Viewing Transform

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Intended Learning Outcomes

- Able to set up a camera coordinate system
- Understand the properties of different projection methods
- Able to set up t atrices and use appropriate Op lize the projection
- Describe the operation and f lipping

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Image generation process

- A camera has its own coordinate system $\mathbf{X}^{(VC)}$-$\mathbf{Y}^{(VC)}$-$\mathbf{Z}^{(VC)}$, called the viewer coordinate system
- viewer coordinate system is alternatively called camera coordinate system
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- To generate a define a camera, then transformi orld coordinate system (WC) to viewing coor m (VC)
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$$\mathbf{X}^{(WC)}\text{-}\mathbf{Y}^{(WC)}\text{-}\mathbf{Z}^{(WC)} \rightarrow \mathbf{X}^{(VC)}\text{-}\mathbf{Y}^{(VC)}\text{-}\mathbf{Z}^{(VC)}$$

- Then projecting each point to a view plane

To specify a viewer coordinate system, we need to specify three vectors

- View Reference Point (**VRP**): origin of the viewing coordinate system (i.e. physical location of the camera)
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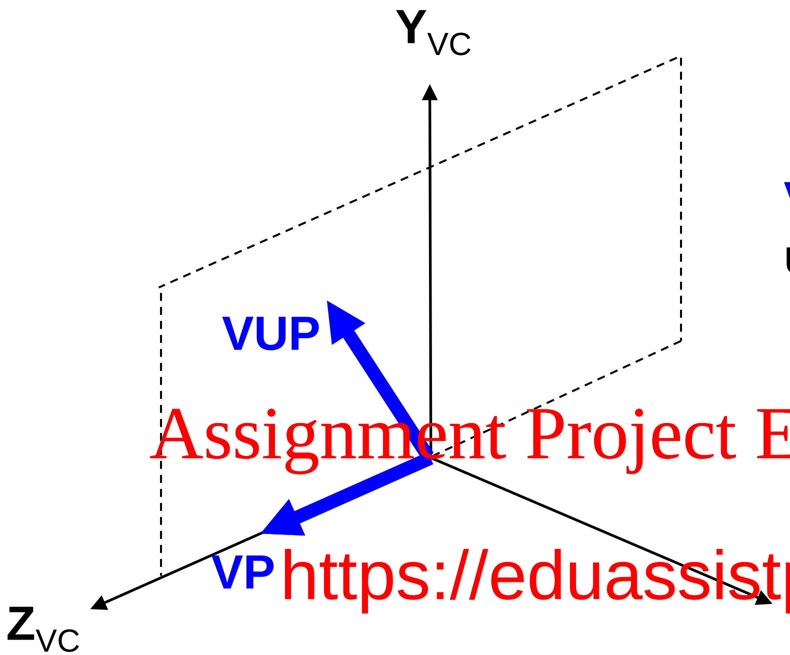
- View Plane No ing the pointing direction of the https://eduassistpro.github.io/ xis of the camera $X^{(VC)}$-$Y^{(VC)}$-$Z^{(VC}$
- View UP Vector (**VUP**) : a ve Add WeChat edu_assist_pro what is the upward direction for the film (i

- Note 1: These vectors do not need to be unit vector
- Note 2: These vectors are in WC



VUP lies on the upper Z_{VC} – Y_{VC} plane

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$\mathbf{Z}_{VC} = |\mathbf{VPN}|$ (unit vector in WC)

$\mathbf{X}_{VC} = |\ \mathbf{VUP} \times \mathbf{VPN}\ |$ (unit vector in WC)

$\mathbf{Y}_{VC} = \mathbf{Z}_{VC} \times \mathbf{X}_{VC}$ (unit vector in WC)

Note: | | is used in the notes to denote normalization to unit vector

Transformation from WC to VC

- $\mathbf{P}^{(VC)} = \mathbf{M}_{VC \leftarrow WC}\, \mathbf{P}^{(WC)}$

- Applying coordinate system transformation method 1:

