Architectural graphics

- In Section 1 of this course you will cover these topics:

- Introduction
- The Autocad 2005 Program
- Preparing To Draw With Autocad 2005
- Block Diagrams
- Plotting

Topic Objective:

At the end of this topic student would be able to:

- Define the term AutoCAD
- Describe the AutoCAD 2005 Program
- Highlight the importance of The AutoCAD 2005 Program

Definition/Overview:

AutoCAD: AutoCAD is a CAD software application for 2D and 3D design and drafting, developed and sold by Autodesk, Inc. Initially released in late 1982, AutoCAD was one of the first CAD programs to run on personal computers, and notably the IBM PC. Most CAD software at the time ran on graphics terminals connected to mainframe computers or mini-computers.

Key Points:

1. **AutoCAD**

In earlier releases, AutoCAD used primitive entities such as lines, polylines, circles, arcs, and text as the foundation for more complex objects. Since the mid-1990s, AutoCAD has supported custom objects through its C++ API. Modern AutoCAD includes a full set of basic solid modeling and 3D tools, but lacks some of the more advanced capabilities of solid modeling applications. AutoCAD supports a number of application programming interfaces (APIs) for customization and automation. These include AutoLISP, Visual LISP, VBA, .NET and ObjectARX. ObjectARX is a C++ class library, which was also the base for products extending AutoCAD functionality to specific fields, to create products such as AutoCAD Architecture, AutoCAD Electrical, AutoCAD Civil 3D, or third-party AutoCAD-based applications.

AutoCAD's native file format, DWG, and to a lesser extent, its interchange file format, DXF, have become de facto standards for CAD data interoperability. AutoCAD in recent years has included support for DWF, a format developed and promoted by Autodesk for publishing CAD data. In 2006, Autodesk estimated the number of active DWG files to be in excess of one billion. In the past, Autodesk has estimated the total number of DWG files in existence to be more than three billion. AutoCAD currently runs exclusively on Microsoft desktop operating systems. Versions for Unix and Macintosh were released in the 1980s and 1990s, but these were later dropped. AutoCAD can run on an emulator or compatibility layer like Virtual PC or Wine, albeit subject to various performance issues that can often arise when working with 3D objects or large drawings.

AutoCAD and AutoCAD LT are available for German, French, Italian, Spanish, Japanese, Korean, Chinese Simplified (No LT), Chinese Traditional, Russian, Czech, Polish, Hungarian (No LT), Brazilian Portuguese (No LT), Danish, Dutch, Swedish, Finnish, Norwegian and Vietnamese. The extent of localization varies from full translation of the product to documentation only.

2. **AutoCAD LT**

   AutoCAD LT is a "scaled down" version of AutoCAD. It costs less (approx. $900 USD versus around $4,000 USD for the full AutoCAD). It is also available for purchase at computer stores, unlike AutoCAD which has to be purchased from an official Autodesk dealer. It was developed so Autodesk could have an entry-level CAD package available to compete in that price class. Today AutoCAD LT is marketed as a CAD package for those who only need 2D functionality. Compared to the full edition of AutoCAD, AutoCAD LT lacks several features. Most notably, it has no 3D modeling capabilities (though it has a full suite of 3D viewing functions for looking at 3D models created in other CAD packages) and does not include any programming interfaces, such as support for most 3rd party programs and does not support LISP programs. A full listing of differences is on the Autodesk website. AutoCAD LT originated by taking the codebase of AutoCAD and commenting out substantial portions, which allowed AutoCAD and AutoCAD LT to be developed simultaneously.

3. **AutoCAD Student Versions**

   AutoCAD is licensed at a significant discount over commercial retail pricing to qualifying students and teachers, with both a 14 month and perpetual license available. The student version of AutoCAD is functionally identical to the full commercial version, with one exception: DWG files created or edited by a student version have an internal bit-flag set (the "educational flag"). When such a DWG file is printed by any version of AutoCAD (commercial or student), the output will include a plot stamp / banner on all four sides. Objects created in the Student Version cannot be used for commercial use. These Student Version objects can and will 'infect' a commercial version DWG file if imported. The Autodesk student community provides registered students with free access to different Autodesk applications. While AutoCAD is not available as standalone downloadable application, students have access to some other applications, which include AutoCAD, such as Civil3D or AutoCAD Architecture.

4. **Vertical programs**

   Autodesk has also developed a few vertical programs, sometimes called Desktops, for discipline-specific enhancements. AutoCAD Architecture (formerly Architectural Desktop), for example, permits architectural designers to draw 3D objects such as walls, doors and windows, with more intelligent data associated with them, rather than simple objects such as lines and circles. The data can be programmed to represent specific architectural products sold in the construction industry, or extracted into a data file for pricing, materials estimation, and other values related to the objects represented. Additional tools allow designers to generate standard 2D drawings, such as elevations and sections, from a 3D architectural model. Similarly, Civil Design, Civil Design 3D, and Civil Design Professional allow data-specific objects to be used, allowing standard civil engineering calculations to be made and represented easily. AutoCAD Mechanical, AutoCAD Electrical, AutoCAD Civil 3D, and AutoCAD Map 3D are other examples of industry-specific CAD applications built on the AutoCAD platform.

Topic Objective:

At the end of this topic student would be able to:

- Learn how to use Co-ordinates
- Learn about Cartesian Co-ordinates
- Develop learning regarding Polar Co-ordinates
- Comprehend the concepts behind UCS Icons
- Identify use of Absolute & Relative Co-ordinates
- Perform a Paper Space Exercise

Definition/Overview:

AutoCad: AutoCAD currently runs exclusively on Microsoft Windows desktop operating systems. Versions for Unix and Mac OS were released in the 1980s and 1990s, but these were later dropped. AutoCAD can run on an emulator or compatibility layer like VMware Workstation or Wine, albeit subject to various performance issues that can often arise when working with 3D objects or large drawings. AutoCAD and AutoCAD LT are available for German, French, Italian, Spanish, Japanese, Korean, Chinese Simplified (No LT), Chinese Traditional, Russian, Czech, Polish, Hungarian (No LT), Brazilian Portuguese (No LT), Danish, Dutch, Swedish, Finnish, Norwegian and Vietnamese. The extent of localization varies from full translation of the product to documentation only.

Key Points:

1. **Using Co-ordinates**
   A good understanding of how co-ordinates work in AutoCAD is absolutely crucial if you are to make the best use of the program. If you are not familiar with co-ordinates and co-ordinate systems, take some time to familiarise yourself with the basic concepts. Co-ordinates fall into two types, namely Cartesian and Polar. A basic understanding of these co-ordinate types will help you to use AutoCAD to construct drawings more easily. In addition, these two co-ordinate types come in two distinct flavours. They can be either Absolute or Relative. Knowing just when and where to use the various types and flavours of co-ordinate is the key to efficient drawing with AutoCAD.

2. **Cartesian Co-ordinates**

Despite the fancy title (named after the French philosopher and mathematician Ren Descartes 1596-1650), the Cartesian co-ordinate system is the standard co-ordinate system. The position of a point can be described by its distance from two axes, X and Y. This results in a simple point description using two numbers separated by a comma e.g. **34.897,45.473**.

In the example on the right the point described lies **34.897** drawing units to the right of the Y axis and **45.473** drawing units above the X axis. The first value (**34.897**) is known as the X co-ordinate because it's value is measured along the X axis. The second value is known as the Y co-ordinate because it's value is measured along the Y axis. The X and Y axes are two lines of infinite

The co-ordinate value of the origin point is always **0,0**. When viewed in plan the X and Y axes are always perpendicular to one another with the X axis in a horizontal position and the Y axis in a vertical position (See illustration). X co-ordinate values become negative to the left of the Y axis and Y co-ordinate values become negative below the X axis. All co-ordinate values (both X and Y) are negative in the lower left hand quadrant and positive in the upper right hand quadrant. Normally we try to work in the positive quadrant. Although this is not essential for AutoCAD to operate, it does tend to make life easier because we don't need to worry about negative numbers.

AutoCAD allows you to use co-ordinates to draw objects rather than using pick points. For example you could draw a line like this:

2.1. Command Sequence

- Command: LINE
- From point: 34.897,45.473
- To point: 54.896,65.395
- To point: (to end)

This sequence draws a line between the two co-ordinate points specified. Note that if you enter a co-ordinate that is off the screen the line will still be drawn to the required point. You will then need to zoom out in order to see the whole line. You can also start the Line command by clicking on the Draw toolbar or from the pull-down menu (Draw Line).

3. Polar Co-ordinates

Polar co-ordinates achieve the same result i.e. the description of the position of a point. The main difference is that polar co-ordinates use one distance and one angle to describe the position of a point rather than the two distances in the Cartesian system. The distance and angle measurements are made relative to an origin. This results in a point description which looks like this **34.897<30** where the first figure is the distance (in drawing units) and the second is the angle. Notice that the separator in the case of polar co-ordinates is the "less than" mathematical symbol. If you look at your keyboard you will see that this symbol is typed by using Shift and comma. AutoCAD angles start at 3 o'clock (i.e. along the positive portion of the X axis) and increase in an anti-clockwise direction. You can specify negative angles if you need to define an angle in a clockwise direction although this is not really necessary because angles are circular, hence an angular value of -30 degrees will give the same result as an angular value of 330 degrees (there are 360 degrees in a full circle).

4. The UCS Icon

In the bottom left hand corner of the AutoCAD drawing window you will see a symbol like the one shown on the right. This is called the UCS (User Co-ordinate System) icon and it is there to remind you which is the X axis and which is the Y axis. The empty box at the intersection of the X and Y axes is there to remind you that you are using "World" co-ordinates and that the UCS icon is not positioned over the true origin of the current co-ordinate system, probably because it is off screen. See the UCS Icon tutorial for more details on this feature.

5. Absolute & Relative Co-ordinates

Both Cartesian and polar co-ordinates come in two flavours, absolute and relative. The distinction is quite simple, absolute co-ordinates relate to the X and Y axes and the origin of the current co-ordinate system, whilst relative co-ordinates relate to the current pick point. When you are specifying co-ordinates you need to tell AutoCAD which type you want. Absolute co-ordinates are typed exactly as in the examples above. To specify a relative co-ordinate you need to use the "at" symbol as a prefix. In the case of the two examples above a relative Cartesian co-ordinate looks like this **@34.897,45.473** and a relative polar co-ordinate looks like this **@34.897<30**. Relative co-ordinates are very useful for drawing objects which you know the size of. For example, you could draw a square of 12 units with its lower left hand point at 30, 40 as follows:

5.1. Command Sequence

- Command: LINE
- From point: 30,40 (an absolute Cartesian co-ordinate)
- To point: @0,12 (a relative Cartesian co-ordinate)
- To point: @12<0 (a relative polar co-ordinate)
- To point: @0,-12 (another relative Cartesian co-ordinate)
- To point: C (to close)

Try this sequence out and watch the square drawn as you enter each co-ordinate value. You can also use this method to quickly draw a rectangle of known size. Say you needed to draw a rectangle 20 drawing units wide and 10 drawing units high and you didn't mind where exactly the rectangle is drawn, you could do this:

5.2. Command Sequence

- Command: RECTANGLE
- Specify first corner point or [Chamfer/Elevation/Fillet/Thickness/Width]: (pick a point near the middle of the drawing area)

- Specify other corner point or [Dimensions]: @20,10

  Note that the relative X co-ordinate determines the rectangle width and the relative Y co-ordinate determines the rectangle height.

6. **Masterplan Exercise**

   The following exercise is designed to show you how to construct simple shapes from given dimensions and to allow you to practice the basic AutoCAD commands which you have already learned. Use the tutorials to cover any topics you are unsure of.

7. **Client Brief**

   Your client owns a site that lies on the Greenwich Meridian (the site is shown below). She has decided to celebrate the forthcoming millennium by developing the site as a public park. She hopes the money to develop the park will come from the millennium commission and that the development of this park will form a part of the "Meridian Tree Line" project. In order to help gain funding you have been asked to develop an illustrative masterplan design for the site that will be used to put the case for funding to the commission. All submissions must be in digital format and you will, therefore, have to use CAD techniques to produce the masterplan. The Millennium Tree Line project is an international project that aims to plant trees along the Greenwich Meridian in celebration of the millennium. This will obviously form a major design element of the site, however, your client would also like to see the introduction of some water into the design and an interpretation centre/cafe.

8. **Site Layout**

8.1. Hints

- To get started, try drawing the first boundary line using a relative polar co-ordinate in the form, @450<60, where "450" is a distance and "60" is an angle. You will find lots of information about co-ordinates in the "Using Co-ordinates" tutorial.
- The Offset command will be very useful when you are constructing the site boundary. You will find the Offset command on the Modify pull-down (Modify Offset) and on the Modify toolbar. You will also find more information about the Offset command on the "Modifying Objects" tutorial.
- The site boundary cannot accurately be drawn without the use of Osnaps such as Endpoint. Use the "Object Snap" tutorial to learn about using object snaps.
- Make sure your drawing has a good layering structure. You can always use the Modify Properties command, to change the layer of objects after they have been drawn. You can start the Modify Properties command from the Modify pull-down, Modify Properties or from the Object Properties toolbar.
- Feel free to interpret the brief in any way you feel appropriate, however, you must also concentrate your efforts to produce a good-looking, illustrative plan. Since trees will be an important element of the design, spend some time developing some useful tree symbols.
- Don't forget to save your drawing regularly.

