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Department of Biomedical Engineering

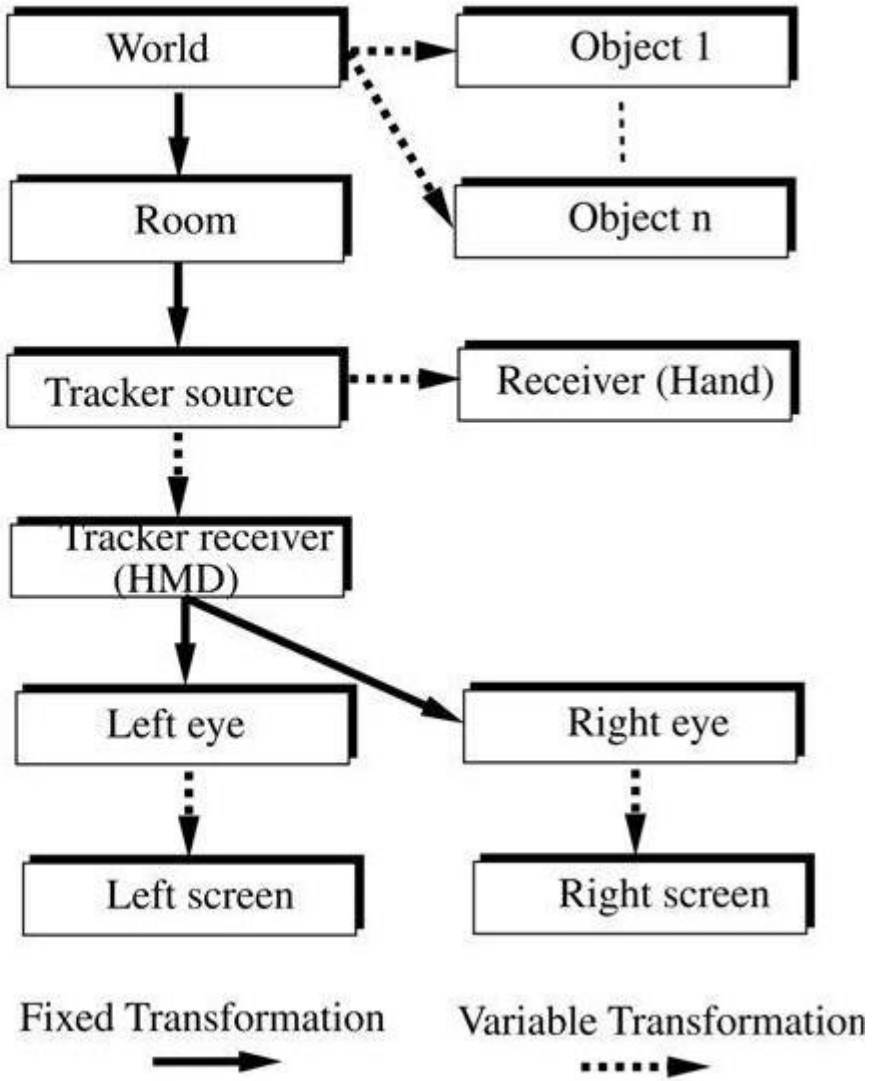
Course Name: 19BMT401 – Virtual Reality in Medicine

