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New Scheme Based On AICTE Flexible Curricula

Computer Science and Engineering, VI-Semester

Departmental Elective - CS603 (B) Computer Graphics & Visualization

Topics Covered

Unit-III: 3D Transformations, Parallel & Perspective Projection: Types of Parallel & Perspective Projection, Hidden Surface elimination: Depth comparison, Back face detection algorithm, Painter's Algorithm, Z-Buffer Algorithm. Curve generation, Bezier and B-spline methods.

Basic Illumination Model: Diffuse reflection, Specular reflection, Phong Shading, Gouraud shading, Ray Tracing, Color models like RGB, YIQ, CMY, HSV.

3D Transformations

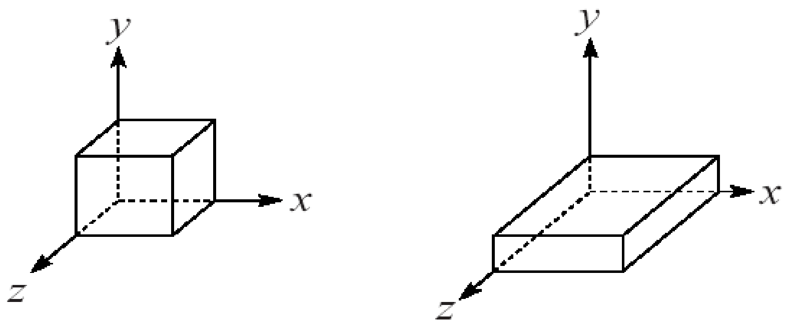
Translation

$$P' = MP$$

$$\begin{pmatrix} x' \\ y' \\ z' \\ 1 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & t_x \\ 0 & 1 & 0 & t_y \\ 0 & 0 & 1 & t_z \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix}$$

Scaling

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} s_x & 0 & 0 & 0 \\ 0 & s_y & 0 & 0 \\ 0 & 0 & s_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$



3D Rotation

Rotate over angle α around z-as:

$x' = x\cos\alpha - y\sin\alpha$

$y' = x\sin\alpha + y\cos\alpha$

$z' = z$

Or

$\mathbf{P}' = \mathbf{R}_z(\alpha)\mathbf{P}$, with

$$\mathbf{R}_z(\alpha) = \begin{pmatrix} \cos\alpha & -\sin\alpha & 0 & 0 \\ \sin\alpha & \cos\alpha & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Rotate over angle α around x-as:

$y' = y\cos\alpha - z\sin\alpha$

$z' = y\sin\alpha + z\cos\alpha$

$x' = x$

Or

$\mathbf{P}' = \mathbf{R}_x(\alpha)\mathbf{P}$, with

$$\mathbf{R}_x(\alpha) = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha & 0 \\ 0 & \sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Rotation around axis, parallel to coordinate axis, through point $\mathbf{Q}$.

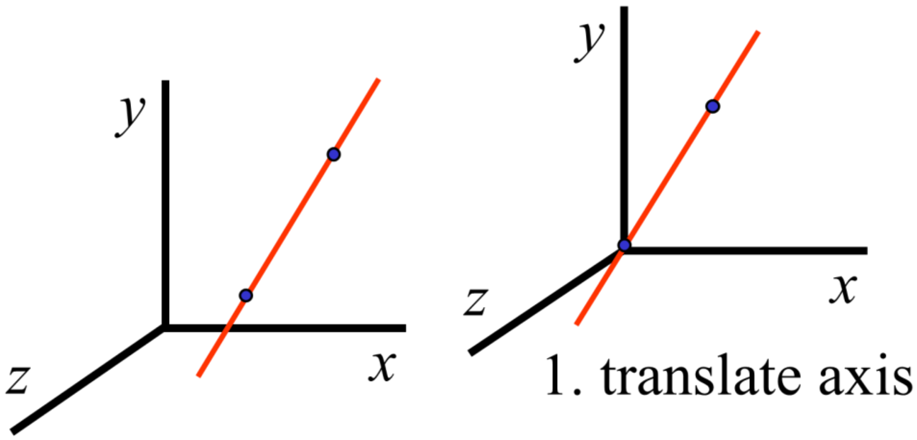
For example. the z-as. Similar as 2D rotation:

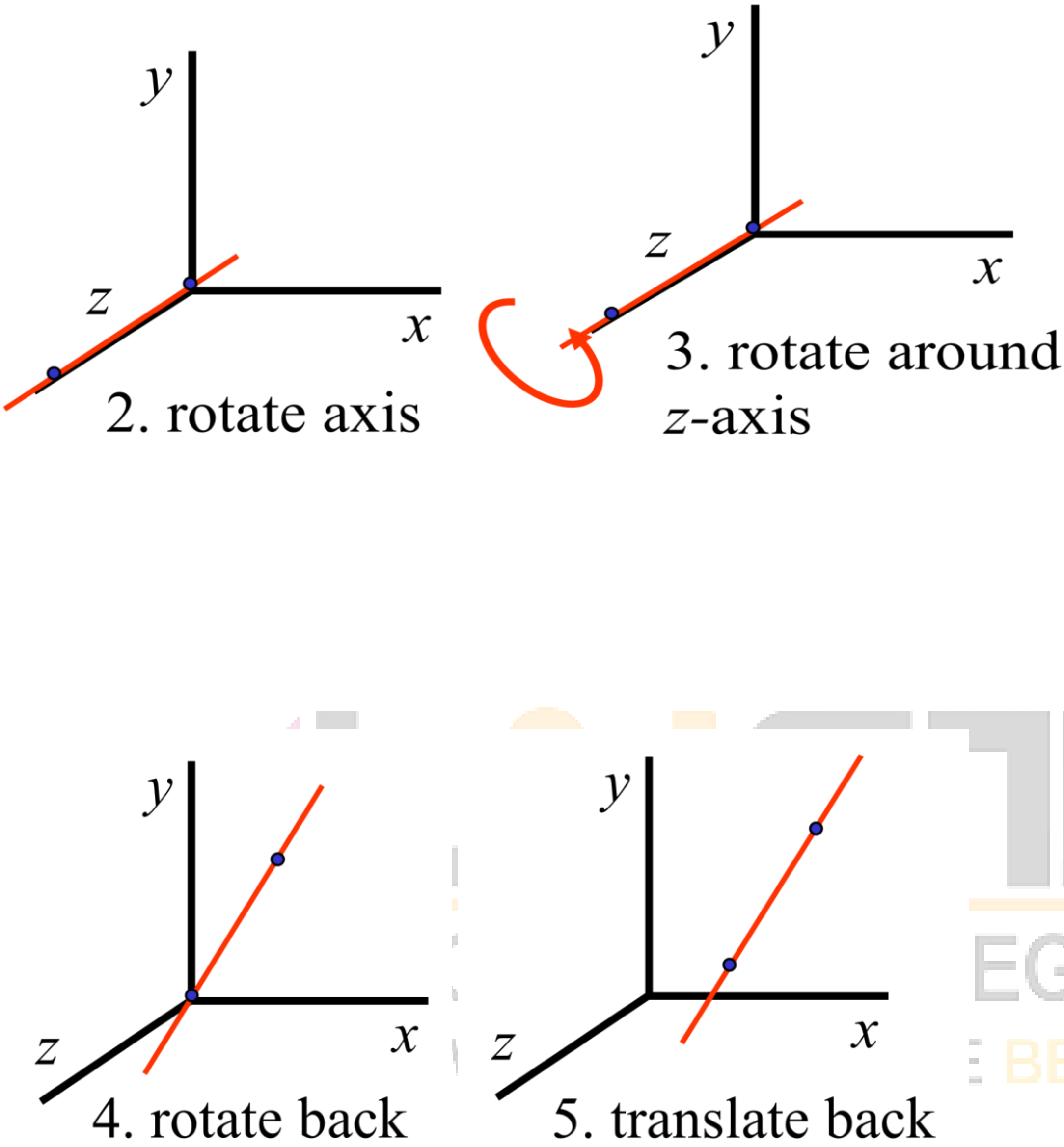
1. Translate over $-\mathbf{Q}$;
2. Rotate around z-axis;
3. Translate back over $\mathbf{Q}$.

Or:

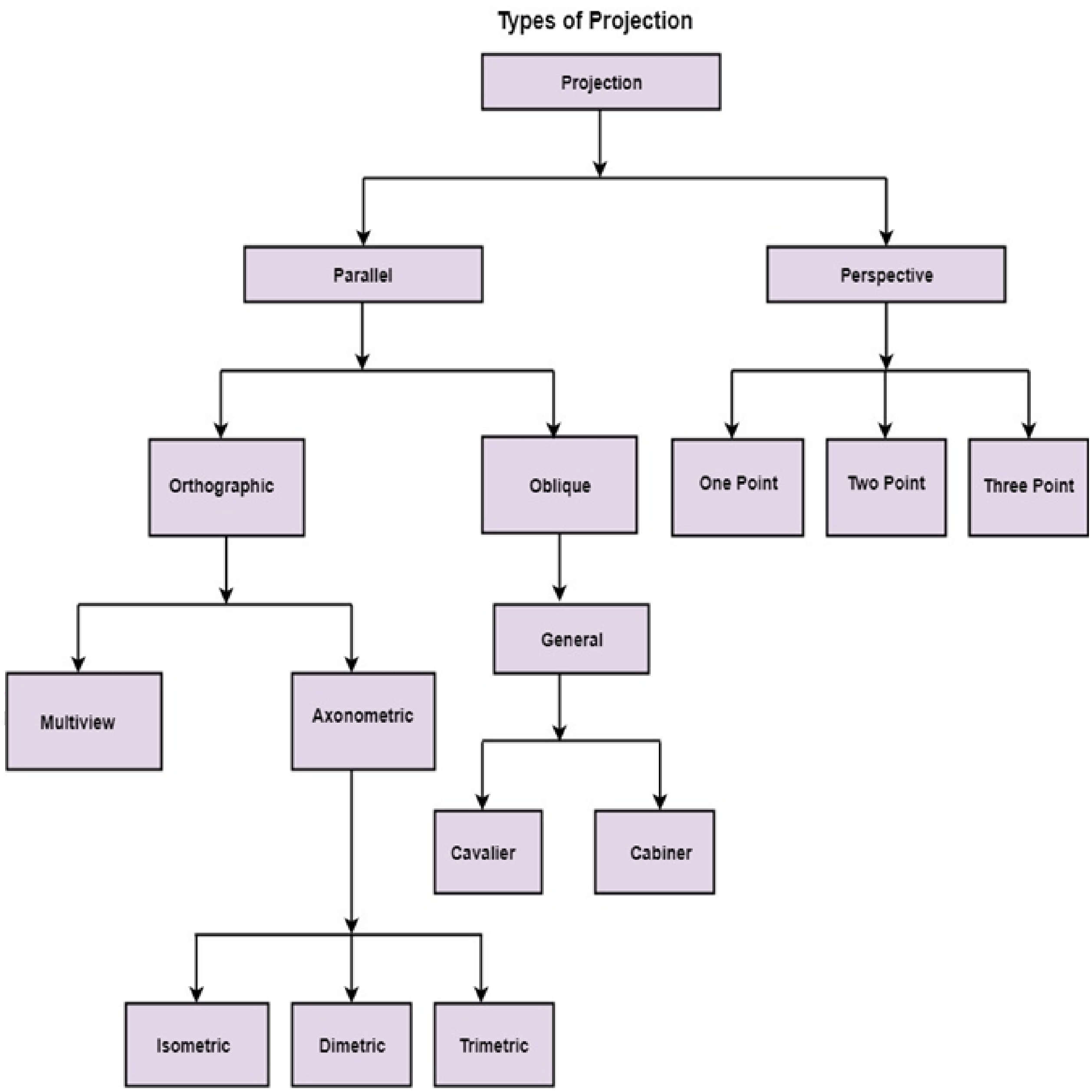
$\mathbf{P}' = \mathbf{T}(\mathbf{Q})\mathbf{R}_z(\alpha)\mathbf{T}(-\mathbf{Q})\mathbf{P}$

3D Rotation around arbitrary axis




y
z
x
2. rotate axis
y
z
x
3. rotate around z-axis
y
z
x
4. rotate back
y
z
x
5. translate back

Projection. It is the process of converting a 3D object into a 2D object. It is also defined as mapping or transformation of the object in **projection** plane or view plane. The view plane is displayed surface.



Perspective Projection

In perspective projection farther away object from the viewer, small it appears. This property of projection gives an idea about depth. The artist use perspective projection from drawing three-dimensional scenes.

Two main characteristics of perspective are vanishing points and perspective foreshortening. Due to foreshortening object and lengths appear smaller from the center of projection. More we increase the distance from the center of projection, smaller will be the object appear.

Vanishing Point

It is the point where all lines will appear to meet. There can be one point, two point, and three point perspectives.

One Point: There is only one vanishing point as shown in fig (a)

Two Points: There are two vanishing points. One is the x-direction and other in the y -direction as shown in fig (b)

Three Points: There are three vanishing points. One is x second in y and third in two directions.

In Perspective projection lines of projection do not remain parallel. The lines converge at a single point called a center of projection. The projected image on the screen is obtained by points of intersection of converging lines with the plane of the screen. The image on the screen is seen as of viewer's eye were located at the centre of projection, lines of projection would correspond to path travel by light beam originating from object.

Important terms related to perspective

1. **View plane:** It is an area of world coordinate system which is projected into viewing plane.
2. **Center of Projection:** It is the location of the eye on which projected light rays converge.
3. **Projectors:** It is also called a projection vector. These are rays start from the object scene and are used to create an image of the object on viewing or view plane.