9. Paper Space Exercise

AutoCAD's paper space mode is a bit like having a page in a scrapbook onto which you can paste different views of your AutoCAD drawing. This whole page can then be plotted. This exercise is designed to help you create an A3 drawing sheet in Paper Space tand to add floating viewports. The exercise also discusses some other Paper Space considerations such as plotting to scale from Paper Space and layer display in viewports.

10. Overview of Paper Space

To create the paper space page you must set the tilemode variable to 0, you can do this by double-clicking on "TILE" on the status bar at the bottom of the screen. Once you have done this you will notice that the UCS icon in the bottom left corner of your screen changes to a triangle. This is to let you know that you are now in paper space. Once you are in paper space you can draw an A3 drawing sheet. You could start out simply by drawing the rectangular outline. Create a new layer called something like "SHEET" and then draw a rectangle 420 x 297 drawing units (this is the correct size of an A3 drawing sheet in millimetres). Centre the rectangle on your screen by using the Zoom Extents command. You are now in a position to create one or more model space viewports. Using the MVIEW command, View Floating Viewports 1 Viewport from the pull-down menu, simply pick two corners of a rectangle to define your view area. These viewports can be moved, scaled, copied and stretched just like any AutoCAD entity.

Create more viewports as required. Once you are happy with the arrangement of viewports (remember you can overlap viewports) you can move to model space by using the MSPACE command, View Model Space (Floating) from the pull-down menu. Once in model space you can work within each viewport as if it were the normal drawing area. You can move from one viewport to another simply by clicking on it. Only one viewport can be active at any one time. The current active viewport is shown with a thick white border. Any changes you make to the drawing in one viewport are simultaneously made in the other viewports. If you need to make changes to the arrangement of your viewports or to make changes to the drawing sheet you have to move back to paper space using the PSPACE command, View Paper Space from the pull-down menu. Don't forget to move back to model space afterwards.

11. Creating a Drawing Sheet in Paper Space

Follow the command sequence below to create your own A3 drawing sheet in Paper Space and to add a number of Viewports to show off your drawing to best effect.

11.1. Setting up the Drawing Sheet

- Open the 3D Tree drawing you created in the previous exercise or open any other 3D drawing you have to hand.
- Move to paper space by double-clicking on the status bar or using the Paper Space command, View Paper Space. Don't worry if the screen goes blank!
- Create a new layer called "SHEET" and make it current .
- Draw an A3 sheet outline in millimetres (420x297) using the RECTANG command . Pick the first point anywhere on screen and define the second point using the relative co-ordinate @420,297.
- Zoom to drawing extents so that you can see your whole sheet. View Zoom Extents or Z E at the keyboard or from the toolbar.
- Design your own personal title block. Include your name, the drawing name, scale and any other information you consider appropriate. Make sure you create new layers for text, lines etc.

11.2. Creating the Viewports

- Create a new layer called "VIEWPORTS".
- Make "VIEWPORTS" the current layer. Create your viewport(s). View Floating Viewports 1 Viewport and then pick the two opposite corners of your new viewport window. You will see your tree appear.
- Arrange your viewports on the sheet. Viewports act just like normal drawing entities so you can move, erase, copy and stretch them.
- Move to model space View Model Space (Floating). Notice that the UCS icon appears in the viewports and that the last viewport you drew is bounded by a thicker line than the others. This viewport is the "active" viewport. To make any viewport the active viewport, just click on it.
- Once a viewport is active you can change the view in exactly the same way as you can when you are in Tiled Model Space. You can use the ZOOM and DDVPOINT

commands to modify the view within each viewport. Change the views in each viewport to show your tree off to its best advantage. See the illustration below.

- Turn the "VIEWPORTS" layer off if you wish to remove the viewport borders and check that the layout looks good. Your drawing is complete and you are ready to plot.

12. Plotting from Paper Space

There are two things to bear in mind when plotting from Paper Space. First of all, since our drawing sheet has been drawn at full size and in millimetres the plot scale is always 1=1. Secondly, if you are plotting 3D objects from Paper Space and you want hidden lines removed, don't bother checking that option in the plot dialogue box, it won't work. You have to tell AutoCAD which viewports you want hidden lines removed from before you start plotting. You do this using the Hideplot option of the MVIEW command or by selecting View Floating Viewports Hideplot from the pull-down. You are prompted to select viewports so the viewport borders must be visible. If you want hidden lines removed turn Hideplot ON. This may seem a bit of a chore but it does allow you to plot some viewports with hidden lines removed and some without.

- **Other Paper Space Considerations**

  You may be wondering how it is possible to plot drawings at a particular scale in Paper Space if drawings are always plotted using a scale of 1=1. The answer is that the scale of a viewport is determined by its zoom factor. You can use the XP option of the ZOOM command to scale your viewports relative to Paper Space. For example, if you zoom a viewport using 1XP, the scale of the drawing in the viewport would be 1:1 when it was plotted. To calculate the XP factor required simply divide 1 by the scale required. For example to zoom to 1:200 the XP factor would be 1/200=0.005. The XP zoom factor described above only holds true when the drawing units are millimetres. Most of the time landscape drawings are in metres so we need to add a correction to the calculation to take this into account. Since there are 1000 millimetres in a metre all we have to do is multiply the XP factor by 1000. So, to plot at a scale of 1:200 when the drawing units are metres the XP factor would be 1/200x1000=5.

- **12.1.2 Layers**

  It is possible to freeze layers in the current viewport but have them remain visible in all other viewports. Using the DDLMODES command or Format Layer from the pull-down you can freeze any layer in the current viewport by clicking the icon in the dialogue box. See the section "Layers in Viewports" in the Object Properties tutorial for more information. Find below the finished drawing

[There are three viewports in the above example, all showing different views of the same drawing. The middle viewport overlaps the other two and plotting of the viewport borders has been suppressed by turning off the layer on which they were created.

Topic Objective:

At the end of this topic student would be able to:

- Define the term block diagram
- Highlight the importance of block diagram

Definition/Overview:

Block diagram: A block diagram is a pictorial model of a process or system. They are heavily used in the engineering world in hardware design, software design, and process flow diagrams.

Key Points:

1. **Block Diagram**

The block diagram is typically used for a higher level, less detailed description aimed more at understanding the overall concepts and less at understanding the details of implementation. Contrast this with the schematic diagram and layout diagram used in the electrical engineering world, where the schematic diagram shows the details of each electrical component and the layout diagram shows the details of physical construction. For example, a block diagram of a radio is not expected to show each and every wire and dial and switch, but the schematic diagram is. The schematic diagram of a radio does not show the width of each wire in the printed circuit board, but the layout diagram does. To make an analogy to the map making world, a block diagram is similar to a highway map of an entire nation. The major cities (functions) are listed but the minor county roads and city streets are not. When troubleshooting, this high level map is useful in narrowing down and isolating where a problem or fault is.

Block diagrams rely on the principle of the black box where the contents are hidden from view either to avoid being distracted by the details or because the details are not known. We know what goes in, we know what goes out, but we can't see how the box does its work. In electrical engineering a design will often begin as a very high level block diagram, becoming more and more detailed block diagrams as the design progresses, finally ending in block diagrams detailed enough that each individual block can be easily implemented (at which point the block diagram is also a schematic diagram). This is known as top down design. Geometric shapes (e.g. rectangles, circles etc.) are often used in the diagram to aid interpretation and clarify meaning of the process or model. The geometric shapes are connected by lines to indicate association and direction/order of traversal. Each engineering discipline has their own meaning for each shape.

2. **Function Block Diagram**

A function block diagram describes a function between input variables and output variables. A function is described as a set of elementary blocks. Input and output variables are connected to blocks by connection lines. An output of a block may also be connected to an input of another block:

- Inputs and outputs of the blocks are wired together with connection lines, or links. Single lines may be used to connect two logical points of the diagram:
- An input variable and an input of a block
- An output of a block and an input of another block
- An output of a block and an output variable

The connection is oriented, meaning that the line carries associated data from the left end to the right end. The left and right ends of the connection line must be of the same type. Multiple right connections, also called divergence can be used to broadcast information from its left end to each of its right ends. All ends of the connection must be of the same type. Function block diagram is one of five languages for logic or control configuration supported by standard IEC 61131-3 for a control system such as a Programmable Logic Controller (PLC) or a Distributed Control System (DCS). The other supported languages are ladder logic, sequential function chart, structured text, and instruction list.

Topic Objective:

At the end of this topic student would be able to:

- Define the term diagram and plotting
- Highlight the importance of plotting

Definition/Overview:

Main diagram types: There are at least the following types of diagrams:

- Graph-based diagrams: these take a collection of items and relationships between them, and express them by giving each item a 2D position, while the relationships are expressed as connections between the items or overlaps between the items; examples of such techniques:
    - tree diagram
    - network diagram
    - flowchart
    - Euler diagram, Venn diagram, existential graph
    - Maps (when stylized, e.g. the map of the London underground)

- Chart-like diagram techniques, which display a relationship between two variables that take either discrete or a continuous ranges of values; examples:
    - histogram, bar chart
    - pie chart
    - function graph
    - scatter plot
    - table / matrix

- Other types of diagrams, e.g.:
    - exploded view

Key Points:

1. **Graph**

In mathematics and computer science, a graph is the basic object of study in graph theory. Informally speaking, a graph is a set of objects called points, nodes, or vertices connected by links called lines or edges. In a proper graph, which is by default undirected, a line from point A to point B is considered to be the same thing as a line from point B to point A. In a digraph, short for directed graph, the two directions are counted as being distinct arcs or directed edges. Typically, a graph is depicted in diagrammatic form as a set of dots (for the points, vertices, or nodes), joined by curves (for the lines or edges).

A graph or undirected graph G is an ordered pair G: = (V,E) that is subject to the following conditions: V is a set, whose elements are called vertices or nodes, E is a multiset of unordered pairs of vertices (not necessarily distinct), called edges or lines. The vertices belonging to an edge are called the ends, endpoints, or end vertices of the edge. V (and hence E) are usually taken to be finite, and many of the well-known results are not true (or are rather different) for infinite graphs because many of the arguments fail in the infinite case. The order of a graph is | V | (the number of vertices). A graph's size is | E | , the number of edges. The degree of a vertex is the number of edges that connect to it, where an edge that connects to the vertex at both ends (a loop) is counted twice. The edges E induce a symmetric binary relation ~ on V which is called the adjacency relation of G. Specifically, for each edge {u,v} the vertices u and v are said to be adjacent to one another, which is denoted u ~ v. For an edge {u, v}, graph theorists usually use the somewhat shorter notation UV.

2. **Plotter**

A plotter is a vector graphics printing device that connects to a computer. Pen plotters print by moving a pen across the surface of a piece of paper. This means that plotters are restricted to line art, rather than raster graphics as with other printers. Pen plotters can draw complex line art, including text, but do so very slowly because of the mechanical movement of the pens. Pen Plotters are incapable of creating a solid region of color; but can hatch an area by drawing a number of close, regular lines. When computer memory was very expensive, and processor power was very slow, this was often the fastest way to produce color high-resolution vector-based artwork, or very large drawings efficiently. Traditionally, printers are primarily for printing text. This makes it fairly easy to control, simply sending the text to the printer is usually enough to generate a page of output. This is not the case of the line art on a plotter, where a number of printer control languages were created to send the more detailed commands like "lift pen from paper", "place pen on paper", or "draw a line from here to here". The two common ASCII-based plotter control languages are Hewlett-Packard's HPGL2 or Houston Instruments DMPL with commands such as "PA 3000, 2000; PD".

Programmers in FORTRAN or BASIC generally did not program these directly, but used software packages such as the Calcomp library, or device independent graphics packages such as Hewlett-Packard's AGL libraries or BASIC extensions or high end packages such as DISSPLA. These would establish scaling factors from world coordinates to device coordinates, and translating to the low level device commands. For example to plot X*X in HP 9830 BASIC, the program would be Early plotters (e.g. the Calcomp 565 of 1959) worked by placing the paper over a roller which moved the paper back and forth for X motion, while the pen moved back and forth on a single arm for Y motion. Another approach (e.g. Computervision's Interact I) involved attaching ball-point pens to drafting pantographs and driving the machines with motors controlled by the computer. This had the disadvantage of being somewhat slow to move, as well as requiring floor space equal to the size of the paper, but could double as a digitizer. A later change was the addition of an electrically controlled clamp to hold the pens, which allowed them to be changed and thus create multi-colored output.

Hewlett Packard and Tektronix created desk-sized flatbed plotters in the late 1970s. In the 1980s, the small and lightweight HP 7470 used an innovative "grit wheel" mechanism which moved only the paper. Modern desktop scanners use a somewhat similar arrangement. These smaller "home-use" plotters became popular for desktop business graphics, but their low speed meant they were not useful for general printing purposes, and another conventional printer would be required for those jobs. One category introduced by Hewlett Packard's MultiPlot for the HP 2647 was the "word chart" which used the plotter to draw large letters on a transparency. This was the forerunner of the modern Powerpoint chart. With the widespread availability of high-resolution inkjet and laser printers, inexpensive memory and computers fast enough to rasterize color images, pen plotters have all but disappeared. Plotters were also used in the Create-A-Card kiosks that were available for a while in the greeting card area of supermarkets that used the HP 7475 6 pen plotter.

