COMP3201 – Computer Graphics

Module 1: Introduction and Graphics Primitives

1.4 Viewing

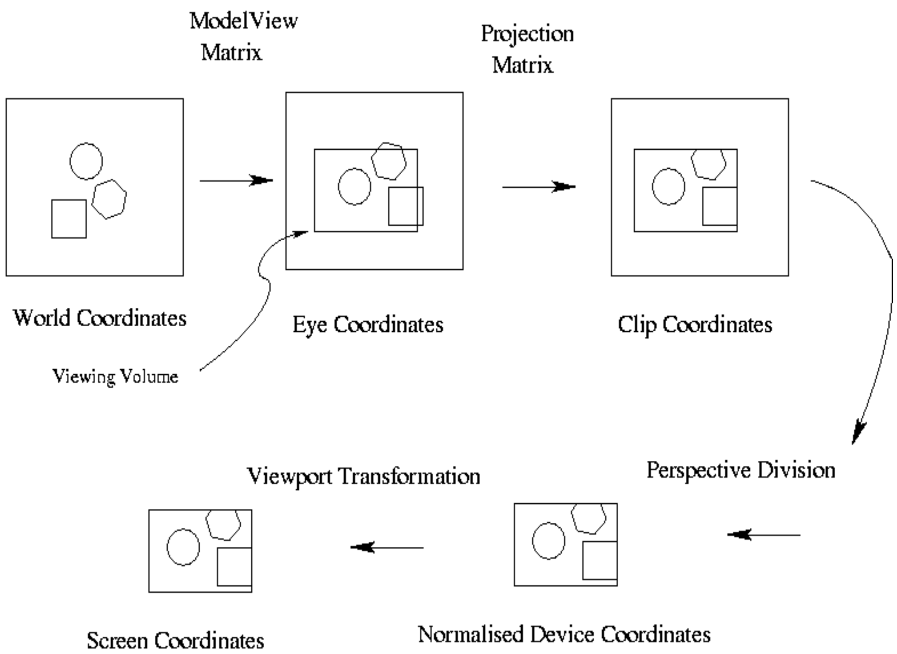

Figure 1.9: Coordinate Systems

1.4.1 World Coordinates

World coordinates (sometimes called object coordinates) are used for defining the scene that you are drawing. Unlike referencing a position in the screen window (which is measured in pixels), the unit of measure for your object creation can be whatever you choose.

1.4.2 Eye Coordinates

This is the coordinate system after all viewing transformations have been made. The viewing volume is specified in this coordinate system.

1.4.3 Viewing Volume

The viewing volume is like a box whose shape is defined by the type of viewing projection required. For example, an orthographic (parallel) projection uses a right parallelopiped for its viewing volume. In contrast, a perspective projection uses a frustum, which is a truncated pyramid. The boundaries of the viewing volume define what part of the scene is projected onto the display.

Any objects completely contained within this 3D volume will be rendered onto the screen window, while objects or parts of objects outside the viewing volume are clipped, but incomplete objects are drawn. For example, clipping occurs if the viewing volume is smaller than the world coordinate system being used.

By default, the viewing volume is an orthographic projection of the 2x2x2 cube centred at the origin. OpenGL also provides built-in support for a perspective viewing volume. User-defined viewing volumes can also be specified (e.g. two point perspective) but these are rarely used.

1.4.4 Orthographic Projection

Initially we will use an orthographic projection (sometimes called parallel projection); this is where the projectors are orthogonal (perpendicular) to the projection plane. By tracing rays from the 3D object onto a piece of paper, you can see how the object will appear on the (2D) screen.

Orthographic projections are useful for CAD or architectural drawings (e.g.) when you want to represent the exact measurements on the screen. Objects that are the same size retain that size in an orthographic projection, regardless of how far away in the scene they may be.

An orthographic projection is obtained by specifying a square or rectangular viewing volume (by defining the near, far, left, right, top and bottom clipping planes).

In OpenGL, use the function

glOrtho(left, right, bottom, top, nearclip, farclip)

to specify the vertex positions of the viewing volume. For example,

glOrtho(-2.0, 2.0, -2.0, 2.0, -2.0, 2.0)

defines a 4x4x4 cube as the viewing volume.

