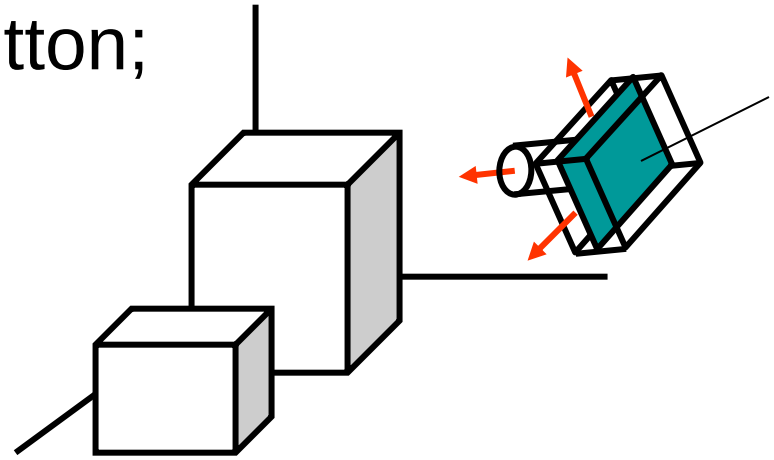
3D – Viewing & Projections

3D Viewing

- Viewing: virtual camera
- Projection
- Visible lines and surfaces
- Surface rendering

3D Viewing

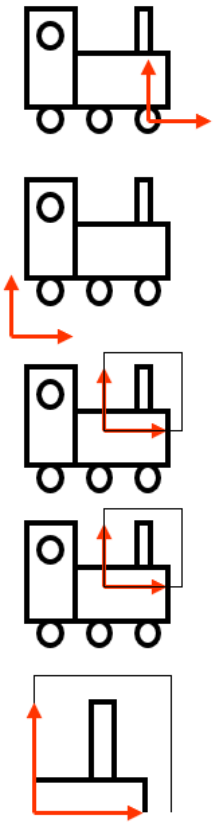
- Similar to making a photo
  - Position and point virtual camera, press button;



Projection plane and Viewing plane

- Pipeline has +/– same structure as in 2D

2D viewing pipeline



MC: Modeling Coordinates

Apply model transformations

WC: World Coordinates

Determine visible parts

VC: Viewing Coordinates

To standard coordinates

NC: Normalized Coordinates

Clip and determine pixels

DC: Device Coordinates

3D Viewing pipeline

MC: Modeling Coordinates

↓ Apply model transformations

WC: World Coordinates

↓ To camera coordinates

VC: Viewing Coordinates

↓ Project

PC: Projection Coordinates

↓ To standard coordinates

NC: Normalized Coordinates

↓ Clip and convert to pixels

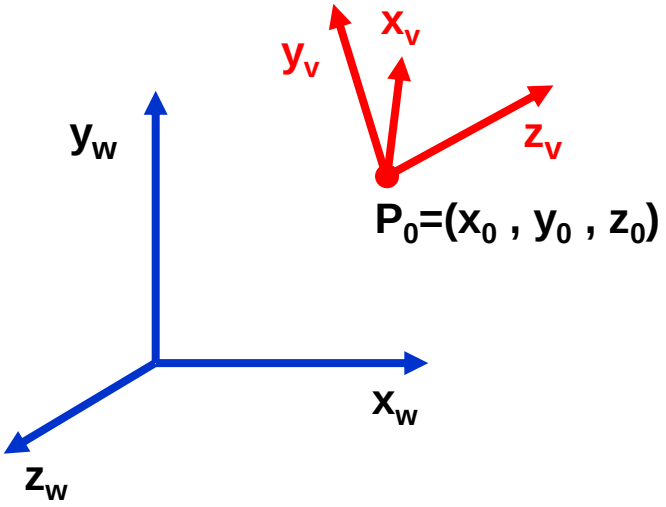
DC: Device Coordinates

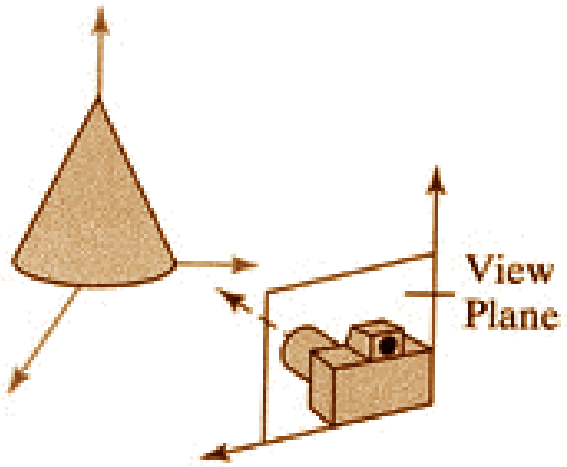
Viewing Coordinates

- Generating a view of an object in 3D is similar to photographing the object.
- Whatever appears in the viewfinder is projected onto the flat film surface.
- Depending on the position, orientation and aperture size of the camera corresponding views of the scene is obtained.

Specifying The View Coordinates

- For a particular view of a scene first we establish viewing-coordinate system.
- A view-plane (or projection plane) is set up perpendicular to the viewing *z*-axis.
- World coordinates are transformed to viewing coordinates, then viewing coordinates are projected onto the view plane.