Plotters are used primarily in technical drawing and CAD applications, where they have the advantage of working on very large paper sizes while maintaining high resolution. Another use has been found by replacing the pen with a cutter, and in this form plotters can be found in many garment and sign shops. If a plotter was commanded to use different colors it had to replace the pen and select the wanted color and/or width. A niche application of plotters is in creating tactile images for visually handicapped people on special thermal cell paper. Pen plotters have essentially become obsolete, and have been replaced by large-format inkjet printers and LED toner based printers. Such printers are often still known as plotters, even though they are raster devices rather than pen based plotters by the definition of this article. The newer plotters still understand vector languages such as HPGL2. This is because the language is an efficient way to describe how to draw the file using just text commands. A technical drawing in HPGL2 can be quite a bit smaller file than the same drawing in a pure raster form.

A pen plotter's speed is primarily limited by the type of pen used. The typical plotter pen uses a cellulose fiber rod inserted through a circular foam tube saturated with ink, with the end of the rod sharpened into a conical tip. As the pen moves across the paper surface, capillary wicking draws the ink from the foam, down the rod, and onto the paper. As the ink supply in the foam is depleted, the migration of ink to the tip begins to slow down, resulting in faint lines. Slowing the plotting speed will allow the lines drawn by a worn-out pen to remain dark, but the fading will continue until the foam is completely depleted. Also as the fiber tip pen is used, the fiber tip slowly wears away from rubbing against the media, wearing down the thin conical tip into a thicker smudged line. Ball-point plotter pens with refillable clear plastic ink reservoirs are available. They do not have the fading or wear effects of fiber pens, but are generally more expensive and uncommon.

3. **Vinyl Sign Cutter**

A vinyl sign cutter (sometimes known as a cutting plotter) is used by professional poster and billboard sign-making businesses to produce brilliant weather-resistant signs, posters, and billboards using self-colored adhesive-backed vinyl film that has a removable paper backing material. The vinyl can also be applied to car bodies and windows for large, bright company advertising and to sailboat transoms. A similar process is used to cut tinted vinyl for automotive windows. Colors available are generally limited only by the collection of vinyl on hand. To prevent creasing of the material, it is stored in rolls. Typical vinyl roll sizes are 24-inch and 36-inch width. Generally the hardware is identical to a traditional plotter except that the ink pen is replaced by a very sharp knife that is use to cut out each shape, and the plotter may have a pressure control to adjust how hard the knife presses down into the vinyl film, allowing designs to be fully or partly cut out. The vinyl knife is usually shaped like a plotter pen and is mounted on ball-bearings so that the knife edge rotates to face the correct direction as the plotter head moves. Once the letters or designs have been cut out, there are two methods for handling the application.

The most common method:

- From the front surface, peel off the surround and unwanted areas of shapes from the letters or design.
- Apply a slightly tacky carrier film over the letters or design (this film is similar to masking tape though clear carrier films are also used.

- Cut out the area which includes the desired design, including the carrier film, vinyl and vinyl backing material.
- Apply a small piece of masking tape to the sides of the resulting sandwich to ease positioning.
- Ensuring that the area to which the vinyl is to be applied is clean, position the sandwich. When it is in the desired position, apply a hinge of masking tape to the lower edge. Remove the two side pieces of masking tape and the sandwich will fold down along the hinge.
- Carefully remove the backing paper by peeling sideways, not away from the letters or design.
- The cut vinyl is now held in position by the carrier film.
- With a small plastic wiper (a credit card will also do), sweep the cut vinyl into contact with the mounting surface, stroking upwards and outwards, taking care to leave no air bubbles.
- When all parts of the cut vinyl is in contact with the mounting surface, gently peel off the front paper sideways, and apply final pressure to the front face of the cut vinyl to produce a weather-resistant sign.

An older method:

- Once the vinyl has been cut, the individual cut-out pieces are peeled off the backing paper and carefully assembled by hand on the mounting surface to form the final image.
- A heat gun may be used to melt/bond the vinyl pieces to the substrate.

Sign cutters are primarily used to produce single-color line art. Multiple colors can be cut and assembled but the assembly process is extremely painstaking if the cut sections are thin and flexible. As with the pen plotter, sign cutting plotters are in decline for general billboard and sign design. They are being replaced by wide-format inkjet printers that use special fade-resistant UV-protected solvent-based inks, which can directly print onto fabrics, vinyls, or plastic sheeting. These large inkjet printers have the added advantage of performing smooth color transitions and photo printing, which sign cutters cannot duplicate. However, sign cutting plotters are still very much in use for precision cutting of graphics produced by wide-format inkjet printers, for example to produce shaped stickers and window graphics.

4. **Static Cutting Table**
   A sign cutter functions primarily like a traditional roll-fed or sheet-fed plotter, in that the media to be cut is stiff and is rigidly held together by the backing sheet as pieces of vinyl are cut out. As the letters are cut, the backing stays properly aligned in the moving rollers. This does not work when cutting a floppy material with no backing, like normal fabric textiles or leather. Cutting a hole or slit will cause the unsupported material to droop and fall out of cutting alignment. The static cutting table extends from the roll-fed sign cutter, to use a large flat vacuum cutting table. The table has a series of small pinholes drilled into the surface. The material to be cut is placed on the table, and a sheet of plastic overlaid onto the fabric. A vacuum pump is turned on, and air pressure pushes down on the plastic cover sheet holding the fabric tightly in place. The table then operates like a normal vector plotter, again using different types of knives to cut holes or slits into the fabric. Even as the fabric and plastic sheeting is cut, the vacuum inside the table continues to hold the material in place until cutting is complete.

- In Section 2 of this course you will cover these topics:

Adding Text And Tables To The Drawing

Geometric Constructions

Using 2d Commands To Draw Orthographic Views

Drawings, Formats, Blocks, And Attributes

The Autocad Designcenter

Topic Objective:

At the end of this topic student would be able to:

- Learn Dealing with Creating Text
- Develop learning regarding how to draw different revolved objects

Definition/Overview:

Overview: The topic is comprised of some advanced tutorials and will make students understand the modes of Creating Text and formatting it into different styles. The second exercise of the chapter will teach students how to draw revolved objects.

Key Points:

1. Exercise 1: Creating Text

Like most things in AutoCAD, there is more than one way to do it. Creating Text is no exception. Below are the common commands for working with text.

Command	Keystroke	Icon	Menu	Result
Text Style	STYLE / ST		Format > Text Style	Opens the Text Style Dialog
Single Line Text	**DTEXT / DT / TEXT**		Draw > Text > Single Line Text	Creates a single line of text
Multiline Text	**MTEXT / T / MT**		Draw > Text > Multiline Text	Creates formatable multiline text
Edit Text	**DDEDIT / ED** (or double-click)		Modify > Object > Text > Edit	Edits and formats text - edits attributes

Spell Check	**SPELL**		Tools > Spelling	Checks for spelling errors in Text, Attributes and Xrefs
Text along an arc	ARCTEXT		Express > Text > Arc-Aligned Text	Aligns test along a selected arc

[Figure 1: Basic Commands for Creating Text]

Creating text in AutoCAD is easy. You may have already done this in the first level of tutorials, but this lesson will go into more detail and explore more options.

1.2 Formatting Text Styles

Most template drawings will have your text styles defined. Generally you won't change these. Occasionally you may need to create a new text style (definition of the way the text will look).

To format text in AutoCAD, you have to create a new text style for each different font and style of text. By default in the acad.dwt file, AutoCAD loads the **txt.shx** font because it is simple to display on the screen. Unfortunately, it is a very basic and 'ugly' font. Here is an example of the default TXT font compared to the 'standard' ROMANS font. Look at the O's in particular. The TXT font has no curves.

It is easy to load in a new style for all of your text. Here's how: Use your pull-down menus Format > Text, or type **ST**, and this dialog box appears.

Select the New... Button and type in a name for your new text style. Click on the Font Name edit box and select "romans.shx" as your new text style. This style will be used for all text and dimensioning in the next assignments. This is a common, clean font that AutoCAD can display quickly on the screen. No other adjustments are needed. Optionally you can set the width factor to a .8 - this allows you to fit text in narrower spaces at an 80% width.

IMPORTANT: Do NOT change the Height in this dialog box unless you really know why you are doing it. If you set a height here, AutoCAD will not be able to scale if for uses such as dimensioning, in other words, it is fixed at the height you set. Annotative text is a new feature in AutoCAD 2008. Click on the in the dialog to read more about it. Once you get into more complex drawings, you will need more than one textstyle (if they aren't in the template). One for notes, one for tables, one for the table header, two or three for the title block - I think you get the picture. If you need more than one text style, click on the new button, type in a new name and press OK.

Now the Text Style dialog box (as shown above) will have the new name in the Style Name field. Select RomanD.shx for this new style. Now when you add text to your drawing, you have 2 choices. Watch the command line to know when to change to another style.

1.3 Adding Text to a drawing

Of course, there a few ways of entering text in AutoCAD. For simple one line text, use the the TEXT command. There's a few parameters needed to add text, but if you follow the command line, it's quite easy.

Command: TEXT

Current text style: "Romans" Text height: 0'-6" Annotative: No

Specify start point of text or [Justify/Style]: <PICK>

Specify height <0'-6">: 12

Specify rotation angle of text <0.000>: <ENTER>

TYPE YOUR TEXT and press <ENTER><ENTER>

You should now have a line of text in your drawing. Start the command again and when prompted for Style, enter the name of the second text style you created.

Once you have used the two different styles, it should look something like this:

In later versions of AutoCAD, there is an easy way to change existing text to a new style. First, select the text, then go up to the Text Style Menu (usually towards the top of the screen) and select the style you want from the droplist (below) and the text will change automatically.

Professional looking and clear text is essential in any CAD drawing. Practice with different styles until you are comfortable with these concepts.

1.4 Multiline Text

Often you will want to enter a block of text, maybe a paragraph explaining a problem. In this case, MTEXT is what you need. Mtext allows you to format your text much like a word processor. Start the Multiline Text command, and pick a spot in the drawing. Drag the cursor over to create a 'rectangle' to represent the area you want your text in, and pick the other corner. As soon as you pick the second point (P2), the full Multiline text editor will appear. Type your text, and press OK when done.

NOTE: AutoCAD uses two types of fonts: true-type and 'SHX' vector fonts. True-type fonts are indicated by a small symbol beside the font name. As a rule, you will want to use the SHX fonts, as AutoCAD can draw these faster. Newer releases of AutoCAD handle true-type faster than before, but they can still slow down your display speed. Another concern when using True-type fonts is that if you are exchanging drawing files with other people, they may not have the same fonts installed on their system. This could lead to formatting problems when they open your files.

1.5 Editing text

The easiest way to edit the contents of your text (what you wrote) is to double click on it. Depending up your method of entering the text, a different editor will appear (Mtext or single line text). If you want to change the shape of your Mtext box, just pick on the text, and use grips to drag the bottom right corner.

Single line text cannot be changed like this. When deciding when to use single or multiline text, think about how the text will be used, if it might be edited later, it's generally a safer bet to use Mtext.

1.6 Arc-Aligned Text

Recently AutoCAD added a selection of commands called "Express Tools". These are regular AutoCAD commands, but they aren't fully supported (meaning don't cry to Autodesk if they don't work). They are also sometimes installed separately from the regular AutoCAD installation, so you may not have them on your screen. But they do offer a nice option to some drawing problems. One of these Express Tools is Arc-Aligned Text. Just like the name suggests, you can place text along an arc. Draw an arc and start the command as shown above. As prompted, select the arc, and this dialog box will appear:

As you can see, there are quite a few options. Use the default settings and you should have text that looks something like this:

You can also erase the arc and the text will remain. This isn't a command that you will use a lot, but it is comforting to know that it's there.

2. Exercise 2: Below is a sample drawing showing 2 different revolved objects (lamp and lampshade). It will also be your goal in this lesson to duplicate similar objects.

So far you've only worked with very basic blocks. Suppose that you need to draw something other than a rectangular cube. You did some new shapes in the previous lesson while lofting. AutoCAD gives you two commands for those times when you need to draw cylindrical objects. One (revsurf) will give you a complex model comprised of a 3-D surface made up of many facets. The other (revolve) will give you a solid object. The method that you use will once again depend on what you need it for. Take a look at the lamp on this page. This is an example of two different types of objects requiring two types of object construction. The lampshade is a 'hollow' object. Essentially it's just a surface. The lamp base is a solid object. The revsurf command was used to create the lampshade, while the revolve command was used to create the base. It's not the greatest looking lamp ever, so in this lesson, you'll be designing a lamp base and a lampshade. You'll start by defining half the profile of each object, then revolving them. This will also be good practice for viewing your 3-D model.

Begin a new drawing using the acad.dwt template.

Create 2 layers called SHADE and BASE and give them different colors.
Make BASE your current layer.

Start the polyline command. Begin the profile for your lamp base. Use Ortho mode to draw a a backwards "C" shape with the vertical line 10 units up and the horizontal lines can be whatever you like (you're the designer now).

Next draw a spline to connect the two ends of your polyline using Osnaps.
Hint, when ending the spline command, you will be asked for the start and end vectors - choose the endpoint just to the right of your end in the vertical line.
Draw a short vertical line as shown in step 3 (make sure Ortho mode is ON).
Make **SHADE** your current layer Draw a short angled **line** as shown in step 4 (this is the beginning of the shade.)
Make **BASE** your current layer. Start the REGION command and create a region from the lines that makeup the base. Don't include the vertical line at the top.

