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COMMUNITY
COLLEGE

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COMPUTER AIDED DESIGN AND DRAFTING

ADVISORY COMMITTEE MEETING

November 13, 1997

4:30 - 6:30 p.m.

Room T-6

AGENDA

1. Dinner
2. Welcome and Introductions
3. Review of Minutes of Last Advisory Committee Meeting
4. Review of Minutes of Follow-Up Meeting: Progress Report
5. Current and Future Trends: Feedback from Industry
6. Open Discussion

Other programmers, with specialized knowledge and experience with a language or operating system, may work in research and development areas such as artificial intelligence or CASE.

Job Outlook

Employment of programmers is expected to grow faster than the average for all occupations through the year 2005 as computer usage expands. The demand for programmers will increase as organizations seek new applications for computers and improvements to the software already in use. The rising demand for information, further automation of offices and factories, advances in health and medicine, and continuing scientific research will stimulate the demand for skilled programmers.

One important area of progress will be data communications. Networking computers so they can communicate with each other is necessary to achieve the greater efficiency that organizations require to remain competitive. Expert systems and other artificial intelligence principles and languages will increasingly be used in the years ahead, becoming productivity-enhancing tools available to programmers. Programmers will be creating and maintaining expert systems and embedding these technologies in more and more products. As this trend continues, knowledge of C++ and other object-oriented languages will become increasingly important.

Employment, however, is not expected to grow as rapidly as in the past as improved software and programming techniques, including CASE and 4GL, simplify or eliminate some programming tasks. Someone who can apply CASE tool programming along with design and systems analysis is able to produce applications quickly and more cheaply. Employers are increasingly interested in workers who can combine both of these skills.

In addition, the introduction of data base management systems is allowing users to take over many of the tasks previously performed by the programmer. Greater use of packaged software such as word processing and spreadsheet packages also may moderate the growth in demand for applications programmers.

Although the proportion of programmers leaving the occupation each year is smaller than in most occupations, most of the job openings for programmers will result from replacement needs. Most of the programmers who leave the occupation transfer to other occupations, such as manager or systems analyst. Opportunities will exist throughout the economy, but jobs for both systems and applications programmers should be particularly plentiful in data processing service firms, software houses, and computer consulting businesses.

Because the number and quality of applicants have increased, employers have become more selective. Competition has increased for entry level positions, affecting even applicants with a bachelor's degree. Graduates of 2-year programs in data processing and people with less than a 2-year degree or its equivalent in work experience are facing especially strong competition for programming jobs. Many observers expect opportunities for people without college degrees to diminish in coming years as programming tasks become more complex. Prospects should be good for college graduates who are familiar with a variety of programming languages, particularly newer languages that apply to computer networking, data base management, and artificial intelligence.

Many employers prefer to hire applicants with previous experience in the field. Firms also desire programmers who develop a technical specialization in areas such as structured methodology programming, multimedia programming, graphic user interface, or 4th and 5th generation programming tools. Therefore, people who want to become programmers can enhance their chances by combining work experience with the appropriate formal training. Students have various options: Holding a summer or part-time job in a data processing department, participating in a college work-study program, or undertaking an internship. Students can greatly improve their employment prospects by also taking courses such as accounting, management, engineering, or science—allied fields in which applications programmers are in demand.

Earnings

Median earnings of programmers who worked full time in 1992 were about $35,600 a year. The lowest 10 percent earned less than $19,700, and the highest 10 percent, more than $58,000. On average, systems programmers earn more than applications programmers.

In the Federal Government, the entrance salary for programmers with a college degree or qualifying experience was about $18,300 a year in 1993; for those with a superior academic record, $22,700.

Related Occupations

Programmers must pay great attention to detail as they write and "debug" programs. Other professional workers who must be detail-oriented include statisticians, engineers, financial analysts, accountants, auditors, actuaries, and operations research analysts.

Sources of Additional Information

State employment service offices can provide information about job openings for computer programmers. Also check with your city's chamber of commerce for information on the area's largest employers.

For information about certification as a computer professional, contact:

☞ Institute for the Certification of Computer Professionals, 2200 East Devon Ave., Suite 268, Des Plaines, IL 60018.

Further information about computer careers is available from:

☞ The Association for Computing Machinery, 1515 Broadway, New York, NY 10036.

Drafters

(D.O.T. 001.261-010, -014; 002.261; 003.131, .261 except -010, 281; 005.281; 007.161-010, -014, and -018, .261, and .281; 010.281 except -022; 014.281; 017 except .261-010 and .684; and 726.364-014)

Nature of the Work

Drafters prepare technical drawings used by production and construction workers to build spacecraft, automobiles, industrial machinery and other manufactured products, as well as structures such as office buildings, houses, bridges, and oil and gas pipelines. Their drawings show the technical details of the products and structures from all sides, with exact dimensions, the specific materials to be used, procedures to be followed, and other information needed to carry out the job. Drafters prepare and fill in technical details, using drawings, rough sketches, specifications, and calculations made by engineers, surveyors, architects, and scientists. For example, working from rough sketches, drafters use knowledge of standardized building techniques to draw the details of a structure, or employ knowledge of engineering and manufacturing theory to arrange the parts of a machine and determine the number and kind of fasteners needed. For this, they may use technical handbooks, tables, calculators, and computers.

There are two methods by which drawings are prepared. In the traditional method, drafters sit at drawing boards and use compasses, dividers, protractors, triangles, and other drafting devices to prepare the drawing manually. Drafters also use computer-aided drafting (CAD) systems. They use computer work stations to create the drawing on a video screen. They may print the drawing on paper but also store it electronically so that revisions and/or duplications can be made more easily. These systems also permit drafters to easily prepare many variations of a design.

When CAD systems were first introduced, some thought a new occupation—CAD operator—would result. It is now apparent that a person who produces a technical drawing using CAD is still a drafter, and needs all the knowledge of traditional drafters as well as CAD skills.

Because the cost of CAD systems is dropping rapidly, by the year 2005 it is likely that almost all drafters will use CAD systems regularly. However, manual drafting probably will still be used in certain applications, especially in low-volume firms that produce many one-of-a-kind drawings with little repetition.

Many drafters specialize. *Architectural drafters* draw architectural and structural features of buildings and other structures. They may specialize by the type of structure, such as schools or office buildings, or by material, such as reinforced concrete or stone.

Aeronautical drafters prepare engineering drawings used for the manufacture of aircraft and missiles.

Electrical drafters draw wiring and layout diagrams used by workers who erect, install, and repair electrical equipment and wiring in powerplants, electrical distribution systems, and buildings.

Electronic drafters draw wiring diagrams, circuit board assembly diagrams, schematics, and layout drawings used in the manufacture, installation, and repair of electronic equipment.

Civil drafters prepare drawings and topographical and relief maps used in civil engineering projects such as highways, bridges, pipelines, flood control projects, and water and sewage systems.

Mechanical drafters draw detailed working diagrams of machinery and mechanical devices, including dimensions, fastening methods, and other engineering information.

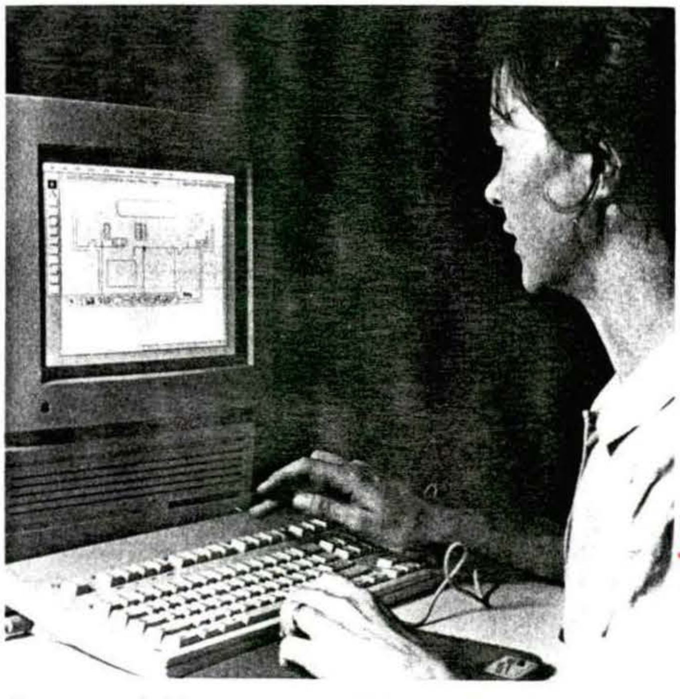
Working Conditions

Drafters usually work in offices or rooms with lighting appropriate to their tasks. They often sit at drawing boards or computer terminals for long periods of time doing detailed work, which may cause eyestrain and back discomfort. Drafters who spend the majority of their time using a computer keyboard for CAD work risk repetitive motion injuries, such as carpal tunnel syndrome.

Employment

Drafters held about 314,000 jobs in 1992. Over one-third of all drafters worked in engineering and architectural services, firms that design construction projects or do other engineering work on a contract basis for organizations in other parts of the economy; about one-third worked in durable goods manufacturing industries, such as machinery, electrical equipment, and fabricated metals; and the remainder were mostly employed in the construction, communications, utilities, and personnel supply services industries.

About 11,000 drafters worked in government in 1992, primarily at the State and local level.



Computer-aided design systems enable drafters to make revisions to designs more easily.

Training, Other Qualifications, and Advancement

Employers prefer applicants for drafting positions who have post-high school training in technical institutes, junior and community colleges, or extension divisions of universities. Employers are most interested in applicants who have well-developed drafting and mechanical drawing skills, a solid background in computer-aided design techniques, and courses in mathematics, science, and engineering technology.

Many types of publicly and privately operated schools provide drafting training. The kind and quality of programs can vary considerably. Therefore, prospective students should be careful in selecting a program. They should contact prospective employers regarding their preferences and ask schools to provide information about the kinds of jobs obtained by graduates, instructional facilities and equipment, and faculty qualifications.

Technical institutes offer intensive technical training but less theory and general education than junior and community colleges. Many offer 2-year associate degree programs, which are similar to or part of the programs offered by community colleges or State university systems. Other technical institutes are run by private, often for- profit, organizations, sometimes called proprietary schools; their programs vary considerably in length and types of courses offered. Some are 2-year associate degree programs.

Junior and community colleges offer curriculums similar to those in technical institutes but may include more theory and liberal arts. Often there may be little or no difference between technical institute and community college programs. However, courses taken at junior or community colleges are more likely to be accepted for credit at 4-year colleges than those at technical institutes. After completing the 2-year program, some graduates qualify for jobs as drafters while others continue their education in a related field at 4-year colleges.

Four-year colleges usually do not offer drafting training, but college courses in engineering, architecture, and mathematics are useful for obtaining a job as a drafter.

Area vocational-technical schools are postsecondary public institutions that serve local students and emphasize training needed by local employers. Most require a high school diploma or its equivalent for admission.

Other training may be obtained in the Armed Forces in technical areas which can be applied in civilian drafting jobs. Some additional training may be needed, depending on the military skills acquired and the kind of job, but often this is gained on the job.

Those planning careers in drafting should be able to draw freehand three-dimensional objects and do detailed work accurately and neatly. Artistic ability is helpful in some specialized fields, as is knowledge of manufacturing and construction methods. In addition, prospective drafters should have good communication skills because they work closely with engineers, surveyors, architects, and other workers.

In 1992, the American Design Drafting Association (ADDA) established a certification program for drafters. Although drafters are not required to be certified, certification demonstrates to employers that nationally recognized standards have been met. Individuals who wish to become certified must pass the Drafter Certification Test, which is administered periodically at ADDA-authorized test sites. Applicants are tested on their knowledge and understanding of basic drafting concepts such as geometric construction, working drawings, and architectural terms and standards.

