Introduction

Image and Objects

An **image** is basically representation of a real world object on a computer. It can be an actual picture display or a stored page in a video memory. Mathematically, an image is a two - dimensional array of data with intensity or a color value at each element of the array.

Objects are real world entities defined in three – dimensional world coordinates. In computer graphics we deal with both 2D and 3D descriptions of an object. We also study the algorithms and procedures for generation and manipulation of objects and images in computer graphics.

Image representation

Image representation is the approximations of the real world displayed in a computer. A picture in computer graphics is represented as a collection of discrete picture elements termed as pixels. A pixel is the smallest element of picture or object that can be represented on the screen of a device like computer.

Pixel

It refers a point on the screen. It is also known as pel and is shortened form of 'picture element'.

Three basic elements for drawing in graphics are:

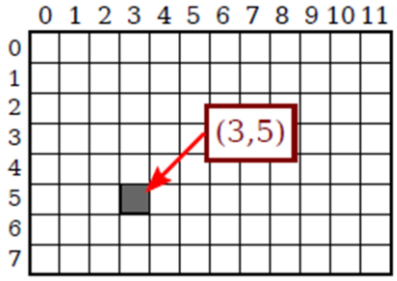
Point: A point marks a position in space. In pure geometric terms, a point is a pair of *x*, *y* coordinates. It has no mass at all. Graphically, however, a point takes form as a dot or a visible mark. A point can be an insignificant fleck of matter or a concentrated locus of power. A mass of points becomes texture, shape, or plane. Tiny points of varying size create shades of gray.

Line: A line is an infinite series of points. Understood geometrically, a line has length, but no breadth. A line is the connection between two points, or it is the path of a moving point. Lines appear at the edges of objects and where two planes meet. Lines can be straight or curved, continuous or broken.

Plane: A plane is a flat surface extending in height and width. A plane is the path of a moving line; it is a line with breadth. A line closes to become a shape, a bounded plane.

Pixel Coordinates

A digital image is made up of rows and columns of pixels. A point in 2D can be identified by a pair of numerical coordinates. A pixel in such an image can be specified by the column and which row those contain it. In terms of coordinates, a pixel can be identified by a pair of integers giving the column number and the row number. For example, the pixel with coordinates (3,5) would lie in column number 3 and row number 5.

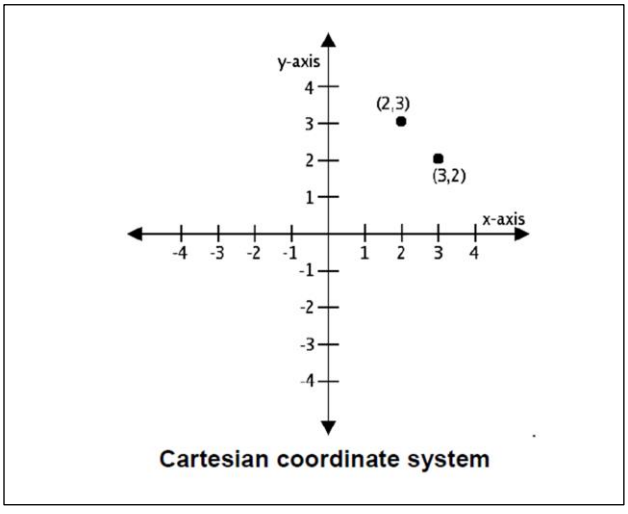


Coordinate System Overview

To define positions of points in space one requires a coordinate system. It is way of determining the position of a point by defining a set of numbers called as coordinates. There are different coordinate systems for representing an object in 2D or 3D.

1- Cartesian coordinate system

It is also known as rectangular coordinate system and can be of two or three dimensions. A point in Cartesian coordinate system can be defined by specifying two numbers, called as *x* –coordinate and the *y* – coordinate of that point.

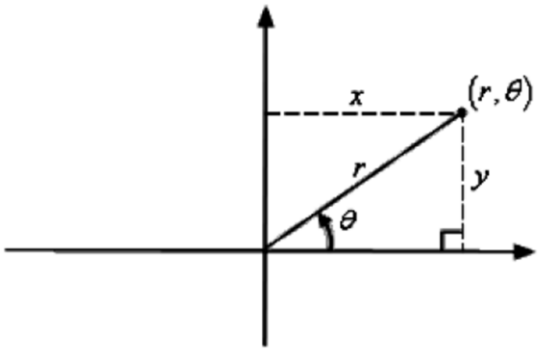


Cartesian coordinate system

In the above figure, there are two points (2, 3) and (3, 2) are specified in Cartesian coordinate system.

