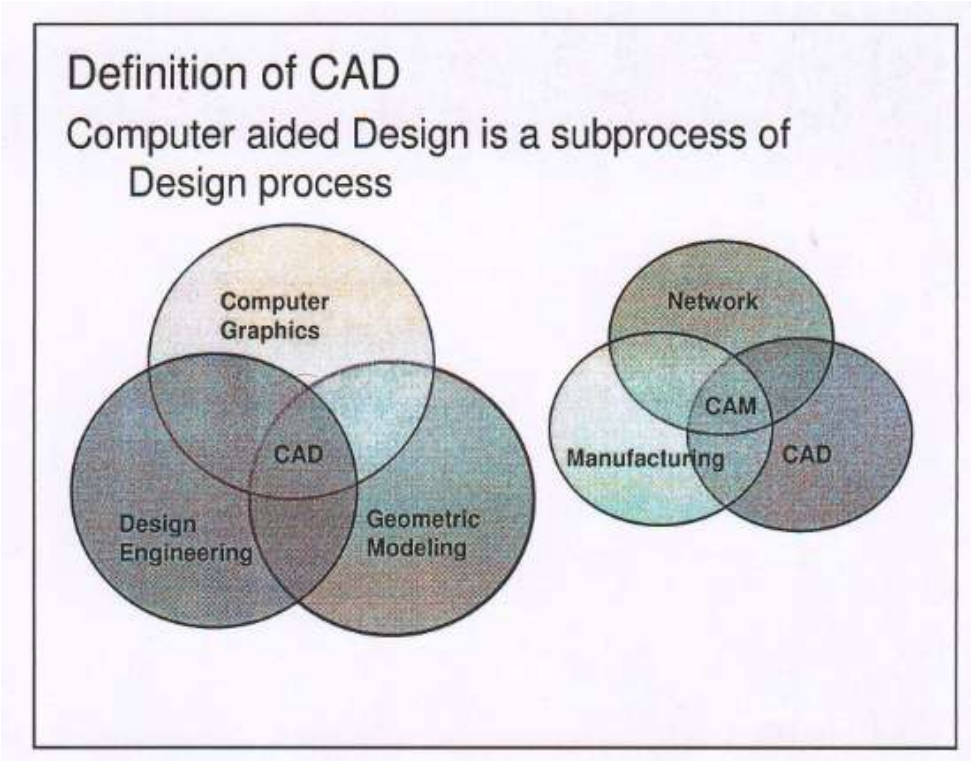
CAD/CAM

1. CAD/CAM Technology:

The story of CAD/CAM was accelerated in early 1950s. Up to year 2012ithas become one of the supreme technology available on Planet earth. It is being used in almost all the fields of engineering but primarily in mechanical engineering branches. The development in the field is still gaining speed.

- CAD Technology = Design Techniques + Computers.
- The CAD Process is the subset of the Design process.
- The CAM Process is a subset of Manufacturing Process.
- Integration of CAD and CAM leads to automation. (as show below)



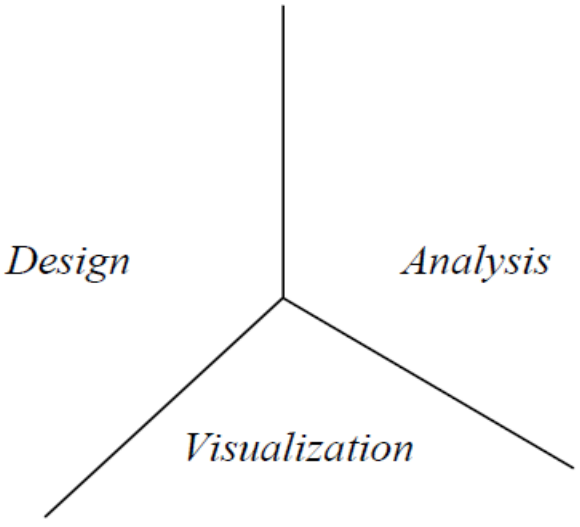
2. Computer Aided Design (CAD):

