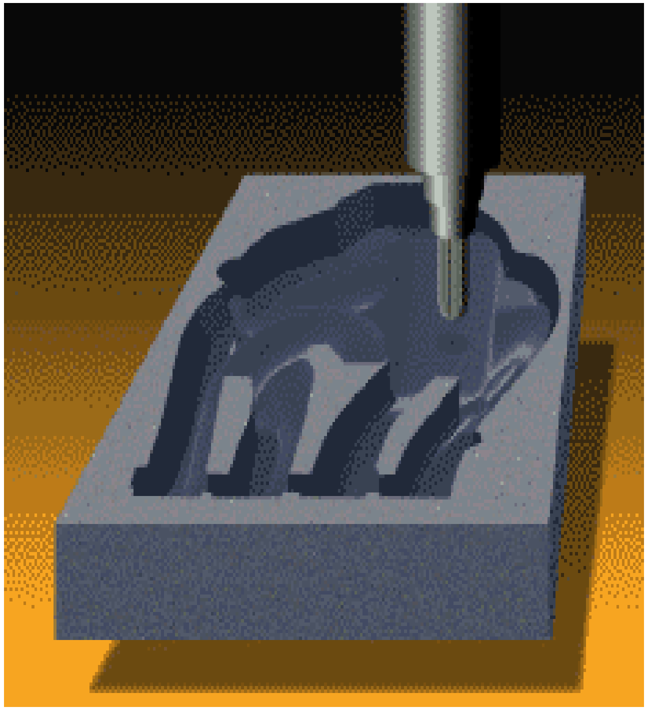
Introduction to Computer Aided Design & Analysis
ME 308

Computer-Aided Design (CAD)

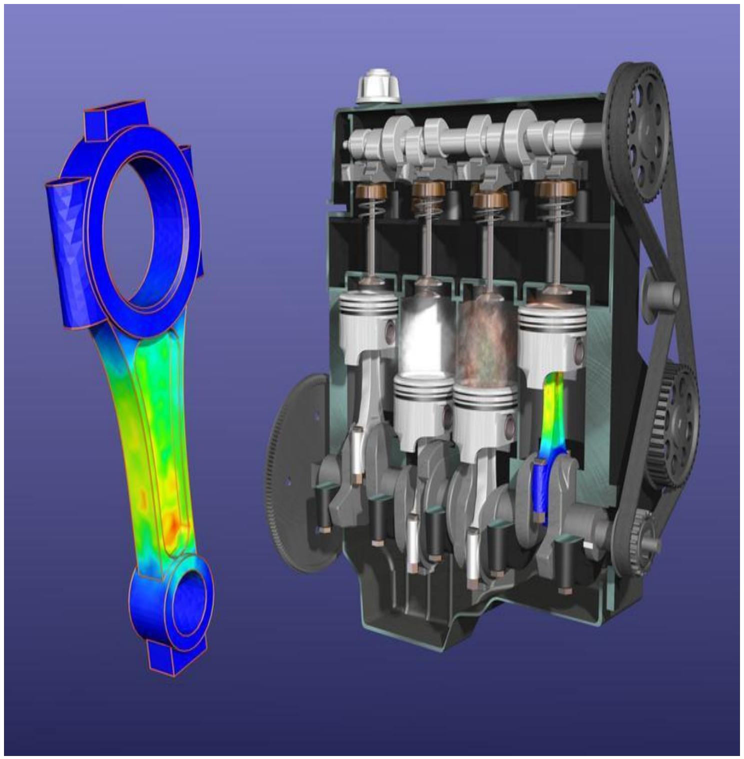
- Use of computer systems to assist in the creation, modification, analysis, and optimization of a design
- Typical tools:
  - Tolerance analysis
  - Mass property calculations
  - Finite-element modeling and visualization
- Defines the geometry of the design

Computer-Aided Manufacturing (CAM)

- Use of computer systems to plan, manage, and control manufacturing operations
- Direct or indirect computer interface with the plant's production resources
- Numerical control of machine tools
- Programming of robots



Computer-Aided Engineering (CAE)

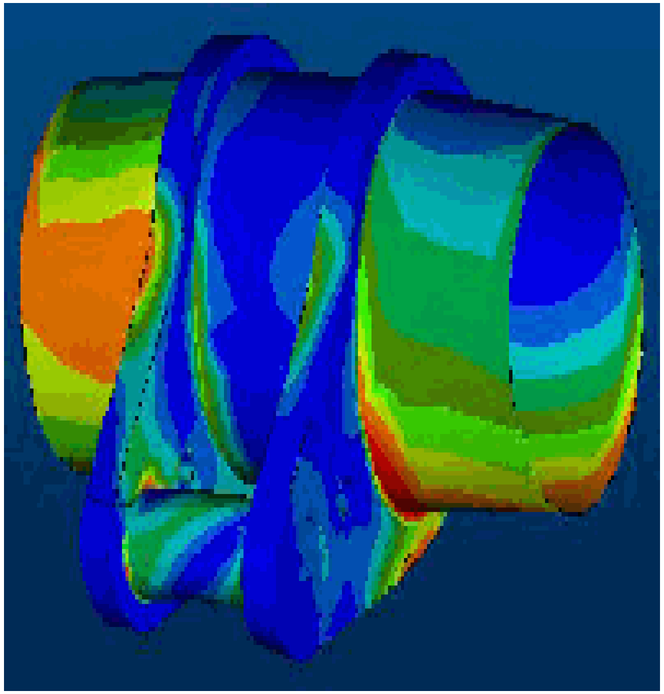


- Use of computer systems to analyze CAD geometry
- Allows designer to simulate and study how the product will behave, allowing for optimization
- Finite-element method (FEM)
  - Divides model into interconnected elements
  - Solves continuous field problems

Computer-Aided Design Process

- Two types of activities: synthesis and analysis
- Synthesis is largely qualitative and hard to capture on computer
- Analysis can be greatly enhanced with computers
- Once analysis is complete, design evaluation- rapid prototyping
- Software packages for design optimization

Components of CAD/CAM/CAE Systems

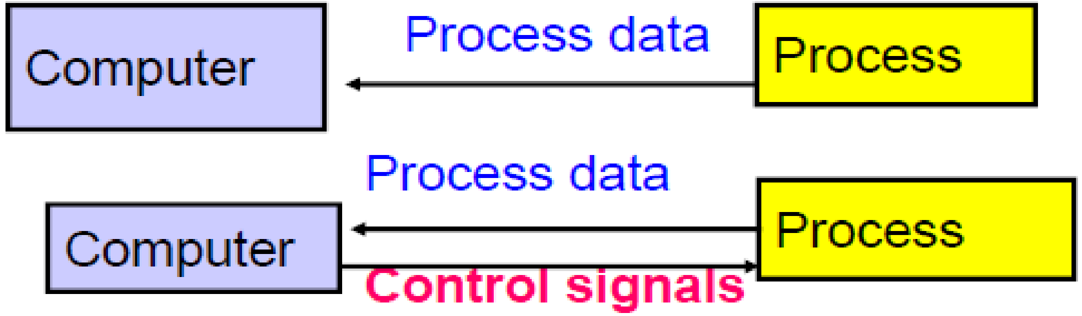


- Major component is hardware and software allowing shape manipulation
- Hardware includes graphic devices and their peripherals for input and output operations
- Software includes packages that manipulate or analyze shapes according to user interaction

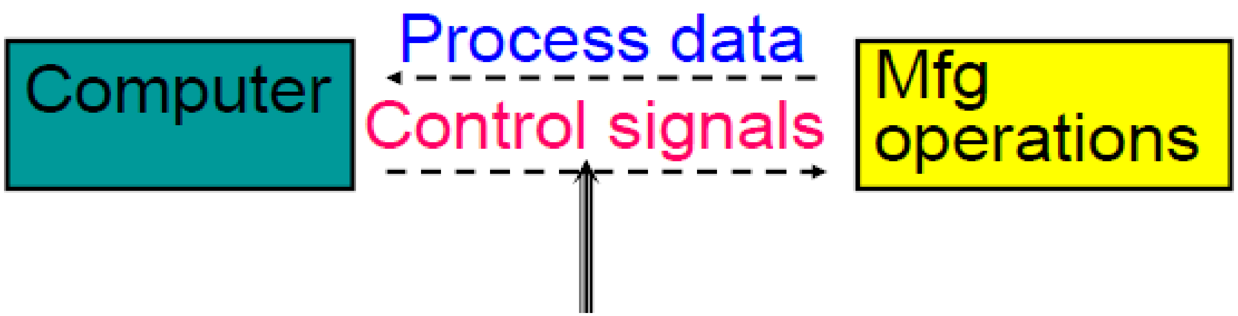
Evolution of CAD/CAM and CIM

From CAM definition, the application of CAM falls into two broad categories:

1. Computer monitoring and control .

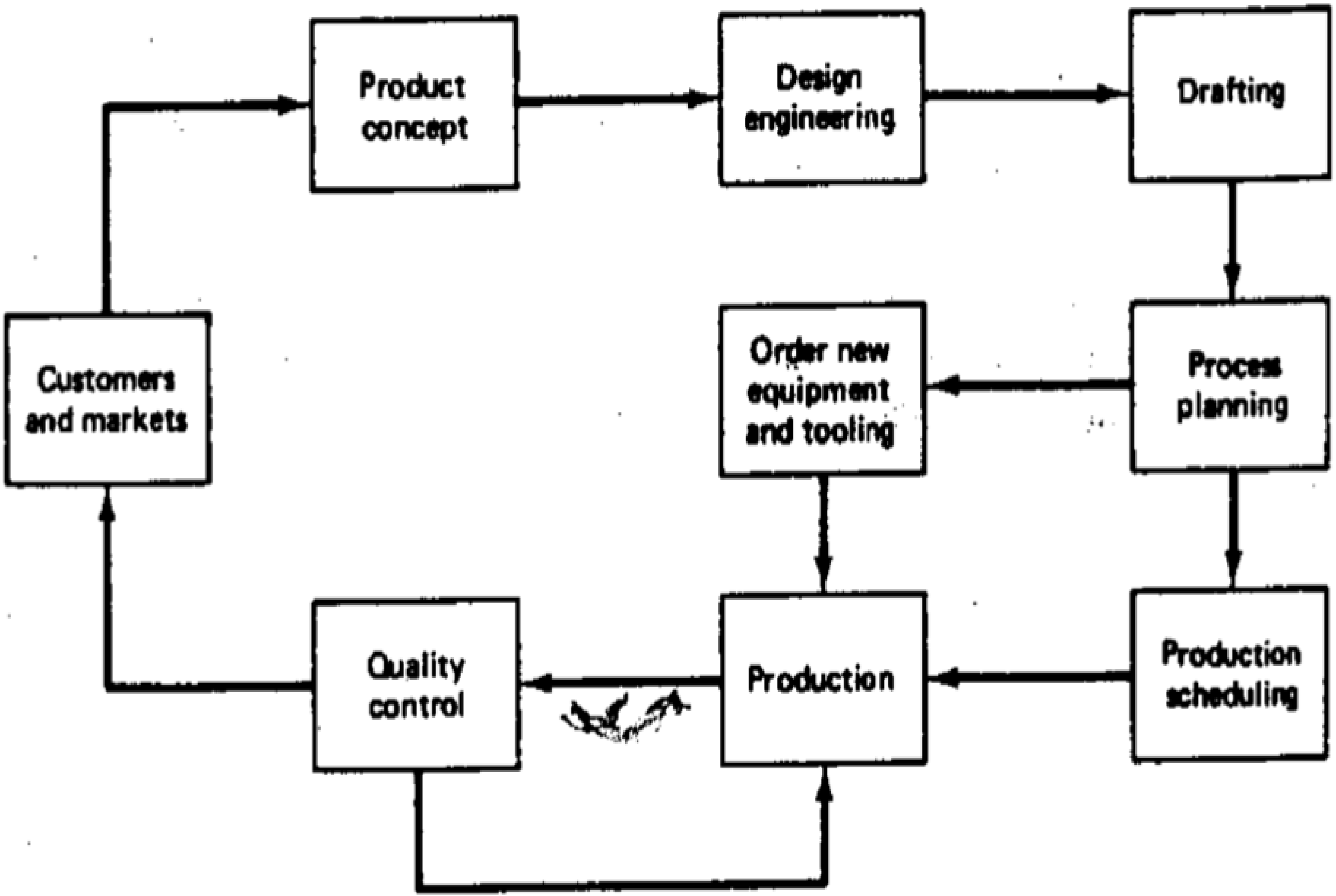


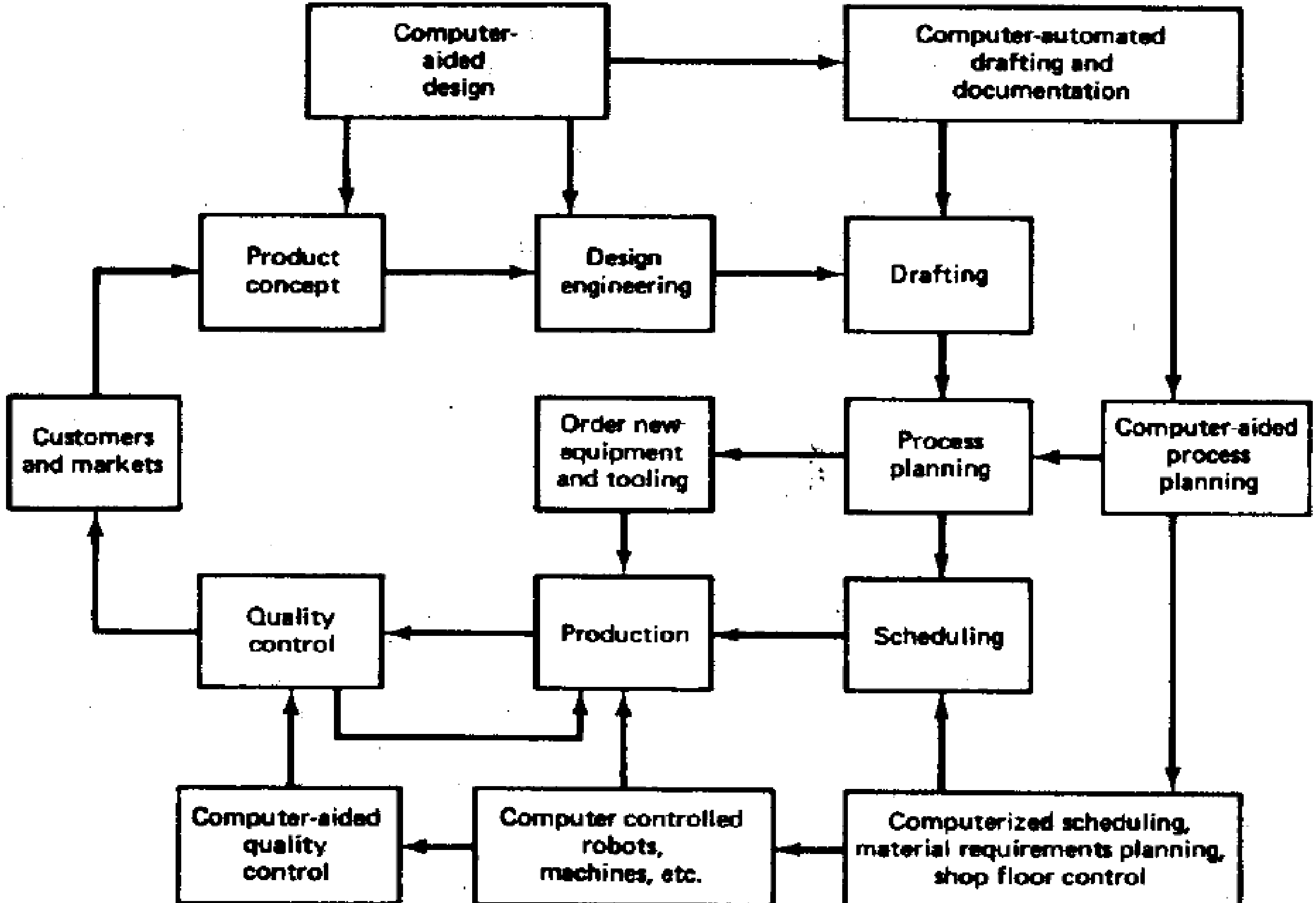
2. Manufacturing support application .



The Product Cycle and CAD/CAM

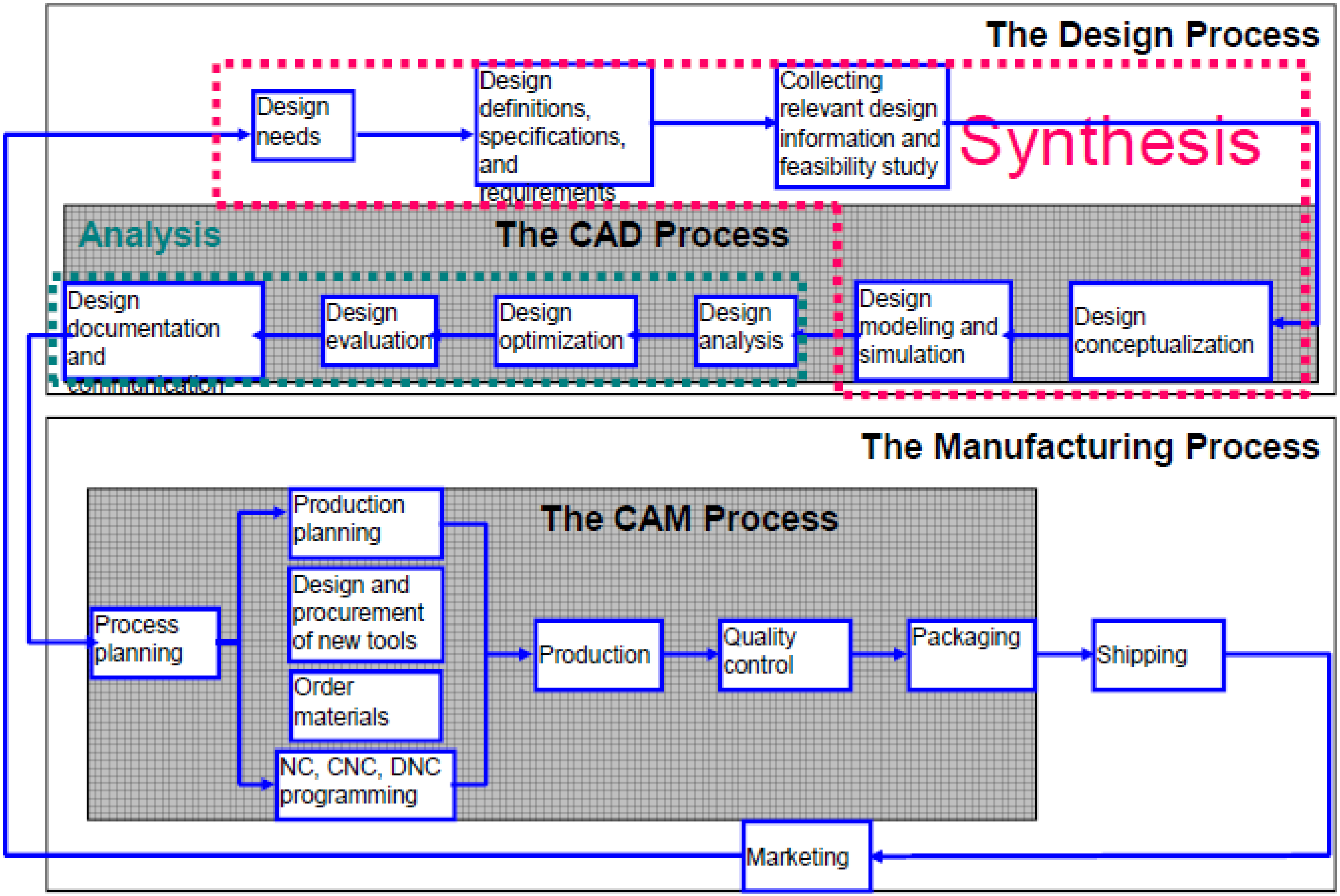
In order to establish the scope and definition of CAD/CAM in an engineering environment and identify existing and future related tools, a study of a typical product cycle is necessary. The following Figure shows a flowchart of such a cycle.


