UNIT 13: 3-D VIEWING

UNIT STRUCTURE

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13.1 LEARNING OBJECTIVES

After going through this unit, you will be able to:

- Learn about Viewing pipeline
- Learn about viewing coordinates
- Learn about view volume
- Learn about general projection transforms and clipping

13.2 INTRODUCTION

We have already been acquainted with the idea of Translation, rotation, scaling, reflection and shear transformations, and composite transformations in the previous unit.

In this unit we will learn about Viewing pipeline, viewing coordinates, view volume and general projection transforms and clipping. In the next unit we will explore the concept of Animation Basic, Computer Animation, Principles of Animation, Types of Animation, Animation Software (Maya, etc.) and Hardware, Common Terms in Animation.

13.3 VIEWING PIPELINE

A 3D projection (or graphical projection) is a design technique used to display a three-dimensional (3D) object on a two-dimensional (2D) surface. These projections rely on visual perspective and aspect analysis to project a complex object for viewing capability on a simpler plane. The viewing-pipeline in 3 dimensions is almost the same as the 2D-viewing-pipeline. Only after the definition of the viewing direction and orientation (i.e., of the camera) an additional projection step is done, which is the reduction of 3D-data onto a projection plane:

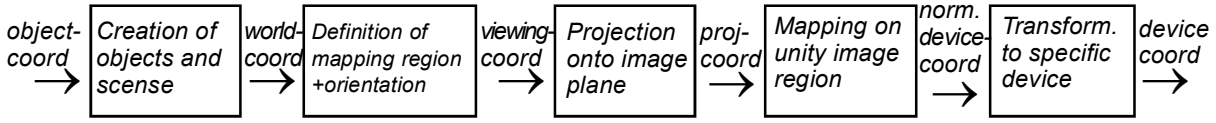


Figure 13.1: Projection step

This projection step can be arbitrarily complex, depending on which 3D-viewing concepts should be used.

13.4 VIEWING COORDINATES

Similar to photography there are certain degrees of freedom when specifying the camera. They are:

- Camera position in space
- Viewing direction from this position
- Orientation of the camera (view-up vector)
- Size of the display window (corresponds to the focal length of a photo-camera) With these parameters the camera-coordinate system is defined (viewing coordinates). Usually the xy-plane of this viewing-coordinate system is orthogonal to the main viewing direction and the viewing direction is in the direction of the negative z-axis.

Based on the camera position the usual way to define the viewing-coordinate system is:

- Choose a camera position (also called eye-point, or view-point).
- Choose a viewing direction = Choose the z- direction of the viewing-coordinates.

- Choose a direction "upwards". From this, the x-axis and y-axis can be calculated: the image-plane is orthogonal to the viewing direction. The parallel projection of the "view-up vector" onto this image plane defines the y-axis of the viewing coordinates.
- Calculate the x-axis as vector-product of the z- and y-axis.
- The distance of the image-plane from the eye-point defines the viewing angle, which is the size of the scene to be displayed.

