, when they are introduced piecemeal, are discernible, but really significant gains /even by factor 6 / can only be realized when an overall integrated CAD/CAM system is developed.

NC machine tools can be controlled by coded instructions presented on tape /paper or mylar/. In DNC systems, instructions can be presented on floppy disks, cassettes, or directly on-line from a computer. Today, the majority of NC systems still rely upon paper tape input.

Minicomputers and micro-based systems can now cope with tape preparation tasks and effective tape verifications. The commands for controlling the motion of the tool are generated through transfor-mation of the mathematical description of the component shape.

An appropriate NC language is used to enter the description into a computer program which generates the necessary sequence of tool motion control signals. Today there are well over one hundred computer languages worldwide for describing part geometry and for producing the necessary NC instructions. The most powerful of these software systems is APT /Automatically Programmed Tools/, developed in the USA, The system is very general and can be used to all machining operations /turning,milling,drilling,etc./. As a rule any NC milling machine with a multiaxis control /2.5,3,4,5/ can not be fully utilized without using the system. The advantage of APT for a large factory is that a same syntaxis and similar types of instructions are used for all machine tools. In many other countries some languages have been developed on the base of the APT language;they are called the "APT-like" languages /COMPACT II,EXAPT,IFAPT,NEL-APT,UNIAPT,POUT-APT,etc./. A special programs,called postprocessors,must be provided to make the program written in APT language suitable for a particular machine. If a job is transferred to another machine,the postprocessor can quickly provide another control tape. So far, the APT-like languages /ie.programming systems for three-dimensional objects/ can be implemented on mainframe computer and in some cases on mini--computers,but not on microcomputers. With microcomputers are available some simplified subsets of APT or specialized languages suitable to specific tasks.

An NC machine may be able to out-produce its conventional, manual equivalents by a factor of three or four,but this advantage will be lost if machines are poorly utilized. In the case of sophisticated DNC, it must be emphasized that it is not necessary to implement DNC all at once;a phased implementation is often preferable. The installed CNC units should include: the necessary communication interfaces, a CRT display and keyboard,provision for monitoring appriopriate signals,program storage facilities,etc. The final step into DNC will involve linking the various CNC and interface units,the machine tools, and the central DNC computer.

NC techniques can be applied to a wide range of metal-cutting, component forming,and assembly operations. The conventional processes of turning,milling,grinding,etc.,are amenable to numerical control, and to incorporation into sophisticated CNC and DNC configurations.

Microprocessors are key elements in extending the scope of NC and other computer-based equipments in the manufacturing environment. It is common for control inputs and outputs to be supervized by programmable logic controllers /PLC/ based on a stored program which can be modified or erased and replaced. PLCs respond faster than a conventional logic relay system,bringing benefits in terms of control efficiency and operator safety. The programmable sequence controller /PSC/ has been specially developed for industrial applica--tions. The user enters information from a simple relay ladder diagram,logic diagram or Boolean equation that specifies the required control sequence. Now PSCs can effectively handle information coming in from thermocouples,pressure sensors,and other devices. With the new and sophisticated micro-based programmable controllers,it is increasingly difficult to distinquish between them and control computers.

Highly automated plants,saturated by the computer-based equipments in the USA,Japan and Europe are now manufacturing cars,engines, earth movers,oilwell machinery,lifts,electrical equipment,machine tools themselves,and other products.

A special attention should be paid to this area of applications in all developing countries,because it has been proved that CAM systems can only be successful in the successful numerical control environment.

3.4. ROBOTS, ASSEMBLY, AND MATERIALS HANDLING

The development of full computer-aided manufacturing involves exploiting the potential of various complementary technologies, including robotics. It has been estimated that by the end of 1984 Japan,the USA and Europe had well 150,000 robots installed of all types,with new systems being installed at the rate of 20,000 a year. Japan is seen as the leading country in flexible manufacturing systems /FMS/,systems generally taken to include several robot-equipped numerically controlled machine tools or machining centres linked to each other and a warehouse by some form of automatic materials-handling device. In such configurations a central computer monitors and controls all operations. Robots load metal blanks onto driverless carts or conveyor belts for transporting to the worksite. Robots unload the materials and isert them into the computer-controlled machine tools. When the machining is finished,the robot replaces the part on the cart or conveyor belt,and it is returned to the warehouse or transported to another work site. For example,Toshiba launched in 1984 flexible manufacturing systems for 35 production lines at computer,semiconductor,telecommunications,and consumer-electronics plants.Only 500 workers is needed on these production lines compared with 2500 employed previously.

