CPS 711
Course Notes

98/99

Jan 18, 1999

Design Process

Graphics and descriptive geometry provide methods of solving technical problems.

Most design problems fall into two categories 1) System Design
2) Product Design

System Design

Arrangements of available products and components with unique combination that yield the desired results.

Example:

Computer Network ------service
-gateway/routers
-communications equipment
-Protocols

Residential Building-----Heating/cooling
-Plumbing
-Electrical System

Product Design

Concerned with design, testing, manufacturing and sale of an item that will be mass produced.
E.g. computer, toy,etc.

PRODUCT DESIGN

1) Market Needs
2) Function
3) Production
4) Distribution
5) Sale
6) Profit

DESIGN PROCESS

1) Identify Needs
2) Ideate (Brainstorm) with user input
3) Refine
4) Analysis -build prototype
5) Decide -if good or bad
6) Implement

Recycle as needed

<u>Components of CAD</u>

Made up of a collection of procedures and sub routines to provide a range of functions.

Libraries for:

1) Numerical Methods
2) Graphics Interface
3) Geometry
4) Interface Package
5) Database Manager
6) Data Structures toolbox

1) Numerical Methods Lib.
   - function manipulation
   - Interpolation, extrapolation, integration
   - Differentiation, least squares, root finding, spline fitting, etc.
   - Matrix Manipulation
     - Multiplication, Decomposition, Eigen value, extraction
     - Optimization Algorithms

2) Graphics Interface Lib
   - Provide visualization capability for the geometric Information

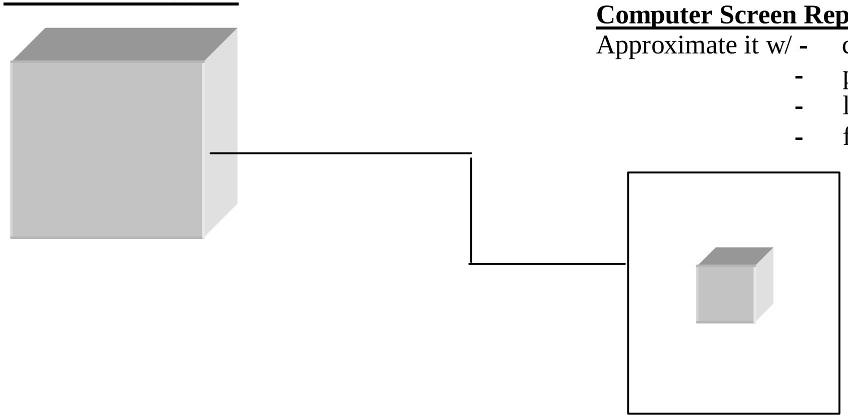
3) Geometry
   - geometry manager creates and manipulates data structures that contain geometric information
   - Geometry Library
     - Supports: Points, Lines, Surfaces, Solid, and volume
   - Geometry Package allows developer to create specific instances of geometric elements and search data for explicit information (Coordinates) and implicit information (Distance between entities, intersections, etc.)
   - Geometry Interface combined with an appropriate interface forms a complete application.

Jan 25, 1999

Knowledge Representation

1) First order predicate Calculus, logical representation of problem
    - Draw inferences given some statements
    - Allow you to prune a tree composed of various states
    - Database search → brute force technique
    - Intelligent search →using logic or "Logical search"
        - Data gets modified
        - Rule based search engine
    - Visual Representation of Knowledge
        - Object Modeling

Nature - Real World



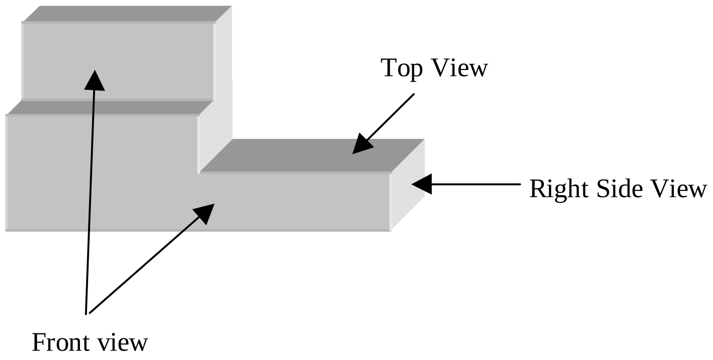
Computer Screen Representation

Approximate it w/
- circles
- points
- lines
- fractals

Object: Nature (Note: does not have smooth edges, has texture and colour)

