From Manual Drafting to CAD

- Electronic drafting using a Computer-Aided Drafting (CAD) system
- Computer graphics and geometric modeling
- Design modeling using an advanced CAD/CAE/CAM system
- Finite element analysis
- Engineering optimization
- Virtual (Soft) prototyping

Questions

- What are the basic CAD techniques?
  - Geometric representation and transformation
  - Solid and surface modeling
  - Parametric modeling and parameter optimization
  - Pre- and post- processors for Finite Element Analysis
  - Design and Mfg. database management
- What are the differences between a conventional 2D electronic drafting package and a full-scale CAD/CAE/CAM system?

  (Computer-Aided Design, Engineering and Manufacturing)
- What do we need to know to be a better user of the CAD system?
  - The basic CAD techniques
  - The capabilities and limitations of various CAD systems

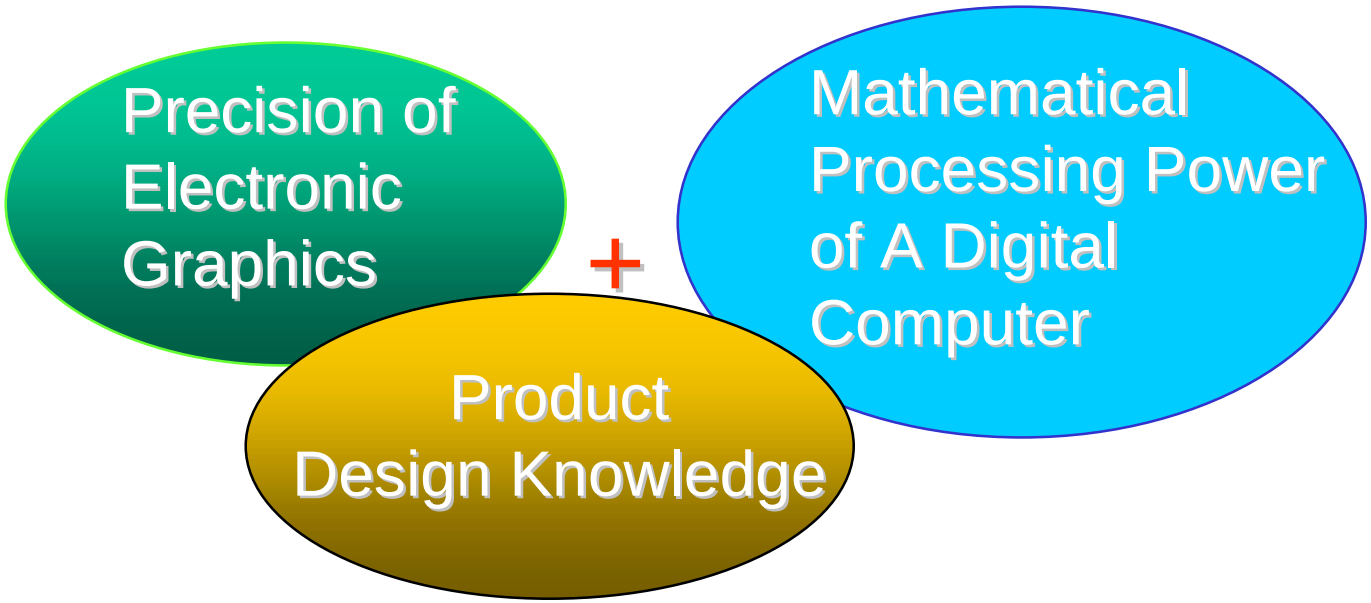
Development of CAD

- **In 1960's**
  - mechanism design satisfying several geometric constraints
  - design parameter optimization
  - simple 2-D graphics
- **In 1970's**
  - wireframe modeling
  - free-form surface modeling – *mainframe computers*
- **Late 1970's**
  - solid modeling
- **Early 1980's**
  - CAD/CAM integration
  - mechanical feature recognition from a CAD database