Roughly categorizing,there are two basic groups of industrial robots:

- pick-and-place robots,designed to transfer an object from one locationto another.The simplest of these devices have freedom of movement in only two directions /eg. up and down/.These devices can be controlled by air,electrical relays or programmable controllers;

- servo-robots,considered to comprise four basic types: programmable,computerized,sensory,and assembly.Servo-robots have considerable freedom of movement,and often exploit the latest microelectronics technology /eg. incorporating microprocessor control or solid-state memory facilities/. The most expensive servo-robot configuration approaches $100,000 in price.

The scope of an industrial robotis determined by its progammability. It is this feature that gives a robot its operational flexibility, its decision-making ability,and its response in changing environmental conditions. The progressive development of new sophisticated robots is,in large part,due to the emergence of new software and control potential. Special languages have been developed as means of providingthe required programming flexibility /AL,AUTOPASS,LANA, INDA,ALFA,etc./. Decision-making ability is a central feature of a robot's programmability. Robots are highly significant in the manufacturing environment in that they can be used for a wide range of industrial tasks. The first operational robots started out doing simple production jobs,mainly welding and simple transfer tasks. Today they are able to carry out a wide range of industrial operations, eg. framing complete car bodies,stamping and assembling frames, feeding materials to machinery,handling glass,moulding plastics, doing foundry work,and managing warehouses. It is estimated that in 1983,the main application areas were: spot welding,pressure diecasting plastic injection moulding,paint and powder spraying,forging and extrusion,loading/unloading,heat treatment.
The major robot builders were: Unimation /16 per cent of world market/, ASEA /13 per cent/,Kawasaki /14 per cent/,Fanuc /13 per cent/, Hitachi /12 per cent/.

The pace of implementation of robot systems in developing countries, including the Arab countries,will be conditioned by estimates of economic benefit,investment policies,government programmes,attitudes to industrial viability,etc. However,robot systems can not be seen as a starting point to computer aided manufacture.

Computer-aided manufacturing is concerned to a large extent with the handling of materials-before,during and after machining and other forming operations. In automated warehouses,optimum inventories are maintained and materials are handled by means of computer-controlled mechanical manipulation systems in accordance with material requirements planning. In sophisticated computer-controlled manufacturing systems, workpieces can be fed to and from machine tools by robots or other automated handling systems.Finished components can be automatically assembled in operations involving positioning,welding,tightening of fasteners,etc. The cost of a product,and hence its commercial viability, depends to a large extent upon the productivity of the method of assembly. Productivity in this area,as in others,has been significantly affected by technological developments in microprocessors,robotics, and new electronic sensors. Assembly operations are traditionally labour-intensive,but the current trend is towards automated methods, particularly for large volume production. Robotic devices,capable of being rapidly re-programmed,are extending automation to an increa--sing range of functions;eg. to embrace the manufacture of varied items made in small volumes. It is estimated,that 40 per cent of all engineering products in developed countries are made in batches of 50 or fewer.

The design of assembly robots aims to cope with positioning tasks and with error minimizing tasks during the mating process. Automobile manufacturers are among the first in industry to automate assembly operations. Automatic assembly systems are being used in the car industry to produce: universal joints,carburators,power steering mechanisms,fuel injectors,fan motors,tyre valves,shock absorbers, disc brakes,cylinder heads and differential assemblies, It is also increasingly common to carry out computerized in-process testing and gauging during assembly. There are various levels of assembly machinery:

- manually-loaded bench types,the simplest assembly machines,normally used with low production runs;
- manually-loaded rotary indexing types,comprising,for example, a rotary indexing table,workheads,an orbital welder,workhead tooling, and an ejector to remove the completed workpiece;
- semiautomatic bench machines with feeders,including automatic screwdrivers,riveters,wire-wrap pin inserters,roll-pin inserters and threaded insert machines;
- fully automatic assembly machines with feeders,where operator involvment is kept to a minimum.

Nevertheless, it must be pointed out,that recent surveys show that most industrial robots are still presenting reliability problems. Breakdowns are relatively high,but despite that,the robots can improve productivity by factor from 3 to 15.

