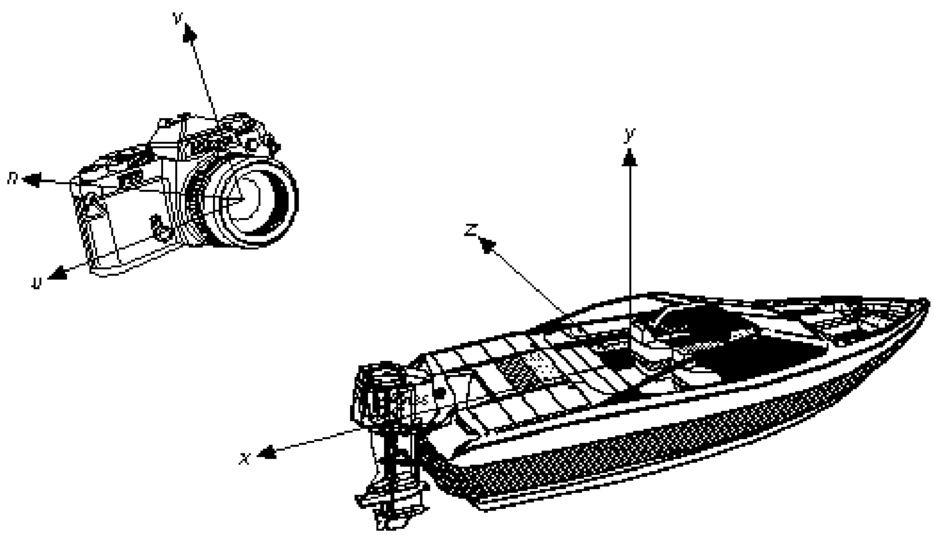
3D Viewing

Basic Problem: Map a 3D object to a 2D display surface

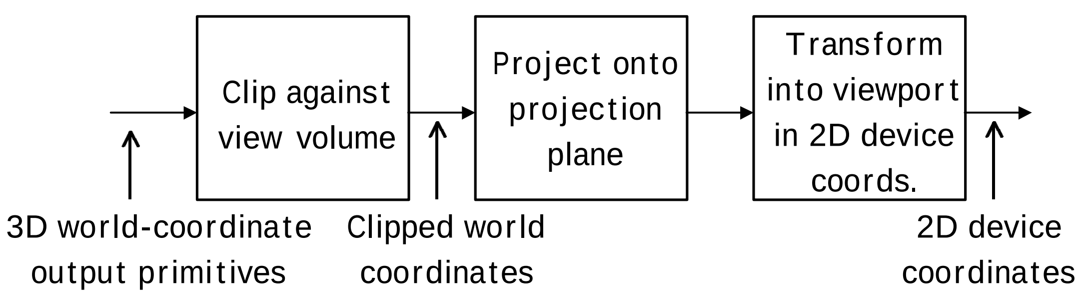
Analogy - Taking a snapshot with a camera



Synthetic camera – virtual camera we can move to any location & orient in any way then create a 2D image of a 3D object

Steps for Viewing in 3D

1. choose a projection type
    - parallel or perspective
2. establish the view
    - specify the viewing parameters
    - position of the viewers eye, location of the view plane
    - two coordinate systems (scene & viewing)
3. clipping in three dimensions
    - Remove portions of the 3D scene that are not candidates for ultimate display
    - clip objects against a 3D view volume
4. project the scene onto the computer display
    - project the view volume onto a 2D projection plane (window)
5. map this image to the viewport (display)

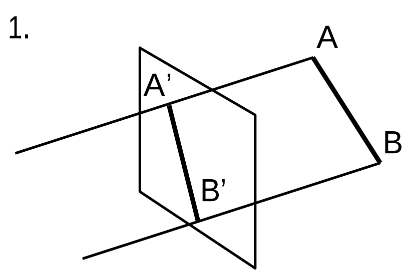


Projections

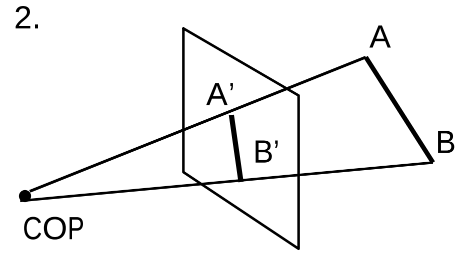
Projections transform points in a coordinate system of dimension n into points in a coordinate system of dimension less than n (eg. 3D – 2D)