Entry level drafters usually do routine work under close supervision. After gaining experience, they do more difficult work with less supervision and may advance to senior drafter, designer, or supervisor. With appropriate college courses, they may become engineers or architects.

Job Outlook

Employment of drafters is expected to grow more slowly than the average for all occupations through the year 2005. Industrial growth and the increasingly complex design problems associated with new products and processes will increase the demand for drafting services. However, greater use of CAD equipment by architects and engineers, as well as drafters, is expected to offset some of this growth in demand. Although productivity gains from CAD have been relatively modest since CAD use became widespread, CAD technology continues to advance. CAD is expected to become an increasingly powerful tool, simplifying many traditional drafting tasks. Nevertheless, as in other areas, the ease of obtaining computer-generated information stimulates a demand for more information, so there will continue to be growth in the occupation. Individuals who have at least 2 years of training in a technically strong drafting program and who have experience with CAD systems will have the best opportunities. Although growth in employment will create many job openings, most job openings are expected to arise as drafters retire or leave the labor force for other reasons.

Drafters are highly concentrated in industries that are sensitive to cyclical swings in the economy, such as engineering and architectural services and durable goods manufacturing. During recessions, when fewer buildings are designed, drafters may be laid off.

Earnings

Median annual earnings of drafters who worked year round, full time were about $27,400 in 1992; the middle 50 percent earned between $20,600 and $35,100 annually; 10 percent earned more than $43,500; 10 percent earned less than $15,900.

According to a survey of workplaces in 160 metropolitan areas, experienced drafters had median earnings of about $30,200 a year in 1992, with the middle half earning between about $27,100 and $34,000 a year.

Related Occupations

Other workers who prepare or analyze detailed drawings and make precise calculations and measurements include architects, landscape architects, engineers, engineering technicians, science technicians, photogrammetrists, cartographers, and surveyors.

Sources of Additional Information

State employment service offices can provide information about job openings for drafters.

Engineering Technicians

(D.O.T. 002.261-014, .262-010; 003.161, .261-010, .362; 005.261; 006.261; 007.161-026 and -030, .167-010, .181 and .267-014; 008.261; 010.261-010 and -026; 011.261-010, -014, -018, and -022, .281, .361; 012.261-014, .267; 013.161; 017.261-010; 019.161-014, .261-018, -022, -026, -030, and -034, .267, .281; 194.381, .382-010; 199.261-014; 726.261-010 and -014; 761.281-014; 828.261-018; and 869.261-026)

Nature of the Work

Engineering technicians use the principles and theories of science, engineering, and mathematics to solve problems in research and development, manufacturing, sales, construction, and customer service. Their jobs are more limited in scope and more practically oriented than those of scientists and engineers. Many engineering technicians assist engineers and scientists, especially in research and development. Others work in production or inspection jobs.

Engineering technicians who work in research and development build or set up equipment, prepare and conduct experiments, calculate or record the results, and help engineers in other ways. Some make prototype versions of newly designed equipment. They also assist in routine design work, often using computer-aided design equipment.

Engineering technicians who work in manufacturing follow the general directions of engineers. They may prepare specifications for materials, devise and run tests to ensure product quality, or study ways to improve manufacturing efficiency. They may also supervise production workers to make sure they follow prescribed procedures.

Civil engineering technicians help civil engineers plan and build highways, buildings, bridges, dams, wastewater treatment systems, and other structures and do related surveys and studies. Some inspect water and wastewater treatment systems to ensure that pollution control requirements are met. Others estimate construction costs and specify materials to be used. (See statement on cost estimators elsewhere in the *Handbook*.)

Electronics engineering technicians help develop, manufacture, and service electronic equipment such as radios, radar, sonar, television, industrial and medical measuring or control devices, navigational equipment, and computers, often using measuring and diagnostic devices to test, adjust, and repair equipment. Workers who only repair electrical and electronic equipment are discussed in several other statements elsewhere in the *Handbook*. Many of these repairers are often called electronics technicians.

Industrial engineering technicians study the efficient use of personnel, materials, and machines in factories, stores, repair shops, and offices. They prepare layouts of machinery and equipment, plan the flow of work, make statistical studies, and analyze production costs.

Mechanical engineering technicians help engineers design and develop machinery, robotics, and other equipment by making sketches and rough layouts. They also record data, make computations, analyze results, and write reports. When planning production, mechanical engineering technicians prepare layouts and drawings of the assembly process and of parts to be manufactured. They estimate labor costs, equipment life, and plant space. Some test and inspect machines and equipment in manufacturing departments or work with engineers to eliminate production problems.

Chemical engineering technicians are usually employed in industries producing pharmaceuticals, chemicals, and petroleum products, among others. They help design, install, and test or maintain process equipment or computer control instrumentation, monitor quality control in processing plants, and make needed adjustments.

Working Conditions

Most engineering technicians work regular hours in laboratories, offices, electronics and industrial plants, or construction sites. Some may be exposed to hazards from equipment, chemicals, or toxic materials.

Like engineers, engineering technicians specialize in a specific area, such as mechanics, electronics, or chemicals.

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CAD/CAM CAREERS

Jan Bone

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CHAPTER 1

COMPUTER-AIDED DESIGN AND COMPUTER-AIDED MANUFACTURING: IMPORTANT TECHNOLOGIES

Seat belts fastened, seats in the upright position, tray tables in place and locked, and all carry-on luggage stowed under your seat or in the overhead compartments . . . You've followed the flight attendant's instructions, and you're ready for takeoff on what may seem like a routine flight.

But if you're a passenger in the newest United Airlines jet, the Boeing 777, you and your more-than-400 fellow travelers probably haven't guessed that you're riding in the first commercial jet designed entirely on a computer system, rather than on paper!

The high-tech design/build approach that allowed Boeing to put together a plane with 85,000 major components and more than four million parts without building a full-scale production mockup—a *first* in the company's half-century history—is an offshoot of CAD/CAM.

Computer-aided design, computer-aided manufacturing, (CAD/CAM) and computer-aided engineering (CAE)—separately, or together—are technologies that offer job opportunities in an ever-increasing variety of fields.

At Boeing, for instance, nearly 4,000 engineers worked with production personnel, supplier representatives, and airline workers in 238 "design/build" teams to create the 777. The most complex commercial plane ever built, this twin-engine jet can carry more passengers farther (over 6,000 miles) than any two-engine commercial jet has previously done.

The 777 was designed in a computer system that consists of eight IBM mainframes, 2,200 workstations, and a sophisticated design application (developed by a French company) that lets design engineers create, configure, specify, and check parts at their workstations.

That's CAD.

In a different application, CAD technology allows the United Group's Craig Smith to "show" a Big Three automaker his concept for a point-of-purchase advertising display for a new-car showroom. Up front.

"I can do a 3-dimensional computer drawing of the project and make it photo-realistic," Smith explains. "On the computer, I can show the client how the light in the showroom will interact with the materials we'll use to build the display, whether they're woodgrain or shiny metal. I can take a photo of an actual showroom, including people, and scan that photo into the computer, merging it with the computer drawings of the display."

In short, before Smith's company ever builds the project, the P-O-P designer and the auto company have agreed on what the display will look like in its final end-user environment. CAD has made it possible for them to "see."

Architectural firms like Houston's Archimage say CAD and computers represent a fundamental change in the way architects do their work. To get clients actively involved in the design process, the company makes presentations on a 37-inch monitor, so everyone is directly involved in making decisions. Realistic two- and three-dimensional animation and multimedia production techniques made possible by integrating CAD with computer animation add life to the company presentations.

"Clients can instantly 'see' on a computer the results of changes in lighting or materials," says Archimage founder and president Richard Buday. "They can get the feel of what a building will look like if it is constructed with glass versus brick." Once the firm has completed the design, the architect can take clients on an animated fly-over and walk-through of the entire building, allowing them to explore every element of the design. On the computer screen, they can even open doors and walk through rooms!

CAD—combined with CAM—speeds turnaround time for designers who make presentations to clients. For instance, designers can send CAD files via modem or disk to Envison Design Centers in San Francisco, Los Angeles, and New York. After the files have been received, they're transferred to LaserCAMM, a high-speed, computer-controlled laser cutter, that cuts up to 1/4-inch thick material from any CAD drawing in a DXF format. The system creates high-quality 3D models, prototypes, or visual aids from plastics, wood, matte board, or fabrics. The Design Centers cut the parts within 24 hours and ship the parts back to the client by overnight air.

Today's modern CAD/CAM systems—especially if they're integrated with management and office functions—store an incredible amount of information. Ingersoll Milling Machine Company, a medium-sized manufacturer of low-cost machine tools for the global market, has a computer-integrated enterprise covering a variety of functions: proposals, comprehensive customer master file, order receipt, engineering design, release to manufacturing, procurement of materials, parts machining, subassembly, final assembly, test, field installation, cost tracking, purchasing, inventory, accounts receivable, CAD, CAM, and comprehensive management reporting for all of these functions.

The company has 287 graphics (CADAM) mainframe workstations, and 600 alphanumeric (CICS) workstations. Its computer operators access the 68 *billion* character integrated database on an average of 9 million times on the first work shift every day! The company runs the system on a central processor with 256 megabytes of main memory and a processing rate of 72 million instructions per second.

ADVENT OF CAD/CAM

Four decades ago, the computer field was dominated by large, centralized computing systems. To a certain extent, especially in large companies like Ingersoll, those systems still play a major role. Today, though, at the other end of the spectrum are smaller (but interconnected) personalized systems—a market driven by innovations that brought the personal computer within technological and financial reach of millions.

Computer developments have also changed the manufacturing scene. In today's highly competitive manufacturing environment, increasing numbers of organizations are considering installing automation or expanding its use. Whether a company chooses to set up islands of automation or to operate a dedicated, hard automated assembly line with virtually no human intervention, one thing is certain. Advances in technology—led by the rapid pace of developments in computers—are changing the demand for workers who develop, maintain, and use that technology.

In the late 1950s, manufacturers began to move towards automation by installing numerical control on machine tools. In the mid-1970s, companies like Ingersoll began to install NC machining centers as islands of automation. And in the future, says Ingersoll's George J. Hess, "We're shifting our focus to the effective use of knowledge, the acquisition of knowing, the recording and classification of knowledge, and to the disbursement of it to critical points throughout the entire enterprise. The next step will be a whole new class of strategically important systems that we are unable to handle with today's procedural deterministic programming methods."

Hess brings up an important point when he talks about *the next step*. Today's successful companies are planning ahead . . . working towards time-based competitiveness. In the manufacturing sphere, that means shortening the time required for product and process design engineering and reducing time-to-market through automation.

Given today's global environment, automation can be the key to survival. To be effective, however, automation must be programmable—that is, automation must be flexible enough to perform a variety of tasks. Computer technology and communications technology make this possible.

FIVE MAJOR TECHNOLOGIES

Five major technologies are involved in programmable automation. They are:

Computer-Aided Design (CAD). Simple forms of CAD are used as an electronic drawing board, often by drafters and design engineers. CAD can also help a designer or engineer make changes in an existing product. In more complex and sophisticated installations, CAD is combined with computer-aided engineering (CAE) to help engineers analyze and improve designs, through modeling and simulation, before products are actually built.

Versions of simulation software, such as Centric Engineering System's Spectrum, can solve problems involving multiple types of physics. It's used for tough problems ranging from design of airbags to simulating metal forming processes.

Numerically Controlled (NC) Tools. NC machine tools are devices that follow programmed instructions to cut or form a piece of metal. The instructions tell the machine the desired dimensions and the steps for the process. The term CNC refers to computer-numerically controlled machine tools.

Flexible Manufacturing Systems (FMS). A computer-integrated group of clusters of multiple NC machines or workstations. They are linked together with work-transfer devices, for the complete automatic processing of different product parts, or the assembly of parts into differing units.