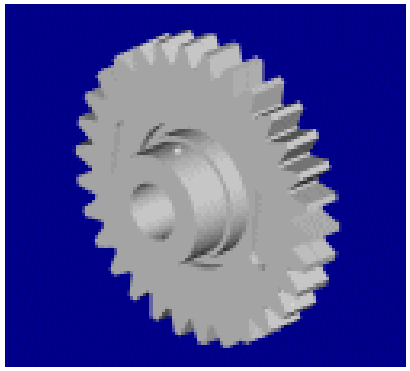
Development of CAD

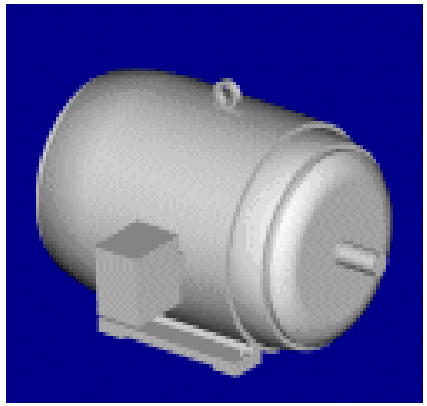
- **Middle 1980's**
  - feature-based CAD system – *mini and micro computers,*
  - parametric design – *PC's & Turnkey systems* (Pro/ENGINEER Products)
- **Late 1980's**
  - design for manufacturing
  - design for automated assembly
- **1990's**
  - concurrent engineering design
  - integrated design, analysis and optimization
  - virtual-prototyping – *workstations and high-end PCs*
- **2000's**
  - robust concurrent design optimization
  - virtual engineering & enterprise

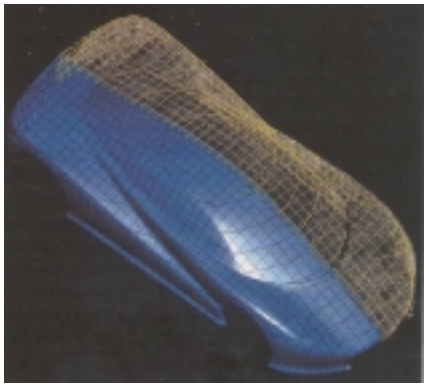
Unique Characteristics of A CAD System

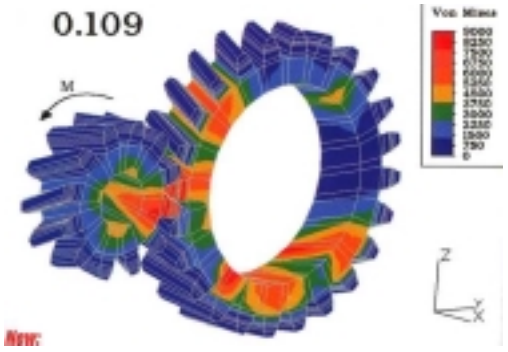


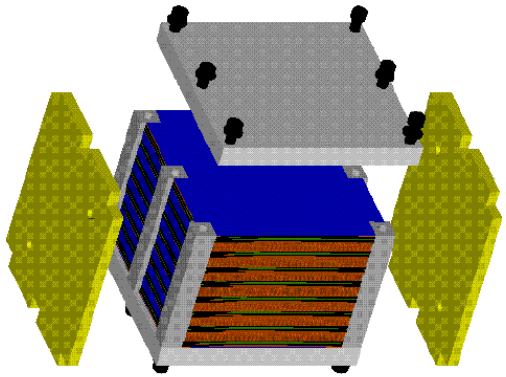
How are these models generated?