Straight projection rays (projectors) that start from a “center of projection” and pass through each point of an object and intersect a “projection plane”

There are two basic types of projections:



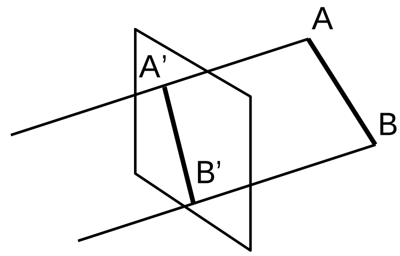
Parallel



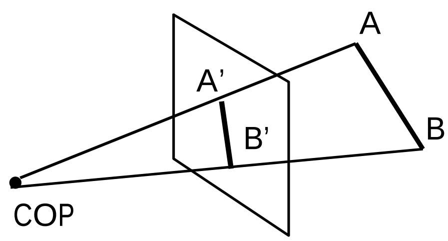
Perspective

We will deal only with planar geometric projections:

- projecting onto a plane rather than a curved surface
- uses straight projectors rather than curved



1. Parallel projection
    - centre of projection (COP) at infinite distance
    - projectors are all parallel
    - specify the direction of projection (DOP) instead of COP
    - less realistic (no perspective foreshortening)
    - good for exact measurements and parallel lines remain parallel
    - angles remain constant only on faces parallel to the projection plane
    - used in engineering and architecture

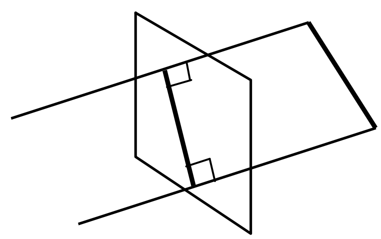


2. Perspective Projection
   - projectors meet at the "center of projection" (COP) (eye, camera…)
   - finite distance between "COP" and "projection plane"
   - approximation of human visual system or photographic system
   - gives perspective foreshortening
     - size of an object varies inversely with the distance of that object from the center of projection
   - adds realism
   - causes distortion – not useful for accurate shapes or measurements

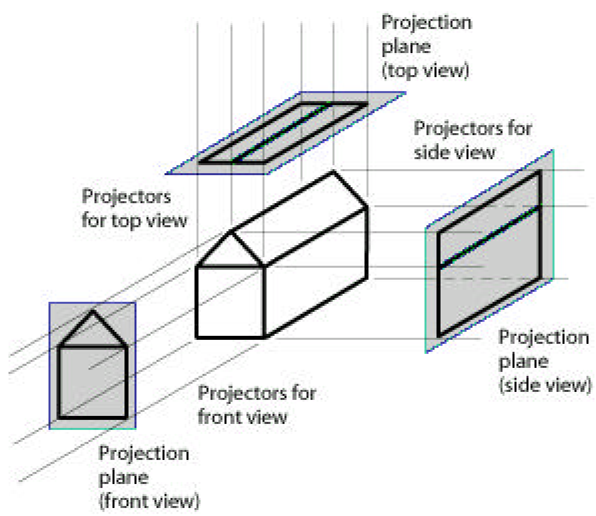
Parallel Projections

- two main types: orthographic and oblique

- Orthographic Projections
    - Direction of projection (DOP) is perpendicular to the projection plane.