Industrial Robots. An industrial robot is basically a manipulator which can be programmed to move objects.

Many countries and users have accepted the definition of the Robotic Industries Association (RIA), a U.S.-based trade association of companies that use or are considering using robotic equipment, as well as companies that manufacture or market robotic equipment. RIA defines robot as "a reprogrammable, multifunctional manipulator designed to move materials, parts, tools or other specialized devices, through variable programmed motions for the performance of a variety of tasks."

Robot technology ranges from simple pick-and-place robots to intelligent robots which can decide actions by means of their sensing function and their recognizing function.

In today's industrial world, robots with grippers perform tasks in such fields as die casting, loading presses, forging and heat treating, and plastic molding. They load and unload other machines. A different kind of robot—one that can handle a tool instead of grippers, or uses its grippers to grasp a special tool—is used in applications like paint spraying; spot or arc welding; grinding, drilling, and riveting in machining.

At Lockheed's giant Sunnyvale, California, plant, robots are used in assembling printed circuit boards. In Japan, robots put tiny screws in watches, tightening them automatically in place. From aerospace plants to automotive assembly lines to appliance manufacturing, robots are helping industry increase production rates while keeping quality control constant.

Robotic Industries Association (RIA), the North American trade group that focuses exclusively on the robotics industry, estimated that in 1993, some 47,000 industrial robots were in use in the United States. Roughly half were being used in the automotive industry. Other leading user industries included appliances, electronics, food and beverage manufacturing, pharmaceuticals, and heavy equipment.

Computer-Integrated Manufacturing (CIM). In computer-integrated manufacturing, programmable automated tools are used for design, manufacturing, and management in an integrated system, with maximum coordination and communication between them. Computer-aided manufacturing (CAM) is just one part of an integrated system; it is with CIM that the most dramatic gains in productivity and cost-savings are being made.

THE CAD/CAM/CAE INDUSTRY

What do experts think about the future of technologies like CAD and CAM? More to the point, what industries are using them, and how are those industries doing? Answers to those questions will affect your chances of getting a job.

One way to keep up with business forecasts for selected industries is to read the *U.S. Industrial Outlook,* a comprehensive, easy-to-use reference book that gives you an overall picture of more than 300 industries. Issued every two years, this reference tool is sold through the U.S. Government Printing Office, Superintendent of Documents, Mail Stop: SSOP, Washington, DC 20402-9328. The book describes domestic and international markets, and forecasts growth for the year of publication, as well as for the long term. Tables and charts illustrate industry revenues, employment, production, market share, and trade patterns.

Four major sectors make up the computer-aided design, computer-aided manufacturing, and computer-aided engineering industry. They are:

Mechanical CAD/CAM/CAE—Involving tools used to design, analyze, document, and manufacture discrete parts, components, and assemblies.

Electronic Design Automation—Involving tools used to automate the design process of a variety of electronic products.

Geographic Information Systems (GIS)—In which users capture, edit, display and analyze geographically referenced data.

Architectural, Construction, and Engineering—Computer-aided software used by architects, contractors, and plant and civil engineers to aid in designing and managing buildings and industrial plants.

Using information from Dataquest, a market research firm that tracks the CAD/CAM/CAE industry, the 1993 *U.S. Industrial Outlook* forecasts the 1996 world market for hardware, software, and services at $21.05 billion . . . up from $15.3 billion in 1992.

In 1992, the CAD/CAM/CAE market for North America ($5.14 billion) represented just over one-third of the world's total. Europe (at $5.68 billion) was 37 percent; Asia (at $4.1 billion) was 26 percent; and the rest of the world was $343 million.

The 1992 figures showed a slight growth in mechanical CAD/CAM/CAE software (compared with 1991 revenues). Many engineers, designers, and architectural drafting personnel use this software; it's important in the design, engineering, and manufacturing of aircraft, automobiles, and consumer goods. World revenues from this software are expected to reach $2.57 billion by 1996—a 5.2 percent growth from 1992.

Electronic design automation (EDA) has several segments: electronic computer-aided engineering, integrated circuit layout, and printed circuit board multichip module. Although the market for electronic design automation (EDA) fell 7 percent in 1992, compared to 1991's figures, sales of software for floor-planning, and automatic placement and routing systems are projected to grow. By 1996, Dataquest predicts worldwide revenue for EDA software at $1.8 billion, up nearly 10 percent over 1992.

GIS/Mapping software (which often uses CAD technology for basic drawing), combines graphics, computer images, and database management software to map or analyze geographic and demographic information. A GIS program usually contains a series of digitized maps based on a database of data and measurements, information about relationships among the data, and a database of alphanumeric (letters and numbers) data that describe features of map areas, lines, or points. Although the U.S. government is the single largest user of the technology, gas, water, and electric utilities, and the petroleum industry, also rely on these programs. This portion of the CAD/CAM/CAE software market is projected to reach $1.3 billion in 1996—*a 20 percent growth over 1992 revenues.*

Architectural, engineering, and construction software (AEC) will also have significant growth, according to Dataquest predictions. Worldwide revenues for this market segment should reach $1.2 billion in 1996, up 14.5 percent over 1992. In 1992, however, AEC software was the fastest-growing area of the CAD/CAM/CAE industry. Increasingly, the U.S. government is demanding that small commercial developers provide it with electronic design data for government-contracted building projects.

CAD/CAM'S FUTURE

While no single source can accurately predict economic activity, you can use the *U.S. Industrial Outlook* to see how experts view the future.

If, for instance, you're thinking of working in CAD/CAM in aerospace, you'll learn that the aerospace industry is expected to decline as a result of the downturn in defense spending. If you're looking at CAD/CAM in the automotive industry, you'll find that the General Motors, Ford, and Chrysler have together established a research and development consortium: the CAD/CAM Partnership. The Partnership is developing generic technology to help bring vehicles to market sooner.

If you're considering CAD/CAM in the printed circuit board industry, you'll learn that in 1991, there were 70,000 jobs with PCB producers and 80,000 jobs with electronic contract assembly firms—many of which provide design services that traditionally use CAD technology. In addition, there are hundreds of thousands of jobs generated by the related material supplier industries and the original equipment manufacturers (OEMs) who make or assemble their own printed circuit boards. PCBs (with mounted components) are a basic building block for computers, consumer electronics, automobile controls, and industrial and military electronic systems. And in 1992, 70 percent of the boards assembled in the United States were produced with automated equipment. Automation will play an even greater role in PCB manufacturing in the future, as companies attempt to cut down their labor costs to stay competitive with offshore producers.

CAD is an essential part of a new technology—Rapid Prototyping & Manufacturing—that's helping industries increase competitiveness because it saves costs and time. RP&M is a vehicle for turning basic research and design work into finished products faster, with higher quality, and at lower cost. The geometric descriptions required for current RP&M equipment are provided by CAD systems, primarily using CAD software that can create closed models quickly and easily.

SCOPE OF THIS BOOK

Because the technology involved with programmable automation is so complex, and changing so rapidly, this book will deal with opportunities in just two main areas: Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) and will touch briefly on robotics. *Opportunities in Robotics Careers* (2nd ed., 1993), another book by the same author in VGM's Career Horizon series, covers robotics in more detail.

Within the limits of either book, it's impossible to cover the field comprehensively. Instead, material about the technologies, stories of people who are currently working in the fields, and information on schools and training, associations, and periodicals will help you learn where to find out what you need to know.

Do *you* want a job in computer-aided design or computer-aided manufacturing? Can you get one?

These are the questions that this edition of *Opportunities in CAD/CAM* tackles. There are no easy answers in today's job market. The global marketplace, the downturn in defense spending, and the economics of the worldwide recession of the 1990s all play a part in *your* job chances. This book, however, will give you information about various components of the CAD/CAM industry. It will give you places to go for more details, tell you how to find and use sources, and (through personal vignettes) let you know how a few people in the industry view their jobs.

One thing is certain—CAD/CAM is exciting! That's what industry veterans say. Both Chris Kidd (who used CAD technology to design cosmetics displays for Procter & Gamble Noxell's Division and a merchandising system for Kiwi shoe products), and Peter Ruszel (who uses CAD-created drawings in his shop for production purposes, interfacing his CAD system with a numerically controlled router) feel computer-aided design and manufacturing are special.

These technologies have their own special character, values, and opportunities for those who work in the industry and love it.

Maybe CAD/CAM will be special for you, too.

CHAPTER 2

HOW COMPUTER-AIDED DESIGN WORKS

The computer equipment and software sectors span seven specific industries. Computer equipment industries are electronic computers (SIC 3571), computer storage devices (SIC 3572), computer terminals (SIC 3575), and computer peripheral equipment not classified elsewhere (SIC 3577). In computer software, industries are computer programming services (SIC 7371), prepackaged software (SIC 7372), and computer integrated services design.

The U.S. government says CAD/CAM/CAE is one of the most dynamic segments of the overall computer equipment. But CAD itself isn't new. In fact, it's been around for over 30 years. In the late 1950s and early 1960s, researchers working on interactive computer graphics began to use computer screens to display and manipulate lines and shapes instead of numbers and text. By 1963, the Department of Defense had funded a project, SKETCHPAD, in which users at the Massachusetts Institute of Technology could draw pictures on a screen and manipulate them with a "light pen"—an object shaped like a pen that was wired to the computer, and located points on the screen.

(Interestingly, pen-based personal computers, introduced to the market in 1989, reached a $100 million market by 1991, with over 100 U.S. companies developing software and hardware for pen-based systems. Pen-based technology is becoming integrated into laptops, notebooks, and personal digital devices. Today, all these systems use a graphical user interface—symbols that identify keyboard functions.)

CAD/CAM: FEATURES, APPLICATIONS AND MANAGEMENT

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Testing is a major part of software development. You cannot be sure of the correctness of any sequence of instructions until the computer has run through them and the result it obtains has been checked. But only one of the many alternative paths can be followed each time the program is run. Although the programmer runs tests which make the program take as many of the possibilities as he can, there will always be some paths unexplored. Of these, one or two will have mistakes in them. After testing, the program goes out to the users who run it over and over again. Eventually, a user puts in a particular set of data which takes the computer down an untested path in which there lurks a mistake and suddenly the program fails. We shall be returning to this matter later when we discuss the reliability of software.

CAD is a very complex application of computers to be placed in the hands of those who are not trained computer professionals. In this chapter we have given a simple picture of how computers work and the particular strengths and problems that result from the way they work so that informed decisions can be made to obtain the best use of the technique.

EXERCISE

Describe the ways in which computers are similar to and the ways in which they differ from human thought processes.

Chapter 2 CAD/CAM and its value

CAD/CAM SYSTEMS

CAD stands for Computer-Aided Design. We can think of a number of ways in which computers could aid designers. These are:

1. Performing design calculations
2. Producing and managing parts lists
3. Storing and retrieving design information
4. Producing drawings
5. Producing programs for numerically controlled (NC) machine tools

Design calculations and parts list processing were the first applications. They were fairly obvious things to use computers for since they involved processing well organised data in well defined ways and the data was just text and numbers.

The use of computers for information storage and retrieval is sadly neglected. Although designers spend a significant amount of time searching for data on standards, test results or the characteristics of components, computer-assisted information retrieval has still not been applied to any great degree. This may be because the data is not very well structured and the procedures not well defined. Nevertheless, the techniques for storing and retrieving large amounts of unstructured information are well known to librarians and information officers who have developed advanced computer software for the purpose. For some strange reason this technology and experience has yet to be applied to the smaller world of the design office.