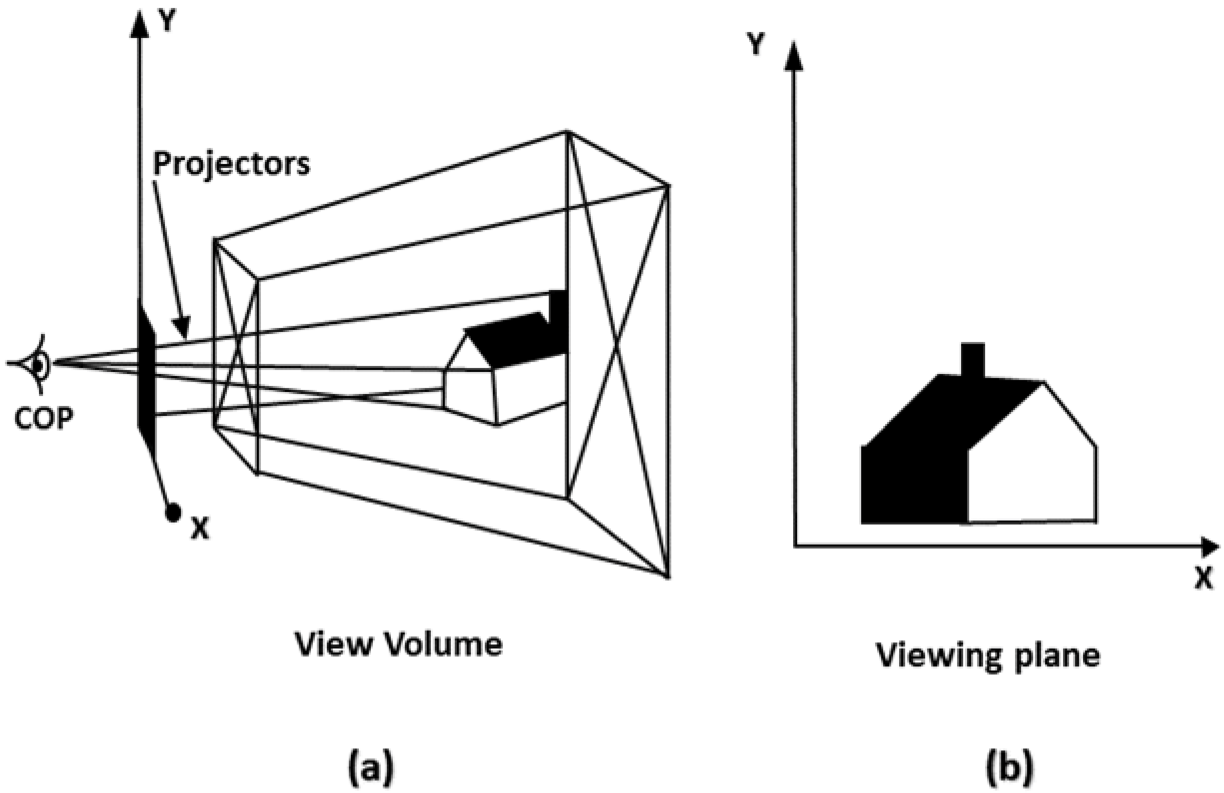
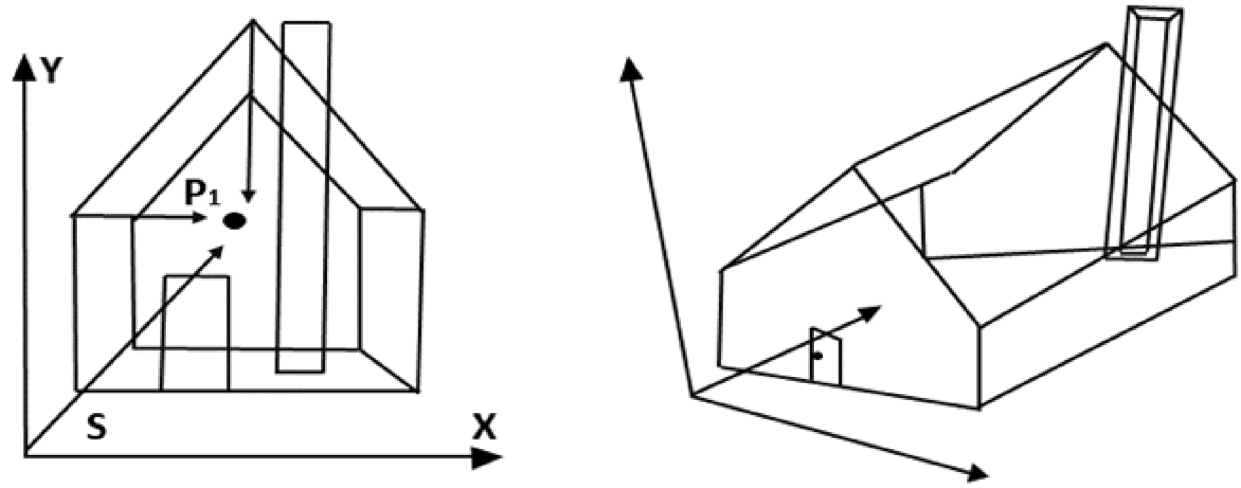


Fig: Prespective Projection

Anomalies in Perspective Projection

It introduces several anomalies due to these object shape and appearance gets affected.

1. **Perspective foreshortening:** The size of the object will be small of its distance from the center of projection increases.
2. **Vanishing Point:** All lines appear to meet at some point in the view plane.
3. **Distortion of Lines:** A range lies in front of the viewer to back of viewer is appearing to six rollers.



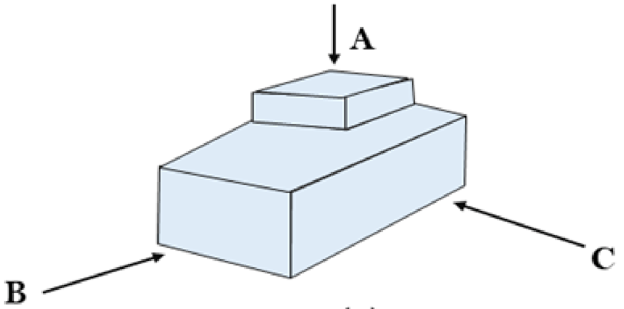
(a) (b)

Foreshortening of the z-axis in fig (a) produces one vanishing point, P_1. Foreshortening the x and z-axis results in two vanishing points and Adding a y-axis foreshortening adds vanishing point along the negative y-axis.

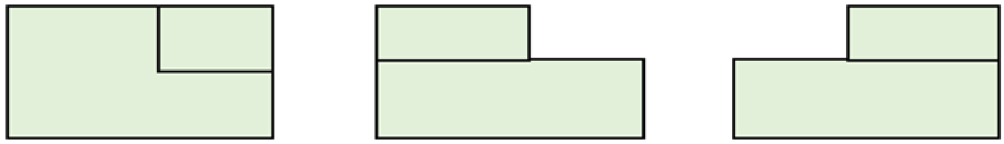
Parallel Projection

Parallel Projection use to display picture in its true shape and size. When projectors are perpendicular to view plane then is called **orthographic projection**. The parallel projection is formed by extending parallel lines from each vertex on the object until they intersect the plane of the screen. The point of intersection is the projection of vertex.

Parallel projections are used by architects and engineers for creating working drawing of the object, for complete representations require two or more views of an object using different planes.



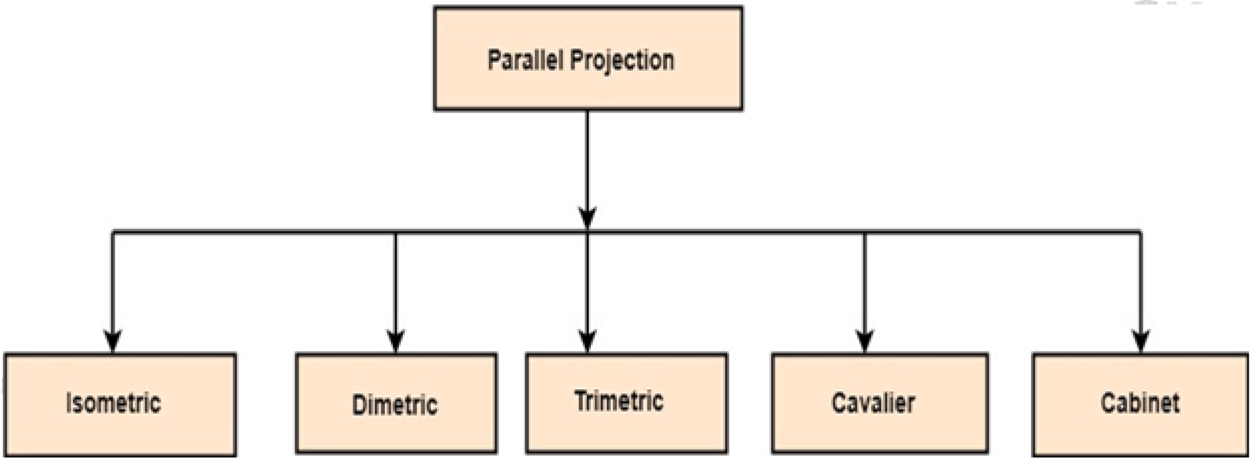
(a)



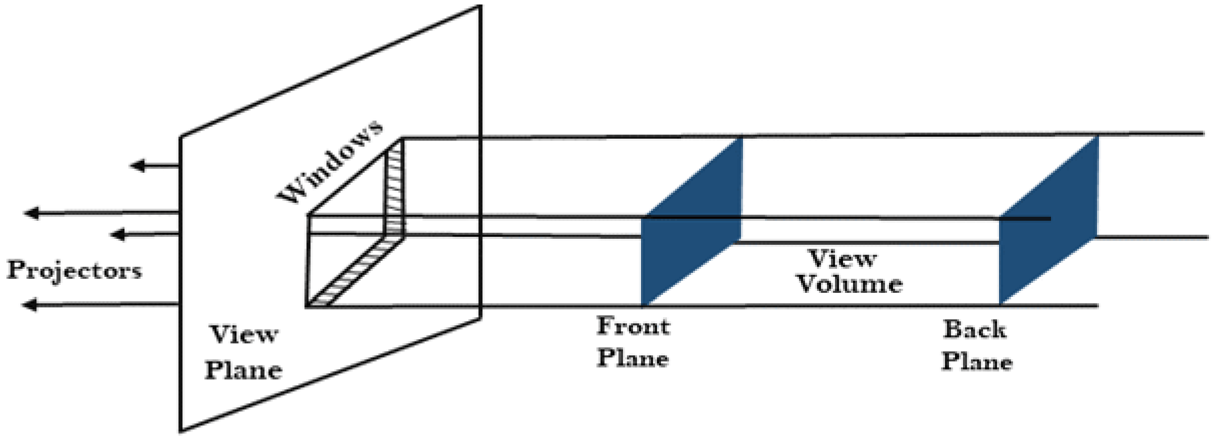
Parallel projection from top i.e. A direction (b)

Parallel projection from top i.e. B direction (c)

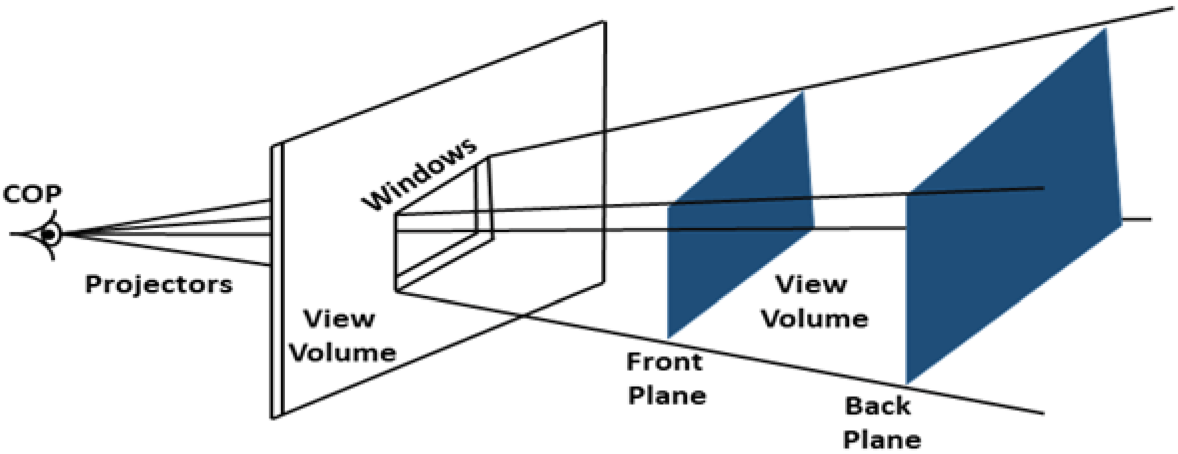
Parallel projection from top i.e. C direction (d)



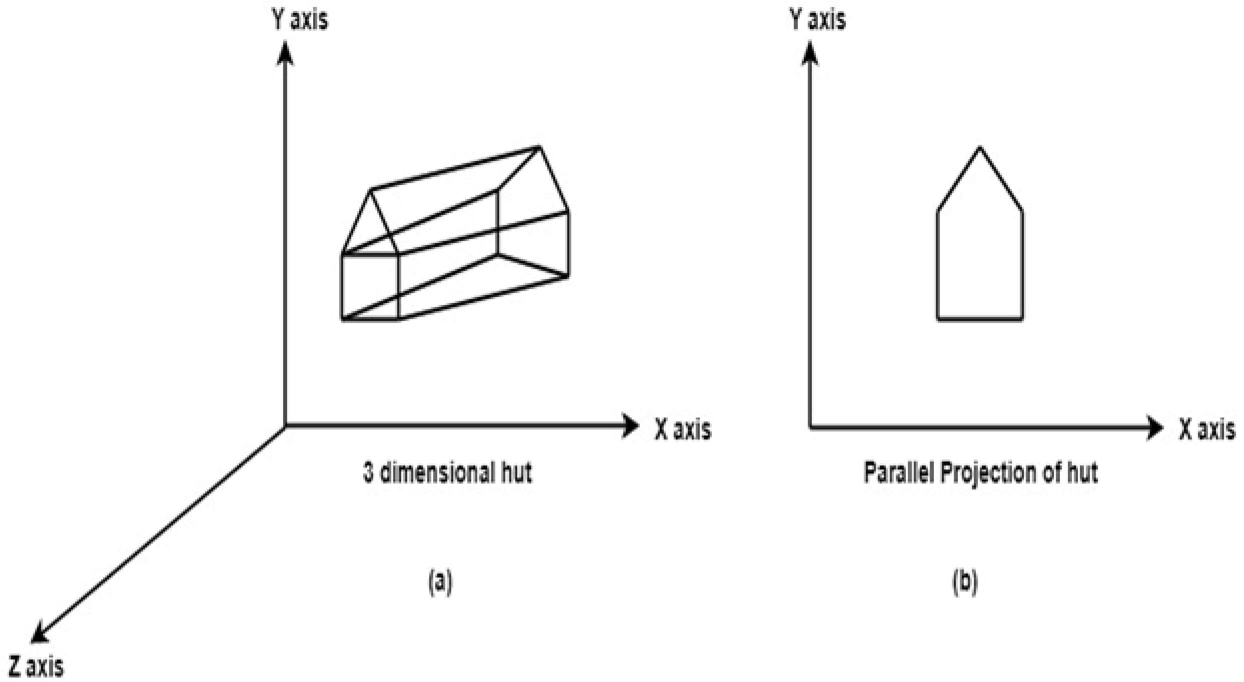
1. **Isometric Projection:** All projectors make equal angles generally angle is of 30°.
2. **Dimetric:** In these two projectors have equal angles. With respect to two principle axis.
3. **Trimetric:** The direction of projection makes unequal angle with their principle axis.
4. **Cavalier:** All lines perpendicular to the projection plane are projected with no change in length.
5. **Cabinet:** All lines perpendicular to the projection plane are projected to one half of their length. These give a realistic appearance of object.