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$$\mathbf{M}_{VC \leftarrow WC} = \begin{pmatrix} \mathbf{X}_{VC} & \mathbf{Y}_{VC} & \mathbf{Z}_{VC} & \mathbf{VRP} \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

- Note: $\mathbf{X}_{VC}$, $\mathbf{Y}_{VC}$, $\mathbf{Z}_{VC}$ are unit column vector in WC

OpenGL commands

- *glMatrixMode (GL_MODELVIEW);*
- *gluLookAt (x0, y0, z0, xref, yref, zref, Vx, Vy, Vz);*

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- **VRP** = (x0, y0,
- **VPN** = (x0, y0,

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- **VUP** = (Vx, Vy, Vz)

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- To remember this, it is convenient to remember (x0, y0, z0) as where the camera is placed, (xref, yref, zref) as where the center of the scene is, and (Vx, Vy, Vz) as a vector that tells where it’s up for the camera

View Plane

- Also called projection plane or image plane
- It is usually a plane defined by Z_{VC} = constant, i.e., parallel to the $\mathbf{X}_{VC}$ – $\mathbf{Y}_{VC}$ plane
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- As the name i Z) in viewer coordinates is ying on the view plane
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- i.e. 3D becomes 2D

Projections : project $(X, Y, Z)^{(VC)}$ to $(x, y)^{(VC)}$

- Two general types: Parallel and Perspective Projections

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Parallel project e projection

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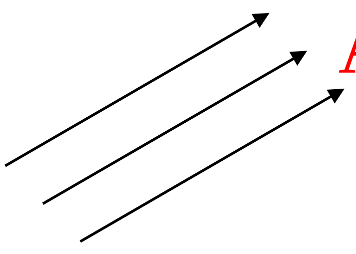

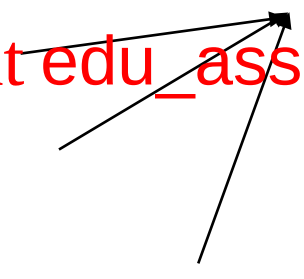

all light rays are parallel

all light rays converge on a common point called projection reference point (PRP)

Parallel projection can be considered as the special case of perspective projection when PRP = ∞

Different properties

Parallel projection	Perspective Projection
coordinate positions are transformed to the projection plane alo i.e. center of projectio	coordinate positions are transformed to the ane along lines that converge lled the center of projection Reference Point)
preserves relative proportions	s not preserve
use in engineering drafting	use in realistic views

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Parallel Projections

- Specify a *projection vector* – a direction vector
- Two types:

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- *Orthographic p* ector ⊥ projection plane

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- *Oblique projection* - pr ctor not ⊥ to projection plane

Orthographic Projection ($\alpha = 90^o$)

- Two types:
- *Front elevation, side elevation, rear elevation, plan view* Y-Z is shown
- *Isometric projection* - pr ector = ($\pm$1, $\pm$1, $\pm$1)
  - For a cube, each side will be displayed equally
  - The 8 possibilities corresponds to viewing in the 8 octants

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Front elevation, side elevation, rear elevation, plan view

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front elevation view

Isometric projection

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Oblique Projection ($\alpha \neq 90^o$)

- Two types:

- *Cavalier projection* - projection vector makes an angle α of $\tan^{-1}1$ with p
  - for a cube, len is will remain the same

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- *Cabinet projection* - projection vector makes an angle α of $\tan^{-1}2$ with projection plane
  - for a cube, length of X axis, Y axis will remain the same; length of Z axis will be halved.