Problems
- Real object is 3D
- Model is 2D, displayed on screen
- Representation of object is not exact

1. **Orthographic Projection:**
   - views of object are projected perpendicularly onto projection planes w/ parallel projections



- Top view is projected onto a horizontal plain (H)
- Right Side view is projected onto a vertical Profile plain (P) perpendicular to the horizontal plain
- Front view uses the frontal plain (F)

Top View	Front View
Side View	

a) Three views completely define a 3D Model
b) Used in manufacturing
c) Drawn to scale
   - Eg. Buildings, Towers, houses, etc.

Advantages:
- This type of modeling is cheep and does not require a great deal of computer power

Disadvantages:
- Cannot perform advanced analysis
- Cannot perform volume analysis
- Cannot perform balance analysis
- Cannot perform surface analysis
- Cannot rotate it
- It's subjective to interpretation

2. **Wire Mesh Models - to scale**
   - Surfaces join together, not a solid

Advantages:

- You can perform
  - Surface analysis
  - Volume analysis
  - Rotation

Disadvantages:

- Not a solid
- No boolean operations possible
- Cannot fit one object into another
- No analysis of gravity
- No light sources manipulation

3. **3D Solids - to scale**

Advantages:

- can do everything listed above
- even translucent objects

Disadvantages:

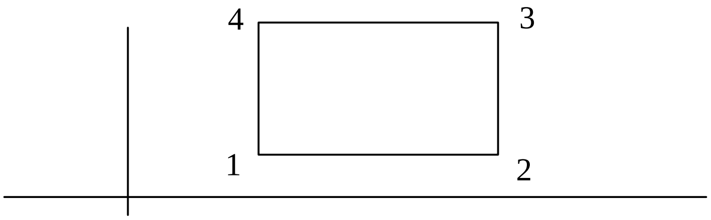
- File sizes get very large
- CPU and memory are maxed out

4. **Perspective -not drawn to scale**
   - Artist's sketch
   - Useful for visualization
   - No possible analysis can be performed

DATA STRUCTURES AND TRANSFORMATIONS Feb 1, 1999

Use of Nodes:
In cartesian geometry, lines and curves are considered as a collection of points. They are related by some equation. Considered to consist of infinite number of points. However, can be uniquely defined by few points.

a) Nodes:
   - Nodes are generally stored as coordinates



Node #	X-Coordinate	Y-Coordinate
1	1.0	1.0
2	5.0	1.0
3	5.0	4.0
4	1.0	4.0

Edge list: how nodes are connected

Node #	First Node	Second Node
1	1	2
2	2	3
3	3	4
4	4	1

- Can add extra edges to the shape by adding it to the edge list.
- To add a diagonal enter into the edge list and entry to join 1 & 3
- Nodes list holds Geometric Data
- Edge list holds Topological Info

Transformation of Nodes

- By changing the coordinates of the nodes, different shapes can be obtained (Rectangle, Parallelogram, etc.)

Three Types of Transformations:

1. Translation
2. Rotation
3. Scaling

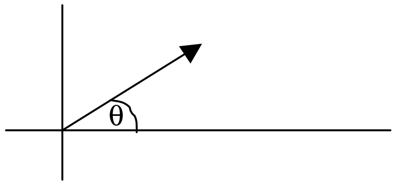
1. Translation; of a point in a plane is a movement of it in x and y direction
   Example:

$X := X+a$

$Y := Y+b$

$X = r\cos(\theta)$

$Y := r\sin(\theta)$



Use anticlockwise angle ϕ of rotation about the origin, the new coordinates are:
$r\cos(\theta+\phi)$ and $r\sin(\theta+\phi)$

2. Rotation; by expand sine and cosine:

-
Rotation can be expressed as:

$$\begin{aligned} X &:= x\cos(\phi) - y\sin(\phi) \\ Y &:= y\sin(\phi) + x\cos(\phi) \end{aligned} \quad \Big\|$$

