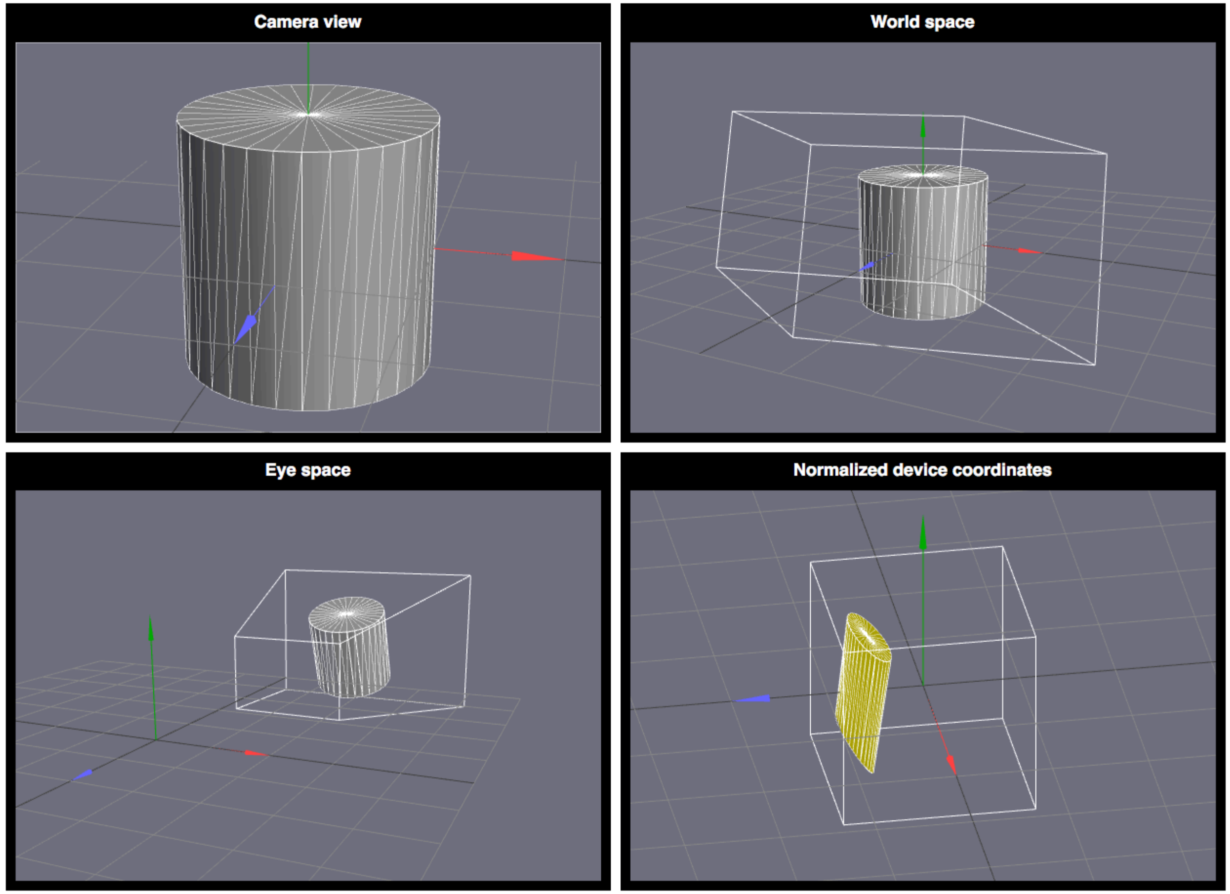


Computer Graphics

Lecture 19

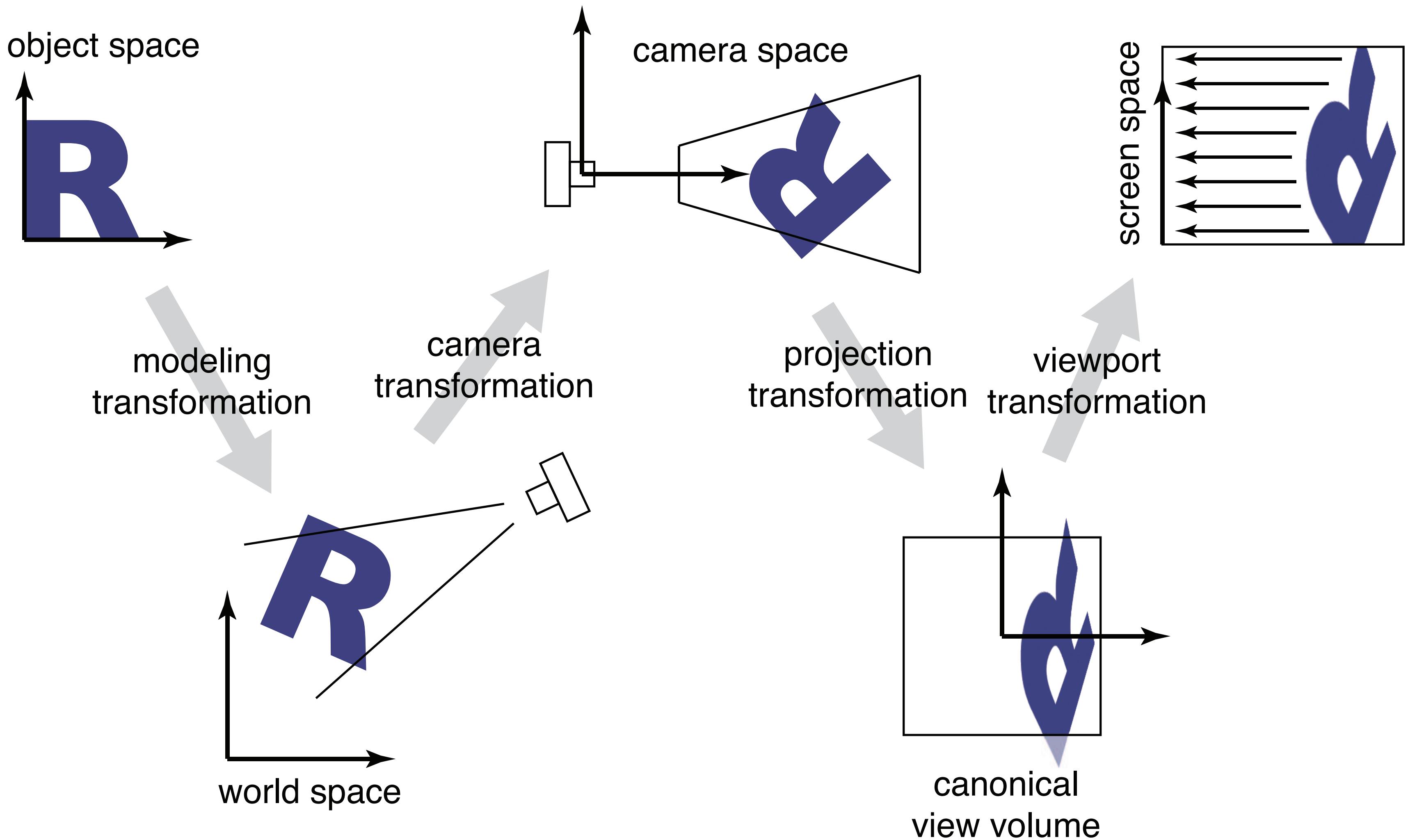
Viewing Transformations - 2

Announcements

- "Midterm" exam is out one week from Friday
  - Takehome; 20% of your grade, inspired by HW
  - Upshot: if you got HW problems wrong, make sure you know how to get them right. You have nearly 2 weeks, so now's the time to start reviewing.
- Also be thinking about final project ideas and groups.

Viewing Transformations: Overview

A standard sequence of transforms to go from **object (model) space** to **screen (image) space**



