Computer Graphics

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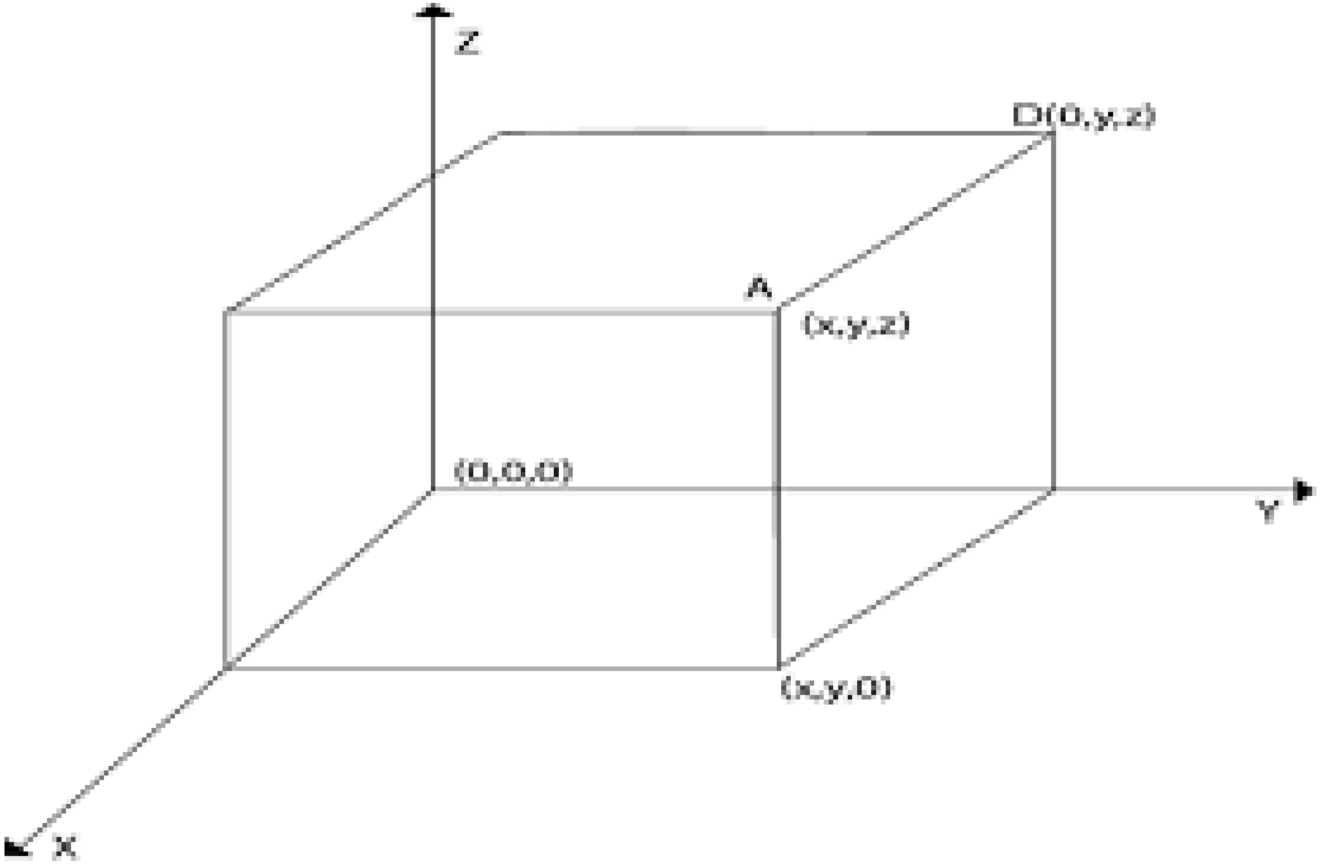
Chapter 3