You have drawn everything you need for this lesson and will use modifying commands to complete the lesson. First you'll create the lampshade. Before you do this, though, you'll have to set two of AutoCAD's system variables (SURFTAB1 & SURFTAB2). These variables control how many facets you'll have in your surface. The default is 6, which will give you a very chunky looking shade (like a hexagon instead of a circle). The number you pick will also influence how fast your computer can display the object as well as how round the shade will appear. The sample on the previous page had the SURFTAB1 variable set to 24 to give the lamp 24 sides. To change these, type in SURFTAB1 at the command prompt enter 24. AutoCAD will show you the current setting and give you a chance to reset it. Set the variable and then set SURFTAB2 enter 2 for this variable. Since the vertical shape is a straight line, you only a setting of 2 (the minimum).

Now you're ready to create the lampshade. Start the REVSURF command. You will be asked to select the path curve. This is the line that represents the lampshade. Then you are asked to select the axis of revolution. Pick the vertical line that you drew. Accept the defaults of 0 for the start angle and full circle for the included angle. This will rotate your line a full 360 degrees.

Command: REVSURF
Current wire frame density: SURFTAB1=24 SURFTAB2=2
Select object to revolve: **<pick the lampshade line>**
Select object that defines the axis of revolution: **<pick the vertical line>**
Specify start angle <0>: <ENTER>
Specify included angle (+=ccw, -=cw) <360>: <ENTER>
You'll see that the lampshade looks like a lampshade now.
Next you will create the base. Start the **REVOLVE** command. You'll be asked to select objects. Pick the region for the lamp base. Next you're asked to select the axis of rotation. With your endpoint Osnap on, pick the top and bottom of the vertical line. Accept the default of **<full circle>** for the angle of revolution. This will revolve the profile around the vertical line 360 degrees and create a <u>solid</u> object.

Command: REV REVOLVE
Current wire frame density: ISOLINES=4
Select objects: <select the region> 1 found
Select objects: <ENTER>
Specify start point for axis of revolution or
define axis by [Object/X (axis)/Y (axis)]: O <ENTER>
Select an object: <SELECT THE VERTICAL LINE ABOVE THE BASE>
Specify angle of revolution <360>: <ENTER>

2.1 Viewing Your Lamp

Use the HIDE (HI)command to see that you really have 3D objects and that the shade blocks the top part of the base. If you switch to your SW Isometric view, you'll see that the lamp is on its side'. To arrange it to be sitting on its base, you will have to use the ROTATE3D command. Begin the command by typing **ROTATE3D** and select the objects that you want to modify and press enter. By accepting to default of 2points, you are going to tell AutoCAD what axis you want the lamp ROTATE3D about. Pick the points as shown in the example below. Make sure you have your Osnaps (Quadrant) on. Refer to the right hand rule for the correct rotation angle.

Command: ROTATE3D
Current positive angle: ANGDIR=counterclockwise ANGBASE=0
Select objects: Specify opposite corner: 2 found
Select objects: <ENTER>
Specify first point on axis or define axis by
[Object/Last/View/Xaxis/Yaxis/Zaxis/2points]: <PICK POINT 1>
Specify second point on axis: <PICK POINT 2>
Specify rotation angle or [Reference]: 90 <ENTER>

Topic Objective:

At the end of this topic student would be able to:

- Define the term geometric construction
- Highlight the importance of geometric construction

Definition/Overview:

Geometric Construction: Compass-and-straightedge or ruler-and-compass construction is the construction of lengths or angles using only an idealized ruler and compass.

The ruler to be used is assumed to be infinite in length, has no markings on it and only one edge, and is known as a straightedge. The compass is assumed to collapse when lifted from the page, so may not be directly used to transfer distances. (This is an unimportant restriction, as this may be achieved via the compass equivalence theorem.)

Every point constructible using straightedge and compass may be constructed using compass alone. A number of ancient problems in plane geometry impose this restriction.

The most famous ruler-and-compass problems have been proven impossible in several cases by Pierre Wantzel, using the mathematical theory of fields. In spite of these impossibility proofs, some mathematical novices persist in trying to solve these problems. Many of them fail to understand that many of these problems are trivially solvable provided that other geometric transformations are allowed: for example, doubling the cube is possible using geometric constructions, but not possible using ruler and compass alone. Mathematician Underwood Dudley has made a sideline of collecting false ruler-and-compass proofs, as well as other work by mathematical cranks, and has collected them into several books.

Key Points:

1. **Compass and straightedge tools**
   The "compass" and "straightedge" of compass and straightedge constructions is an idealization of rulers and compasses in the real world. The compass can be opened arbitrarily wide, but (unlike some real compasses) it has no markings on it. It can only be opened to

widths that have already been constructed, and it collapses when not used for drawing. The straightedge is infinitely long, but it has no markings on it and has only one edge, unlike ordinary rulers. It can only be used to draw a line segment between two points or to extend an existing line. Each construction must be exact. "Eyeballing" it (essentially looking at the construction and guessing at its accuracy, or using some form of measurement, such as the units of measure on a ruler) and getting close does not count as a solution. Stated this way, compass and straightedge constructions appear to be a parlour game, rather than a serious practical problem; but the purpose of the restriction is to ensure that constructions can be proven to be exactly correct. One of the chief purposes of Greek mathematics was to find exact constructions for various lengths; for example, the side of a pentagon inscribed in a given circle. The Greeks did not find constructions for three problems:

- **Squaring the circle**: Drawing a square the same area as a given circle.
- **Doubling the cube**: Drawing a cube with twice the volume of a given cube.
- **Trisecting the angle**: Dividing a given angle into three smaller angles all of the same size.

For 2000 years people tried to find constructions within the limits set above, and failed. All three have now been proven under mathematical rules to be impossible generally some angles, for example, can in fact be trisected, but many (in particular the innocent looking $\pi/3$) cannot.

2. **Computer-Aided Design**

Computer-aided design (CAD) is the use of computer technology to aid in the design and especially the drafting (technical drawing and engineering drawing) of a part or product, including entire buildings. It is both a visual (or drawing) and symbol-based method of communication whose conventions are particular to a specific technical field. In recent years, an underground movement known as 'CAD Club' has sprung up across many urban strongholds, spreading from its initial drawing ground in London, all the way to New York, Hong Kong and many other far flung corners of the globe. CAD Club, the brainchild of founder and leader, the AristoCAD, was initially developed as an outlet for like-minded

CAD professionals to get together and let off steam in a CAD-friendly environment. It has been widely speculated that the AristoCAD drew his inspiration from the hit Brad Pitt movie, Fight Club. Many parallels can be drawn between the two. In recent years, far from being a purely drawing-orientated environment, the meetings have taken on more of a glue sniffing purpose. This is put down mainly to the influence that Thomson, the AristoCADs alter-ego, has had on proceedings.

Drafting can be done in two dimensions ("2D") and three dimensions ("3D"). Drafting is the integral communication of technical or engineering drawings and is the industrial arts sub-discipline that underlies all involved technical endeavors. In representing complex, three-dimensional objects in two-dimensional drawings, these objects have traditionally been represented by three projected views at right angles. Current CAD software packages range from 2D vector-based drafting systems to 3D solid and surface modellers. Modern CAD packages can also frequently allow rotations in three dimensions, allowing viewing of a designed object from any desired angle, even from the inside looking out. Some CAD software is capable of dynamic mathematic modeling, in which case it may be marketed as CADD computer-aided design and drafting. CAD is used in the design of tools and machinery used in the manufacture of components, and in the drafting and design of all types of buildings, from small residential types (houses) to the largest commercial and industrial structures (hospitals and factories).

CAD is mainly used for detailed engineering of 3D models and/or 2D drawings of physical components, but it is also used throughout the engineering process from conceptual design and layout of products, through strength and dynamic analysis of assemblies to definition of manufacturing methods of components. CAD has become an especially important technology within the scope of computer-aided technologies, with benefits such as lower product development costs and a greatly shortened design cycle. CAD enables designers to lay out and develop work on screen, print it out and save it for future editing, saving time on their drawings.

3. **Fields of use**

- Architecture, engineering, and construction (AEC) industry
    - Architecture
    - Architectural engineering
    - Interior design
    - Interior architecture
    - Building engineering
    - Civil engineering and infrastructure
    - Construction
    - Roads and highways
    - Railroads and tunnels
    - Water supply and hydraulic engineering
    - Storm drain, wastewater and sewer systems
    - Mapping and surveying
    - Chemical plant design
    - Factory layout
    - Heating, ventilation and air-conditioning (HVAC)

- Mechanical (MCAD) engineering
    - Fully editable digital multi-CAD mockup
    - Fully editable digital multi-CAD mockup
        - Automotive - vehicles
        - Aerospace
        - Consumer goods
        - Machinery
        - Shipbuilding
        - Bio-mechanical systems

- Electronic design automation (EDA)

  - Electronic and electrical computer-aided design (ECAD)
  - Digital circuit design

- Electrical engineering
  - Power engineering or Power systems engineering
  - Power systems CAD
  - Power analytics

- Manufacturing process planning
- Industrial design
- Software applications
- Apparel and textile design
  - Fashion design

- Designing musical instruments
- Garden design
- Lighting design
- Medicine
- Production design

Topic Objective:

At the end of this topic student would be able to:

- Define the term orthographic projection
- Highlight the importance of orthographic projection

Definition/Overview:

Orthographic Projection: Orthographic projection is a means of representing a three-dimensional (3D) object in two dimensions (2D). It is a form of parallel projection, where the view direction is orthogonal to the projection plane. It is further divided into multiview orthographic projections and axonometric projections.

Orthographic projection corresponds to a perspective projection with a hypothetical viewpointe.g., one where the camera lies an infinite distance away from the object and has an infinite focal length, or "zoom".

Key Points:

1. **Multiview orthographic projections**

With multiview orthographic projections, up to six pictures of an object are produced, with each projection plane parallel to one of the coordinate axes of the object. The views are positioned relative to each other according to either of two schemes: first-angle or third-angle projection. In each, the appearances of views may be thought of as being projected onto planes that form a 6-sided box around the object.

2. **Quadrants in descriptive geometry**
   Modern orthographic projection is derived from Gaspard Monge's descriptive geometry. Monge defined a reference system of two viewing planes, horizontal H ("ground") and

vertical V ("backdrop"). These two planes intersect to partition 3D space into 4 quadrants, which he labeled:

- I: above H, in front of V
- II: above H, behind V
- III: below H, behind V
- IV: below H, in front of V

These quadrant labels are the same as used in 2D planar geometry, as seen from infinitely far to the "left", taking H and V to be the X-axis and Y-axis, respectively. The 3D object of interest is then placed into either quadrant I or III (equivalently, the position of the intersection line between the two planes is shifted), obtaining first- and third-angle projections, respectively. Quadrants II and IV are also mathematically valid, but their use would result in one view "true" and the other view "flipped" by 180 through its vertical centerline, which is too confusing for technical drawings. Monge's original formulation uses two planes only, and obtains the top and front views only. The addition of a third plane to show a side view (either left or right) is a modern extension. The terminology of quadrant is a mild anachronism, as a modern orthographic projection with three views corresponds more precisely to an octant of 3D space.

3. **First-angle projection**

   In first-angle projection, the object is conceptually located in quadrant I, i.e. it floats above and before the viewing planes, the planes are opaque, and each view is pushed through the object onto the plane furthest from it. (Mnemonic: an "actor on a stage".) Extending to the 6-sided box, each view of the object is projected in the direction (sense) of sight of the object, onto the (opaque) interior walls of the box; that is, each view of the object is drawn on the opposite side of the box:

4. **Third-angle projection**

   In third-angle projection, the object is conceptually located in quadrant III, i.e. it lurks below and behind the viewing planes, the planes are transparent, and each view is pulled onto the plane closest to it. (Mnemonic: a "shark in a tank", esp. that is sunken into the floor.) Using the 6-sided viewing box, each view of the object is projected opposite to the direction (sense) of sight, onto the (transparent) exterior walls of the box; that is, each view of the object is drawn on the same side of the box. The box is then unfolded to view all of its exterior walls.

5. **Additional information**

   First-angle projection is as if the object were sitting on the paper and, from the "face" (front) view, it is rolled to the right to show the left side or rolled up to show its bottom. It is standard throughout Europe (excluding the UK) and Asia. First-angle projection used to be common in the UK, and may still be seen on historical design drawings, but has now fallen into disuse in favour of third-angle projection. Third-angle is as if the object were a box to be unfolded. If we unfold the box so that the front view is in the center of the two arms, then the top view is above it, the bottom view is below it, the left view is to the left, and the right view is to the right. It is standard in the United Kingdom, USA and Canada. Both first-angle and third-angle projections result in the same 6 views; the difference between them is the arrangement of these views around the box. A great deal of confusion has ensued in drafting rooms and engineering departments when drawings are transferred from one convention to another. On engineering drawings, the projection angle is denoted by an international symbol consisting of a truncated cone, respectively for first-angle (FR) and third-angle (US):

The 3D interpretation of the symbol can be deduced by envisioning a solid truncated cone (Mnemonic: a "gift-wrapped megaphone"), standing upright with its large end on the floor and the small end upward. The top view is therefore two concentric circles ("donut"). In particular, the fact that the inner circle is drawn with a solid line instead of dashed disambiguates this view as the top view, not the bottom view. In first-angle projection, the "top" view is pushed down to the floor, and the "front" view is pushed back to the rear wall; the intersection line between these two planes is therefore closest to the large end of the cone, hence the first-angle symbol shows the cone with its large end open toward the donut. In third-angle projection, the "top" view is pulled up to the ceiling, and the "front" view is pulled forward to the front wall; the intersection line between the two planes is thus closest to the small end of the cone, hence the third-angle symbol shows the cone with its large end away from the donut.