3.5. CHEMICAL PROCESS ENGINEERING

Many process control facilities are independent of industry sector; they are relevant equally to ethylene production and to generation of petrochemical products. Microprocessors have extended the scope of control and instrumentation in the process environment. It has been found that digital controllers /often micro-based/ offer a number of advantages,in terms of flexibility,reliability,and improved control,over equivalent analog systems.There is now a developing combination of process computer flexibility and analog hardware.

Computers aid design in the petrochemical and other chemical process industries as they aid design in other industry sectors. Software has been developed/and implemented in some Arab countries/ for the pipework design needed in complex process plant,distillation towers,reactors pumps,heat exchangers,flash drums,etc. Software carries out modelling and simulation tasks. One consequence of sophisticated process control technology is that the human operator does not need to understand chemical process in detail and may only be trained to respond to predictable contingencies. Alarm systems need to be designed to present the operator with unambiquous and adequate information.

Micro-based facilities can co-operate with larger computer systems in providing effective process control. For example,mini- and micro--computers have been combined to aid the development and operation of an advanced control strategy for the processing of heavy crude oil. The expansion of computer-aided process control is having far-reaching consequences for production methods, product ranges and employment. The rational response to such circumstances has a political dimension. In some Arab countries /Kuweit,Abu Dhabi,Iraq,Saudi Arabia,etc./ have been installed computer control systems in refineries. Almost all of these systems has been acquired on the typical turnkey basis, what is not recommended for developing countries. Operation and after-sale services and consultancies are considered to be an extremely important factor. Therefore,the countries of the region must exert serious efforts to develop adequate indigenous capabilities.

3.6. MEASUREMENT, TESTING, QUALITY CONTROL

Computer potential is increasingly influencing the design of instrumentation. Microprocessor-based instruments are used in basic research prior to the design of new products,during the design and production process,and after manufacture in such tasks as inspection and testing for quality control. In some sophisticated CNC systems it is possible for the machine axes to be automatically offset and in the light of inspection results to establish a new machine reference with respect to the workpart. The probes can be used to check that the machining tools are in satisfactory conditions.

The use of computers for inspection and testing at many levels /raw materials,workpieces,machines,finished products,process performance. worker activity,etc./ is helping to improve manufacturing productivity and product quality.The majotity of industrial measurement systems may be considered to contain three elements:

- a transducer to convert a physical variable being measured /temperature,pressure,fluid flow,etc./ into an electrical signal. This is usually an analog voltage or current directly proportional to the quantity being measured;
- a signal conditioning element to provide signal amplification. This element usually also filters the input signal to improve the signal-to-noise ratio;
- an output or display element.

The relation between the physical variable being measured and the transducer output is termed the transfer function.Transducers with linear transfer functions greatly ease the task of the signal conditioning elements, but transducers are usually linear only over a limited range/some suffer from ageing/creep/ effects/.

There is still heavy shopfloor reliance on such conventional measuring devices as the micrometers,verniers.plug and gap gauges, slip gauges,dial indicators,etc. Digital measuring equipment has so far made a relatively small impact in this area. It has been suggested that some digital equipment is not sufficiently robust or sufficiently portable for shopfloor applications,though a range of tough,compact microelectronic equipment for factory-floor measurement purposes has emerged lately. The newly emerging CNC multiaxis coordinate measuring machines are offering new levels of inspection versatility and speed.

Automatic test equipment has for several years exploited microprocessors potential, and has itself been directed at testing micros and other solid-state circuits.

Inspection and testing procedures are increasingly benefiting from the development of vision systems. Some of these are being developed in connection with industrial robots,some as adjuncts to traditional inspection equipment in quality control departments. Available devices with the visual function range from simple photo--electric devices / such as photo-diodes and photo-transistors/ to sophisticated pattern recognition systems capable of carrying out fast Fourier transforms. Solid-state image sensors have advanced rapidly in recent years. The development of computer vision systems will ,to a large extent,influence the design of inspection facilities.

The increasing use of computers in automatic tests is paralleled by the increasing availability of robots to carry out remote inspection tasks. This can be important in environments /chemical,thermal, nuclear,etc./ which are hazardous to humans.