Cavalier Projection

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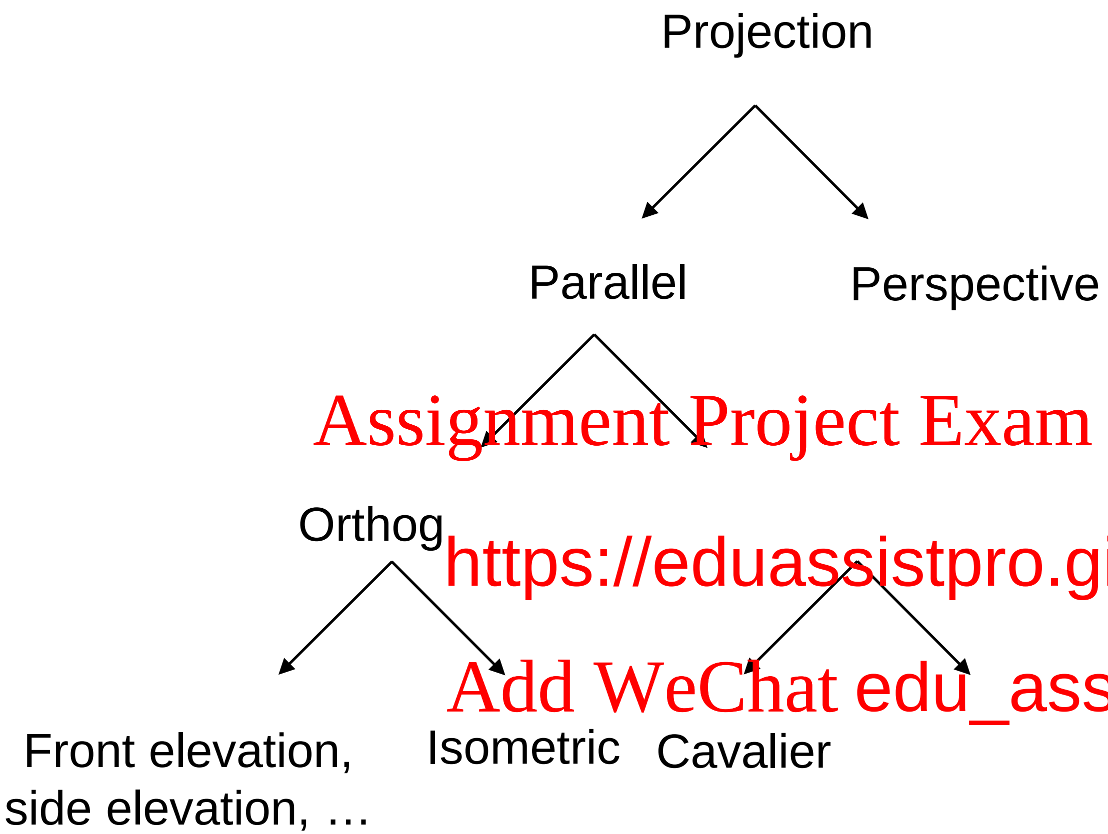
Cabinet Projection



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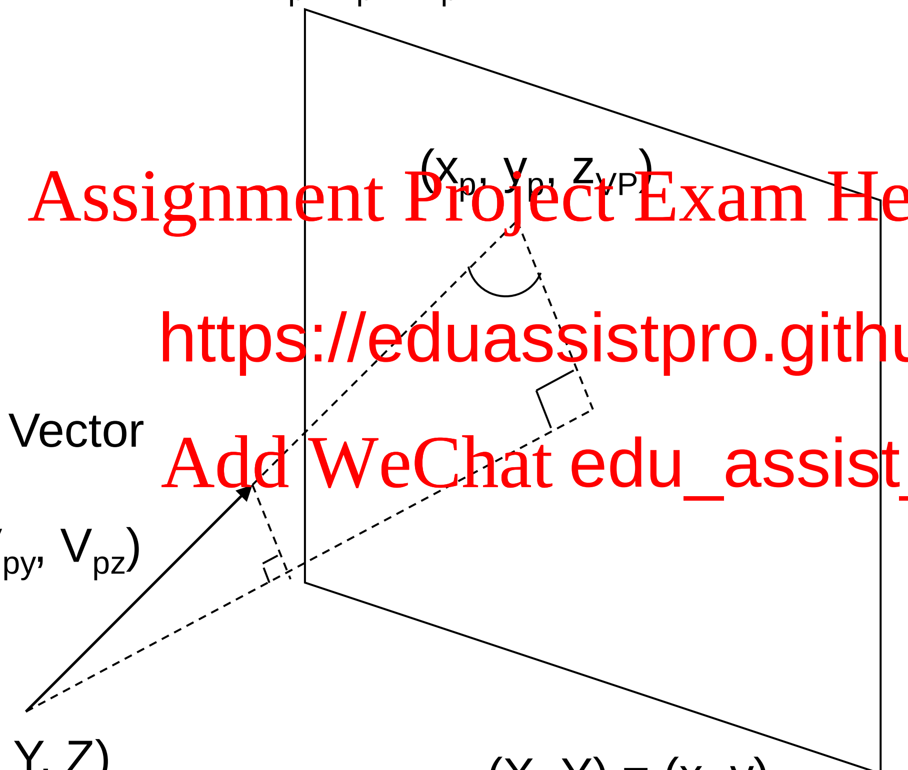
4 x 4 Transform for Parallel Projection