(a) Viewing Volume in orthographic projection



(b) Viewing volume in perspective projection



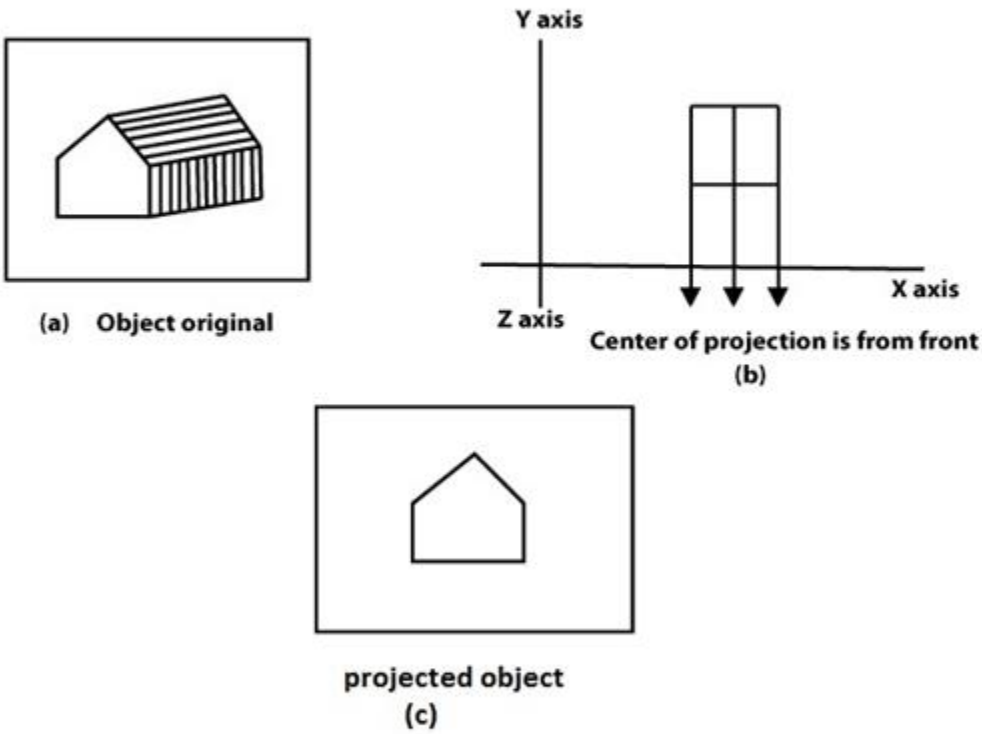
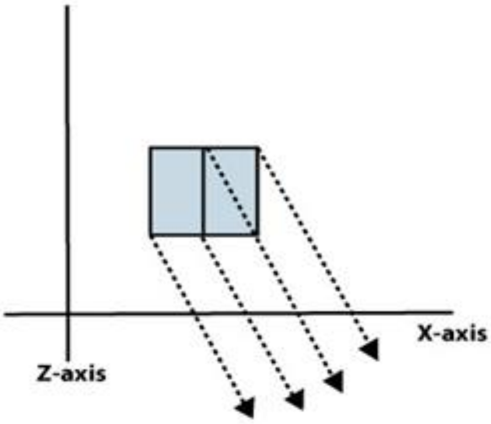
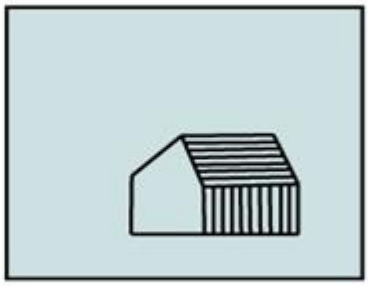


Fig (a) shows original object. Fig (b) shows object when projection is taken. Fig (c) gives projected object.



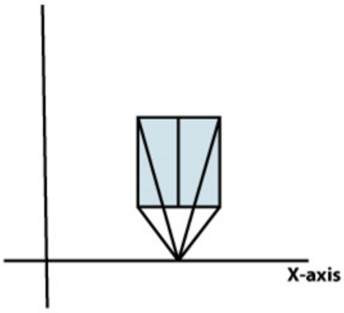
(d)



(e)

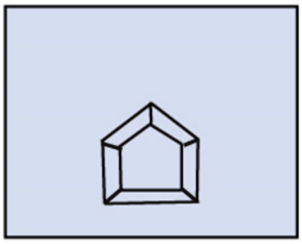
Fig (d) changes the direction of projection

Fig (e) shows object after changing direction of projection.

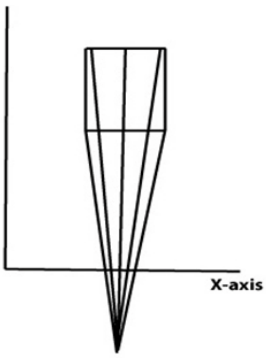


Center of projection meet at a chosen point

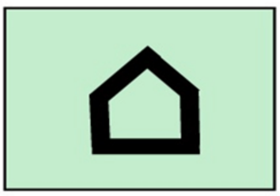
(a)



(b)



(a)



(b)

Hidden Surface Removal

This technique of "**hidden surface elimination**" may be done by extending the pixel attributes to include the "depth" of each pixel in a scene, as determined by the object of which it is a part.

1. One of the most challenging problems in computer graphics is the removal of hidden parts from images of solid objects.
2. In real life, the opaque material of these objects obstructs the light rays from hidden parts and prevents us from seeing them.
3. In the computer generation, no such automatic elimination takes place when objects are projected onto the screen coordinate system.
4. Instead, all parts of every object, including many parts that should be invisible are displayed.
5. To remove these parts to create a more realistic image, we must apply a hidden line or hidden surface algorithm to set of objects.
6. The algorithm operates on different kinds of scene models, generate various forms of output or cater to images of different complexities.
7. All use some form of geometric sorting to distinguish visible parts of objects from those that are hidden.
8. Just as alphabetical sorting is used to differentiate words near the beginning of the alphabet from those near the ends.
9. Geometric sorting locates objects that lie near the observer and are therefore visible.
10. Hidden line and Hidden surface algorithms capitalize on various forms of coherence to reduce the computing required to generate an image.
11. Different types of coherence are related to different forms of order or regularity in the image.
12. Scan line coherence arises because the display of a scan line in a raster image is usually very similar to the display of the preceding scan line.
13. Frame coherence in a sequence of images designed to show motion recognizes that successive frames are very similar.
14. Object coherence results from relationships between different objects or between separate parts of the same objects.
15. A hidden surface algorithm is generally designed to exploit one or more of these coherence properties to increase efficiency.
16. Hidden surface algorithm bears a strong resemblance to two-dimensional scan conversions.

Types of hidden surface detection algorithms

1. Object space methods
2. Image space methods

Object space methods: In this method, various parts of objects are compared. After comparison visible, invisible or hardly visible surface is determined. These methods generally decide visible surface. In the wireframe model, these are used to determine a visible line. So these algorithms are line based instead of surface based. Method proceeds by determination of parts of an object whose view is obstructed by other object and draws these parts in the same color.

Image space methods: Here positions of various pixels are determined. It is used to locate the visible surface instead of a visible line. Each point is detected for its visibility. If a point is visible, then the pixel is on, otherwise off. So the object close to the viewer that is pierced by a projector through a pixel is determined. That pixel is drawn is appropriate color.

These methods are also called a **Visible Surface Determination**. The implementation of these methods on a computer requires a lot of processing time and processing power of the com The image space method requires more computations. Each object is defined clearly. Visibility of each object surface is also determined.

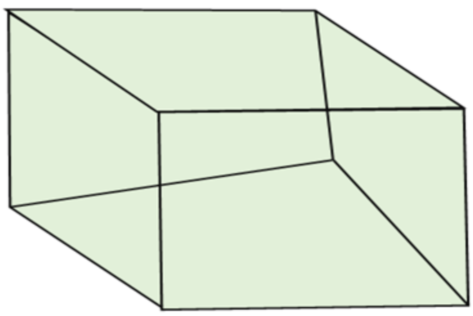
Differentiate between Object space and Image space method

Object Space	Image Space
1. Image space is object based. It concentrates on geometrical relation among objects in the scene.	1. It is a pixel-based method. It is concerned with the final image, what is visible within each raster pixel.
2. Here surface visibility is determined.	2. Here line visibility or point visibility is determined.
3. It is performed at the precision with which each object is defined, No resolution is considered.	3. It is performed using the resolution of the display device.
4. Calculations are not based on the resolution of the display so change of	4. Calculations are resolution base, so the change is difficult to adjust.

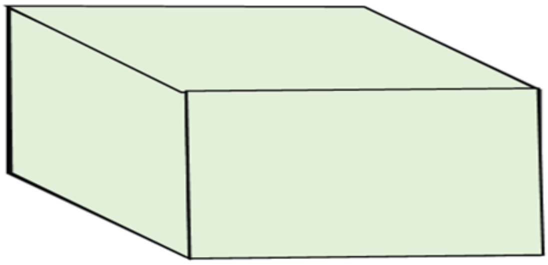
object can be easily adjusted.	
5. These were developed for vector graphics system.	5. These are developed for raster devices.
6. Object-based algorithms operate on continuous object data.	6. These operate on object data.
7. Vector display used for object method has large address space.	7. Raster systems used for image space methods have limited address space.
8. Object precision is used for application where speed is required.	8. There are suitable for application where accuracy is required.
9. It requires a lot of calculations if the image is to enlarge.	9. Image can be enlarged without losing accuracy.
10. If the number of objects in the scene increases, computation time also increases.	10. In this method complexity increase with the complexity of visible parts.

Similarity of object and Image space method

In both method sorting is used a depth comparison of individual lines, surfaces are objected to their distances from the view plane.



Object with hidden line



Object when hidden lines removed

Coherence

It is used to take advantage of the constant value of the surface of the scene. It is based on how much regularity exists in the scene. When we moved from one polygon of one object to another polygon of same object color and shearing will remain unchanged.

Types of Coherence

1. Edge coherence
2. Object coherence
3. Face coherence
4. Area coherence
5. Depth coherence
6. Scan line coherence
7. Frame coherence
8. Implied edge coherence

1. Edge coherence: The visibility of edge changes when it crosses another edge or it also penetrates a visible edge.

2. Object coherence: Each object is considered separate from others. In object, coherence comparison is done using an object instead of edge or vertex. If A object is farther from object B, then there is no need to compare edges and faces.

3. Face coherence: In this faces or polygons which are generally small compared with the size of the image.

4. Area coherence: It is used to group of pixels cover by same visible face.

5. Depth coherence: Location of various polygons has separated a basis of depth. Depth of surface at one point is calculated, the depth of points on rest of the surface can often be determined by a simple difference equation.

6. Scan line coherence: The object is scanned using one scan line then using the second scan line. The intercept of the first line.

7. Frame coherence: It is used for animated objects. It is used when there is little change in image from one frame to another.

8. Implied edge coherence: If a face penetrates in another, line of intersection can be determined from two points of intersection.

Algorithms used for hidden line surface detection

1. Back Face Removal Algorithm
2. Z-Buffer Algorithm
3. Painter Algorithm
4. Scan Line Algorithm
5. Subdivision Algorithm
6. Floating horizon Algorithm

Back Face Removal Algorithm

It is used to plot only surfaces which will face the camera. The objects on the back side are not visible. This method will remove 50% of polygons from the scene if the parallel projection is used. If the perspective projection is used then more than 50% of the invisible area will be removed. The object is nearer to the center of projection, number of polygons from the back will be removed.

It applies to individual objects. It does not consider the interaction between various objects. Many polygons are obscured by front faces, although they are closer to the viewer, so for removing such faces back face removal algorithm is used.

When the projection is taken, any projector ray from the center of projection through viewing screen to object pieces object at two points, one is visible front surfaces, and another is not visible back surface.

This algorithm acts a preprocessing step for another algorithm. The back face algorithm can be represented geometrically. Each polygon has several vertices. All vertices are numbered in clockwise. The normal M_1 is generated a cross product of any two successive edge vectors. M_1represent vector perpendicular to face and point outward from polyhedron surface

$N_1=(v_2-v_1)(v_3-v_2)$
If $N_1.P\geq 0$ visible
$N_1.P<0$ invisible

Advantage

1. It is a simple and straight forward method.
2. It reduces the size of databases, because no need of store all surfaces in the database, only the visible surface is stored.

Back Face Removed Algorithm

Repeat for all polygons in the scene.

1. Do numbering of all polygons in clockwise direction i.e.
   $v_1\ v_2\ v_3.....v_z$
2. Calculate normal vector i.e. N_1
   $N_1=(v_2-v_1)*(v_3-v_2)$
3. Consider projector P, it is projection from any vertex
   Calculate dot product
   Dot=N.P
4. Test and plot whether the surface is visible or not.
   If Dot $\geq$ 0 then
   surface is visible
   else
   Not visible

Z-Buffer Algorithm

It is also called a **Depth Buffer Algorithm**. Depth buffer algorithm is simplest image space algorithm. For each pixel on the display screen, we keep a record of the depth of an object within the pixel that lies closest to the observer. In addition to depth, we also record the intensity that should be displayed to show the object. Depth buffer is an extension of the frame buffer. Depth buffer algorithm requires 2 arrays, intensity and depth each of which is indexed by pixel coordinates (x, y).

Algorithm

For all pixels on the screen, set depth [x, y] to 1.0 and intensity [x, y] to a background value.

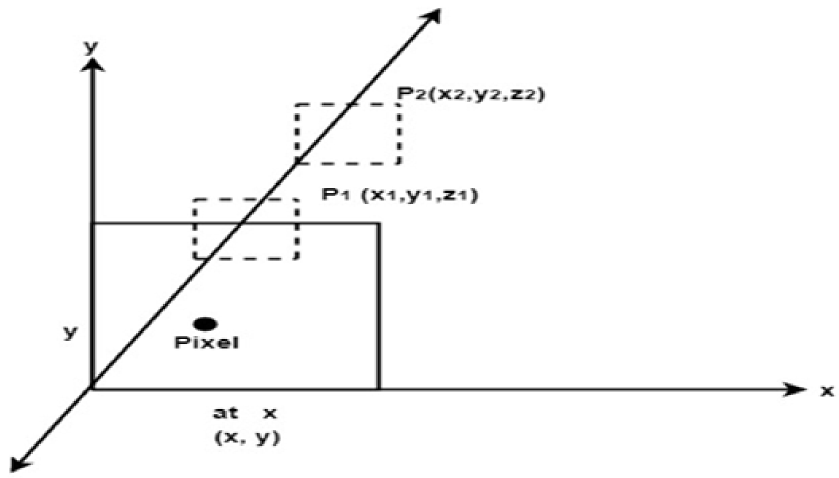
For each polygon in the scene, find all pixels (x, y) that lie within the boundaries of a polygon when projected onto the screen. For each of these pixels:

(a) Calculate the depth z of the polygon at (x, y)

(b) If z < depth [x, y], this polygon is closer to the observer than others already recorded for this pixel. In this case, set depth [x, y] to z and intensity [x, y] to a value corresponding to polygon's shading. If instead z > depth [x, y], the polygon already recorded at (x, y) lies closer to the observer than does this new polygon, and no action is taken.

3. After all, polygons have been processed; the intensity array will contain the solution.

4. The depth buffer algorithm illustrates several features common to all hidden surface algorithms.



5. First, it requires a representation of all opaque surface in scene polygon in this case.

6. These polygons may be faces of polyhedral recorded in the model of scene or may simply represent thin opaque 'sheets' in the scene.

7. The IInd important feature of the algorithm is its use of a screen coordinate system. Before step 1, all polygons in the scene are transformed into a screen coordinate system using matrix multiplication.

Limitations of Depth Buffer

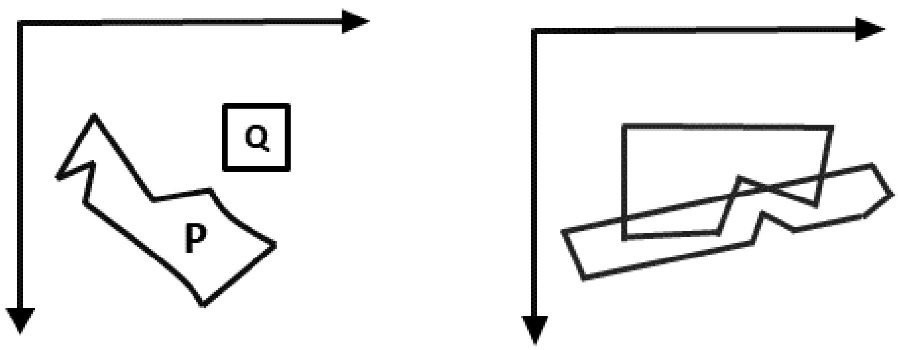
1. The depth buffer Algorithm is not always practical because of the enormous size of depth and intensity arrays.
2. Generating an image with a raster of 500 x 500 pixels requires 2, 50,000 storage locations for each array.
3. Even though the frame buffer may provide memory for intensity array, the depth array remains large.
4. To reduce the amount of storage required, the image can be divided into many smaller images, and the depth buffer algorithm is applied to each in turn.
5. For example, the original 500 x 500 faster can be divided into 100 rasters each 50 x 50 pixels.
6. Processing each small raster requires array of only 2500 elements, but execution time grows because each polygon is processed many times.
7. Subdivision of the screen does not always increase execution time instead it can help reduce the work required to generate the image. This reduction arises because of coherence between small regions of the screen.