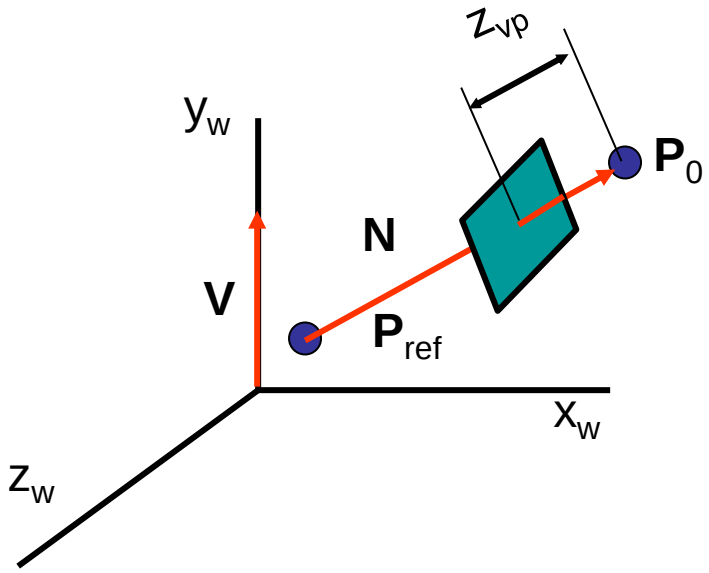


Specifying The View Coordinates

- To establish the viewing reference frame, we first pick a world coordinate position called the view reference point.

- This point is the origin of our viewing coordinate system. If we choose a point on an object, we can think of this point as the position where we aim a camera to take a picture of the object.

3D viewing coordinates 1



Specification of projection:

$\mathbf{P}_0$: *View* or *eye point*

$\mathbf{P}_{ref}$: *Center* or *look-at point*

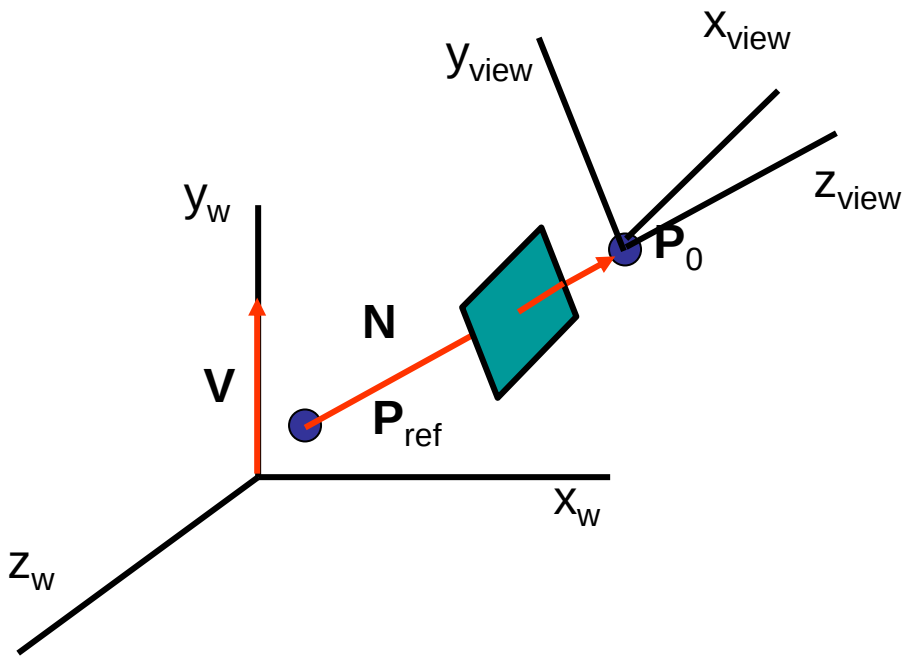
V: *View-up vector* (*projection along vertical axis*)

z_{vp} : *view plane*

$\mathbf{P}_0$, $\mathbf{P}_{ref}$, **V**: define viewing coordinate system

Several variants possible

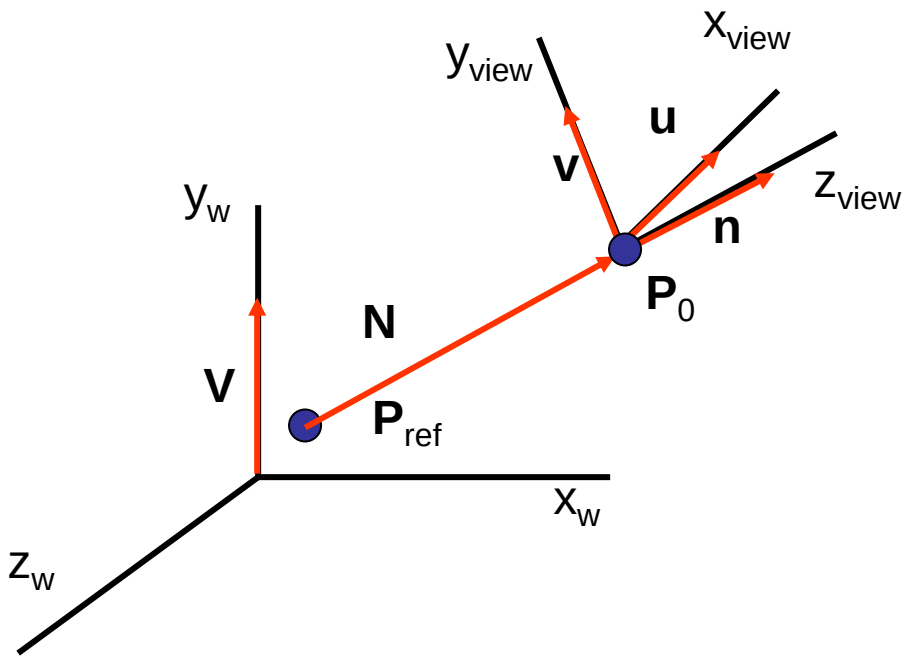
3D viewing coordinates 2



$\mathbf{P}_0$, $\mathbf{P}_{ref}$, $\mathbf{V}$: define viewing coordinate system