All quantities in this slide are already in VC

$\mathbf{P}^{(VC)} = (X, Y, Z)$ $\mathbf{P}^{(im)} = (x_p, y_p, z_{vp})$



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$\alpha = 90^o$ Orthographic projection $\alpha \neq 90^o$ Oblique projection

By similar triangles,

$$\frac{x_p - X}{z_{vp} - Z} = \frac{V_{px}}{V_{pz}}$$

$$\frac{y_p - Y}{z_{vp} - Z} = \frac{V_{py}}{V_{pz}}$$

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Rearranging,

$$x_p = X + (z_{vp} - Z)\frac{V_{px}}{V_{pz}}$$

$$y_p = Y + (z_{vp} - Z)\frac{V_{py}}{V_{pz}} \qquad (1)$$

- $\mathbf{P}^{(im)} = (x_p, y_p, z_{vp}, 1)$ $\mathbf{P}^{(VC)} = (X, Y, Z, 1)$
- $\mathbf{P}^{(im)} = \mathbf{M}_{parallel}\ \mathbf{P}^{(VC)}$

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$$\mathbf{M}_{parallel} = \begin{pmatrix} 1 & 0 & -\frac{V_{px}}{V_{pz}} & z_{vp}\frac{V_{px}}{V_{pz}} \\ 0 & 1 & -\frac{V_{py}}{V_{pz}} & z_{vp}\frac{V_{py}}{V_{pz}} \\ 0 & 0 & 0 & z_{vp} \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

- Verify that the first two rows implement eqn (1) above
- The third row is such that the projected point is at Z = z_{vp}. However, this is not maintained; in OpenGL, $\mathbf{p}^{(im)}$ = (x_p, y_p, Z), i.e. the original Z is kept for depth tests

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- Third row of eqn (10-13), pg. 350 of text is set to 0 0 1 0, which t as maintaining the original Z.

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Perspective Projection

- ALL light rays goes through the Projection Reference Point (**PRP**), also called center of projection.