The production of drawings, designs and NC programs using computer aids, which is the subject of this book, seems to have become the activity that many people mean by the term CAD. This is probably not so much on account of its usefulness as of its spectacular nature and the misconception that because drawings are what come out of a design department the designers spend all their time drawing. The following similar abbreviations are currently in use:

CAD Computer-aided design

CAE Computer-aided engineering

CAM Computer-aided manufacturing

As can be seen from their full names, they refer to the use of computers to assist in the three activities respectively. In this book we shall restrict ourselves to the facilities which are currently provided on what are usually called CAD/CAM systems. Without wasting space on what might be the precise definition of the term "CAD/CAM" we can characterise the equipment sold under this description as really geometric data processing systems for engineering. They rarely handle non-geometric data except in association with geometric data, they do not handle manufacturing data except that which is directly derived from the geometric data, they are used almost exclusively by the engineering department and they usually reside there.

ELECTRONIC PENCIL OR PRODUCT MODELLER?

CAD/CAM has been sold principally as a way of increasing "productivity" in the Design Department. This emphasis has unfortunately led to a misconception of the nature of CAD and obscured an important benefit with the result that many users do not take full advantage of it. On the surface of it CAD looks very much like a super electronic pencil - a kind of graphical word-processor with all sorts of ways of producing lines on paper very quickly. But below the surface something much more significant and very different from making lines on paper is taking place. The computer program supporting the graphical effects is doing very precise calculations and storing the location of each point and the parameters of each line to a degree of precision only possible with a computer. Thus, if the designer draws two parallel lines 20 mm apart, they are recorded by the computer program in its data area (i.e. the CAD drawing) as 20.0000 mm apart and with an angle of 0.00000°. This is different to a paper drawing where the lines will be 20.1 mm apart because the designer cannot position his pencil more precisely than 0.1 mm.

The accuracy to which the data is recorded is actually higher than can be achieved in the workshop for most CAD systems. The result of all this is that the data represents the real world far better than the scaled drawing on paper attempted to, and in fact better than the manufacturing process will eventually achieve. Far from being an alternative to a piece of paper, a CAD drawing is a model of the actual product being designed. Because of this the designer can analyse it for clearances, volumes and surface areas etc. The drawing becomes what the paper drawing attempted to be: a truly precise definition of the product.

Now although CAD is able to be precise it will not be precise if the designer still treats the screen as a sheet of paper. If two hole centres are supposed to coincide the designer can either locate one point over another by positioning his cursor by eye or he can ask the CAD program to make the two points coincide. The results in either case may look the same but only one is a precise model which will give correct answers for analysis.

THE BENEFITS OF CAD/CAM

CAD gives benefits in three areas:

1. Quality of design

2. Design labour

3. Lead time

Better quality is obtained in two ways. Firstly, the overall accuracy of the design is improved so that less errors are discovered when it is implemented. Secondly, a better product can be designed. Labour can be reduced in two ways also: firstly, the time taken to generate or modify lines on paper is reduced and secondly, the labour required in other parts of the company to extract the information needed from the design can be reduced. Finally, the lead time is reduced because it takes less time to produce drawings.

Going into more detail the overall accuracy of the design is better because a CAD "drawing" is actually a precise mathematical model of the real object being designed. A paper drawing was to some extent a model of the real object because it was drawn to scale but the accuracy of the representation was severely limited by the quality and thickness of the pencil lines. In a CAD drawing, every point has a very precise pair of coordinates so that the distances between points and the lengths of lines etc. can be calculated exactly. Two advantages follow. Firstly, the designer can get the software to give him precise information about his design at any time. In particular he can find out clearances which would be invisible on a paper drawing. This helps in developing his design. Secondly, the "drawing" becomes a complete and unambiguous statement of the design on its own. This is particularly apparent when dimensioning. The computer itself writes the dimension over a line by calculating the actual length between the points at the ends. In a paper design the length has to be remembered or calculated from other design data. The dimension only represents the distance the designer intended if he takes care.

But it is not only in the geometric data that a CAD drawing can become a complete definition of the design. The large size of present-day computer storage means that the drawing can hold much more data than a sheet of paper. As much qualitative, textual non-geometric data as is needed can be held along with the geometric data. The processing ability of the software means that, although a very large amount of data is present, only that required for the particular purpose in hand is displayed at any one time, thus avoiding the confusion you would get with a large sheet of paper cluttered up with printing.

So far we have only considered the quality of the drawing as a definition of the design. But the thing itself can be designed better. The precision of the design allows accurate design calculations to be made by the computer and, because they are done faster with less human effort, more alternative cases can be examined in the time available. The speed with which modified versions of a design can be produced also allows more options to be examined in the time available. Besides this there are certain things which are almost impossible to define on paper. Complex doubly curved surfaces present great difficulties simply because of the limitations of representing three-dimensional objects on paper. CAD enables them to be defined precisely and visualised easily as can be seen in Figure 4.1 on page 32. Another example is provided by integrated circuits where the number of components on the chip would be just too big for a sheet of paper.

Turning now to the labour and time-saving properties of CAD the work in producing a drawing is reduced simply because an engineering drawing is composed of many almost identical simple outlines. With CAD, a copy of an outline can be used again in another position. New outlines can be produced by transforming previously drawn outlines with magnifications and rotations. In the same way the work in modifying an existing design is considerably reduced by using these transformations.

But it is not just in the Design Department that labour can be saved. CAD/CAM provides potential labour savings in other parts of the company as well. This comes about because of a combination of two factors. Firstly, a CAD design is readable by other computers and secondly, it can be a complete and precise definition of the product in a way that a drawing cannot be. Complete because the CAD "drawing" can hold as much geometric and non-geometric data as is needed and precise because the geometric data is held as numerical values. The computers used in other departments can therefore read the design, extract the

relevant data and then process it into the form they require, thus saving clerical effort and avoiding clerical error.

We have outlined three areas of benefit: quality, labour reduction and lead time reduction. Which of these three areas of benefit is the most profitable? The factor most often used for the economic justification of CAD is that of labour reduction or productivity. This is probably because it requires expensive capital equipment in a department which previously used quite inexpensive equipment - drafting machines and boards. Furthermore, the equipment is revolutionary, dramatically changing the way designers work. The expense and the lack of precedent mean that a thoroughly credible case for the purchase has to be made in advance, leading to the need to project quantifiable savings.

But although the productivity case is impressive because numbers can be quoted and precise-looking cost-benefit calculations done, it is not a good one. To start with, the productivity is only obtained for the time actually spent putting lines down on paper. Observation of designers actually at work reveals that only a part of the designers' time is spent in this activity. They spend significant amounts of time on other things such as looking up specifications and standards, doing calculations and conferring with colleagues. For example, a recent study on one firm showed the distribution of time in a Design Department outlined in Table 2.1. This means that any productivity gain which might be obtained from the CAD/CAM system is diluted by the other activities: in the example given by around 70%. The productivity case can be further weakened by the rather low gains obtained in certain areas. For instance, in original mechanical design it is normally less than 2:1 so that one person combined with a CAD/CAM system produces a little less than that produced by two people. To get a net financial gain the equipment would have to cost significantly less than one person to run. The productivity gain would be marginal but with care, careful choice and efficient use, one could get the equipment at least to pay for itself. However, there are certain activities where clear gains can be obtained and the productivity case is strong. These are parameterised drawing, where the designer supplies a few parameters and the system produces a drawing or a set of drawings in return, and the well established area of electrical draughting and printed circuit board design. The conclusion to all this is that one has got to work hard (or cook the figures!) to present a good productivity case.

Though not quantifiable, a far better case comes from considering the effect on quality. Here, substantial gains are possible. Taking the improvement in accuracy, a design is issued, and arising from it materials are purchased, metal is cut and labour is expended. The discovery and correction of errors becomes increasingly expensive as time goes on. There is thus a high value on avoiding errors in the design. The errors need not

Table 2.1 Distribution of time in a Design Department

Activity	% of day spent	
	Designer	Draughtsman
Geometric manipulation	27	37
Searching for drawings	9	30
Calculations	30	3
Looking for written data	13	14
Internal meetings	5	3
Text creation	7	5
Personal	9	8

be just slips in dimensioning which are usually picked up in the checking process but clashes between components due to an inadequate appreciation of spatial relationships or due to piece parts being designed with inadequate reference to the original layout design.

Then there is the opportunity to design a better product. In commercial competition, a better product can radically change the fortunes of the whole company simply by tipping the competitive balance, whether it is better because of its performance or because it is cheaper to manufacture.

A good case can be made on lead time reduction for companies in the capital goods business where contracts for specially designed equipment are obtained by competitive tender. Presentation, timeliness, responsiveness to customer requirements and a competitive time scale are all factors made available by CAD/CAM and they can confer large benefits by tipping the balance.

To sum up, the biggest benefits are to be obtained from the various quality improvements possible although these are not quantifiable. For some operations, significant labour savings are possible and there will be certain companies where the lead time reduction is the main factor.

THE DISADVANTAGES OF CAD/CAM

The combination of hard selling and novelty has resulted in a certain amount of hype being applied to the subject. It is therefore important to look at the pitfalls.

1. There is the high initial cost. This is composed of two components: the obvious purchase price and, not nearly so obvious but very important nevertheless, the hidden cost entailed in the initial inefficiency produced by staff having to use radically new methods and skills. The purchase price can be avoided by using a bureau service but the inefficiency cannot be avoided in any way. It can be reduced by choosing a system with a good user interface which will reduce learning time.

2. There is the running cost. Like the initial cost this has both a visible and a hidden component. The visible component is the maintenance required on the computers, air conditioning and software. All of these can be reduced with careful management and good judgement to balance risk against cost, since all maintenance contracts are very much like insurance policies. The hidden component is the additional time required to manage the installation, which can also be minimised with care.

3. There is the effect on working relationships. A new technology is being introduced. It may lead the management to decide that it needs to bring in specialist knowledge in the form of a CAD/CAM manager. How does his role fit in with the role of the existing supervisor who no longer completely understands the tool he is using but has to retain the respect of his subordinates? What is his relationship with the supervisor? Does he advise or does he provide a service? What if the supervisor, being older, has difficulties in understanding the new tool and finds that some of his younger subordinates understand it better?

4. There is the danger that certain kinds of design cannot be done on the system because it lacks particular features overlooked during the initial evaluation. In this connection it is worth noting that there are many activities in the design process which cannot be done on computers at all, principally because the variety and nature of the data being manipulated is beyond current software. Clarke elaborates on this in Reference (1).

5. It is unfortunately possible to procure a software package that is always breaking down because of poor quality programming and testing or insufficient exposure to use in the field.

6. The following two features of a CAD/CAM system make it less suitable for early conceptual design. It demands precise numbers and the size of the screen prevents the designer from seeing the whole design at full scale, thus preventing him from using his judgement about sizes.

EXERCISE

Some years ago a CAD vendor used the slogan "We sell Productivity". Is this a good description of CAD? If not, what would be a better description?

Chapter 3 The graphics screen

GRAPHICS DISPLAY LIMITATIONS

The graphics screen is by far the most critical part of the whole CAD/CAM system. Computer hardware technology and the software techniques it supports are now well up to the task they have to perform on price and performance and both technologies continue to develop. Compared with the drawing board and the paper it replaces, however, the graphics screen still has deficiencies. To start with, it is so very much smaller than the drawing board. Figure 5.1 on page 44 shows a graphics screen in use. The size might be increased by some kind of projection system but if you did this you would not get a picture which was any easier to use, because it would be just a coarser picture. The problem is not in fact the size. The electronics which generates the picture on a display treats the screen like a rectangular array of squares to be filled in with black, white or a colour. Each square is called a *pixel* and is the smallest possible point which can be displayed. The number of pixels in the array is limited by fundamental characteristics of the circuitry. Current devices can achieve screens with about 2000 pixels from one side to the other and a corresponding number from top to bottom. Analysing an A0 sheet of paper in these terms, the smallest dot possible is about 0.2 mm across. The width of the paper is about 1180 mm so that there are about 5900 "pixels" from one side to the other, which means an A0 sheet of paper can hold three times the detail of a high resolution cathode ray tube (CRT) display.