Several variants possible

3D view coordinates 3



Derivation axis frame:

$$\mathbf{N} = \mathbf{P}_0 - \mathbf{P}_{\text{ref}}$$

$$\mathbf{n} = \frac{\mathbf{N}}{|\mathbf{N}|} = (n_x, n_y, n_z)$$

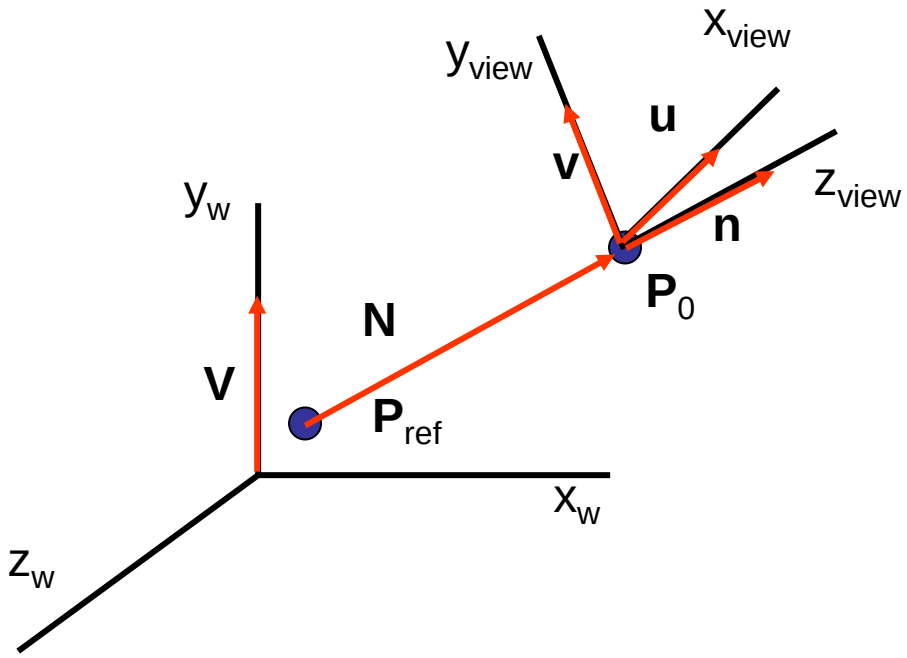
u perpendicular to **V** and **n**:

$$\mathbf{u} = \frac{\mathbf{V} \times \mathbf{n}}{|\mathbf{V}|} = (u_x, u_y, u_z)$$

v perpendicular to **n** and **u**:

$$\mathbf{v} = \mathbf{n} \times \mathbf{u} = (v_x, v_y, v_z)$$

3D viewing coördinaten 4



Transformation world $\rightarrow$ view :

First, translate with $\mathbf{T}(-\mathbf{P_0})$

Next, rotate with $\mathbf{R}$:

$$\mathbf{R} = \begin{pmatrix} u_x & u_y & u_z & 0 \\ v_x & v_y & v_z & 0 \\ n_x & n_y & n_z & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Or :

$$\mathbf{M}_{WC,VC} = \mathbf{RT}$$

3D Viewing

- Viewing in 3D involves the following considerations: -
  - We can view an object from any spatial position, eg. In front of an object, Behind the object, In the middle of a group of objects, Inside an object, etc.

- 3D descriptions of objects must be projected onto the flat viewing surface of the output device.

Projections

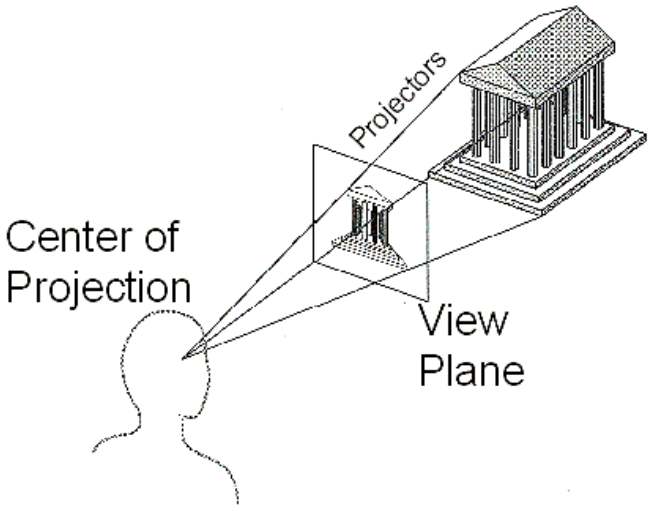
Projection

- General definition
  - Transform points in n-space to m-space(m<n)
- In computer graphics
  - Map viewing coordinates to 2D screen coordinates
- Terms:

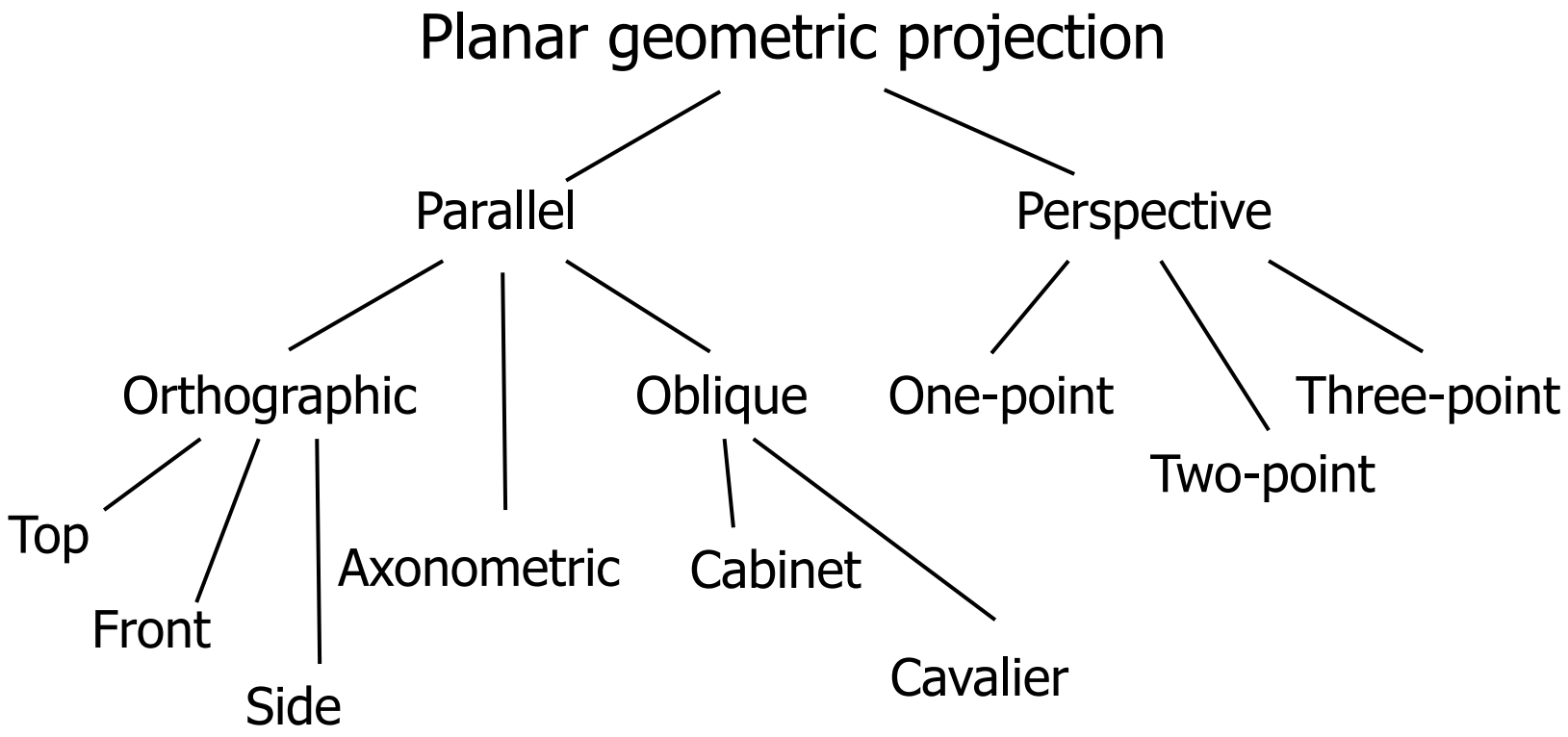
  Center of projection – point from where projection is taken. It can be either light source or eye position

  Projection plane – plane on which projection of the object is formed

  Projectors – Lines emerging from center of projection and hitting the projection plane after passing through a point in the object to be projected.