IV Year : VII Semester

Unit II –MODELING

Topic : VR Kinematics Modeling

VR Kinematics Modeling

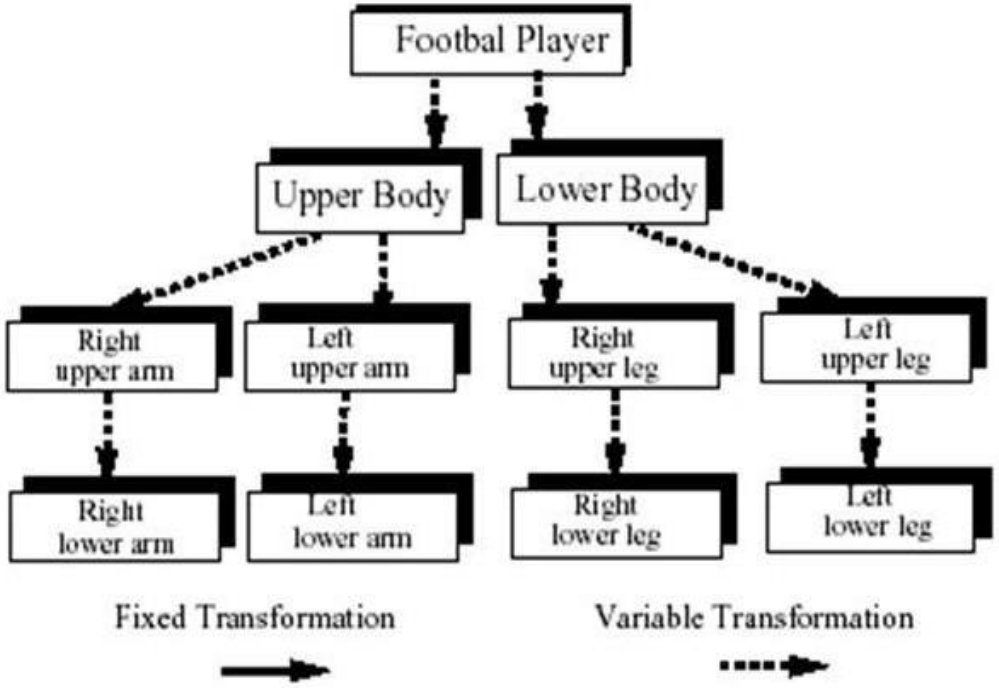


Object Hierarchies:

- ✓ Allows models to be partitioned into a hierarchy, and become dynamic;
- ✓ Segments are either parents (higher level object) or children (lower level objects).
- ✓ The motion of a parent is replicated by its children but not the other way around.
- ✓ Example – the virtual human and the virtual hand;
- ✓ At the top of the hierarchy is the "world global transformation" that determines the view to the scene.

VR Kinematics Modeling

a)



b)

Model hierarchy: a) static model (Viewpoint Datalabs); b) segmented model.

Object hierarchy for a Virtual Hand:

✓Transformation matrices can be compounded to obtain the motion of the fingertip versus the world coordinates.

$$T_{global \leftarrow fingertip}(t) = T_{global \leftarrow W}(t)\, T_{W \leftarrow source}\, T_{source \leftarrow palm}(t) \bullet T_{palm \leftarrow 1}(t) T_{1 \leftarrow 2}(t)\, T_{2 \leftarrow 3}(t)\, T_{3 \leftarrow fingertip}$$

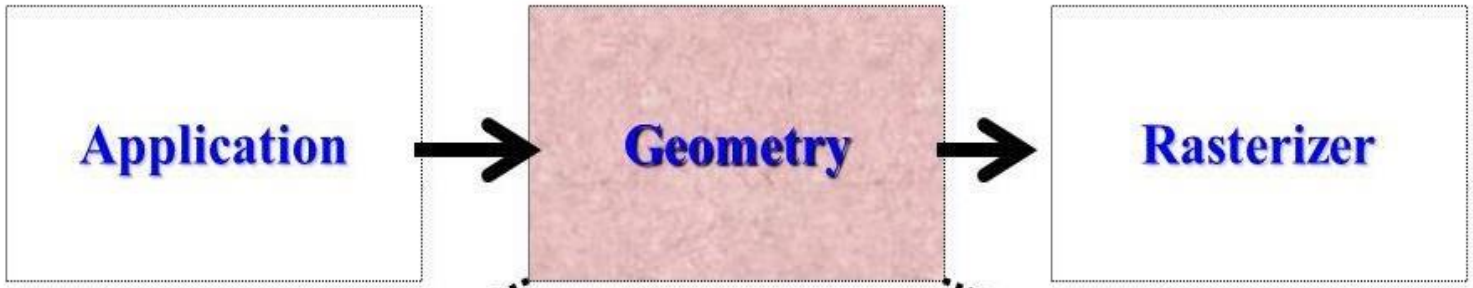
$T_{W \leftarrow palm}(t)$ is given by the glove tracker

$T_{palm \leftarrow 1}(t)$, $T_{1 \leftarrow 2}(t)$, $T_{2 \leftarrow 3}(t)$ are given by the sensors on the glove

VR Kinematics Modeling:

- ✓ Homogeneous transformation matrices;
- ✓ Object position;
- ✓ Transformation invariants;
- ✓ Object hierarchies;
- ✓ **Viewing the 3-D world.**