2. Scaling:
   - Manipulation of the x and y coordinate by suitable factors

$$\begin{aligned} x &:= SxX \\ y &:= SyY \end{aligned} \quad \Big\|$$

- Expressed as a column vector:

$$\begin{pmatrix} X \\ \\ Y \end{pmatrix} \qquad \begin{pmatrix} \cos(\phi) & -\sin(\phi) \\ :\,= & \\ \text{Sin}(\phi) & \cos(\phi) \end{pmatrix} \begin{pmatrix} X \\ \\ Y \end{pmatrix}$$

- scaling can be written as:

$$\begin{pmatrix} X \\ Y \end{pmatrix} :\,= \begin{pmatrix} S_x & 0 \\ 0 & S_y \end{pmatrix} \begin{pmatrix} X \\ Y \end{pmatrix}$$

- This will produce a doubling of length in the x-direction and a rotation of 60^0;

- Effect of scaling followed by a rotation on (5,1) is:

Apply this transformation to all the nodes and maintaining the same edge list produces:

Matrix Transformations **Feb 8, 1999**

Geometry of Rotation and 2D - Images

Fundamentals of Digital Images

- Film images are represented by continuous analog wave forms
- A digital image is represented by digital values derived from sampling the analog image.
- Analog values are continuous; digital values are discrete

- Computer stores image data in a couple of different ways:
    - Vector graphing
    - Roster graphics

- an image does not return any of the structure of the original picture
- Consists of elements (lines, circles, etc)
- When viewed by a human, a human conveys information to the conscience mind via eye/brain system
- Simulation of real world model
- Images can be monchrom

  or
- while elements on black background

  or
- black elements on white background
- subtlety in the range of intensity can be obtained by shading
- shades of gray obtained by grouping black dots on white background with varying intensity
- used in newsprint

<u>Vector Graphics (O-O design)</u>

- Images generated by using straight lines or dots (degenerated lines)
- Images are stored as a display list describing the location and property of the object making up the image, such as shapes, arches and lines
- Vector refresh display devices:
    - Instruction to "Pen" about how the image is to be drawn.

Example: move to (X1, Y1, draw a line (X2,Y2) etc.

- pen plotters receive a "Pen down" instruction followed by a write line" instruction "Pen" could be an electron beam that writes on a display screen

<u>Raster Graphics (Bitmap Graphics)</u>

- Created by scanner and digital cameras
- Raster images are "painted" across the computer screen in an array of square elements called pixels. (Picture elements)
- Each pixel stored in an array of memory (bit map)
- Storage requirements for vector graphics is for less than raster graphics
- Quality of raster image is determined by
    - spatial resolution
    - Brightness
    - Resolution

- Pixel size = f(rate at which scanner samples image)
- Long sampling intervals produces an image of low spatialization
- Shorter sampling intervals produces high resolution
- Simulate gray by grouping black and white pixels called dithering of half-tone
- 8 – bit
- For an image containing 256 colours, use 8-bits. (8bits=256 possible colours in decimal)
- In 24 bit images, each pixel is described by 8-bit sets of number representing the brightness values for red, green and blue (8 for red, 8 for green and 8 for blue)
- Each pixel has one of 256 brightness values for green, red and blue

<u>Encoding</u>

Analog to digital encoding

- encoding data into signals to send them from one place to another

- Information is of two types: digital or analog
- Signals can be of two types: digital of analog

1. Digital to Digital Encoding

- Binary values → voltage
- Data from computer to printer
- Binary 1's and 0's are transmitted into a sequence of voltage pulses

0100110 Encoding

<u>Unipolar Encoding</u>

- not used
- only one of two states is represented

<u>Program Files</u>

Creating objects using stdin (kb, mous, etc)

Advantages:

- you can see the model as you are creating it.
- Changes are instantaneous
- Suitable for "one-of-a-kind" objects

Disadvantages:

- Time consuming
- Hard to create complex shapes:
    - Splines, helixes (high-order) etc.
    - No use of parameters

Program files: Provide one important function "repeatability"

Two types of files:

1. Marco
2. Program files

1) Marco files: a recording of a sequence of I-DEAS commands stored in an external text file created solely through I-DEAS