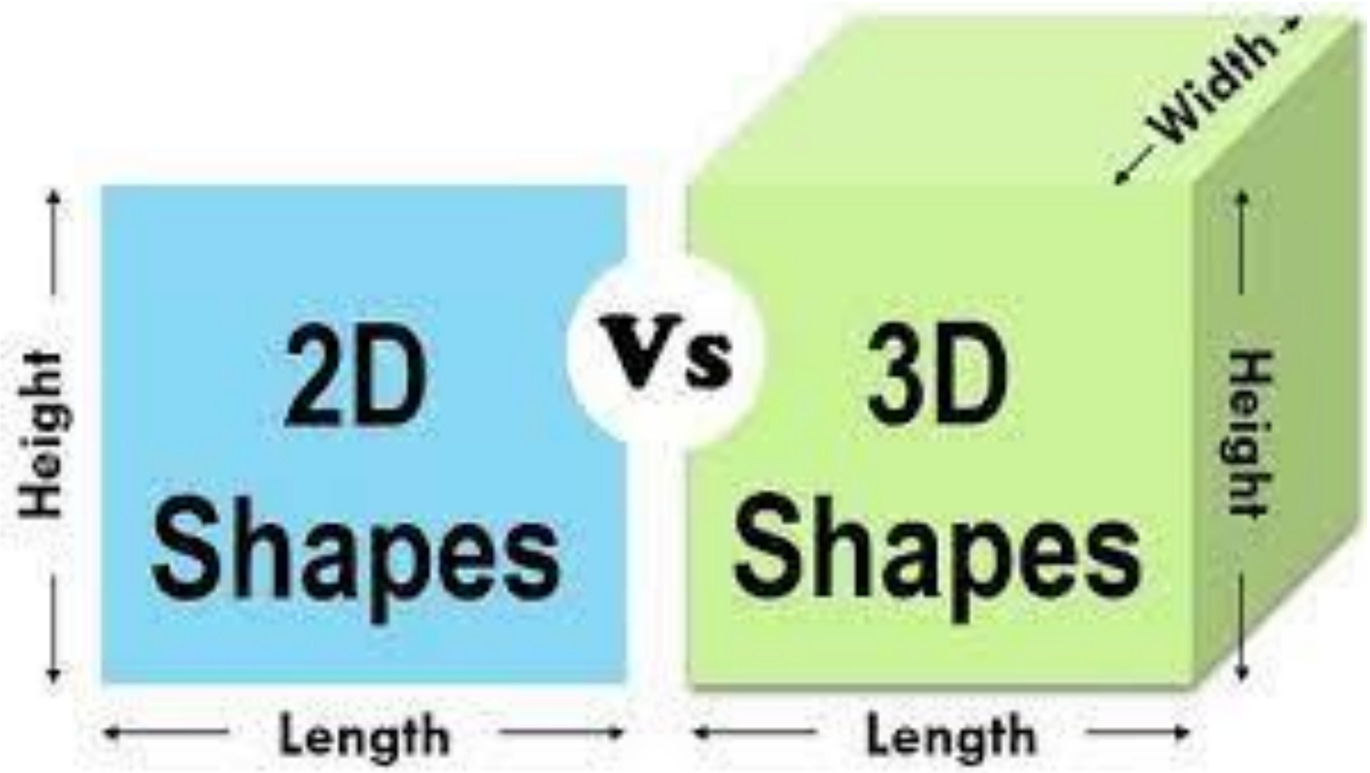
Three Dimensional Graphics

Three dimensional graphics are graphics that use a three-dimensional representation of geometric data that is stored in the computer for the purposes of performing calculations and rendering 2D images. The resulting images may be stored for viewing later (possibly as an animation) or displayed in real time. Unlike 3D film and similar techniques, the result is two-dimensional, without the illusion of being solid.



Z
D(0,y,z)
A
(x,y,z)
(0,0,0)
Y
(x,y,0)
X

3D computer graphics rely on many of the same algorithms as 2D computer vector graphics in the wire-frame model and 2D computer raster graphics in the final rendered display. In computer graphics software, 2D applications may use 3D techniques to achieve effects such as lighting, and similarly, 3D may use some 2D rendering techniques.


2D
Shapes
Vs
3D
Shapes
Height
Length
Width
Height
Length

A 3D model is a mathematical representation of any three-dimensional object; a model is not technically a graphic until it is displayed. A model can be displayed visually as a two-dimensional image through a process called 3D rendering, or it can be used in non-graphical computer simulations and calculations. With 3D printing, models are rendered into an actual 3D physical representation of themselves, with some limitations as to how accurately the physical model can match the virtual model.

3D computer graphics production workflow falls into **three basic phases**:

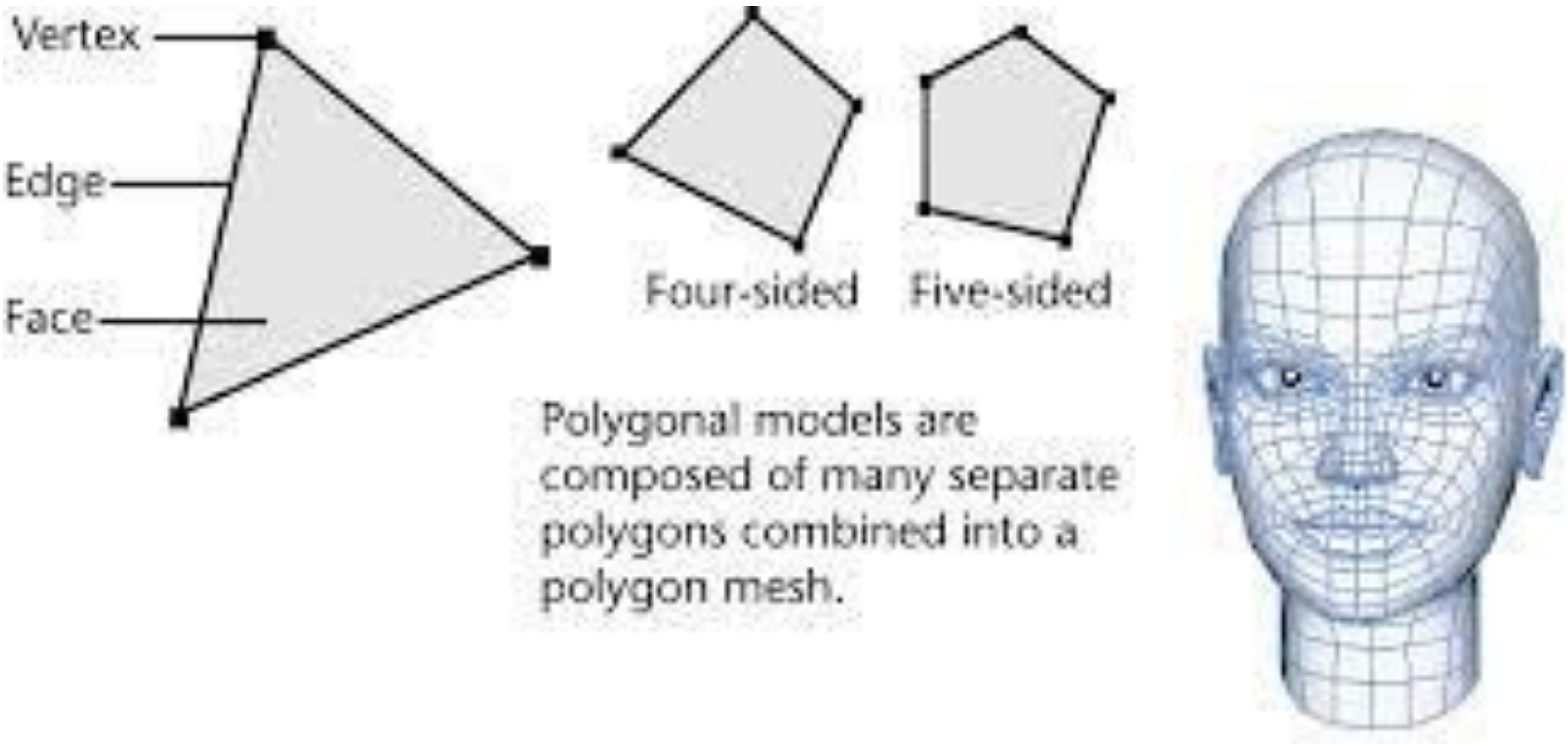
- 3D modeling: the process of forming a computer model of an object's shape.
- Layout and animation: the placement and movement of objects (models, lights etc.) within a scene.
- 3D rendering: the computer calculations that, based on light placement, surface types, and other qualities, generate (rasterize the scene into) an image.