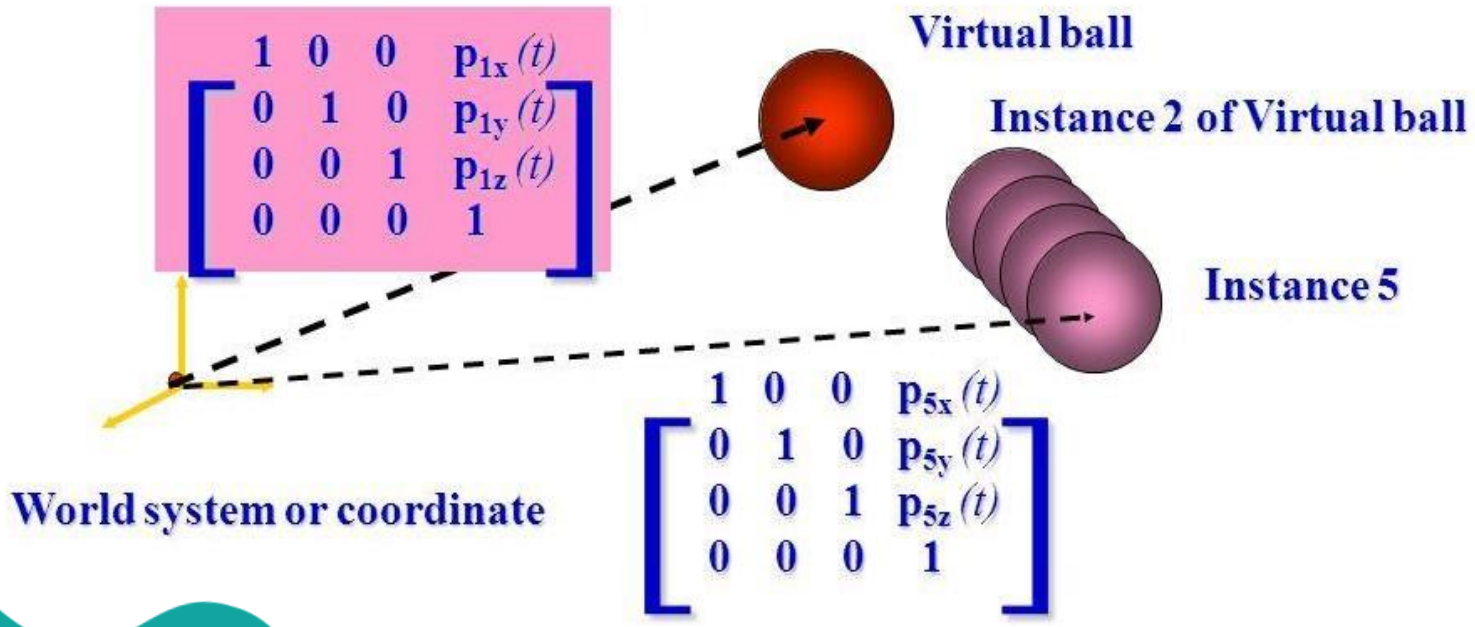
The Rendering Pipeline



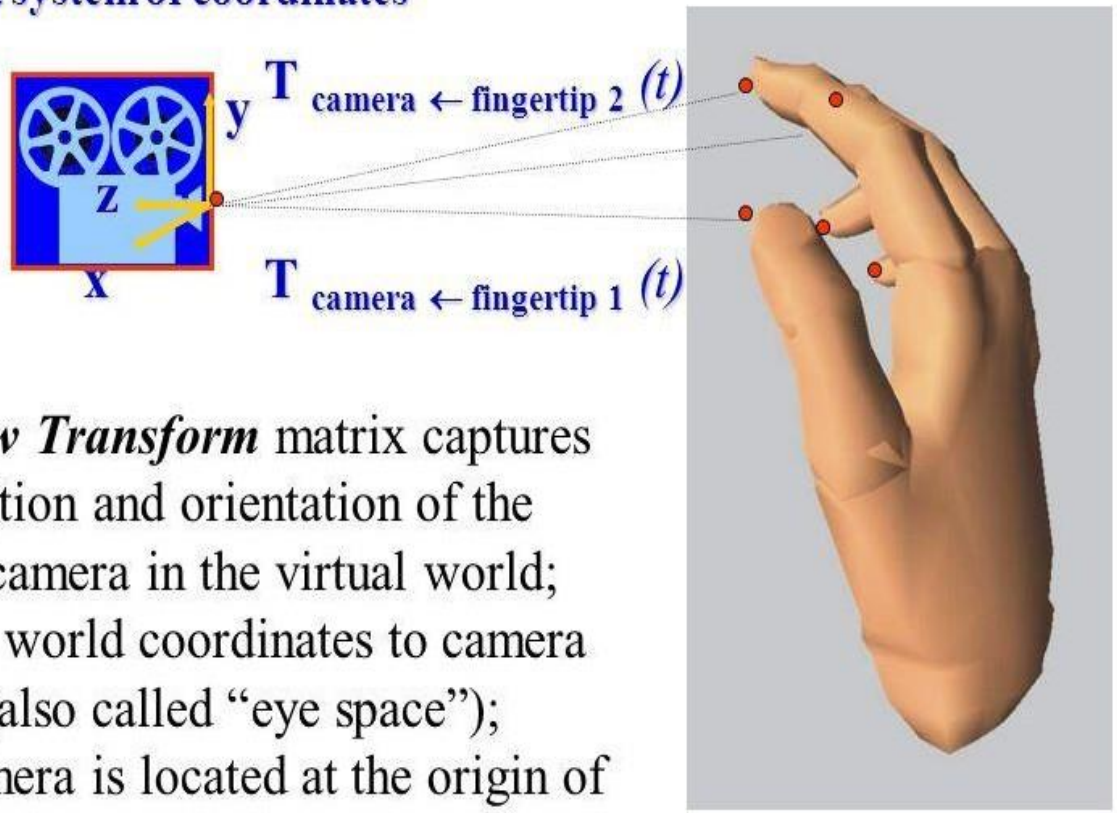
The Geometry Functional Sub-Stages

Model and Viewing Transformations:

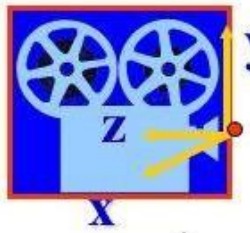
- Model transforms link object coordinates to world coordinates. By changing the model transform, the same object can appear several times in the scene. We call these ***instances***.