    - most common types involve the projection plane being perpendicular to a principle axis:



      – front-elevation (front-view) (z-axis)
      – top-elevation (top or plan view) (y-axis)
      – side-elevation (side-view) (x-axis)
      - each projection only shows one face of an object, therefore the 3D nature is difficult to comprehend

Orthographic projection matrixes:

$$0xy\begin{bmatrix}1 & 0 & 0 & 0\\0 & 1 & 0 & 0\\0 & 0 & 0 & 0\\0 & 0 & 0 & 1\end{bmatrix} 0xz\begin{bmatrix}1 & 0 & 0 & 0\\0 & 0 & 0 & 0\\0 & 0 & 1 & 0\\0 & 0 & 0 & 1\end{bmatrix} 0yz\begin{bmatrix}0 & 0 & 0 & 0\\0 & 1 & 0 & 0\\0 & 0 & 1 & 0\\0 & 0 & 0 & 1\end{bmatrix}$$

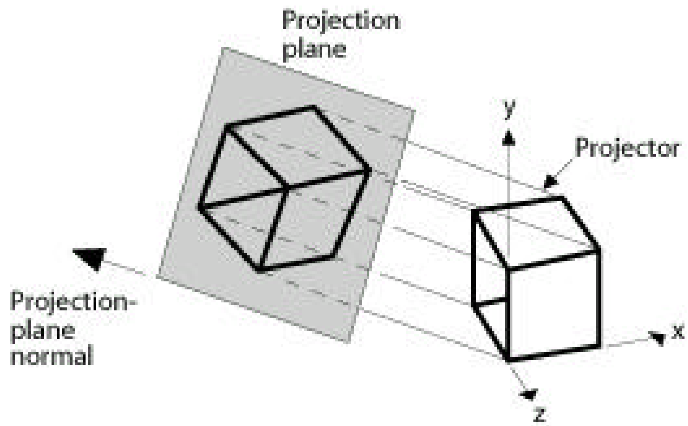
front-elevation top-elevation side elevation

*easy, just discard one of the coordinates (e.g. for a front-elevation, discard the z coordinates)

Examples:

http://mane.mech.virginia.edu/~engr160/Graphics/Exercise1.html

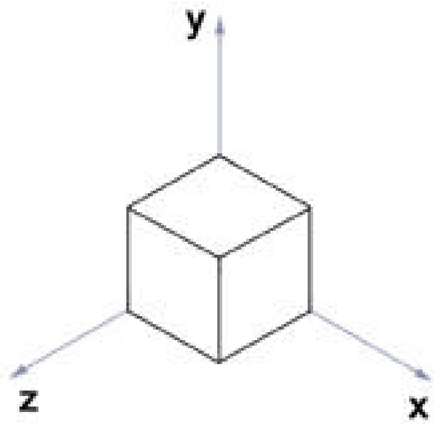
- Axonometric Orthographic Projection
  - use projection planes that are NOT perpendicular to a principal axis
  - therefore, can show several faces of an object at once



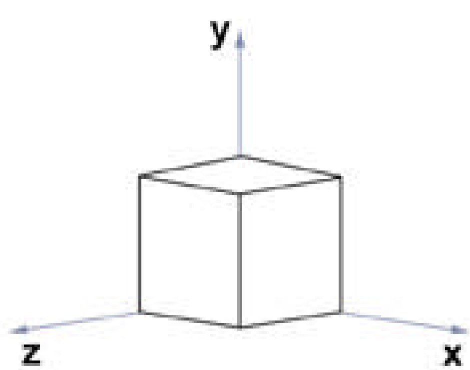
Three classes of axonometric proejctions depending on the number of major axes which are forshortened

1. Isometric Projection

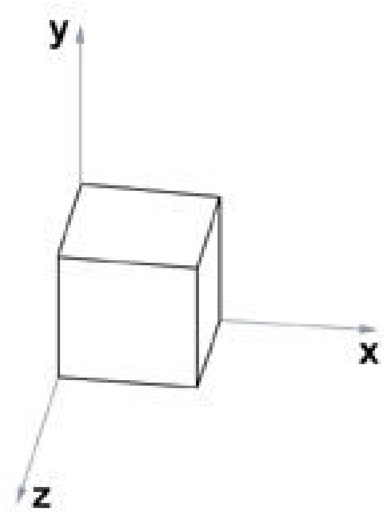
– special case of an axonometric projection
– direction of the projection is at equal angles to all axes
– all three major axes are foreshortened equally
– if projection plane normal is (dx, dy, dz), then: |dx| = |dy| = |dz| or +-dx = +-dy = +-dz
– there are only eight directions (one in each octant that can satisfy this condition