In general, a Computer Aided Design (CAD) package has three components: a) Design, b) Analysis, and c) Visualization, as shown in the sketch. A brief description of these components follows.

a) **Design**: Design refers to geometric modeling, i.e. 2-D and 3-D modeling, including, drafting, part creation, creation of drawings with various views of the part, assemblies of the parts, etc.

b) **Analysis**: Analysis refers to finite element analysis, optimization, and other number crunching engineering analyses. In general, a geometric model is first created and then the model is analyzed for loads, stresses, moment of inertia, and volume, etc.

c) **Visualization**: Visualization refers to computer graphics, which includes: rendering a model, creation of pie charts, contour plots, shading a model, sizing, animation, etc.



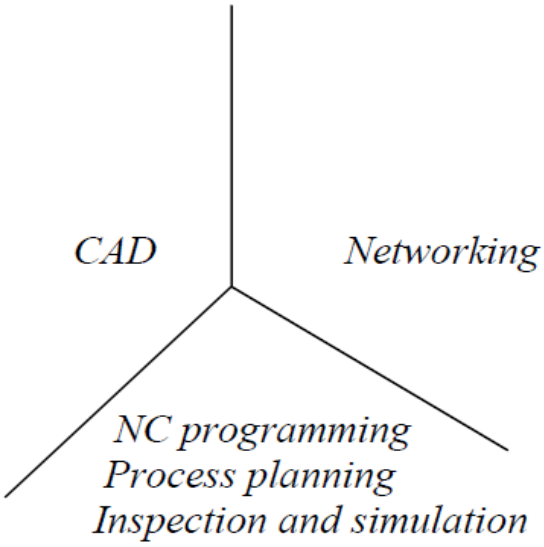
Components of Computer Aided Design

Each of these three areas has been extensively developed in the last 30 years. Several books are written on each of these subjects and courses are available through the academic institutions and the industry.

Most commercial CAD packages (software) consist of only a single component: design or analysis or visualization. However, a few of the vendors have developed an integrated package that includes not only these three areas, but also includes the manufacturing software (CAM). Due to the large storage requirement, integrated packages use either an UNIX workstation or a mainframe platform, and not the popular PC platform. With the improvement in PC computing speed, it's only a matter of time before we see an integrated package run on a PC. CAD has revolutionized the modern engineering practice; small and large companies use it alike, spending several billion dollars for the initial purchase or lease alone. CAD related jobs are high in demand and the new graduates have advantage over their senior colleagues, as they are more up to date and more productive.

3. Computer Aided Manufacturing (CAM):

CAM is the next stage of CAD. A part created in CAD can be downloaded and manufactured, without a human hand touching the part. The process is called CAM, and involves CAD, Networking, and NC programming, as shown below.



4. CAD/CAM History:

The concept of CAD and CAM is relatively new. The usage is linked with the development of computers. The actual application of CAD/CAM in industry, academia and government is only approximately 30 years old. Formal courses in CAD and Finite Element Analysis (FEA) were introduced in 1970's. The major application thrust of CAD came in 1980's, with the availability of PCs and workstations. In its early stage of usage, very few engineering companies could afford the expense of mainframe computers; however, PCs and workstations have evolved into affordable and adequate platform to support comprehensive CAD packages that initially were designed to run on the mainframe platform. A brief history of the evolution of CAD/CAM, according to the decade and the major CAD/CAM developments, is outlined below.