2) Program Files: a super set of a macro created partially within and partially outside, or created completely absent of I-DEAS. A program file may include functionality not available through the creation of macro

When a macro is created by I-DEAS one may include different levels of output including:

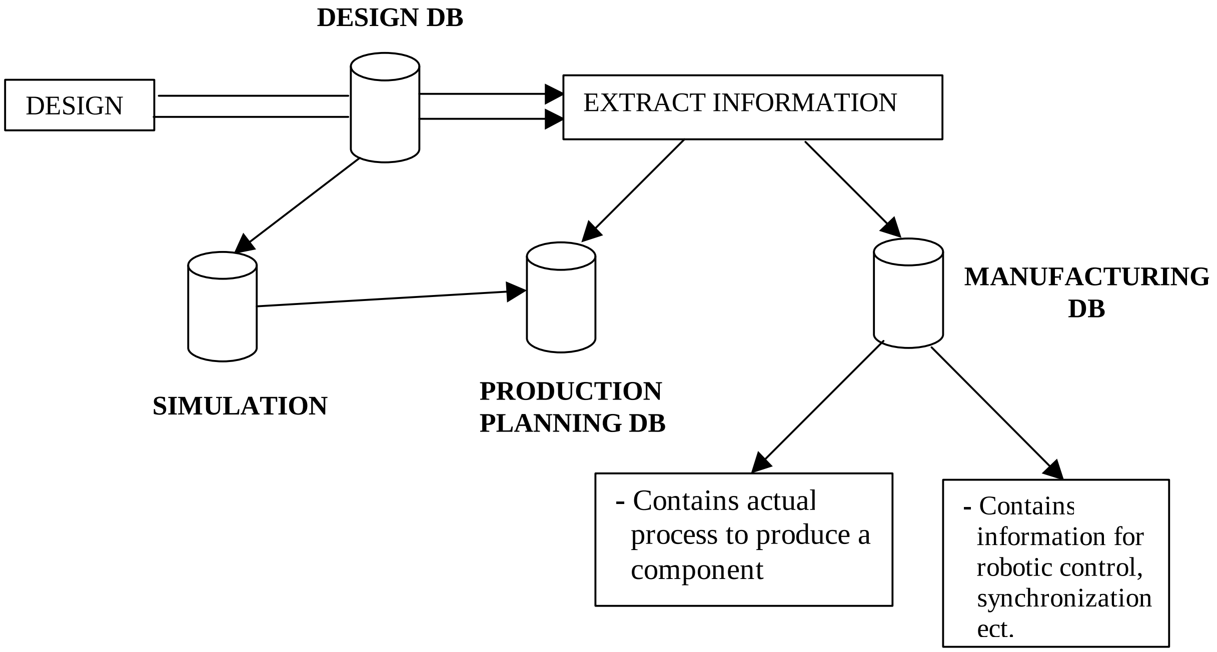
- Output of list windows
- Output of prompts
- Capture all menu displayed during macro generation

Though the output from options (especially the menu capture) can be verbose, they may be valuable assistance when later modifying the record macro.
One extension of the macro language is the ability to store and retrieve variables and use arithmetic expressions in the program files.

Character	Meaning
CL	Output to the list region
CM	Output to the menu region
CP	Output to the prompt region
K	Normal keyboard input
AP	Displays (viewing positions, context specific and application specific. Is dynamicnavegation feedback so do not edit)
BP	Initial position of screen pick Button Press
BR	Release position of screen pick Button Release
E	Logical E.O.F

Protocols for Communicating is a Manufacturing Environment March/1/1999

Only about 20% of thousands of programmable tools, instrument controls and system already installed in GM are able to communicate with one another.
-Data '97


DESIGN DB
DESIGN
EXTRACT INFORMATION
MANUFACTURING DB
SIMULATION
PRODUCTION PLANNING DB
- Contains actual process to produce a component
- Contains information for robotic control, synchronization ect.