2- Polar coordinate system

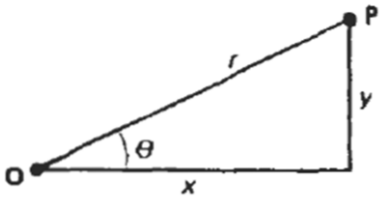
In polar coordinate system, the position of a point is defined by specifying the distance (radius) from a fixed point called as origin and the angle between the line joining the point and the origin and the polar axis (horizontal line passing through the origin).



Polar coordinate system

The above figure shows a point (r, θ) in polar coordinates.

The relation between Cartesian and polar coordinates is shown in the figure in below.



We transform from polar coordinates to Cartesian coordinates with the expressions:

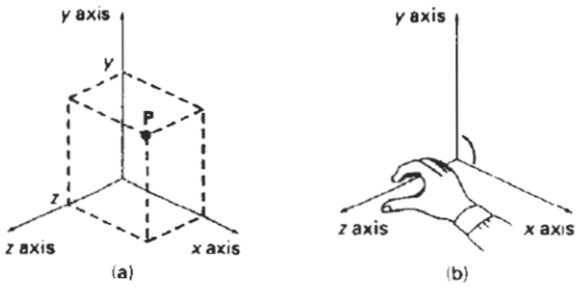
$$x = r\cos\theta, \qquad y = r\sin\theta$$

The inverse transformation from Cartesian to polar coordinates is:

$$r = \sqrt{x^2 + y^2}, \qquad \theta = \tan^{-1}\left(\frac{y}{x}\right)$$

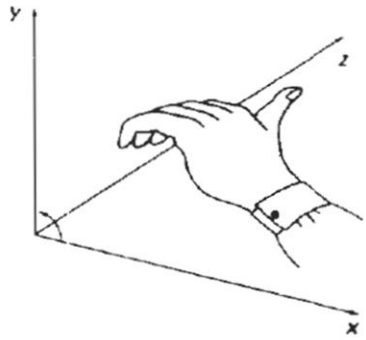
3- Three-Dimensional Cartesian Reference System

Figure (**a)** in below shows the conventional orientation for the coordinate axes in a three-dimensional Cartesian reference system. This is called a right-handed system because the right-hand thumb points in the positive *z* direction when we imagine grasping the *z* axis with the fingers curling from the positive *x* axis to the positive *y* axis (through 90°), as illustrated in Fig. (**b**).



Coordinate representation of a point P at position (*x*, *y*, *z*) in a right-handed Cartesian reference system.

Another possible arrangement of Cartesian axes is the left-handed system shown in the figure in below. For this system, the left-hand thumb points in the positive *z* direction when we imagine grasping the *z* axis so that the fingers of the left hand curl from the positive *x* axis to the positive y axis through 90°.



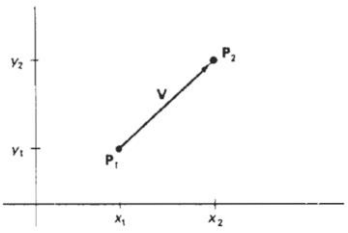
Left-handed Cartesian coordinate system superimposed on the surface of a video monitor.

Points and Vectors

There is a fundamental difference between the concept of a point and that of a vector. A point is a position specified with coordinate values in some reference frame, so that the distance from the origin depends on the choice of reference frame.

A vector, on the other hand, is defined as the difference between two point positions. Thus, for a two-dimensional vector (the figure in below), we have:

$$\begin{aligned}\mathbf{V} &= \mathbf{P}_2 - \mathbf{P}_1 \\ &= (x_2 - x_1, y_2 - y_1) \\ &= (V_x, V_y)\end{aligned}$$



Vector V in the *xy* plane of a Cartesian reference frame.

where the Cartesian components (or Cartesian elements) V_x and V_y are the projections of **V** onto the *x* and *y* axes. We can describe a vector as a directed line segment that has two fundamental properties: magnitude and direction. For a two-dimensional vector, we calculate vector magnitude using the Pythagorean Theorem:

$$|\mathbf{v}| = \sqrt{V_x^2 + V_y^2}$$