Camera system of coordinates

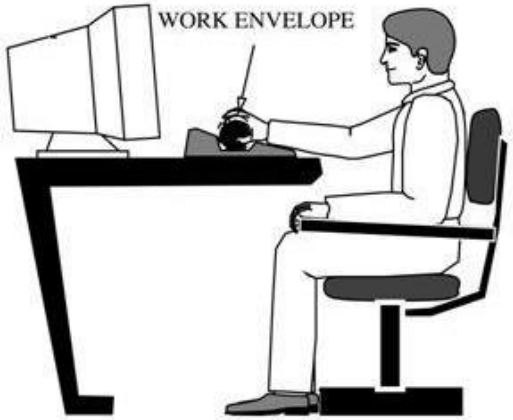


- The ***View Transform*** matrix captures the position and orientation of the virtual camera in the virtual world;
- It maps world coordinates to camera space (also called "eye space");
- The camera is located at the origin of the camera coordinate system, looking in the negative ***Z*** axis, with ***Y*** pointing upwards, and ***X*** to the right.



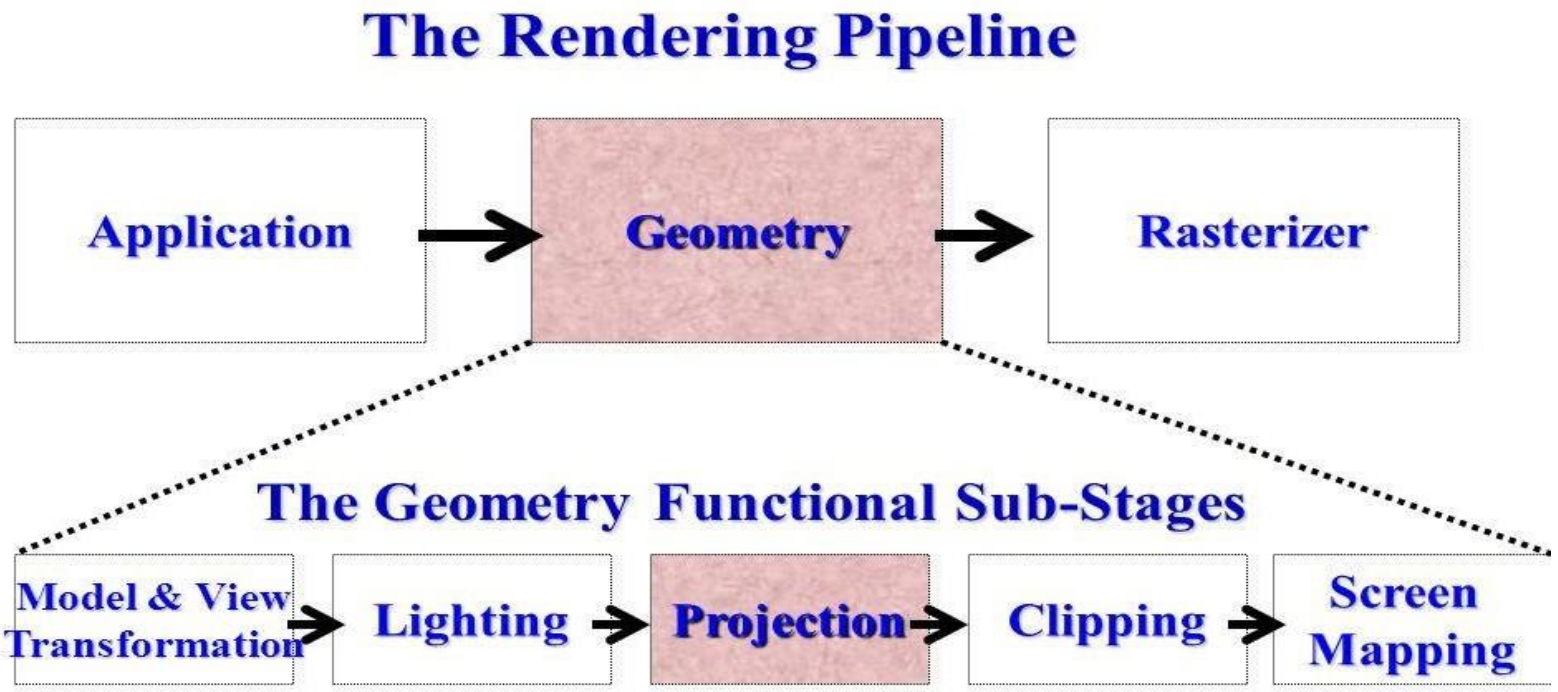
Camera "fly-by"