6. **Multiviews without rotation**

Orthographic multiview projection is derived from the principles of descriptive geometry and may produce an image of a specified, imaginary object as viewed from any direction of space. Orthographic projection is distinguished by parallel projectors emanating from all points of the imaged object and which intersect a plane of projection at right angles. Above, a technique is described that obtains varying views by projecting images after the object is rotated to a desired position. Descriptive geometry customarily relies on obtaining various views by imagining an object to be stationary, and changing the direction of projection (viewing) in order to obtain the desired view. Using the rotation technique above, note that no orthographic view is available looking perpendicularly at any of the inclined surfaces. Suppose a technician desired such a view to, say, look through a hole to be drilled perpendicularly to the surface. Such a view might be desired for calculating clearances or for dimensioning purposes. To obtain this view without multiple rotations requires the principles of Descriptive Geometry.

Topic Objective:

At the end of this topic student would be able to:

- Define the term AutoCAD
- Describe the AutoCAD 2005 Program
- Highlight the importance of The AutoCAD 2005 Program

Definition/Overview:

Drawings, Formats, Blocks, and Attributes: Drawings, Formats, Blocks, and Attributes

Include Block diagrams, orthographic drawings, dimensioned drawings, tolerance drawings, sectional drawings, 3D drawings, solid models

Architectural, civil, electronic, electromechanical, technical illustrations

Key Points:

1. **Block Diagram**

   A block diagram is a pictorial model of a process or system. They are heavily used in the engineering block diagram is typically used for a higher level, less detailed description aimed more at understanding the overall concepts and less at understanding the details of implementation. Contrast this with the schematic diagram and layout diagram used in the electrical engineering world, where the schematic diagram shows the details of each electrical component and the layout diagram shows the details of physical construction. For example, a block diagram of a radio is not expected to show each and every wire and dial and switch, but the schematic diagram is. The schematic diagram of a radio does not show the width of each wire in the printed circuit board, but the layout diagram does. To make an analogy to the map making world, a block diagram is similar to a highway map of an entire nation. The major cities (functions) are listed but the minor county roads and city streets are not. When troubleshooting, this high level map is useful in narrowing down and isolating where a problem or fault is. Block diagrams rely on the principle of the black box where the contents are hidden from view either to avoid being distracted by the details or because the details are not known. We know what goes in, we know what goes out, but we can't see how the box does its work.

   In electrical engineering a design will often begin as a very high level block diagram, becoming more and more detailed block diagrams as the design progresses, finally ending in block diagrams detailed enough that each individual block can be easily implemented (at which point the block diagram is also a schematic diagram). This is known as top down design. Geometric shapes (e.g. rectangles, circles etc.) are often used in the diagram to aid interpretation and clarify meaning of the process or model. The geometric shapes are connected by lines to indicate association and direction/order of traversal. Each engineering discipline has their own meaning for each shape.

Topic Objective:

At the end of this topic student would be able to:

- Define the term AutoCAD
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- Highlight the importance of The AutoCAD 2005 Program

Definition/Overview:

Using AutoCAD DesignCenter to Create Libraries: The simplest way to improve AutoCAD productivity is to develop one or more collections of commonly used objects. Commonly known as block libraries, the objects in these collections are typically grouped by type or function. For example, an architect might create libraries of doors, windows or wall details. Prior to AutoCAD 2000i, block libraries were actually drawing libraries. Block objects occur within a drawing file, much like a layer or dimension style. A drawing file inserted into the current drawing creates a block within the current drawing. AutoCAD DesignCenter gives users access to the content contained within drawings. Blocks, dimension styles, layers, layouts, linetypes, text styles and layouts are all examples of drawing content that may be accessed using AutoCAD Design Center.

Blocks viewed using AutoCAD DesignCenter can be displayed in list, detail or preview format, offering using several methods to select the desired block.

The AutoCAD DesignCenter palate at the right shows the House Designer library, included with AutoCAD, in the Preview format. Blocks can be inserted into the current drawing, just by clicking on the block icon and dragging it into the drawing. Blocks can also be inserted by double-clicking on the block icon or right-clicking and selecting Insert Block from the menu. Both of these methods allow scale and rotation options for inserting the block.

Key Points:

1. **The Today Window**
   The Today Window is the easiest way to use AutoCAD Design Center to insert blocks. If you have the Today Window turned off, select Today from the Standard toolbar or type TODAY at the command line.

   Clicking on one of the library names will open the drawing containing the blocks in AutoCAD Design Center.

2. **Adding to the Symbol Libraries in Today**
   It's really very simple to add a library to the Today Window, but before you can add a library you must create it.

- Begin a new drawing
- Insert drawings to make blocks
- Draw objects and convert to blocks
- Copy objects from other drawings and convert to blocks
- Rename blocks they have unique, descriptive names (Tip: Spaces are allowed and you can use more than 31 characters.)
- Save the drawing (Tip: Locate the drawing on a shared network drive so your co-workers can use it too!)

- Click on Edit in the Today Window

- The DesignCenter Symbols Libraries are really just links to drawings containing blocks.
- Once you have created and saved your container drawing, you can create a link to it.
- Click on the Add link button.
- Find the drawing containing the blocks.
- Use the Move up or Move down buttons to arrange the list of libraries.
- You're ready to use your new Library!

3. **Tips for Making Blocks**

Taking a couple minutes to properly construct your blocks will pay off in the long run.

3.1. **Properties**

Placing the objects that comprise your block on Layer 0, with Color, Linetype and Lineweight (Plot Style if using Named Plot Styles) set to ByBlock will allow the greatest amount of flexibility in assigning properties without exploding your block. When objects inside a block are assigned to Layer 0, they will take on the properties of the layer the block is inserted on. When Color, Linetype and Lineweight properties are set to ByBlock, the objects will inherit the property assigned to the block. If these properties are not set to ByBlock, they can only display the properties associated with the Layer.

3.2. **Scale**

Blocks representing components, like doors, gears and fasteners, should be drawn 100% accurately and inserted at a scale of 1. Block representing symbols, like North arrows and surface texture marks, should be drawn at the size desired on the finished print. When inserted into Model Space the insert scale needs tocompensate for the plot scale. Insert at a scale of 1 in Paper Space.

- In Section 3 of this course you will cover these topics:

External References (Xrefs)

Using Raster Images In Autocad Drawings

Dimensioning And Tolerancing

Sectional Drawings And Hatching

Topic Objective:

At the end of this topic student would be able to:

- Define the term AutoCAD
- Describe the AutoCAD 2005 Program
- Highlight the importance of The AutoCAD 2005 Program

Definition/Overview:

External References: External references, or "xrefs", constitute one of the keys to efficient drafting, especially of building plans. Xrefs help you minimize duplication of geometry, thereby making editing more efficient and helping to keep drawings in synch. Xrefs also can help keep file sizes down when you use the same large components (e.g., elaborate title blocks) in multiple drawings.

AutoCAD R13 added:

- Overlay as an alternative way of incorporating xrefs (in addition to the old attach method).
- A new "Bind as insert" method of binding xrefs (in addition to the old "bind as bind").

AutoCAD R14 added:

- Xref clipping, so that you now can control which parts of an xref display in the parent drawing.
- Xref project files search path, in an attempt to address the "xref in a different directory from the drawing that refers to it" problem.
- An xref demand loading feature for speeding up xref access in situations where only a small part of a large xref is needed.
- AutoCAD 2000 added:
- In-place xref editing.

AutoCAD keeps track of several kinds of organizational objects in addition to the ordinary geometrical entities that you draw. The objects that are important for our present purposes are layers, blocks, text styles, dimension styles, and linetypes. AutoCAD refers to these as "named objects" (or, in certain contexts, "dependent symbols").

	Blocks	Xrefs
Childs geometry:	Copied into parent DWG and stored there.	Not copied into parent DWG; loaded temporarily each time you load parent DWG.
Updating parent when child changes:	Must redefine block (with INSERT blkname= or BLOCK).	Happens automatically.

Named objects:	Parent definitions override child definitions.	Parent and child definitions are maintained separately.
Named object names:	Normal.	Prefixed with xrefname|.
Attribute definitions:	Supported.	Ignored.

Key Points:

1. **Commands**

   The primary command for manipulating xrefs is XREF. You can launch it in any of the following ways:

- External Reference dialog box:
  Type: XREF or XR
  Pull-down menu: Insert, Xref Manager
  Draw toolbar: External Reference (in the Insert Block fly-out toolbar)
- Command line version:
  Type XREF

The External Reference dialog box includes these options:

Xref dialog box option	Purpose	Notes
Attach	Create an external reference attachment or overlay.	Analogous to INSERT for blocks. You can go directly to this option with the XATTACH command (XA or Insert, External Reference)

Detach	Delete all instances of a previously attached xref.	Analogous to ERASE and then PURGE for blocks.
Reload	Refresh xref definitions from external DWG files.	Useful on networks when someone else is editing your children as you work on the parent.
Unload	Remove an xref from the screen (and from memory), but leave the attachment for later Reloading.	
Bind	Convert an xref into a block.	Useful for archiving or sending a drawing to a recipient whos not xref-savvy. Options to bind as block or as xref.
Xref Found At	Display (and optionally change) the path where AutoCAD looks for an xref.	Useful for re-specifying or removing xref paths.
List View / Tree View	Change between showing a list of xrefs with all details and showing a hierarchical tree ox ref names.	Use Tree View to inspect the hierarchical relationship of a complicated set of xrefs.

The XREF command line version includes a similar set of options.

-XREF command line options	Purpose	Notes
?	List currently attached xrefs.	
Bind	Convert an xref into a block.	Doesnt include the "bind as block" option, so youll always end up with lots of weird named object names.
Detach	Delete all instances of a previously attached xref.	
Path	Change the path where AutoCAD looks for an xref (or strip the path entirely).	Useful for stripping hard-coded xref paths.
Unload	Remove an xref from the screen (and from memory), but leave the attachment for later Reloading.	
Reload	Refresh xref definitions from external DWG files.	
Overlay	Create an external reference overlay.	
Attach	Create an external reference attachment.	

AutoCAD includes these additional xref-related commands:

Command	Purpose	Notes
REFEDIT	Edit an xref (or block	New in AutoCAD 2000.

	insert) in place.	
VISRETAIN (a system variable, actually)	Control whether parents or childs settings of childs layers govern at load time.	0 = childs layer settings control. 1 = parents layer settings control.
XATTACH (XA)	Create an external reference attachment.	Same as clicking Attach in the Xref Manager dialog box.
XBIND (XB)	Permanently add a named object from an xref to the current drawing.	Seldom used.
XCLIP (XC)	Clip an xref using a rectangle or polygon.	Handy for building plans that require multiple sheets and match lines.

2. **When to use xrefs**

   There are many applications for xrefs, including:

- Title blocks: Reference elements that need to appear in multiple drawings (e.g., wall outlines, site topography, column grids).

Assemblies that are repeated in one or more drawings, especially if the assemblies are likely to change together (e.g., repeated framing assemblies, bathroom layout, modular furniture layout). Pasting up several drawings (e.g., details or a couple of plans) onto one plot sheet. Temporarily attaching a background drawing for reference or "tracing" purposes. On the other hand, blocks remain useful in simpler circumstances. Remember that every xref requires keeping track of a separate file. Some situations in which you might stick with a block are:

- Components that arent likely to change.
- Small components.

- A simple assembly thats used repeatedly, but in only one drawing. (You can easily update a block in one drawing by inserting it in a blank area, exploding and editing it, and then redefining it with the BLOCK command.)
- Also, its important that everyone in the office be reasonably consistent about when to use and when not to use xrefs.

3. **Xref guidelines**

   Following are some guidelines for working with xrefs:

- Document xref dependencies for each project. Maintain control of the xref structure. If you cant keep it in your head, its too complicated.
- Attach each xref on an appropriate layer. For example: attach a grid on the S-GRID layer. If you cant think of an appropriate layer, make one called XREF.
- Be aware of potential problems with xrefs in different directories from the parent drawings. The simplest way to avoid problems is to make sure that parent and child drawings always reside in the same directory.
- Do not bind xrefs in working drawings. The only time you should bind xrefs is when creating a set of drawings for archiving or for sending out to a recipient that requests no xrefs. Always do the binding on a copy of the working drawing (i.e., open the drawing, SAVEAS newname, then bind).
- Set VISRETAIN consistently in your drawings. I prefer when possible to set VISRETAIN to 0 and thereby control the visibility and properties of xrefed layers from the child drawings. You may want to or need to set VISRETAIN to 1 and control xref layer visibility and properties from the parent drawings (in order to be able to assign different properties to the same layer in different parent drawings, for example).
- Before sending out or archiving a set of drawings (assuming that xrefs arent bound), always verify that the drawing set includes all xrefs. Use your project documentation as a checklist and/or the Pack n Go Express tool.