Painter Algorithm

It came under the category of list priority algorithm. It is also called a **depth-sort algorithm**. In this algorithm ordering of visibility of an object is done. If objects are reversed in a particular order, then correct picture results.

Objects are arranged in increasing order to z coordinate. Rendering is done in order of z coordinate. Further objects will obscure near one. Pixels of rear one will overwrite pixels of farther objects. If z values of two overlap, we can determine the correct order from Z value as shown in fig (a).

If z objects overlap each other as in fig (b) this correct order can be maintained by splitting of objects.



(a) (b)

Depth sort algorithm or painter algorithm was developed by Newell, sancha. It is called the painter algorithm because the painting of frame buffer is done in decreasing order of distance. The distance is from view plane. The polygons at more distance are painted firstly.

The concept has taken color from a painter or artist. When the painter makes a painting, first of all, he will paint the entire canvas with the background color. Then more distance objects like mountains, trees are added. Then rear or foreground objects are added to picture. Similar approach we will use. We will sort surfaces according to z values. The z values are stored in the refresh buffer

Steps performed in-depth sort

1. Sort all polygons according to z coordinate.
2. Find ambiguities of any, find whether z coordinate overlap, split polygon if necessary.
3. Scan convert each polygon in increasing order of z coordinate.

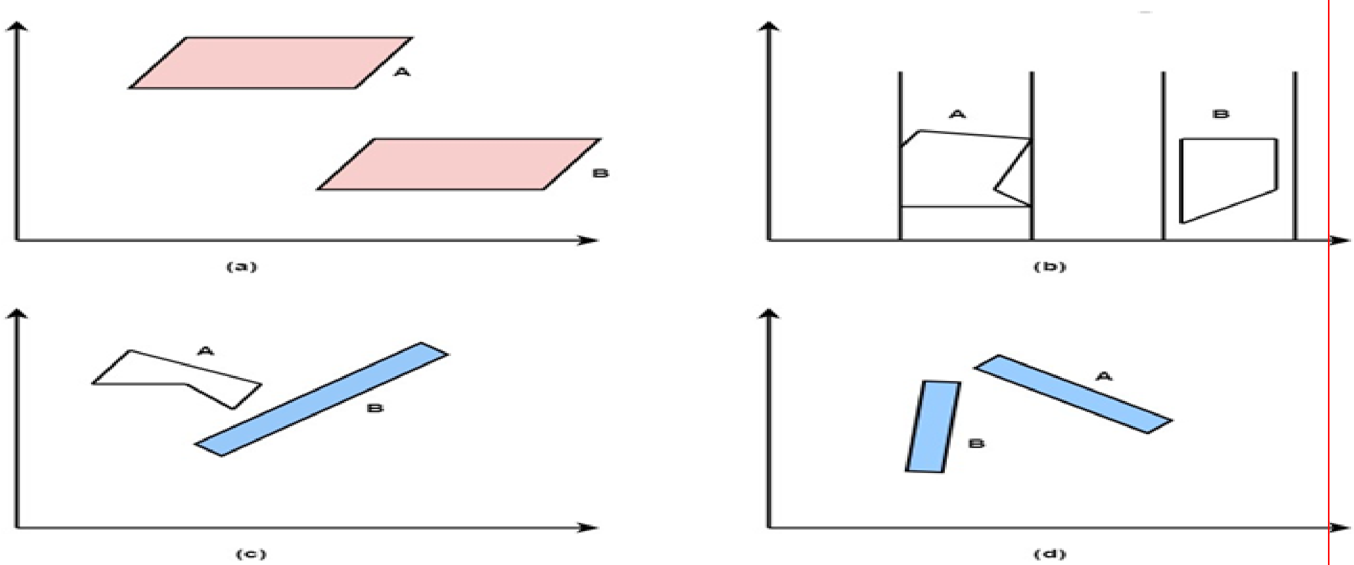
Painter Algorithm

Step1: Start Algorithm

Step2: Sort all polygons by z value keep the largest value of z first.

Step3: Scan converts polygons in this order.
Test is applied

1. Does A is behind and non-overlapping B in the dimension of Z as shown in fig (a)
2. Does A is behind B in z and no overlapping in x or y as shown in fig (b)
3. If A is behind B in Z and totally outside B with respect to view plane as shown in fig (c)
4. If A is behind B in Z and B is totally inside A with respect to view plane as shown in fig (d)



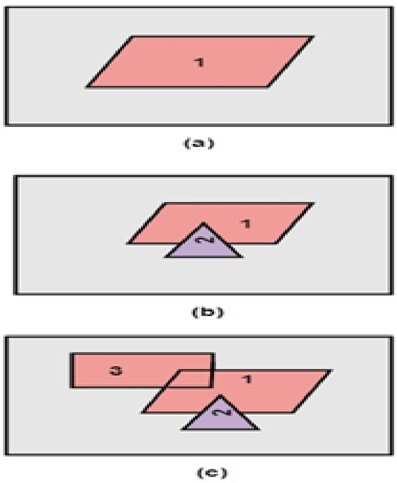
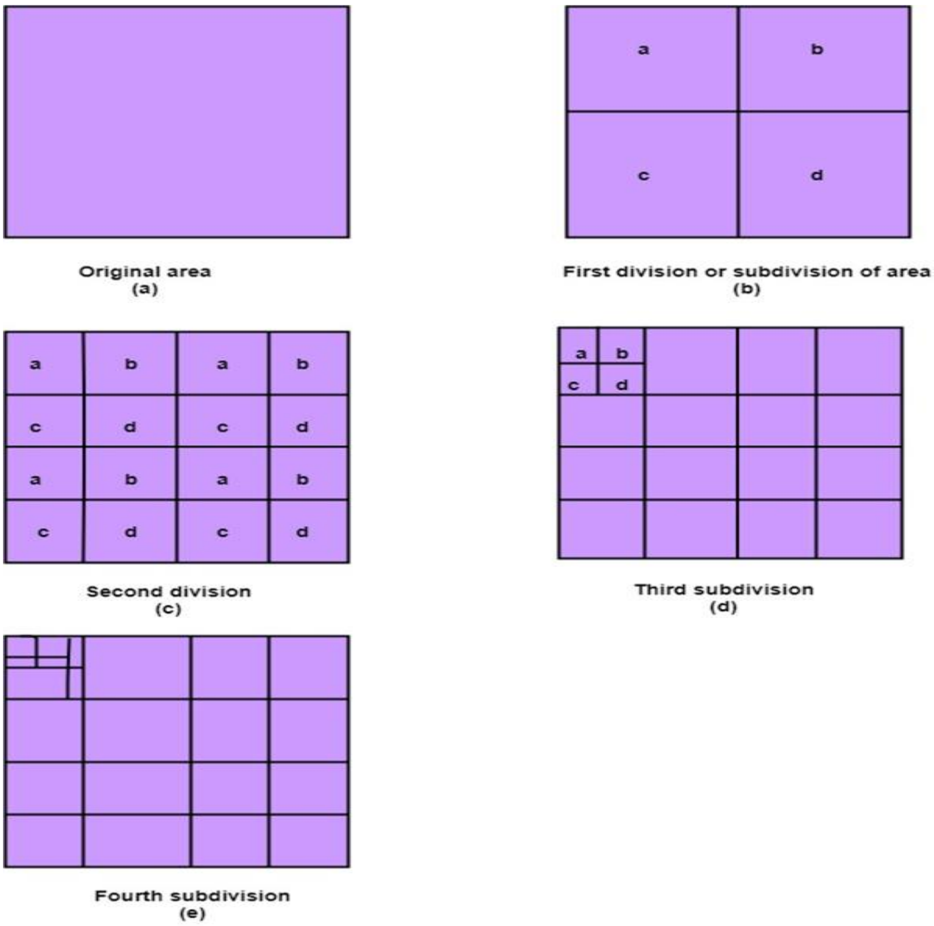


Figure showing addition of surface one by one and then painting done using painter algorithm

Area Subdivision Algorithm

It was invented by John Warnock and also called a Warnock Algorithm. It is based on a divide & conquer method. It uses fundamental of area coherence. It is used to resolve the visibility of algorithms. It classifies polygons in two cases i.e. trivial and non-trivial.

Trivial cases are easily handled. Non trivial cases are divided into four equal subwindows. The windows are again further subdivided using recursion until all polygons classified trivial and non trivial.



Classification of Scheme

It divides or classifies polygons in four categories:

1. Inside surface
2. Outside surface
3. Overlapping surface

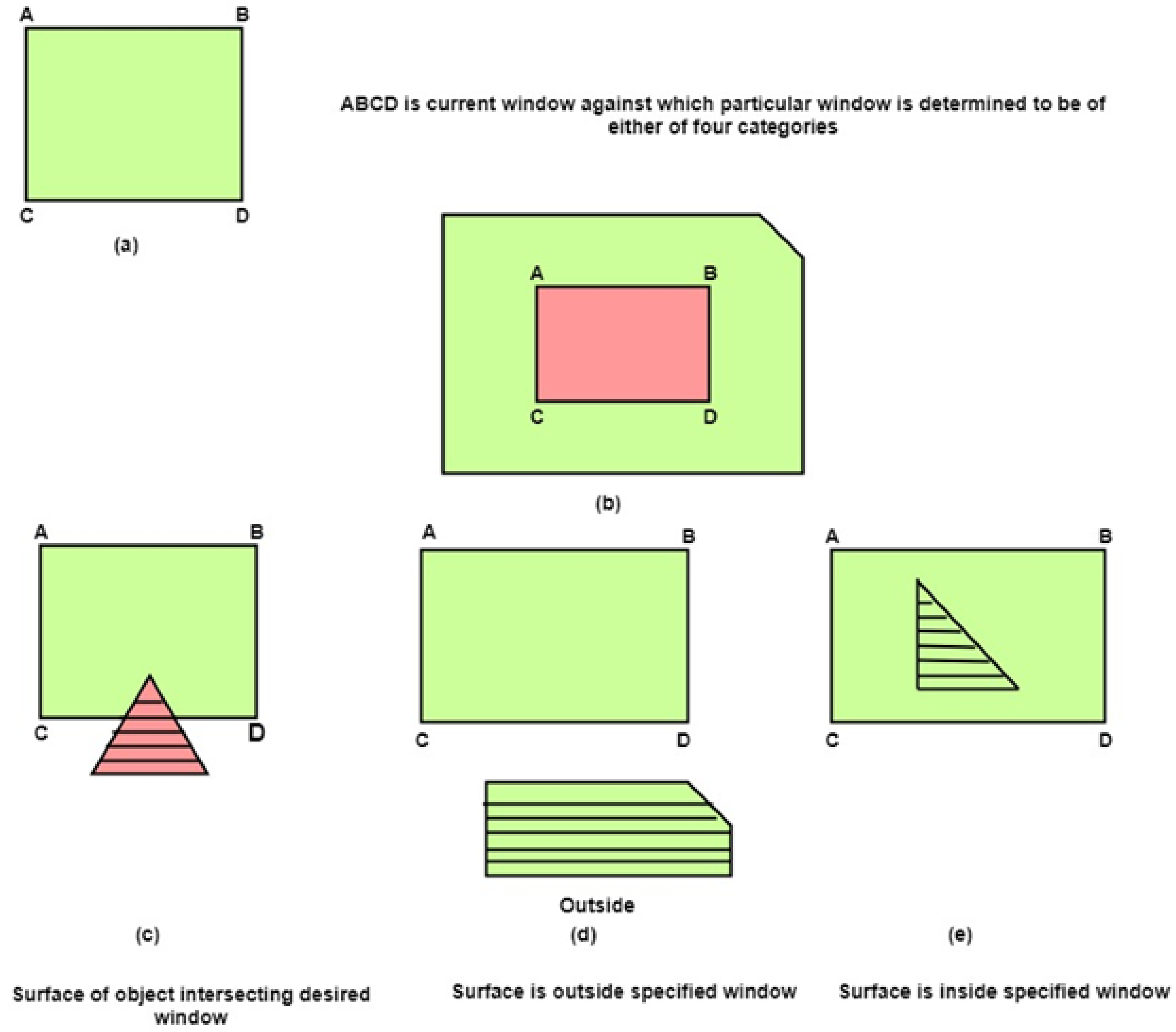
4. Surrounding surface

1. Inside surface: It is surface which is completely inside the surrounding window or specified boundary as shown in fig (c)

2. Outside surface: The polygon surface completely outside the surrounding window as shown in fig (a)

3. Overlapping surface: It is polygon surface which completely encloses the surrounding window as shown in fig (b)

4. Overlapping surface: It is surface partially inside or partially outside the surface area as shown in fig (c)



Bezier curve

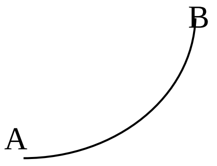
Bezier curves are used in computer graphics to draw shapes, for CSS animation and in many other places.They are a very simple thing, worth to study once and then feel comfortable in the world of vector graphics and advanced animations.

Control Point:

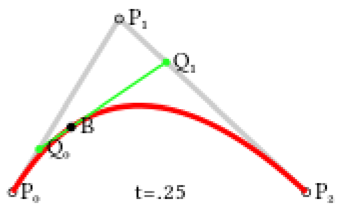
A bezier curve is defined by control points.

There may be 2, 3, 4 or more.

For instance, two points curve:

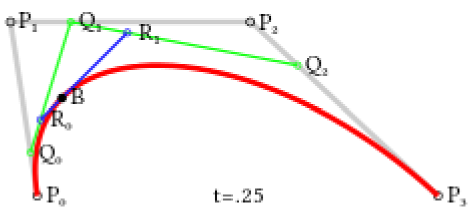


- Bezier Curve is parametric curve defined by a set of control points.
- Two points are ends of the curve.
- Other points determine the shape of the curve.