3D Modeling

3D modeling The model describes the process of forming the shape of an object. **The two most common sources of 3D models** are those that an artist or engineer originates on the computer with some kind of 3D modeling tool, and models scanned into a computer from real-world objects (Polygonal Modeling, Patch Modeling and NURBS Modeling are some popular tools used in 3d modeling).

Models can also be produced procedurally or via physical simulation. Basically, a 3D model is formed from points called vertices that define the shape and form polygons. A polygon is an area formed from at least three vertices (a triangle). A polygon of n points is an n-gon. The overall integrity of the model and its suitability to use in animation depend on the structure of the polygons.

Polygonal Modeling: Polygons consist of geometry based on vertices, edges, and faces that you can use to create three-dimensional models. Polygons are useful for constructing many types of 3D models and are widely used in the development of 3D content for animated effects in film, interactive video games, and the internet. Polygons are straight-sided shapes (3 or more sides), defined by three-dimensional points (**vertices**) and the straight lines that connect them (**edges**).


Vertex
Edge
Face
Four-sided
Five-sided
Polygonal models are composed of many separate polygons combined into a polygon mesh.

The interior region of the polygon is called the **face**. Vertices, edges, and faces are the basic components of polygons. You select and modify polygons using these basic components. When you model with polygons you usually use three-sided polygons called triangles or four-sided polygons called quadrilaterals (quads). Maya also supports the creation of polygons with more than four sides (n-gons) but they are not as commonly used for modeling.

An individual polygon is commonly called a face, and is defined as the area bounded by three or more vertices and their associated edges. When many faces are connected together they create a network of faces called a polygon mesh (also referred to as a polyset or a polygonal object). You create your 3D polygonal models using polygon meshes. Polygon meshes can be created using a variety of techniques.