- Custom software needed to interface these different processes
- This necessitates user unique communication methods
- Stand alone machines from a variety of suppliers and develop custom solutions as needed.
- A standard was developed for communications
    - Major players were:

        - GM
        - Hp
        - IBM
        - Digital

        Use LAN w/ OSI Model

Layer	Mac Version Protocol
7	File Transfer protocol, manufacture message with formal standard
6	ASCII & Binary Encoding
5	ISO Session 8327 Full Duplex
4	ISO Transport 8073
3	ISO Internet 8473 – connection less – connection oriented
2	ISO Logical Link 8802/3 IEEE
1	ISO Token Passing Bus – Media Access Control

How signal is carried:

Base Band: signal transmitted in original form, not changed by modulation.

Broad Band: use of multiple channels by FDM (Frequency Division Multiplexing).

Bridge: Equipment to connect segments of a single LAN.

Gateway: Equipment to connect different network architectures using different protocols by providing protocol translation.

Node: A terminal device on a network or common to two or more branches of the network.

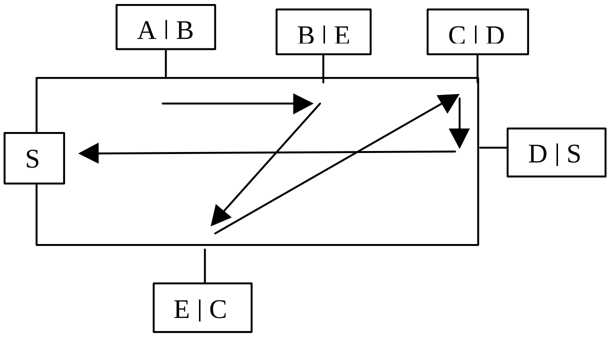
Router: Equipment similar to a bridge, commonly used to connect several networks at a common point.

Topology Most Commonly Used in Manufacturing Plant

Token – Passing control access -Token Ring
-Token Bus

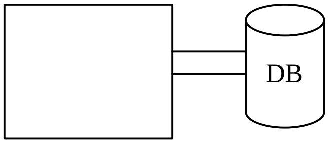
LANs
- Ethernet CSMA/CD – Non deterministic prone to collisions
- Token Ring or Token Bus - Deterministic, no collision
  - Increased overhead
- Broadcast Protocol

Token Bus used in factory manufacturing plant



- Routing table at each workstation allows you to change the order or processes control

Manufacturing Data Bases March/22/1999



Design Process - Geometric information

- Coordinates, distance between points etc.

- Representation of objects
  - Raster info - pixel display

The use of other databases is needed.

1. Production Planning Databases
2. Marketing info Databases

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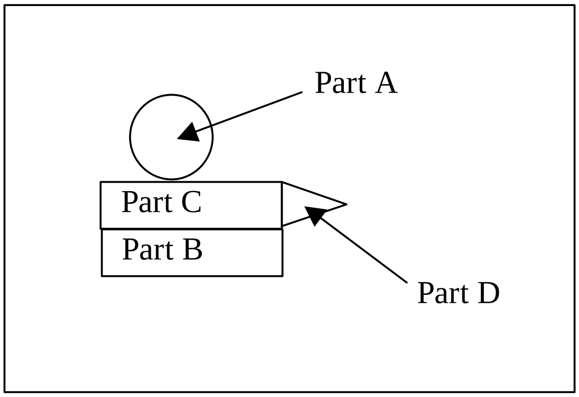
Production PlanningDB

Contains info such as:

- Delivery dates of parts for assembly process
- Origin of parts of in assembly
- Material of parts in assembly
- Cost of parts in assembly

- Enhances Geometric information is accomplished in different ways
  - By adding “attributes” to each of the parts in the assembly