Product concept
Design engineering
Drafting
Customers and markets
Order new equipment and tooling
Process planning
Quality control
Production
Production scheduling



Product cycle revised with CAD/CAM overlaid.

Typical Product Life Cycle



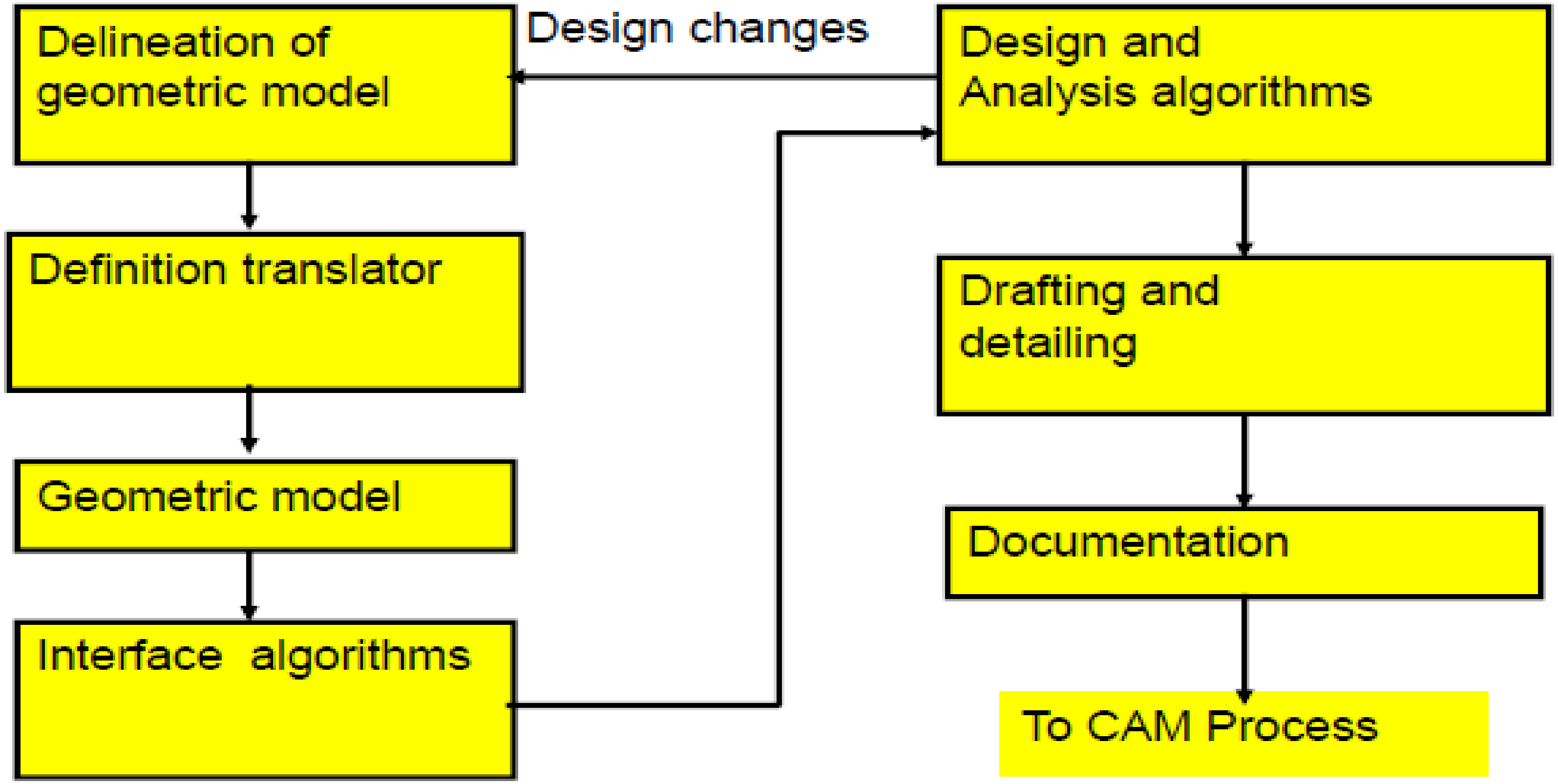
- The product begins with a need which is identified based on customers' and markets' demands.
- The product goes through two main processes from the idea conceptualization to the finished product:

1. **The design process.**
2. **The manufacturing process.**

The main sub-processes that constitute the design process are:

1. Synthesis.
2. Analysis.

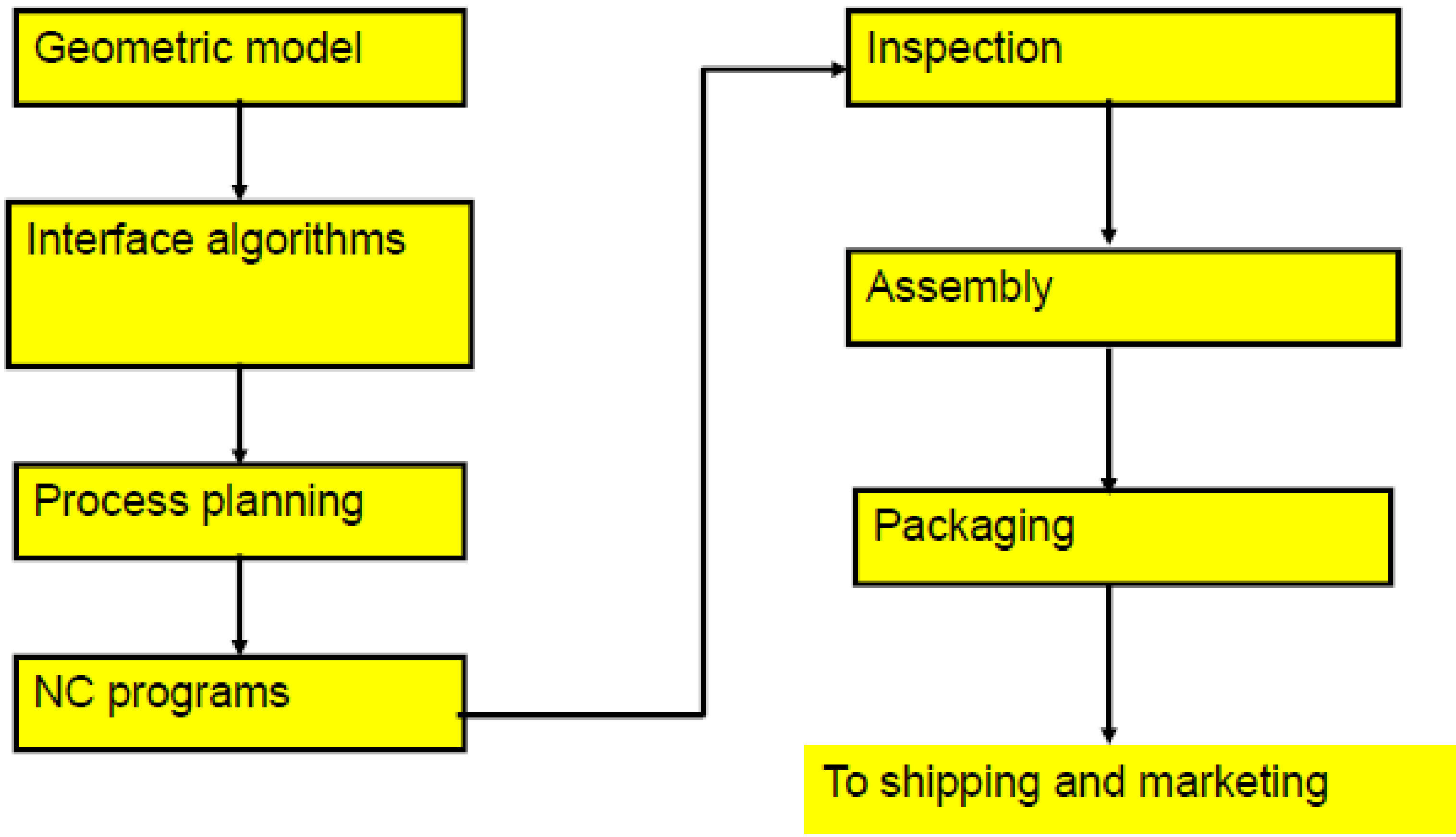
Implementation of a Typical CAD Process on a CAD/CAM system



CAD Tools Required to Support the Design Process

Design phase	Required CAD tools
Design conceptualization	Geometric modeling techniques; Graphics aids; manipulations; and visualization
Design modeling and simulation	Same as above; animation; assemblies; special modeling packages.
Design analysis	Analysis packages; customized programs and packages.
Design optimization	Customized applications; structural optimization.
Design evaluation	Dimensioning; tolerances; BOM; NC.
Design communication and documentation	Drafting and detailing…

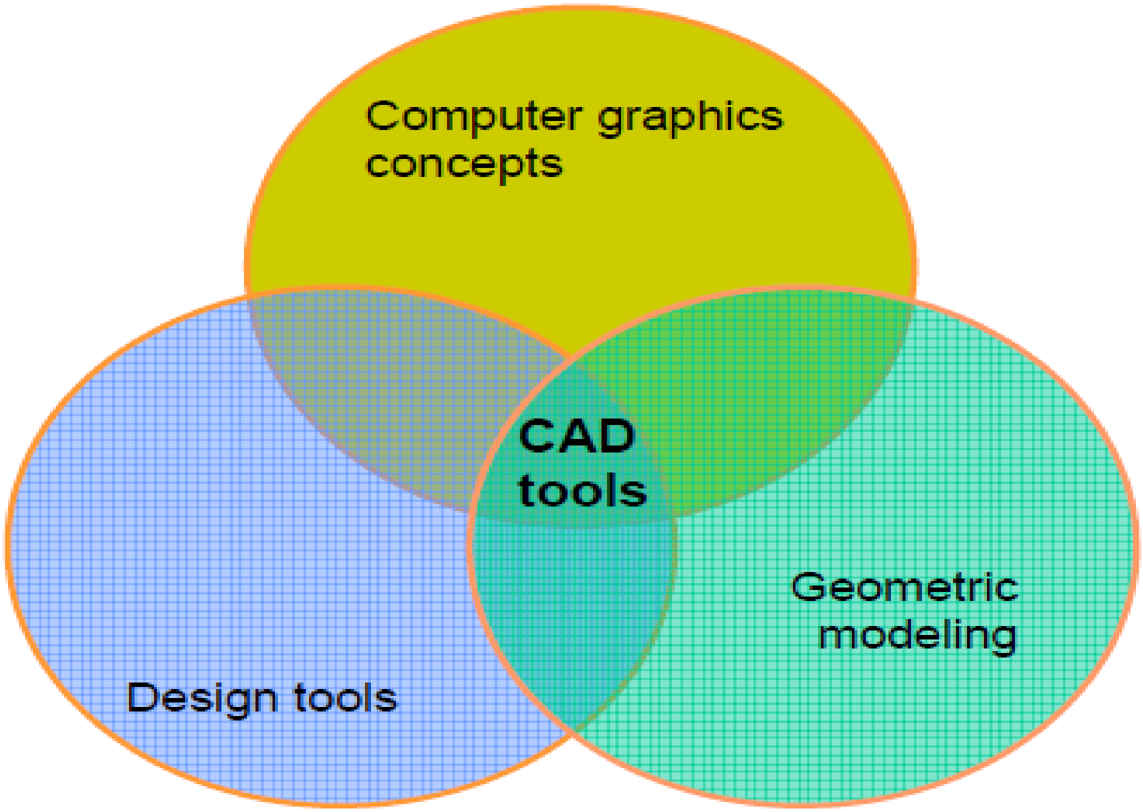
Implementation of a Typical CAM Process on a CAD/CAM system



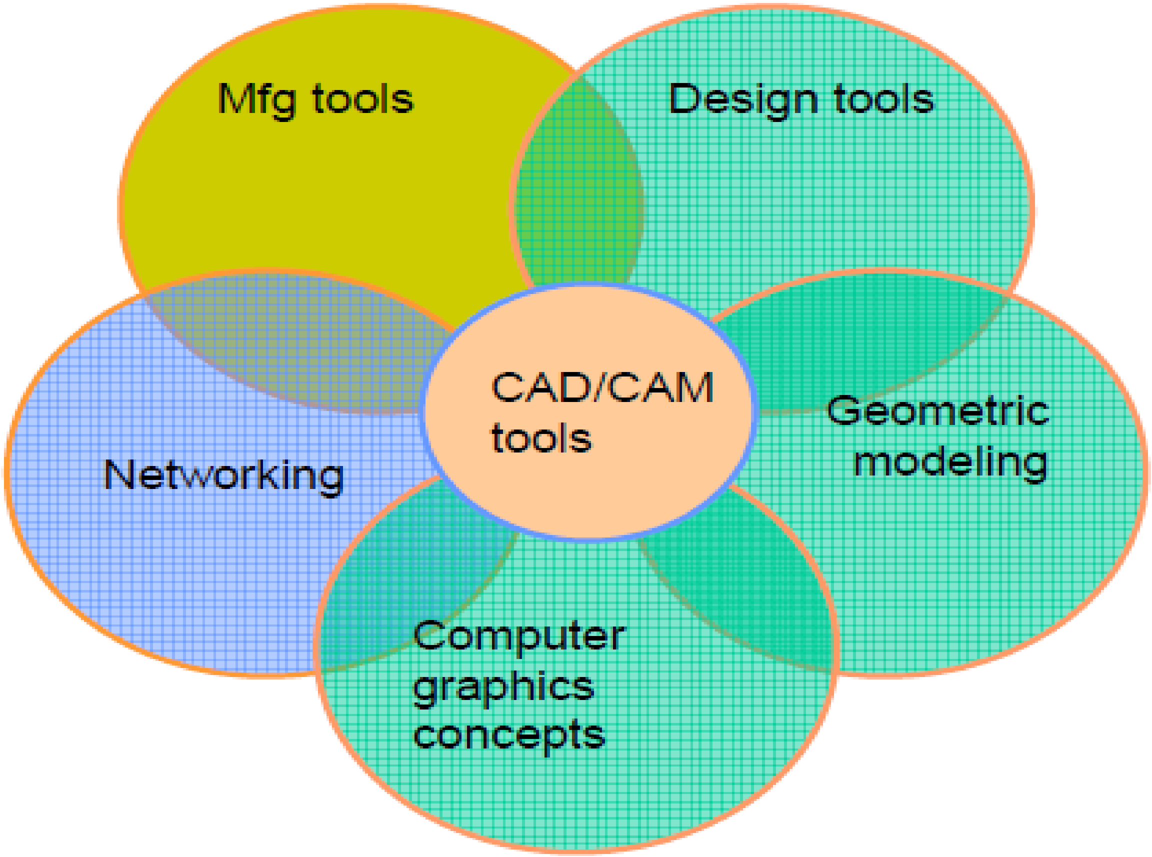
CAM Tools Required to Support the Design Proces

Manufacturing phase	Required CAM tools
Process planning	CAPP techniques; cost analysis; material and tooling specification.
Part programming	NC programming
Inspection	CAQ; and Inspection software
Assembly	Robotics simulation and programming

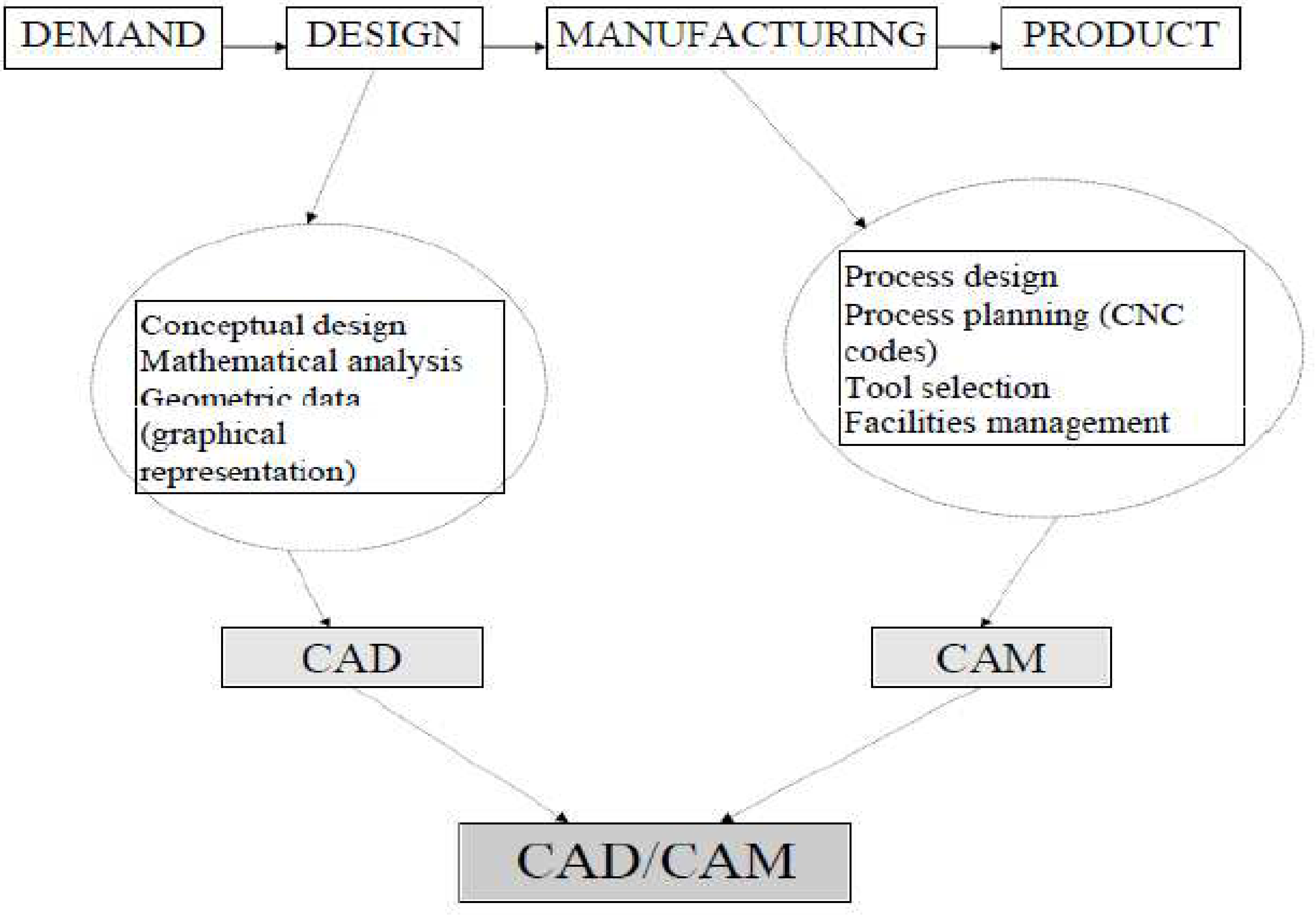
Definitions of CAD Tools Based on Their Constituents