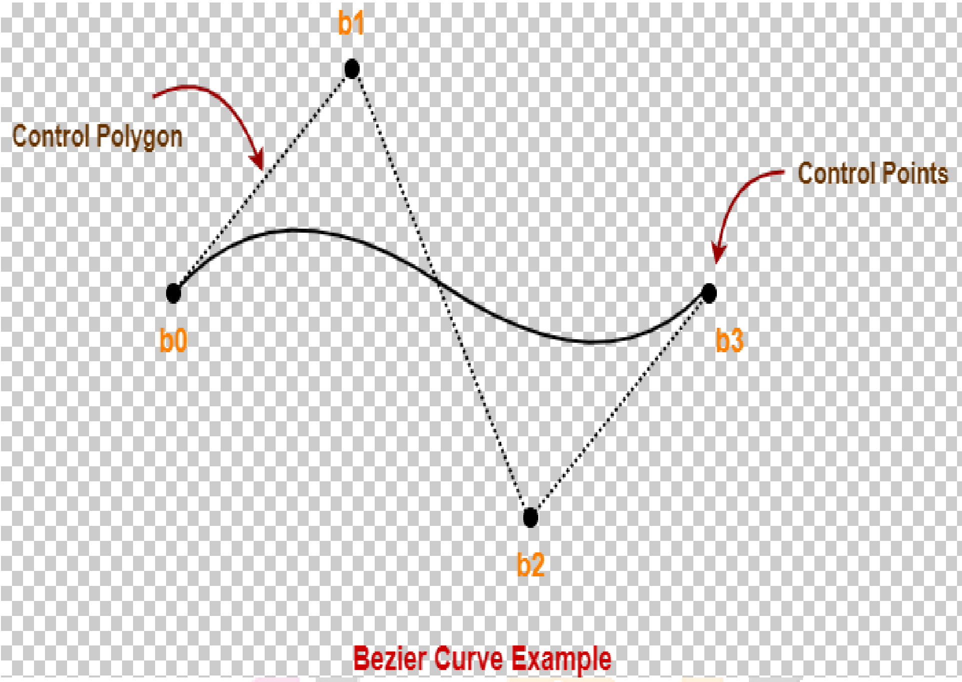
Here no. of control points=3

Degree of curve=2



Here no. of control points=4

Degree of curve=3



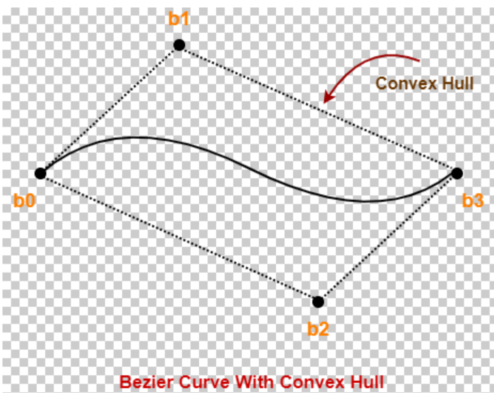
Here,

- This bezier curve is defined by a set of control points b_0, b_1, b_2 and b_3.
- Points b_0 and b_3 are ends of the curve.
- Points b_1 and b_2 determine the shape of the curve.

Bezier Curve Properties-

Property-01:

Bezier curve is always contained within a polygon called as convex hull of its control points.



Property-02:

- Bezier curve generally follows the shape of its defining polygon.
- The first and last points of the curve are coincident with the first and last points of the defining polygon.

Property-03:

The degree of the polynomial defining the curve segment is one less than the total number of control points.

Degree = Number of Control Points – 1

Property-04:

The order of the polynomial defining the curve segment is equal to the total number of control points.

Order = Number of Control Points

Property-05:

- Bezier curve exhibits the variation diminishing property.
- It means the curve do not oscillate about any straight line more often than the defining polygon

Bezier Curve Equation-

A bezier curve is parametrically represented by-

$$P(t) = \sum_{i=0}^{n} B_i J_{n,i}(t)$$

Bezier Curve Equation

Here,

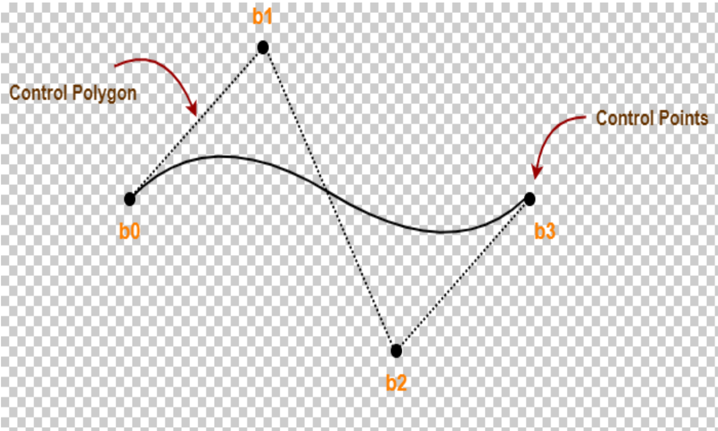
- t is any parameter where 0 <= t <= 1
- P(t) = Any point lying on the bezier curve
- B_i = i^{th} control point of the bezier curve
- n = degree of the curve
- $J_{n,i}(t)$ = Blending function = $C(n,i)t^i(1-t)^{n-i}$ where C(n,i) = n! / i!(n-i)!

Cubic Bezier Curve-

- Cubic bezier curve is a bezier curve with degree 3.
- The total number of control points in a cubic bezier curve is 4.

Example-

The following curve is an example of a cubic bezier curve-



Cubic Bezier Curve

Here,

- This curve is defined by 4 control points b_0, b_1, b_2 and b_3.
- The degree of this curve is 3.
- So, it is a cubic bezier curve.

Cubic Bezier Curve Equation-

The parametric equation of a bezier curve is-

$$P(t) = \sum_{i=0}^{n} B_i J_{n,i}(t)$$

Bezier Curve Equation

Substituting n = 3 for a cubic bezier curve, we get-

$$P(t) = \sum_{i=0}^{3} B_i J_{3,i}(t)$$

Expanding the above equation, we get-

$P(t) = B_0J_{3,0}(t) + B_1J_{3,1}(t) + B_2J_{3,2}(t) + B_3J_{3,3}(t)$ ………..(1)

Now,

$$J_{3,0}(t) = \frac{3!}{0!\,(3-0)!} t^0 (1-t)^{3-0}$$

$$J_{3,0}(t) = (1-t)^3 \quad \text{............(2)}$$

$$J_{3,1}(t) = \frac{3!}{1!\,(3-1)!} t^1 (1-t)^{3-1}$$

$$J_{3,1}(t) = 3t(1-t)^2 \quad \text{............(3)}$$

$$J_{3,2}(t) = \frac{3!}{2!\,(3-2)!} t^2 (1-t)^{3-2}$$

$$J_{3,2}(t) = 3t^2(1-t)^2 \quad \text{............(4)}$$

$$J_{3,3}(t) = \frac{3!}{3!\,(3-3)!} t^3 (1-t)^{3-3}$$

$$J_{3,3}(t) = t^3 \quad \text{............(5)}$$

Using (2), (3), (4) and (5) in (1), we get-

$P(t) = B_0(1-t)^3 + B_13t(1-t)^2 + B_23t^2(1-t) + B_3t^3$

This is the required parametric equation for a cubic bezier curve.

Applications of Bezier Curves-

- Bezier curves are widely used in computer graphics to model smooth curves.
- The curve is completely contained in the convex hull of its control points.
- So, the points can be graphically displayed & used to manipulate the curve intuitively.

PRACTICE PROBLEMS BASED ON BEZIER CURVE IN COMPUTER GRAPHICS-

Problem-01:

Given a bezier curve with 4 control points-

$B_0[1\ 0]$, $B_1[3\ 3]$, $B_2[6\ 3]$, $B_3[8\ 1]$

Determine any 5 points lying on the curve. Also, draw a rough sketch of the curve.

Solution-

We have-

- The given curve is defined by 4 control points.
- So, the given curve is a cubic bezier curve.

The parametric equation for a cubic bezier curve is-

$$\mathbf{P(t) = B_0(1-t)^3 + B_13t(1-t)^2 + B_23t^2(1-t) + B_3t^3}$$

Substituting the control points B_0, B_1, B_2 and B_3, we get-

$P(t) = [1\ 0](1-t)^3 + [3\ 3]3t(1-t)^2 + [6\ 3]3t^2(1-t) + [8\ 1]t^3$ ……..(1)

Now,

To get 5 points lying on the curve, assume any 5 values of t lying in the range 0 <= t <= 1.

Let 5 values of t are 0, 0.2, 0.5, 0.7, 1

For t = 0:

Substituting t=0 in (1), we get-

$P(0) = [1\ 0](1-0)^3 + [3\ 3]3(0)(1-t)^2 + [6\ 3]3(0)^2(1-0) + [8\ 1](0)^3$

$P(0) = [1\ 0] + 0 + 0 + 0$

$P(0) = [1\ 0]$

For t = 0.2:

Substituting t=0.2 in (1), we get-

$P(0.2) = [1\ 0](1-0.2)^3 + [3\ 3]3(0.2)(1-0.2)^2 + [6\ 3]3(0.2)^2(1-0.2) + [8\ 1](0.2)^3$

$P(0.2) = [1\ 0](0.8)^3 + [3\ 3]3(0.2)(0.8)^2 + [6\ 3]3(0.2)^2(0.8) + [8\ 1](0.2)^3$

P(0.2) = [1 0] x 0.512 + [3 3] x 3 x 0.2 x 0.64 + [6 3] x 3 x 0.04 x 0.8 + [8 1] x 0.008

P(0.2) = [1 0] x 0.512 + [3 3] x 0.384 + [6 3] x 0.096 + [8 1] x 0.008

P(0.2) = [0.512 0] + [1.152 1.152] + [0.576 0.288] + [0.064 0.008]

P(0.2) = [2.304 1.448]

For t = 0.5:

Substituting t=0.5 in (1), we get-

$P(0.5) = [1\ 0](1-0.5)^3 + [3\ 3]3(0.5)(1-0.5)^2 + [6\ 3]3(0.5)^2(1-0.5) + [8\ 1](0.5)^3$

$P(0.5) = [1\ 0](0.5)^3 + [3\ 3]3(0.5)(0.5)^2 + [6\ 3]3(0.5)^2(0.5) + [8\ 1](0.5)^3$

P(0.5) = [1 0] x 0.125 + [3 3] x 3 x 0.5 x 0.25 + [6 3] x 3 x 0.25 x 0.5 + [8 1] x 0.125

P(0.5) = [1 0] x 0.125 + [3 3] x 0.375 + [6 3] x 0.375 + [8 1] x 0.125

P(0.5) = [0.125 0] + [1.125 1.125] + [2.25 1.125] + [1 0.125]

P(0.5) = [4.5 2.375]

For t = 0.7:

Substituting t=0.7 in (1), we get-

$P(t) = [1\ 0](1-t)^3 + [3\ 3]3t(1-t)^2 + [6\ 3]3t^2(1-t) + [8\ 1]t^3$

$P(0.7) = [1\ 0](1-0.7)^3 + [3\ 3]3(0.7)(1-0.7)^2 + [6\ 3]3(0.7)^2(1-0.7) + [8\ 1](0.7)^3$

$P(0.7) = [1\ 0](0.3)^3 + [3\ 3]3(0.7)(0.3)^2 + [6\ 3]3(0.7)^2(0.3) + [8\ 1](0.7)^3$

P(0.7) = [1 0] x 0.027 + [3 3] x 3 x 0.7 x 0.09 + [6 3] x 3 x 0.49 x 0.3 + [8 1] x 0.343

P(0.7) = [1 0] x 0.027 + [3 3] x 0.189 + [6 3] x 0.441 + [8 1] x 0.343

P(0.7) = [0.027 0] + [0.567 0.567] + [2.646 1.323] + [2.744 0.343]

P(0.7) = [5.984 2.233]

For t = 1:

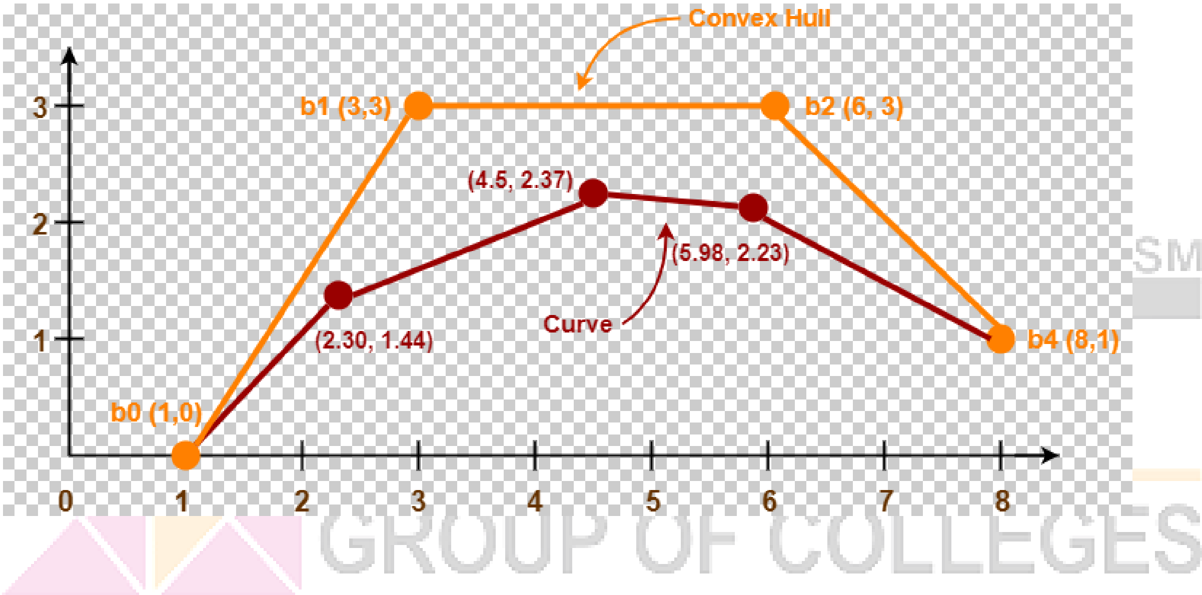
Substituting t=1 in (1), we get-

$P(1) = [1\ 0](1-1)^3 + [3\ 3]3(1)(1-1)^2 + [6\ 3]3(1)^2(1-1) + [8\ 1](1)^3$

P(1) = [1 0] x 0 + [3 3] x 3 x 1 x 0 + [6 3] x 3 x 1 x 0 + [8 1] x 1

P(1) = 0 + 0 + 0 + [8 1]

P(1)=[8 1]



B Spline Surface

Given the following information:

- a set of m+1 rows and n+1 control points pi,j, where 0 <= i <= m and 0 <= j <= n;
- a knot vector of h + 1 knots in the u-direction, U = { u0, u1, ..., uh };
- a knot vector of k + 1 knots in the v-direction, V = { v0, v1, ..., vk };
- the degree p in the u-direction; and
- the degree q in the v-direction;

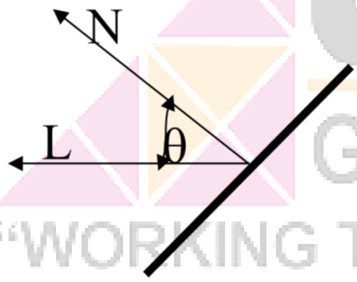
the B-spline surface defined by these information is the following:

$$\mathbf{p}(u,v) = \sum_{i=0}^{m}\sum_{j=0}^{n} N_{i,p}(u)N_{j,q}(v)\mathbf{p}_{i,j}$$

Illumination Model

- A surface point could be illuminated by
  - ***local illuminatio***n, light directly emitted by light sources
  - ***global illuminatio***n, light reflected from and transmitted through its own and other surfaces
- ***Illumination models*** express the factors which determine the surface color at a given point on a surface and compute the color at a point in terms of both local and global illumination. It is calculated in three stages, diffuse reflection, specular reflection and transparency effect to create realism of texture of every type.
- Complete Equation of Illumination Model IL(d)IL(a)+IL(spec)+IL(Trans)
- Summation of Intensity of diffuse reflection, Ambient Light, Specular reflection and transparency effect

Diffuse Reflection



$$I = I_p k_d \overline{N} \bullet \overline{L}$$

k_d is diffuse reflecting I_p intensity of ambient light diffuse reflection is because of ambient light source as well as any other single light source.

- ***Diffuse reflection*** also called ***Lambertian reflection*** is a characteristic of dull, matte surfaces like chalk
- Amount of light reflected from a point on the surface is equal in all directions
- The brightness depends on the angle between the direction to the light source *L* and the surface normal *N*
- The brightness is independent of the viewing direction

Intensity of Ambient light

- The ambient light is: $I = I_a k_a$
- I_a is the intensity of ambient light

  and k_a is the materials *ambient reflection coefficient* ranging from 0 to 1

- By adding the ambient term to the diffuse reflection the illumination equation is

$$I = I_a k_a + I_p k_d (\overline{N} \bullet \overline{L})$$

Diffuse reflection is constant over each surface independent of the viewing direction.