Data acquisition is an essential element in effective quality control and other industrial activity.Recently,the data collection systems on the factory floor have massively expanded. The cost of a typical data acquisition system is now fairly evenly distributed among hardware,software development and software maintenance,though it is expected that hardware costs will continue to diminish as a proportion of the total. It suggests the policy for developing countries,when going into this area of computer application.

SUMMARY

Summarizing the chapter,it is safe to predict a growing use of computer-based techniques in all areas of product design and manufacture.Many of the developments in the field of CAD/CAM will derive from general enhancements and innovations in computer hardware and software.Small computers /mini and micro / will become more powerful and high-level languages will continue to be developed for specific design and manufacturing purposes.The trend toward the computer-automated factory has been established in industralized societies / USA,Europe,Japan,etc./. There are general social and economic factors promoting the development of such a factory:

1. The need for greater productivity.
2. The desire to increase machine utilization.
3. The high cost of in-process inventory.

4. The need to respond quickly to customer demand-this means shorter manufacturing lead times.
5. The high cost of row materials and energy-this means that both of these resources must be used efficiently.
6. The trend of the labour force away from production of goods and into the service sector.This means fewer workers in manufacturing,and higher wage rates for those who remain.
7. The demand by workers for more meaningful work.
8. Regulations regarding worker safety,noise,and so on.

The impetus for advances in production automation in developing countries,including those of the ECWA region,depends on how important are these factors in their national economy and particularly in their social life.

4.CONCLUSIONS AND RECOMMENDATIONS

4.1. Because the advanced engineering software is closely related to the area of applications, it is necessary to identify all possible CAD/CAM systems for the products, which are to be produced in countries of the region for the several oncoming years. The most suitable areas are numerical control and factory automation, production control, computer-aided design and graphics, chemical process engineering, robots, assembly and materials handling, measurement, testing and quality control. These applications can be incorporated in industry sectors existing in the region, such as civil engineering and architecture, metalworking plants, shipbuilding industry, petrochemical industry, electrical and electronics industry, automotive industry, communications, etc. Experience accumulated in applying CAD/CAM methods in each industry sector should be unequivocally evaluated on both national and regional levels, and ensuing further steps should be determined in order to achieve qualitative upgrading of computer-based techniques. Special attention should be given to the modular approach towards CAD/CAM development. At present, comprehensive integrated CAD/CAM systems can not be regarded as cost-effective solutions to the regional industries.

4.2. Both the engineering and scientific software available in the region should be cataloqued and arranged according to the area of applications, programming languages used, operating system requirements, and experience gained. It will be a worthwhile effort due to increasing costs of software as a proportion of the whole hardware-software costs/around 70 per cent/. General scientific and engineering software was made several years ago and the software offered now is usually modified and/or reprogrammed versions of the known programs implemented on a new hardware. The efforts can be fully successful when a systematic regional coordination and cooperation will be assured. The basic scientific and engineering software is necessary for engineers in the field of specific computer-based systems, otherwise, the CAD/CAM introduction onto industry level will be unduly prolonged.

4.3. To establish CAD/CAM centres in the region within respective sectors of industry with the following goals:

- implementation of CAD and CAM projects;
- developing the engineering software relevant to specific needs of the plant concerned;

- modification and maintenance of the application software;
- training of the personnel in the area of CAM and CAD systems implemented in the industry sector.

The centres would significantly enhance the regional capabilities to choose,absorb,adapt,develop and optimize technologies that best suit local socio-economic goals of development.
If a research and development centre already exists for a industry sector,the CAD/CAM group may be organized within the R and D centre.
The CAD/CAM projects need not only persons with computer science knowledge,but in the first place persons with a deep knowledge of application areas together with the requisite capability in systems analysis and programming.
A successful software centre relies more on technical experts than any other engineering organization,therefore,it is important to provide career path for technical experts so that they can achive a high social standing without turning into management.
The bulk of the productivity on CAD/CAM project comes from a relatively small number of highly qualified participants /5-10 persons/.

4.4. Wide-scale training programmes on the CAD/CAM technology should be promoted by governmental and other concerned institutions and agencies.The CAD/CAM introduction onto factory level can be jeopardized by the shortage of skilled manpower.
In the frame of CAD/CAM , special attention must be given to the numerical control manufacturing.There are at least several tens of modern sophisticated NC machines in the region, but the adequate NC technology is not introduced into plants concerned.For full utilization of the CAM technology the training process must reach a relatively large percentage of plant's staff.The following functional groups should be included: design engineering ,planning,tooling,production,quality control,and,in the first place, the managerial level.