A Wireframe Rendering Algorithm

```
Form matrices
```
$M_{vp}, M_{proj}, M_{cam}, M_{model}$

$M \leftarrow M_{vp} M_{proj} M_{cam} M_{model}$

`for each line segment` $\mathbf{a}_i, \mathbf{b}_i$:

    $\mathbf{p} \leftarrow M\mathbf{a}_i$

    $\mathbf{q} \leftarrow M\mathbf{b}_i$

    `draw_line(`$\mathbf{p}, \mathbf{q}$`)`

Viewing Transformations: Demo

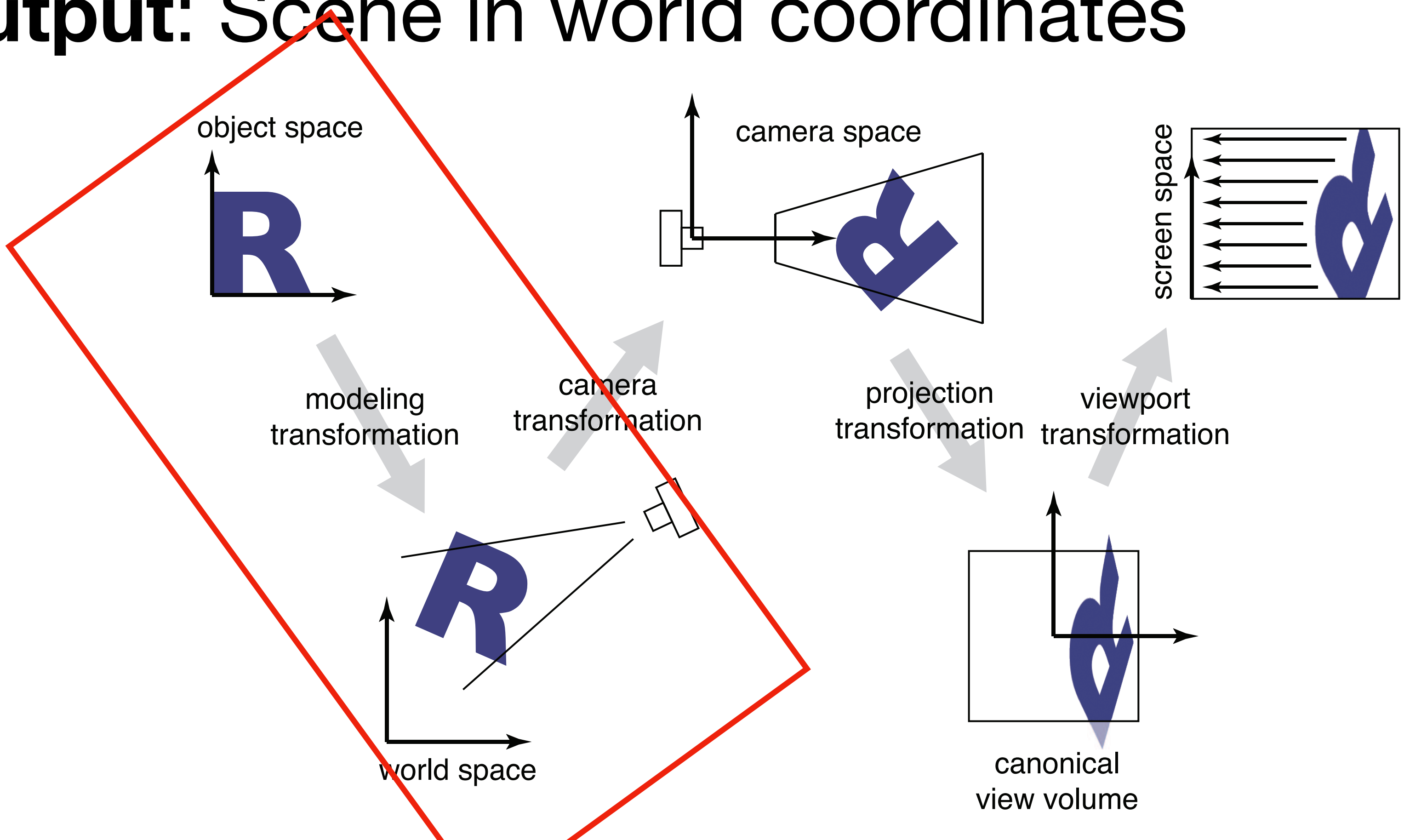
- https://www.cs.cornell.edu/courses/cs4620/2020fa/demos_cs4620/view_explore/view_explore.html