4. **Tips and tricks**

Following are some tips that will make working with xrefs easier and more efficient. AutoCAD looks for xrefs first in the saved path, then in the directories that make up the library search path (AutoCAD startup directory, current DWGs directory, support file search path directories, AutoCAD driver directory, Acad.exe directory). To remove a hard-coded path, run the XREF command, select the xref, delete the path (i.e., everything except for filename.dwg) in the Xref Found At field, and press ENTER. If AutoCAD cant find an xref (usually because the DWG file got renamed or moved), AutoCAD displays a warning and writes some text at the xrefs insertion point. To fix the problem, restore the xrefed file and run XREF Reload, or modify or remove the xrefs Saved Path. With xrefs, assembling a set of drawings for archiving or sending out becomes trickier. You need to make sure that you include all children of all parent DWGs; otherwise the recipient will end up looking at a partial drawing (and will regard you as inept). To avoid this embarrassment, be organized. Make a map that shows xref dependencies for the . You can use the Pack n Go Express Tools command to help you bundle up a set of drawings with all of the necessary xrefs and fonts. When you bind an xref, AutoCAD converts the vertical bar between the xref name and symbol name to n, where n is a number (usually 0). The result is a lot of peculiar names for layers, blocks, and other named objects. As a result, you should avoid binding unless youre archiving drawings or sending out a set to someone who doesnt want to deal with xrefs and doesnt mind the weird names. To avoid the peculiar named object names, set Bind Type to Insert when you bind. Alternatively, detach the xref and then insert it as a block (or as individual geometry with INSERT *dwgname). AutoCAD R14 and previous versions limit the names of layers to 31 characters. AutoCAD won't let you attach an xref if any of the resulting layer names (xrefname|layername) would be longer than 31 characters. Similarly, AutoCAD won't let you bind an xref (in bind "As Bind" mode) if the resulting layer name (xrefname$n$layername) would be longer than 31 characters. The same limitation applies to other named objects. If you encounter this problem, you'll need to use the RENAME command to rename the offending named object(s) in the child drawings to something shorter.

5. **Command line tips and tricks**
   If you choose to use the old command line version of the XREF command (type XREF in AutoCAD 2000 or R14), here are some additional tips. All of the -XREF subcommands accept wildcards, the most useful of which is * (for "all xrefs"). Use -XREF ? to get a list of xrefs that you can copy to a text or word processing document. Xref features added in AutoCAD R13, R14, and 2000 The following xref features were new in AutoCAD R13, R14 or 2000. Overlay vs. attach (R13): The difference between overlaying and attaching an xref appears only when you have multiple levels of xrefs (e.g., A.dwg references B.dwg, which references C.dwg). If you attach C.dwg in B.dwg, and then attach B.dwg in A.dwg, you see C.dwgs geometry in both B.dwg and A.dwg. If instead you overlay C.dwg in B.dwg, you see C.dwgs geometry in B.dwg, but not in A.dwg. In other words, an overlaid xref displays only one level up in the hierarchy. Above that one level, it disappears. "Bind as insert vs. "bind as bind" (R13): When you bind as bind, AutoCAD creates a slew of unwieldy names containing 0 for xref layers and other named objects. When you bind as insert, AutoCAD merges the xrefs named objects with those of the current drawing, thus eliminating the unwieldy names. There is one potential danger with bind as insert, though: If an xref has a layer or other named object that uses the same name as one in the parent drawing, but is defined differently (e.g., S-GRID is red in the parent but gray in the xref), then the properties of the xref objects will change when you bind as insert.

   Xref clipping (R14): Xref clipping allows you to define a clipping boundary that limits which part of the xref displays. For example, you can draw a full plan in one DWG file, xref it into multiple "plot sheet" DWG files, and in each plot sheet clip the xref so that only the desired area displays. This method is similar to the older paper space approach, but it isnt limited to paper space or rectangular viewports. Theres nothing wrong with using paper space, but the xref clipping procedure is more intuitive than creating paper space viewports and zooming the model inside of them. With xref clipping, you can create everything on your plot sheet clipped plan, title block, and additional notes in model space if you want to. Also, you can clip xrefs to irregular polygonal areas, which avoids the rectangular limitation of paper space view ports. You can define various project names in the Preferences dialog box, specify xref search directories for each project, and then specify the project with which a particular drawing is associated (and thus in which additional directories AutoCAD should look for xrefs when opening that file). The project files search path feature can help on one computer, but it doesnt really address the drawing exchange problem that xrefs in different directories cause. For that reason, I dont think its a very helpful feature for most people. I continue to recommend keeping parent and child drawings in the same folder.

Demand loading (R14): When you open a drawing containing an xref, AutoCAD normally must load the entire xrefed DWF file from the disk into memory. Demand loading allows AutoCAD to load only those portions of the xref that are displayed in the parent drawing. If you use xref clipping to show a small portion of a large xref, or you freeze layers containing a large amount of xrefed geometry, then demand loading might help improve performance. Taking advantage of demand loading requires that you set the INDEXCTL system variable to a non-zero value in the xrefed DWGs so that AutoCAD creates the necessary indices. You also must set XLOADCTL to a non-zero value so that AutoCAD knows to use demand loading. Warning: The default XLOADCTL setting of 1 is not good in a networked office where one AutoCAD user may need to open a drawing thats attached as an xref in a parent drawing that another user has open. Change XLOADCTL either to 0 (turn off demand loading) or to 2 (make a local temporary copy of any xrefs). In-place xref editing (2000): With the new REFEDIT command, you can edit an xref (or block insert) "in place" that is, you dont have to open the child drawing.

- In Section 4 of this course you will cover these topics:
- Isometric Drawing And Gradient Hatch Rendering
- Basic 3-D
- Customizing Toolbars, Menus, And Palettes
- 3-D Surface Modeling

Topic Objective:

At the end of this topic student would be able to:

- Define the term AutoCAD
- Describe the AutoCAD 2005 Program
- Highlight the importance of The AutoCAD 2005 Program

Definition/Overview:

Isometric Drawing: Isometric projection is a form of graphical projection, more specifically, a form of axonometric projection. It is a method of visually representing three-dimensional objects in two dimensions, in which the three coordinate axes appear equally foreshortened and the angles between any two of them are 120.

Key Points:

1. **Isometric**
   The term "isometric" comes from the Greek for "equal measure", reflecting that the scale along each axis of the projection is the same (this is not true of some other forms of graphical projection). An isometric view of an object can be obtained by choosing the viewing direction in a way that the angles between the projection of the x, y, and z axes are all the same, or 120. For example when taking a cube, this is done by first looking straight towards

one face. Next the cube is rotated 45 about the vertical axis, followed by a rotation of approximately 35.264 (precisely arcsin(tan 30)) about the horizontal axis. Note thatwith the cube, see image, the perimeter of the 2D drawing is a perfect regular hexagon: all the black lines are of equal length and all the cube's faces are the same area. In a similar way an isometric view can be obtained for example in a 3D scene editor. Starting with the camera aligned parallel to the floor and aligned to the coordinate axes, it is first rotated downwards around the horizontal axes by about 35.264 as above, and then rotated 45 around the vertical axes. Another way in which isometric projection can be visualized is by considering a view within a cubical room starting in an upper corner and looking towards the opposite, lower corner. The x-axis extends diagonally down and right, the y-axis extends diagonally down and left, and the z-axis is straight up. Depth is also shown by height on the image. Lines drawn along the axes are at 120 to one another.

2. **Mathematics**

There are 8 different orientations to obtain an isometric view, depending into which octant the viewer looks. The isometric transform from a point $a_{x,y,z}$ in 3D space to a point $b_{x,y}$ in 2D space looking into the first octant can be written mathematically with rotation matrices as:

Where, and . As explained above, this is a rotation around the vertical (here y) axis by β, followed by a rotation around the horizontal (here x) axis by α. This is then followed by an orthographic projection to the x-y plane:

The other seven possibilities are obtained by either rotating to the opposite sides or not, and then inverting the view direction or not.[1]

3. **Limits of axonometric projection**
   As with all types of parallel projection, objects drawn with axonometric projection do not appear larger or smaller as they extend closer to or away from the viewer. While advantageous for architectural drawings, this results in a perceived distortion, as unlike perspective projection, it is not how our eyes or photography normally work. It also can easily result in situations where depth and altitude are difficult to gauge, as is shown in the illustration to the right. Once popular in sprite-based video games, most contemporary video games have avoided these sorts of situations by switching over to perspective 3D instead. Such illusions were also popular in Op art such as M. C. Escher's "impossible architecture" drawings. *Waterfall* (1961), in which the drawing of the building makes use of axonometric projection, but the faded background uses perspective projection, is a well-known example. Another advantage is that, in engineering drawings, 60 angles are easier for novices to construct using only a compass and straightedge.

   In this isometric drawing for example, the blue sphere is two levels higher than the red one. However, this difference in elevation is not apparent if one covers the right half of the picture, as the boxes (which serve as clues suggesting height) are then obscured.

Topic Objective:

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- Define the term AutoCAD
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Definition/Overview:

3D Computer Graphics: 3D computer graphics (in contrast to 2D computer graphics) are graphics that use a three-dimensional representation of geometric data that is stored in the computer for the purposes of performing calculations and rendering 2D images. Such images may be for later display or for real-time viewing. Despite these differences, 3D computer graphics rely on many of the same algorithms as 2D computer vector graphics in the wire frame model and 2D computer raster graphics in the final rendered display. In computer graphics software, the distinction between 2D and 3D is occasionally blurred; 2D applications may use 3D techniques to achieve effects such as lighting, and primarily 3D may use 2D rendering techniques. 3D computer graphics are often referred to as 3D models. Apart from the rendered graphic, the model is contained within the graphical data file. However, there are differences. A 3D model is the mathematical representation of any three-dimensional object (either inanimate or living). A model is not technically a graphic until it is visually displayed. Due to 3D printing, 3D models are not confined to virtual space. A model can be displayed visually as a two-dimensional image through a process called 3D rendering, or used in non-graphical computer simulations and calculations.

Key Points:

1. **3D Computer Graphics**
   The process of creating 3D computer graphics can be sequentially divided into three basic phases: 3D modeling which describes the process of forming the shape of an object, layout and animation which describes the motion and placement of objects within a scene, and 3D rendering which produces an image of an object.

2. **Modeling**
   The model describes the process of forming the shape of an object. The two most common sources of 3D models are those originated on the computer by an artist or engineer using some kind of 3D modeling tool, and those scanned into a computer from real-world objects. Models can also be produced procedurally or via physical simulation.

3. **Layout and animation**
   Before objects are rendered, they must be placed (layout/laid out) within a scene. This is what defines the spatial relationships between objects in a scene including location and size. Animation refers to the temporal description of an object, i.e., how it moves and deforms over time. Popular methods include keyframing, inverse kinematics, and motion capture, though many of these techniques are used in conjunction with each-other. As with modeling, physical simulation is another way of specifying motion.

4. **Rendering**

Rendering converts a model into an image either by simulating light transport to get photorealistic images, or by applying some kind of style as in non-photorealistic rendering. The two basic operations in realistic rendering are transport (how much light gets from one place to another) and scattering (how surfaces interact with light). This step is usually performed using 3D computer graphics software or a 3D graphics API. The process of altering the scene into a suitable form for rendering also involves 3D projection which allows a three-dimensional image to be viewed in two dimensions.

5. **Communities**

There are a multitude of websites designed to help educate and support 3D graphic artists. Some are managed by software developers and content providers, but there are standalone sites as well (such as Renderosity). These communities allow for members to seek advice, post tutorials, provide product reviews or post examples of their own work.

6. **Distinct from photorealistic 2D graphics**

Not all computer graphics that appear 3D are based on a wireframe model. 2D computer graphics with 3D photorealistic effects are often achieved without wireframe modeling and are sometimes indistinguishable in the final form. Some graphic art software includes filters that can be applied to 2D vector graphics or 2D raster graphics on transparent layers. Visual artists may also copy or visualize 3D effects and manually render photorealistic effects without the use of filters.

Topic Objective:

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Definition/Overview:

Toolbar: In a graphical user interface on a computer monitor a **toolbar** is a panel on which onscreen buttons, icons, menus or other input or output elements are placed. Earlier forms of toolbars were defined by the programmer and had set functions, and thus there was no difference between a toolbar with buttons or just a row of buttons. Most modern programs and operating systems however, allow the end user to modify and customize toolbars to fit their personal needs. Some prominent examples of customizable toolbars are panels of the GNOME and KDE desktop environments, functions of which range from expandable menus and buttons for applications, window lists, notification areas, clocks and resource monitors to volume controls and weather report widgets.

Menu: Menu In computing and telecommunications, a **menu** is a list of commands presented to an operator by a computer or communications system. They may be thought of as *shortcuts* to frequently used commands that avoid the operator having to have a detailed knowledge or recall of syntax. A menu is used in contrast to a command line interface where instructions to the computer are given in the form of commands (or verbs).

Platter: Platter is a component of a hard disk drive: it is the circular disk on which the magnetic data are stored. The rigid nature of the platters in a hard drive is what gives them their name (as opposed to the flexible materials which are used to make floppy disks). Hard drives typically have several platters which are mounted on the same spindle.

Key Points:

1. **Toolbar**
   Detachable toolbars of Inkscape. Shown inside is Inkscape with undetached toolbars. Some applications, e.g. graphics editors, allow their toolbars to be detached and moved between windows and other toolbars. The first toolbar appeared on the Xerox Alto computer in 1973. Toolbars are seen in office suites such as OpenOffice.org, graphics editors and web browsers such as Inkscape and Mozilla Firefox.