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

- Application of CAM in government, industry and academia
- National organization formed
- Beginning of usage of computer graphics
- 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

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

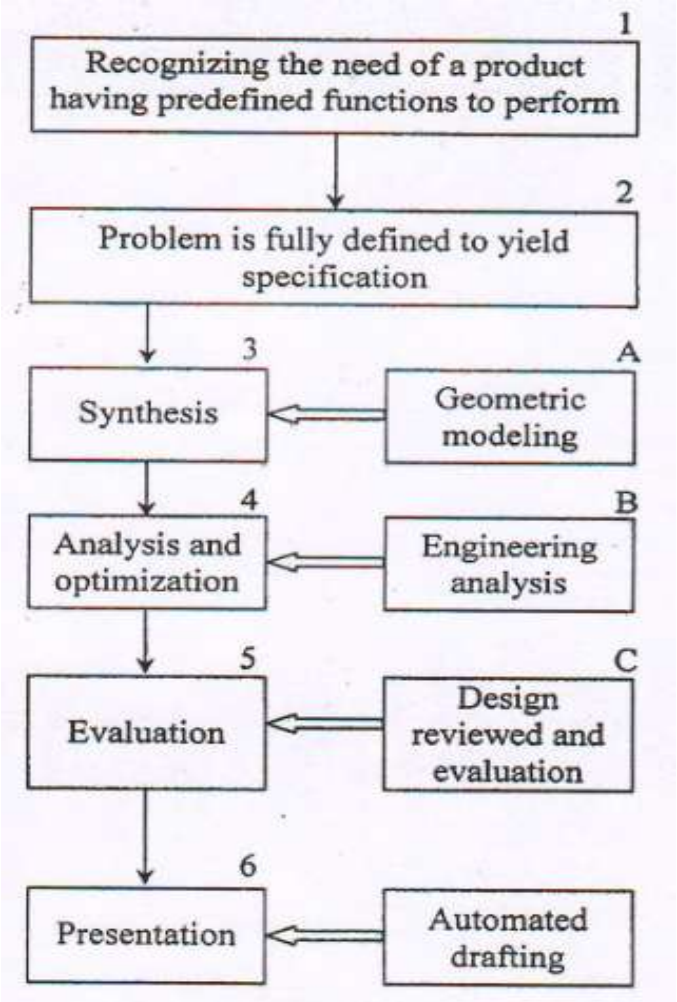
1990's

- Concept of concurrent engineering developed
- Increased use of CAD/CAM on PCs and workstations
- Improvements in hardware and software

CAD/CAM

5. Design Process:

The process of Design is segmented into Six Stages, details of which have been shown in below figure .The design process is repetitive as well as creative. The repetitive tasks can be performed by computers; however, the creative tasks (stages 1 and 2) are always done only on the human being. Show in this figure.



Stage1: Recognizing the fact that there is a need for a new product for intended function. It may also include the modification in the existing product.

Stage2: Problem is fully defined in terms of functionality and meeting other requirements such as ergonomic, performance-data, statutory, etc.

Stage3: The design undergoes synthesis, joining its various elements.

Stage4: Product analysis reveals the weaknesses and thus weaknesses can be considered for improvement. This process is repeated until an acceptable Design achieved.

Stage5: The optimized Design is reviewed from the point of view of expected performance. It can be done through proto-type modeling and testing against the set standard.

Stage6: Stages 4 and 5 are repeated until acceptable, optimized design is achieved. These stages are basically iterative in-nature. Iteration depends on the creativeness, ingenuity (skill for devising) and experience of designers and the software (tools) available. The process (stage 1 and 2) are human dependent while the stages 3, 4, 5 and 6 (four stages) are computer based (CAD).

(A) Geometric modeling: - It implies the existence of a computer graphics screen and some interaction with the computer to generate the geometry and topology of the part.

(B) Engineering analysis: - Communicates with the data base to retrieve the part description and with the user to obtain the design constraints, boundary conditions, and other details of the analysis.

(C) Evaluation module: - Allows the user to check the correctness, manufacturability, and processing details of the part.