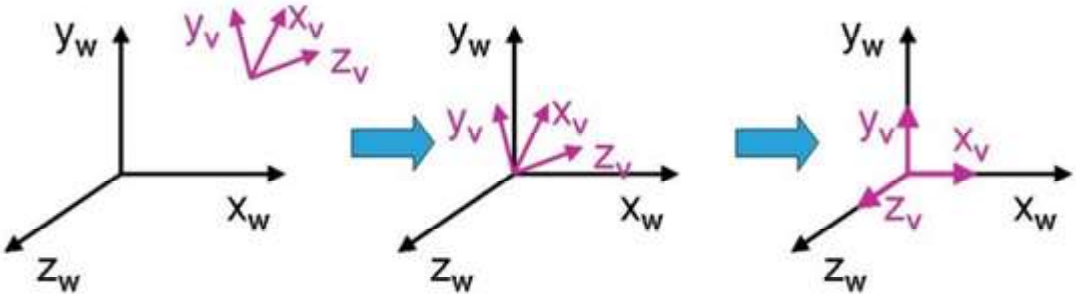


Fig.13.2: Viewing Coordinates



Fig.13.3: World Coordinates

In animations the camera-definition is often automatically calculated according to certain conditions, e.g. when the camera moves around an object or in flight-simulations, such that desired effects can be achieved in an uncomplicated way. To convert world-coordinates to viewing-coordinates a series of simple transformations is needed: mainly a translation of the coordinate origins onto each other and afterwards 3 rotations, such that the coordinate-axes also coincide (two rotations for the first axis, one for the second axis, and the third axis is already correct then). Of course, all these transformations can be merged by multiplication into one matrix, which looks about like this: $M_{WC,\ VC} = R_z \cdot R_y \cdot R_x \cdot T$

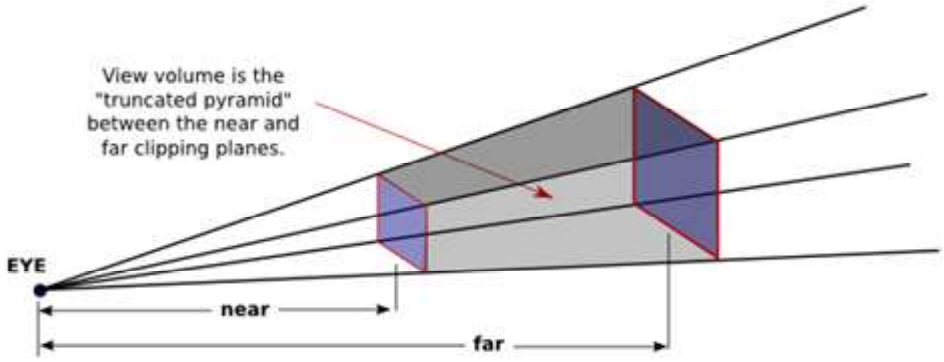


The volume of space that is actually rendered into the image is called the view volume. Things inside the view volume make it into the image; things that are not in the view volume are clipped and cannot be seen. For purposes of drawing, OpenGL applies a coordinate transform that maps the view volume onto a cube.

EXERCISE

1. What is world coordinates?

13.5 VIEW VOLUME



The view volume is bounded by six planes-the four sides plus the top and bottom of the truncated pyramid. These planes are called clipping planes because anything that lies on the wrong side of each plane is clipped away. The projection transformation maps the six sides of the truncated pyramid in eye coordinates to the six sides of the clipping cube in clip coordinates.

3D view volume Define a volume in which objects are visible for parallel projection, a box for perspective projection, a frustum surfaces outside this volume are clipped or removed and not drawn.

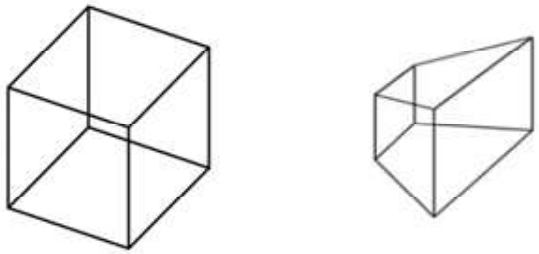


Figure 13.5: objects

CHECK YOUR PROGRESS

Q 1: Define view volume.

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13.6 GENERAL PROJECTION TRANSFORMS

Once a 3D model has been completed, its co-ordinates need to be converted to 2 dimensions in order to display the scene on a flat computer monitor or to print it on paper. This process of converting from 3D to 2D is called projection. The visual appearance of a 3D model depends on the position of the viewer (among other things), so this must be taken into account when projecting a model. There are two main types of projection available, parallel and perspective. n three-dimensional viewing, a rectangular view window, or projection window, in the view plane is used to the same effect. Edges of the view window are parallel to the x,y axes, and the window boundary positions are specified in viewing coordinates. The view window can be placed anywhere on the view plane.