Model Matrix

Input: Scene in model coordinates

Parameters: Pose, scale, etc of model in scene

Output: Scene in world coordinates

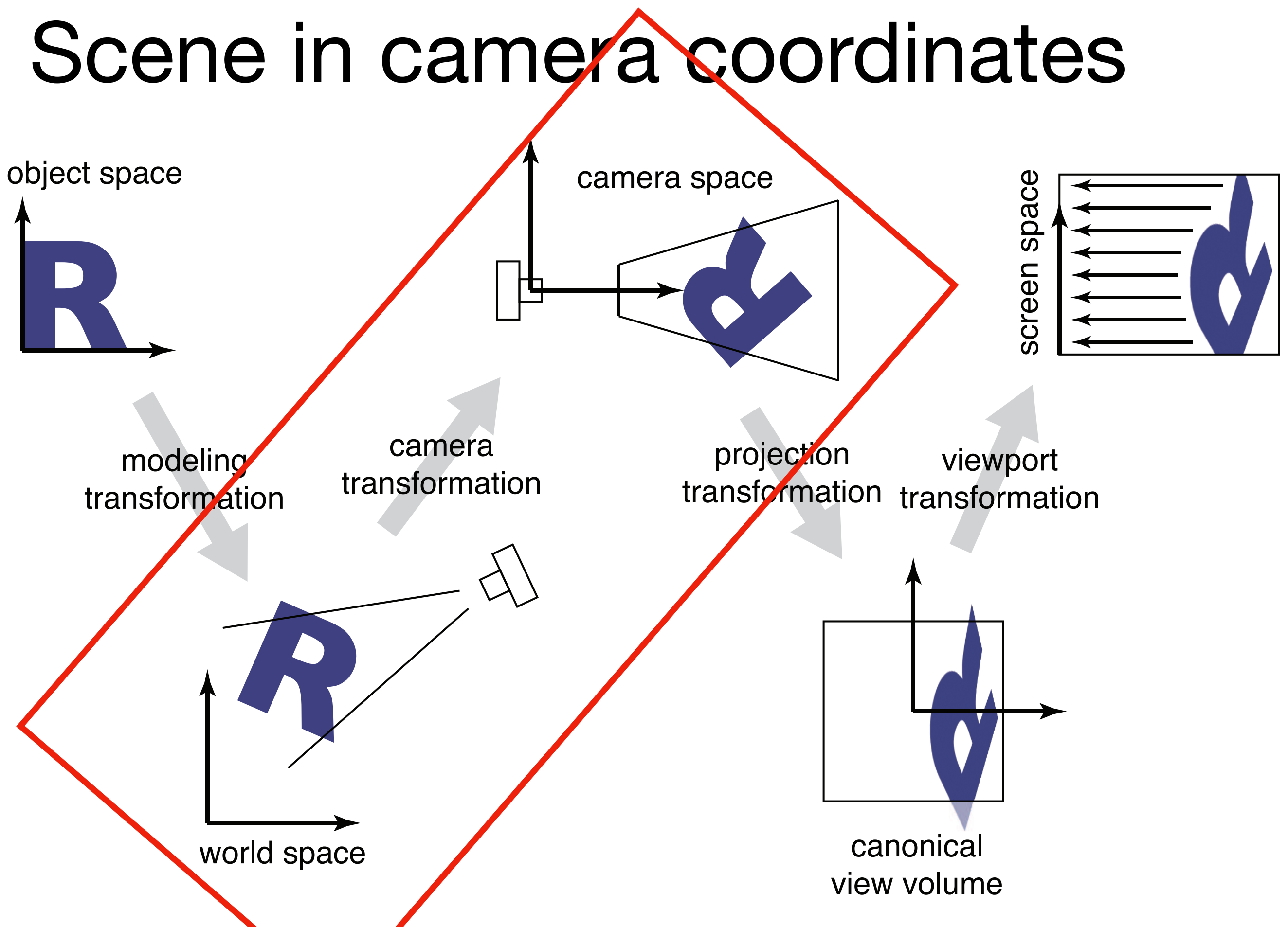


Camera Matrix

Input: Scene in world coordinates

Parameters: Camera frame (**u**, **v**, **w**, **e**)