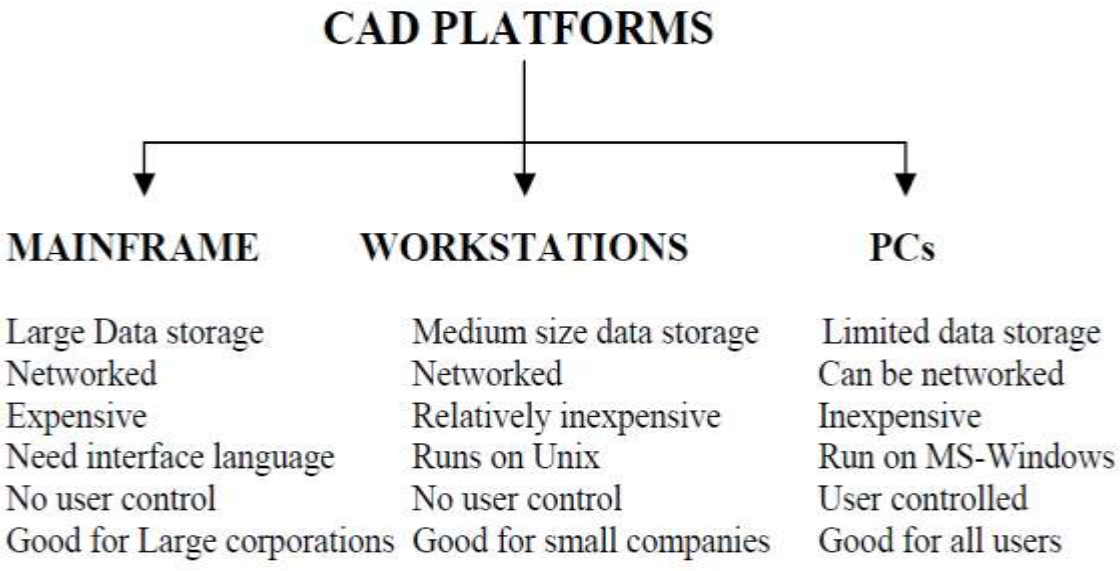
(D) The drafting and documentation module: - Contains some of both the oldest and newest technologies/Computer plotting of engineering drawings.

6. CAD Hardware:

There are basically two types of devices that constitute CAD hardware: a) Input devices, and b) Output devices. A brief description follows.

6.1. CAD Platform:

In general, we can run CAD software on three different CAD platforms: Mainframe, Workstation, and PC. When the CAD programs first became available, they could only be run on a mainframe computer. However, as the PCs have become faster and cheaper, almost all the CAD vendors have introduced a version of their CAD software that will effectively run on a Pentium or higher computer. Currently, the most popular platforms are PCs and Workstations. Popularity of Workstations stems from their ability to network easily with other computers, and also, due to their large memory storage capability. However, PC platform is still the most preferred medium for most engineers. Increasing popularity of the PC platform can be attributed to several factors, including, total user control, the speed, capability of storing large memory, ease of hardware upgrading and maintenance, and the overall reasonable cost.



6.2. Input Devices:

These are the devices that we use for communicating with computer, and providing our input in the form of text and graphics. The text input is mainly provided through keyboard. For graphic input, there are several devices available and used according to the work environment. A brief description of these devices is given here.

Mouse: This is a potentiometric device, which contains several variable resistors that send signals to the computer. The functions of a mouse include locating a point on the screen, sketching, dragging an object, entering values, accepting a software command, etc. Joystick and trackballs are analogous to a mouse device, and operate on the same principle.

Digitizers: Digitizers are used to trace a sketch or other 2-D entities by moving a cursor over a flat surface (which contains the sketch). The position of the cursor provides a feedback to the computer connected with the device. There are electrical wires embedded in orthogonal directions that receive and pass signals between the device and the computer. The device is basically a free moving puck or pen shaped stylus, connected to a tablet.

Light Pens: Lockheed's CADAM software utilized this device to carry out the graphic input. A light pen looks like a pen and contains a photocell, which emits an electronic signal. When the pen is pointed at the monitor screen, it senses light, which is converted to a signal. The signal is sent to the computer, for determination of the exact location of the pen on the monitor screen.