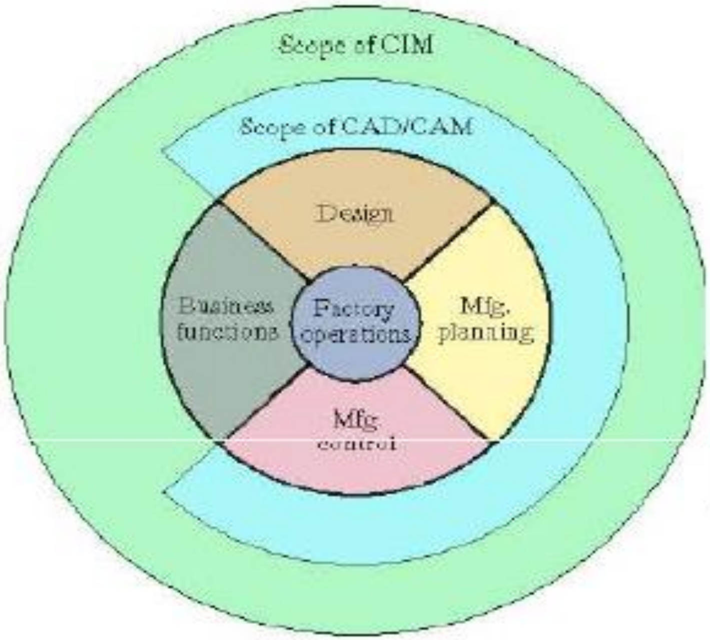
Definitions of CAD/CAM Tools Based on Their Constituents

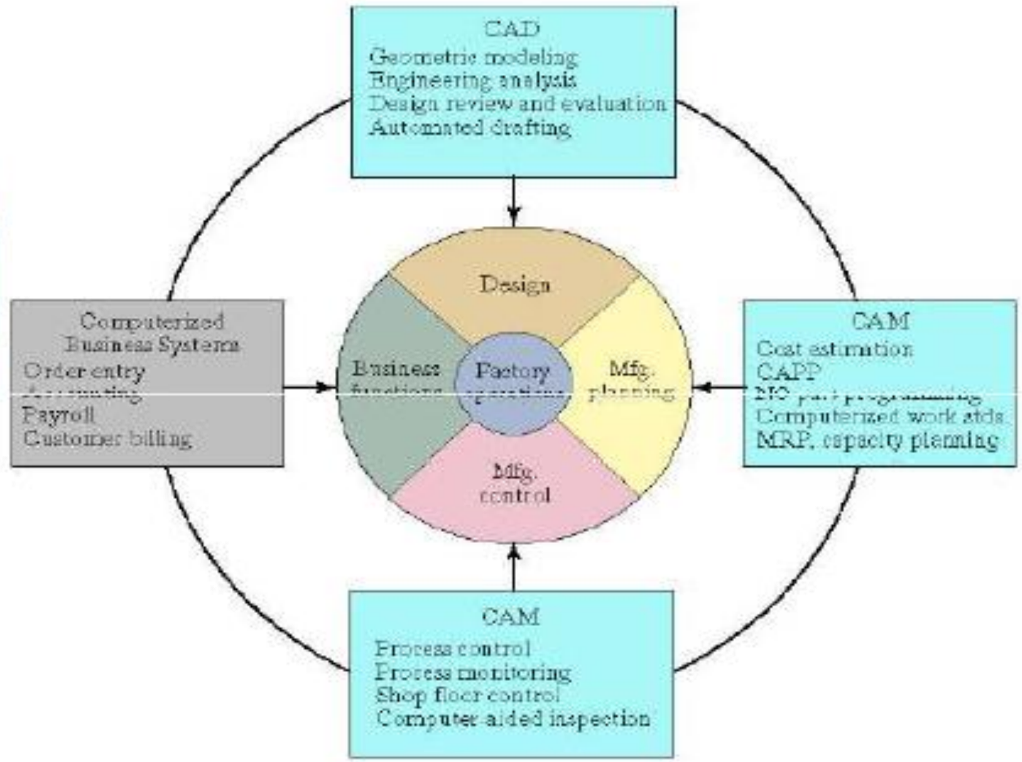


The structure of CAD/CAM



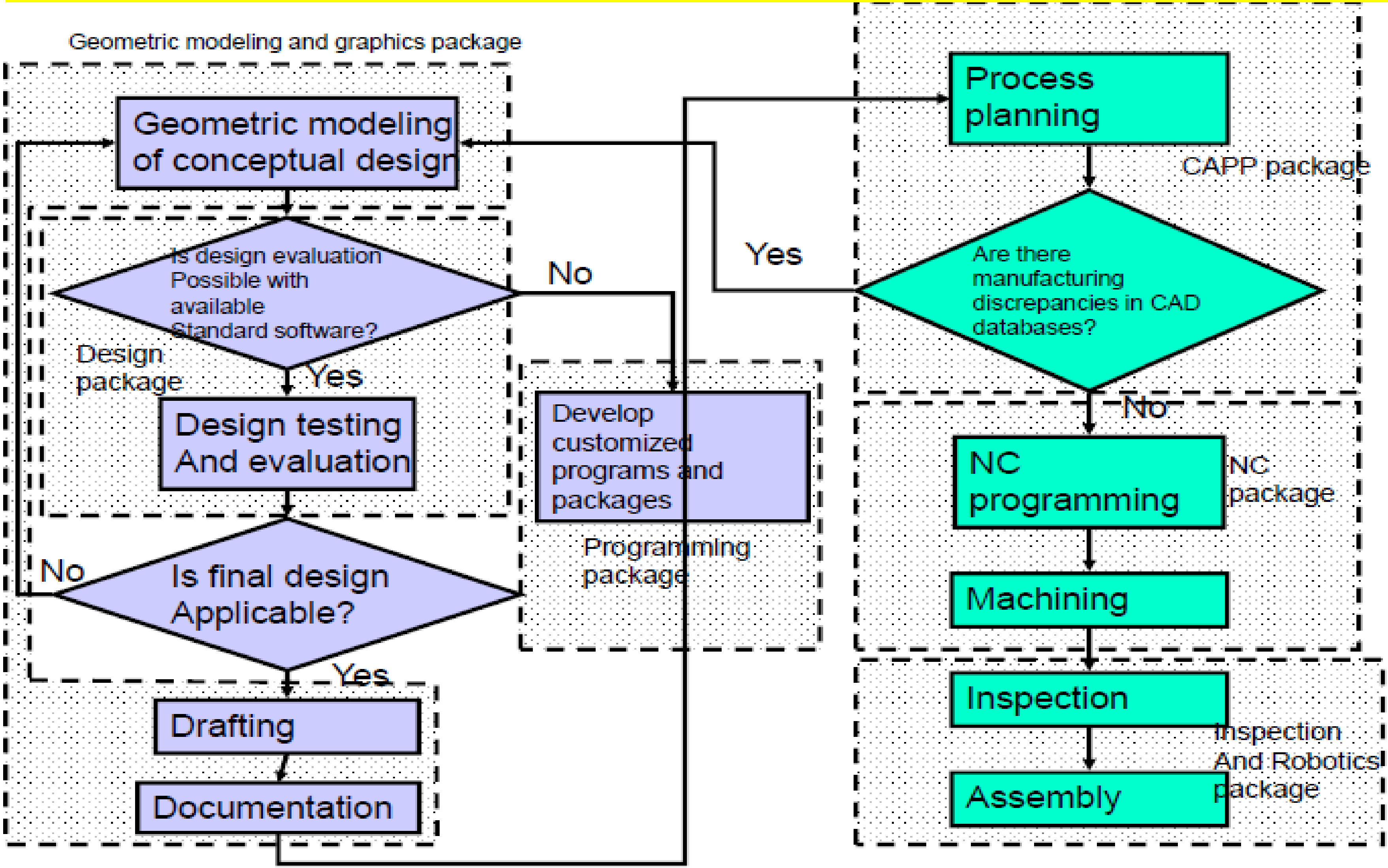
The scope of CAD/CAM and CIM





Computerized elements of a CIM system

Typical Utilization of CAD/CAM Systems in an Industrial Environment

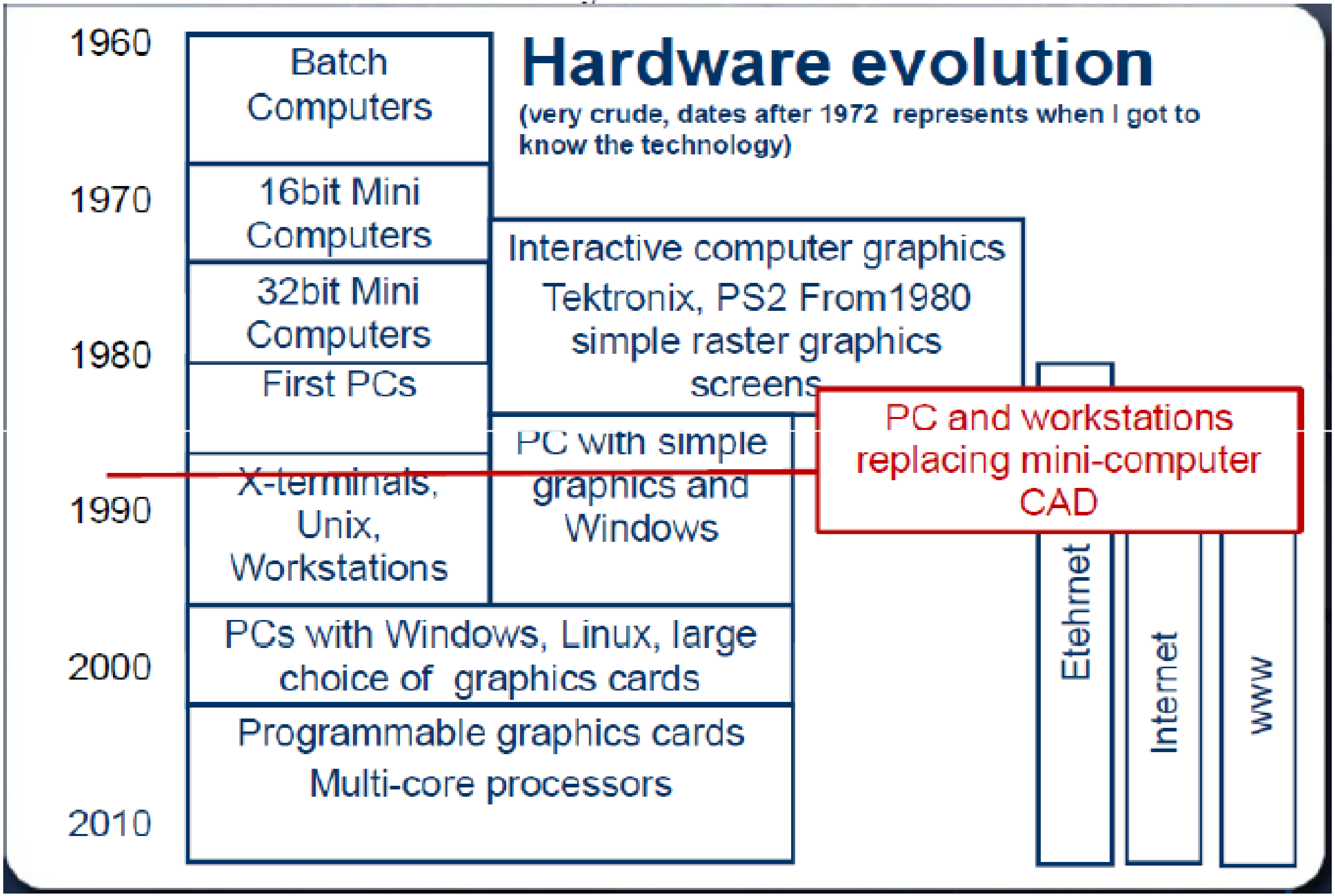


Advantages of CAD/CAM systems

- Greater flexibility.
- Reduced lead times.
- Reduced inventories.
- Increased Productivity.
- Improved customer service.
- Improved quality.
- Improved communications with suppliers.

- Better product design.
- Greater manufacturing control.
- Supported integration.
- Reduced costs.
- Increased utilization.
- Reduction of machine tools.
- Less floor space.

1.1 History of CAD/CAM



1.1 History of CAD/CAM

A brief history of the evolution of CAD/CAM, according to the decade and the major CAD/CAM developments, is outlined below.

1950s: Start of interactive computer graphics,

CRT (Cathode Ray Tube), NC (Numerical Control),

APT (Automatically Programmed Tools)

1960's

- Development in Interactive computer graphics research
- Sketchpad system developed by Ivan Sutherland in 1962
- CAD term coined
- First major commercial CAD/CAM software available: CADAM by Lockheed, in 1965
- Bell Telephone's - Graphics 1 remote display system developed

1970's

- Potential of interactive computer graphics was realized by industry,
- Application of CAM in government, industry and academia
- Beginning of usage of computer graphics

1.1 History of CAD/CAM

- Initial Graphics Exchange Specification (IGES),
- Turnkey system available for drafting
- Wireframe and surface modeling software became available
- Mass property calculation and FEA software became available
- NC tape generating, verification, and integrated circuit software became available

National organization formed
Special Interest Group on GRAPHic (SIGGRAPH),
National Computer Graphics Assiciation(NCGA),

1980's

- CAD/CAM used for engineering research and development
- New CAD/CAM theories and algorithms developed
- Integration of CAD/CAM
- Solid modeling software became available
- Use of PCs and workstation began

1.1 History of CAD/CAM

1990's

- Concept of concurrent engineering developed
- Increased use of CAD/CAM on PCs and worksations
- Improvements in hardware and software
- Computer Integrated Manufactur(CIM)
- Enterprise Database (EDB)
- Product Data Management (PDM)
- Computer Aided Logic Systems (CALS)
- Virtual Reality (VR)

The present day CAD/CAM development focuses on efficient and fast integration and automation of various elements of design and manufacturing along with the development of new algorithms. There are many commercial CAD/CAM packages available for direct usages that are user-friendly and very proficient.

1.1 History of CAD/CAM

Below are some of the commercial packages in the present market.

- AutoCAD and Mechanical Desktop are some low-end CAD software systems, which are mainly used for 2D modeling and drawing.
- NX, Pro-E, CATIA and I-DEAS are high-end modeling and designing software systems that are costlier but more powerful. These software systems also have computer aided manufacturing and engineering analysis capabilities.
- Ansys, Abaqus, Nastran, Fluent and CFX are packages mainly used for analysis of structures and fluids. Different software are used for different proposes. For example, Fluent is used for fluids and Ansys is used for structures.
- Alibre and CollabCAD are some of the latest CAD systems that focus on collaborative design, enabling multiple users of the software to collaborate on computer-aided design over the Internet