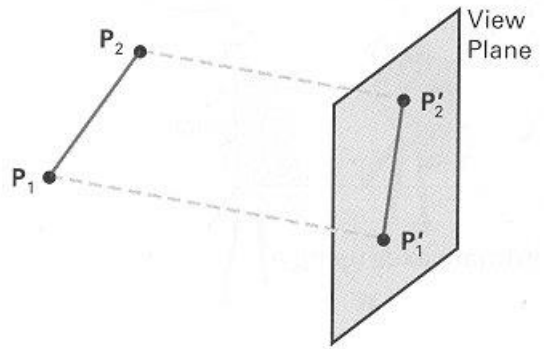


Taxonomy of Projections

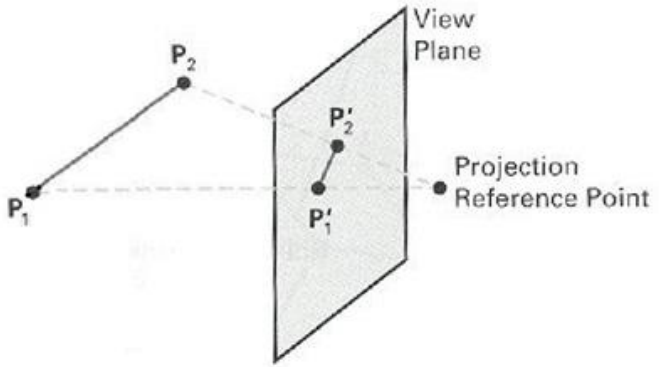


Parallel & Perspective

- Parallel Projection

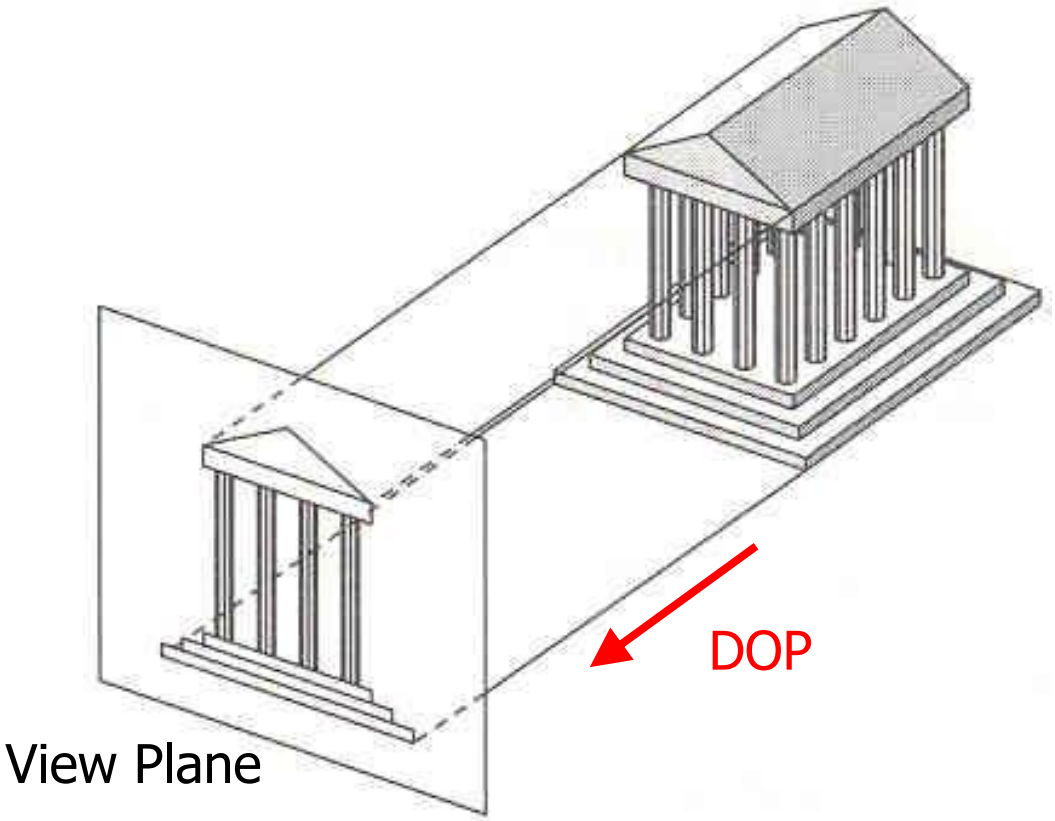


- Perspective Projection



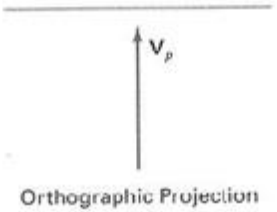
Parallel Projection

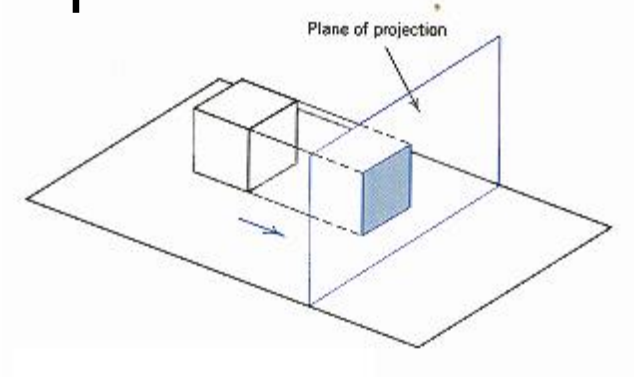
- Center of projection is at infinity
  - Direction of projection (DOP) same for all points



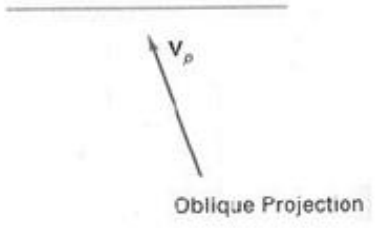
Orthographic & Oblique

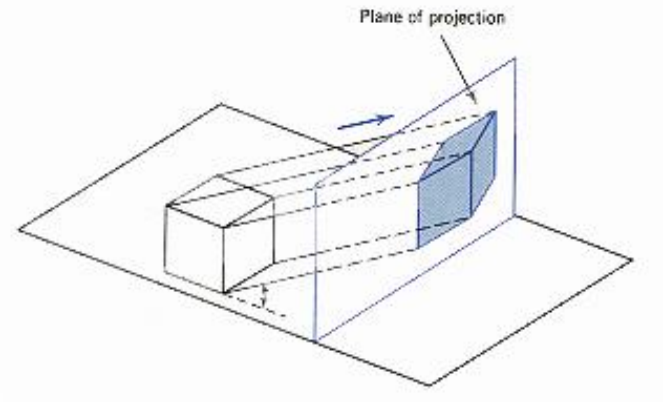
- Orthographic parallel projection
  - the projection is perpendicular to the view plane





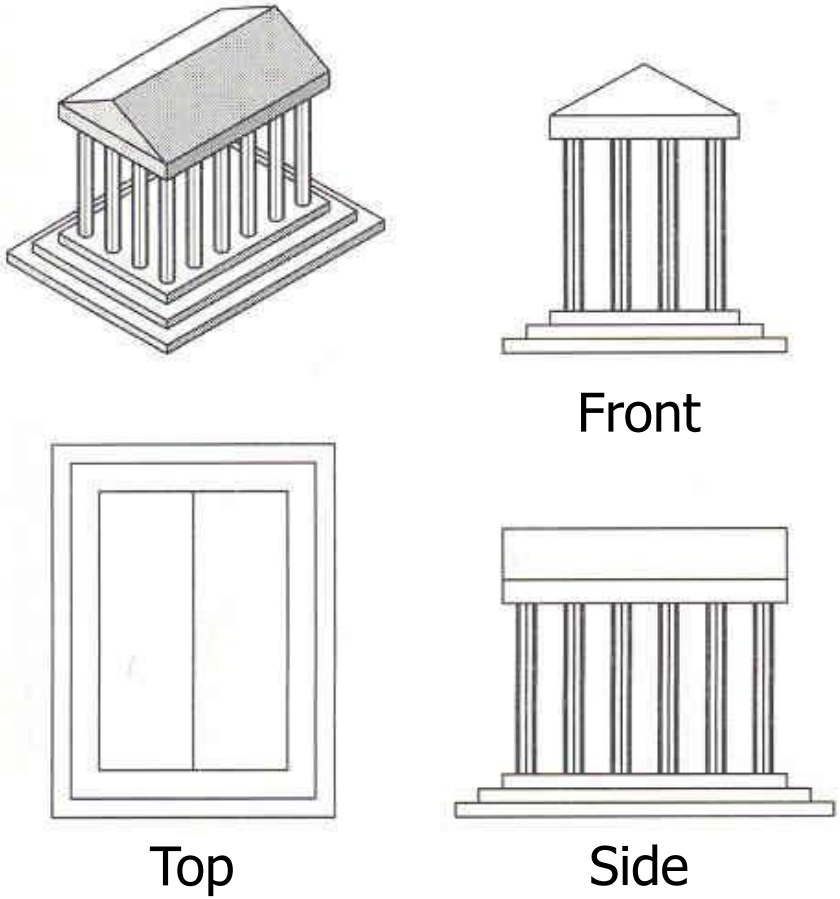
- Oblique parallel projection
  - The projectors are inclined with respect to the view plane