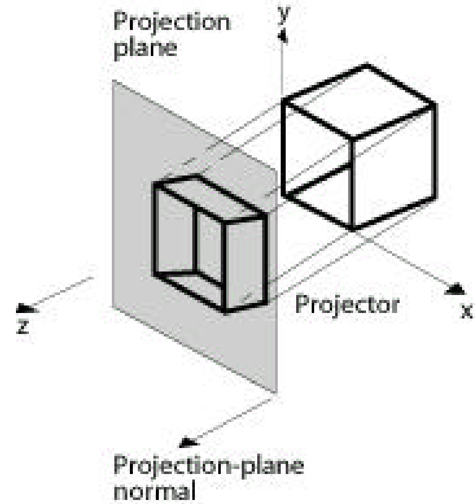
2. Dimetric Projections
   - direction of the projection makes equal angles with two of the axes
   - |dx| = |dy| or |dy| = |dz| or |dx| = |dz|
   - only lines drawn along the two equally forshortened axes are scaled to the same factor



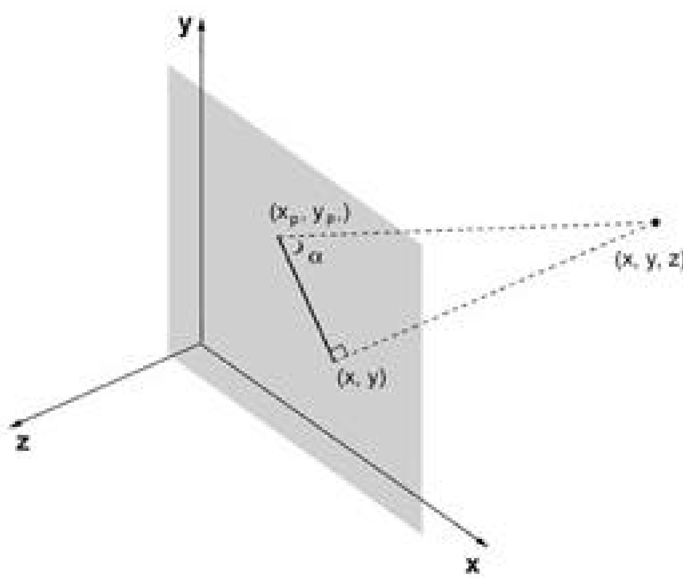
3. Trimetric Projections
   - direction of the projection makes different angles with all three axes
   - can be used to display different orientations by placing different amounts of emphasis on the faces



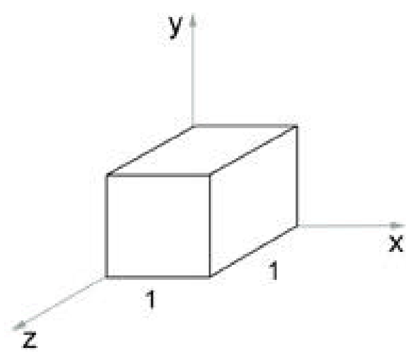
- Oblique Projection
    - direction of projection is NOT perpendicular to the projection plane



    - the projection plane is perpendicular to a principal axis

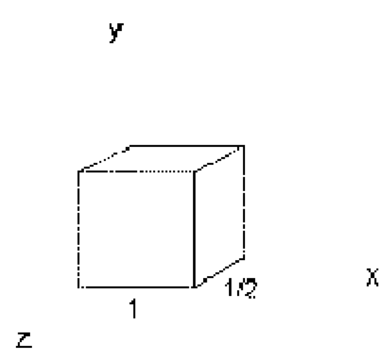


- two types:
  - cavalier projection:
    - $\alpha = 45°$
    - all sides will maintain equal lenghts
    - edges can be measured directly
    - looks elongated