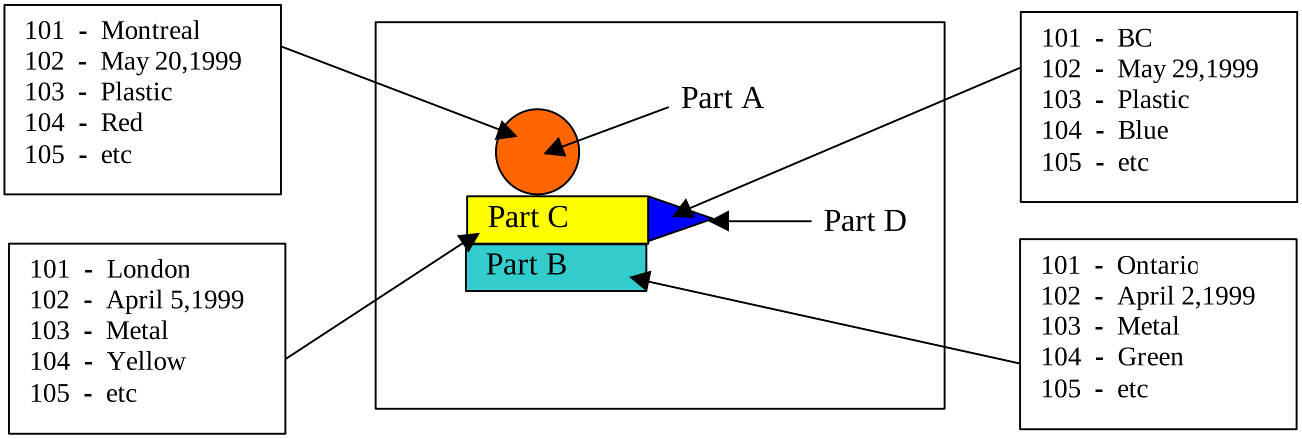
Eg.



Add Attributes to each of the parts:

Standards for Suppliers:

Standards	Description
101	Origin
102	Delivery Date
103	Type of Material
104	Colour of Material
105	etc



101 - Montreal
102 - May 20,1999
103 - Plastic
104 - Red
105 - etc

101 - London
102 - April 5,1999
103 - Metal
104 - Yellow
105 - etc

101 - BC
102 - May 29,1999
103 - Plastic
104 - Blue
105 - etc

101 - Ontario
102 - April 2,1999
103 - Metal
104 - Green
105 - etc

- Can have as many as 100 attributes per part
- Some of these attributes use similar parts technology

- **<u>Queries can be Performed</u>**
    - Visually the parts get highlighted after you request a query

- **Programs ca be written**
    - can query attributes eg. Costs, connections etc.

*****Note: I-DEAS does not support attributes*****

Ideas Interface Program

- Bill of materials (BOM)
- As each part is produced you place it in a Bin – Bin1, Bin2, Bin3 … etc.
- By placing similar parts in the same bin you get an accumulation (inc. count)

-Ideas produces a RAW BOM

Part Name	Part No	Qty
A	-optional	2
B	-optional	1
C	-optional	2

- Can be produced inside a program as well written outside I-DEAS

- there is an example in the course directory -> BOM.TXT

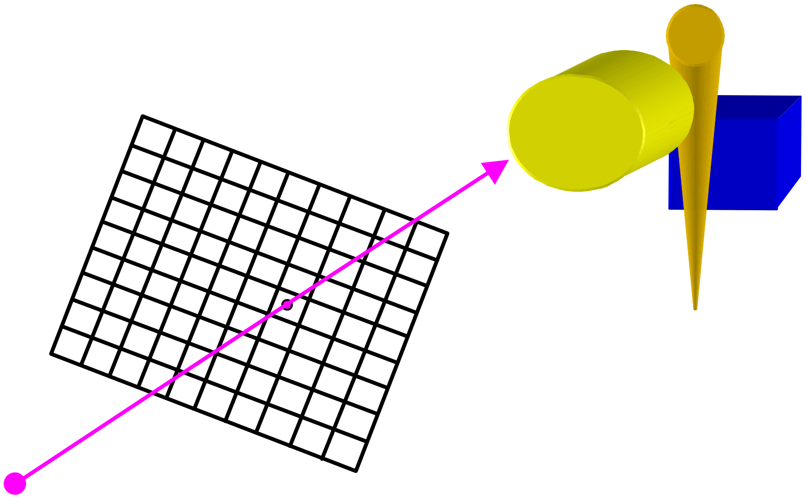
Database (Which contains this type of info)

Part Name	Part Number	Origin	Delivery Date	Colour	Cost	Qty
A	-optional	Montreal	May 20,1999	Red	100	1

When the product is manufactured the Qty for the parts used is automatically decremented.