But besides its better resolution, paper can be viewed comfortably in a wide range of lighting conditions, and the contrast remains high under all lighting levels and there is no glare. CRT displays, on the other hand, require carefully adjusted lighting levels and the glass envelopes they use catch reflections of ceiling lights and other bright surfaces so as to cause uncomfortable bright spots and glare.

As a consequence, one should not skimp on the graphics screen when selecting equipment. There are many software features one can do without but one cannot do without a good quality graphics screen. Obtain as high a resolution as possible and make a critical assessment of the quality of the picture, which can differ between screens of the same resolution. Picture quality is discussed later in the chapter.

Visualisation is not only needed in sales, it is often needed for communication within a company itself: for supporting proposals to higher management or assisting installation or manufacturing departments (particularly for complex pipework). Solid modelling should be considered as an alternative to industrial scale models of process plant for deciding if a proposed design is convenient to operate and maintain. It is possible to locate the eye anywhere inside a solid model. This cannot be done in an industrial model.

Analysis

The advantage that solid modellers have over surface modellers is the vastly greater range of complex shapes possible, including solids with empty space within them. As the result is a true solid and not just a volume enclosed more or less by surfaces the accuracy of the calculated volume, surface area, centroid position etc is assured.

Clash detection

Because solid modellers can show the shape and position of and calculate the volume of any portion of one solid that overlaps another solid they are uniquely suited to finding and correcting clashes in a design.

EXERCISE

What are the strengths and weaknesses of solid modelling compared with surface modelling?

Chapter 16 Numerical control program generation

Numerically controlled (NC) machine tools arise as a result of putting accurate digital measuring devices on the movements of machine tools and using electronically controlled motors to position them. Numbers coded into electronic signals can then position spindle and workpiece precisely without a human operator. If these signals are recorded on tape with other codes to activate the cutter motor and any auxiliary devices, clamping devices etc then the entire cycle of the machine can be controlled by a tape. Which codes achieve what is decided by the designer of the machine tool control circuits and can be different for different models of machine. The wide use of NC machine tools led to the development of languages for specifying the program of the cycle independently of the particular codes required for a particular machine. Using these languages, NC machine tools are programmed like a computer, the work being done by a part programmer who studies the drawings of the component and, using his knowledge of machining practice and the machine tool in particular, writes a program for the machine in the language. The program is compiled and the result is a cutter location file which is still independent of the particular codes of the machine tool. This file is then converted by a program written specifically for the machine, known as a post-processor, into the particular codes it requires. Figure 16.1 illustrates the process. For a fuller treatment of NC programming see Reference (11).

Various part programming languages have been devised from time to time. The one most widely used is APT. It is now incorporated into an international standard (Reference (12)). Numerous sub-sets of the language have been developed for various purposes.

The cutter location file is literally a sequence of cutting tool positions held in binary numbers. The logical structure of the file has been standardised (References (13) and (14)) but the actual physical format will vary from one part programming system to another. For example, a floating-point number may occupy 4 or 8 bytes depending on the software producing it. As it is in binary it cannot be printed out as such although it is frequently processed on to the screen or printer via a utility program. The important difference between cutter location code and part program code, besides one being in binary and the other in text, is that the part program works at a much higher level. In other words, where the part

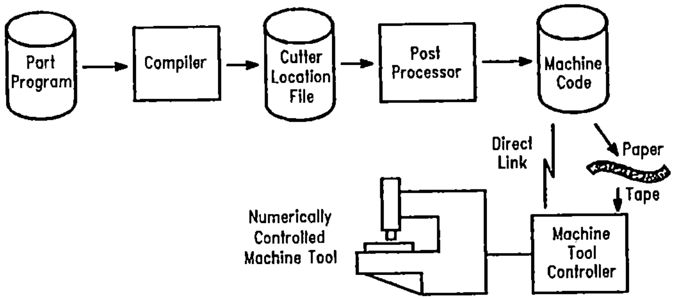

Figure 16.1 Numerically controlled machine tool programming

programme may have one statement requiring that a pocket be machined out, the corresponding cutter location code will contain all the positions of the cutter as it goes round and round the pocket.

Machine code is the actual sequence of codes read by the machine tool controller. Like the cutter location code, it has become standardised also, the form eventually adopted being the "word address format" (see References (15) and (16)). Despite the standardisation, machines still vary over what they require from the machine code in, for example, the number of decimal places used for coordinates or the way of doing circular interpolation. Machine tool suppliers may invent new uses requiring new codes or there may be no suitable codes for, say, pocketing routines in the machine tool controller. It is for this reason that the cutter location code has to be processed by a post-processor which is specific to a particular model of machine controller. Because of the many machine controllers produced it is always a problem finding post-processors to serve the particular controllers in use by a company, and so a CAM system is often judged by the extent of its post-processor library. This will be discussed in more detail later under the topic of selecting CAM software.

With the reducing cost of processing power there is little reason why the machine tool controller should not accept a higher level of language and some controllers have been produced which will accept a cutter location file directly as input. A new standard (known as BCL) has been produced for this purpose (see Reference (17)).

LINKING CAD TO CAM

If the drawing of the part is digitally encoded because it has been produced on a CAD system there is the opportunity to convert automatically the CAD drawing into a part program. You might think that as a result there would be no need for a part programmer as all the information is present. Unfortunately, it is not as simple as that.

A machine tool program includes the following types of information:

1. The path the cutting tool follows when cutting.

2. The path the cutting tool follows before and after cutting which must avoid the clamps holding the workpiece in position.

3. The speed with which the cutting tool moves which must be chosen in relation to the quality of the finished item, the load the machine tool can stand and the life expectancy of the cutting tool.

4. The sequence of passes where the complete job requires several separate passes.

5. Activation of auxiliary devices.

The only type of information the CAD drawing can possibly supply is the first in the list above: the path the cutting tool follows when cutting. The other four types have less to do with the actual shape of the component, being determined more by the characteristics of the particular machine to be used.

Even then the path of the tool when cutting is not determined entirely by the shape and dimensions of the component as given in the CAD drawing. Firstly, the component is rarely produced in one operation. There can be several intermediate operations as metal is progressively removed. Each stage may involve repositioning the workpiece on the machine bed, for example to machine the underside. None of the intermediate stages are drawn by the designer yet each produces a separate physical object for which a cutter path has to be generated. The intermediate shapes are determined by purely production considerations such as the balance between throughput and quality and the shape of the blank at the start.

Secondly, no product has a single set of dimensions. The drawing does not represent a single unique object. It represents a quantity of almost but not exactly identical objects: a population of objects. That is what tolerances are for: they specify how much variation is permissible within the population. But the geometry in a CAD drawing is that of one unique object corresponding to the nominal dimensions. Although tolerances appear in the drawing they are only text and are not held in the data in the same way that the coordinates of the vertices are held, and are not therefore usable by any automatic part programming system. All that NC path generation software can read from the drawing is the geometry of this unique nominal object. The designer might as well print "or thereabouts" after each dimension as far as NC path generation is concerned.

Once programmed, the NC path cuts an object upon which the actual variations and errors of the cutting process between one object and another will be superimposed to produce the population of production components. But will this actual variation meet what the designer has specified? Only if a human being has read the drawing and interpreted the tolerances, using his knowledge of the machine tool, into suitable feed rates and cutting depths. But what if the cutting errors come out equally spaced either side of the nominal dimension when the designer has specified tolerances which prohibit any divergence below it? An automatically generated path will be no good and human interpretation and intervention is needed. An important factor in CAD/CAM implementation is ensuring designers produce CAD models with dimensions at their mean values.

Lastly, machining experience is needed to determine the order of cuts. Many possible sequences of cuts can turn a particular blank into the desired result but the optimum sequence requires experience. Designing it automatically is beyond current practical computing techniques.

It is clear that if automatic NC path generation is to be employed then designs must be done specially for it. Anyone who talks glibly of just feeding a CAD drawing into NC path generation software is either ignorant of the realities of machining or trying to sell you something!

CAD FACILITIES FOR NC

Having noted the things a CAD drawing cannot contribute to a part program we must nevertheless admit that the geometry accounts for a large part of the information in the part program and this the CAD system can supply. Because of its numerical nature it is more open to human error in transcription so there is a distinct advantage in reading the geometry automatically from the CAD system. Thus, although the CAD drawing cannot be automatically turned into a finished part program, it can provide a large part of the data needed. The other information must come from people with manufacturing and machining experience.

The simplest provision a CAD system can make for NC program generation is just to output to a file the geometry of any line or surface selected by the user. The file is then input to a separate specialised NC program. Such an approach makes sense as the program will often be generated in a separate department which will prefer its own choice of software. However, many systems like to offer a complete package and this makes sense as the kind of facilities useful in defining a cutting path have much in common with those for defining geometry.

The main function an integrated CAD/CAM package provides is determining the path the cutting tool must follow in order to produce the shape defined in the CAD drawing. Having determined the path the software will usually draw it on the screen to allow the user to assess it visually. When satisfactory it will then be output to a file either in the form of one of the NC programming languages or of a cutter location file.

In determining the cutter path, several things have to be taken into account. It is the path of a particular point in the cutting tool since the tool is a solid object. As the tool moves, it sweeps out a closed volume in space and the shape produced is the result of subtracting this volume from the material being cut. To generate the path, one has to work backwards from the shape presented by the CAD design to the path which will produce it. Generally, the tool has a cylindrical or spherical shape and so the calculation is largely a matter of offsetting the tool centre from the desired surface by the tool radius. Performing these calculations is well suited to CAD software and provides a valuable facility, particularly where complex three-dimensional curves are involved. Having said this, there are still problems which require human intelligence to solve when the surface being cut is so concave that it interferes with the tool.

Another important facility is in determining the pitch between successive passes through the material. To cut a surface, whether plane or curved, the tool has to follow a series of parallel paths. If the tool is cylindrical or spherical, a little cusp or scallop of material is left standing between adjacent paths corresponding to the intersection of the two circular cross-sections of each path. The software can calculate the pitch between paths for the desired height of scallop.

NC software can be classified according to the limitations set on the path which can be generated. 2D software generates a path on a specified plane and can be used for lathes, punches and flame cutting. 2½D software fully controls the path in two dimensions but only makes step changes in the third dimension. Full 3D three-axis software generates a path moving smoothly in three dimensions. Multi-axis software caters for machine tools in which the orientation of the tool axis can alter as well as its position. Using these machines with the extra control (up to six axes) it is possible to generate virtually any surface shape.

MEETING THE REQUIREMENTS OF MANUFACTURING

The facilities just described fit very nicely into a CAD system and ease the task of generating a tool path. But the NC program has to work in the manufacturing environment. Here, the main concern is to make the most efficient use of particular machine tools with particular resources and to maintain production when machines are taken out of service for maintenance. For the sake of minimising cycle times and to avoid the requirement for too much memory in the machine controller the part program must make as much use as it can of the particular subroutines built into the controller for performing such things as area clearance etc. But this can mean that a particular program is only efficient on a particular machine so that switching to another machine requires a new part program. Software which makes it easy to change machines will be an important consideration. Another aspect is the link with process planning systems. The NC program is closely tied in with production routings and a process planning program may need to store, record or register it.

It is therefore very important for production staff to evaluate the CAM end of a CAD/CAM package if one is being considered or to ensure that if the part programming department is going to use its own separate NC package or CAD/CAM system that the links between the Production and Design Department are satisfactory. Will the CAD system produce a language which the CAM system will accept? How will the file be transmitted between the systems? They could be on a local area network or share the same computer. Alternatively, a diskette or half-inch magnetic tape could be used. Above all, if the supplier cannot provide adequate post-processors, any investment in money or effort will be wasted as the aim of CAM is to cut metal efficiently using the available machine tools. The selection of CAD/CAM software will be discussed further in "Making the case" on page 225.