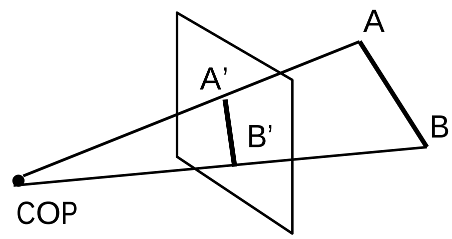


cabinet projection:

- $\alpha = 63.4°$
- projection of a line perpendicular to the projection plane are ½ their actual length
- looks more realistic

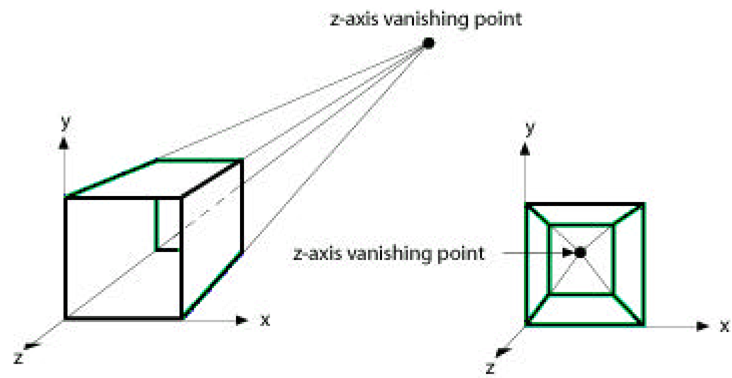


Perspective Projections



- objects of equal size at different distances from the viewer will be projected at different sizes (nearer objects will appear closer)

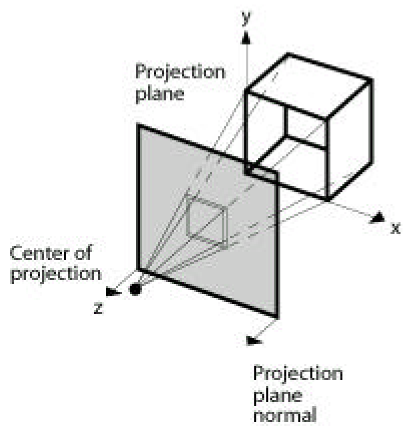
- any lines of the object NOT parallel to the projection plane BUT parallel in the object (scene) will converge to a point – vanishing point



- if the set of lines is parallel to one of the three principal axes, the vanishing point is called an "axis vanishing point"
- perspective projections are categorized by their number of principal vanishing points (therefore the number of axes the projection plane cuts)

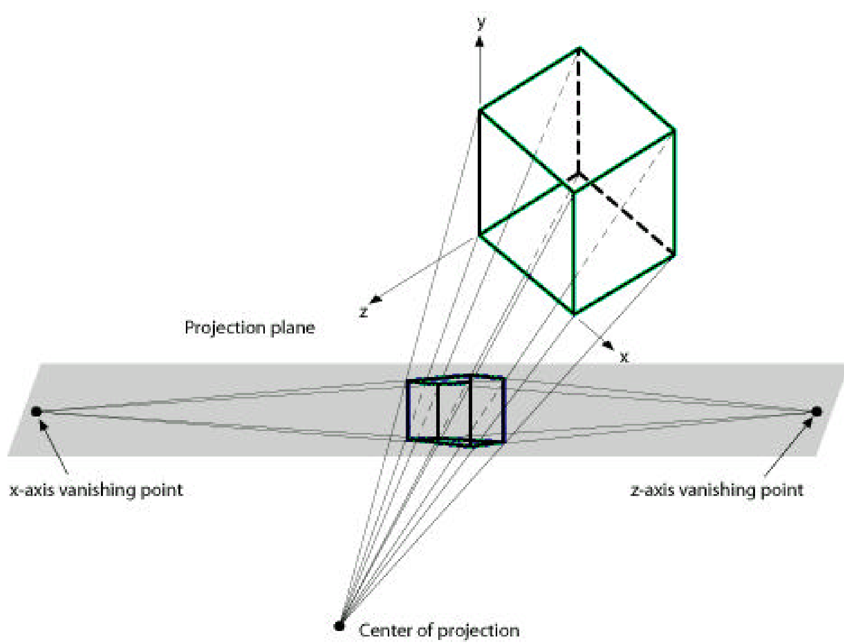
1-point perspective

- one vanishing point
- projection plane cuts 1 axis only (perpendicular), other 2 axes are parallel to the plane.