Specular Reflection

Specular reflection is direction dependent when we look at illuminated shiny surface ,we see a highlight or bright spot t in certain viewing direction. This phenomenon is know as specular reflection. According to phong's model this will vary as per angle of incidence of light.

Specular reflection parameter is determined by type of the surface for shiny surface, it is having large value and for dull surface it is equal to 1.

Diffuse reflection model is necessary for illumination of the surface of any type where as specular reflection is required typically for shiny surfaces. This is large at specific point but diffuse selection is constant over the surface.

Objects other than ideal reflectors exhibit specular reflections over a finite of viewing position around vector R,(light reflection direction). The intensity of specular reflection depends on material properties of the surface and angle of incidence.

We can approximate model as monochromatic specular intensity variations using specular reflection coefficient w (θ) of surface.

w (θ) varies in angel of 0 to 90° As angle of incidence increases w (θ)tends to increase. The variation of specular intensity with angle of incidence is describe as freshel's laws of reflection under Phong's specular reflection model.

Ispec = w(θ) I, cos ^{ns} ϕ (developed by Phong)

Where I_1 is intensity of light source and is varying selective to specular reflection R

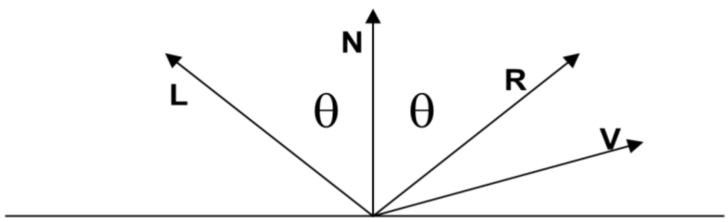
At angle = 90° w (θ) = 1 and all incident light is reflected

V unit vector is viewing direction

R specular refln direction

cos ϕ is dot product or V.R

Where ^{ns} is specular refl ^{n} coefficient of material



- In case of multiple light sources, the terms for each light source are summed. So for ***m*** light sources the illumination equation is

  $$I = I_a k_a + \sum_{i \le i \le m} I_{pi}[k_d(\bar{N} \bullet \bar{L}_i) + k_s(\bar{R}_i \bullet \bar{V})^n]$$

  Due to transparency effect, illumination is

  I=(1-kt)I_{refl} + Kt I_{trans}

- Kt -> Transparency Coefficient
- I_{trans} -> trasmitted intensity through surface

Local Illumination Considers light sources and surface properties only

$$I_\lambda = I_a k_a + \sum_{p=1}^{lights} \frac{I_p}{(s_o + k)}[k_d(\bar{N} \bullet \bar{L}) + k_s(\bar{V} \bullet \bar{R})^n] + I_t k_t$$

Application of Illumination model

To apply intensity and color intensity to all 3D surfaces, mathematical model called shading model is used. Shading is referred to as the implementation of the illumination model at the pixel points or polygon surfaces of the graphics objects.Shading model is used to compute the intensities and colors to display the surface

Shading models are classifies as

- Constant Shading
- Gourad shading
- Phong shading

Constant Intensity Shading

A fast and straightforward method for rendering an object with polygon surfaces is constant intensity shading, also called Flat Shading. In this method, a single intensity is calculated for each polygon. All points over the surface of the polygon are then displayed with the same intensity value. This is based on assumption that the object is a polyhedron and is not an approximation of an object with a curved surface.

Gourad Shading Model

Gourad shading model is based on intensity interpolation scheme for rendering polygon surfaces. Intensity values for each polygon are matched with values of adjacent polygons.

The steps for rendering are as:-

- Determine average unit normal vector as each vertex
- Apply illumination model to calculate vertex intensity.
- Linearly interpolate the intensities for intermediate points

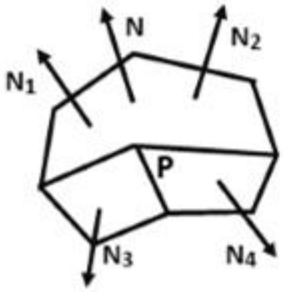


Fig: The normal vertex at vertex V is calculated as the average of surface normal for each polygon sharing the vertex.

$$N_V = \frac{\sum_{k=1}^{n} N_k}{\left|\sum_{k=1}^{n} N_k\right|}$$

average normal vector calculation

Gourad shading model is based on intensity interpolation method. Calculates different intensities for different pixels on surface area. Low intensity light areas and bands are created producing mach band effect.

Mach Band Effect

Highlights on the surface are displayed with anomalous shapes and liner intensity inter polation can cover bright or dark intensity streaks called much bands, appearing on surface.

Constant shading model generates constant intensity throughout the surface. But there is problem of intensities discontinuities for smooth surface display this is not useful for smooth surface display limer interpolation is useful.

Mach band effect is more problematic in case of gourad shading here as in case of phong shading model intensity calculations using an approximated normal vector produces more accurate results than the direct interpolation phong shading model requires more calculation is the only problem. Mach band effect is considerably decreased in case of phong shading than gourad shading or constant shading model

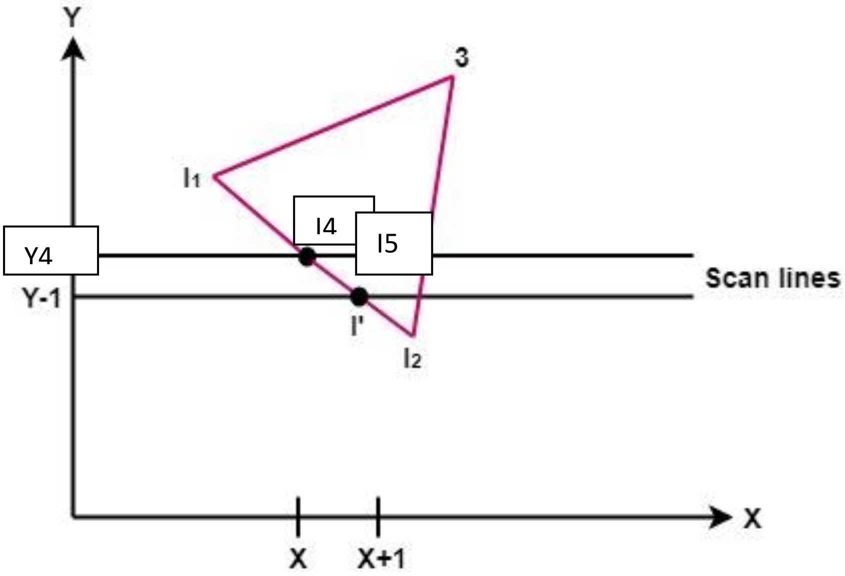


Fig: Incremental Interpolation of intensity value along a polygon edge for successive scan lines.

At vertex, I1, scan line is y1 and at vertex I2 scan line is y2, by interpolating intensities with difference of scan lines, intermediate intensity at I4 is interpolated and calculated. This point I4 is along the polygonal edge, where as at any interior point I5 is calculated as interpolation of intersections I4 and another intersection along the same scan line Y4 with x value differences. Thus x and y values of pixels are used for interpolating intensities.

$$I_4 = \frac{y_4 - y_2}{y_1 - y_2} I_1 + \frac{y_1 - y_4}{y_1 - y_2} I_2$$

Phong Shading Model

A polygon surface is rendered using following steps:-

1.determine the average unit normal vector at each vertex

2. Linearly interpolate the vertex normal vector the surface

3. Apply illumination model to calculate pixel intensities at points intensity calculation using an approximation vectors at each point along the scan line . It produces

more accurate results than direct interpolation in gourad shading . It produces more realistic specular high lights. It interpolate normal vectors and then apply illumination model.

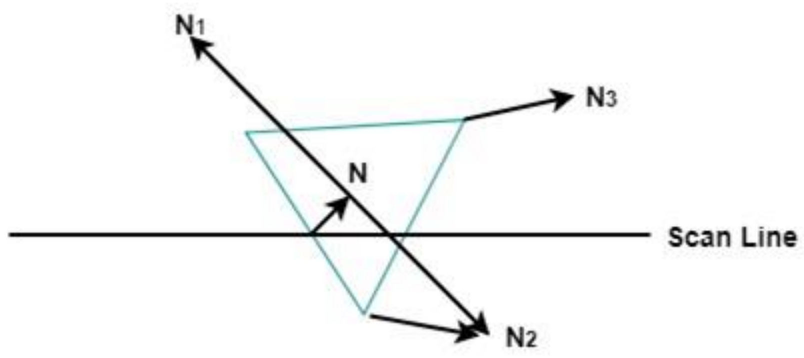


Fig: Interpolation of surface normals along a polygon edge.

$$N = \frac{y - y_2}{y_1 - y_2} N_1 + \frac{y_1 - y}{y_1 - y_2} N_2$$

Fig. Normal Vector interpolation with scan line difference

Highlights on the surface displayed with anomalous shapes and can not create smooth fading effect. Phong shading model is based or normal vector interpolation on it user more accurate method for rendering polygon surface. Same surface is subdivided into greater no. of polygon faces and normal vectors are interpolated. Mathematically interpolated normal vector is going to generate accurate intensities calculations than direct interpolation.This reduces mach band effect and try to produce more realistic appearance.

Phong shading increases calculatiues as compased to gourad shading and also difficult to implement it taken around six or seven times longer then gourad shading model.

Global illumination

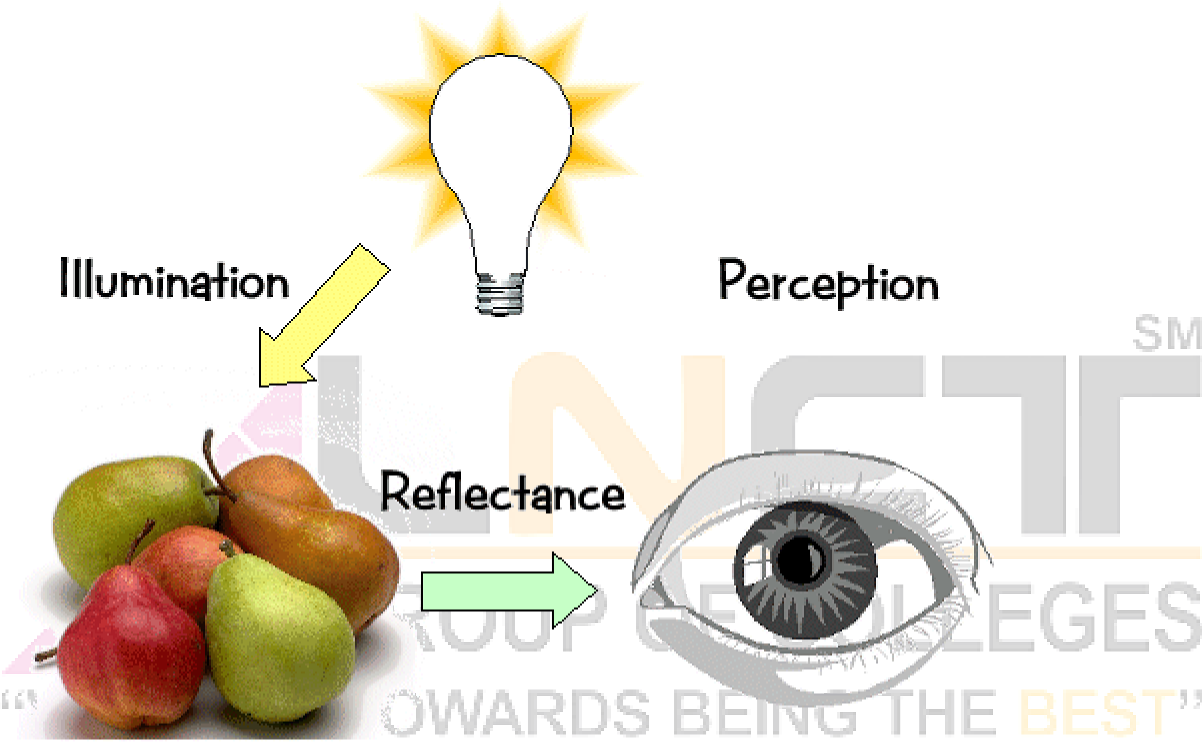
– The notion that a point is illuminated by more than light from local lights; it is illuminated by all the emitters and reflectors in the global scene

Rendering equation

- Jim Kajiya (Current head of Microsoft Research) developed this in 1986
- I(x, x') is the total intensity from point x' to x
- g(x, x') = 0 when x/x' is hidden and $1/d^2$ otherwise (d = distance between x and x')
- e(x, x') is the intensity emitted by x' to x
- r(x, x',x'') is the intensity of light reflected from x'' to x through x'
- S is all points on all surfaces
- The light that hits x from x' is the direct illumination from x' and all the light reflected by x' from all x''
- To implement:
    - Must handle recursion effectively and shadowing model effectively
    - Must support diffuse and specular light

Color model

To understand how to make realistic images, we need a basic understanding of the physics and physiology of vision.



- Computer scientists frequently use:
  - Hue - The color we see (red, green, purple)
  - Saturation - How far is the color from gray (pink is less saturated than red, sky blue is less saturated than royal blue)
  - Brightness (Luminance) - How bright is the color

Generic XYZ Color model

The three standard primaries are imaginary colors. The set of CIE primaries is referred as XYZ color model where X,Y,Z three vectors represented by 3-D additive color space.

Any color C_x is XX+YY+ZZ where X,Y,Z represents amounts of standard primaries.

To normalize the amount is against luminance (X+Y+Z) Normalized amount are calculated as.

X= X/(X+Y+Z)   Y=Y/(X+Y+Z)

Z= Z/(X+Y+Z)

Where X+Y+Z=1

Parameters X and Y are called as chromaticity values. A complete description of a color is with three values X,Y and Y

`   X=(X/Y)Y   Z(Z/Y)Y

Where Z = 1-X-Y

Any color can be obtained by using the two values X and Y in hue and saturation.

CIE Chromaticity Diagram

The *CIE* (Commission Internationale d'Eclairage) came up with three hypothetical lights X, Y, and Z with these spectra.

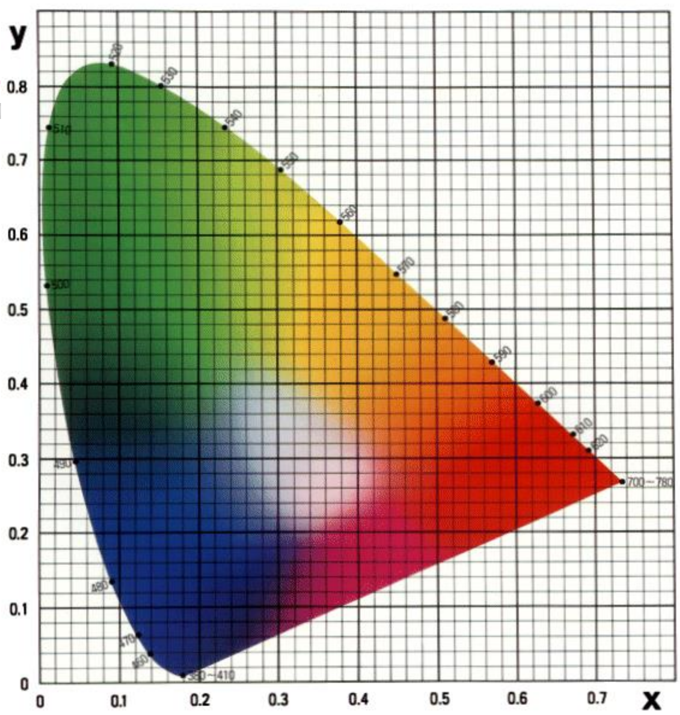
CIE chromaticity diagram is represented as tongue shaped curve points along the curve are the "pure" colors in electromagnetic spectrum auording to wavelength from the red end to violet end of the spectrum.