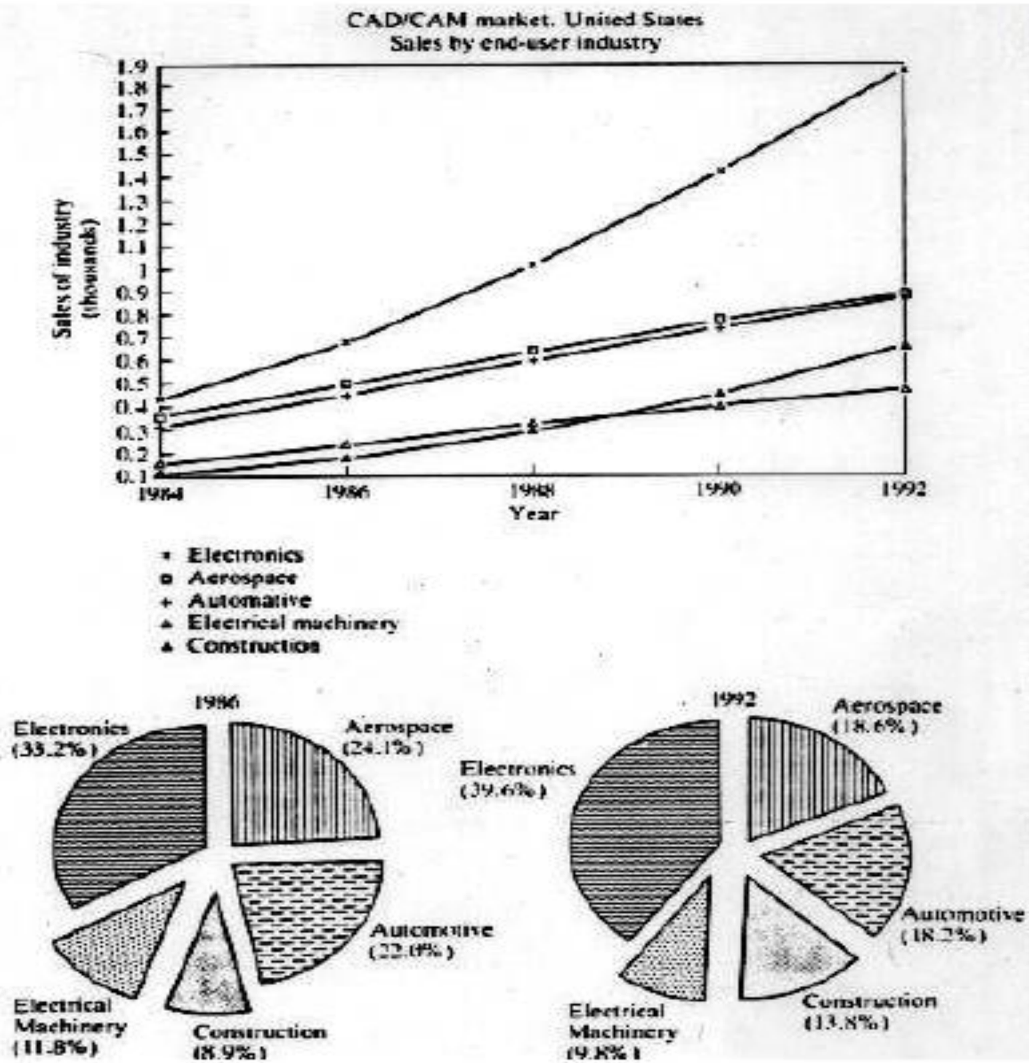


Fig.1-4 CAD/CAM market by end-user industry

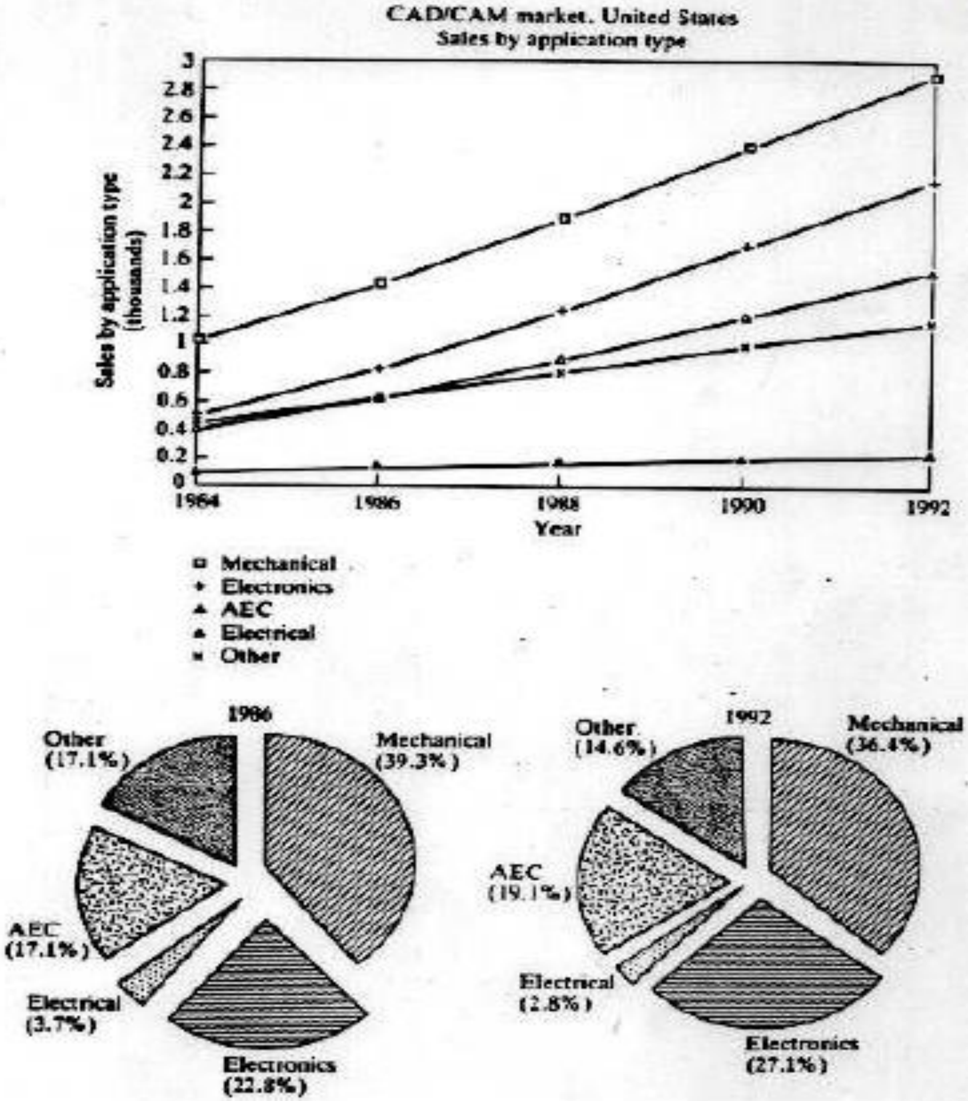
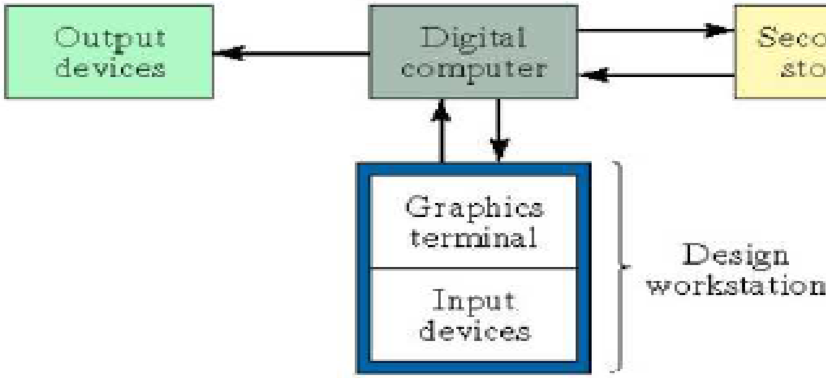
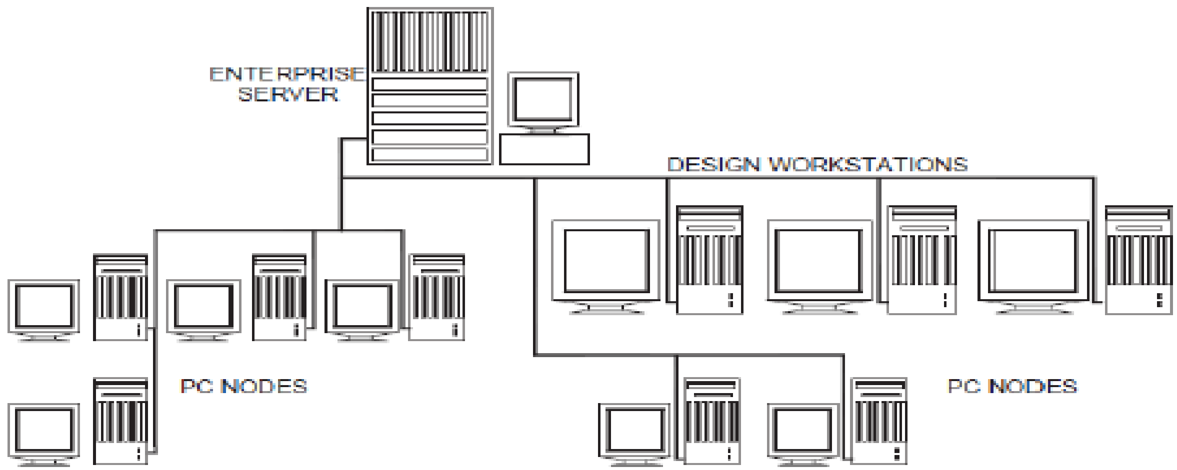


Fig.1-5 CAD/CAM market by application type

Computers and Workstation



Configuration of a typical CAD system



A Typical Computer Hardware Configuration

Computers and Workstation

Computers are commonly divided into the following types:

i. Personal Computer or Microcomputers
ii. Mini Computers
iii. Mainframes
iv. Supercomputers

The hardware of a Pentium computer consists of the following:

i. Mother board
ii. Hard disc/floppy disc controller card
iii. Graphics adapter card
iv. Input/Output card
v. Switch mode power supply
vi. Floppy disc drive
vii. Hard disc drive
viii. CD-ROM drive

Specifications of a Typical PC

2.8 GHz or faster CPU
ATX Motherboard with on board LAN or network adapter
512 MB RAM
40 GB or higher 7200 rpm IDE hard disc drive
1.44 MB 3.5" Floppy disc drive
CD- RW 40 X Read, 24X Write, 10 X Rewrite drive
17" LCD Monitor or 17" CRT Monitor
On- board sound or Creative Live sound card and amplified speakers
PS2 Key Board and Mouse
nVidia GeForce video card, on board Intel Extreme Graphics Card

DESIGN WORK STATIONS

Engineering workstations are computer systems with adequate computing power, based on 32 or 64 bit microprocessors. Workstations are typically divided into two broad categories: Low-end and high-end.

Low-end work stations generally consist of personal computers. Appropriate software and special hardware like graphics accelerator cards are added to these for boosting the performance. The processing capability of personal computers is generally enhanced by the addition of a co-processor in the microprocessor circuit which increases the processing speed by two or three times. Special custom-built graphics boards increase resolution and decrease drawing times. High resolution color monitors and multifunction cards improve the versatility of personal computers.

High-end workstations are designed around one or more powerful RISC processors.

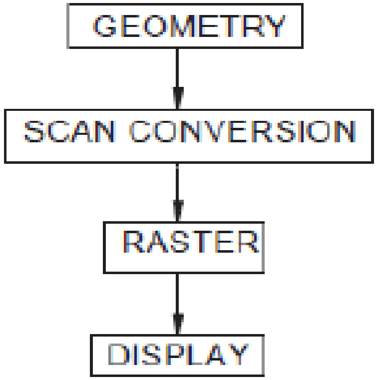
Workstations consist of three basic components:

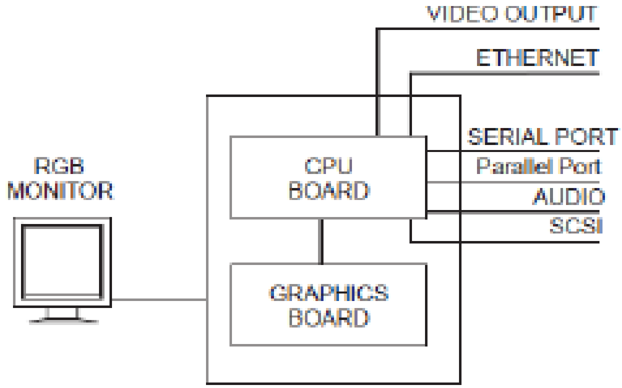
1. A primary processor
2. Associated memory
3. Graphics display system and software

DESIGN WORK STATIONS

Graphics system consists of four subsystems:

a. Geometry engine subsystem
b. Scan conversion subsystem
c. Raster subsystem
d. Display subsystem





System Level Block Diagram of a Graphics Workstation

The geometry engine accepts 3-D world co-ordinate data and converts them into X, Y screen co-ordinates.

The scan conversion subsystem carries out polygon decomposition, edge slope calculations, span slope calculations and span interpolation.

The raster subsystem will have usually 24 bit planes. This will provide eight bit planes for each primary color (RGB) so that (24) shades of a single color can thus obtain.

The display subsystem has multi-mode graphics processors which manage the display, send the Red, Green, Blue color (RGB) data to the respective digital to analog converters as well as provide a video output.

Elements of Interactive graphics

Interactive graphics is an important component of CAD providing a window through which the communication with the computer can be realized. Such systems which enable communication between the human operators and the computer are called "user- friendly" or simply friendly computers.

The display devices be can classified into two groups:

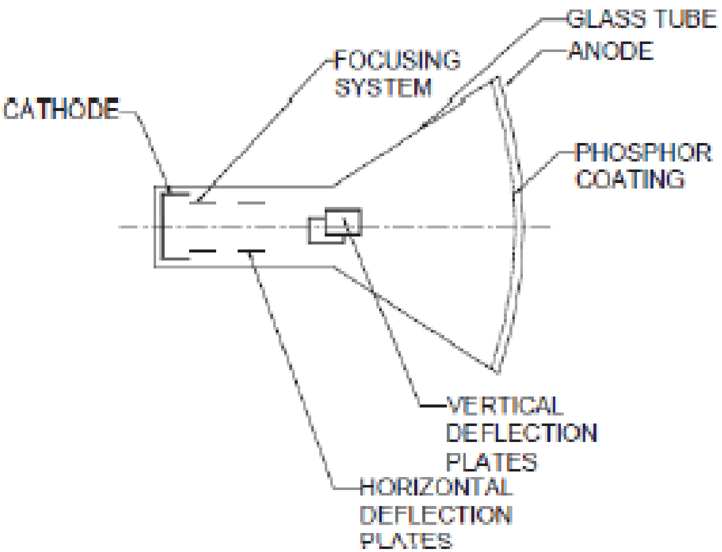
i. Display devices based on CRT principle ii. Flat screens

i. Display devices based on CRT principle

The position of the visible trace on the CRT screen is controlled by a focusing system and a set of horizontal and vertical deflection plates as shown in Fig

Elements of Interactive graphics

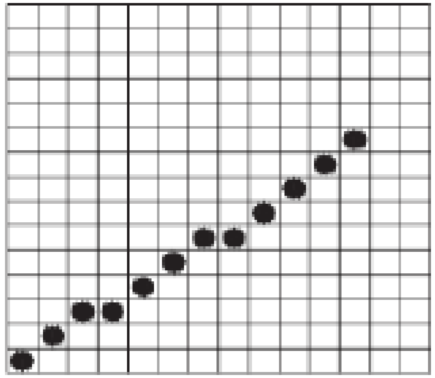
In a color CRT, there are three electron guns, one each for red, green and blue. The phosphor dots for red, green and blue are arranged in a triangular pattern. The individual beams intersect at a shadow mask which directs a red beam to a red phosphor dot and so on.



Principle of a CRT

Raster ScanTechnique

The screen of a monitor can be considered to consist of a large number of minute subdivisions called picture elements (pixels, in short). For example, in a typical *Super Video Graphics Array (*SVGA) monitor, the screen is divided horizontally into 1024 units and vertically into 768 units. The resolution of this monitor is then 1024 x 768.

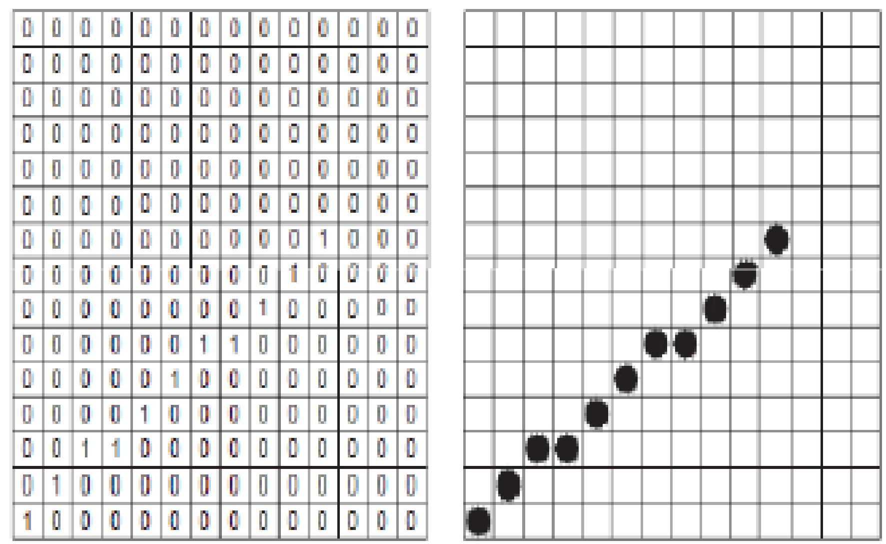


Line Drawing

Elements of Interactive graphics-Raster ScanTechnique

A raster CRT graphics device can be considered a matrix of discrete cells each of which can be made bright. Thus it is basically a point plotting device. If a line is to be drawn, it can be approximated by a series of dots close to the path of the line. Figure illustrates this concept.

A frame buffer is a common method of implementing a raster CRT graphics device. It can be considered to be a large contiguous piece of computer memory. In the simplest can, there can be one memory bit for each pixel in the raster. This amount of memory is called a bit plane. A 320 X 200 raster requires 64 K memory bits in a single plane. The picture is built in the frame buffer one bit at a time. The memory bits can be either in 0 or 1 state. If a particular pixel is to be addressed, the corresponding bit in the frame buffer is changed from 0 to 1.



Frame Buffer

Elements of Interactive graphics-Raster ScanTechnique

Since the raster CRT is an analog device, it requires an electrical voltage and the digital data of the frame buffer has to be converted to an analog voltage through a digital to analog converter (DAC). This is schematically shown in Fig.

A single bit plane yields a black and white display. Color or different grey levels can be achieved by using additional bit planes. Fig. 4.15 shows 4 bit plane frame buffer. The intensity of each pixel in the CRT is decided by the combination of the pixel values. (1111 in the picture shown). Since there are four bit planes, there can be 16 combinations. The resulting binary number is interpreted as an intensity level between 0 and 15. This is converted into a voltage between 0 (dark) and 15 (full intensity), by the digital to analog converter.

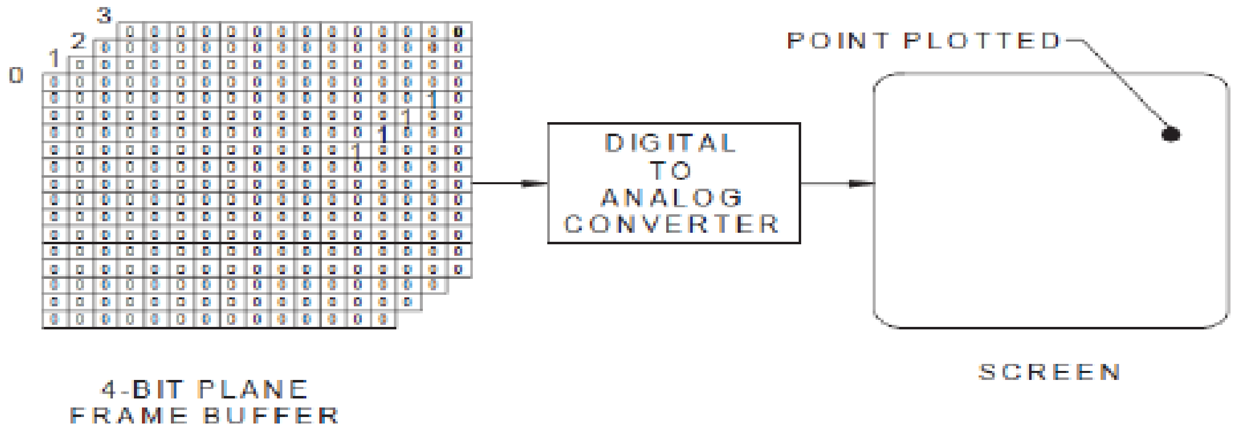


Fig. 4.15 4-bit Plane Frame Buffer

Elements of Interactive graphics-Flat Screens

CRT has the disadvantage that it is extremely bulky. Moreover, CRT consumes considerable power with increased heat dissipation requirements. Portability is reduced because of the size and the material of CRT. These disadvantages have prompted the manufacturers try different types of flat screens as output devices for computers. Flat screens are necessary for laptop, notebook and palm top computers. Flat screens operate on the principle of liquid crystal display.

Input Devices

For interactive graphic tasks more often several input devices are used. These allow entering data in an easily interpretable graphic form.

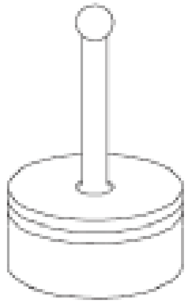
Keyboard:- The keyboard interacts with the computer on a hardware and software level. The keyboard contains a keyboard controller (like 8042 or 8048) to check if any key is pressed or released. If any key remains closed for more than half a second the controller sends a repeat action at specific intervals.

Input Devices

Touch screens:- are direct devices. They are used by simply touching CRT display with one's finger or a pointing device. Two types of touch screens (mechanical and optical) are used in CAD applications.

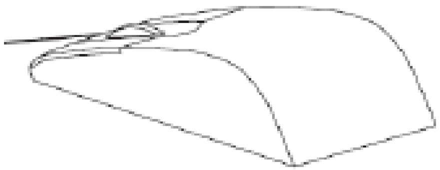
Mechanical type is a transparent screen overlay which detects the location of the touch. Optical touch screen systems use rows of light emitters and receptors mounted just in front of the screen with the touched location determined by broken beams.

Joystick:- is a potentiometric device that contains sets of variable resistors which feed signals that indicates the device position to the computer. These devices rely on the operator's sense of touch and hand-eye co-ordination to control the position of the cursor on the screen.



Track ball:- has a ball and socket construction but the ball must be rolled with fingers or the palm of the hand. The cursor moves in the direction of the roll at a rate corresponding to rotational speed.

Mouse:- is today one of the widely used input devices in graphics applications. Mouse is a small hand held puck like instrument which is attached to the computer (Fig. 4.17). Mouse can be moved around by the operator on any flat surface to provide graphic input. Its ability to rapidly position the cursor on the screen is its most important advantage. Mouse is available as a mechanical or optical graphic input device. In the case of a mechanical mouse, the rolling ball at the bottoms of the mouse causes two encoders to rotate. The movement of the mouse is thus converted into pulses which move the cursor in the X and Y direction in proportion to the movement of the mouse. Mouse can be operated in a limited space. Since the mouse can be used without looking at it, the user can concentrate on the screen and hence design productivity can be considerably increased.