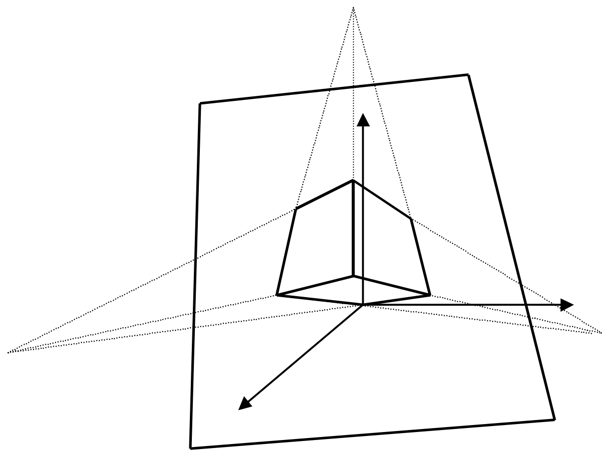
2-point perspective

- two vanishing points
- projection plane cuts 2 axes



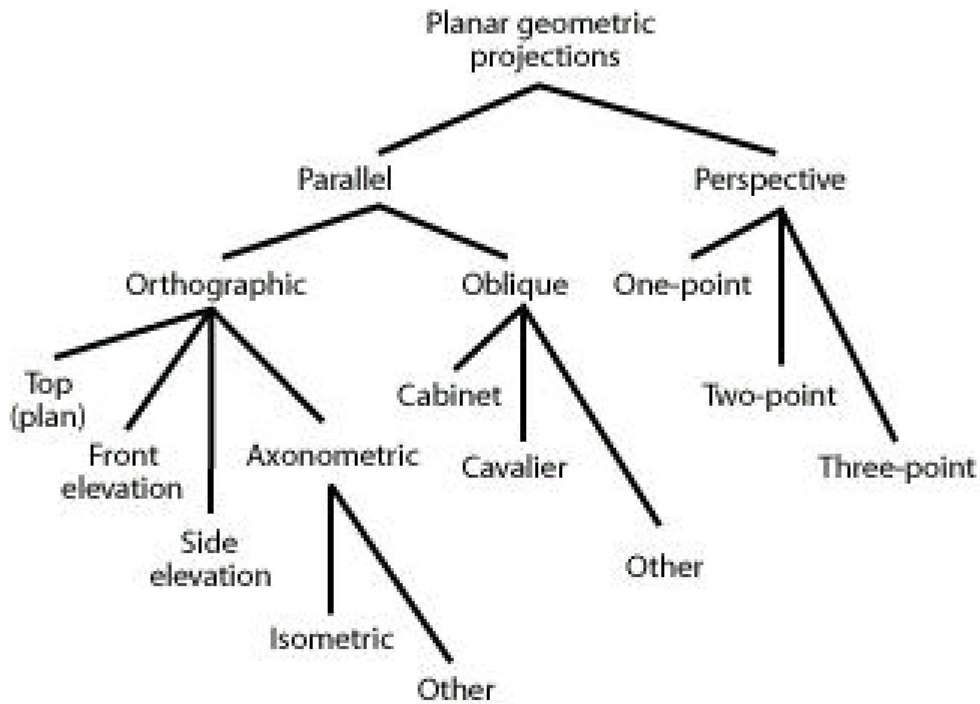
3-point perspective

- three vanishing points
- projection plane cuts all 3 axes

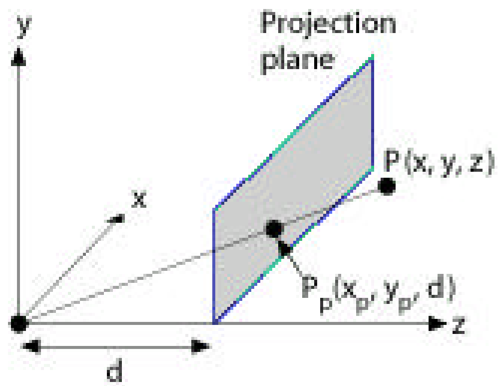


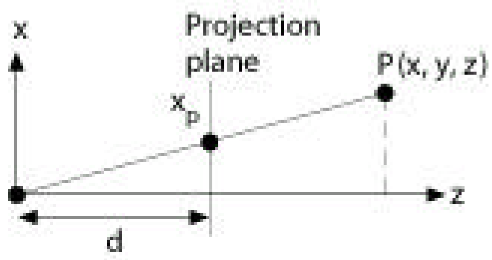
Vanishing point examples