The projection matrix is typically a scale and perspective projection. The projection transformation converts the viewing frustum into a cuboid shape. The near end of the viewing frustum is smaller than the far end, which has the effect of expanding objects that are near to the camera. This is how perspective is applied to the scene. In the viewing frustum, the distance between the camera and the origin of the viewing transformation space is defined arbitrarily as D, so the projection matrix looks like the following illustration.

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1/D \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The viewing matrix translates the camera to the origin by translating in the z-direction by -D. The translation matrix is as follows.

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & -D & 1 \end{bmatrix}$$

Multiplying the translation matrix by the projection matrix (T*P) gives

the composite projection matrix. It looks like the following illustration.

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1/D \\ 0 & 0 & -D & 0 \end{bmatrix}$$

The following illustration shows how the perspective transformation converts a viewing frustum to a new coordinate space. Notice that the frustum becomes cuboid and also that the origin moves from the upper-right corner of the scene to the center.

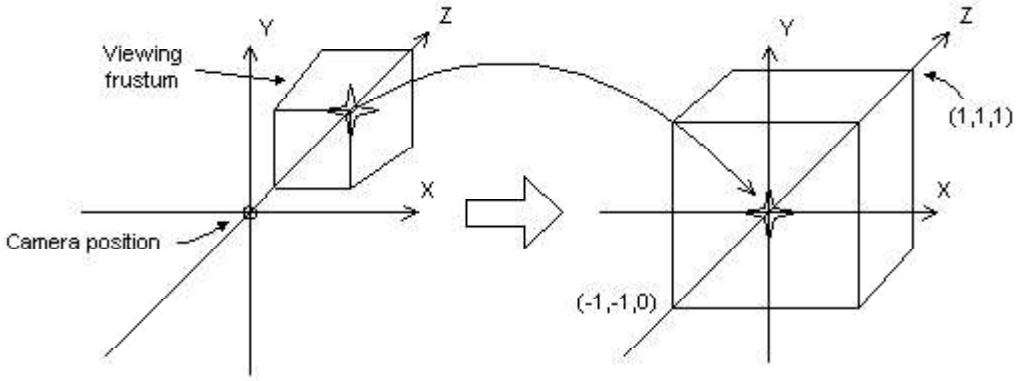


Figure 13.6: Cuboid

In the perspective transformation, the limits of the x- and y-directions are -1 and 1. The limits of the z-direction are 0 for the front plane and 1 for the back plane.

This matrix translates and scales objects based on a specified distance from the camera to the near clipping plane, but it does not consider the field of view (fov), and the z-values that it produces for objects in the distance can be nearly identical, making depth comparisons difficult. The following matrix addresses these issues, and it adjusts vertices to account for the aspect ratio of the viewport, making it a good choice for the perspective projection.

$$\begin{bmatrix} w & 0 & 0 & 0 \\ 0 & h & 0 & 0 \\ 0 & 0 & Q & 1 \\ 0 & 0 & -QZ_n & 0 \end{bmatrix}$$

In the following matrix, Zn is the z-value of the near clipping plane. The variables w, h, and Q have the following meanings. Note that fovw and fovk represent the viewport's horizontal and vertical fields of view, in radians.

$$w = \cot\left(fov_w / 2\right)$$
$$h = \cot\left(fov_k / 2\right)$$
$$Q = \frac{Z_t}{Z_f - Z_x}$$

For your application, using field-of-view angles to define the x- and y-scaling coefficients might not be as convenient as using the viewport's horizontal and vertical dimensions (in camera space). As the math works out, the following two formulas for w and h use the viewport's dimensions, and are equivalent to the preceding formulas.

$$w = \frac{2.Z_x}{V_w}$$
$$h = \frac{2.Z_x}{V_k}$$

In these formulas, Z_n represents the position of the near clipping plane, and the V_w and V_h variables represent the width and height of the viewport, in camera space.