EXERCISE

Discuss the management issues in introducing CAD/CAM (not just CAD).

Chapter 17 Finite element analysis

AN APPROXIMATION TECHNIQUE

The finite element (FE) method is a technique for solving certain kinds of mathematical problem using approximations. As with all other occasions when approximations are made in mathematical calculations it cannot give a precisely correct answer. The answer is sufficiently correct for practical purposes provided the approximations have been made with an intelligent understanding of the physical characteristics of the problem.

The technique is used where a physical parameter, usually a displacement resulting from a collection of applied stresses, varies smoothly and continuously over the interior of a complicated shape and obtaining a precise mathematical function for the variation is either difficult or impossible. The method is closely analogous to approximating a curve using straight lines and suffers from similar drawbacks. The longer the line segments the further they depart from the true curve.

The shape is subdivided into a mesh of small elements with simple geometrical forms as shown in Figure 17.1. The assumption is then made that the variation of the displacement is a simple function, such as linear or quadratic, of the distance across the element. Using that assumption, the strain energy of the element is calculated in terms of the displacements occurring at its boundaries with its neighbours. The result is a set of relationships, one for each element, involving all the displacements at the edges of the elements. It is known that the displacements will distribute themselves so as to minimise the total strain energy of the shape and the condition for this is that the partial derivative of the total energy with respect to each displacement is zero. Forming these partial derivatives gives a set of simultaneous equations which can be solved. Thus, the problem has been converted into the solution of a large number of algebraic equations. The penalty is the loss of accuracy resulting from assuming a simple function for the distribution of displacement within each element. This loss of accuracy appears in two forms. Firstly, the displacement at any point inside each element is highly inaccurate because a gross

GRADUATE FOLLOW-UP SURVEY
NAME AND LOCATION OF CAD GRADUATES EMPLOYERS
(8-88 through 8-91)

4/90
General Motors
30001 VanDyke
Warren, MI

4/91
General Dynamics
P.O. Box 2074
Warren, MI 48090-2074

4/91
Borg Wagner
Livonia, MI

4/89
Troy Design
Saginaw St.
Flint, MI

4/91
Kelp Corp.
28740 Mound
Warren, MI 48092

4/89
Dell Marking Systems
821 Wanda
Ferndale, MI 48220

6/89
Clawson Tank Co.
White Lake Rd.
Clarkston, MI

4/90
S&H Fabricating & Engineering
26800 Haggerty
Farmington, MI 48333

12/90
Marisa Industries Incorporated
1091 Centre Rd., Suite 130
Auburn Hills, MI 48326

6/90
GM Truck and Bus
660 South Blvd.
Pontiac, MI

4/89
G. Ward Enterprises
13850 12 Mile Rd.
Warren, MI 48093

6/89
Wilson Automation

12/89
General Motors Corporation
CPC- HQ 30001 Van Dyke Ave.
Warren, MI 48090

4/91
GM, BOC Automotive Division
4100 S. Saginaw
Flint, MI 48345

4/89
Engineering Service Inc.
21556 Telegraph Rd.
Southfield, MI 48037

6/90
Redwood Reliance Trailor Manf.
7911 Redwood Dr.
Cotati, CA 94928

4/91
Whitney Designs
Southfield

4/91
Hudson's
Waterford

4/89
Jessup Engineering, Inc.
2745 Bond Street
Rochester Hills, MI 48309

8/91
Modern Engineering
Troy MI

12/90
Chrysler Corp.

4/91
Contract Professionals Inc.
4141 W. Walton Blvd.
Waterford, MI 48239

6/90
General Motors
Warren, MI

4/90
CPI - Modern Engineering
Waren, MI

12/89
General Motors CPC
Warren, MI 48089

4/90
Trans Tube, Inc.
34 W. Sheffield
Pontiac, MI 48340

8/88
(GM) LPL HQ (Tech Center)
30001 Van Dyke
Warren, MI 48090

12/89
Ford Motor Co.
Livonia, MI

SSN RESPONDENTS SOCIAL SECURITY NUMBER

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	65409877	1	2.1	2.1	2.1
	164525569	1	2.1	2.1	4.3
	290304037	1	2.1	2.1	6.4
	290568413	1	2.1	2.1	8.5
	307627505	1	2.1	2.1	10.6
	362609519	1	2.1	2.1	12.8
	362862290	1	2.1	2.1	14.9
	362968747	1	2.1	2.1	17.0
	363627734	1	2.1	2.1	19.1
	363743225	1	2.1	2.1	21.3
	363927594	1	2.1	2.1	23.4
	365583853	1	2.1	2.1	25.5
	366720584	1	2.1	2.1	27.7
	366945119	1	2.1	2.1	29.8
	367824230	1	2.1	2.1	31.9
	368581065	1	2.1	2.1	34.0
	370749354	1	2.1	2.1	36.2
	372744534	1	2.1	2.1	38.3
	372841135	1	2.1	2.1	40.4
	374825286	1	2.1	2.1	42.6
	374904607	1	2.1	2.1	44.7
	376725833	1	2.1	2.1	46.8
	378721589	1	2.1	2.1	48.9
	378862670	1	2.1	2.1	51.1
	379902189	1	2.1	2.1	53.2
	380567154	1	2.1	2.1	55.3
	380761686	1	2.1	2.1	57.4
	380780559	1	2.1	2.1	59.6
	380841107	1	2.1	2.1	61.7
	381901245	1	2.1	2.1	63.8
	382722607	1	2.1	2.1	66.0
	382842265	2	4.3	4.3	70.2
	383728284	1	2.1	2.1	72.3
	383843666	1	2.1	2.1	74.5
	383847382	1	2.1	2.1	76.6
	383865742	1	2.1	2.1	78.7
	384520828	1	2.1	2.1	80.9
	385627218	1	2.1	2.1	83.0
	385944446	1	2.1	2.1	85.1
	386643538	2	4.3	4.3	89.4
	386868292	3	6.4	6.4	95.7
	386883501	1	2.1	2.1	97.9
	549906259	1	2.1	2.1	100.0
	Total	47	100.0	100.0	

Valid cases 47 Missing cases 0

```
GET FILE='GFS.SYS'.
The SPSS/PC+ system file is read from
    file GFS.SYS
The file was created on  9/29/92 at  7:45:46
and is titled GFS COMMAND FILE
The SPSS/PC+ system file contains
   6535 cases, each consisting of
     81 variables (including system variables).
     81 variables will be used in this session.
```

```
This procedure was completed at 13:56:19
SELECT IF (SSN GT 000000001).
SELECT IF (SSN LT 999999999).
SELECT IF (PROGRAM EQ 'CAD').
RECODE COLLEGE(8888=9999).
RECODE MAJOR(888=999).
RECODE LOOK(88=99).
RECODE TITLE(888=999).
RECODE RELATED USING TO MORE(8=9).
RECODE SALARY(99998=99999).
FREQUENCIES VARIABLES=SCHOOL COLLEGE MAJOR EMPLOYED LOOK TITLE RELATED USING
The raw data or transformation pass is proceeding
     77 cases are written to the compressed active file.
   DO MORE.

***** Memory allows a total of   7065 Values, accumulated across all Variables.
      There also may be up to     883 Value Labels for each Variable.
```

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SCHOOL EDUCATIONAL STATUS

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
CURRENTLY ATTENDING	1	23	29.9	46.0	46.0
NOT CURRENTLY ATTEND	5	27	35.1	54.0	100.0
NO RESPONSE/UNKNOWN	9	27	35.1	Missing	
	Total	77	100.0	100.0	

Valid cases 50 Missing cases 27

COLLEGE COLLEGE NAME

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Charles S. Mott Comm	1225	3	3.9	25.0	25.0
Lawrence Technologic	1399	3	3.9	25.0	50.0
Oakland University	1497	1	1.3	8.3	58.3
Macomb Community Col	1521	1	1.3	8.3	66.7
Oakland Community Co	1607	2	2.6	16.7	83.3
University Of Michig	1853	1	1.3	8.3	91.7
Sonoma State Univers	4723	1	1.3	8.3	100.0
Unknown	9999	65	84.4	Missing	
	Total	77	100.0	100.0	

Valid cases 12 Missing cases 65

- -

MAJOR CURRENT MAJOR FIELD

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Automotive Technolog	47	3	3.9	30.0	30.0
Civil Engineering	96	1	1.3	10.0	40.0
Engineering	214	5	6.5	50.0	90.0
Computer Aided Desig	686	1	1.3	10.0	100.0
Unknown/No Response	999	67	87.0	Missing	
	Total	77	100.0	100.0	

Valid cases 10 Missing cases 67

EMPLOYED EMPLOYMENT STATUS

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
FULL TIME	1	45	58.4	90.0	90.0
PART TIME	2	1	1.3	2.0	92.0
UNEMPLOYED	4	2	2.6	4.0	96.0
NOT EMPLOYED BY CHOI	5	2	2.6	4.0	100.0
UNKNOWN/NO RESPONSE	9	27	35.1	Missing	
	Total	77	100.0	100.0	

Valid cases 50 Missing cases 27

- -

LOOK MONTHS LOOKING FOR JOB

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
HAD A JOB	0	39	50.6	84.8	84.8
	1	3	3.9	6.5	91.3
	2	1	1.3	2.2	93.5
	4	1	1.3	2.2	95.7
	9	2	2.6	4.3	100.0
UNKNOWN/NO RESPONSE	99	31	40.3	Missing	
	Total	77	100.0	100.0	

Valid cases 46 Missing cases 31

TITLE JOB TITLE

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
Computer Programmer	41	2	2.6	4.5	4.5
Computer Systems Ana	42	4	5.2	9.1	13.6
Stock Clerk	63	1	1.3	2.3	15.9
Wholesale Sales Repr	112	1	1.3	2.3	18.2
Drafter	143	14	18.2	31.8	50.0
Electrical & Electro	144	1	1.3	2.3	52.3
Industrial Engineer	146	2	2.6	4.5	56.8
Mechanical Engineer	149	15	19.5	34.1	90.9
Auto Body Repairer	154	1	1.3	2.3	93.2
Telecommunications A	232	1	1.3	2.3	95.5
Commercial Artist	327	1	1.3	2.3	97.7
Optical Laboratory T	379	1	1.3	2.3	100.0
Unknown	999	33	42.9	Missing	
	Total	77	100.0	100.0	

Valid cases 44 Missing cases 33

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RELATED JOB RELATED TO PROGRAM

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
YES	1	38	49.4	82.6	82.6
NO	5	8	10.4	17.4	100.0
UNKNOWN/NO RESPONSE	9	31	40.3	Missing	
	Total	77	100.0	100.0	

Valid cases 46 Missing cases 31

USING USING KNOWLEDGE AND SKILLS

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
YES	1	43	55.8	95.6	95.6
NO	5	2	2.6	4.4	100.0
UNKNOWN/NO RESPONSE	9	32	41.6	Missing	
	Total	77	100.0	100.0	

Valid cases 45 Missing cases 32

- -

DO HELPED ME DO THE JOB

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
YES	1	26	33.8	59.1	59.1
NO	5	18	23.4	40.9	100.0
UNKNOWN/NO RESPONSE	9	33	42.9	Missing	
	Total	77	100.0	100.0	

Valid cases 44 Missing cases 33

- -

MORE MORE TRAINING WAS REQUIRED

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
YES	1	17	22.1	38.6	38.6
NO	5	27	35.1	61.4	100.0
UNKNOWN/NO RESPONSE	9	33	42.9	Missing	
	Total	77	100.0	100.0	

Valid cases 44 Missing cases 33

This procedure was completed at 13:57:37
MEANS LOOK BY RELATED.