Point C in diagram corresponds to the white light position Illuminate CF is standard approx . for average day light luminance values are not available in chromacity diag. The chromacity diagram is useful for comparing color garents for different primaries

1.Identifying complementary colors

2.Determining dommant wavelength and purity of a given color

Color gamats are presented on the chromaticity diagram as straight line segments or as polygons.

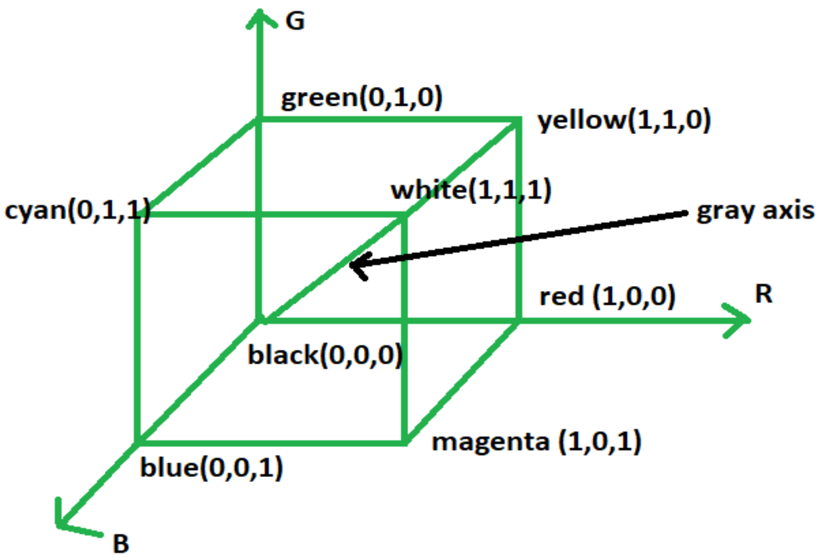


RGB Color Model

The RGB color model is one of the most widely used color representation method in computer graphics. It use a color coordinate system with three primary colors:

R(red), G(green), B(blue)

Each primary color can take an intensity value ranging from 0(lowest) to 1(highest). Mixing these three primary colors at different intensity levels produces a variety of colors. The collection of all the colors obtained by such a linear combination of red, green and blue forms the cube shaped RGB color space.



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The corner of RGB color cube that is at the origin of the coordinate system corresponds to black, whereas the corner of the cube that is diagonally opposite to the origin represents white. The diagonal line connecting black and white corresponds to all the gray colors between black and white, which is also known as **gray axis**.
In the RGB color model, an arbitrary color within the cubic color space can be specified by its color coordinates: (r, g.b).

Example:

(0, 0, 0) for black, (1, 1, 1) for white,

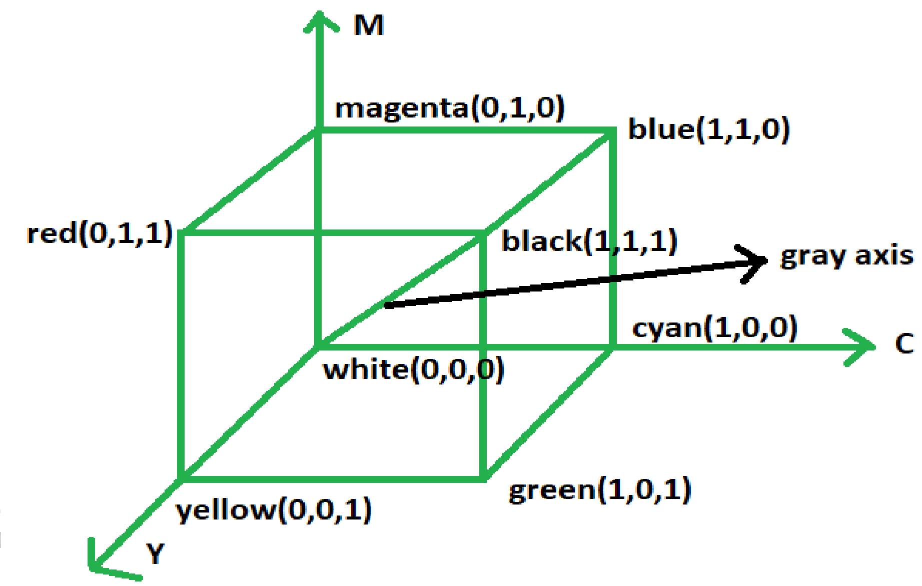
(1, 1, 0) for yellow, (0.7, 0.7, 0.7) for gray

Color specification using the RGB model is an **additive process**. We begin with black and add on the appropriate primary components to yield a desired color. The concept RGB color model is used in **Display monitor**. On the other hand, there is a complementary color model known as **CMY color model**. The CMY color model use a **subtraction process** and this concept is used in the **printer**.

In CMY model, we begin with white and take away the appropriate primary components to yield a desired color.

Example:
If we subtract red from white, what remains consists of green and blue which is cyan. The coordinate system of CMY model use the three primaries' complementary colors:
C(cray), M(magenta) and Y(yellow)

CMY Color Model



The corner of the CMY color cube that is at (0, 0, 0) corresponds to white, whereas the corner of the cube that is at (1, 1, 1) represents black. The following formulas summarize the conversion between the two color models:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} C \\ M \\ Y \end{bmatrix} \qquad \begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

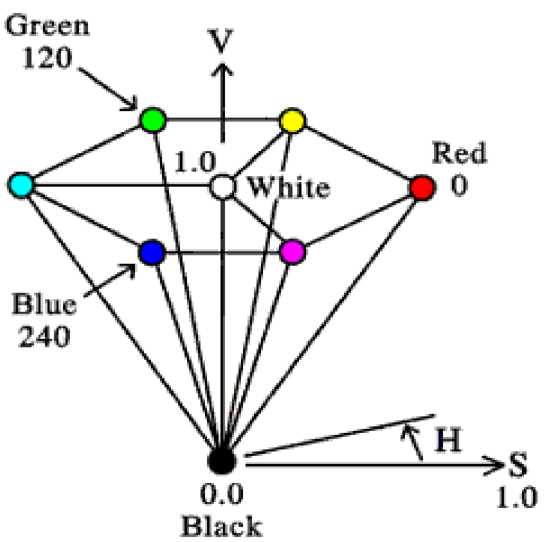
Difference between additive color model and subtractive color model:-

ADDITIVE COLORS
VERSUS
SUBTRACTIVE COLORS

Criterion	Additives	Subtractive
Definition	Occurs with the simultaneous action of various color 'irritants' on the eye.	Not mixing of color 'irritants', but creating color by subtraction
Basic colors	red, green, and blue	cyan, magenta and yellow
Color combinations	green + red = yellow, blue + red = magenta, blue + green = cyan	yellow + magenta = red, yellow + cyan = green, magenta + cyan = blue
Systems	RGB	CMYK

DB Difference Between.net

HSV Color Model



RAJIV GANDHI PROUDYOGIKI VISHWAVIDYALAYA, BHOPAL

New Scheme Based On AICTE Flexible Curricula

Computer Science and Engineering, VI-Semester

Departmental Elective - CS603 (B) Computer Graphics & Visualization

Topics Covered

Unit-IV Visualization: Visualization of 2D/3D scalar fields: color mapping, ISO surfaces. Direct volume data rendering: ray-casting, transfer functions, segmentation. Visualization of Vector fields and flow data, Time-varying data, High-dimensional data: dimension reduction, parallel coordinates, Non-spatial data: multi-variate, tree/graph structured, text Perceptual and cognitive foundations, Evaluation of visualization methods, Applications of visualization, Basic Animation Techniques like traditional, key framing

Introduction

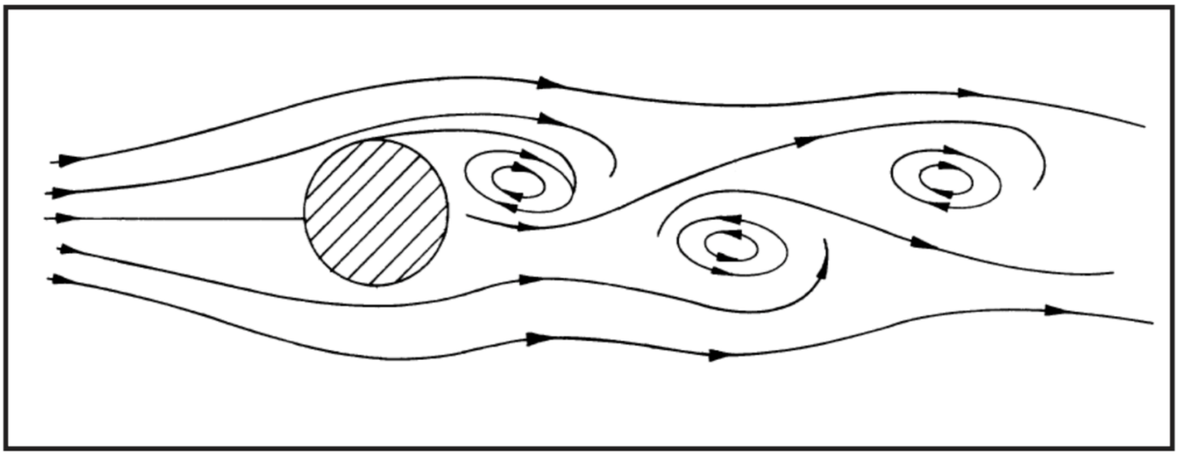
Visualization is the process of representing data graphically and interacting with these representations in order to gain insight into the data. Traditionally, **computer graphics** has provided a powerful mechanism for creating, manipulating, and interacting with these representations

Scientific visualisation is gaining importance in all domains of medical science, data analytics, computer vision, neural network, deep learning, weather and satellite imagery. It draws from and contributes to work in algorithms, human perception, art, **animation**, **computer** vision, and image processing.

With visualisation, Computer graphics technology enables creation of synthetic 3D or 2D environments and user interfaces for different industries: entertainment (movies, video games), simulation (medical, military), scientific visualization and consumer electronics (mobile phones, media players).

Although in the real world, space and time are continuous, in a numerical simulation we generally use discrete space and time to describe the system. Commonly, simulation output contains a set of sample points, data values associated with each sample and an interpolation rule. Generally, output data can be categorized by sampling patterns, or by the dimension of data values associated with each sample point.Typical sampling patterns include regular (Cartesian) grid, curvilinear(structured) grid and unstructured (irregular) grid.

For ex. How to create following diagram in computer graphics and visualisation



Background

Dimensionality of value

Data can be classified as scalar, vector, or tensor field by the dimension of associated value with each sample.

A scalar field associates a scalar to every sample point, and is often used to indicate some physical properties such as temperature, pressure and density. For a vector field, the quantity is specified by a vector, giving a direction as well as a magnitude, such as velocity and magnetic field.

Interactive visualization of the resulting time-varying data allow scientists to freely explore how selected properties of the data change over time, and gain insight into the relationships between values that might not be apparent in the raw data and this is where visualisation helps the researchers.

For ex. For physics

The resulting data sets share some common characteristics with data from other scientific simulations: • Data are sampled on a curvilinear grid.

• For any time instant, several physical properties are measured: –

Scalar field: density, temperature.

Vector field: velocity, magnetic field. • Data are captured at thousands of time steps

Basic unit of visualisation is voxel.

A **voxel** represents a value on a regular grid in three-dimensional space. As with pixels in a **2D** bitmap, **voxels** themselves do not typically have their position (coordinates) explicitly encoded with their values. ... **Voxels** are frequently used in the **visualization** and analysis of medical and scientific data (e.g. GIS).

Visualization

Visualization is the process of representing data graphically and interacting with these representations in order to gain insight into the data. Traditionally, **computer graphics** has provided a powerful mechanism for creating, manipulating, and interacting with these representations. At IBM, graphics and visualization research addresses the problem of converting data into compelling, revealing, and interactive graphics that suit users' needs. Visualization includes studying visual analytics, developing languages and models of interaction with visualizations, designing novel information visualizations for smarter visual analytics, developing new representations of 3D geometry, strategies for collaborative and social visualization, and designing software systems that support a full range of display formats ranging from smart phones to immersive multi-display visualization environments. Computer graphics technology enables creation of synthetic 3D or 2D environments and user interfaces for different industries: entertainment (movies, video games), simulation (medical, military), scientific visualization and consumer electronics (mobile phones, media players).

2D scalar visualisation techniques

1. **Color mapping** is a common **scalar visualization** technique that **maps scalar** data to **colors**, and displays the **colors** on the computer system. The **scalar mapping** is implemented by indexing into a **color** lookup table. **Scalar** values then serve as indices into this lookup table. The lookup table holds an array of **colors**.
2. **Isosurface** extraction is a powerful tool for investigating volumetric **scalar** fields. An isosurface in a **scalar** volume is a **surface** on which the data value is constant, separating regions of higher and lower value.
3. The characteristic of **direct volume rendering** is the **direct** mapping of voxels on pixels of a **2D** image plane. It allows for the "global" representation integrating physical characteristics, but prohibits interactive display due to its numerical complexity in general.
4. **Ray casting** is the use of **ray**–surface intersection tests to solve a variety of problems in 3D **computer graphics** and computational geometry. The term was first used in **computer graphics** in a 1982 paper by Scott Roth to describe a method for rendering constructive solid geometry models. It computes 2D images from 3D volumetric data sets (3D scalar fields).

Color Mapping

A **color map** (often called a **color** table or a palette) is an array of **colors** used to **map** pixel data (represented as indexes into the **color** table) to the actual **color** values.
Some **graphic** displays, especially older ones, cannot show an arbitrary **color** for every pixel.

Direct Volume Visualization With Ray Casting:

The idea of Direct Volume Rendering (DVR) is to get a 3D representation of the volume data directly. The data is considered to represent a semi-transparent light-emitting medium.

Therefore also gaseous phenomena can be simulated. The approaches in DVR are based on the laws of physics (emission, absorption, scattering). The volume data is used as a whole (we can look inside the volume and see all interior structures). In DVR either backward or forward methods can be used. Backward methods use image space/image order algorithms. They are performed pixel by pixel. An example is Ray Casting which well be discussed in detail below.

Ray Casting:

Ray Casting is similar to ray tracing in surface-based computer graphics. In volume rendering we only deal with primary rays, i.e. no secondary rays for shadows, reflection or refraction are considered. Ray Casting is a natural image order technique. Since we have no surfaces in DVR we have to carefully step through the volume. A ray is cast into the volume, sampling the volume at certain intervals. The sampling intervals are usually equidistant, but they don't have to be (e.g. importance sampling). At each sampling location, a sample is interpolated/reconstructed from the voxel grid. Popular filter are nearest neighbor (box), trilinear, or more sophisticated (Gaussian, cubic spline). Volumetric ray integration: The rays are casted through the volume. Color and opacity are accumulated along each ray (compositing).

3D Vector Visualisation Techniques

Rapid advances in hardware have been transforming revolutionary approaches in computer graphics into reality. One typical example is the raster graphics that took place in the seventies, when hardware innovations enabled the transition from vector graphics to raster graphics. Another example which has a similar potential is currently shaping up in the field of volume graphics. This trend is rooted in the extensive research and development effort in scientific visualization in general and in volume visualization in particular.