Relationships among various types of projections:

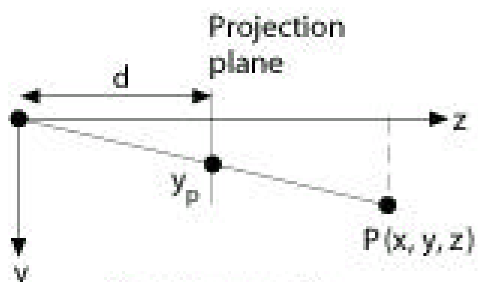


Perspective Planar Geometric Projections





View along y axis



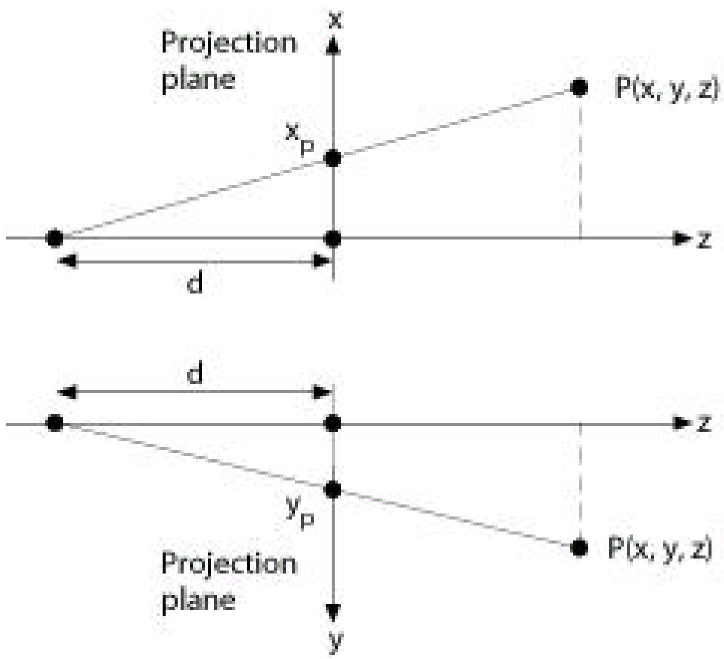
View along x axis

For simplicity:

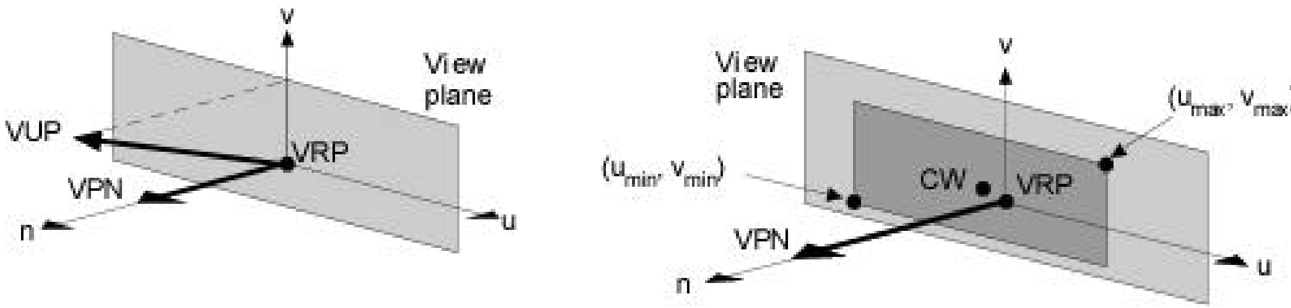
- projection plane is normal to the z-axis at z=d