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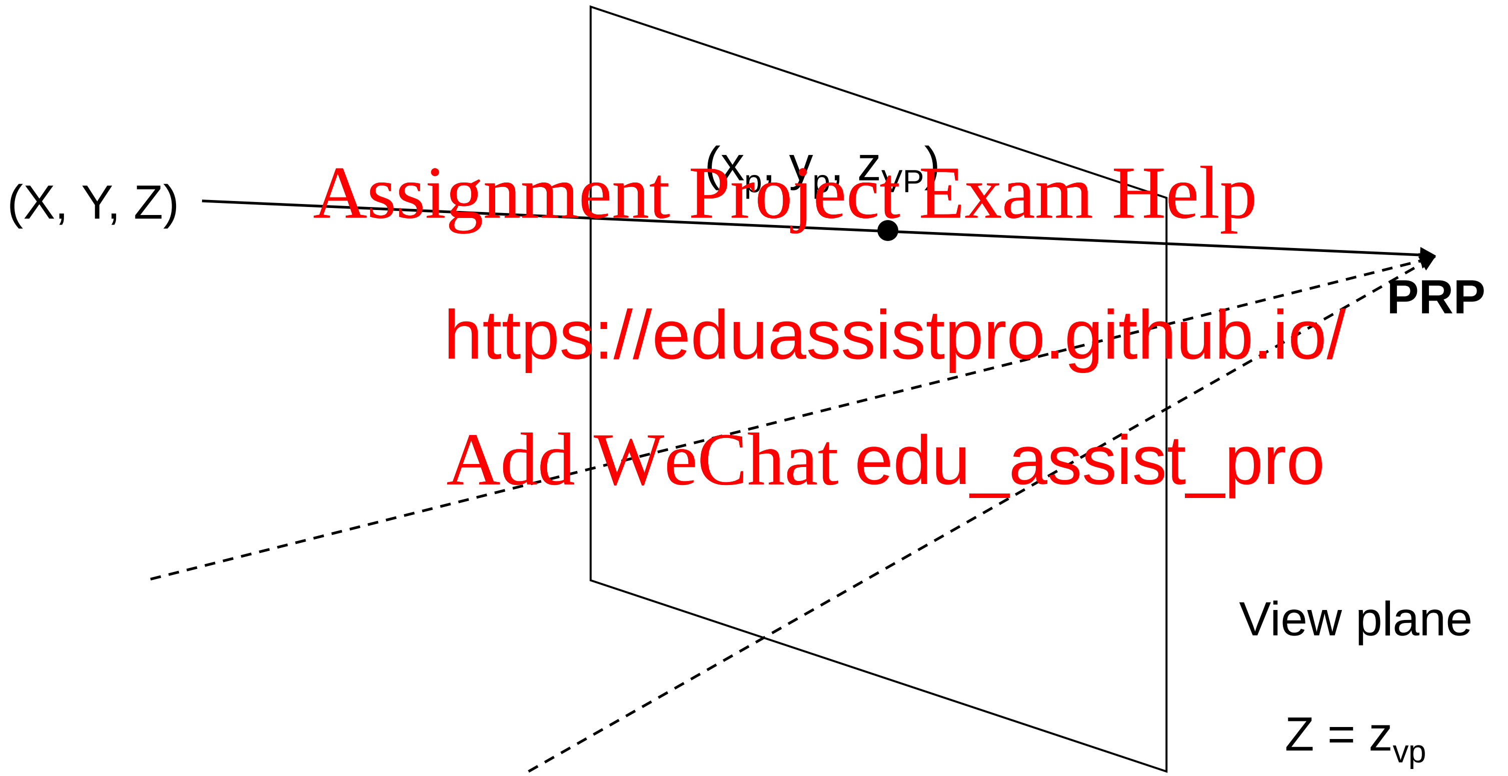

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Example:

i) **PRP** = **VRP**
ii) Z = z_{vp} is the view plane

By similar triangles,

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$$\frac{x_p}{z_{vp}} = \frac{X}{Z} \qquad \frac{y_p}{z_{vp}} = \frac{Y}{Z}$$

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Multiplying each side by z_{vp} yields

$$x_p = \frac{z_{vp} \cdot X}{Z} = \frac{X}{Z / z_{vp}} \qquad (2)$$

$$y_p = \frac{z_{vp} \cdot Y}{Z} = \frac{Y}{Z / z_{vp}}$$

- $\mathbf{P}^{(VC)} = (X, Y, Z, 1)$
- $\mathbf{P}^{(im)} = \mathbf{M}_{perspective}\ \mathbf{P}^{(VC)}$

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$$\mathbf{M}_{perspective} = \begin{bmatrix} 0 & 1 & & \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1/z_{vp} & 0 \end{bmatrix}$$

- Verify that the first two rows and the fourth row implements eqn (2) above using homogeneous coordinates operation