CHECK YOUR PROGRESS

Q 2: What is projection matrix?

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13.7 CLIPPING

When we have to display a large portion of the picture, then not only scaling & translation is necessary, the visible part of picture is also identified. This process is not easy. Certain parts of the image are inside, while others are partially inside. The lines or elements which are partially visible will be omitted.

For deciding the visible and invisible portion, a particular process called clipping is used. Clipping determines each element into the visible and invisible portion. Visible portion is selected. An invisible portion is discarded.

Types of Lines:

- Visible: A line or lines entirely inside the window is considered visible
- Invisible: A line entirely outside the window is considered invisible
- Clipped: A line partially inside the window and partially outside is clipped. For clipping point of intersection of a line with the window is determined.

Applications of clipping:

- It will extract part we desire.
- For identifying the visible and invisible area in the 3D object.
- For creating objects using solid modelling.
- For drawing operations.
- Operations related to the pointing of an object.
- For deleting, copying, moving part of an object.

Clipping can be applied to world co-ordinates. The contents inside the window will be mapped to device co-ordinates. Another alternative is a complete world co-ordinates picture is assigned to device co-ordinates, and then clipping of viewport boundaries is done.

Types of Clipping:

- Point Clipping
- Line Clipping
- Area Clipping (Polygon)
- Curve Clipping
- Text Clipping
- Exterior Clipping



CHECK YOUR PROGRESS

Q 3: What is the need of clipping?

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13.8 LET US SUM

- A 3D projection is a design technique used to display a three-dimensional object on a two-dimensional surface.
- Viewing Coordinates system, [u, v, w], describes 3D objects with respect to a viewer.
- A viewing plane (projection plane) is set up perpendicular to w and aligned with (u, v).
- The view volume is bounded by six planes-the four sides plus the top and bottom of the truncated pyramid. These planes are called clipping planes because anything that lies on the wrong side of each plane is clipped away
- Once a 3D model has been completed, its co-ordinates need to be converted to 2 dimensions in order to display the scene on a flat computer monitor or to print it on paper. This process of converting from 3D to 2D is called projection.
- Clipping determines each element into the visible and invisible portion. Visible portion is selected.



13.9 FURTHER READINGS

1) D. Hearn and P.M. Backer, Computer Graphics, Prentice Hall of India, 1986.
2) W. Newman and R.F. Sproul, Principles of Interactive Computer Graphics, McGraw Hill Publication, 1980.
3) W.K. Giloi, Interactive Computer Graphics, Prentice Hall of India, 1978.



13.10 ANSWERS TO CHECK YOUR PROGRESS

Ans to Q No1: The view volume is bounded by six planes-the four sides plus the top and bottom of the truncated pyramid. These planes are called clipping planes because anything that lies on the wrong side of each plane is clipped away. The projection transformation maps the six sides of the truncated pyramid in eye coordinates to the six sides of the

clipping cube in clip coordinates.

Ans to Q No 2: The projection matrix is typically a scale and perspective projection. The projection transformation converts the viewing frustum into a cuboid shape. The near end of the viewing frustum is smaller than the far end, which has the effect of expanding objects that are near to the camera. This is how perspective is applied to the scene. In the viewing frustum, the distance between the camera and the origin of the viewing transformation space is defined arbitrarily as D, so the projection matrix looks like the following illustration.

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1/D \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Ans to Q No 3: For deciding the visible and invisible portion, a particular process called clipping is used. Clipping determines each element into the visible and invisible portion. Visible portion is selected. An invisible portion is discarded.



13.11 MODEL QUESTIONS

Q 1: Explain 3D viewing.

Q 2: What is the need of viewing coordinates?

Q 3: What is 2D viewing?

Q 4: How can we convert 3D viewing to 2 D viewing?

Q 5: What is the need of view volume?

Q 6: what is the use of clipping? Explain few of its application.

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