Output: Scene in camera coordinates

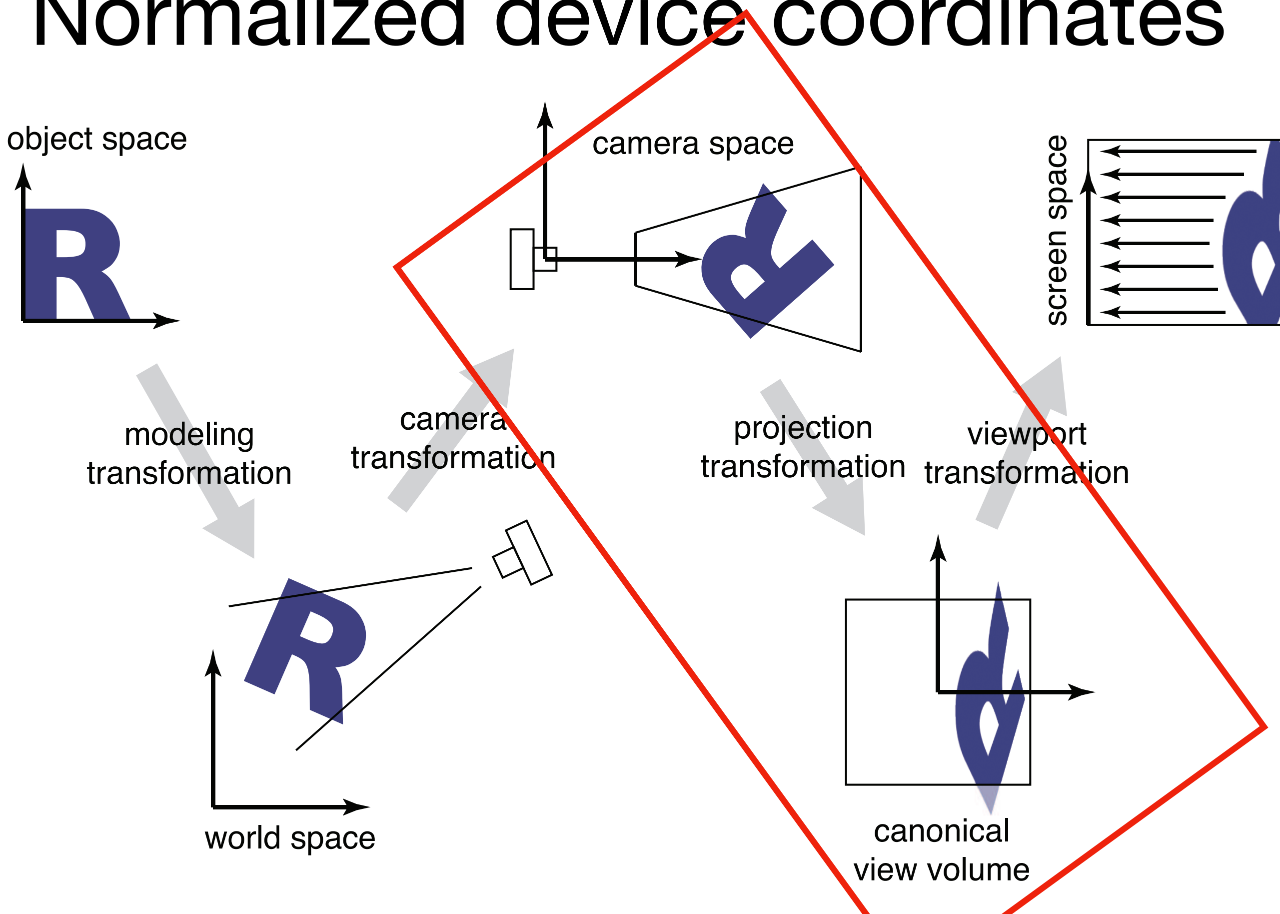


Projection Matrix - Orthographic

Input: Scene in (canonically-posed) camera coordinates

Parameters: Orthographic viewport dimensions

Output: Normalized device coordinates

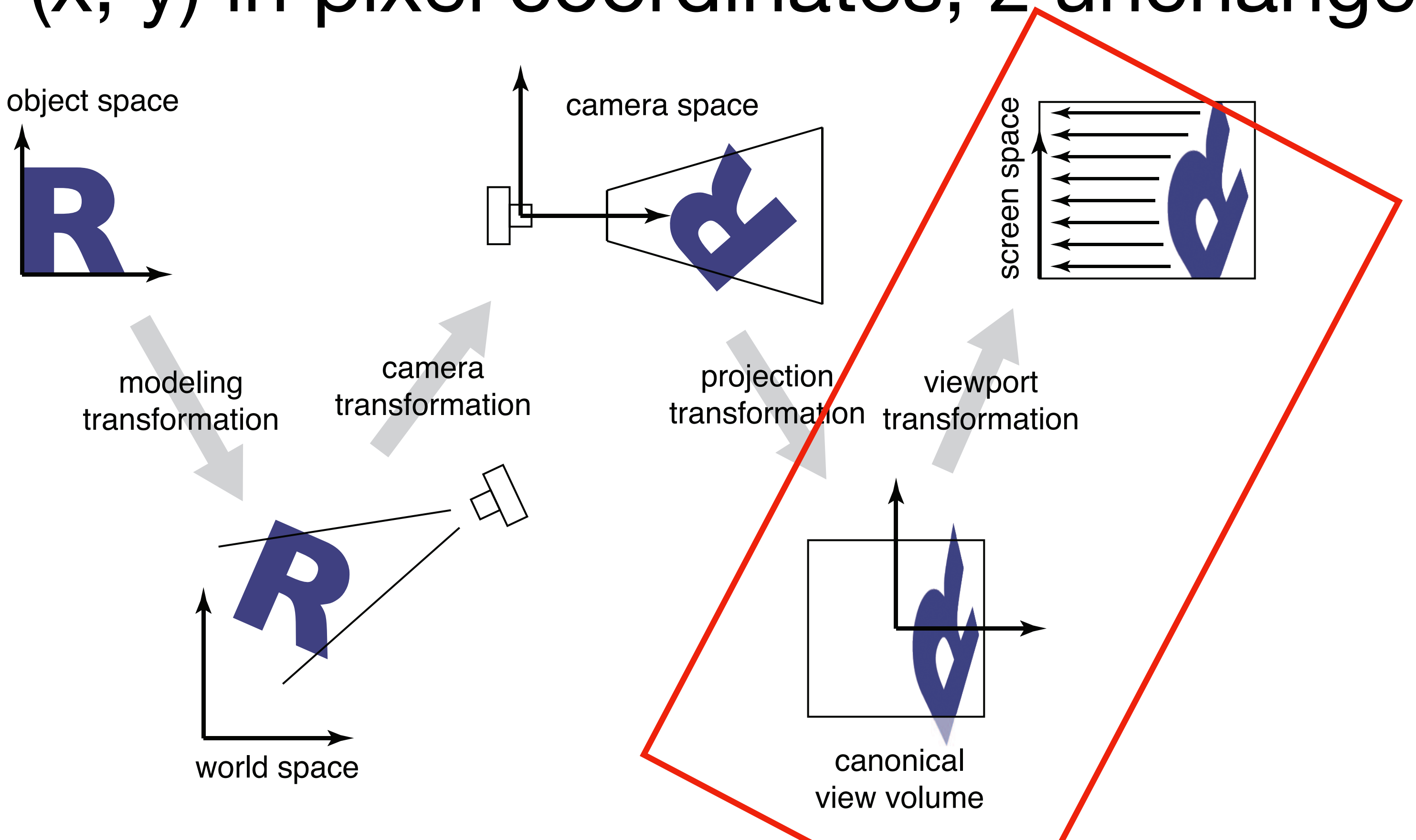


Viewport Matrix