2. **Web browser toolbar add-ons**
   Third-party toolbars for browsers are best known for adding functionality and ease-of-use options to the end user. While the browser itself handles basic browsing navigation (Back, Stop, Reload, etc) using its own toolbars, external toolbars often add additional functionality to browsers (additional search fields, form-fill, links back to popular sites. etc) In computing and telecommunications, a **menu** is a list of commands presented to an operator by a computer or communications system. They may be thought of as *shortcuts* to frequently used commands that avoid the operator having to have a detailed knowledge or recall of syntax. A menu is used in contrast to a command line interface where instructions to the computer are given in the form of commands (or verbs).

   For a menu, choices given from a menu may be selected by the operator by a number of methods (called interfaces):

- depressing one or more keys on the keyboard or mouse
- positioning a cursor or reverse video bar by using a keyboard or mouse
- using an electromechanical pointer, such as a light pen
- touching the display screen with a finger

- speaking to a voice-recognition system

A computer using a graphical user interface presents menus with a combination of text and symbols to represent choices. By *clicking* on one of the symbols, the operator is selecting the instruction that the symbol represents. A *context menu* is a menu in which the choices presented to the operator are automatically modified according to the current context in which the operator is working. A common use of menus is to provide convenient access to various operations such as saving or opening a file, quitting a program, or manipulating data. Most widget toolkits provide some form of pull-down or pop-up menu. Pull-down menus are the type commonly used in menu bars (usually near the top of a window or screen), which are most often used for performing actions, whereas pop-up menus are more likely to be used for setting a value, and might appear anywhere in a window. According to traditional human interface guidelines, menu names were always supposed to be *verbs*, such as "file" "edit" and so on. This has been largely ignored in subsequent UI developments. A single word verb however is sometimes unclear, and so as to allow for multiple word menu names, the idea of a vertical menu was invented, as seen in NeXTSTEP.

The magnetic surface of each platter is divided into small sub-micrometre-sized magnetic regions, each of which is used to represent a single binary unit of information. A typical magnetic region on a hard disk platter (in 2006) is about 200-250 nanometers wide (in the radial direction of the platter) and extends about 25-30 nanometers in the down-track direction (the circumferential direction on the platter), corresponding to about 100 billion bits (100 gigabits) per square inch of disk area. The material of the main *magnetic medium* layer is usually a cobalt-based alloy. In today's hard drives each of these magnetic regions is composed of a few hundred magnetic grains, which are the base material that gets magnetized. However, future hard drives may use different systems to create the magnetic regions. As a whole, each magnetic region will have a magnetization. One reason magnetic grains are used as opposed to a continuous magnetic medium is that they reduce the space needed for a magnetic region. In continuous magnetic materials, formations called Neel spikes tend to appear. These are spikes of opposite magnetization, and form for the same reason that bar magnets will tend to align themselves in opposite directions. These cause problems because the spikes cancel each other's magnetic field out, so that at region boundaries, the transition from one magnetization to the other will happen over the length of the Neel spikes. This is called the transition width.

Comparison of the transition width caused by Neel Spikes in continuous media and granular media, at a boundary between two magnetic regions of opposite magnetization Grains help solve this problem because each grain is in theory a single magnetic domain (though not always in practice). This means that the magnetic domains cannot grow or shrink to form spikes, and therefore the transition width will be on the order of the diameter of the grains. Thus, much of the development in hard drives has been in reduction of grain size. Platters are typically made using an aluminium or glass substrate. In disk manufacturing, a thin coating is deposited on both sides of the substrate, mostly by a vacuum deposition process called magnetron sputtering. The coating has a complex layered structure consisting of various metallic (mostly non-magnetic) alloys as underlayers optimized control of crystallographic orientation and grain size of the actual magnetic media layer on top of them, i.e. the film storing the bits of information. On top of it a protective carbon-based overcoat is deposited in the same sputtering process. In post-processing a nanometer thin polymeric lubricant layer is deposited on top of the sputtered structure by dipping the disk into a solvent solution, after which the disk is buffed by various processes to eliminate small defects and verified by a special sensor on a flying head for absence of any remaining asperities or other defects (where the size of the bit given above roughly sets the scale for what constitutes a significant defect size). In the hard disk drive the hard drive heads fly and move radially over the surface of the spinning platters to read or write the data. Extreme smoothness, durability, and perfection of finish are required properties of a hard disk platter.

In the 2005-2006 a major shift in technology of hard disk drives and of magnetic disks/media began. Originally, in-plane magnetized materials have been used to store the bits but perpendicular magnetization is now taking over. The reason for this transition is the need to continue the trend of increasing storage densities, with perpendicularly oriented media offering a more stable solution for a decreasing bit size. Orienting the magnetization perpendicular to the disk surface has major implications for the disk's deposited structure and the choice of magnetic materials, as well as for some of the other components of the hard disk drive (head, electronic channel, etc.).

Topic Objective:

At the end of this topic student would be able to:

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- Highlight the importance of The AutoCAD 2005 Program

Definition/Overview:

3D Modeling: In 3D computer graphics, 3D modeling is the process of developing a mathematical, wireframe representation of any three-dimensional object (either inanimate or living) via specialized software. The product is called a 3D model. It can be displayed as a two-dimensional image through a process called 3D rendering or used in a computer simulation of physical phenomena. The model can also be physically created using 3D Printing devices. Models may be created automatically or manually. The manual modeling process of preparing geometric data for 3D computer graphics is similar to plastic arts such as sculpting.

Key Points:

1. **Models**

   3D models represent a 3D object using a collection of points in 3D space, connected by various geometric entities such as triangles, lines, curved surfaces, etc. Being a collection of data (points and other information), 3D models can be created by hand, algorithmically (procedural modeling), or scanned.

   3D models are widely used anywhere 3D graphics are used. Actually, their use predates the widespread use of 3D graphics on personal computers. Many computer games used pre-rendered images of 3D models as sprites before computers could render them in real-time. Today, 3D models are used in a wide variety of fields. The medical industry uses detailed models of organs. The movie industry uses them as characters and objects for animated and real-life motion pictures. The video game industry uses them as assets for computer and video games. The science sector uses them as highly detailed models of chemical compounds. The architecture industry uses them to demonstrate proposed buildings and landscapes. The engineering community uses them as designs of new devices, vehicles and structures as well as a host of other uses. In recent decades the earth science community has started to construct 3D geological models as a standard practice.

2. **Representation**

Almost all 3D models can be divided into two categories:

Solid - These models define the volume of the object they represent (like a rock). These are more realistic, but more difficult to build. Solid models are mostly used for nonvisual simulations such as medical and engineering simulations, and for specialized visual applications such as ray tracing and constructive solid geometr

Shell - these models represent the surface, not the volume (like an eggshell). These are easier to work with than solid models. Almost all visual models used in games and film are shell models.

Because the appearance of an object depends largely on the exterior of the object, boundary representations are common in computer graphics. Two dimensional surfaces are a good analogy for the objects used in graphics, though quite often these objects are non-manifold. Since surfaces are not finite, a discrete digital approximation is required: polygonal meshes (and to a lesser extent subdivision surfaces) are by far the most common representation, although point-based representations have been gaining some popularity in recent years. Level sets are a useful representation for deforming surfaces which undergo many topological changes such as fluids. The process of transforming representations of objects, such as the middle point coordinate of a sphere and a point on its circumference into a polygon representation of a sphere, is called tessellation. This step is used in polygon-based rendering, where objects are broken down from abstract representations ("primitives") such as spheres, cones etc, to so-called meshes, which are nets of interconnected triangles. Meshes of triangles (instead of e.g. squares) are popular as they have proven to be easy to render using scanline rendering. Polygon representations are not used in all rendering techniques, and in these cases the tessellation step is not included in the transition from abstract representation to rendered scene.

3. **Modeling processes**

There are three popular ways to represent a model:

Polygonal modeling - Points in 3D space, called vertices, are connected in a linear fashion to form a polygonal mesh. Used for example by 3DS Max. The vast majority of 3D models today are built as textured polygonal models, because they are the most flexible and quickest for the computer to handle. However, polygons cannot be bent. Curved surfaces are approximated by using many small flat surfaces.

NURBS modeling - NURBS Surfaces are defined by Spline curves, which are influenced by weighted control points. The curve follows (but does not necessarily interpolate) the points. Increasing the weight for a point will pull the curve closer to that point. NURBS are truly smooth surfaces, not approximations using small flat surfaces, and so are particularly suitable for organic modelling. Maya is the most well-known commercial software that uses NURBS natively. Splines&Patches modeling - Like NURBS, Splines and Patches depend on curved lines to define the visible surface. Patches fall somewhere between NURBS and polygons in terms of flexibility and ease of use. The modeling stage consists of shaping individual objects that are later used in the scene.

There are a number of modeling techniques, including:

- Constructive solid geometry
- Implicit surfaces
- Subdivision surfaces

Modeling can be performed by means of a dedicated program (e.g., Maya, 3DS Max, Blender, Lightwave, Modo) or an application component (Shaper, Lofter in 3DS Max) or some scene description language (as in POV-Ray). In some cases, there is no strict distinction between these phases; in such cases modelling is just part of the scene creation process (this is the case, for example, with Caligari trueSpace and Realsoft 3D). Complex materials such as blowing sand, clouds, and liquid sprays are modeled with particle systems, and are a mass of 3D coordinates which have either points, polygons, texture splats, or sprites assign to them.

4. **Scene setup**

Scene setup involves arranging virtual objects, lights, cameras and other entities on a scene which will later be used to produce a still image or an animation. Lighting is an important aspect of scene setup. As is the case in real-world scene arrangement, lighting is a significant contributing factor to the resulting aesthetic and visual quality of the finished work. As such, it can be a difficult art to master. Lighting effects can contribute greatly to the mood and emotional response effected by a scene, a fact which is well-known to photographers and theatrical lighting technicians. It is usually desirable to add color to a model's surface in a user controlled way prior to rendering. Most 3D modeling software allows the user to color the model's vertices, and that color is then interpolated across the model's surface during rendering. This is often how models are colored by the modeling software while the model is being created. The most common method of adding color information to a 3D model is by applying a 2D texture image to the model's surface through a process called texture mapping. Texture images are no different than any other digital image, but during the texture mapping process, special pieces of information (called texture coordinates or UV coordinates) are added to the model that indicate which parts of the texture image map to which parts of the 3D model's surface. Textures allow 3D models to look significantly more detailed and realistic than they would otherwise. Other effects, beyond texturing and lighting, can be done to 3D models to add to their realism. For example, the surface normals can be tweaked to affect how they are lit, certain surfaces can have bump mapping applied and any other number of 3D rendering tricks can be applied.

3D models are often animated for some uses. They can sometimes be animated from within the 3D modeler that created them or else exported to another program. If used for animation, this phase usually makes use of a technique called "keyframing", which facilitates creation of complicated movement in the scene. With the aid of keyframing, one needs only to choose where an object stops or changes its direction of movement, rotation, or scale, between which states in every frame are interpolated. These moments of change are known as keyframes. Often extra data is added to the model to make it easier to animate. For example, some 3D models of humans and animals have entire bone systems so they will look realistic when they move and can be manipulated via joints and bones, in a process known as skeletal animation.

5. **Compared to 2D methods**

   3D Photorealistic effects are often achieved without wireframe modeling and are sometimes indistinguishable in the final form. Some graphic art software includes filters that can be applied to 2D vector graphics or 2D raster graphics on transparent layers. Advantages of wireframe 3D modeling over exclusively 2D methods include:

- Flexibility, ability to change angles or animate images with quicker rendering of the changes;
- Ease of rendering, automatic calculation and rendering photorealistic effects rather than mentally visualizing or estimating
- Accurate photorealism, less chance of human error in misplacing, overdoing, or forgetting to include a visual effect

Disadvantages compare to 2D photorealistic rendering may include a software learning curve and difficulty achieving certain hyperrealistic effects. Some hyperrealistic effects may be achieved with special rendering filters included in the 3D modeling software. For the best of both worlds, some artists use a combination of 3D modeling followed by editing the 2D computer-rendered images from the 3D model.

6. **3D model market**

   There is a large and thriving market for 3D models (as well as 3D-related content, such as textures, scripts, etc.), either as individual models or large collections. Online marketplaces for 3D content allow individual artists to sell content that they have created. Often, the artists' goal is to get additional value out of assets they have previously created for projects. By doing so, artists can earn more money out of their old content, and companies can save money by buying pre-made models instead of paying an employee to create one from scratch. These marketplaces typically split the sale between themselves and the artist that created the asset, often in a roughly 50-50 split. In most cases, the artist retains ownership of the 3d model; the customer only buys the right to use and present the model. Collections of hundreds to thousands of 3D models on CD, often royalty free, are for sale. These models include different types of people, animals, objects, plants, rocks, tools, furniture, buildings, landscapes, historical objects, cartoon characters, monsters, science fiction objects, medieval fantasy objects, etc. A person who buys such a CD can import these posable ready-made models into their computer animation program.