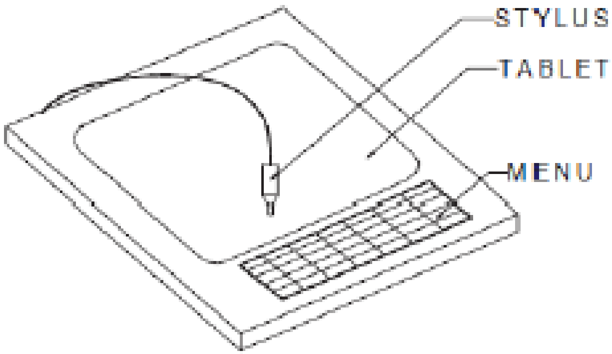


An optical mouse works on the basis of signal generated by the reflecting light from a special metallic plate or which the mouse is moved. The source of light is an LED located underneath the mouse. There are no moving parts in an optical mouse and that is an advantage over the mechanical mouse. Slippage at the contacting surfaces is a disadvantage of mouse.

Digitizer:- Digitizer boards or tablets are electro-mechanical vector graphic input devices that resemble a drafting board. These are used together with a movable stylus or reticule called a cursor or a puck. They are used to enter drawings into computer graphics systems by taping the drawing to the surface of the digitizing board and placing the cursor over points whose co-ordinates are to be entered. Figure 4.18 shows a digitizer

Input Devices

A digitizer consists of three basic elements: a locator in the form of a pen or stylus or puck or cursor, a tablet and a software package. A digitizer can be used to copy existing drawings and send the geometric data directly to the computer. But more frequently digitizers are used to create a drawing using an interactive drafting package to enter a sketch or a drawing which can then



be redrawn or edited as the display appears on the CRT screen. The operation of a digitizer is similar to that of a mouse. The user moves the stylus or puck across the flat surface of the tablet. The surface of the tablet is magnetized and is embedded with wires in X and Y directions. The tablet surface can be configured to represent the screen. The physical motion of the stylus is converted by the wires into digital location signals received by the locator. The coded electrical or acoustic signal is then routed to the computer and displayed on the graphic terminal.

Thumb wheels:- are potentiometric devices. Two of them are provided for X and Y movements of cursor. These also have the advantage that one can look at the screen and move the cursor.

AUTOMATED ENTRY

One of the major needs of design offices switching over to CAD is the necessity to convert existing paper drawings to computer files. Many automated devices are now available for entering drawings into CAD database. These units can scan a drawing and convert them into a form useful for CAD with little manual intervention. A typical automated drawing entry device contains a scanner and a workstation for viewing and editing the drawing. Software is required for rasterizing and vectorizing the scanned drawings.

Most systems begin the data entry process by scanning a document to create a raster image. A scanning rate of 13 dots/mm is adequate for most engineering applications. The pixel data may be stored or manipulated by converting it into vectors with the aid of sophisticated software. At the work station vectors are organized into graphic primitives such as line, arcs, circles, etc. symbols and text may also be recognized by the system and are converted into a single piece of data. Many systems can even recognize handwritten lettering.

Recently artificial intelligence techniques similar to those employed in robot vision technology have been used for automatic entry of drawing into the computer. Texts are usually entered in separate layers to enable easy revision.

OUTPUT DEVICES

A CAD system is not complete unless it can make hard copies of designs or analysis created on the computer. Determining the best output device for a typical CIM application is a three-step process: specifying how hard copies will be used, identifying quality and cost criteria and selecting equipment most suitable for the application. Quality of the hard copy depends on the resolution of the hard copy unit. Speed and frequency of operation of hard copy equipment are also of importance.

Plotters

Plotters are classified based several factors. Depending on the maximum size of the drawing plotters are designated as A0, A1, A2, A3 and A4. There are plotters capable of creating drawings larger than A0 size. Generally plotters plot drawings on cut sheets. Some special plotters are capable of creating drawings on rolls also. Drawings are created through a series of short vectors which requires movement to the pen in X and Y direction. Plotters can be classified on the basis of their construction. A flat bed plotter has the pen moving on a flat surface on which the drawing paper is fixed. The linear movements in the X and Y direction generate the required drawing. In the case of a drum plotter, the paper is wound around on a cylindrical drum. The pen holder is attached to a moving slide.

The co-ordinated motion generated by the rotation of the drum and linear movement draws the pictures on the paper. In the third type, i.e. the pinch roller plotter, the paper is tightly held between two sets of rollers. One roller in each pair has a rough surface and

OUTPUT DEVICES-Plotters

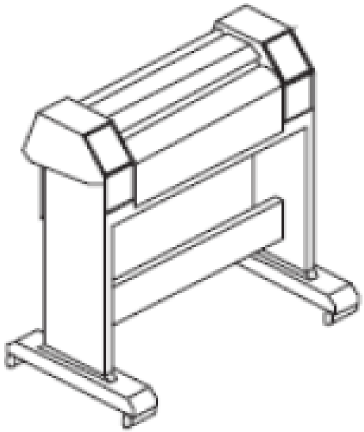
the linear motion to the paper in one direction is imparted by the rotation of the roller. The movement in the other direction is through a linear motion imparted to the pen holder.

Plotters can also classify as pen plotters and electrostatic plotters. Pen plotters use 1, 4, 8 or more different color pens. The drawings thus can be made in several colors. Pencil plotters are also available. Electrostatic plotters are faster but there is no color variety. They are also cheaper.

Plotters have high resolution which is specified by dots/mm. The pen speed and pen pressure are programmable. Various line thicknesses can be obtained by using pens of different tip sizes. Generally fibre tip pens are used.

Pen plotters are slow and shading is difficult. Pen plotters also require more maintenance and the ink or fibre tip or ball point pens should be changed frequently to keep line quality high.

Inkjet plotters are the ones that are now commonly used. These are available in color or monochrome versions. These are fast, reliable and more accurate than pen plotters. Figure 4.19 shows a plotter.



OUTPUT DEVICES-Printers

Several types of printers are available:

(i) Impact printers: They use small hammers or print heads containing small pins to strike a ribbon to form dot matrix images. Colors are introduced through the use of multiple ribbons or single ribbons with different color bands. Color intensity is fixed and creating shades is almost impossible. Because of the low resolution, copy quality is poor. Impact printers are suitable for high speed, low cost, high volume hard copies.

(ii) Inkjet printer: Inkjet printers produce images by propelling fine droplets of ink on to the medium to be printed. Droplets can be generated in continuous streams or pulses. Some of the droplets get charged and are returned to the reservoir, while uncharged droplets attach to the printing surface to form graphics. The laser jet printers are capable of giving good quality color prints with shading at reasonable cost.

(iii) Laser printer: Laser printer is one of the most widely used output devices. This type combines high speed with high resolution and the quality of output is very fine.

Storage devices in CAD

The computer will have a number of mass storage devices built into it. Common types of mass storage devices are floppy discs, hard discs, CD-ROMS and removable storage devices. Another type of mass storage device is the cartridge tape. Softwares are usually stored in the hard disc and they can be loaded into the primary memory as and when required. In a networked environment, the software is stored in the hard disc of the server and the users can access the software from the different terminals or nodes connected to the server. Hard discs are also used for storing data files, drawing files and other related files. A magnetic tape is used to backup the files so that vital files and information are not lost in the event of a disc failure. Optical discs (CD-ROMs) are widely used nowadays for mass storage.

Storage devices in CAD

Design	Application	Features
Executive storage	EPROM	Non- volatile and widely used
Part program storage	Dynamic RAM CMOS RAM Bubble memory	Semi conductor memory Fast access and volatile Nonvolatile, slower than semi- conductor memory
Machine constant	EPROM	Nonvolatile and can be field programmed. Needs battery back up
Memory (parameter)	CMOS RAM	Intermediate working
Scratch pad RAM Static RAM area	MOS RAM	
Off-line data storage	Magnetic digital cassette Magnetic disc Floppy disc Hard disc CD-ROM	

Complementary metal–oxide–semiconductor (CMOS); erasable programmable read only memory(EPROM)

Networking of CAD systems

Networking is a convenient technique for tying together the various "islands of automation" and in the process makes integration possible through high-speed data exchange between different automated segments.

Communication networks can be classified into four categories depending upon the physical separation of the communicating devices:

(i) Miniature (< 50 m): Such networks are concerned with the interconnection of multiple computational elements.

(ii) Small (< 500 m): These are concerned with the interconnection of multiple computational units.

(iii) Medium (< 1 km usually): These networks are concerned with the interconnection of multiple computational units (office workstations, CAD systems, shop floor computers and data collection terminals, CNC systems, Robots etc.). These are connected through a Local Area Network (LAN), or Intranet. LAN may cover distances more than one 1 km too.

(iv) Large (> 1 km): Large networks involve connection of remote mainframes, networking of a minicomputer system to a remote mainframe or terminals etc. It can be citywide (Metropolitan Area Network-MAN) or countrywide or Worldwide-WAN). With Internet becoming more and more popular, the intranetinternet- extranet technologies have found favour with manufacturing companies.

NETWORK TECHNIQUES

Network technology can be broadly classified into two categories. They are Local area network (LAN) or Wide area networks (WAN). LANs are intended to serve a number of users who are physically located close together. WANs are more akin to telephone network, tying different people in different buildings, cities or even countries.

A message is routed through several interim points before reaching its final destination; a WAN may also incorporate the ability to automatically change to an alternate message routing path if the computer at one location fails. A LAN (local area network) has 2 to 10 times more traffic on it than a wide area network (WAN). Each individual point within a network that can communicate through the network is called a node. Each node is assigned a unique address. This way, a destination address can be put into each message and it can be sent to correct recipient.

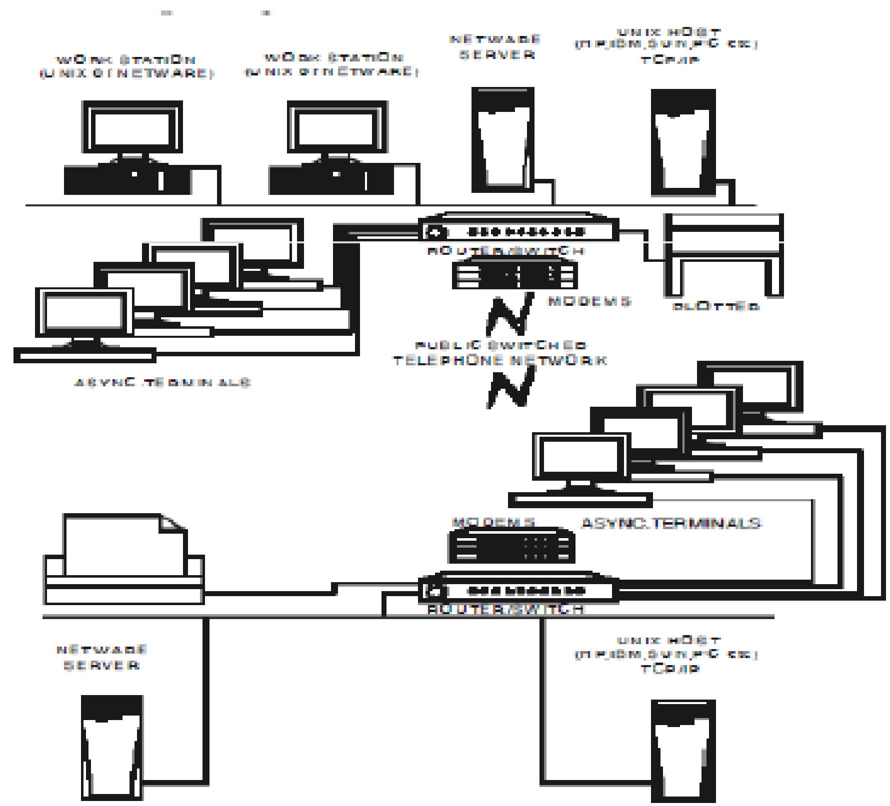
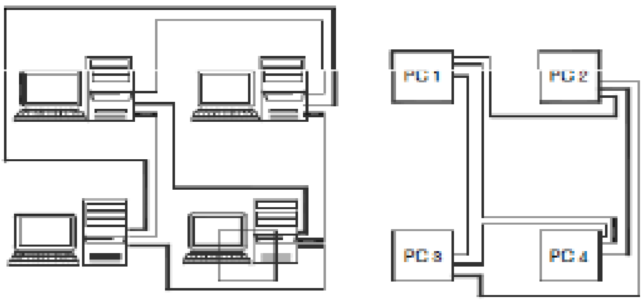


Fig.15.1 A Typical Local Area Network

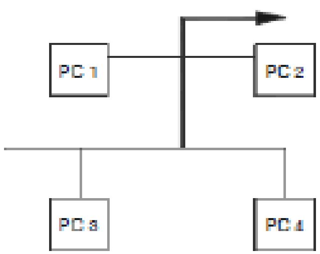
NETWORK TECHNIQUES

Components of a small LAN

(i) Computers
(ii) Network Cable
(iii) Network Interface Card (NIC)
(iv) Network Server
(v) Central Mass Storage:



POINT TO POINT



MULTI-DROP

Cables Used in Networking

Type	*Data Transmission Rate*	*Distance*	*Remarks*
Twisted pair	1 M bit/sec	Short distance100 m	Least Expensive base band, single channel
Coaxial Cable -base band -broad band	 10 M bit/sec 5 M bit/sec	 up to 4 km up to 50 km	 Multi Channel Capability
Fibre Optics	100 M bits or more		Multi Channel Large Capacity Expensive

'WORK WIRING METHODS

NETWORK TOPOLOGIES

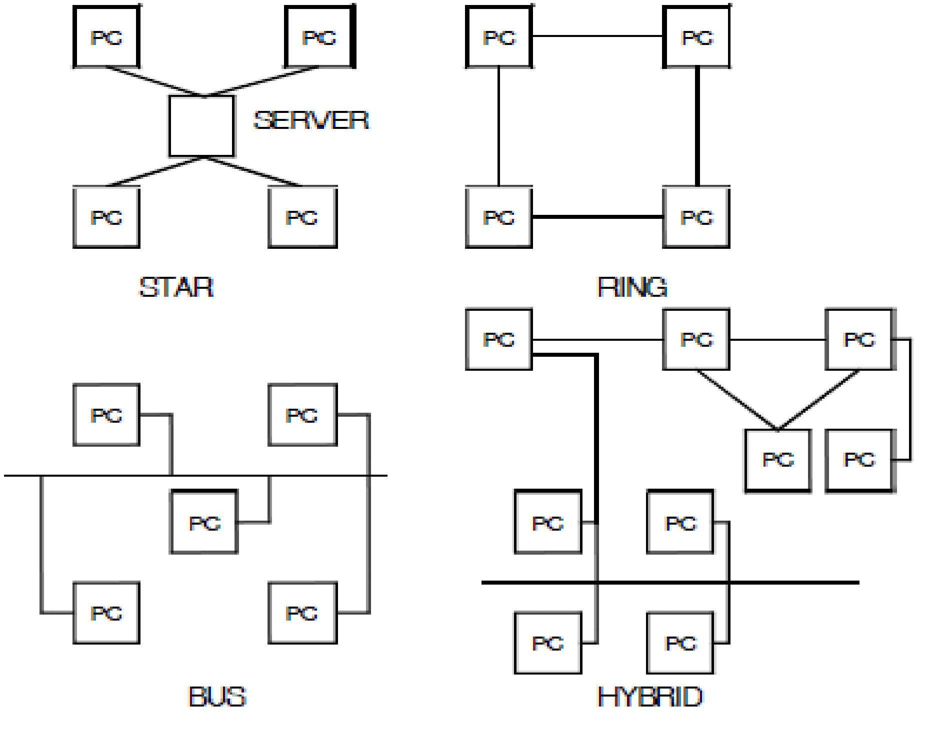
(i) Star Network: (ii) Ring Network: (iii) Bus Networks: (iv) Hybrid Networks:

TRANSMISSION MEDIA

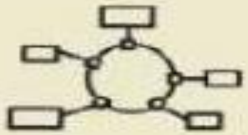
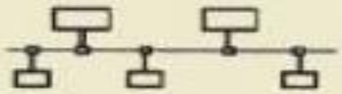
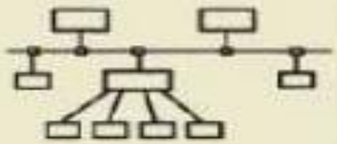
(i) Two-wire open lines
(ii) Twisted pair lines
(iii) Co-axial cable
(iv) Optical fibre
(v) Microwaves

INTERFACES

RS-232C, RS-422, Modem



Topologic structure of networks and their advantages/disadvantages.

Star	Ring	Bus	Tree
			
Common structure	Each station needs an active transmitter and receiver	Coaxial cable as passive medium	Branches off of main trunk
ADVANTAGE: Failure of a unit has no effect on the network	Easy to connect new devices	Stations can be switch on and off as desired	For separated networks or later expansions
DISADVANTAGE: High costs for lines over large distances	Two paired cables needed for safety if a station fails	Failure in case of cable damage	Expansion is complex, costly for different networks

Introduction

- What is Virtual Reality(VR)?

  Virtual Reality refers to a high-end user interface that involves real-time simulation and interactions through multiple sensorial channels.

▪

Introduction (Cont’d)

- Why VR?

  VR is able to immerse you in a computer-generated world of your own making: a room, a city, the interior of human body. With VR, you can explore any uncharted territory of the human imagination.

Brief History

- In 1950s, flight simulators were built by US Air Force to train student pilots.
- In 1965, a research program for computer graphics called “The Ultimate Display” was laid out.
- In 1988, commercial development of VR began.
- In 1991, first commercial entertainment VR system "Virtuality" was released.

Types of VR System

- Windows on World(WoW)
  - Also called Desktop VR.
  - Using a conventional computer monitor to display the 3D virtual world.
- Immersive VR
  - Completely immerse the user's personal viewpoint inside the virtual 3D world.
  - The user has no visual contact with the physical word.
  - Often equipped with a Head Mounted Display (HMD).

Types of VR System(Cont'd)

- Telepresence
  - A variation of visualizing complete computer generated worlds.
  - Links remote sensors in the real world with the senses of a human operator. The remote sensors might be located on a robot. Useful for performing operations in dangerous environments.