***** Given WORKSPACE allows for 4317 Cells with 1 Dimensions for MEANS.

Summaries of LOOK MONTHS LOOKING FOR JOB
By levels of RELATED JOB RELATED TO PROGRAM

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population			.5870	1.9388	46
RELATED	1	YES	.7105	2.1170	38
RELATED	5	NO	.0000	.0000	8

Total Cases = 77
Missing Cases = 31 OR 40.3 PCT.

This procedure was completed at 13:57:39
MEANS SALARY BY RELATED.

***** Given WORKSPACE allows for 4317 Cells with 1 Dimensions for MEANS.

Summaries of SALARY YEARLY SALARY
By levels of RELATED JOB RELATED TO PROGRAM

Variable	Value	Label	Mean	Std Dev	Cases
For Entire Population			28757.0588	10434.9252	34
RELATED	1	YES	28655.3846	10848.2659	26
RELATED	5	NO	29087.5000	9636.4542	8

Total Cases = 77
Missing Cases = 43 OR 55.8 PCT.

```
This procedure was completed at 13:57:41
SELECT IF (RESPONSE NE 'N').
FREQUENCIES VARIABLES=SSN.
The raw data or transformation pass is proceeding
     47 cases are written to the compressed active file.

***** Memory allows a total of   7065 Values, accumulated across all Variables.
      There also may be up to     883 Value Labels for each Variable.
```

SSN RESPONDENTS SOCIAL SECURITY NUMBER

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	65409877	1	2.1	2.1	2.1
	164525569	1	2.1	2.1	4.3
	290304037	1	2.1	2.1	6.4
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	368581065	1	2.1	2.1	34.0
	370749354	1	2.1	2.1	36.2
	372744534	1	2.1	2.1	38.3
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	380841107	1	2.1	2.1	61.7
	381901245	1	2.1	2.1	63.8
	382722607	1	2.1	2.1	66.0
	382842265	2	4.3	4.3	70.2
	383728284	1	2.1	2.1	72.3
	383843666	1	2.1	2.1	74.5
	383847382	1	2.1	2.1	76.6
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	386643538	2	4.3	4.3	89.4
	386868292	3	6.4	6.4	95.7
	386883501	1	2.1	2.1	97.9
	549906259	1	2.1	2.1	100.0
	Total	47	100.0	100.0	

Valid cases 47 Missing cases 0

This procedure was completed at 13:57:46
FINISH.

End of Include file.

OAKLAND
COMMUNITY
COLLEGE

Auburn Hills Campus
2900 Featherstone Road, Auburn Hills, MI 48326-2845 (248) 340-6500 Fax: (248) 340-6507

COMPUTER AIDED DESIGN AND DRAFTING TECHNOLOGY

ADVISORY COMMITTEE MEETING

November 13, 1997

Present: David Carr, Chrysler Corporation
Phil Crockett, Manufacturing & Technological Services, OCC
Jeff Figa, ITT Automotive
Harminder Grover, General Motors Truck Group
Sally Kalson, Coordinator of Cooperative Education, OCC
Tahir Khan, Chair, Technology Department, OCC
Pat May, Counselor, OCC
Donna Nissen, Paraprofessional, OCC
Q. W. (Buz) Nowicki, IBM
Dr. Carlos Olivarez, Dean, Academic and Student Services, OCC
Dale O. Orchard, Rochester Adams High School
Douglas Riddering, Counselor, OCC
Tom Sawasky, Faculty, OCC
Erich Senft, General Motors Truck Group
Ruth Springer, Secretary, OCC
Chris Victor, United Technologies Automotive
Claudia M. Von Drak, Chrysler Corporation
Steve Ward, Chrysler Corporation

Current and Future Trends in the Field

Dr. Carlos Olivarez welcomed the group and invited the members to introduce themselves. As a part of the introductions, he asked industry representatives to give their opinions as to current and future trends in the field of computer aided design.

Mr. Steve Ward said that the trend is toward no more drafting boards. He believes we should question the validity of having so many board drafting classes in the curriculum.

Mr. Buz Nowicki expressed the belief that drafting boards should be used for the basic classes, and then students should move on to computer aided design. In regard to trends in manufacturing, there is more and more of a process orientation with the use of CADCAM. Colleges are in an excellent position to train people if they can continue to stay current with the technology. There is a universal problem of financing the technological equipment needed to provide this training. Mr. Nowicki has a new assignment at IBM to install CATIA in more colleges. He reported that OCC is very fortunate to have the technology it has. Many colleges do not have the level of technology which OCC has.

Mr. Chris Victor expressed his agreement with what Mr. Nowicki said about trends. Mr. Victor believes that, in advertising, OCC should emphasize the low cost of the training it provides, since it costs triple OCC's price to get the same training out in industry. Also, it is good to study over a period of 15 weeks, as the material is retained better than when it is learned in a short period of time. Mr. Victor emphasized the necessity for students to have an understanding of manufacturing processes in order to be successful in CAD classes. Perhaps this material needs to be taught in the CAD classes. This could be done by making a class process-centered, teaching each step involved in the manufacturing process, so students have the background understanding needed to make a design. In regard to drafting boards, Mr. Victor stated that he has used a board in the past, but now he finds himself unable to think on the board; he has to do his work on a CAD system.

Ms. Claudia Von Drak explained that she supervises CATIA training at Chrysler. They have recently brought in four co-op students and are using them to do features function testing and application testing on new software products which may be integrated into their training classes. In regard to trends in the field, she expressed the view that keeping up with changing technology is a major issue. At Chrysler, they are reinventing the way they provide training, believing that learning still begins in a classroom setting, but real learning takes place in the workplace where employees apply what they have learned. Instructors are on a cycle which has them in the classroom for a certain period of time, then working in the design area for awhile, then back in the classroom. This allows them to continually bring what is new and practical in the workplace into the training process. Ms. Von Drak agreed with what had been said about the importance of process training. Students must know, not just how to push buttons, but also the process that is involved. Everyone in Chrysler is embracing the process approach. Its importance cannot be stressed too much.

Mr. Erich Senft agreed with the emphasis on process training. In regard to the need for board drafting classes, he reported that, at General Motors, they have reduced the size and content of their drawings, but he still believes students need to know the basics of design in order to function successfully in industry. Designers need to be able to take a 3D image and manipulate it, so there is a need for instruction in descriptive geometry.

Mr. Victor agreed that there is a need for descriptive geometry, but he believes it can be taught on the computer.

Mr. Jeff Figa reported that, at ITT Automotive, he sees people's lack of knowledge of the process. Designers focus on the part they are designing, rather than on what will happen later in the process of production. People don't know the difference between a good solid and a bad solid. When their model crashes, they don't understand why it crashed. Another important issue is data exchange between the different CAD platforms used by suppliers. A design may be done in CATIA and then transferred to Unigraphics for a particular customer. Many people do not understand how data exchange works. This will be a major issue until the time when there is just one CAD package in use, and Mr. Figa does not believe that will happen in his lifetime.

Mr. Harminder Grover reported that math checking is now being done on the computer before the part is sent for production. Development time is being cut by doing structure analysis up front.

Ms. Pat May reported that the CAD Program is very popular with students, and that Auto Body Design is the most popular option. Students who have had manual drafting courses prior to taking their first CAD course usually do better that those who have no drafting background. She is in favor of requiring students who have not had drafting in high school to take the first drafting course before taking CAD courses.

Mr. Phil Crockett commented that descriptive geometry is a necessary building block for design. If we stop teaching it, industry will be complaining in a few years because students are not learning the basics.

Mr. Tahir Khan agreed that students who begin taking CAD classes without a background in drafting do have difficulties. He believes students need to take the three basic Drafting classes before they get into heavy design on the computer. The CAD Program has no prerequisites. Anyone is accepted, even if they have no background in drafting and design. Those with no background are encouraged to enroll simultaneously in Drafting and CAD classes. Mr. Khan would like the advisory committee to address the question of how to fine tune the Auto Body Option so it has less than 85 credit hours. Four manual Drafting classes are included in the Auto Body Option: DDT 100, Fundamentals for the Drafting Industry; DDT 105, Product Drafting; DDT 115, Descriptive Geometry; and ADT 110, Introduction to Body Drafting. General Motors Truck Group has told us that they want more manual drafting skills taught and less CAD. Mr. Khan would like the advisory committee to address the question of whether we need more manual drafting classes, or whether we can teach some fundamental design concepts on the computer. Also, can we cut down on the 85 credit hours required in the Auto Body Design Option?

Mr. Khan reported that a program with Central Michigan University is almost in place under which students in the Auto Body Design Option would be able to continue their studies at Central Michigan and earn a Bachelor of Science in Vehicle Design. CMU has identified a set of courses that they will accept; they will not accept the entire associate degree.

Mr. Tom Sawasky reported that an emphasis on manufacturing processes is one of the major elements of the CMU program. They are not looking for board drafting skills, but they are looking for the concepts which have traditionally been taught in board drafting classes.

Mr. Figa suggested that descriptive geometry might be taught using the draw side of CATIA. Mr. Grover agreed that this could be done if students already know the CATIA system.

Mr. Khan asked the group for feedback on the request from General Motors that OCC concentrate on teaching manual drafting and leave the CAD instruction to be taught by General Motors to its employees.

Mr. Senft reported that there are two camps at General Motors. One wants to emphasize manual drafting. However, the truth is that, at General Motors, when they do body design, they do not usually start with clay, but on the CAD system. They are doing surface development with new technology that eliminates the way it was done in the past. Virtual reality will soon be in use. Mr. Senft does not see the need for manual drafting to do surface development. Manual drafting is not utilized at General Motors.

Mr. David Carr reported that there are no drafting boards in the room in which he works at Chrysler. They have all been discarded. No drawings are being done. He sees little need for learning manual drafting. He took manual drafting first, and it did help him when he started using CAD. However, he is not sure it is needed now.

Mr. Victor reported that the technical drawing book being used now places emphasis on CAD rather than on board drawing. The old book emphasized board drafting. However, the new book has one small chapter on board drafting, with the rest of the book focusing on CAD.

Mr. Senft suggested that there is a need for a course that teaches the basic language and terminology, which are the same whether the work is done manually or on a computer. .

Progress Report on Advisory Committee Recommendations

The minutes of the Computer Aided Design and Drafting Technology Advisory Committee meeting held on April 24, 1997, were reviewed and approved as written. The minutes of the follow-up meeting of OCC members of the advisory committee held on July 14, 1997, were reviewed, and a progress report was given on each committee recommendation, as follows:

1. **That OCC attempt to find out whether there is a need for the Automotive/Industrial Modeling Option in industry.**

Mr. Khan expressed the opinion that there is a need to revamp this program option to make it a computer aided manufacturing option. Students would take manufacturing courses, along with design courses, including finite element modeling and analysis. We are in the process of changing from a mainframe system to stand-alone work stations. This will open more avenues for us to offer new classes that could not be offered in the past due to capacity problems in the CAD Lab. Once the work stations are in place and a couple of new Unigraphics courses have been developed, as more rooms become available, this new option could be developed.

2. **That CAD 214, Kinematics, be added to the Automotive Body Design and Drafting Option.**

Mr. Khan reported that this recommendation was not approved. This program option already has 85 credit hours. It is not possible to keep adding additional courses to it. CAD 214 will still be offered for those who wish to take it, and students who do not need the co-op course will still be able to substitute CAD 214 for it. However, it will not be added officially to the program. This option should concentrate on providing students with the fundamental skills needed by body designers.

3. **That OCC explore the possibility of offering as one course the content of MEC 101, Introduction to Manufacturing Processes, and MEC 102, Manufacturing and Fabrication Practices, which is needed by a body designer.**

Dr. Olivarez reported that yesterday there was a meeting of himself, Mr. Khan, Mr. Sawasky, and Mr. Steve Atma, who teaches MEC 101 and MEC 102.