$T_{camera \leftarrow tree}(t)$



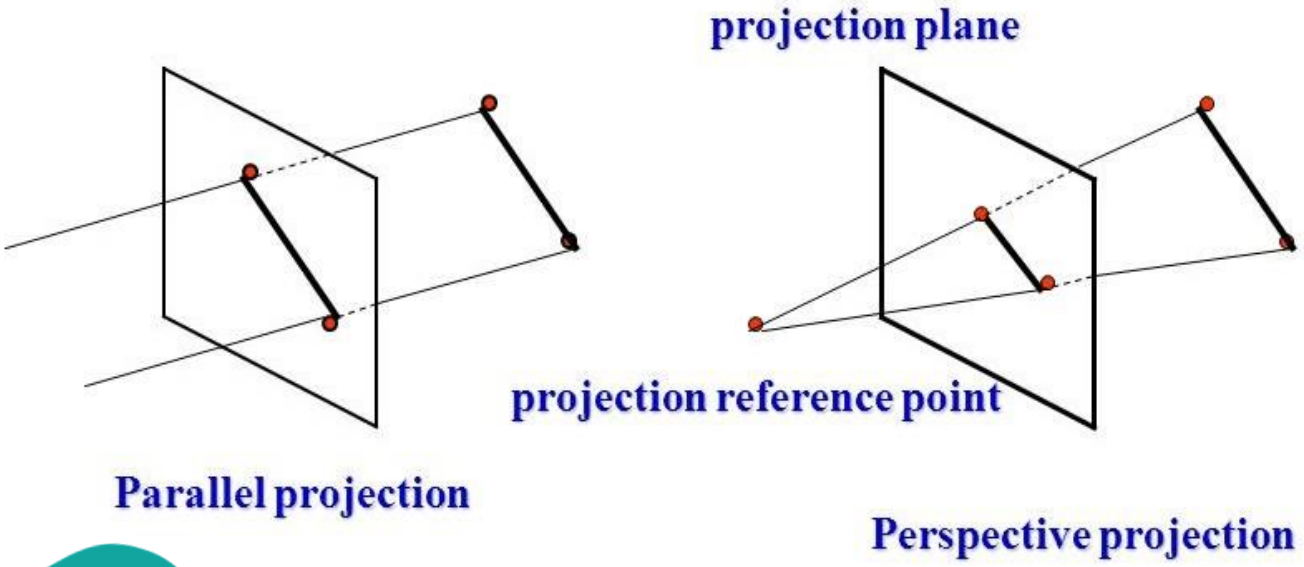
User interactively changes the ***viewing transform*** by changing the position and aim of the virtual camera = "fly-by."

VR Modeling


The Rendering Pipeline
Application
Geometry
Rasterizer
The Geometry Functional Sub-Stages
Model & View Transformation
Lighting
Projection
Clipping
Screen Mapping

Projection Transformations:

✓Models what portion (volume) of the virtual world the camera actually sees. There are two kinds of projections, ***parallel*** projection and ***perspective*** projection VR uses perspective.

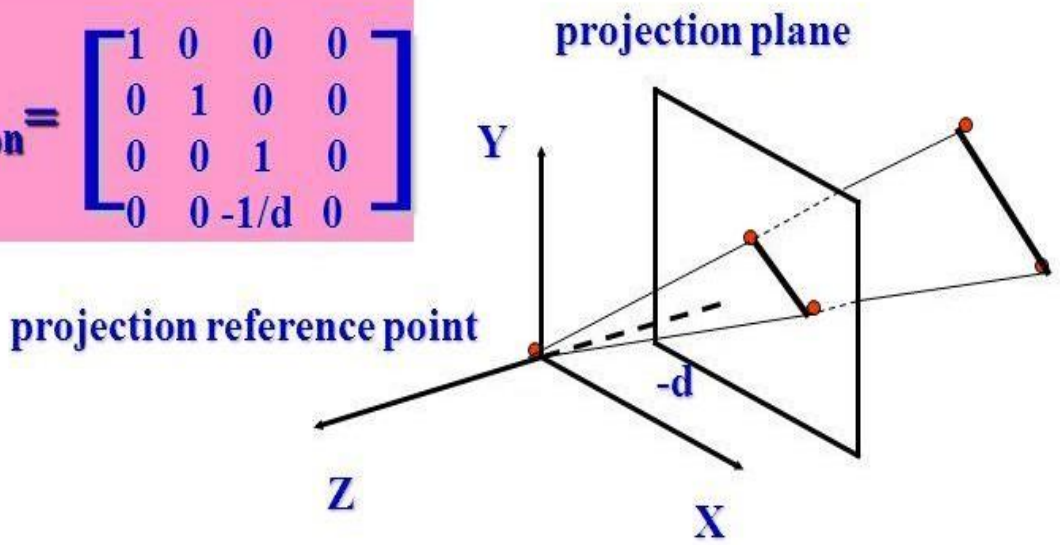


Perspective Projection Transformation:

✓If the projection reference point is at the origin of the system of coordinates, and the projection plane is at $-d$,

Then the (non invertible) perspective projection transformation matrix is:

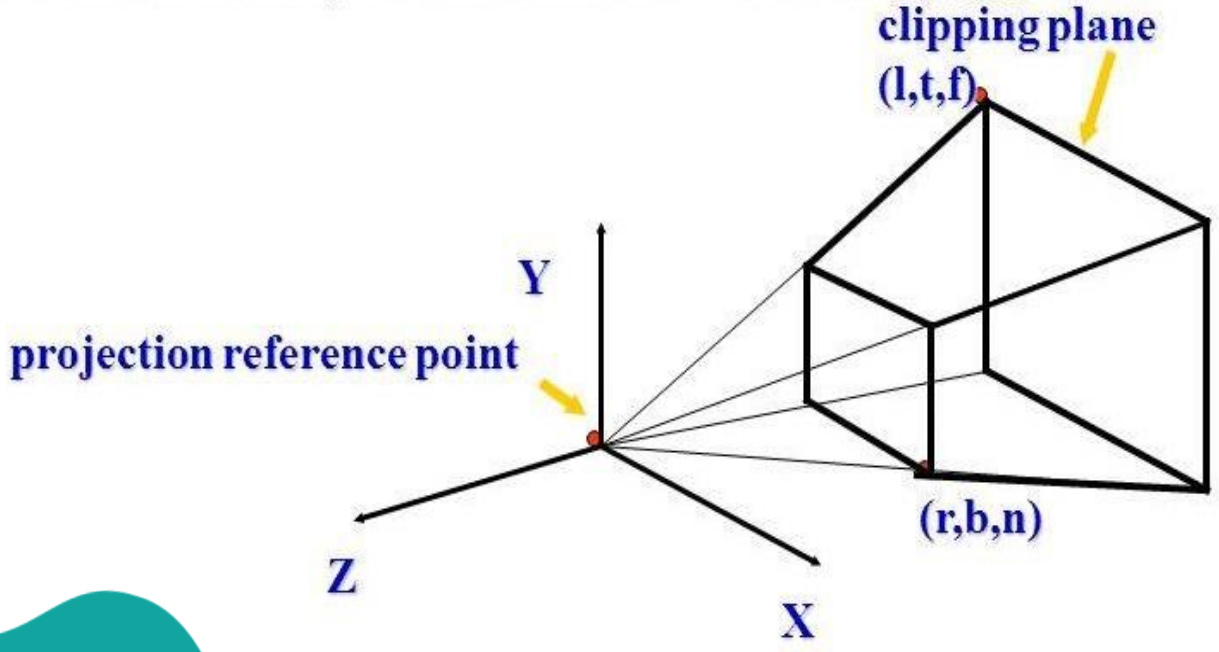
$$T_{projection} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & -1/d & 0 \end{bmatrix}$$



Second Perspective Projection Transformation:

- The portion of the virtual world seen by the camera at a given time is limited by front and back "clipping planes".

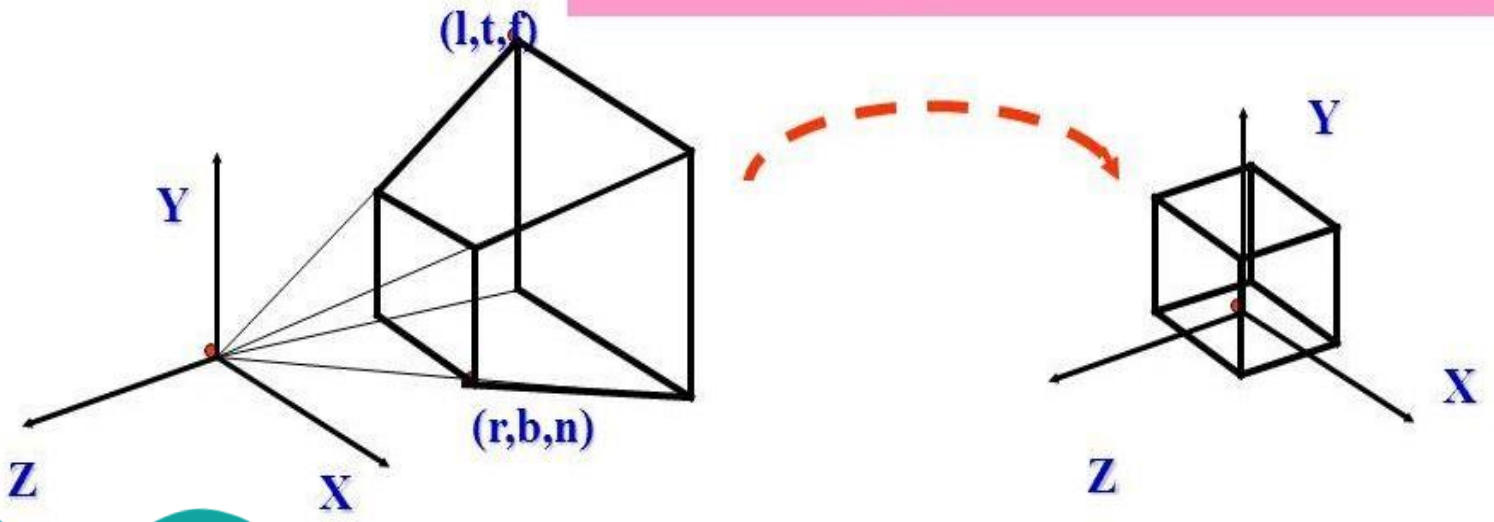
These are at $z=n$ and $z=f$. Only what is within the viewing cone (also called fulcrum) is sent down the rendering pipe.