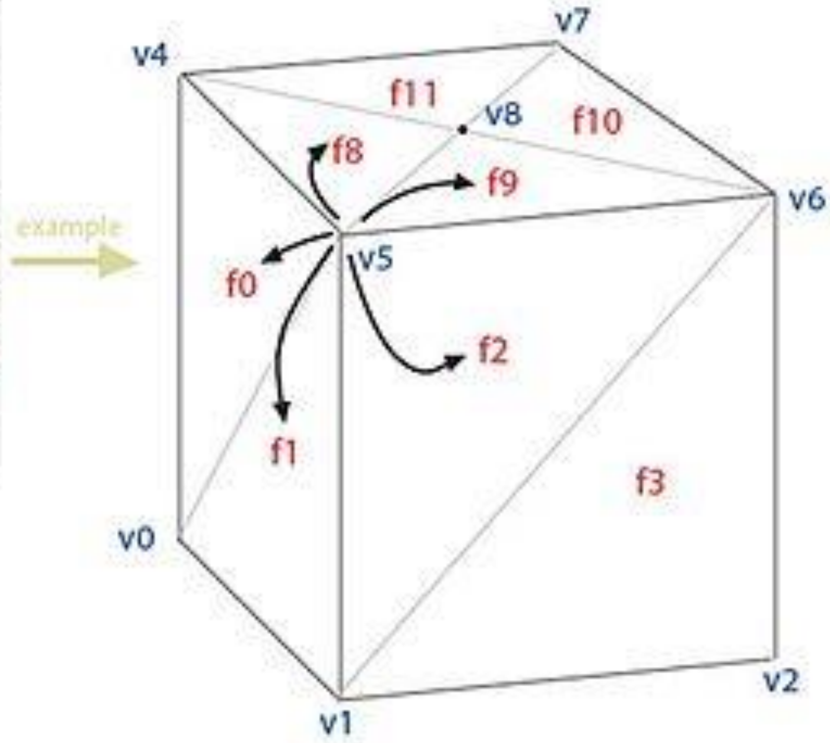
Face-Vertex Meshes

Face List

f0	v0 v4 v5
f1	v0 v5 v1
f2	v1 v5 v6
f3	v1 v6 v2
f4	v2 v6 v7
f5	v2 v7 v3
f6	v3 v7 v4
f7	v3 v4 v0
f8	v8 v5 v4
f9	v8 v6 v5
f10	v8 v7 v6
f11	v8 v4 v7
f12	v9 v5 v4
f13	v9 v6 v5
f14	v9 v7 v6
f15	v9 v4 v7

Vertex List

v0	0,0,0	f0 f1 f12 f15 f7
v1	1,0,0	f2 f3 f13 f12 f1
v2	1,1,0	f4 f5 f14 f13 f3
v3	0,1,0	f6 f7 f15 f14 f5
v4	0,0,1	f6 f7 f0 f8 f11
v5	1,0,1	f0 f1 f2 f9 f8
v6	1,1,1	f2 f3 f4 f10 f9
v7	0,1,1	f4 f5 f6 f11 f10
v8	.5,.5,0	f8 f9 f10 f11
v9	.5,.5,1	f12 13 14 15

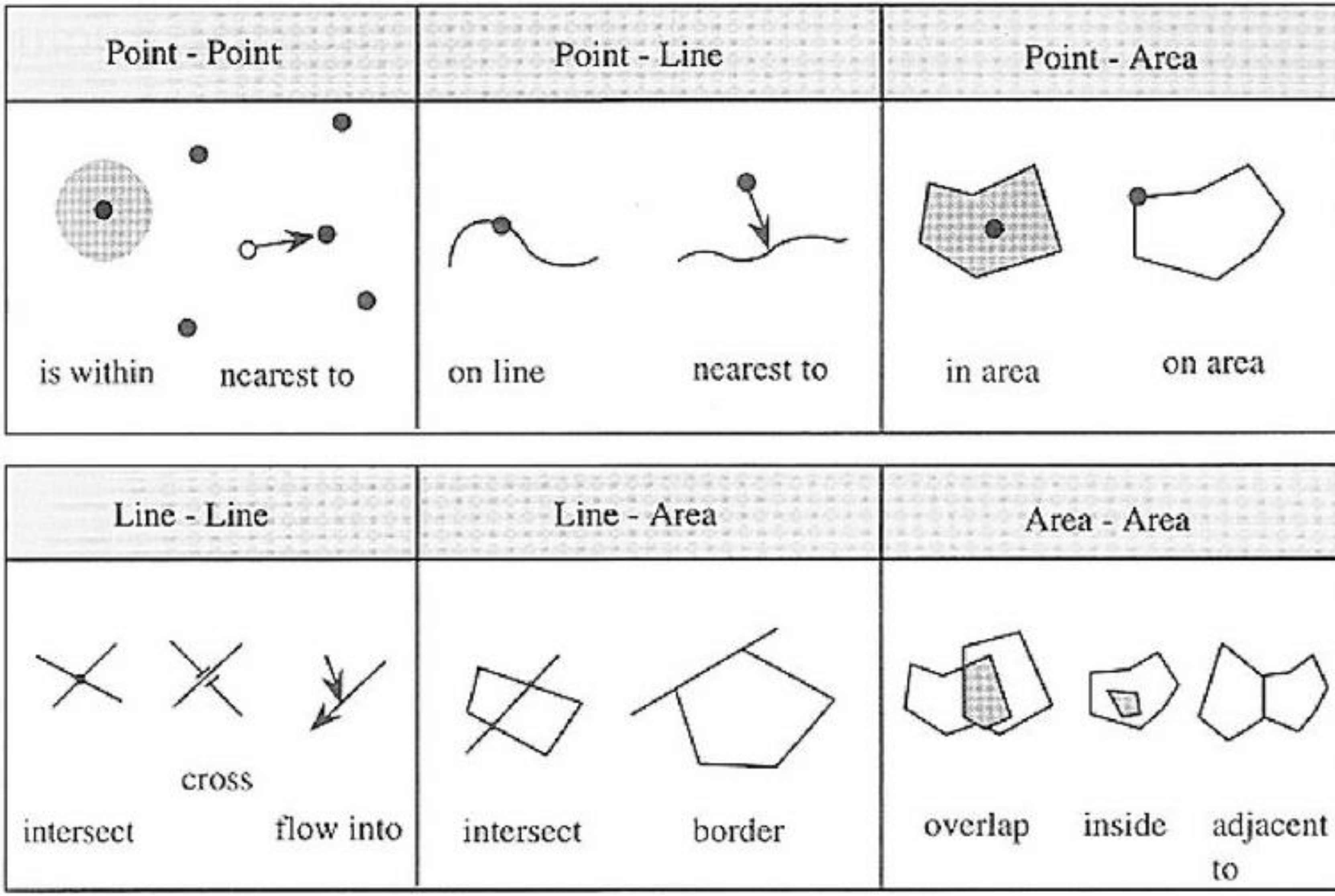


Polygon meshes normally share the vertices and edges that are common between the individual faces. These are referred to as shared vertices or shared edges. A polygon mesh can also be composed of several disjointed sets of connected polygons called shells. The outside edges of a mesh or shell are referred to as border edges.