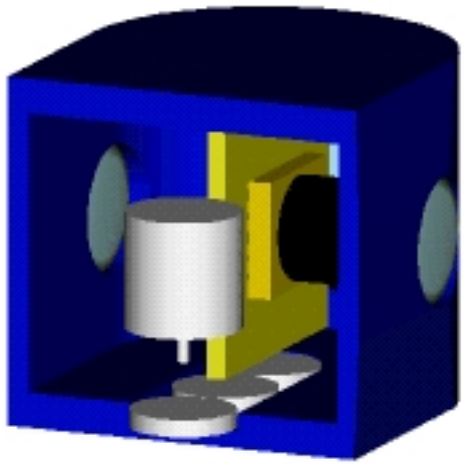












How is Geometry represented in a CAD system?

- Wireframe Model (low-level entities)

  Points and Lines

- Solid Model (middle to high-level entities)

  Points, Primitives and Boolean Operations

- Surface Model (middle-level entities)

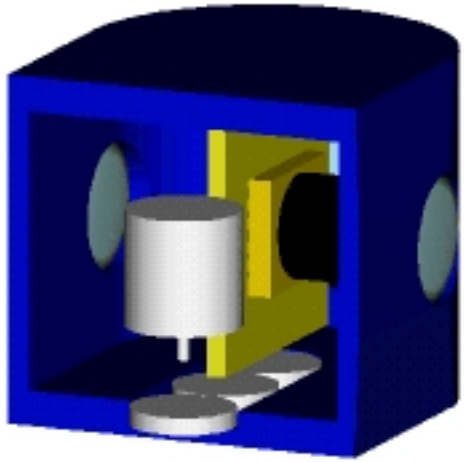
  Points, Boundary and Control Curves; Surface Patches

Representation of Low-level Geometry Entities:

- Points: A 2D point – $[x\ y]$; and A 3D point – $[x\ y\ z]$

  A vector representation of a 3D point: $\boldsymbol{p} = x\,\boldsymbol{i} + y\,\boldsymbol{j} + z\,\boldsymbol{k}$

- Lines: two points
- Planes: a collection of boundary lines
- Components: a collection of boundary planes

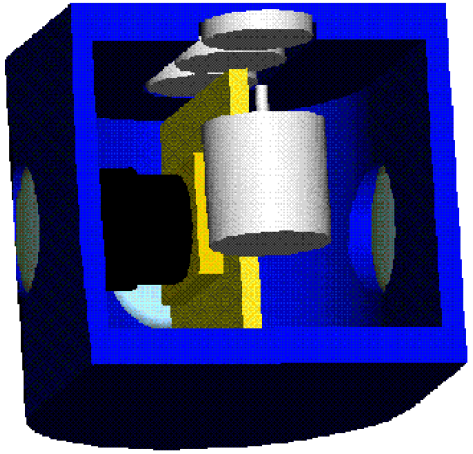


Why geometry transformation?

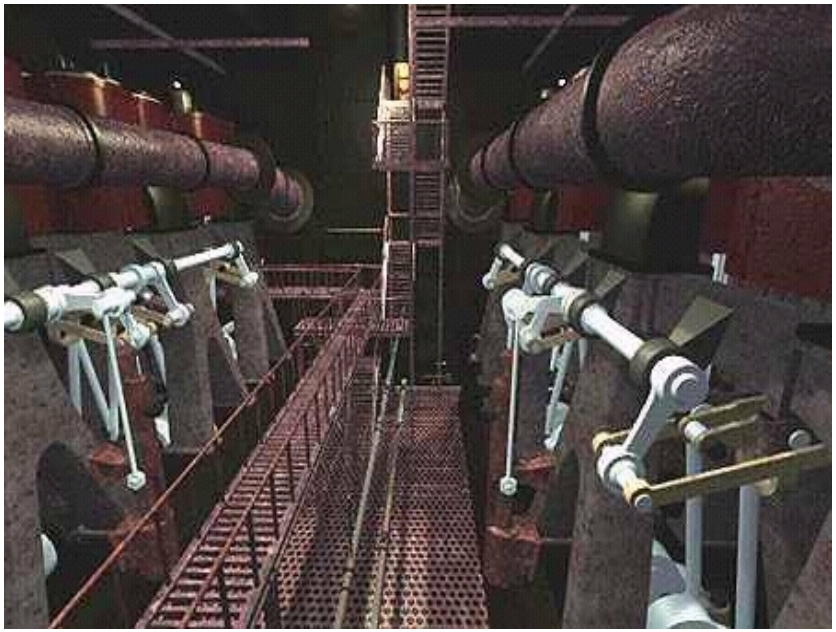
- Better understanding of the design
- Communication with customers
- Generating various outputs