4.5. Identification of successful CAD/CAM implementations,which could be transported as a model from one to another country of the region,is of very great value.Governmental and UN agencies could facilitate this by creating forums for exchange of experience. It is important for UN agencies to ensure continued availability of expertise,advice,consultancy,and design know-how from developed countries to countries of the region.

4.6. Significant efforts should be taken to include the subjects, interrelated with CAD/CAM technology,in university curricula in the region.This can be the only long-term solution for higher computer education.Usually it is composed of: numerical methods in mathematics,high-level programming languages, simulation and optimization methods,numerical geometry and computer graphics,fundamentals of computer system architecture, finite element methods,production systems and computer-aided manufacturing.These subjects are already in university curricula of many engineering departments in developed countries.

4.7. The recommendations cited may be considered as a brief outline of problems to be solved.It seems that UNIDO and ECWA are the most competent institutions to elaborate detailed, organizational steps and plan of action related to the CAD/CAM development in the region.

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TRAINING PROGRAMME IN CAD/CAM

Supplement to the report
"CAD/CAM TECHNOLOGY IN COUNTRIES OF THE ECWA REGION"

by
Stanislaw Zietarski *
UNIDO consultant

* Technological University of Warsaw /Politechnika Warszawska/
Warsaw, Poland

INTRODUCTION

Developments in CAD/CAM technology will certainly lead to changes in the demand for a skilled manpower. The availability of the appropriate skilled manpower is an important factor in the adoption of these technologies in the region. In order to meet these requirements, initiatives need to be taken by countries of the region and by UN organizations. Assistance from the UN organizations such as UNIDO and ECWA should in general be catalytic - it should help to achieve the industrial stage of the CAD/CAM technology in the region. UNIDO activities related to this area of computer applications are undertaken as part of its efforts to strengthen the technological capabilities-education and training playing an important role in these efforts.

UNIDO can, in cooperation with ECWA, be involved in assisting countries in the region to plan and carry out appriopriate training and development programmes in the CAD/CAM technology with an emphasis on its impact on industrialization. In the early stages this could focus on sharing experience and expertise in building up the institutional structures for training and education in the field of industrial applications of computers. Institutional infrastructure appriopriate to education, research, and development in CAD/CAM technology must be provided in the region. These might involve attaching CAD/CAM laboratories to university - level institutions in different countries, with each laboratory being allocated a clearly defined area of interest in chosen industry sectors. Education and training centres must be equipped with relevant hardware.

An absolute prerequisite for the success of any strategy for CAD/CAM development will be the creation of an awareness at the highest levels, of the value of CAD/CAM as an essential factor in industrial development.

The countries of the ECWA region have special requirements in relation to software - hardware aspects of CAD/CAM. The pace and extent of the diffusion of computer hardware is relatively high in comparison with other regions, but these hardware is not fully utilized. A wide range of computer applications is directly linked to manufacturing, e.g. production management, process control, design, and control of machinery. Most of these systems are supplied on a turn-key basis by a limited number of manufacturers from the industrialized countries. While the hardware costs are going down, the costs of skilled manpower and software are increasing.

There is no reason why the activities making up the bulk of the cost as software development, systems integration, interfacing, installation, applications development, maintenance, user training, etc. should not be done locally on a national or regional basis. It should be borne in mind, that this approach implies orientation of education and training programmes for the region, because indigenous software production is more immediately attractive and cost-effective than hardware manufacture.

1. TRAINING PROGRAMMES IN CAD/CAM TECHNOLOGY

The CAD/CAM technology in itself is so all encompassing that the training programme must of necessity reach a large percentage of a plant's personnel. Therefore, when the CAD/CAM technology is introduced into a plant, a complete training programme is to be not only recommended but considered an absolute must.

Generally speaking, if industry itself does not train or help to train personnel, the necessary skilled manpower will not be available. The shortage of skilled manpower in computer-based techniques is not temporary, and if a plant relies only on its recruiting ability, rather than arranging to train its own personnel, then the whole productivity of that plant is in danger. The first question arising in management's mind is to whom should be given CAD/CAM training, and the answer is: First to management itself - because without a knowledgeable managerial level, full utilization of the CAD/CAM technology is not possible. The special attention must also be given to the design engineering department staff and to the planning, tooling, production and quality control staff.