Layout and Animation

Before rendering into an image, objects must be **laid out** in a scene. This defines spatial relationships between objects, including location and size. **Animation** refers to the temporal description of an object (i.e., how it moves and deforms over time. Popular methods include keyframing, inverse kinematics, and motion capture). These techniques are often used in combination. As with animation, physical simulation also specifies motion.

A spatial relation specifies how some object is located in space in relation to some reference object. When the reference object is much bigger than the object to locate, the latter is often represented by a point. The reference object is often represented by a bounding box. In Anatomy it might be the case that a spatial relation is not fully applicable. Thus, the degree of applicability is defined which specifies from 0 till 100% how strongly a spatial relation holds.


Point - Point
Point - Line
Point - Area
is within
nearest to
on line
nearest to
in area
on area
Line - Line
Line - Area
Area - Area
cross
intersect
flow into
intersect
border
overlap
inside
adjacent to

Animation refers to the movement on the screen of the display device created by displaying a sequence of still images. Animation is the technique of designing, drawing, making layouts and preparation of photographic series which are integrated into the multimedia and gaming products. Animation connects the exploitation and management of still images to generate the illusion of movement. A person who creates animations is called animator.

Animators have invented and used a variety of different animation techniques. Basically there are **animation techniques.**

1-Frame by Frame is traditionally most of the animation was done by hand. All the frames in an animation had to be drawn by hand. Since each second of animation requires 24 frames, the amount of efforts required to create even the shortest of movies can be tremendous.

2- Keyframing: In this technique, a storyboard is laid out and then the artists draw the major frames of the animation. Major frames are the ones in which prominent changes take place. They are the key points of animation. Keyframing requires that the animator specifies critical or key positions for the objects. The computer then automatically fills in the missing frames by smoothly interpolating between those positions.

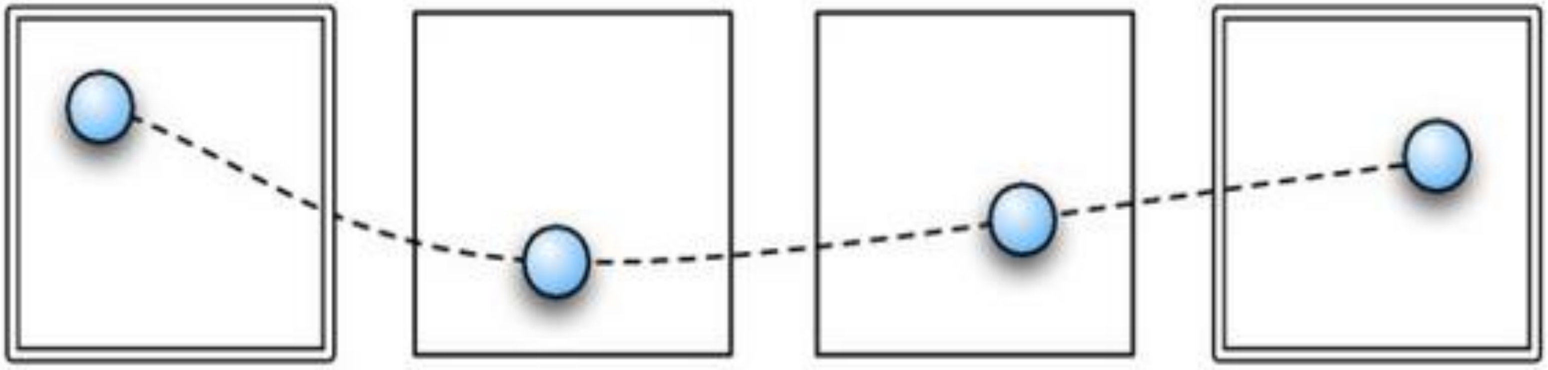


Fig. : Example of keyframe animation. The first and last frames are keyframes while the second and third frames are tween frames. The dashed line represents a spline that describes the trajectory of the circle.

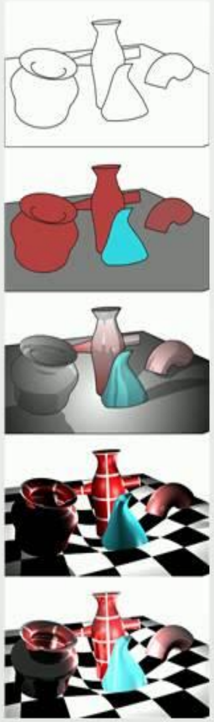
3-Procedural: In a procedural animation, the objects are animated by a procedure : a set of rules not by keyframing. The animator specifies rules and initial conditions and runs simulation. Rules are often based on physical rules of the real world expressed by mathematical equations.