Mr. Sawasky explained that an enormous number of manufacturing processes and related materials are covered in these two courses. He believes that a good designer needs to be familiar with all the materials and processes involved in the production of the part being designed. A great deal of discussion at today's meeting has centered around process orientation. Mr. Sawasky thinks we need to explore this issue more before taking action to create a single Manufacturing Processes class.

Dr. Olivarez agreed that, if process is important in industry, perhaps this would not be a good idea. At yesterday's meeting, Mr. Atma stated that he did not see how the two classes could be combined and still teach all the necessary material adequately.

Mr. Sawasky added that these are hands-on courses. Students do such things as running the lathes and mills, doing plastic welding, and casting parts. They actually perform the processes.

Mr. Ward asked whether it might be possible to have MEC 101 include the material needed for the Body Design Option, and MEC 102 cover the material needed for the Machine Tool Option. The group discussed this possibility, and mentioned a number of subject areas that should be covered in class.

Ms. Von Drak stated that, at Chrysler Vehicle Engineering Operations, they do all the things mentioned in this discussion. Perhaps it would be a good idea if Mr. Sawasky, Mr. Khan, and Mr. Atma could meet with someone in the manufacturing area to discuss what needs to be taught in these classes. Mr. Khan agreed that this might be a good idea.

4. That a field trip/industry tour be made part of the standard syllabus for all CAD courses.

Mr. Khan reported that students in the higher level classes are being taken on field trips. Recently students in Drafting and CAD classes went on a field trip to the AUTOFACT show. Field trips are a good idea, and we will continue to do them.

Mr. Crockett mentioned that he is the student advisor for OCC's student chapter of the Society of Manufacturing Engineers (SME). Lots of tours are available through SME. He suggested that instructors tell their classes about SME and the availability of tours.

5. That one week in the MEC class be spent on fasteners.

Mr. Crockett reported that a week in the MEC class has always been spent on fasteners. This recommendation has been completed.

6. That industry representatives be consulted about what kind of part students should be able to do after they finish each class, so students are learning what is needed by industry.

Mr. Khan reported that this has been done for a long time by using adjunct faculty who are employed in the design industry to teach many of the CAD classes. This recommendation has been completed and will not appear in future minutes.

7. That steps be taken to provide an adequate amount of open lab time for students in all classes. That, if necessary, OCC consider the possibility of leasing training computers on Saturday and Sunday from Chrysler or another company for the use of students for open lab time.

Mr. Khan agreed that there is always a problem with open lab time, especially in the evening when the labs are constantly in use for classes. It is hoped that, once the newly renovated F Building has been occupied, some of the vacated space in A Building can be used to create a dedicated open lab, with no classes scheduled in it.

Mr. Victor commented that students have asked for help on CATIA. There is a reference tool online called Think Cad Blue which can be downloaded onto work stations. It is a valuable tool which could be used by students for quick reference.

Mr. Khan mentioned that IBM also has a great deal of online documentation. He plans to have all the work stations equipped with online documentation and see that students are shown how to use it.

Mr. Ward asked whether it might be possible for OCC and Chrysler to agree to use some of Chrysler's training space for open lab at times when it is not being used by Chrysler employees. Ms. Von Drak responded that there would be issues to resolve, such as who would supervise the students after hours, since any reprogramming of a work station would cause major problems for Chrysler training the following morning. There would also be security issues, such as who lets the students in and out and sees them safely to their cars. If those issues could be resolved, perhaps this would be a possibility.

Mr. Sawasky explained the work of the Tech Prep group and invited Ms. Von Drak to become a member. There is a need for Chrysler representation in the group, and this might also be a vehicle through which this type of partnership could be developed between OCC and Chrysler. Perhaps some Chrysler people could also become mentors for OCC students.

8. That CAD 235, CAD Applications in Die Design, be added to the Body Design Option.

It had been suggested that perhaps DDT 105, Product Drafting, could be replaced by CAD 235 in the Body Design Option.

Mr. Sawasky noted that there had been discussion at today's meeting regarding whether fundamentals should be taught in board drafting classes. Mr. Sawasky believes that application to geometry can best be taught in a math class or on the board. It could be taught on the computer, but things happen so quickly on the computer that it is difficult for the student to absorb what is happening. He is considering revamping DDT 105 so that it would emphasize the teaching of drafting standards and the theory behind them, as well as geometric dimensioning and tolerancing (GD&T). QAT 104, Geometric Dimensioning and Tolerancing - Principles and Applications, is not currently a required course in the CAD curriculum. Perhaps it could become a Drafting class, including applications, standards, and drafting conventions. Perhaps fasteners could be covered in such a course, including how to determine what fasteners should be used, and how to represent a fastener. Mr. Sawasky believes that product detailing should probably be done on a computer. A great deal of product detailing is done in CAD 120, Product Detailing. His experience teaching CAD 110, Introduction to Computer Aided Design and Drafting, and CAD 120 is that students who have no basic understanding of geometry have a hard time being successful. He believes basic Drafting classes should be taught with that emphasis. Perhaps the basic Drafting and CAD classes could be linked in the schedule, so students would be required to register for both at the same time. Or perhaps the first class students take could cover standards, practices, and conventions. Then the second class could deal with computer applications.

Mr. Victor mentioned that there is a CATIA product called Functional Dimensioning and Tolerancing (FD&T). Many suppliers are required to be compliant in this.

Mr. Khan stated that the book now being used in CAD 120 has a chapter on basic GD&T, so some material on the subject is being introduced in that class. He hopes to have a meeting of all CAD instructors to see how they can carry that concept into the more advanced classes, covering certain modules in each class, so by the time students have finished, they have had a good exposure to GD&T and will be able to use it on the job. He believes it can be incorporated into the existing courses, rather than creating a separate course to teach it.

Mr. Carr asked whether DDT 105 can be replaced in the program by CAD 235. He believes that an understanding of die design is more important for body designers than the subject matter taught in DDT 105.

Mr. Khan asked the group for their opinion about CAD 220, Product Design and Layout. He explained that this course was initially taught on a CADAM system. Now the program is being revamped to eliminate the use of CADAM. Some of the body design faculty from Chrysler think that some of the concepts taught in CAD 220 are also included in other courses they are teaching. He asked the group whether they believe there is a need for CAD 220 in the Body Design Option at this time, or are we giving students redundant information that is taught in other courses using another CAD system? Should we be concentrating on teaching concepts rather than software? Is CAD 220 still needed in the Body Design Option, or should we remove it from that option but continue to include it in the Machine Tool Option? We need an answer to these questions, since we are adding a new course, CAD 135, Assemblies and Components, to the Body Design Option, and it would be good if we could remove another course so the program does not become any longer than it presently is.

Mr. Khan suggested that perhaps CAD 220 should be revamped to emphasize tool creation. However, General Motors Truck Group thought this course should not be taught. He is also hearing that this course is redundant, that students do not get anything new in this class. Students would have to take CAD 135 before taking CAD 220, which would make the program 89 credits.

Mr. Carr pointed out that students are required to take another layout course, CAD 270.1, Applications of Body Design. Mr. Senft recommended that CAD 220 and CAT 270.1 be combined. Mr. Ward agreed.

Mr. Sawasky pointed out that the math requirements for the Auto Body Option are higher than for the new Computer Aided Engineering Option. He believes we are losing students from this option because they are required to take Trigonometry. Mr. Khan asked the group whether students need to take Trigonometry in order to be successful body designers.

Mr. Ward and Mr. Figa stated that they do not use trigonometry. Mr. Carr agreed that it is not used much. However, he believes that there is a need for a couple of classes that are demanding and teach discipline. Mr. Khan agreed that math does provide students with practice in problem-solving.

Mr. Sawasky asked whether we could offer students the possibility of taking applied math, so they could learn trigonometry as it is applied to practical industrial situations. Mr. Khan responded that applied math courses are not recognized by institutions to which students might transfer.

Mr. Senft pointed out that, with the sophisticated tools that are included in CAD systems today, designers do not need trigonometry. It is true that trigonometry does teach mental discipline, but the tools in use today are so easy to use that he does not believe students need trigonometry. It was pointed out that trigonometry is needed to do design calculations. However, Mr. Senft responded that there are analysis tools in the system, so the designer does not need to know trigonometry.

Ms. Von Drak commented that OCC needs to provide students with the foundation that will enable them to be successful in industry. It is not possible to anticipate everything students will need in the work situation and include it all in the curriculum, as well as teaching three different CAD systems. We need to determine what the basics are that we need to teach, and let industry teach the more advanced subjects. Employees do not need trigonometry to work out a simple analysis. If something further needs to be done, it can be sent to an engineer who has the background in trigonometry. Perhaps we need to look at simplification of the curriculum to concentrate on teaching the basics.

Mr. Khan said that he will do a survey and see what feedback we get from industry regarding three or four possible math classes. Perhaps we could take out the Trigonometry class and add CAD 235.

Mr. Senft stressed again that die design is very important. He suggested that CAD 220 be combined with CAD 270.1, and that CAD 235 be added to the curriculum.

9. That additional instruction in finite element modeling be added to the Computer Aided Engineering Technology Option.

Mr. Khan stated that there is a limit to what we can teach, due to the math background of the students. He doesn't believe this can be taught in a two-year program. We are attempting to prepare students to be finite element modeling technologists. Mr. Tom Kudzia teaches CAD 216, Finite Element Modeling, and does an excellent job.

10. **That a class in design simulation be added to the Computer Aided Engineering Technology Option.**

Mr. Khan reported that he would like to develop a class in design simulation. He was thinking of using Deneb, but we only have a license to have their software on five stations on campus. He is also looking at 4D Navigator within the CATIA system.

Mr. Crockett mentioned that he is still looking at Deneb. They have a PC based package which might be used.

Mr. Victor pointed out that there are lots of tools in CATIA for robotics.

11. **That instruction in Draw Mode on CATIA be included in CAD 210.1, Three Dimensional Wire Frame Design and Surfacing.**

Mr. Khan reported that this will be done.

12. **That OCC consider the possibility of including instruction in 2D-3D space integration in the CAD program.**

Mr. Khan reported that this is being done in CATIA and Unigraphics.

13. **That OCC consider the possibility of teaching such concepts as plan view, projections, and planes using CATIA, rather than in manual drafting classes.**

This was discussed extensively earlier in the meeting.

14. **That OCC consider offering a draw class that looks at more than one system and compares systems.**

Mr. Khan pointed out that students already receive training on AutoCAD, Unigraphics, and CATIA. Those who go through the program receive instruction on each software and are able to compare the systems as they go. A dedicated class to compare systems is not necessary. This recommendation was not approved.

15. **That OCC provide a forum for students to talk with people in the industry and receive career suggestions from them.**

Mr. Khan reported that this is being done through Co-op Day, which is sponsored by the Co-op Office. Employers come in once a year and interview students for prospective employment.

16. **That OCC consider the possibility of holding a yearly technology fair with industry coming in to show students what they are doing with the systems taught on campus.**

Each year the Auburn Hills Campus holds an open house for high school students and their parents. We have never held a technology fair as such. Perhaps something like this could be done in conjunction with the Tech Prep Drafting/Design competition which is held each year at this campus for high school students.

Mr. Crockett reported that the marketing committee is encouraging cluster activities. Perhaps the Technology Department could have their own activity, rather than just having the one big open house.

Mr. Sawasky explained about the drafting contest for high school students which will be held here in March. He invited all the committee members to participate as judges or perhaps be on the committee to help develop problems for the contest.

New Advisory Committee Recommendations

17. That OCC consider the possibility of teaching descriptive geometry using the draw side of CATIA.

18. That OCC consider replacing DDT 105, Product Drafting, with CAD 235, CAD Applications in Die Design, in the Body Design Option.

19. That CAD 220, Product Design and Layout, and CAD 270.1, Applications of Body Design, be combined into a single course.

20. That MAT 156, Trigonometry, be deleted from the Body Design Option.

Respectfully submitted,

Ruth Springer

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