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- Note that the f anymore
- The third row i point is at Z = z_{vp}. However, this is not mai penGL, $\mathbf{p}^{(im)}$ = (x_p, y_p, Z), i.e. the original Z is pth tests

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Clipping

- Any object not within the clipping volume does not need to be processed – this eliminates most of the objects at one go
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- For a convex c by planes, one can check whehttps://eduassistpro.github.io/ checking the signs of the plane equations (2).
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OpenGL – first set matrix mode

- *glMatrixMode (GL_PROJECTION);*

- Note: *GL_PROJECTION* is used as it deals with projection
- There are two mation matrices: *GL_MODELVIEW* and *GL_P* *N*
- A point is pre-multiplied by

  [*GL_PROJECTION*] [*GL_MODELVIEW*]

- *glOrtho* and *gluPerspective* commands may be used

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OpenGL – Orthographic projection

- *glOrtho (xwmin, xwmax, ywmin, ywmax, dnear, dfar)*

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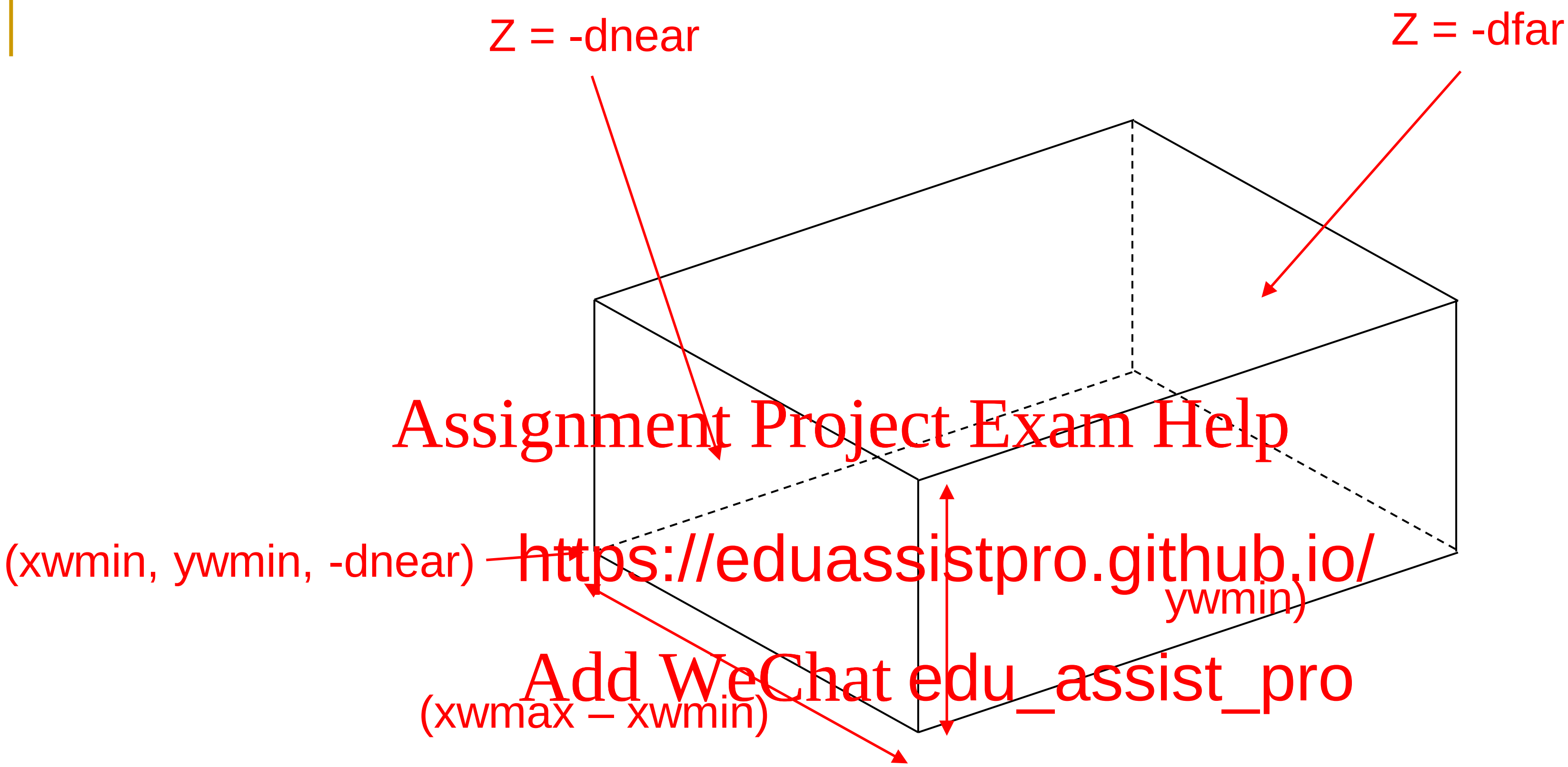
  - Projection v
  - Clipping pla https://eduassistpro.github.io/ far
  - Near clipping plane, Z = -d erve as the view plane Add WeChat edu_assist_pro
  - Only points whose X and Y are in |xwmin, xwmax| and |ywmin, ywmax| respestively are displayed
  - Clipping volume is a rectangular box