Input: Scene in the canonical view volume

Parameters: W, H (image dimensions in pixels)

Output: (x, y) in pixel coordinates; z unchanged



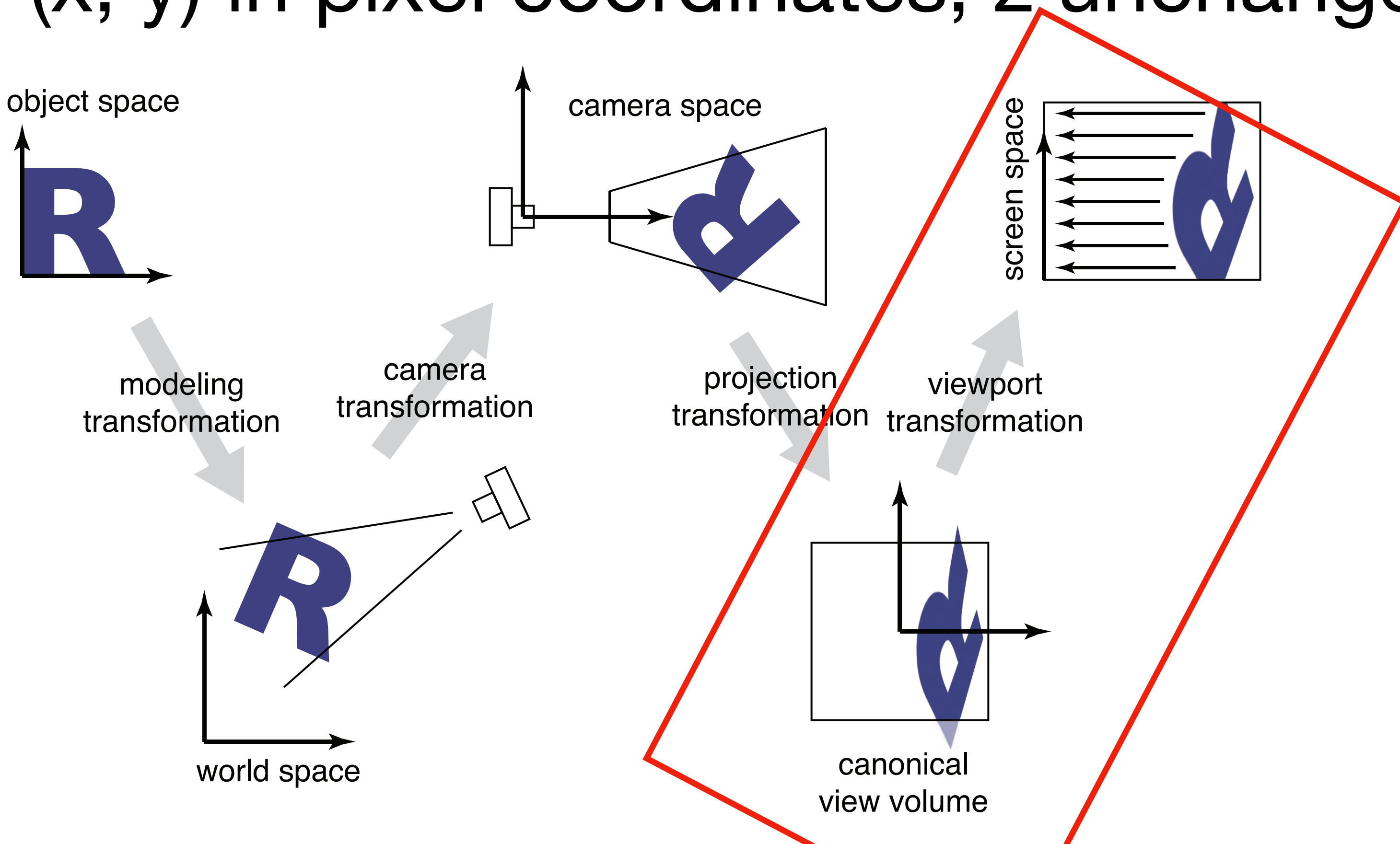
Let's build it

Viewport Matrix

Input: Scene in the canonical view volume

Parameters: W, H (image dimensions in pixels)