Touch Sensitive Screens: This device is embedded in the monitor screens, usually, in the form of an overlay. The screen senses the physical contact of the user. The new generation of the Laptop computers is a good example of this device.

Other Graphic Input Devices: In addition to the devices described above, some CAD software will accept input via Image Scanners, which can copy a drawing or schematic with a camera and light beam assembly and convert it into a pictorial database.

The devices just described are, in general, independent of the CAD package being used. All commercial CAD software packages contain the device drivers for the most commonly used input devices. The device drivers facilitate a smooth interaction between our input, the software, and the computer. An input device is evaluated on the basis of the following factors:

- **Resolution**
- **Accuracy**
- **Repeatability**
- **Linearity**

6.3. Output Devices:

After creating a CAD model, we often need a hard copy, using an output device. Plotters and printers are used for this purpose. A plotter is often used to produce large size drawings and assemblies, whereas, a laser jet printer is adequate to provide a 3-D view of a model. Most CAD software requires a plotter for producing a shaded or a rendered view.

7. CAD Software:

CAD software is written in FORTRAN and C languages. FORTRAN provides the number crunching, whereas, C language provides the visual images. Early CAD packages were turnkey systems, i.e., the CAD packages were sold as an integrated software and hardware package, with no flexibility for using second vendor hardware (1970s and 80s). These systems were based on 16-bit word, and were incapable of networking. The modern CAD software utilizes the open architecture system, i.e., software vendors do not design and manufacture their own hardware. Third party software can be used to augment the basic CAD package. Most popular CAD package

will facilitate integration of the Finite Element Analysis and other CAD software from more than one vendor. For example, IDEAS preprocessor can work with almost all the FEA packages for pre and post analyses.

Networking is an important consideration in applications of CAD software. A model created by one engineer must be readily accessible to others in an organization, which is linked by a LAN or other means. The designer, analyst, management, marketing, vendor, and others generally share a model. This is the concurrent engineering in action, mentioned earlier.

8. CAD Evaluation Criteria:

In the current CAD market, ProE and AutoCAD are arguably the most dominating CAD software. AutoCAD is basically a 2-D program, with some capability to create 3-D models, whereas, ProE is a truly 3-D CAD package. Besides this software, there is several other CAD software, listed in the previous section that has sales exceeding $100 millions. No one CAD package is suitable for all the CAD users in the world. The product we are designing dictates the type of CAD package we need. A good CAD package includes good software, as well as, a compatible hardware. Following is a brief description of the general criteria for evaluating a CAD package.

Hardware: Most desirable features in a good hardware are:

- *Open architecture*
- *High speed, large storage*
- *Compact size*
- *Inexpensive components*
- *Inexpensive upgrading*

Software: In general, the most comprehensive software are written to satisfy almost all the modeling needs of a modeler, consequently, the software tend to be very complex and hard to learn. To create a simple

model, we go through several unnecessary steps, and lack the intuitiveness of a simple, straightforward program. ProE is a good example, where we have to go through several layers of menus to create a simple solid. On the other hand, if we were to use a simpler CAD program, the same solid can be created by only a few simple commands. There are several other factors that we should consider when evaluating software. Following is a brief description of these factors.