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Only objects inside the rectangular shaped clipping volume is further processed

OpenGL – Perspective projection

- *gluPerspective (theta, aspect, dnear, dfar)*
  - **PRP** = **VRP**
  - Z = -*dnear* i e –ve sign)
  - dnear and df ar clipping planes
    Z = -*dnear* and Z = -*dfar* re
  - *theta* is the angle of view
  - *aspect* = (width /height)
  - *theta* and *aspect* together determines size of image window
  - clipping volume is a frustum

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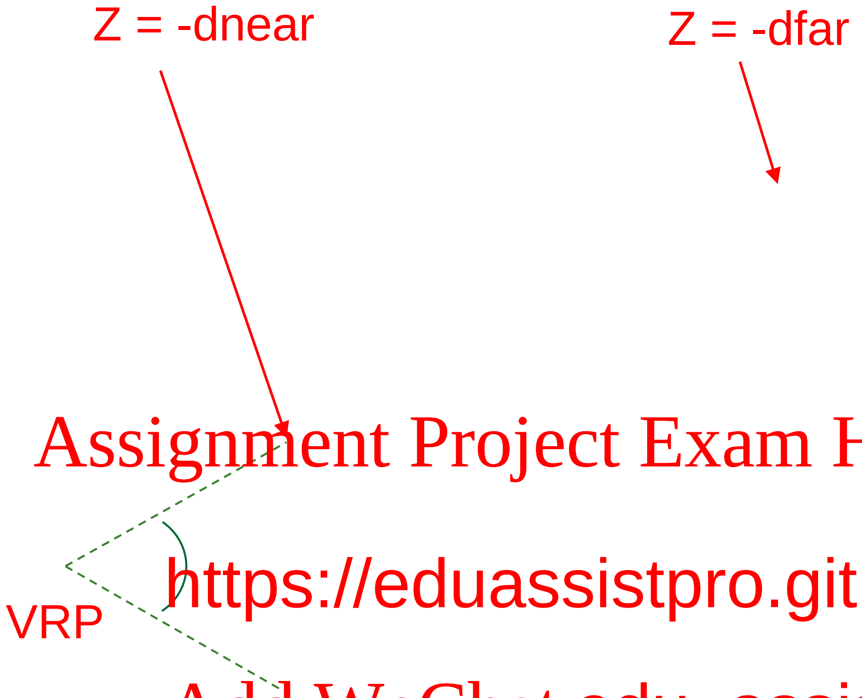

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aspect = width /height of the blue plane

Only objects inside the frustum shaped clipping volume is further processed

References

- Text : Ch. 10.2–10.7 discusses the viewing transform and the various types of projection
- Text : Ch. 10.8 discusses general perspective projection and then discu We only discuss the special cas
- Text : Ch. 10.9–10.10 discus nGL commands

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