Common transformations:

- Translation
- Rotation
- Scaling



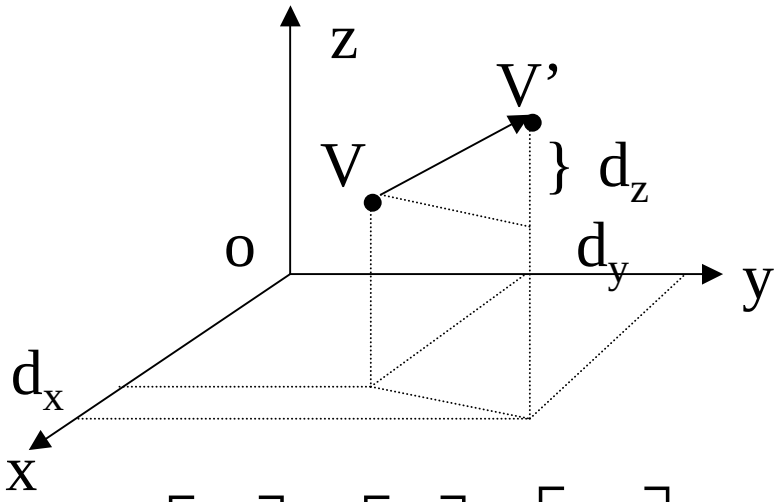
Applications of geometry transformation?



3-D Transformation

Translation

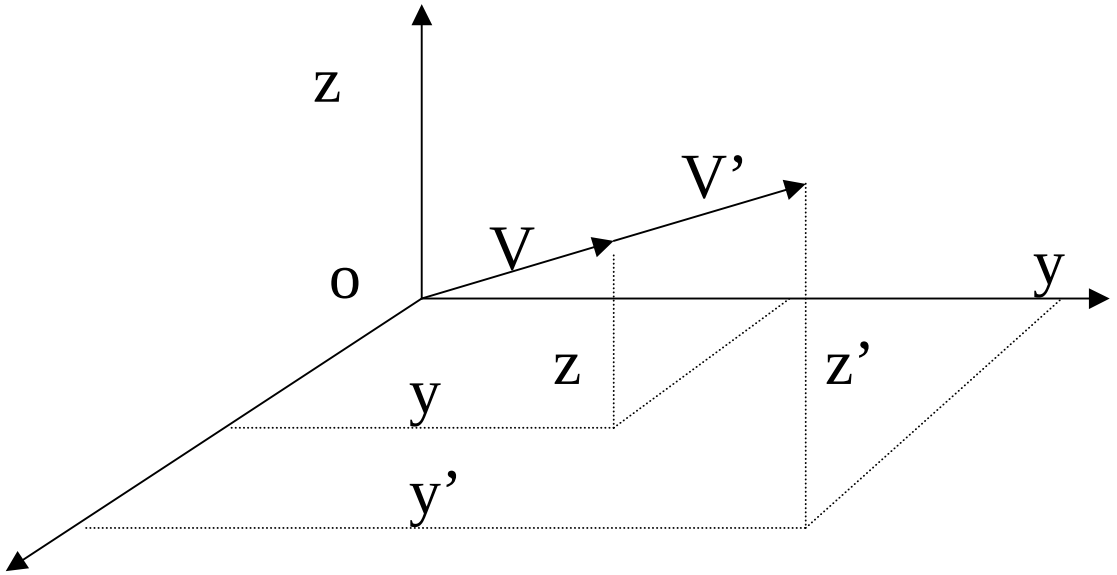
Translate point V(x, y, z) by (dx, dy, dz) to point V'(x', y', z')