4-Motion Capture, in which magnetic or vision-based sensors record the actions of a human or animal object in three dimensions. A computer then uses these data to animate the object. This technology has enabled a number of famous athletes to supply the actions for characters in sports video games. Motion capture is pretty popular with the animators mainly because some of the commonplace human actions can be captured with relative ease. However, there can be serious discrepancies between the shapes or dimensions of the subject and the graphical character and this may lead to problems of exact execution.

Rendering

Rendering or image synthesis is the process of generating a photorealistic or non-photorealistic image from a 2D or 3D model by means of a computer program. The resulting image is referred to as the render. Multiple models can be defined in a scene file containing objects in a strictly defined language or data structure. The scene file contains geometry, viewpoint, texture, lighting, and shading information describing the virtual scene.

Rendering (computer graphics)

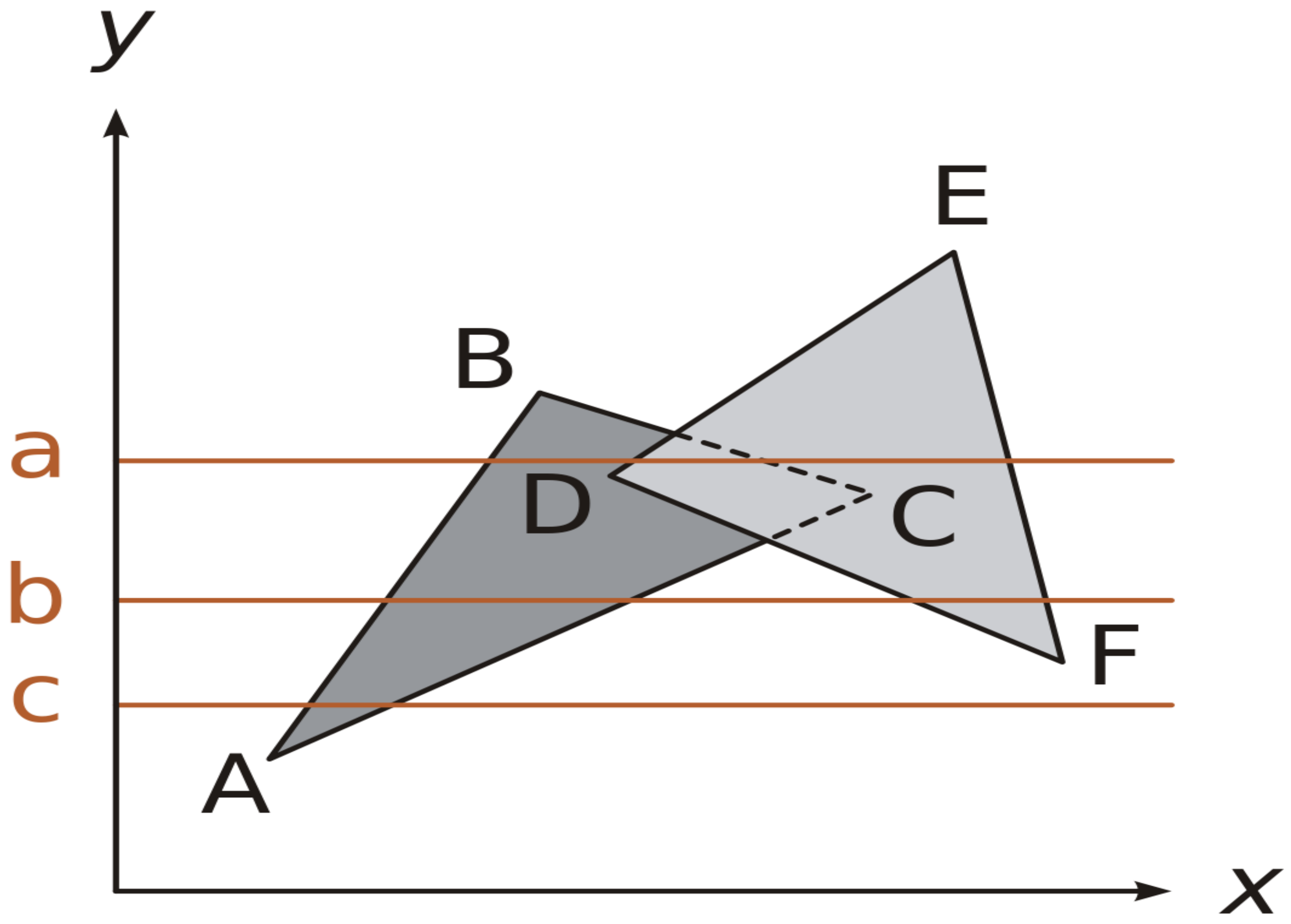


The data contained in the scene file is then passed to a rendering program to be processed and output to a digital image or raster graphics image file. The term "rendering" is analogous to the concept of an artist's impression of a scene. The term "rendering" is also used to describe the process of calculating effects in a video editing program to produce the final video output.

Rendering has uses in architecture, video games, simulators, movie and TV visual effects, and design visualization, each employing a different balance of features and techniques. A wide variety of renderers are available for use. Some are integrated into larger modeling and animation packages, some are stand-alone, and some are free open-source projects. On the inside, a renderer is a carefully engineered program based on multiple disciplines, including light physics, visual perception, mathematics, and software development.