- **Operating System**: UNIX or Windows/NT. PCs in general use Microsoft Windows, whereas, operating system for Workstations is Unix. For a large organization, Workstations are preferable.
- **User Interface**: Most popular CAD software have menu driven commands, which is preferable to the old system of non-menu driven, where user interface was completely by responding to software commands. The most popular CAD programs work with menu driven interface, with some input/action required through command prompts.
- **Documentation and Support**: Learning software can be very difficult if the software lacks good documentation. Documentation usually comes in the form of a user's manual, a tutorial book, and commands manual and on-line help. The recent trend is to provide access to the above-mentioned documentation through the Internet, or provide the manuals on a CD ROM. Some CAD vendors provide additional technical support help through phone – ProE is a very good example of this type of support.
- **Maintenance**: Cost of the hardware and software upgrades can significantly impact the small and medium size companies' decision to choose one software over the others. Most CAD vendors go through an upgrade, on the average, every two years. Usually, hardware upgrade is not as frequent.
- **Modeling Capabilities**: In, general, a CAD software can be classified as either a 2-D or a 3-D program. If we were basically involved in 2-D drawings, any well established 2-D software, similar to AutoCAD would suffice our needs. On the

other hand, if we need to create 3-D models and assemblies, we will be better off with a 3-D molder – ProE, SOLIDWORKS, etc.

- **Ease of Modeling**: As a rule-of-thumb, general, all-purpose type CAD software is much more complex and difficult to learn than a special purpose CAD package.
- **Interface with other CAD Packages and Data Transferability**: A CAD package is used to create models that will be used for analysis, manufacturing, or some other applications. Therefore, CAD software should be capable of transferring and accepting files from other CAD or CAM programs, without this provision, the CAD program has only a very limited use.
- **Design Documentation**: Besides creating a model, the software should be capable of creating drawings, assemblies, dimensioning, various views (isometric, orthogonal, etc.), labels and attributes, etc.

9. Mechanical Engineering Applications of CAD:

Following is a brief description of the applications of CAD in mechanical engineering.

- **Two Dimensional Drafting**: This is the most common use of a CAD package. 2-D drawings are used for manufacturing a product.
- **Report Generating**: To generate reports and bill of materials. Spreadsheets and word-processors can be linked to provide a report writing facility.
- **3-D Modeling**: To create the wireframe, surface and solid models. The 3-D models are for concept verification, manufacturing, FEA, etc.
- **Finite Element Analysis**: FEA package is used for pre-processing, analysis, and post-analysis of structures. For this application, a CAD package contains both the modeling and analysis modules.
- **Manufacturing**: manufacturing software is usually called CAM, and contains CAD software as one of the components. CAM software provides capabilities of carrying out 2 and 3-axes machining.

CAD/CAM

2. Computer Graphics: - Computer graphics is the computer-to-user communication medium used in computer-aided design and drafting systems. An object's definition is primarily geometric; it is convenient to be able to display the geometry of the part on a computer screen or from any given viewing angle in a variety of sizes. This section explains techniques for 2-D and 3-D graphics and realistic image generation

2.1. Interactive Graphics :- Interactive computer graphics is used in five different areas: (1) to modify the display, i.e., to change the view, type of projection, or object attributes and such as color, line type line style, surface type, rotation angle (2) for data entry and data modification (3)In command and monitoring (4) for simulation and (5) for design.

2.2 Graphics in CAD: - Every problem in computer graphics and, therefore, in has three major parts an application, hardware and software.

a) An application: Is a; software program written by user writ specific purpose mind. One application would computer-aided drafting. Another application may be finite-element analysis or circuit design. In any case, the application is specific to the particular use intended for the graphics system or for the computer-aided design system.

