

SNS COLLEGE OF TECHNOLOGY

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<u>UNIT IV</u>

Modelling and 3D Coordinate Systems in Computer Graphics

Coordinate systems act as the backbone for 3D transformation and rotation. Coordinate systems help accurately model, manipulate, and render objects in a three-dimensional environment. In this chapter, we will see various coordinate systems used in 3D design, including the differences between right-hand and left-hand coordinate systems which are used in several software in 3D designs.

Coordinate Systems

In 3D design also in mathematics, a coordinate system defines how points in space are represented. In the most useful coordinate system, every point in 3D space is specified by three values (x, y, z) known as coordinates. These values correspond to distances along three perpendicular axes: the x-axis (horizontal), y-axis (vertical), and z-axis (depth).

Coordinate systems show a way to position and manipulate objects in a virtual environment. Without them, it would be impossible to specify where an object is located or how it should be oriented. There are various types of coordinate systems used in 3D design, each suited for different tasks and representations. We will explore them one by one in the following sections of this chapter.

Cartesian Coordinate System

The Cartesian coordinate system is the most widely used system in 3D design. It consists of three perpendicular axes (x, y, z) that define a 3D space. Each point in this space is represented by three values corresponding to the distances along these axes from the origin (0, 0, 0).

Cartesian Coordinate System

Polar Coordinate System

The polar coordinate are used in 2D. A point is represented by angles and distances from a central origin.



Polar Coordinate System

Here red point coordinate is (45, 2) and blue point is at (-45, -4)



Spherical Coordinates

Spherical coordinates extend polar coordinates to three dimensions. It adds radial distance and two angles. Instead of specifying coordinates as (x, y, z), polar coordinates use a radius r and two angles (azimuthal) and (polar). This system is useful in cases where rotational symmetry is involved, such as modelling spherical objects or camera positioning.



Cylindrical Coordinates

In cylindrical coordinates, a point in 3D space is described by a height along the z-axis, a radius from the z-axis, and an angle around the z-axis. This system is ideal for modelling objects like pipes, cylinders, or any structure that extends vertically while retaining circular symmetry in the horizontal plane.



Right-Hand Coordinate System

In a right-hand coordinate system, the direction of the axes is determined using your right hand. If you point your thumb in the direction of the positive x-axis, your index finger in the direction of the positive y-axis, and your middle finger in the direction of the positive z-axis, you will have the orientation of the right-hand system.



Right-Hand Coordinate System

This system is widely used in many 3D graphics applications, including OpenGL. It offers an intuitive way to visualize and apply transformations such as rotations and translations.

Key Features of Right-Hand Coordinate System

Following are the key features of Right-Hand Coordinate System -

The z-axis typically points out of the screen or towards the viewer.

It's commonly used in most 3D software, making it the standard in many cases.

Left-Hand Coordinate System

In a left-hand coordinate system, the orientation of the axes is reversed compared to the right-hand system. To visualize this, point your left thumb along the positive x-axis, your index finger along the positive y-axis, and your middle finger along the positive z-axis.

Left-Hand Coordinate System

This system is often used in certain 3D applications and game engines, such as DirectX.

Key Features of Left-Hand Coordinate System

Following are the key features of Left-Hand Coordinate System -

The z-axis usually points into the screen or away from the viewer.

It's commonly used in specific applications like game development, where compatibility with certain engines or frameworks requires it.

Differences Between Right-Hand and Left-Hand Systems

The main difference between these systems lies in the direction of the z-axis. In the right-hand system, the positive z-axis points outward, while in the lefthand system, it points inward. This difference can lead to flipped models or mirrored transformations if the wrong system is used.

Understanding which system your software uses is crucial for correctly positioning and orienting objects in 3D space.

Why the Choice of Coordinate System Matters?

Choosing between a right-hand or left-hand system is more than just a technical detail. It affects:

Camera views – The direction in which the camera looks will change depending on the coordinate system, which can influence how scenes are rendered.

Modelling consistency – When working with models across different software platforms, inconsistent coordinate systems can lead to mirrored or incorrectly aligned objects.

Animation and physics – Rotations and forces applied to objects will behave differently depending on the coordinate system, potentially causing problems in animations or simulations if not handled properly.

Modelling in 3D Design

Modelling is the process of creating a 3D representation of an object or scene. To do this effectively, understanding coordinate systems and how to manipulate objects within them is essential.

Object Positioning – To create a 3D object, the first step is to define its position within the coordinate system. This involves specifying the object's coordinates in terms of x, y, and z. The origin (0, 0, 0) is typically the central reference point, and objects are positioned relative to it.

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Scaling and Transformation – Once an object is positioned, various transformations can be applied to it.

Translation – Moves the object along one or more axes. For example, moving an object 5 units along the x-axis changes its x-coordinate.

Rotation – Involves rotating an object around one or more of the coordinate axes. Rotation can be complex, especially when multiple axes are involved.

Scaling – Adjusts the size of the object along each axis. Scaling can make objects larger or smaller, or even stretch them in one direction.

Local and World Coordinates – Objects in 3D space are often manipulated in both local and world coordinate systems –

Local coordinates – These are the object's coordinates relative to its own origin. For example, when a car model is rotated around its own centre, this happens in local coordinates.

World coordinates – These refer to the object's position in the overall scene. For example, moving a car model along the road requires adjusting its position in the world coordinate system.

Conclusion

In this chapter, we explained the fundamental role of coordinate systems in 3D design. We understood the different types of coordinate systems, including Cartesian, polar, spherical, and cylindrical systems, and the importance of choosing between right-hand and left-hand coordinate systems for 3D modelling.

We also covered the key aspects of modelling in 3D space, such as positioning, scaling, and rotating objects, and the distinction between local and world coordinates.