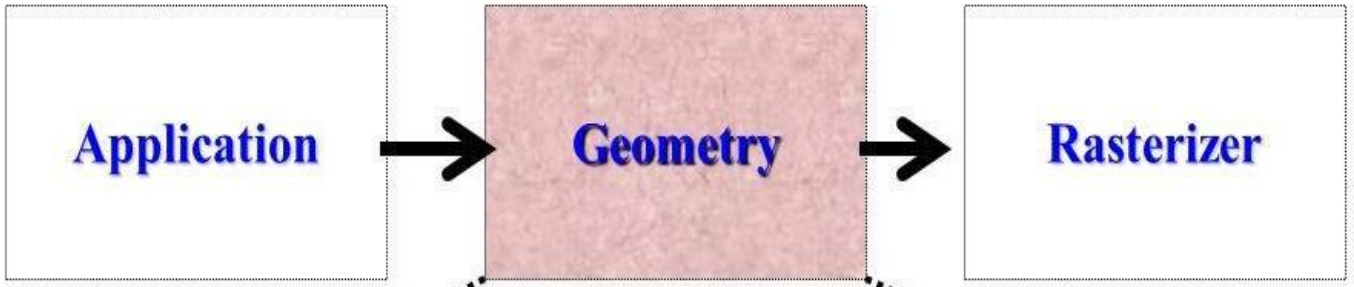
Canonical Mapping:

✓The second projection transform maps the viewing volume to a unit cube with extreme points at (-1,-1,-1) and (1,1,1). This is called the ***canonical view volume***.

$$T'_{projection} = \begin{bmatrix} \frac{2n}{(r-l)} & 0 & \frac{-(r+l)}{(r-l)} & 0 \\ 0 & \frac{2n}{(t-b)} & \frac{-(t+b)}{(t-b)} & 0 \\ 0 & 0 & \frac{(f+n)}{(f-n)} & \frac{-2fn}{(f-n)} \\ 0 & 0 & 1 & 0 \end{bmatrix}$$