3D rendering process usually takes a lot of time and could cause a severe headache, especially when you do not have much time left to complete a project. Although many 3D rendering techniques are available to make 3D modeling stand out and appealing, the time required is a challenge. Despite a wide array of rendering software solutions on the market, there is a need to streamline the entire process to save time and achieve the best results.

1- Scanline Rendering Technique: is an algorithm for visible surface determination, in 3D computer graphics, that works on a row-by-row basis rather than a polygon-by-polygon or pixel-by-pixel basis. All of the polygons to be rendered are first sorted by the top y coordinate at which they first appear, then each row or scan line of the image is computed using the intersection of a scanline with the polygons on the front of the sorted list, while the sorted list is updated to discard no-longer-visible polygons as the active scan line is advanced down the picture.


y
E
B
a
D
C
b
F
c
A
x

The main advantage of this method is that sorting vertices along the normal of the scanning plane reduces the number of comparisons between edges. Another advantage is that it is not necessary to translate the coordinates of all vertices from the main memory into the working memory—only vertices defining edges that intersect the current scan line need to be in active memory, and each vertex is read in only once. The main memory is often very slow compared to the link between the central processing unit and cache memory, and thus avoiding re-accessing vertices in main memory can provide a substantial speedup.

2- Ray tracing is a rendering technique that can realistically simulate the lighting of a scene and its objects by rendering physically accurate reflections, refractions, shadows, and indirect lighting. Ray tracing generates computer graphics images by tracing the path of light from the view camera (which determines your view into the scene), through the 2D viewing plane (pixel plane), out into the 3D scene, and back to the light sources.

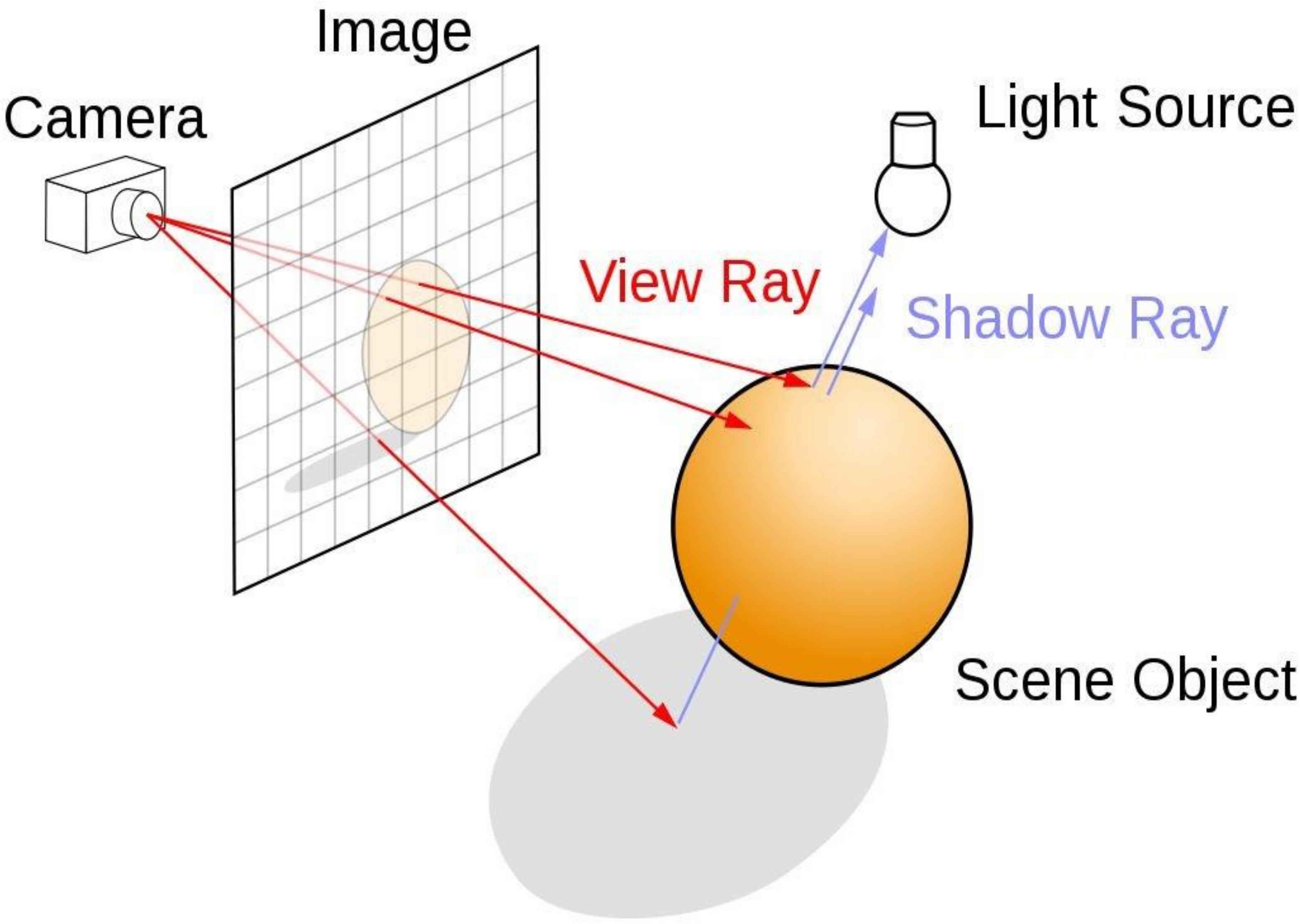


Image
Camera
Light Source
View Ray
Shadow Ray
Scene Object

As it traverses the scene, the light may reflect from one object to another (causing reflections), be blocked by objects (causing shadows), or pass through transparent or semi-transparent objects (causing refractions). All of these interactions are combined to produce the final color and illumination of a pixel that is then displayed on the screen. This reverse tracing process of eye/camera to light source is chosen because it is far more efficient than tracing all light rays emitted from light sources in multiple directions.