Output: (x, y) in pixel coordinates; z unchanged

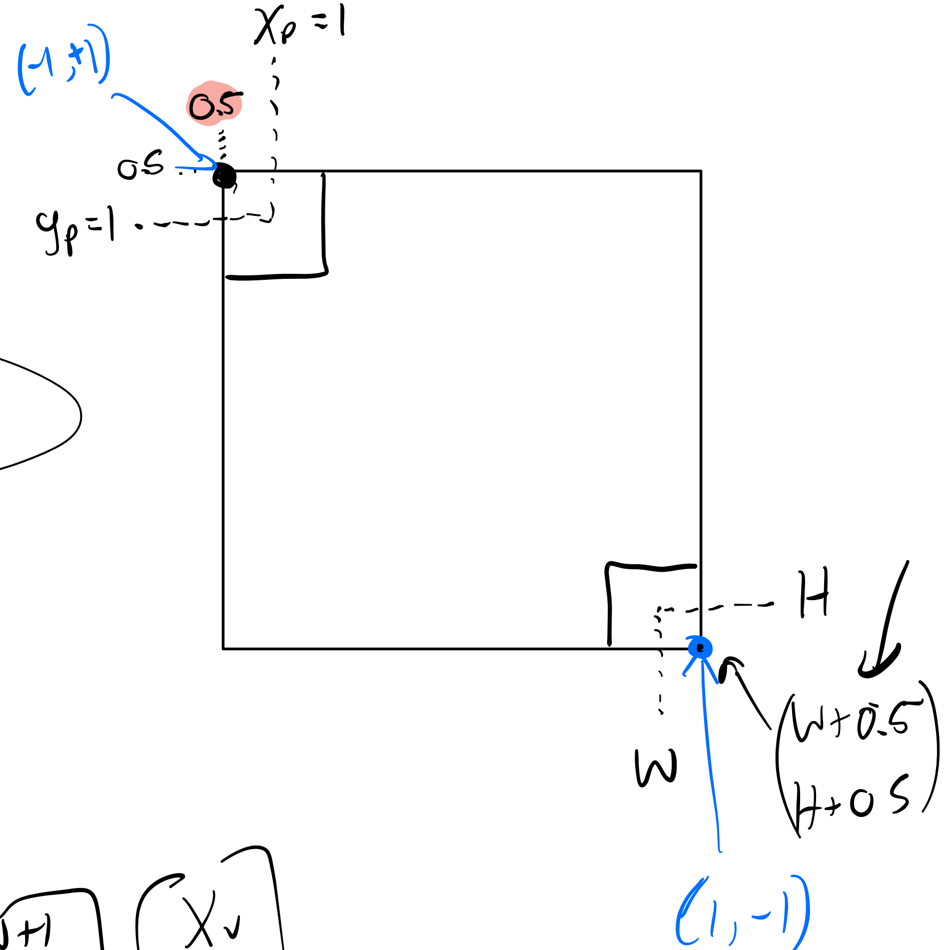


(j)

$$X_p = \left(\frac{X_v + 1}{2}\right) w + \frac{1}{2}$$

$$y_p = \left(\frac{-y_v + 1}{2}\right) h + \frac{1}{2}$$

$$z_p = z_v$$



$$\begin{bmatrix} x_p \\ y_p \\ z_p \\ 1 \end{bmatrix} = \begin{bmatrix} w/2 & 0 & 0 & \frac{w+1}{2} \\ 0 & -h/2 & 0 & \frac{h+1}{2} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_v \\ y_v \\ z_v \\ 1 \end{bmatrix}$$