$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} d_x \\ d_y \\ d_z \end{bmatrix}$$

3-D Transformation

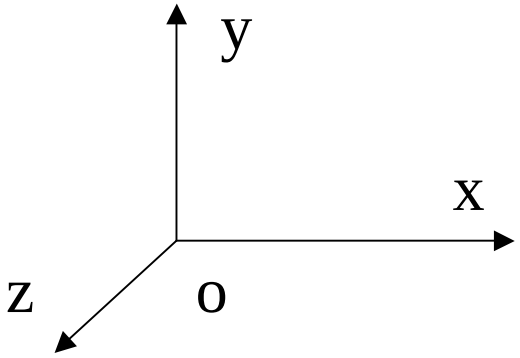
Scaling



$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} s_x & 0 & 0 \\ 0 & s_y & 0 \\ 0 & 0 & s_z \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

3-D Transformation

Rotation

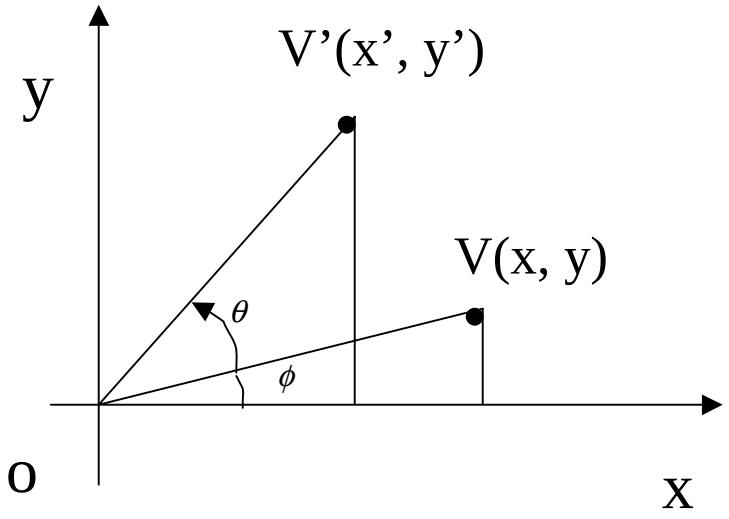


About z

$$z' = z$$

$$x' = x\cos\theta - y\sin\theta$$

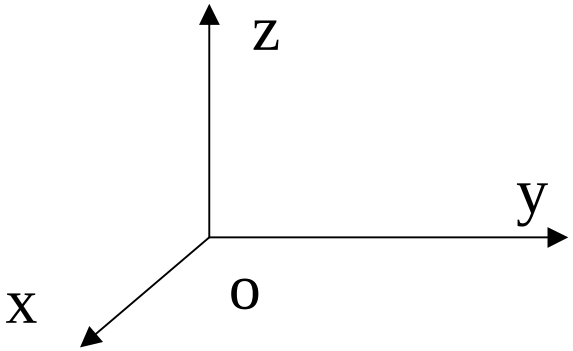
$$y' = x\sin\theta + y\cos\theta$$



$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

3-D Transformation

Rotation

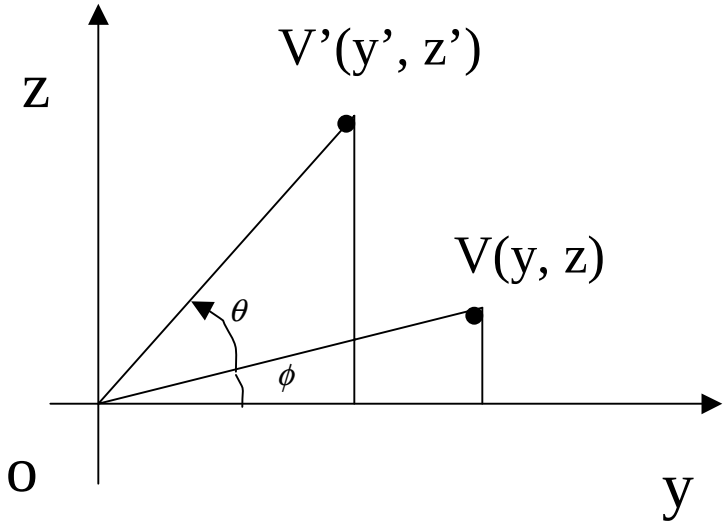


About x

$$x' = x$$

$$y' = y\cos\theta - z\sin\theta$$

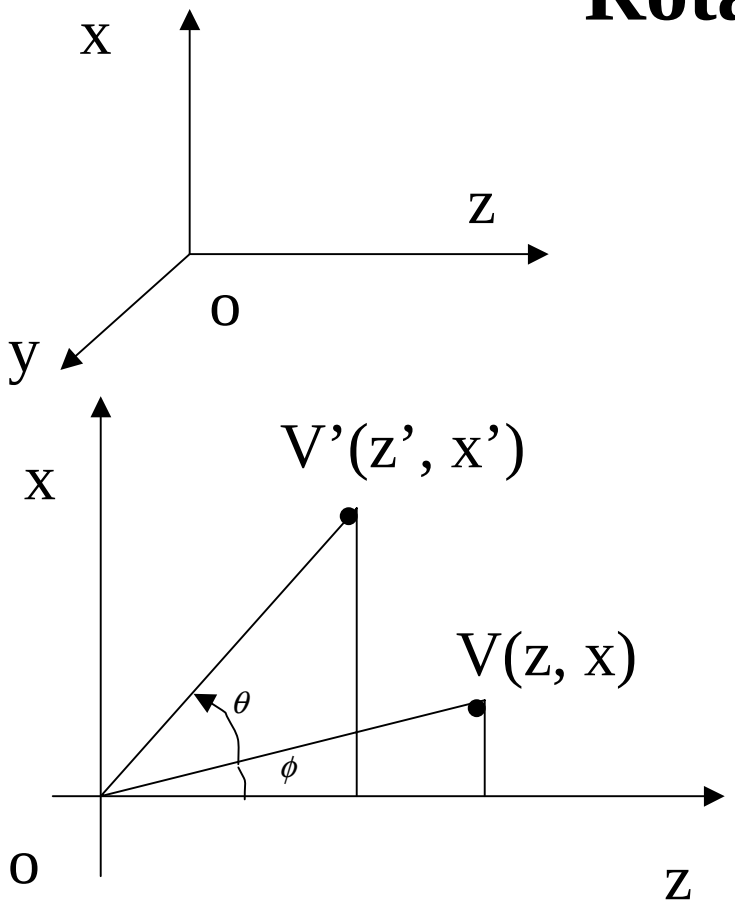
$$z' = y\sin\theta + z\cos\theta$$



$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

3-D Transformation

Rotation



About y

$$y' = y$$

$$x' = z\sin\theta + x\cos\theta$$

$$z' = z\cos\theta - x\sin\theta$$

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

Homogeneous Representation

The representation is introduced to express all geometric transformations in the from of matrix multiplication for the convenience of manipulation.

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & d_x \\ 0 & 1 & 0 & d_y \\ 0 & 0 & 1 & d_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

Dummy (n+1)th coordinate to facilitate multiplication

Homogeneous Representations

Scaling

$$[H] = \begin{bmatrix} s_x & 0 & 0 & 0 \\ 0 & s_y & 0 & 0 \\ 0 & 0 & s_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Rotation

$$[H_y] = \begin{bmatrix} \cos\theta & 0 & \sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\theta & 0 & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Composition of Transformation

$$V' = [H_n][H_{n-1}]\cdots[H_1]V$$