Note the apparent paradox where **nearclip** = -2 and **farclip** = +2; this is because OpenGL uses **–nearclip** and **–farclip** internally.

The vertex positions for the viewing volume are specified in eye coordinates.

In the eye coordinate system, the projection plane is the (x,y) plane, with the projection operating along the z-axis; i.e. the orthographic projection maps each 3D coordinate (x,y,z) to (x,y).

1.4.5 Perspective Projection

A perspective projection gives improved realism over an orthographic projection. Objects near the back of the scene will appear smaller than similar objects that are closer to the front of the scene. Parallel lines in 3D (e.g. railway tracks) will appear to converge in the distance in a perspective projection.

The clipping volume for a perspective projection is a frustum (like a pyramid with the top cut off).

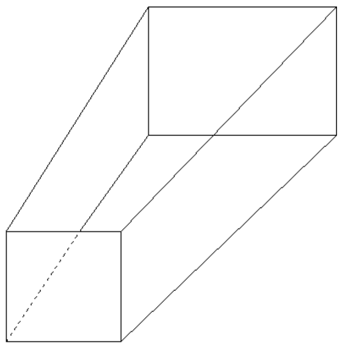

Figure 1.10: Frustum

In OpenGL, this viewing volume is defined by

glFrustum(left, right, bottom, top, nearclip, farclip)

where the parameters define the clipping planes. As the camera is pointing in the negative *z*-direction, note that the near clipping plane is the plane $z = -nearclip$, and the far clipping plane is $z = -farclip$.

The viewing volume for a perspective projection can also be defined using a field-of-view angle, using the OpenGL function

gluPerspective(fovy, aspect, nearclip, farclip);

the field-of-view angle is in the *y-z* plane; it is the angle at the apex of the viewing pyramid. The parameter **aspect** gives the aspect ratio (width/height) of the projection plane.

Troubleshooting Tip

If you are using a perspective projection but just cannot see your scene, set a wide viewing angle (e.g. fovy = 175 degrees) together with a near clipping plane (e.g. 0.0001) and a distant far clipping plane (e.g. 10,000). Then you should be able to see where your model really is, and make adjustments accordingly.

1.4.6 Canonical Viewing Volume

The canonical viewing volume is the 2x2x2 cube centred at the origin in clip coordinates. The objects that are mapped by the projection transformation into the canonical viewing volume are the ones which are displayed on the screen.

1.4.7 Viewports

The viewport is the area of the display window where the image appears. By default, the viewport is the entire image window, but it is also possible to set up several viewports within the one window.

To change the size of the viewport or to define several viewports within the one window, use the function **glViewport** whose parameters are *x* and *y* (for the coordinates of the lower left corner of the viewport) along with the required width and height for this viewport: **glViewport(x, y, w, h)**.

The viewport arguments are given in pixels, relative to the lower left corner of the window. OpenGL automatically maps clip coordinates to the screen coordinates of the viewport.

Multiple viewports are used, for example, to provide alternative views of the same scene. When driving a car, one viewport could be used to show the contents of the rear-view mirror. Also, when navigating a scene, an alternative viewport could be used to provide a birds-eye view of the scene. Multiple viewports can also be used to create a tiling effect.

In a practical sense, to use multiple viewports, specify the first viewport and do the drawing in it, then specify the second viewport and do its drawing, and so on.

1.4.8 Windows

It is possible to have more than one window in an OpenGL application, but for this course we will only use a single window.

1.4.9 Aspect Ratio

Given a viewing volume, the data points inside this volume are projected onto the canonical viewing volume and are then mapped to the viewport on the screen.

The aspect ratio is defined to be the ratio of the width to height. If the aspect ratio of the projected viewing volume does not match that of the viewport, then the images will appear distorted.

To avoid this distortion, use the aspect ratio of the viewport (namely width/height) when setting the (orthographic or perspective) projection to be used.

1.4.10 Viewpoint

The viewpoint is defined to be (0, 0, 0, 1) in the eye coordinate system. If the viewing volume has been defined by a perspective projection, then the viewpoint can be considered to be "the camera". This analogy to a camera does not work for the orthographic projection.