OR

- projection plane at z=0



Specifying a View Volume



Projection plane -> View Plane

View reference point (VRP) – a point on the view plane

View plane normal (VPN) – normal of the view plane

(the viewplane can be in front of, cut through, or be behind objects)

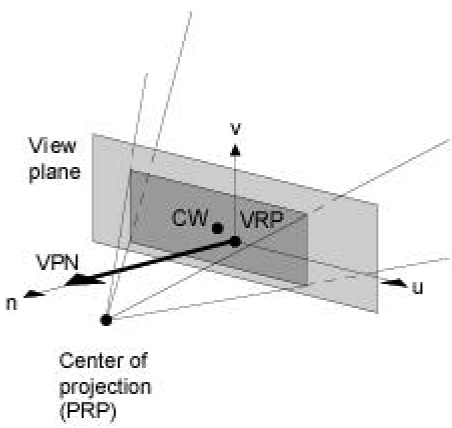
Given a view plane, a "window" which contents are mapped to the viewport (e.g. clipping)

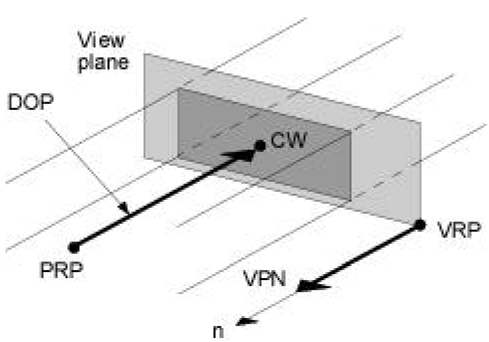
- specify min & max window coordinates
- axes part of 3D Viewing Reference Coordinate (VRC) System
- one axis (n) is VPN
- one axis (v) is coincident with projection of VUP parallel to VPN

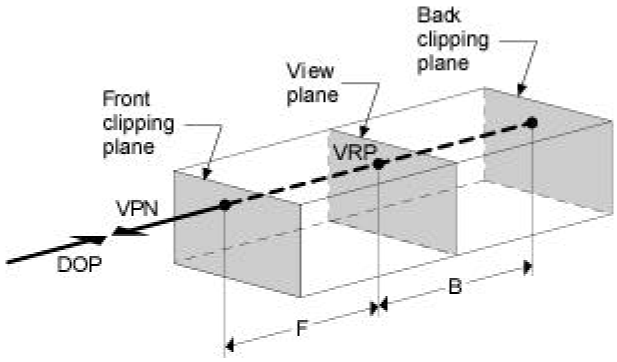
- one axis (u) is defined such that u, v, and n form a right handed coordinate system
- min & max of u & v define the window

PRP – projection reference point

- center of projection for perspective viewing
- direction of projection for parallel viewing (specified DOP from the PRP to the center of the window)






Back
clipping
plane
View
plane
Front
clipping
plane
VRP
VPN
DOP
B
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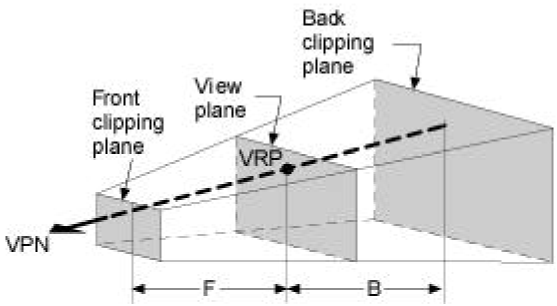
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