Types of VR System(Cont'd)

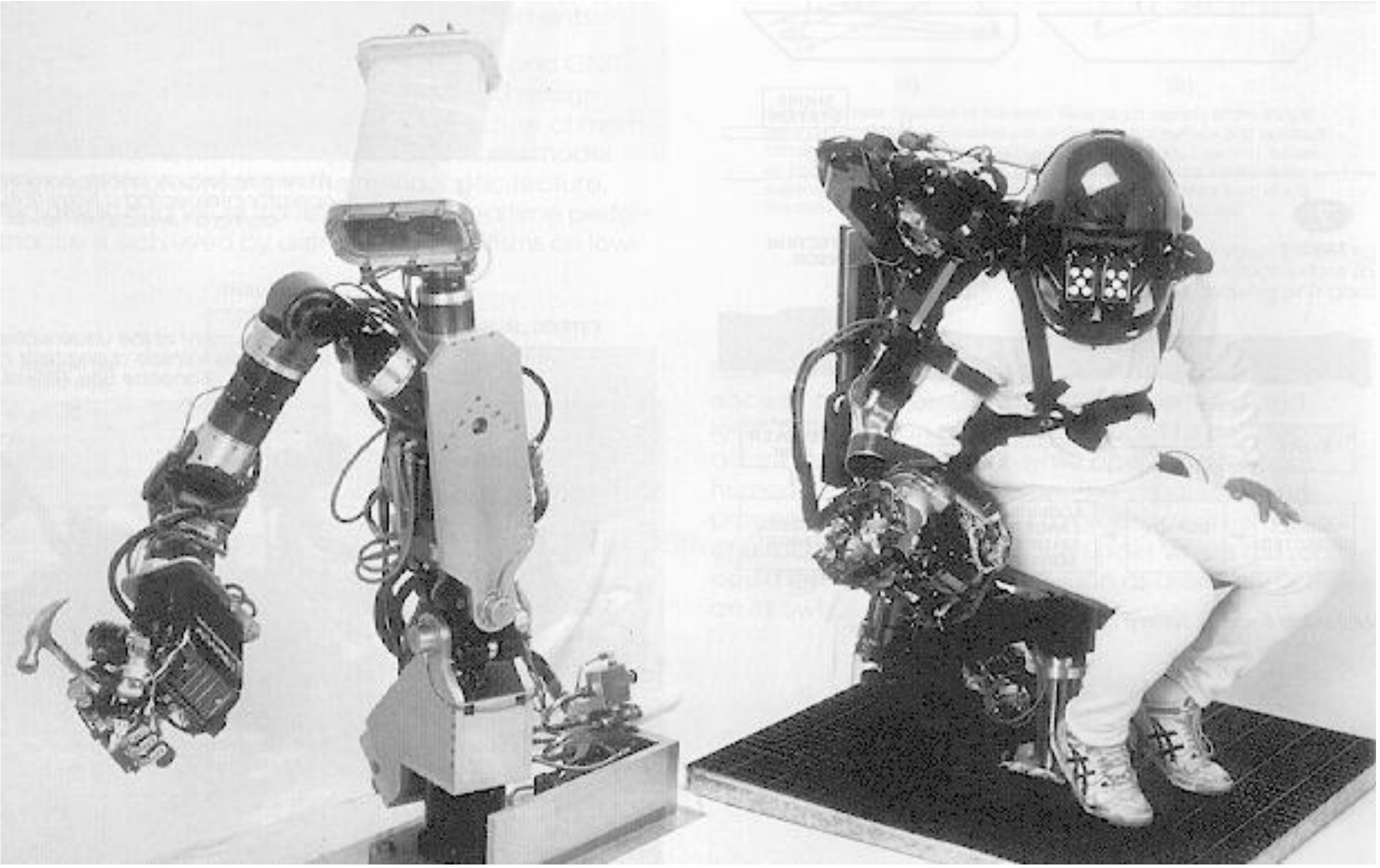
- Mixed Reality(Augmented Reality)
  - The seamless merging of real space and virtual space.
  - Integrate the computer-generated virtual objects into the physical world which become in a sense an equal part of our natural environment.

Distributed VR

- A simulated world runs on several computers which are connected over network and the people are able to interact in real time, sharing the same virtual world.

VR Examples (Cont'd)

- Telepresence VR



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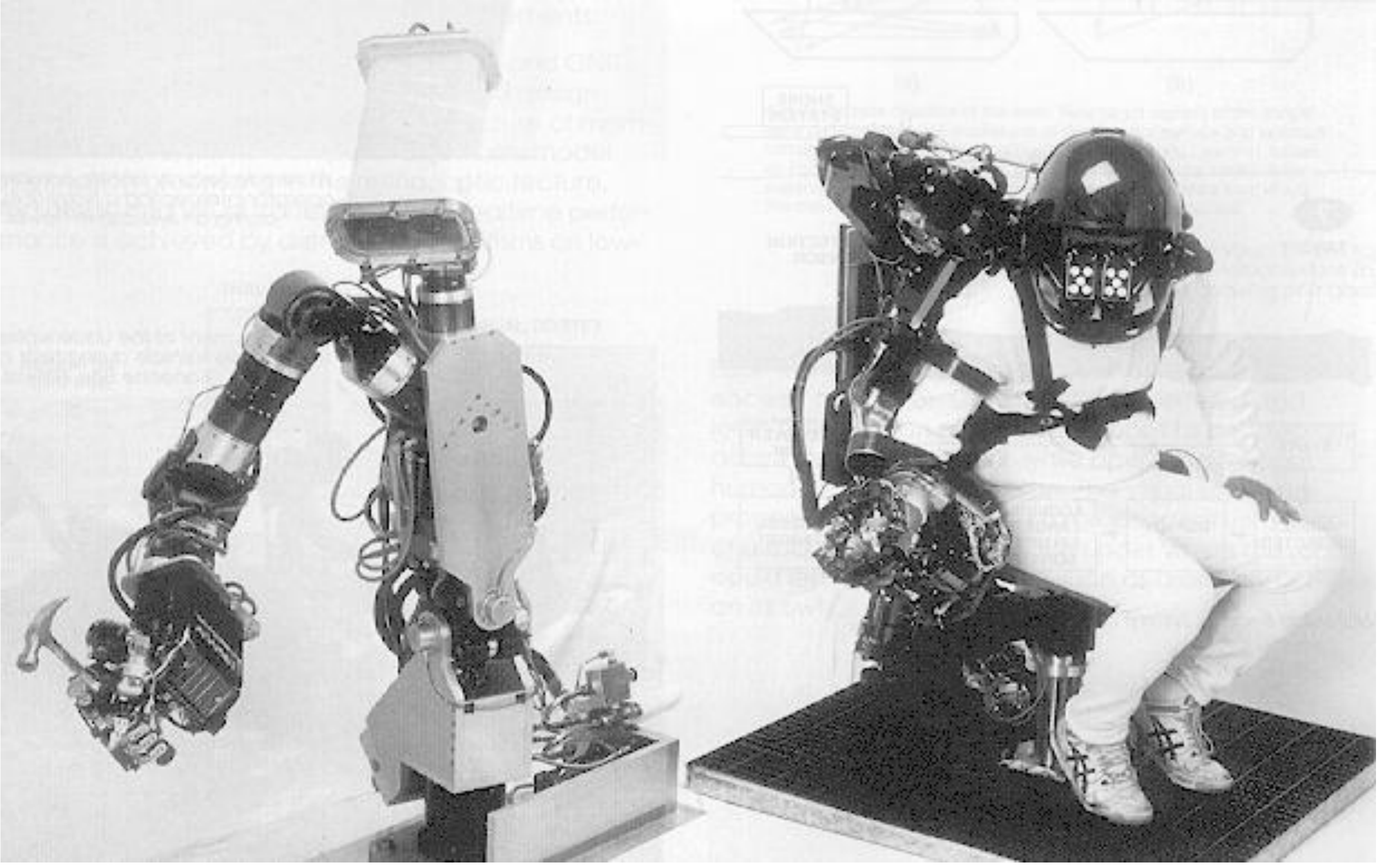
- Telepresence VR

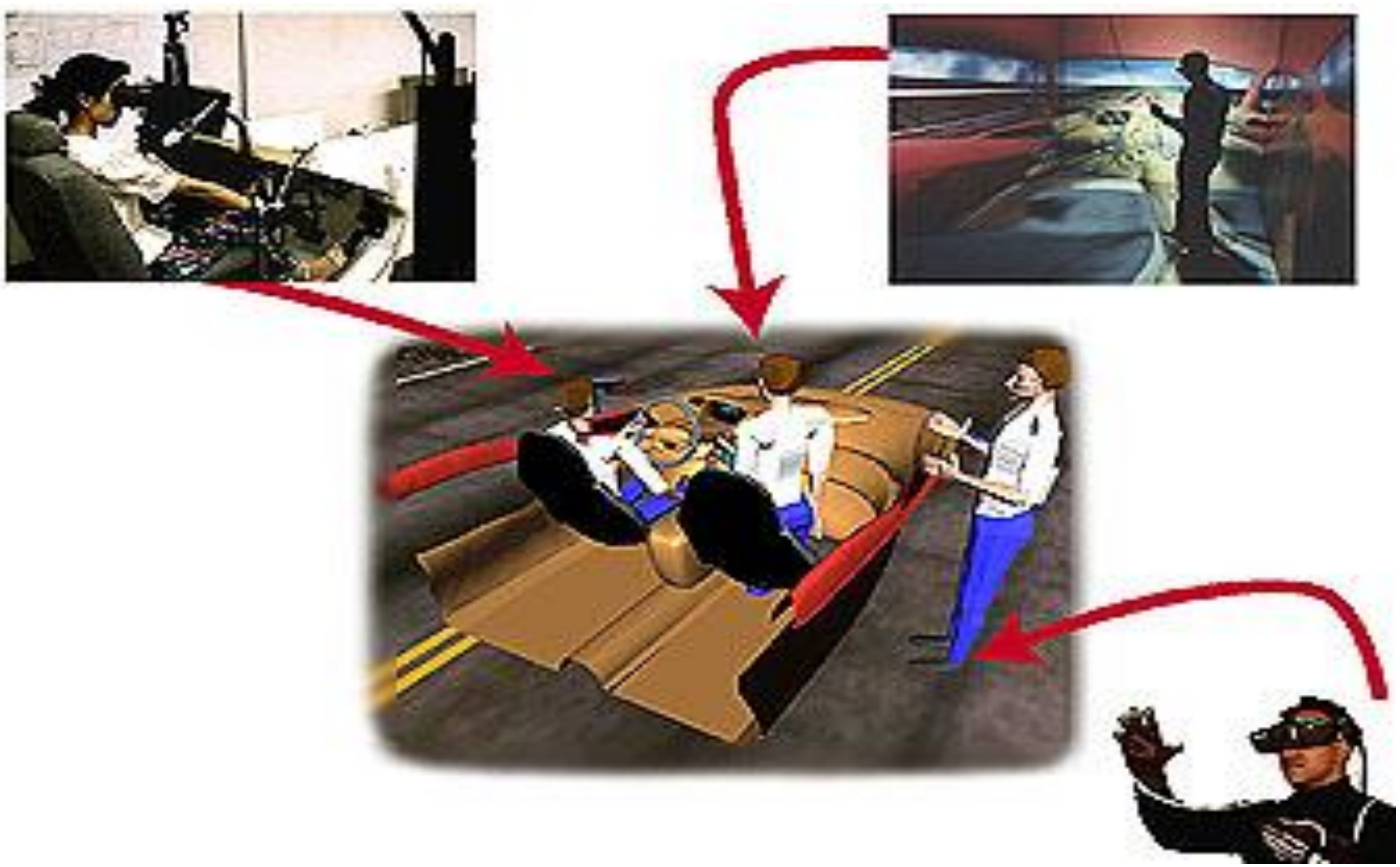


VR Examples (Cont'd)

- Augmented VR

VR Examples (Cont'd)

- Distributed VR

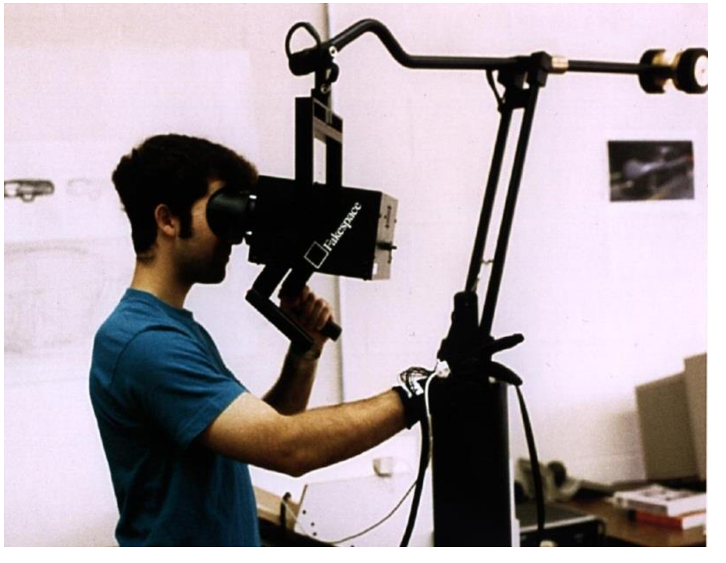


Technologies of VR--Hardware

- Head-Mounted Display (HMD)
  - A Helmet or a face mask providing the visual and auditory displays.
  - Use LCD or CRT to display stereo images.
  - May include built-in head-tracker and stereo headphones

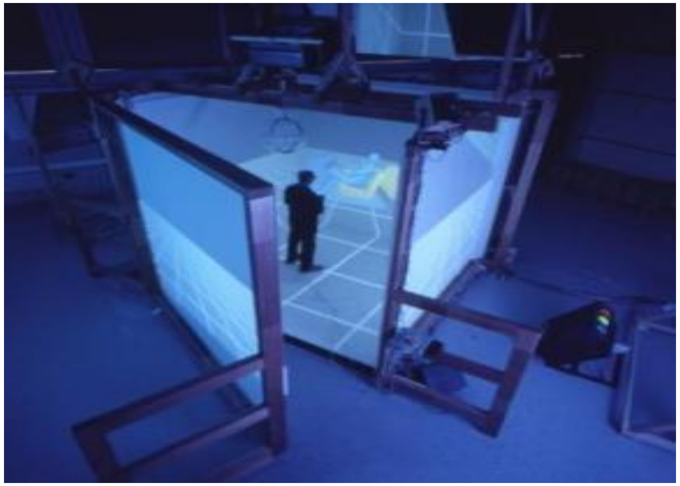
Technologies of VR--Hardware

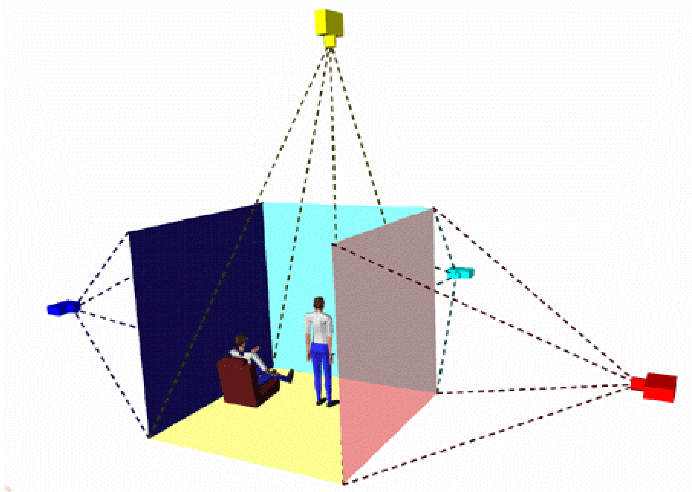
- Binocular Omni-Orientation Monitor (BOOM)
  - Head-coupled stereoscopic display device.
  - Uses CRT to provide high-resolution display.
  - Convenient to use.
  - Fast and accurate built-in tracking.



Technologies of VR--Hardware

- **Cave Automatic Virtual Environment (CAVE)**
  - Provides the illusion of immersion by projecting stereo images on the walls and floor of a room-sized cube.
  - A head tracking system continuously adjust the stereo projection to the current position of the leading viewer.





Technologies of VR--Hardware

- Data Glove
  - Outfitted with sensors on the fingers as well as an overall position/orientation tracking equipment.
  - Enables natural interaction with virtual objects by hand gesture recognition.

Technologies of VR--Hardware

- Control Devices
  - Control virtual objects in 3 dimensions.

Technologies of VR--Software

- Toolkits
  - Programming libraries.
  - Provide function libraries (C & C++).
- Authoring systems
  - Complete programs with graphical interfaces for creating worlds without resorting to detailed programming.

Technologies of VR--Software

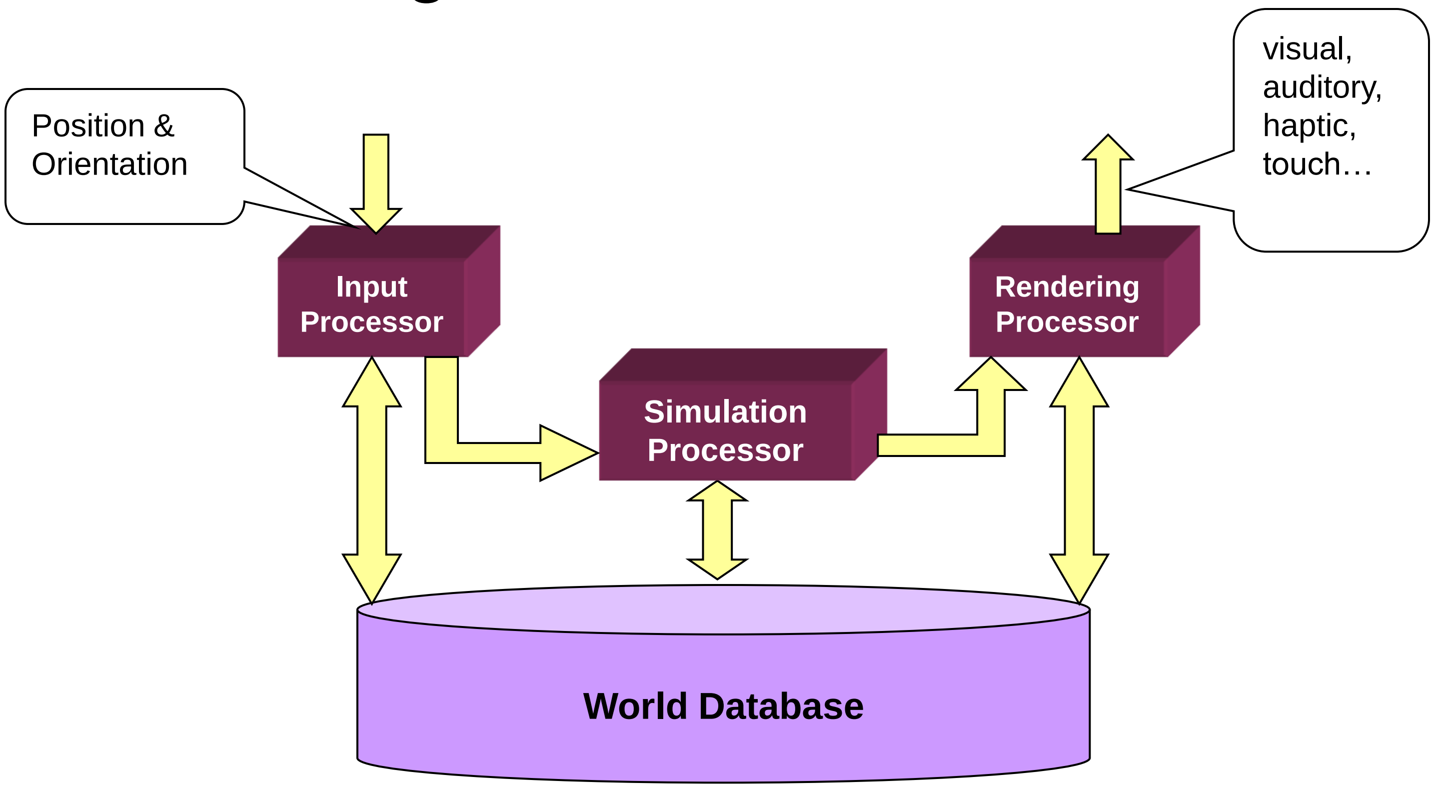
- Software packages available in market
  - **Multiverse (Freeware)**
  - **Virtual Reality Studio** ($100)
  - **Sense8 World Tool Kit (WTK)** (over $1000)
  - **Autodesk Cyberspace Development kit** (over $1000)

Technologies of VR--Software

- VRML(Virtual Reality Modeling Language)
  - Standard language for interactive simulation within the World Wide Web.
  - Allows to create "virtual worlds" networked via the Internet and hyperlinked with the World Wide Web.
  - Aspects of virtual world display, interaction and internetworking can be specified using VRML without being dependent on special gear like HMD.
  - VR models can be viewed by Netscape or IE with a browser plug-in.