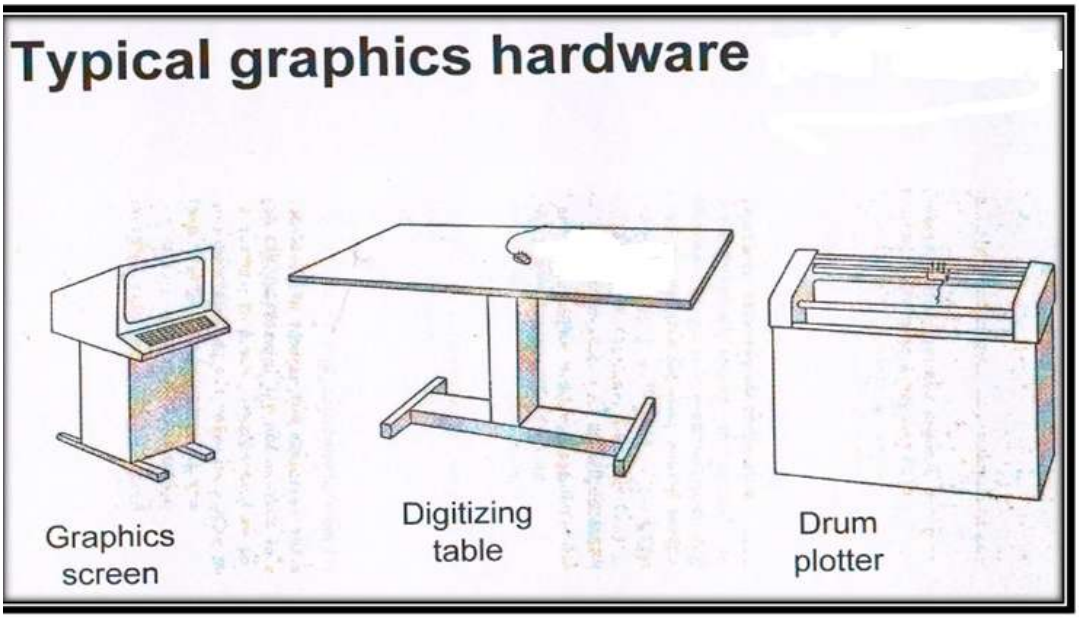
b) Hardware: Modern computer graphics displays are simple in construction. They consist of basically three components.

1- Monitor

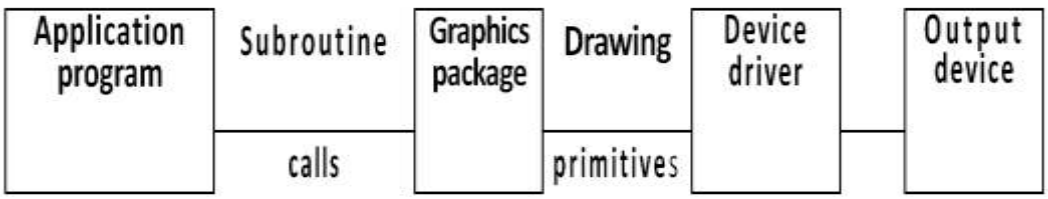
2- Digital Memory

3- Display Controller

Most of the computer graphics displays use CRT which is a matrix of discrete cells each of which can be made bright. A graphic entity like line or circle is represented as a series of "points or dots" on the screen.



c) Software: Includes the programs necessary to receive-graphical data and put the required image on the screen. The image may be as simple as a 2-D wireframe, or as complex as 3-D. The graphics software in the program receives geometric primitives such as lines, points, and surfaces and paints them on the screen or on the output device according to the object attributes. The result of this three-step process (application, hardware, and software) is graphical output.



The layers of a CAD graphics program

2.3. Two-Dimensional Graphics: - In order to draw 2-D images on the display, there must be at least two functions or subroutines available in the basic graphics package. The first is a MOVE (X.Y) subroutine, which moves the pen to an (x, y) location without drawing (with the pen up case of the plotter, or the beam off in the case of a CRT). The second command is the LINE(X,Y) subroutine, which moves the beam to an (x, y) location with the pen down, thus drawing a line. Alternative specific instances of these commands appear in various graphics packages.

2.4. Three-Dimensional Graphics: - In the case of three-dimensional graphics, a z coordinate is added to all points. Rotations must deal with angles around the x, y, and z axes instead of just the z axis. The following sections will discuss operations necessary to start with a three-dimensionally fined object, place it in space in the correct location, and draw it on a two-dimensional output device. The concepts involve three-dimensional transformations, perspective and orthographic projections, viewing transforms, and window-to-viewport mapping, all in three dimensions.