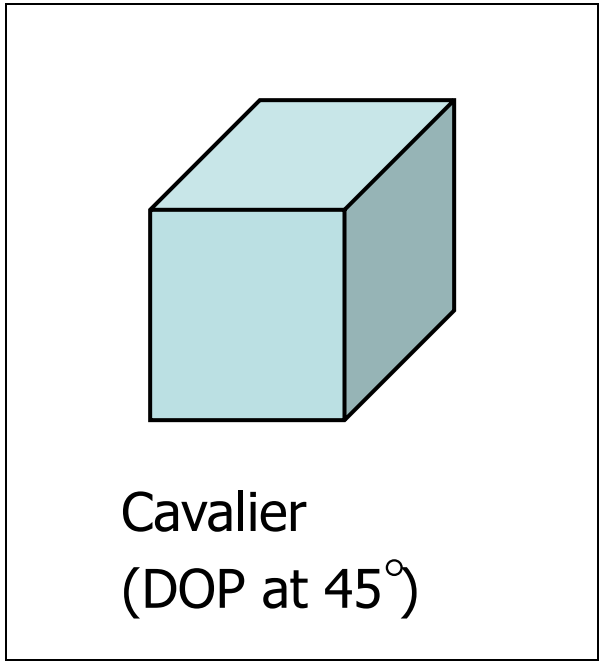
Orthographic Projections

- DOP perpendicular to view plane

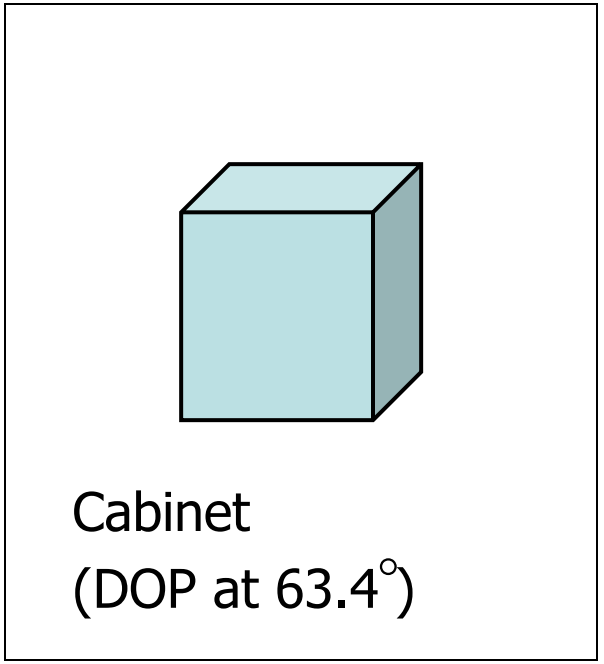


Oblique Projections

- DOP not perpendicular to view plane



Cavalier
(DOP at 45°)

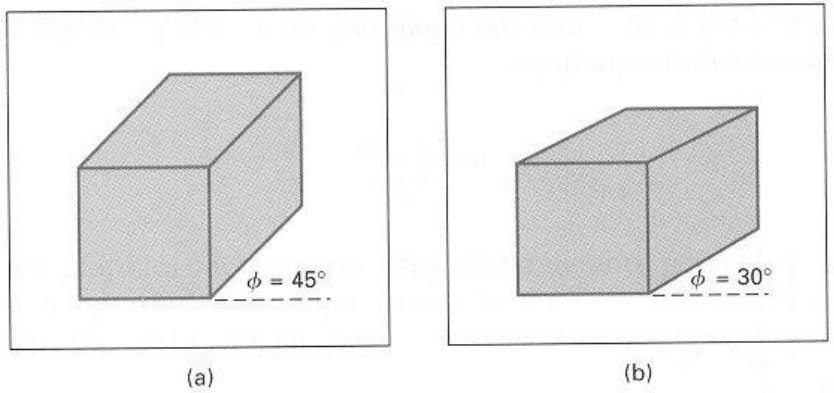


Cabinet
(DOP at 63.4°)

Oblique Projections

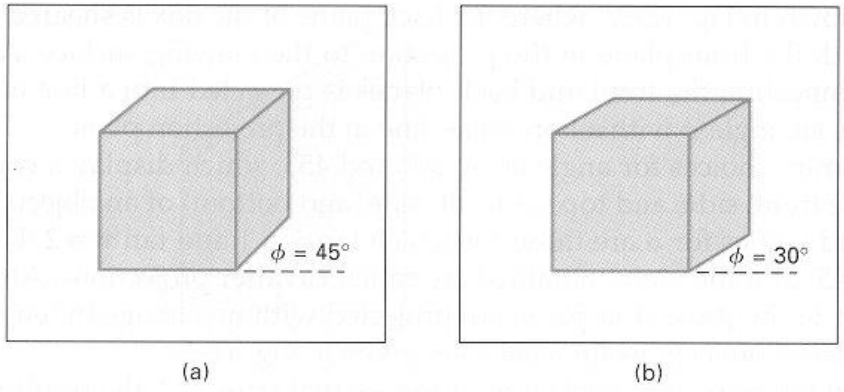
- DOP not perpendicular to view plane
  - Cavalier projection