Architecture of VR System

- Input Processor, Simulation Processor, Rendering Processor and World Database.



Components of VR System (Cont'd)

- Input Processor
  - Control the devices used to input information to the computer. The object is to get the coordinate data to the rest of the system with minimal lag time.
  - Keyboard, mouse, 3D position trackers, a voice recognition system, etc.

Components of VR System (Cont'd)

- World Database (World Description Files)
  - Store the objects that inhabit the world, scripts that describe actions of those objects.

Components of VR System (Cont’d)

- Rendering Processor
  - Create the sensations that are output to the user.
  - Separate rendering processes are used for visual, auditory, haptic and other sensory systems. Each renderer take a description of the world stat from the simulation process or derive it directly from the World Database for each time step.

Components of VR System (Cont'd)

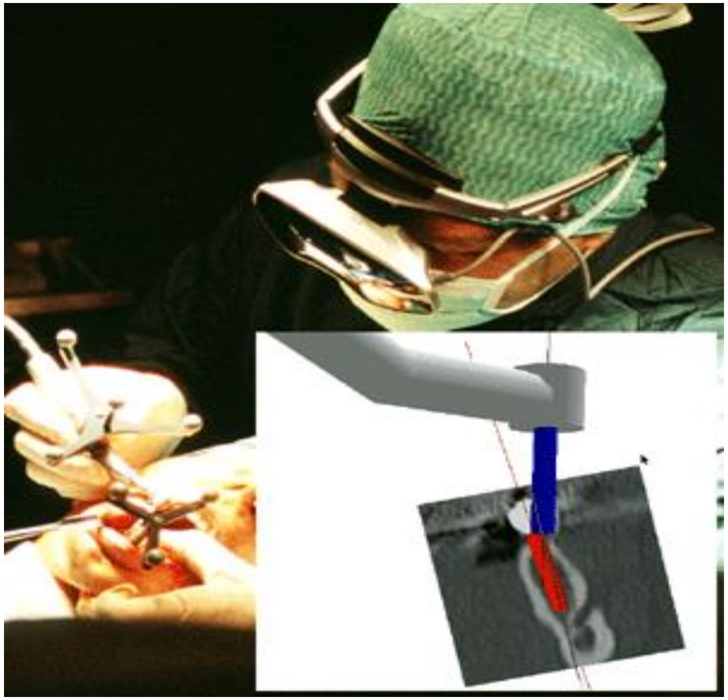
- Simulation Processor
  - Core of a VR system.
  - Takes the user inputs along with any tasks programmed into the world and determine the actions that will take place in the virtual world.

Applications

- **Entertainment**
  - More vivid
  - Move exciting
  - More attractive

Applications (Cont'd)

- **Medicine**
  - Practice performing surgery.
  - Perform surgery on a remote patient.
  - Teach new skills in a safe, controlled environment.



Applications (Cont'd)

- Manufacturing
  - Easy to modify
  - Low cost
  - High efficient

Applications (Cont'd)

- Education & Training
  - Driving simulators.
  - Flight simulators.
  - Ship simulators.
  - Tank simulators.

Current problems & Future work

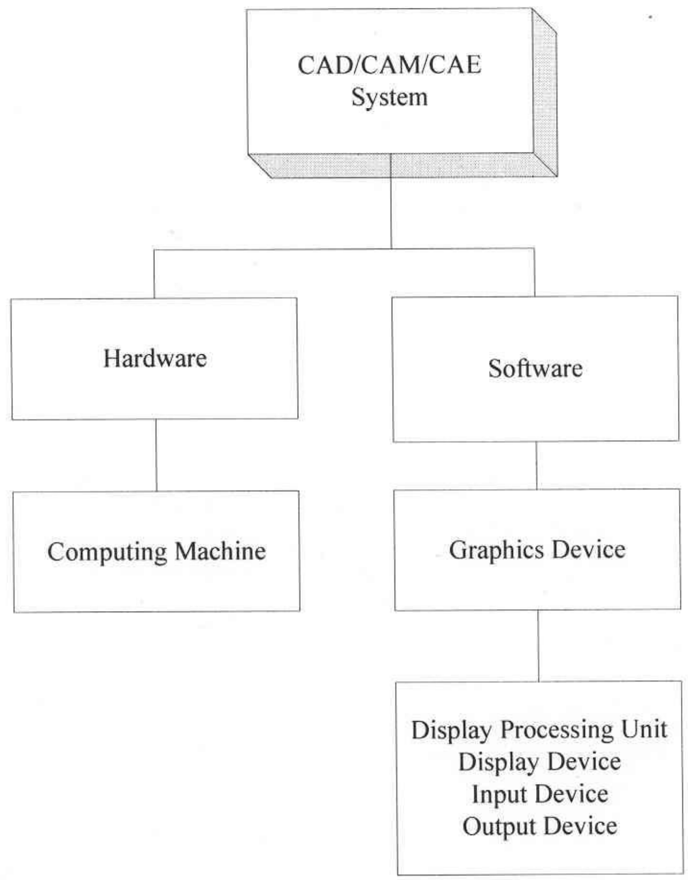
- ☹ Cybersickness / simulator sickness
- ☹ Low-fidelity
- ☹ Expensive
- ☹ Lack of integration between application packages

- ☺ High-fidelity system
- ☺ Cost-saving
- ☺ Collaborative
- ☺ High-level contact between participants in distributed VR

Summary

- Visualization of complicated, large data is helpful for understanding and analysis.
- VR offers us a new way to interact with computer.
- VR enables us to experience the virtual world that is impossible in real world.
- VR is changing our life, eventually VR will increasingly become a part of our life.

Components of CAD/CAM/CAE Systems



Hardware Components

- Graphic device is composed of a display processing unit, a display device, and one or more input devices
- Input devices:
  - Mouse
  - Space ball
  - Data tablet with a puck or stylus
  - Keyboard
- Output Devices:
  - Plotters
  - Color laser printers

Software Components

- CAD software allows the designer to create and manipulate a shape interactively and store it
- CAM software plans, manages and controls the operations of a manufacturing site
- CAE software analyzes design geometry, allowing designer to study product behavior

Windows-Based CAD Systems

- User interface is similar to Windows
- Employs component technology, in which best key software elements are selected from among available software
- Use object-oriented technology, which modularizes the program
- Capable of either parametric or variational modeling
- Internet support

CAD/CAM

- CAD/CAM = Computer Aided Design and Computer Aided Manufacturing. It is the technology concerned with the use of computers to perform design and manufacturing functions.

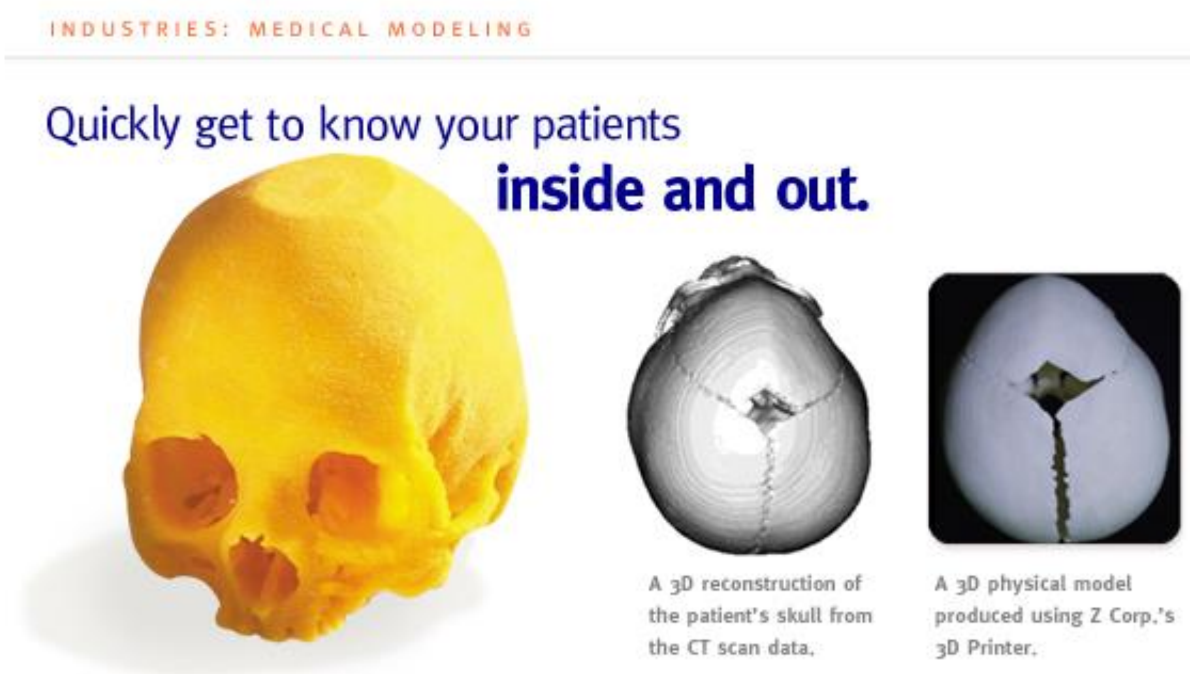
- **CAD** can be defined as the use of computer systems to perform certain functions in the design process.
- **CAM** is the use of computer systems to plan, manage and control the operations of manufacturing plant through either direct or indirect computer interface with the plant's production resources.

Rapid Prototyping

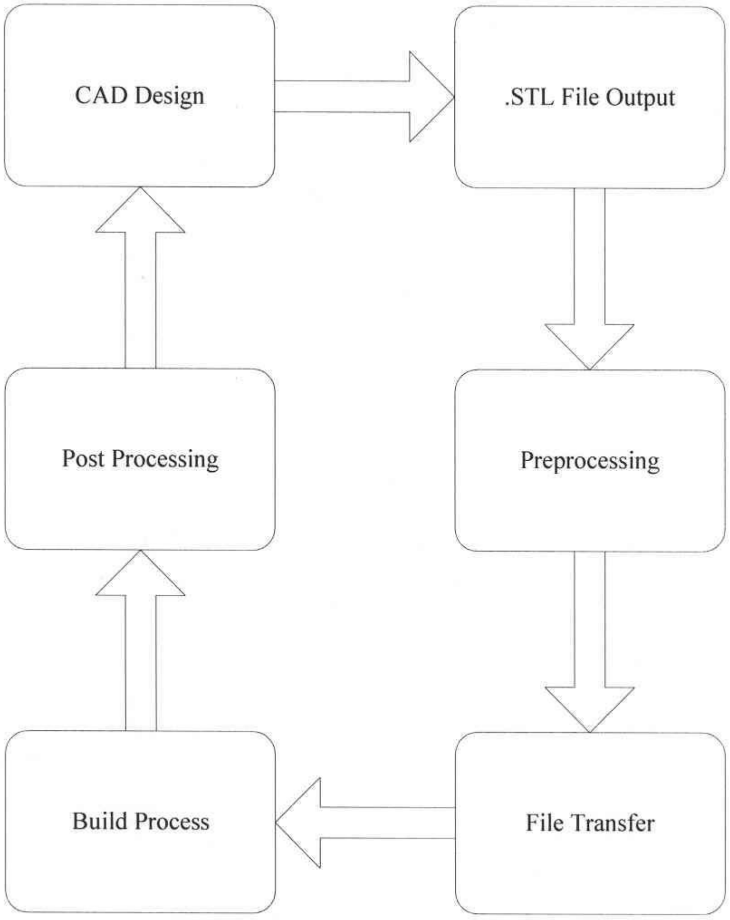
Rapid Prototyping has surgical applications

- Layer by layer fabrication of three-dimensional physical models from CAD
- Fast and inexpensive alternative for producing prototypes and functional models
- Build parts in thin layers
- Minimum operation time; typically runs unattended

Medical Modeling - Zcorp



Rapid Prototyping Cycle



Rapid Prototyping Cycle

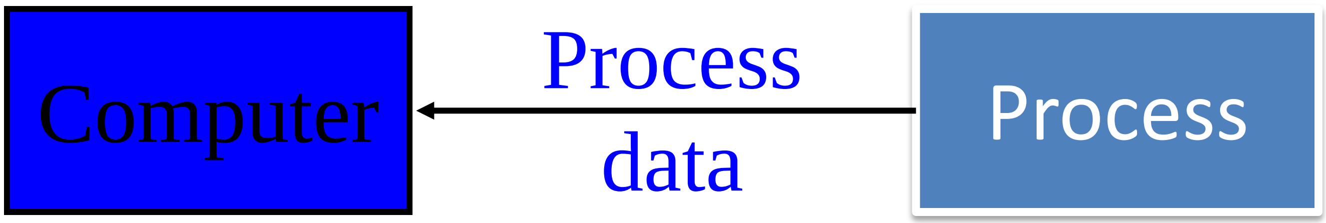
- .STL is standard file format for all U.S. rapid prototyping systems
- Preprocessing prepares .STL file for various rapid prototyping systems
- Build process can last from a few hours to several days
- Post processing: removal of part from machine, support removal, sanding

Rapid Prototyping Process (Damvig)

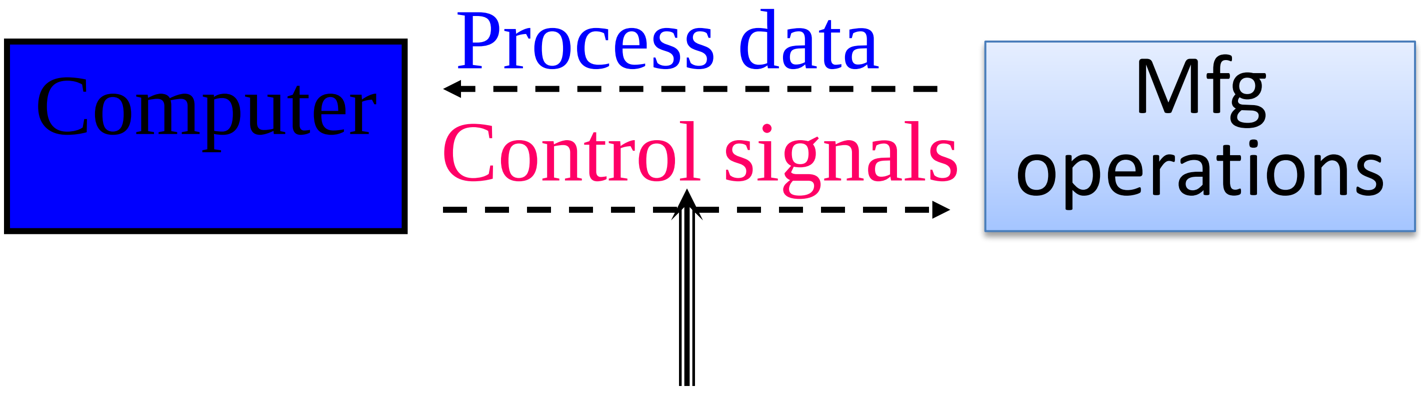
"A computer-controlled laser beam is scanned across the surface of a vat of liquid photopolymer, instantly solidifying the liquid at each point of contact. Using data generated from a CAD file, individual cross-sections of the three-dimensional geometry are solidified in turn to build up a solid part layer by layer. In this way even highly complex geometries can be built in a few hours without requiring any tools. "

From CAM definition, the application of CAM falls into two broad categories:

1. Computer monitoring and control .



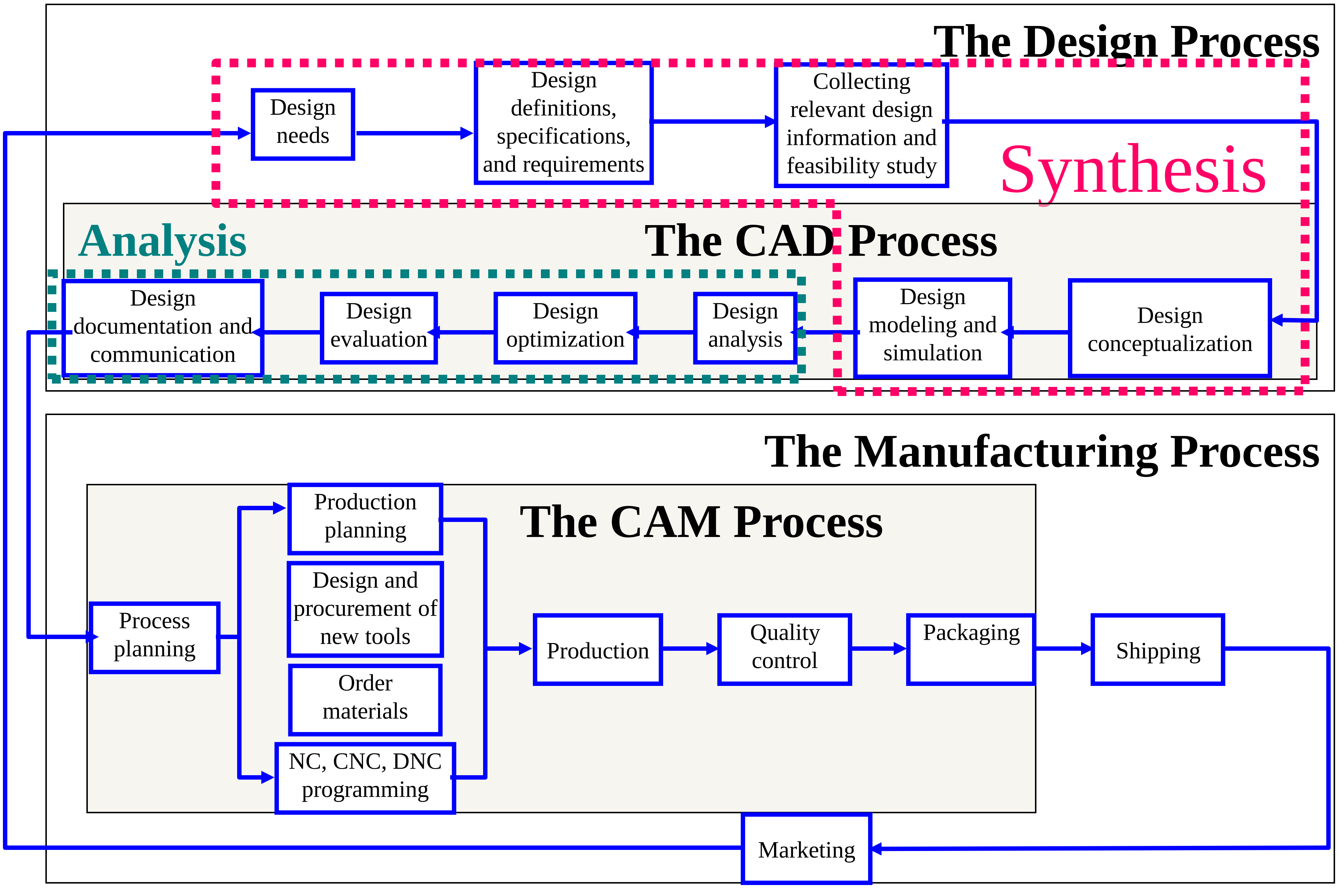
2. Manufacturing support application .



The Product Cycle and CAD/CAM

In order to establish the scope and definition of CAD/CAM in an engineering environment and identify existing and future related tools, a study of a typical product cycle is necessary. The following Figure shows a flowchart of such a cycle.