$$x_p = \frac{w x_v}{2} + \frac{w+1}{2}$$

$$y_p = -\frac{h}{2} y_v + \frac{h+1}{2}$$

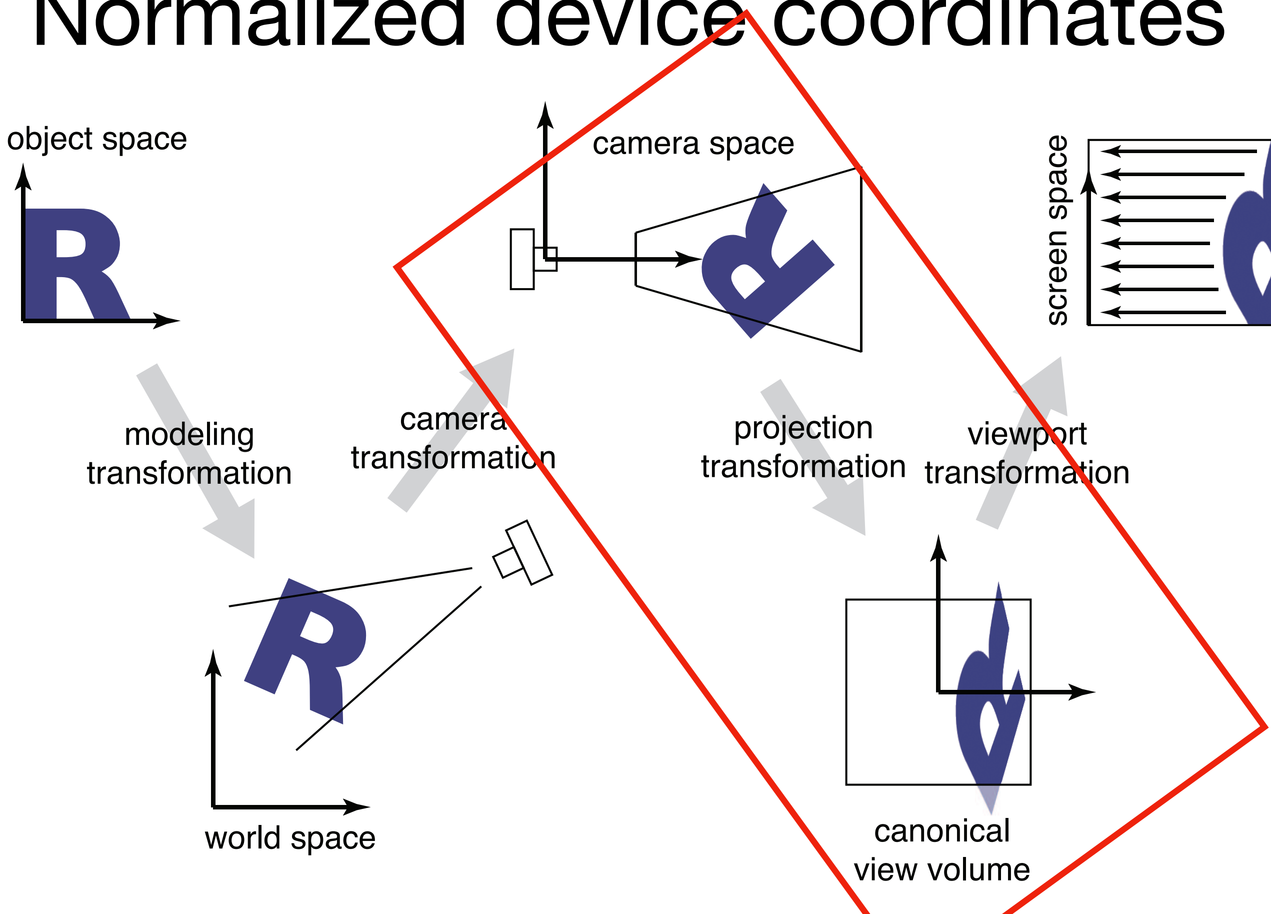
$$z_p = z_v$$

Projection Matrix - Orthographic

Input: Scene in (canonically-posed) camera coordinates

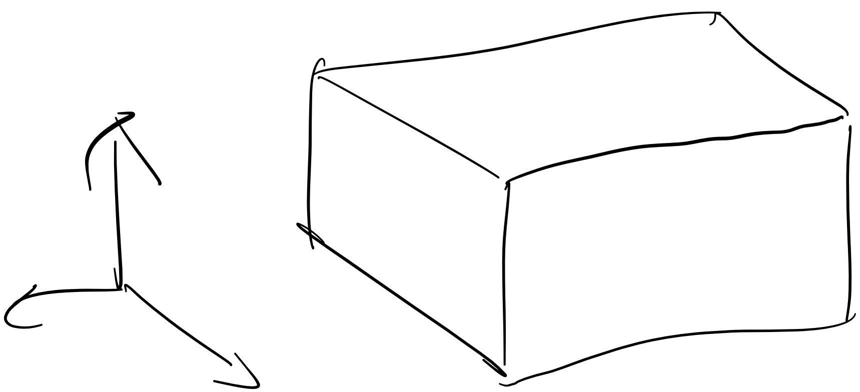
Parameters: Orthographic viewport dimensions

Output: Normalized device coordinates



Given: (l, b, n) and (r, t, f)

1. Translate (l, b, n) to $(0, 0, 0)$
2. Scale $r-l$, $t-b$, $n-f$ → $(2, 2, 2)$
3. Translate $(1, 1, 1)$ to $(0, 0, 0)$



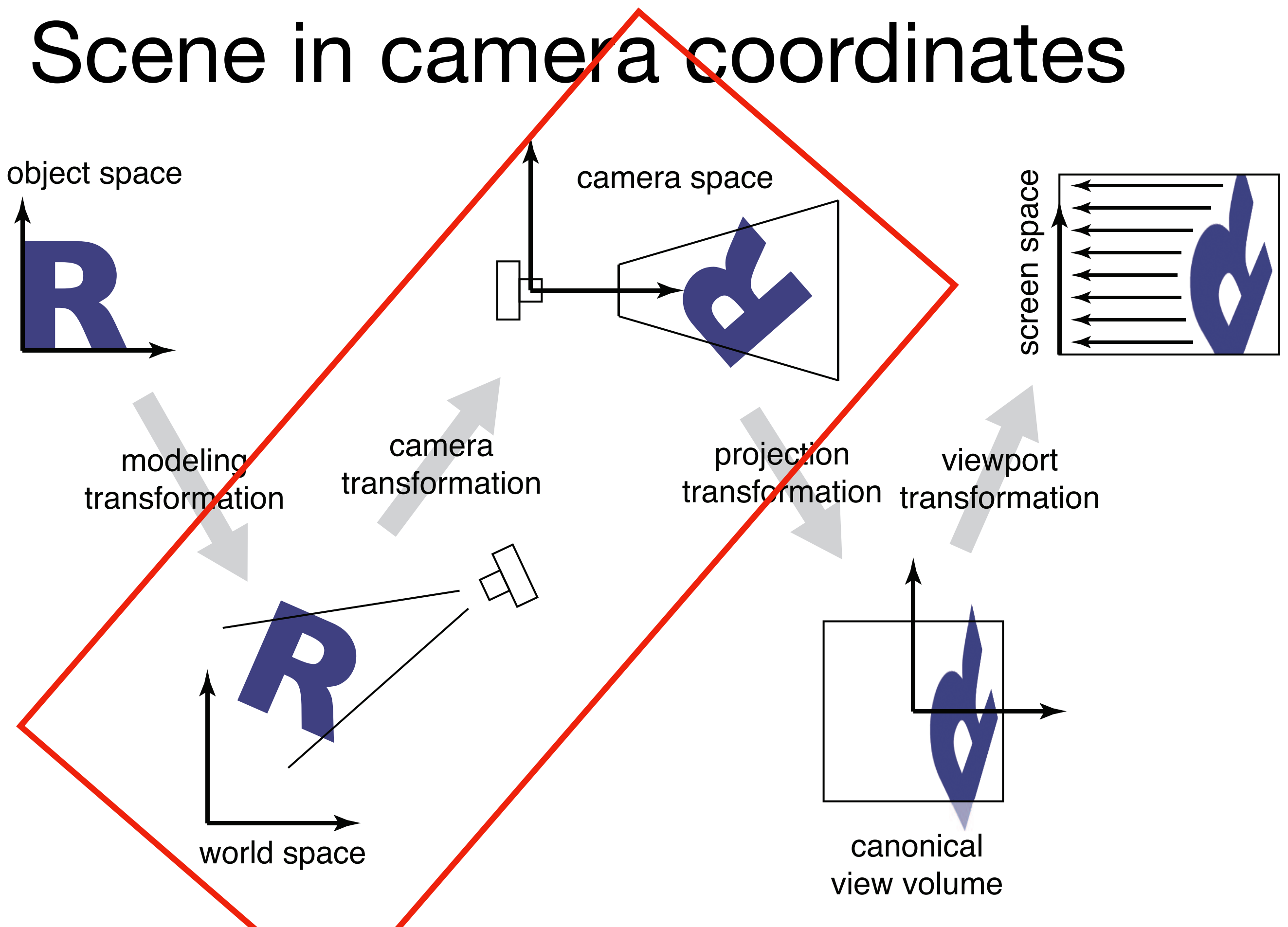
$$
\underset{(3)}{\begin{bmatrix} I_{3\times3} & \begin{matrix}-1\\-1\\-1\end{matrix} \\ 0\ 0\ 0 & 1 \end{bmatrix}}
\underset{(2)}{\begin{bmatrix} \frac{2}{r-l} & 0 & 0 & 0 \\ 0 & \frac{2}{t-b} & 0 & 0 \\ 0 & 0 & \frac{2}{n-f} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}}
\underset{(1)}{\begin{bmatrix} I_{3\times3} & \begin{matrix}-l\\-b\\-n\end{matrix} \\ 0\ 0\ 0 & 1 \end{bmatrix}}
$$