$$\tan\alpha = 1, \quad \alpha = 45°$$



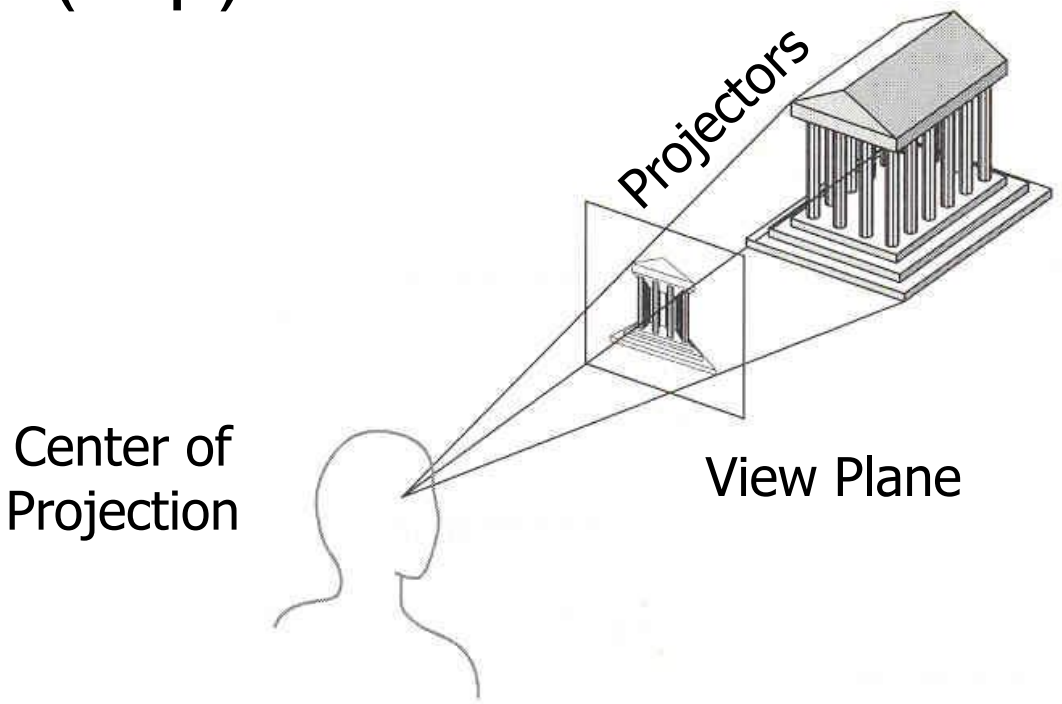
  - Cabinet projection

$$\tan\alpha = 2, \quad \alpha = 63.4°$$



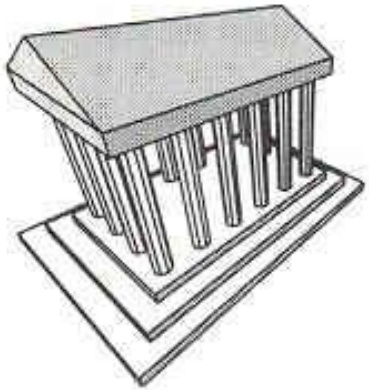
Perspective Projection

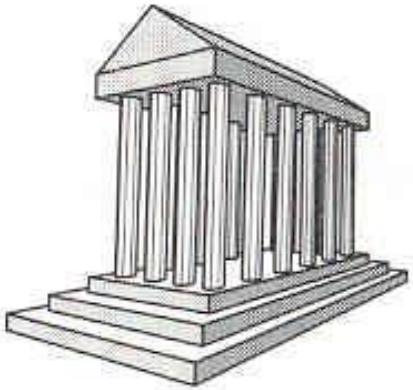
- Map points onto “view plane” along “projectors” emanating from “center of projection”(cop)

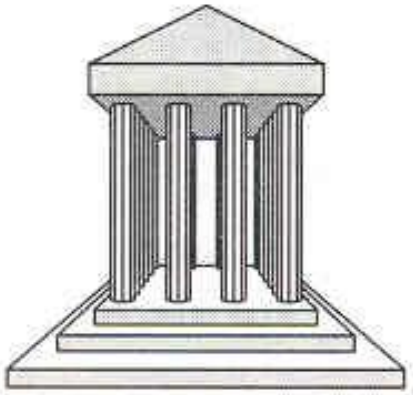


Perspective Projection

- How many vanishing point?