Ray Tracing April/5/99

- Language used is "Povray"
- Ray tracing (ray casting) determines the visibility of surfaces by tracing imaginary rays of light from the viewer's eye to the objects in the scene.
- A center projection (viewers eye) and a window on a n arbitrary view plane are selected.
- Window represents a rectangular grid whose elements correspond to pixels at a desired resolution.
- For each pixel in the window, an "eye ray" is fired from the center of projection through the pixel center into the scene. Pixels colour is set to that of the object at the closest point of intersection.
- Ray Casting → visible - surface algorithm
- Ray Tracing → recursive algorithm



Psuedocode for a simple Ray Trace:

```
Select center of projection and window or view plane
    For each scan line in image do
        For each pixel in scan line do
            Begin
                Determine ray from center projection through pixel;
                For each object in scene do
                        If obj. is intersected and is closest to window then
                                Record intersection & obj. name
                                Set pixel colour to that at closest obj intersection
                        End if
                 End do
        End do
    End do
```

Computing Intersection

- determine the intersection of a ray with an object
- each point (x,y,z) along a ray from (x_o,y_o,z_o) to (z_1,y_1,z_1) is defined by some value "t" such that:

$x = x_o + t\ (x_1 - x_o)$; $y = y_o + t\ (y_1 - y_o)$; $z = z_o + t\ (z_1 - z_o)$

Let $\Delta x = (x_1 - x_0)$; $\Delta z = (z_1 - z_0)$; $\Delta z = (z_1 - z_0)$

Thus
$$x = x_0 + t\Delta x$$
$$y = y_0 + t\Delta y$$
$$z = z_0 + t\Delta z$$

Example of Sphere:

Sphere with center (a,b,c) and radius $(x-a)^2 + (y-b)^2 + (z-c)^2 = r^2$

Intersection is found by expanding the equation and substitute the value of x,y,z.

$(x-a)\ (x-a) + (y-b)\ (y-b) + (z-c)\ (z-c) = r^2$
$x^2 + 2ax + a^2 + y^2 + 2by + b^2 + z^2 + 2cz + c^2 = r^2$

know substitute in the values of x y and z from above : $x = x_0 + t\Delta x$
$y = y_0 + t\Delta y$
$z = z_0 + t\Delta z$

$$\begin{array}{cccccccccccccc} x^2 & + & 2a & x & + a^2 + & y^2 & + 2b & y & + & b^2 & + & z^2 & + 2c & z + c^2 = r^2 \\ (x_0+t\Delta x)^2 & + & 2a & (x_0+t\Delta x) & + a^2 + & (y_0+t\Delta y)^2 & + 2b & (y_0+t\Delta y) & + & b^2 & + & (z_0+t\Delta z)^2 & + 2c & (z_0+t\Delta z)+c^2 = r^2 \end{array}$$

Expand the expressions inside the brackets:

$(x_0+t\Delta x)\ (x_0+t\Delta x) + 2a(x_0+t\Delta x) + a^2 +$
$(y_0+t\Delta y)\ (y_0+t\Delta y) + 2b(y_0+t\Delta y) + b^2 +$
$(z_0+t\Delta z)\ (z_0+t\Delta z) + 2c(z_0+t\Delta z) + c^2 = r^2$

$$\downarrow$$

$(x_0{}^2 + 2x_0t\Delta x + t^2\Delta x^2) + 2a(x_0+t\Delta x) + a^2 +$
$(y_0{}^2 + 2y_0t\Delta y + t^2\Delta y^2) + 2b(y_0+t\Delta y) + b^2 +$
$(z_0{}^2 + 2z_0t\Delta z + t^2\Delta z^2) + 2c(z_0+t\Delta z) + c^2 = r^2$

substitute in your values for x_0, $y_{0,}$ $z_{0,}$ Δx, Δy, Δz, a, b ,c and then solve the Quadratic for t.

If t has no real roots then the ray does not intersect the sphere.
If t has one real root then the ray grazes the sphere.
If t has two real roots then the ray directly hit the shere.

Note: The smaller the t the closer that point is to the window/view plane.
Also, between objects, those t’s that are smaller tell you that one object is closer then another.

The End

Final examination review:

You must be able to construct an object, form first principals in IDEAS/SHELL

- create a polyline
- create a circle
- create a prg file that will do the above automatically
- translate objects to different points (be able to move object)

1 hour exam – w71 lab.