Camera Matrix

Input: Scene in world coordinates

Parameters: Camera frame (**u**, **v**, **w**, **e**)

Output: Scene in camera coordinates



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Parameters: Pose, scale, etc of model in scene

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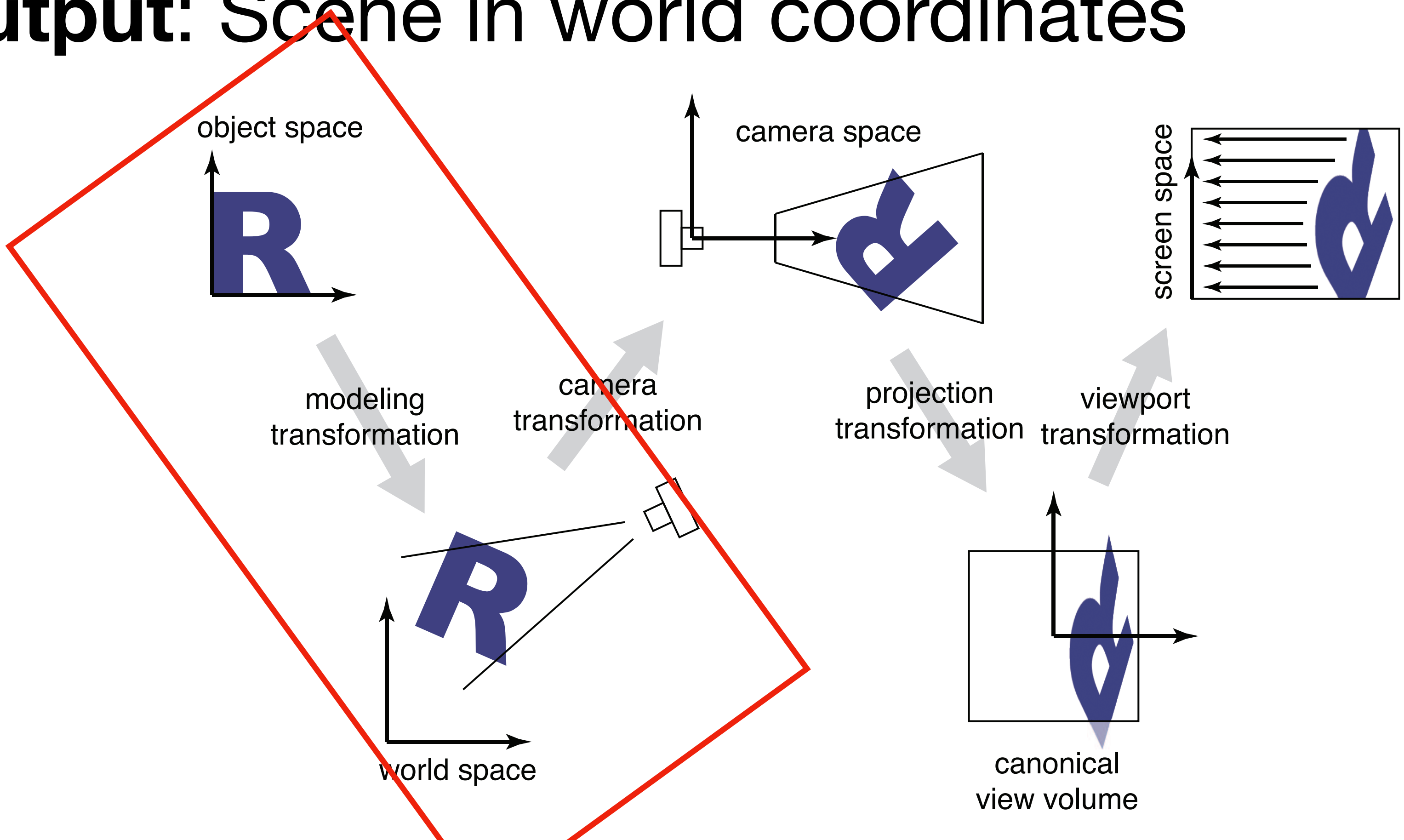

What about perspective cameras?

- https://www.cs.cornell.edu/courses/cs4620/2020fa/demos_cs4620/view_explore/view_explore.html

Perspective Projection

Exercise:
Find $\mathbf{y_s}$, the y coordinate of the point where (x, y, z) projects onto the viewport.