Typical Product Life Cycle



- The product begins with a need which is identified based on customers' and markets' demands.
- The product goes through two main processes from the idea conceptualization to the finished product:

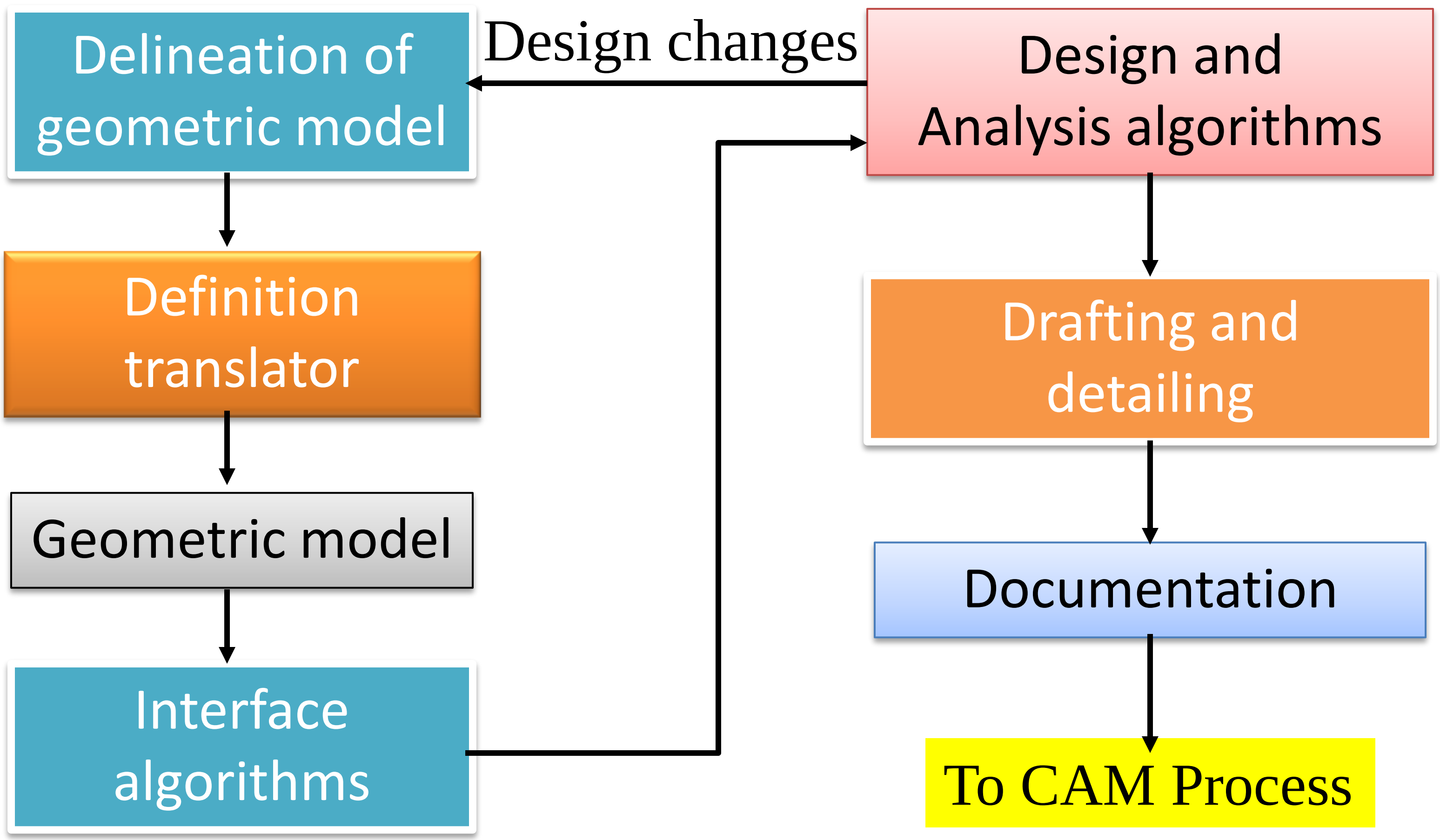
1. The design process.

2. The manufacturing process.

The main sub-processes that constitute the design process are:

1. Synthesis.
2. Analysis.

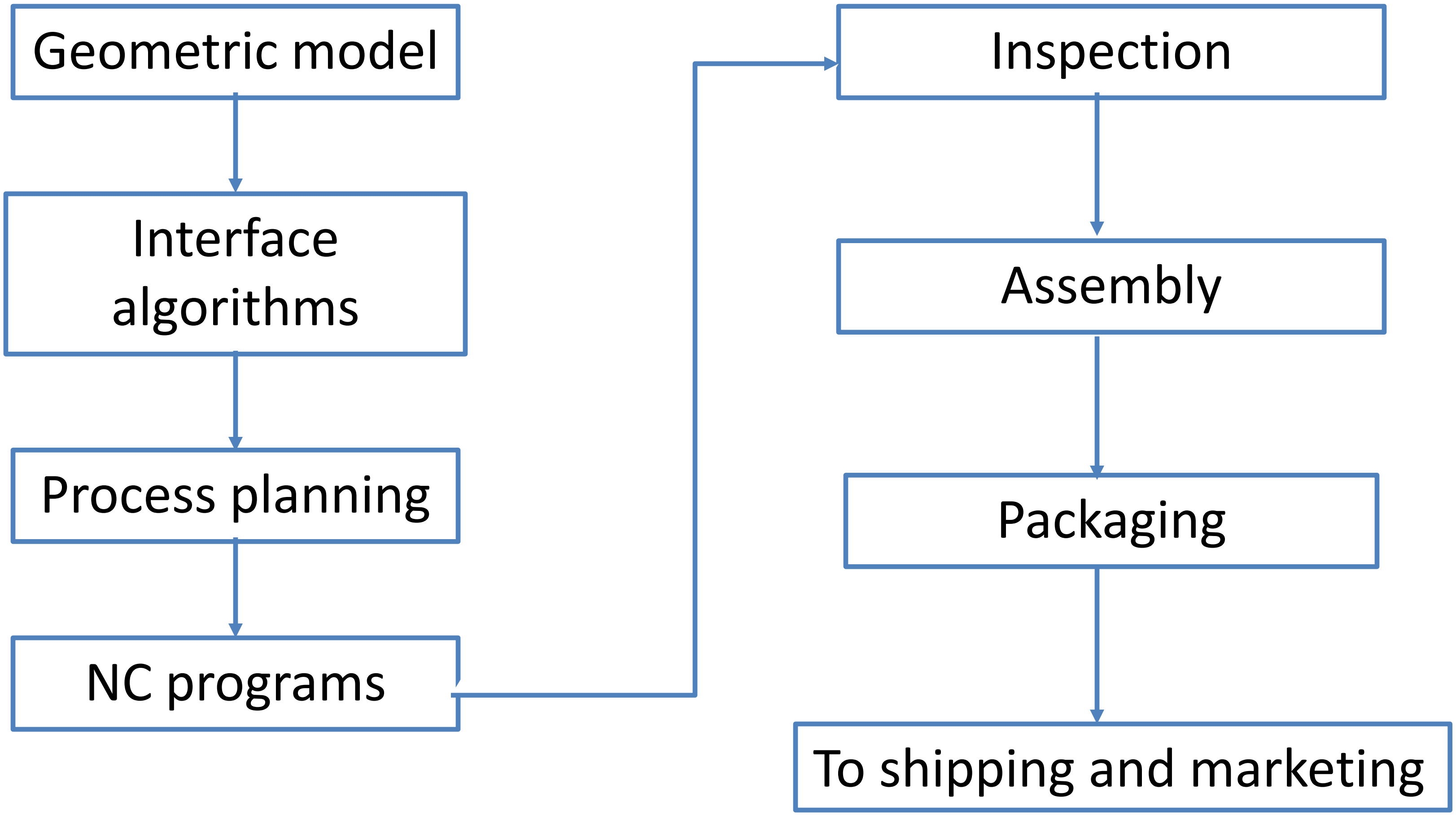
Implementation of a Typical CAD Process on a CAD/CAM system



CAD Tools Required to Support the Design Process

Design phase	Required CAD tools
Design conceptualization	Geometric modeling techniques; ; manipulations; and visualization
Design modeling and simulation	Same as above; ; special modeling packages.
Design analysis	; customized programs and packages.
Design optimization	Customized applications;
Design evaluation	; BOM; NC.
Design communication and documentation	…

Implementation of a Typical CAM Process on a CAD/CAM system



CAM Tools Required to Support the Design Process

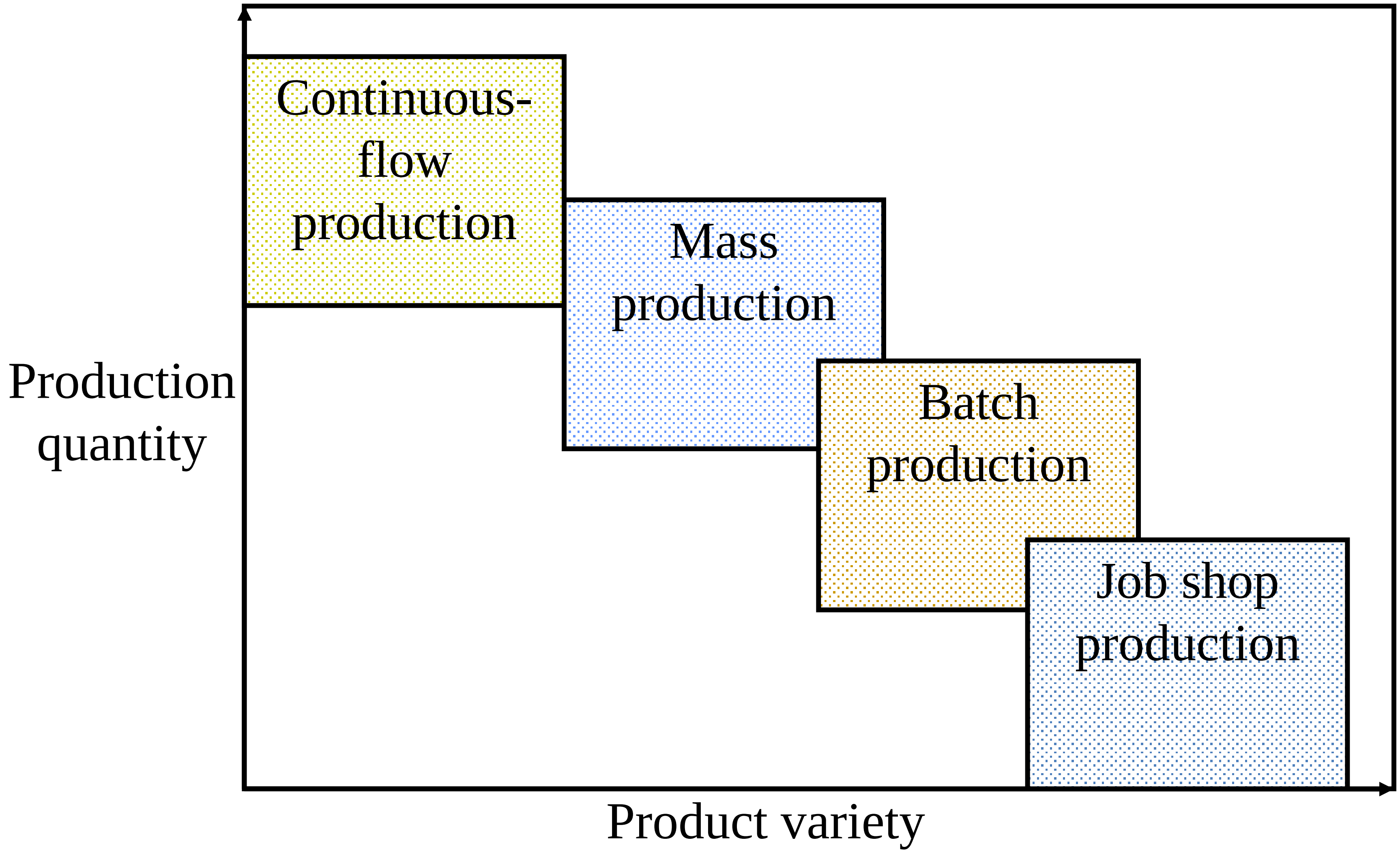
Manufacturing phase	Required CAM tools
Process planning	CAPP techniques; cost analysis; material and tooling specification.
Part programming	NC programming
Inspection	CAQ; and Inspection software
Assembly	Robotics simulation and programming

Automation and CAD/CAM

Automation can be defined as the technology concerned with the application of complex mechanical, electronic, and computer-based systems in the operation and control of manufacturing systems.

TTypes of Manufacturing Systems

1. **Continuous-flow processes**. Continuous dedicated production of large amount of bulk product. Continuous manufacturing is represented by chemicals, plastics, petroleum, and food industries.
2. **Mass production of discrete products**. Dedicated production of large quantities of one product (with perhaps limited model variations). Examples include automobiles, appliances and engine blocks.
3. **Batch production.** Production of medium lot sizes of the same product. The lot may be produced once or repeated periodically. Examples: books, clothing and certain industrial machinery.
4. **Job-shop production**. Production of low quantities, often one of a kind, of specialized products. The products are often customized and technologically complex. Examples: prototypes, aircraft, machine tools and other equipment.


Continuous-flow production
Mass production
Batch production
Job shop production
Production quantity
Product variety

Category	Automation achievements
Continuous-flow process	•Flow process from beginning to end •Sensors technology available to measure important process variables •Use of sophisticated control and optimization strategies •Fully computer automated lines
Mass production of discrete products	•Automated transfer machines •Dial indexing machines •Partially and fully automated assembly lines •Industrial robots for spot welding, part handling, machine loading, spray painting, etc. •Automated material handling systems •Computer production monitoring
Batch production	•Numerical control (NC), direct numerical control (DNC), computer numerical control (CNC). •Adaptive control machining •Robots for arc welding, parts handling, etc. •CIM systems.
Job shop production	•Numerical control, computer numerical control

Computer Technology in Automation

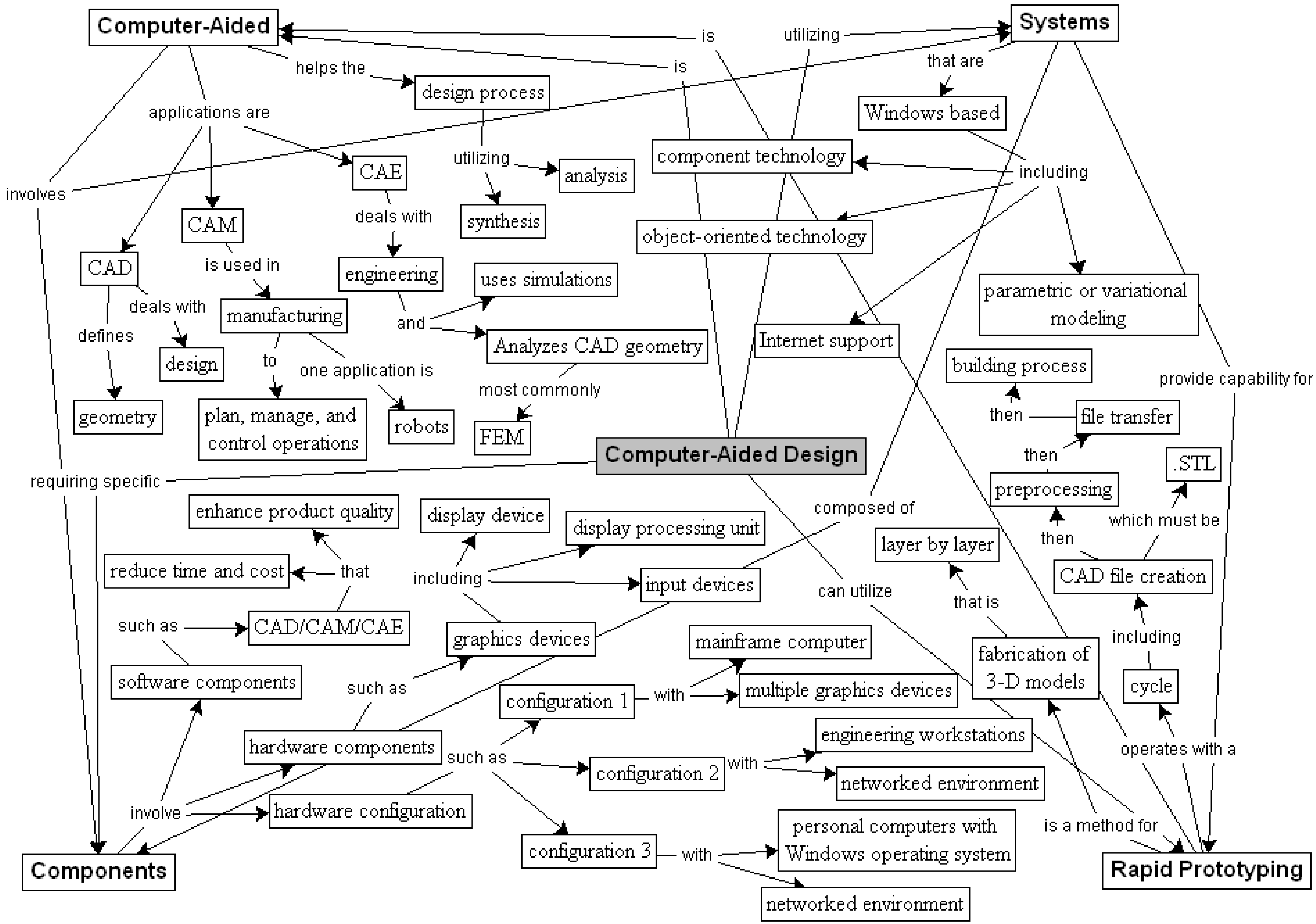
Most of the automated production systems implemented today make use of computers. CAD/CAM in addition to its particular emphasis on the use of computer technology, is also distinguished by the fact that it includes not only the manufacturing operations but also the design and planning functions that precede manufacturing.

To emphasize the differences in scope between automation and CAD/CAM, consider the following mathematical model:

Advantages of CAD/CAM systems

- Greater flexibility.
- Reduced lead times.
- Reduced inventories.
- Increased Productivity.
- Improved customer service.
- Improved quality.
- Improved communications with suppliers.

- Better product design.
- Greater manufacturing control.
- Supported integration.
- Reduced costs.
- Increased utilization.
- Reduction of machine tools.
- Less floor space.



Computer-Aided
Systems
helps the
design process
applications are
utilizing
is
that are
Windows based
component technology
including
involves
CAE
analysis
CAM
synthesis
deals with
object-oriented technology
CAD
is used in
engineering
uses simulations
parametric or variational modeling
deals with
manufacturing
and
defines
design
Analyzes CAD geometry
Internet support
to
one application is
building process
most commonly
provide capability for
geometry
plan, manage, and control operations
robots
FEM
then
file transfer
Computer-Aided Design
then
requiring specific
.STL
preprocessing
composed of
enhance product quality
display device
display processing unit
which must be
then
layer by layer
reduce time and cost
that
including
input devices
CAD file creation
can utilize
that is
such as
CAD/CAM/CAE
graphics devices
mainframe computer
including
fabrication of 3-D models
software components
such as
configuration 1
with
multiple graphics devices
cycle
hardware components
engineering workstations
such as
configuration 2
with
operates with a
networked environment
involve
hardware configuration
is a method for
configuration 3
with
personal computers with Windows operating system
Components
Rapid Prototyping
networked environment