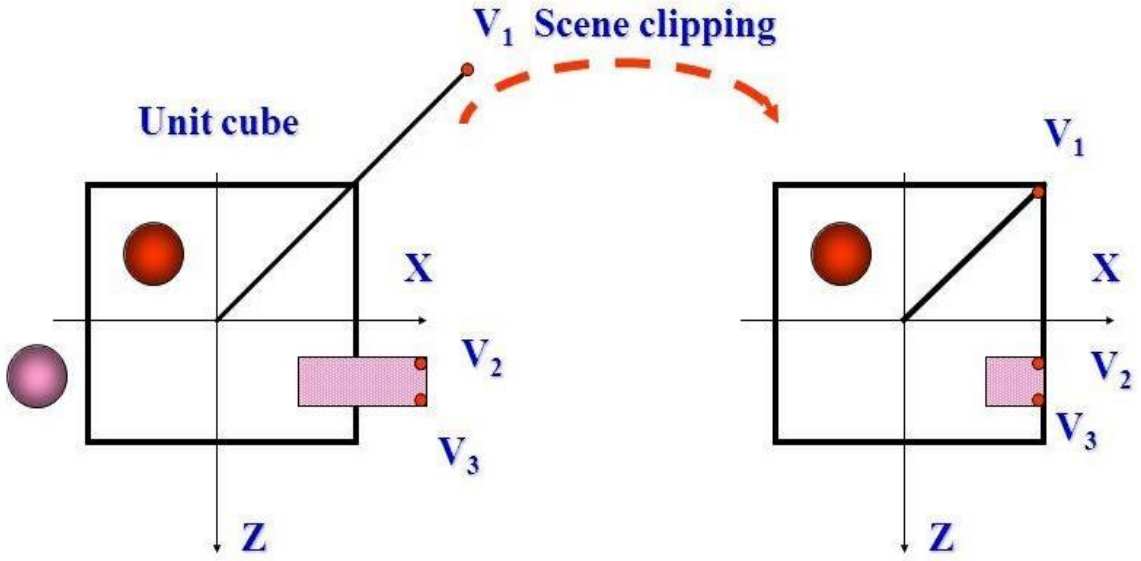
The Rendering Pipeline



The Geometry Functional Sub-Stages

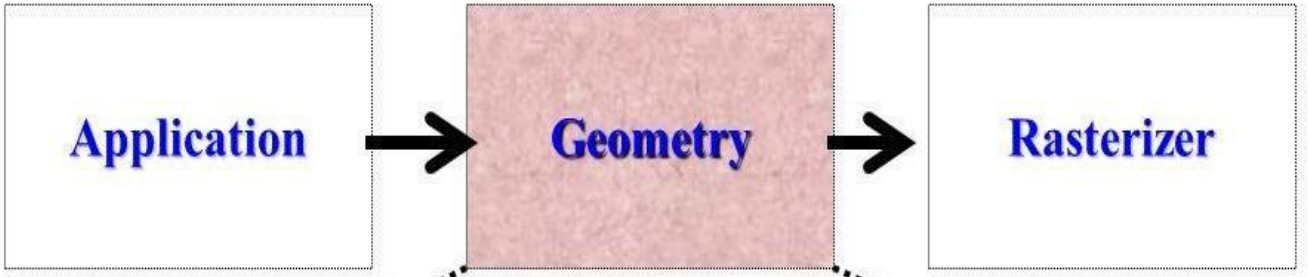
Clipping Transformation:

✓Since the fulcrum maps to the unit cube, only objects inside it will be rendered. Some objects are partly inside the unit cube (ex. the line and the rectangle). Then they need to be "clipped". The vertex V_1 is replaced by new one at the intersection between the line and the viewing cone, etc.



VR Modeling

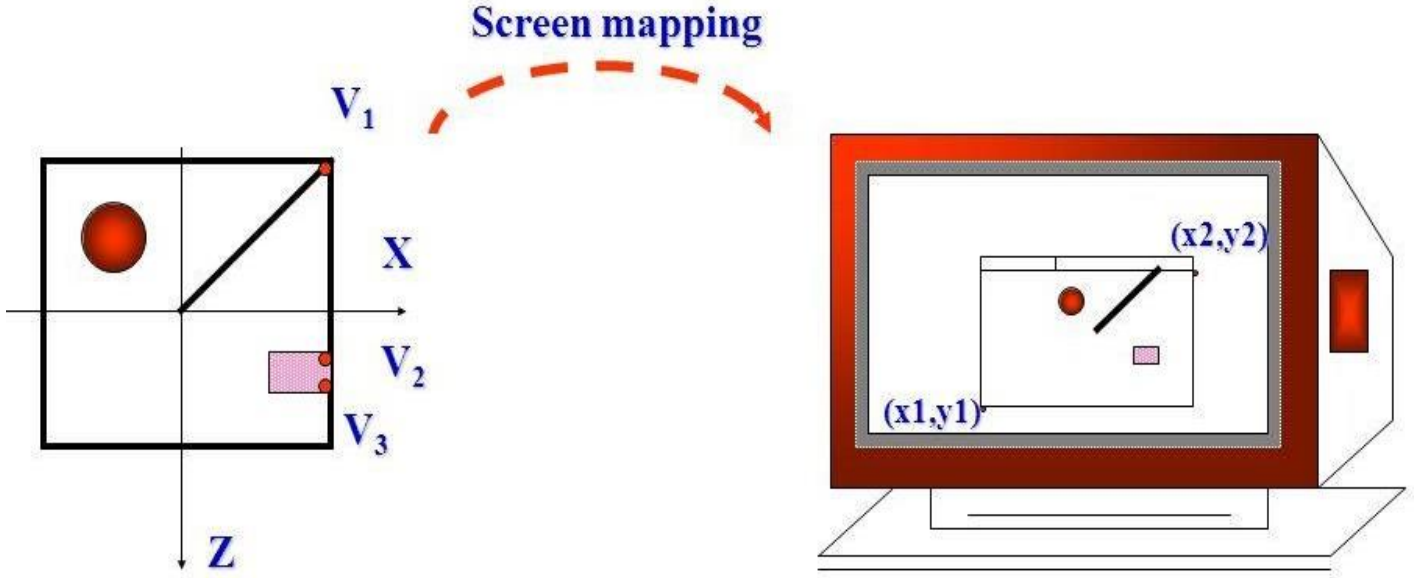
The Rendering Pipeline



The Geometry Functional Sub-Stages

Screen Mapping (Viewport Transformation):

- The scene is rendered into a window with corners (x_1,y_1), (x_2,y_2)
- Screen mapping is a translation followed by a scaling that affects the **x** and **y** coordinates of the primitives (objects), but not their z coordinates. Screen coordinates plus $z \in [-1,1]$ are passed to the rasterizer stage of the pipeline.



Thank You