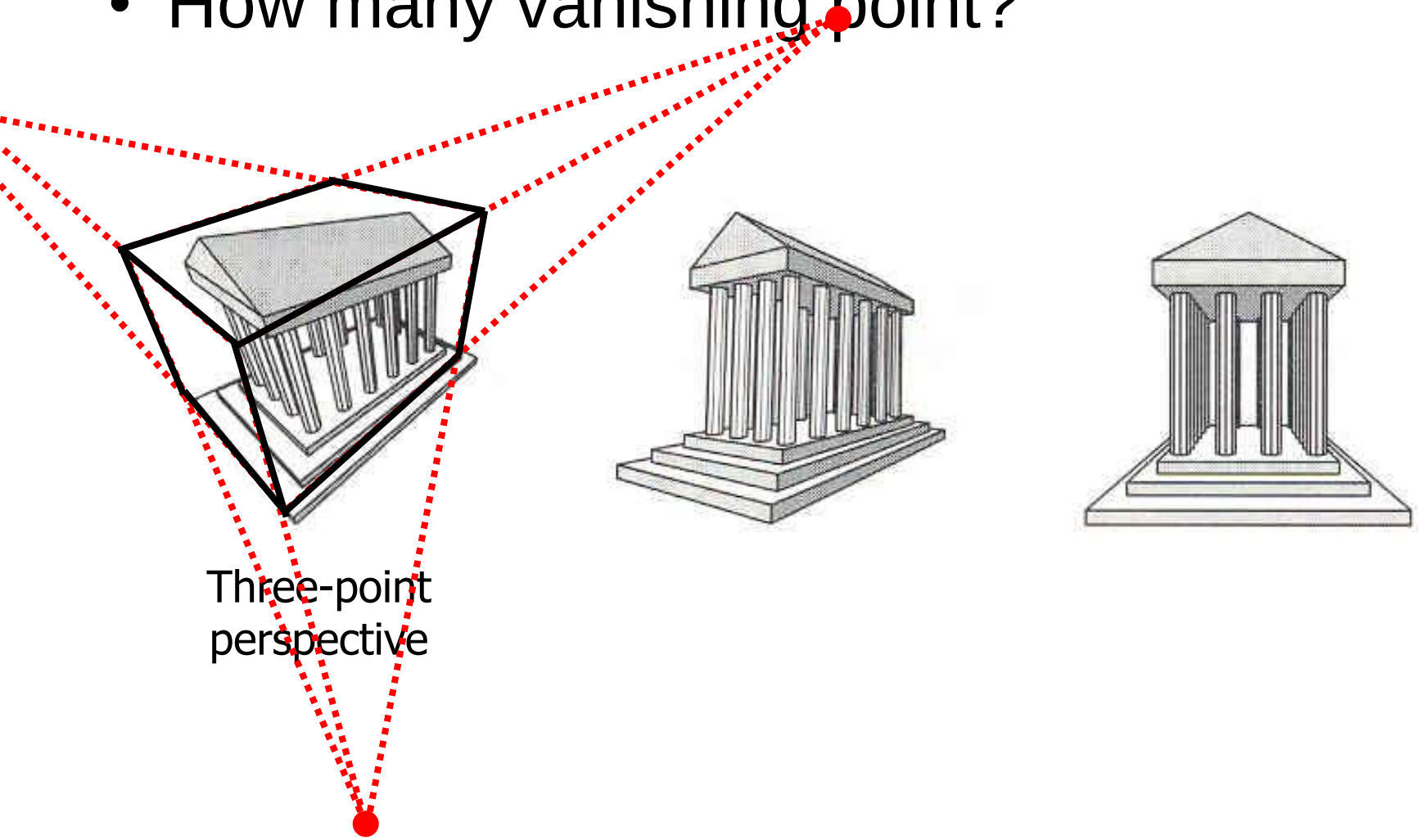






Perspective Projection

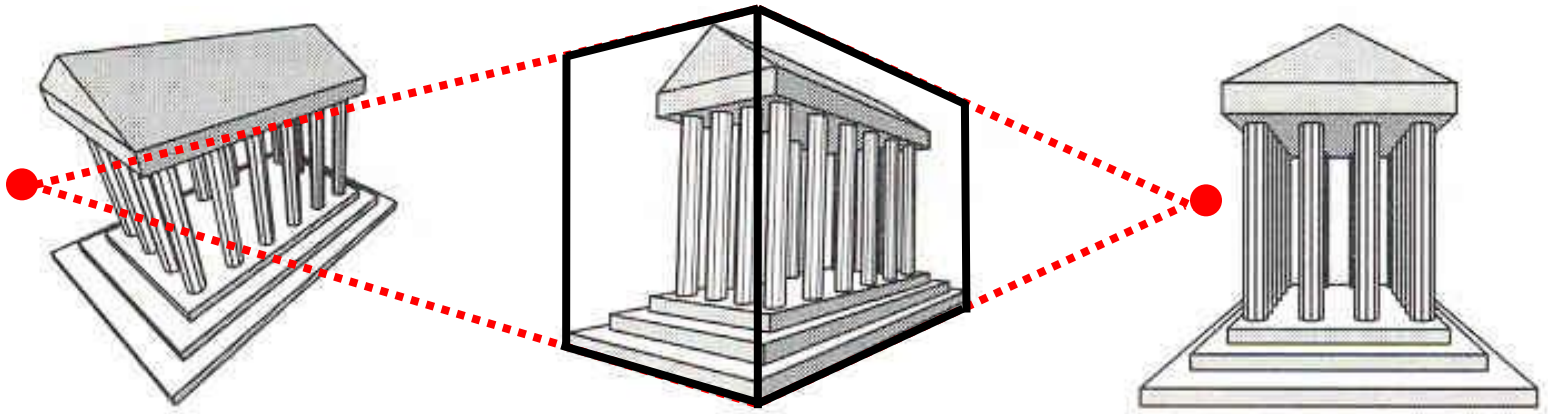
- How many vanishing point?



Three-point perspective

Perspective Projection

- How many vanishing point?

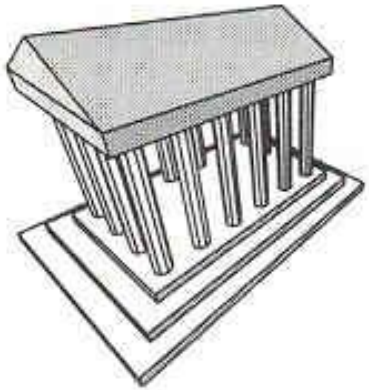


Three-point perspective

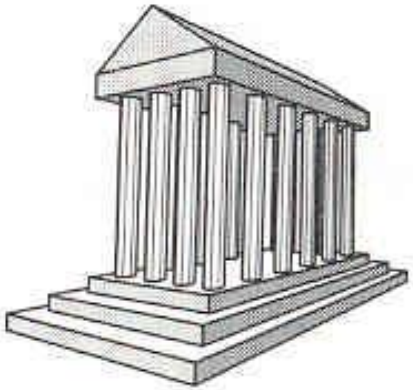
Two-point perspective

Perspective Projection

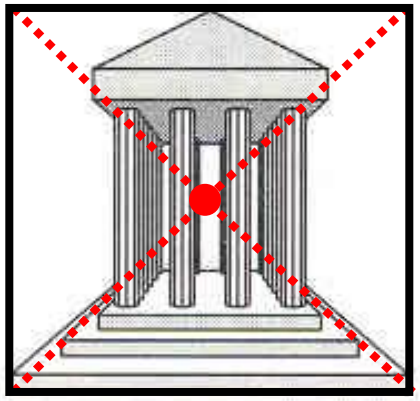
- How many vanishing point?



Three-point perspective



Two-point perspective



One-point perspective