3- Ray casting is the methodological basis for 3D CAD/CAM solid modeling and image rendering. It is essentially the same as ray tracing for computer graphics where virtual light rays are "**cast**" or "**traced**" on their path from the focal point of a camera through each pixel in the camera sensor to determine what is visible along the ray in the 3D scene.

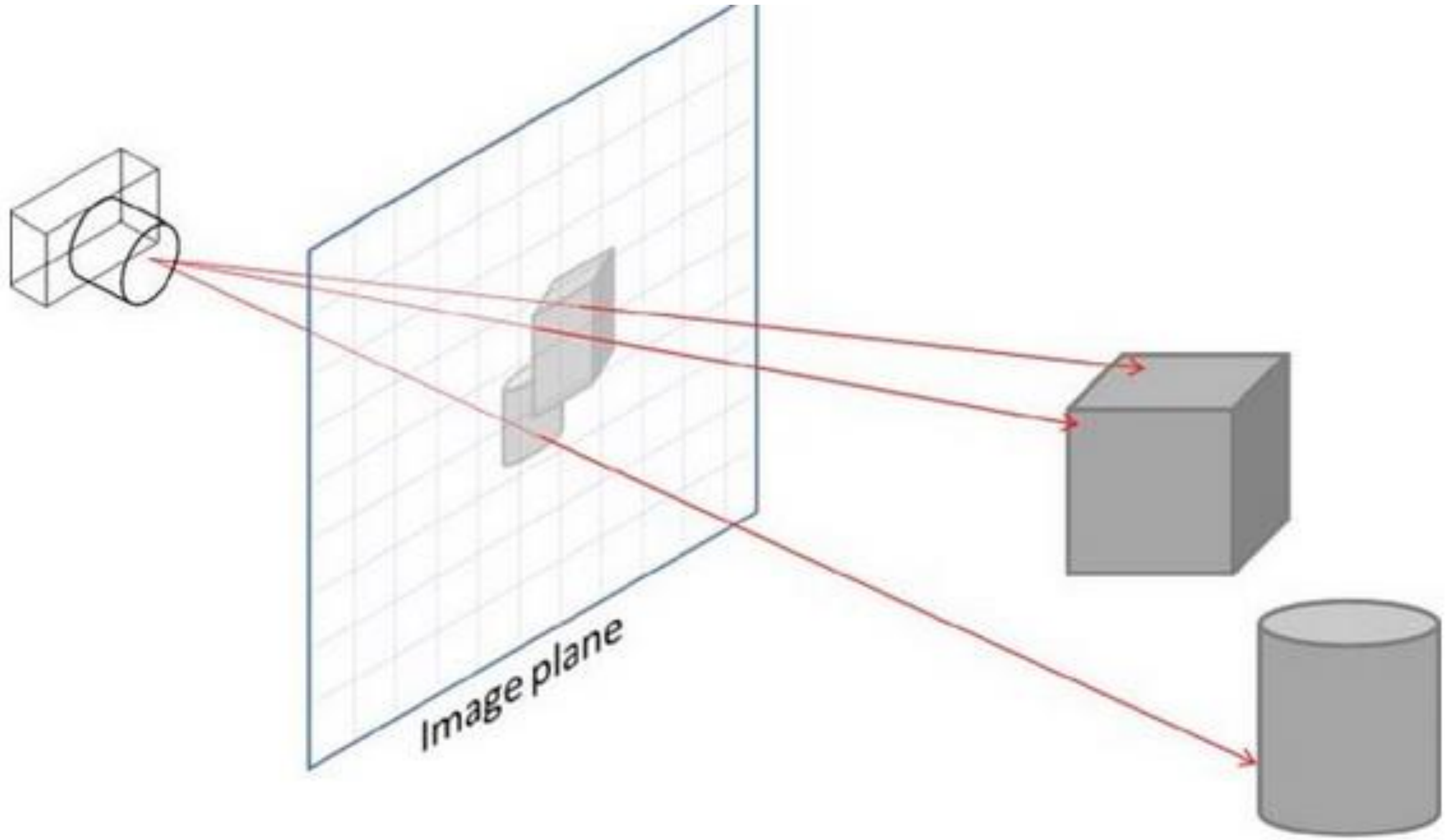


Image plane

Ray casting greatly simplified image rendering of 3D objects and scenes because a line transforms to a line. So, instead of projecting curved edges and surfaces in the 3D scene to the 2D image plane, transformed lines (rays) are intersected with the objects in the scene. A homogeneous coordinate transformation is represented by 4x4 matrix. The mathematical technique is common to computer graphics and geometric modeling. A transform includes rotations around the three axes, independent scaling along the axes, translations in 3D, and even skewing. Transforms are easily concatenated via matrix arithmetic.