The programmes of seminars, courses and conferences should concentrate on application - oriented education and on applied research seeking practical ways in which CAD/CAM technology can be utilized most effectively in the region industrial environment. Generally speaking, there are three main goals for these educational and training programmes:

- general training in the development of CAD/CAM technology /usually for a managerial level/;
- retraining of qualified specialists from particular industrial sectors /experienced specialists are introduced and then trained in the concerned CAD/CAM software/;
- general and advanced training of fully qualified CAD/CAM engineers and researchers in a concerned area of industry /for personnel of R and D centres, or CAD/CAM centres, within a specific industry sector/.

In order to meet these goals, an usual approach is to make up the syllabus of the courses from individual, self-contained modules.

It is recommended to use the following modules for the CAD/CAM courses:

1. <u>Fundamental Concepts in Manufacturing and Automation</u>

- basic manufacturing industries;
- general models of production operations;
- economic analysis in production, investment analysis;
- conventional automation, methods of workpart transport, machining operations and assembly;
- analysis of automated flow lines, flow line balancing;
- computer simulation of automated flow lines.

2. <u>Numerical Control Manufacturing</u>

- types of NC systems, applications of NC, the economics of NC;
- Numerical Control programming, manual and computer - assisted programming;
- APT-like languages, postprocessors;
- analytic surfaces and sculptured surfaces;
- CNC, DNC, adaptive control, process optimization;
- programmable controllers, industrial robots, applications.

3. <u>Computer - Aided Design</u>

- modelling and simulation methods;
- design data bases;
- finite-element methods, FEM software;
- interactive graphics, drafting and plotting;
- general - purpose and special purpose graphics software;
- CAD applications.

4. Computer - Aided Manufacturing in Manufacturing Industries

- computer in manufacturing, mainframes, mini- and micro-computers;
- computer programming languages;
- hierarchical structure of computer control in CAM systems;
- production monitoring systems;
- production systems at the operations level, machinability data systems, cutting conditions optimization;
- production systems at the plant level;
- production planning and control, material requirements planning /MRP/;
- capacity planning, shop floor control.

5. Computer - Aided Manufacturing in Process Industries

- computers in process industries, mainframes, mini- and macro-computers;
- process control fundamentals, modelling and analysis;
- transfer functions and block diagrams;
- linear systems analysis, system design;
- direct digital control, analog control;
- supervisory computer control;
- steady-state optimal control and adaptive control.

6. Computer - Integrated Manufacturing

- integration of CAD and CAM systems;
- group technology, parts classification and coding;
- production flow analysis;
- flexible manufacturing systems /FMS/, system components;

- assembly automation;
- automated factory, industrial robots;
- examples of CIM systems.

Each of the modules, excluding "Fundamental Concepts in Manufacturing and Automation", can be exposed to the participants on two levels: general, introductory level and an advanced level with practical extensive exercises in relevant CAM or CAD systems. A unique role, among the modules, plays "Numerical Control Manufacturing", which must be seen as a starting point and a substantial component of any successfull computer application in the industrial environment. It may be assummed, that one competent lecturer can not cover more than two modules on the advanced level.

The suggested duration of the modules:

1. Fundamental Concepts in Manufacturing and Automation		18 hours
2. Numerical Control Manufacturing	general level	45 hours
	advanced level	90 ÷ 130 hours
3. Computer - Aided Design	general level	30 hours
	advanced level	60 ÷ 90 hours
4. Computer - Aided Manufacturing in Manufacturing Industries	general level	30 hours
	advanced level	60 ÷ 90 hours
5. Computer - Aided Manufacturing in Process Industries	general level	20 hours
	advanced level	40 ÷ 50 hours

6. Computer - Integrated Manufacturing	general level	20 hours
	advanced level	40 + 50 hours

The programme of the training course for the experienced specialists from engineering industry of Arab countries, as an example:

1. Fundamental Concepts in Manufacturing and Automation	18 hours
2. Numerical Control Manufacturing	90 hours
3. Computer - Aided Design	60 hours
4. Computer - Aided Manufacturing in Manufacturing Industries	60 hours
6. Computer - Integrated Manufacturing	20 hours
Total:	248 hours

The CAD/CAM course programmes can be designed from the modules to fit various course requirements, which are determined by the course goals and participants' engineering background.