- In Section 5 of this course you will cover these topics:

Surface Modeling: Blocks And 3-D Orbit

Using Model Space, Paper Space, Layouts, And Sheet Sets To Create, Document, And Present 2-D And 3-D Shapes

3-D Solid Modeling: Solids, Regions, And 3d Models From The Design Center Online

3-D Solid Modeling Exercises, Including Rendering And Publishing To The Web

Topic Objective:

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- Define the term AutoCAD
- Describe the AutoCAD 2005 Program
- Highlight the importance of The AutoCAD 2005 Program

Definition/Overview:

Freeform surface modeling: Freeform surface modelling is the art of engineering Freeform Surfaces with a CAD or CAID system.

Key Points:

1. **Surface Modeling**
   The technology encompasses two main fields. Either creating aesthetic (Class A surfaces) that also perform a function; for example, car bodies and consumer product outer forms, or technical surfaces for components such as gas turbine blades and other fluid dynamic engineering components. CAD software packages use two basic methods for the creation of surfaces. The first begins with construction curves (splines) from which the 3D surface is then swept (section along guide rail) or meshed (lofted) through. The second method is direct creation of the surface with manipulation of the surface poles/control points. From these initially created surfaces, other surfaces are constructed using either derived methods such as offset or angled extensions from surfaces; or via bridging and blending between groups of surfaces.

2. **Surfaces**

   Freeform surface, or freeform surfacing, is used in CAD and other computer graphics software to describe the skin of a 3D geometric element. Freeform surfaces do not have rigid radial dimensions, unlike regular surfaces such as planes, cylinders and conic surfaces. They are used to describe forms such as turbine blades, car bodies and boat hulls. Initially developed for the automotive and aerospace industries, freeform surfacing is now widely used in all engineering design disciplines from consumer goods products to ships. Most systems today use nonuniform rational B-spline (NURBS) mathematics to describe the surface forms; however, there are other methods such as Gorden surfaces or Coon surfaces. The forms of freeform surfaces (and curves) are not stored or defined in CAD software in terms of polynomial equations, but by their poles, degree, and number of patches (segments with spline curves). The degree of a surface determines its mathematical properties, and can be seen as representing the shape by a polynomial with variables to the power of the degree value. For example, a surface with a degree of 1 would be a flat cross section surface. A surface with degree 2 would be curved in one direction, while a degree 3 surface could (but does not necessarily) change once from concave to convex curvature. Some CAD systems use the term order instead of degree. The order of a polynomial is one greater than the degree, and gives the number of coefficients rather than the greatest exponent.

   The poles (sometimes known as control points) of a surface define its shape. The natural surface edges are defined by the positions of the first and last poles. (Note that a surface can have trimmed boundaries.) The intermediate poles act like magnets drawing the surface in their direction. The surface does not, however, go through these points. The second and third poles as well as defining shape, respectively determine the start and tangent angles and the curvature. In a single patch surface (Bzier surface), there is one more pole than the degree values of the surface. Surface patches can be merged into a single NURBS surface; at these points are knot lines. The number of knots will determine the influence of the poles on either side and how smooth the transition is. The smoothness between patches, known as continuity, is often referred to in terms of a C value:

- **C0**: just touching, could have a nick

- **C1**: tangent, but could have sudden change in curvature
- **C2**: the patches are curvature continuous to one another

Two more important aspects are the U and V parameters. These are values on the surface ranging from 0 to 1, used in the mathematical definition of the surface and for defining paths on the surface: for example, a trimmed boundary edge. Note that they are not proportionally spaced along the surface. A curve of constant U or constant V is known as an isoperimetric curve, or U (V) line. In CAD systems, surfaces are often displayed with their poles of constant U or constant V values connected together by lines; these are known as control polygons.

3. **Modelling**

When defining a form, an important factor is the continuity between surfaces - how smoothly they connect to one another. One example of where surfacing excels is automotive body panels. Just blending two curved areas of the panel with different radii of curvature together, maintaining tangential continuity (meaning that the blended surface doesn't change direction suddenly, but smoothly) won't be enough. They need to have a continuous rate of curvature change between the two sections, or else their reflections will appear disconnected.

The continuity is defined using the terms

- **G0** position (touching)
- **G1** tangent (angle)
- **G2** curvature (radius)
- **G3** acceleration (rate of change of curvature)

To achieve a high quality NURBS or Bezier surface, degrees of 5 or greater are generally used. Depending on the product and production process, different levels of accuracy are used but tolerances usually range from 0.02 mm to .001 mm (for example, in the fairing of BIW concept surfaces to production surface). For ship building, this need not be so tight, but for precision gears and medical devices it is much finer.

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Definition/Overview:

Model Space: HSL and HSV are two related representations of points in an RGB color space, which attempt to describe perceptual color relationships more accurately than RGB, while remaining computationally simple.

Key Points:

1. **Model Space**
   HSL stands for hue, saturation, lightness, while HSV stands for hue, saturation, value. HSI and HSB are alternative names for these concepts, using intensity and brightness; their definitions are less standardized, but they are typically interpreted as synonymous with HSL. Both HSL and HSV describe colors as points in a cylinder whose central axis ranges from

black at the bottom to white at the top with neutral colors between them, where angle around the axis corresponds to hue, distance from the axis corresponds to saturation, and distance along the axis corresponds to lightness, value, or brightness.

The two representations are similar in purpose, but differ somewhat in approach. Both are mathematically cylindrical, but while HSV (hue, saturation, value) can be thought of conceptually as an inverted cone of colors (with a black point at the bottom, and fully-saturated colors around a circle at the top), HSL conceptually represents a double-cone or sphere (with white at the top, black at the bottom, and the fully-saturated colors around the edge of a horizontal cross-section with middle gray at its center). Note that while hue in HSL and HSV refers to the same attribute, their definitions of saturation differ dramatically. Because HSL and HSV are simple transformations of device-dependent RGB, the color defined by a (h, s, l) or (h, s, v) triplet depends on the particular color of red, green, and blue primaries used. Each unique RGB device therefore has unique HSL and HSV spaces to accompany it. An (h, s, l) or (h, s, v) triplet can however become definite when it is tied to a particular RGB color space, such as sRGB. Both models were first formally described in 1978 by Alvy Ray Smith, though the concept of describing colors by these three dimensions, or equivalents such as hue, chroma, and tint, was introduced much earlier.

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Definition/Overview:

Solid Modeling: Solid modeling (or modelling) is the unambiguous representation of the solid parts of an object, that is, models of solid objects suitable for computer processing. Other modeling methods include surface models (used extensively in automotive and consumer product design as well as entertainment animation) and wire frame models (which can be ambiguous about solid volume). Primary uses of solid modeling are for CAD, engineering analysis, computer graphics and animation, rapid prototyping, medical testing, product visualization and visualization of scientific research. There are several ways by which a solid model may be constructed, usually from simpler objects (such as surfaces, lines, and/or points).

Key Points:

1. **Practical applications**

   1.1. **Parametric Solid modeling CAD**

   Solid modelers have become commonplace in engineering departments in the last ten years due to faster PCs and competitive software pricing. They are the workhorse of machine designers. Solid modeling software creates a virtual 3D representation of components for machine design and analysis. Interface with the human operator is highly optimized and includes programmable macros, keyboard shortcuts and dynamic model manipulation. The ability to dynamically re-orient the model, in real-time shaded 3-D, is emphasized and helps the designer maintain a mental 3-D image. Design work on components is usually done within context of the whole product using assembly modeling methods.

A solid model generally consists of a group of features, added one at a time, until the model is complete. Engineering solid models are built mostly with sketcher-based features; 2-D sketches that are swept along a path to become 3-D. These may be cuts, or extrusions for example. Another type of modeling technique is 'surfacing' (Freeform surface modeling). Here, surfaces are defined, trimmed and merged, and filled to make solid. The surfaces are usually defined with datum curves in space and a variety of complex commands. Surfacing is more difficult, but better applicable to some manufacturing techniques, like injection molding. Solid models for injection molded parts usually have both surfacing and sketcher based features.

Engineering drawings are created semi-automatically and reference the solid models. The learning curve for these software packages is steep, but a fluent machine designer who can master these software packages is highly productive. The modeling of solids is only the minimum requirement of a CAD systems capabilities. Parametric modeling uses parameters to define a model (dimensions, for example). The parameter may be modified later, and the model will update to reflect the modification. Typically, there is a relationship between parts, assemblies, and drawings. A part consists of multiple features, and an assembly consists of multiple parts. Drawings can be made from either parts or assemblies.

2. **Entertainment**
   Animation of computer generated characters is, technically, an example of parametric modeling, though few in the industry would consider it to be. Characters' skin is modelled with NURBS patches and stitched together or polygon modelled. The skin of characters is then parametrically associated to a skeleton within characters (with many characters' skins now being driven by muscle simulation systems). The skeleton of a character is rotated into poses, which parametrically drives the shape of the characters' skin for each frame to create animation.

3. **Medical solid modeling**

Modern computed axial tomography and magnetic resonance imaging scanners can be used to create solid models of internal body features. Optical 3D scanners can be used to create point clouds or polygon mesh models of external body features.

For example, A shaft is created by extruding a circle 100 mm. A hub is assembled to the end of the shaft. Later, the shaft is modified to be 200 mm long (click on the shaft, select the length dimension, modify to 200). When the model is updated the shaft will be 200 mm long, the hub will relocate to the end of the shaft to which it was assembled, and the engineering drawings and mass properties will reflect all changes automatically.

Examples of parameters are: dimensions used to create model features, material density, formulas to describe swept features, imported data (that describe a reference surface, for example). Related to parameters, but slightly different are Constraints. Constraints are relationships between entities that make up a particular shape. For a window, the sides might be defined as being parallel, and of the same length. Parametric modeling is obvious and intuitive. But for the first three decades of CAD this was not the case. Modification meant re-draw, or add a new cut or protrusion on top of old ones. Dimensions on engineering drawings were created, instead of shown

Parametric modeling is very powerful, but requires more skill in model creation. A complicated model for an injection molded part may have a thousand features, and modifying an early feature may cause later features to fail. Skillfully created parametric models are easier to maintain and modify. Parametric modeling also lends itself to data re-use. A whole family of capscrews can be contained in one model, for example.

Basic Theoretical Concepts of Solid Modeling

- Sweeping
  - An area feature is "swept out" by moving a primitive along a path to form a solid feature. These volumes either add to the object ("extrusion") or remove material ("cutter path").
  - Also known as 'sketch based modeling'.
  - Analogous to various manufacturing techniques such as extrusion, milling, lathe and others.
- Boundary representation (BRep)
  - A solid object is represented by boundary surfaces and then filled to make solid.
  - Also knowing as 'surfacing'.
  - Analogous to various manufacturing techniques; Injection moulding, casting, forging, thermoforming, etc.
- Parameterized primitive instancing.
  - An object is specified by reference to a library of parameterized primitives.
  - For example, a bolt is modeled for a library, this model is used for all bolt sizes by modifying a set of its parameters.

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Key Points:

1. **History**
   Solid modeling has to be seen in context of the whole history of CAD, the key milestones being the development of Romulus which went on to influence the development of Parasolid and ACIS and thus the mid-range Windows based feature modelers such as IronCAD, Alibre Design, SolidWorks, and Solid Edge and the arrival of parametric solid models system like T-FLEX CAD and Pro/ENGINEER.

2. **Solid Modeling & Transformations**
   Three Stages In The Development of The Solid Model

- First, build a 3D wireframe model that may consist of lines, arcs, circles or any other graphic primitives that may serve as the basis for generating the solids. Use the Accudraw Construction System in order to facilitate the 3D construction of your wireframe model as described in the Microstation User's Guide.

- Second, use the wireframe as a basis for creating primitive solid elements, such as projected solid walls and similar architectural elements. Or, using the wireframe modeling as a geometrical point of reference only, create more directly solid model primitives such as spheres, boxes, and cones.
- Third, apply *Boolean* commands to the primitive solids so as to develop more refined 3D shapes.

The following three figures show a development of Mies van der Rohe's German Pavilion on the computer. Figures 1 and 2 are of the plan and elevation as you might have produced them in exercise 2. Note that different architectural elements are grouped together by color/layer so as to make the drawings more readable. Figure 3 describes a "wireframe" rendering of the the projected solid geometry of the German Pavilion in three dimensions. Figure 4 describes a simple shaded image of the solid elements, such as the "solids of projection" discussed in the Microstation User's Guide.

Considering Geometrical Order in Your Approach

As you had done in exercise 2, re-examine the work of architecture or design in terms of its geometrical elements and order. For example, take note of what symmetries may be evident. It may be possible to use mirror, rotate, and copy operations within the CAD system to revisit these symmetries within your three dimensional model. Attempt to understand your project as a composition of abstract geometrical forms and consider how you might approach the modeling process as one of a sequenced ordered assembly. That is make note of what symmetries may be present as a basis for move, copy, mirror, rotate and scale operations. Use layers as a way to further give organizational clarity to geometrical elements. You may optionally choose to explore the application of "cells" (also referred to as instantiated figures) to deal efficiently with repetitive components which vary only in scale.

In order to get a feeling for how to schematically view the geometrical organization of a work of design, you may wish to browse through the *Precedents in Architecture* textbook by Roger H.

Clark and Michael Pause as cited in the lecture with respect to exercise 1. The textbook is perhaps a bit oversimplified in its descriptions of some buildings. However, it develops an interesting system of analysis in taking on some geometrical organizing principles such as "Plan to Section", "Massing", "Unit to Whole", "Repetitive to Unique", "Geometry", and "Symmetry", suggests approaches to viewing a work of design schematically that may be used as the basis for a modeling exercise.