Visualization is the usage of computer-supported, interactive, visual representations of data to amplify cognition. Scientific visualization is the visualization of physically based data.

Volume visualization is a method of extracting meaningful information from volumetric datasets through the use of interactive graphics and imaging, and is concerned with the representation, manipulation, and rendering of volumetric datasets.

Its objective is to provide mechanisms for peering inside volumetric datasets and to enhance the visual understanding.

Traditional 3D graphics is based on surface representation. Most common form is polygon-based surfaces for which affordable special-purpose rendering hardware have been developed in the recent years. Volume graphics has the potential to greatly advance the field of 3D graphics by offering a comprehensive alternative to conventional surface representation methods.

The object of this thesis is to examine the existing methods for volume visualization and to find a way of efficiently rendering scientific data with commercially available hardware, like PC's, without requiring dedicated systems.

Volume Rendering

Our display screens are composed of a two-dimensional array of pixels each representing a unit area. A volume is a three-dimensional array of cubic elements, each representing a unit of space. Individual elements of a three-dimensional space are called volume elements or voxels. A number associated with each point in a volume is called the value at that point. The collection of all these values is called a scalar field on the volume. The set of all points in the volumewith a given scalar value is called a level surface. Volume rendering is the process of displaying scalar fields. It is a method for visualizing a three dimensional data set. The interior information about a data set is projected to a display screen using the volume rendering methods. Along the ray path from each screen pixel, interior data values are examined and encoded for display. How the data are encoded for display depends on the application. Seismic data, for example, is often examined to find the maximum and minimum values along each ray. The values can then be color coded to give information about the width of the interval and the minimum value. In medical applications, the data values are opacity factors in the range from 0 to 1 for the tissue and bone layers. Bone layers are completely opaque, while tissue is somewhat transparent . Voxels represent various physical characteristics, such as density, temperature, velocity, and pressure. Other measurements, such as area, and volume, can be extracted from the volume datasets. Applications of volume visualization are medical imaging (e.g., computed tomography, magnetic resonance imaging, ultrasonography), biology (e.g., confocal microscopy), geophysics (e.g., seismic measurements from oil and gas exploration), industry (e.g., finite element models), molecular systems (e.g., electron density maps), meteorology (e.g., stormy (prediction), computational fluid dynamics (e.g., water flow), computational chemistry (e.g., new materials), digital signal and image processing (e.g., CSG). Numerical simulations and sampling devices such as magnetic resonance imaging (MRI), computed tomography (CT), positron emission tomography (PET), ultrasonic imaging, confocal microscopy, supercomputer simulations, geometric models, laser scanners, depth images estimated by stereo disparity, satellite imaging, and sonar are sources of large 3D datasets.

3D scientific data can be generated in a variety of disciplines by using sampling methods. Volumetric data obtained from biomedical scanners typically come in the form of 2D slices of a regular, Cartesian grid, sometimes varying in one or more major directions. The typical output of supercomputer and Finite Element Method (FEM) simulations is irregular grids. The raw output of an ultrasound scan is a sequence of arbitrarily oriented, fan-shaped slices, which constitute partially structured point samples . A sequence of 2D slices obtained from these scanners is reconstructed into a 3D volume model. Imaging machines have a resolution of millimeters scale so that many details important for scientific purposes can be recorded .

It is often necessary to view the dataset from continuously changing positions to better understand the data being visualized . The real-time interaction is the most essential requirement and preferred even if it is rendered in a somewhat less realistic way . A real-time rendering system is important for the following reasons :

- to visualize rapidly changing datasets,
- for real-time exploration of 3D datasets, (e.g. virtual reality)
- for interactive manipulation of visualization parameters, (e.g. classification)
- for interactive volume graphics.

Rendering and processing does not depend on the object's complexity or type, it depends only on volume resolution. The dataset resolutions are generally anywhere from 128^3 to 1024^3 and may be non-symmetric (i.e. 1024 x 1024 x 512).

Classification of Volume Rendering Algorithms

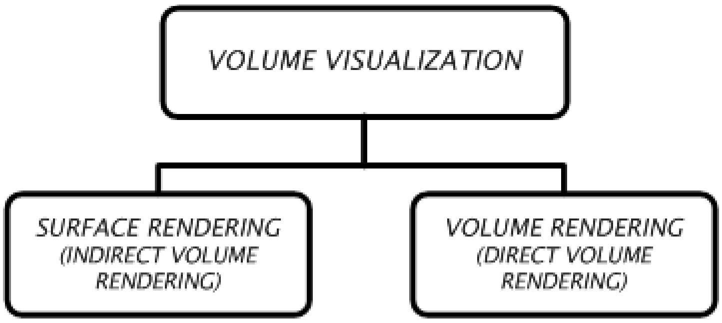
The object of this chapter is to give the general background of volume graphics together with a general classification. It is important to mention that there is not a complete agreement on a standard volume visualization vocabulary yet, a nomenclature is approaching consensus, where multiple terms exist for the same concept. And even a standard classification of volume visualization algorithms is not available. The classification of the algorithms given below is therefore not binding. All of the names of the algorithms are carefully taken into consideration and emphasized.

Volume visualization has been the most active sub-area of researches during last 20 years in scientific visualization. To be useful, volume visualization techniques must offer understandable data representations, quick data manipulation, and reasonably fast rendering. Scientific users should be able to change parameters and see the resultant image instantly. Few present day systems are capable of this type of performance; therefore researchers are still studying many new ways to use volume visualization effectively.

The rendering approaches :

1.Surface rendering (or indirect volume rendering),

2.Volume rendering (or direct volume rendering).



Surface rendering (indirect rendering or surface oriented) algorithms are standard for nearly all 3D visualization problems. Surface oriented algorithms first fit geometric primitives to values in the data, and then render these primitives. The data values are usually chosen from an iso-surface, which is the set of locations in the data where the scalar field equals some value. In typical datasets from medical or scientific applications, the iso-surface forms a connected surface, such as the air/skin or brain/bone boundary in a CT dataset. With dedicated vector hardware, these models can be calculated very efficiently. Examples of surface oriented hardware are Reality Engine, HP, SUN, IBM, and PIXAR. Typical visualization problems to be solved in the medical context are e.g. tissues that have no defined surface or blood vessels whose size is close to the limit of imaging resolution. However surface oriented methods leave these problems unsolved.

An indirect volume rendering system transforms the data into a different domain (e.g., compression, boundary representation, etc.). Typically, the data is transformed into a set of polygons representing a level surface (or iso-surface); then conventional polygon rendering methods are used to project the polygons into an image . Many methods exist for indirect volume rendering (surface rendering), which are defined as visualizing a volumetric dataset by first transferring the data into a different domain and rendering directly from the new domain. Indirect volume rendering can be classified as *surface tracking*, *iso-surfacing*, and *domain-based rendering*. Indirect methods are often chosen because of a particular form of hardware acceleration or because of a speed advantage .

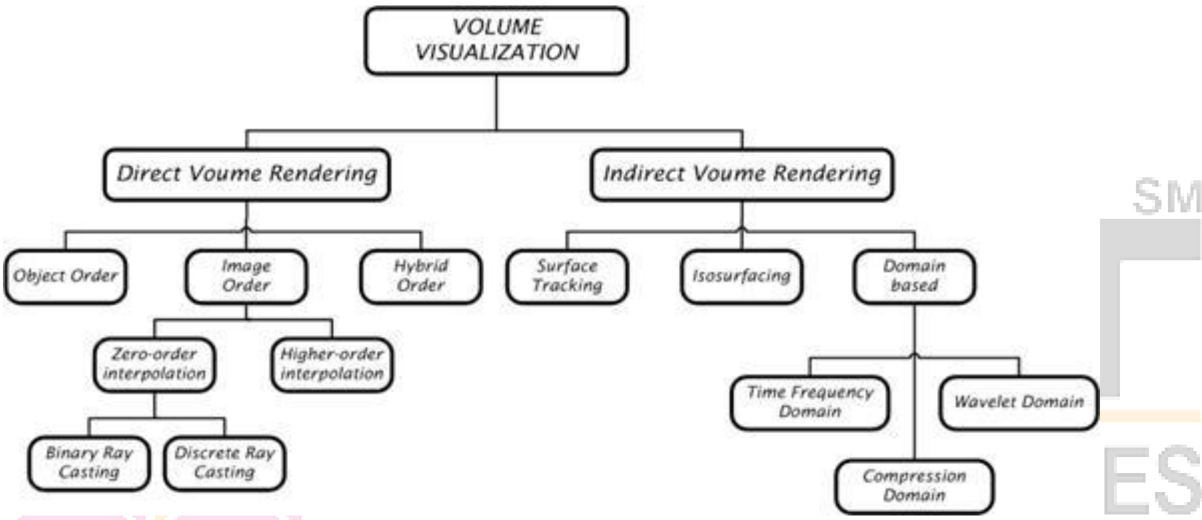


Figure : Detailed classification of volume rendering algorithms

Iso-surfacing

Surface Detection (iso-surface) is an operation that given a scene outputs a connected surface as a binary shell. Connectedness means that within the output shell it is possible to reach to any shell element from any shell element without leaving the shell. If the input is a binary scene, the shell constitutes a connected interface between 1-cells and 0-cells. If the input is a (grey) scene, the interface between the interior and exterior of the structure is usually difficult to determine. Thresholding can be used to determine this interface, in which the shell constitutes essentially a connected interface between cells that satisfy the threshold criterion and cells that do not. In a particular thresholding operation specified by a single intensity value, the resulting surface is called an *iso-surface*. The common iso-surfacing algorithms are Opaque Cubes (Cuberille), Marching Cubes, Marching Tetrahedra, and Dividing Cubes.

Transfer Function

In order to strengthen transfer function (TF)'s ability in identifying meaningful features and simplify interactive mode, we present a TF design method based on 2D histogram image segmentation with the guidance of feature difference evaluation. A **transfer function** is used to assign RGB and alpha values for every voxel in the volume. One is two manually define the **transfer functions** by specifying the RGBA values for the isovalues (what we will be doing), and another is through visual controls and widgets.

Segmentation:

Image segmentation is the division of an image into regions or categories, which correspond to different objects or parts of objects. Every pixel in an image is allocated to one of a number of these categories. A good segmentation is typically one in which:

• pixels in the same category have similar greyscale of multivariate values and form a connected region, • neighbouring pixels which are in different categories have dissimilar values.

Segmentation is often the critical step in image analysis: the point at which we move from considering each pixel as a unit of observation to working with objects (or parts of objects) in the image, composed of many pixels. If segmentation is done well then all other stages in image analysis are made simpler.

There are three general approaches to segmentation, termed thresholding, edge-based methods and region-based methods.

In thresholding, pixels are allocated to categories according to the range of values in which a pixel lies. Image boundaries which were obtained by thresholding the muscle fibres image. Pixels with values less than 128 have been placed in one category, and the rest have been placed in the other category. The boundaries between adjacent pixels in different categories has been superimposed in white on the original image. It can be seen that the threshold has successfully segmented the image into the two predominant fibre types.

• **In edge-based segmentation**, an edge filter is applied to the image, pixels are classified as edge or non-edge depending on the filter output, and pixels which are not separated by an edge are allocated to the same category

• **Finally, region-based segmentation** algorithms operate iteratively by grouping together pixels which are neighbours and have similar values and splitting groups of pixels which are dissimilar in value.

Vector Field Visualization

The need to visualize vector fields in two or three dimensions is common in many scientific disciplines, as well as it is necessary in some industrial branches. Examples of vector fields include velocities of wind and ocean currents, results of fluid dynamics solutions, magnetic fields, blood flow or components of stress and strain in materials. Existing techniques for vector field visualization differ in how well they represent such attributes of the vector field as magnitude, direction and critical points.

Vector:

A mathematical object having the properties of magnitude and direction, usually pictorially represented by a line segment with an arrowhead. In 3D modeling a vector is often given a geometric interpretation, for example, position or displacement. Vector algebra and calculus are effective tools for creating and manipulating certain kinds of models.

Vector field:

A region of space under the influence of some vector quantity, such as magnetic field strength, in which each point can be described by a vector.

The vector field is given by a n−tupel (f 1 ,…., f n) with $f_k = f_k$ (x_1 ,… , x_n),n>=2∧1<=k<=n and specific transformation properties. Typically the dimension is n=k=2 or n=k=3n 3D vector data set each point is represented by a vector that stands for a direction and magnitude.

The main application of vector field visualization is flow visualization with the following attributes:

• Motion of fluids (gas, liquids)

• Geometric boundary conditions

• Velocity (flow) field v (x ,t)

• Pressure p

• Temperature T

• Vorticity ∇ ×v (rotation operator)

• Density

• Conservation of mass, energy, and momentum

• Navier-Stokes equations

• CFD (Computational Fluid Dynamics) CFD data based flow visualization with lines, icons and glyphs. By extending the lines to 2D bands, one can see if the band rotates around the own

Time-varying data

Time-stamped data is a dataset which has a concept of time ordering defining the sequence that each data point was either captured (event time) or collected (processed time).This type of data is typically used when collecting behavioral data (for example, user actions on a website) and thus is a true representation of actions over time. Time series data is data in a series of particular time intervals or periods. If we see scientifically, most of the measurements are executed over time.

High-dimensional data

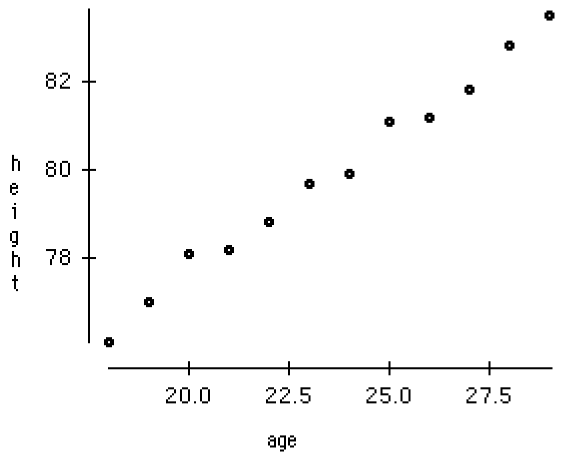
High-dimensional data is a term being popularized in relation to facial recognition technologies. Due to the massively complex number of contours on a human face, we need new expressions of data that are multi-faceted enough to be able to handle computations that are capable of describing all the nuances and individualities that exist across out facial physiognomies.

Dimensionality Reduction

We are generating a tremendous amount of data daily. In fact, 90% of the data in the world has been generated in the last 3-4 years! The numbers are truly mind boggling. Below are just some of the examples of the kind of data being collected:

- Facebook collects data of what you like, share, post, places you visit, restaurants you like, etc.
- Your smartphone apps collect a lot of personal information about you
- Amazon collects data of what you buy, view, click, etc. on their site
- Casinos keep a track of every move each customer makes

As data generation and collection keeps increasing, visualizing it and drawing inferences becomes more and more challenging. One of the most common ways of doing visualization is through charts. Suppose we have 2 variables, Age and Height. We can use a scatter or line plot between Age and Height and visualize their relationship easily:



Parallel coordinates

`Parallel plot` or parallel coordinates plot allows to compare the feature of several individual observations (`series`) on a set of numeric variables. Each vertical bar represents a variable and often has its own scale. (The units can even be different). Values are then plotted as series of lines connected across each axis. Parallel coordinates is a common way of visualizing high-dimensional geometry and analyzing multivariate data. This visualization is closely related to time series visualization, except that it is applied to data where the axes do not correspond to points in time, and therefore do not have a natural order. Therefore, different axis arrangements may be of interest.

Non spatial data:

A non spatial database (or "traditional database") lacks spatial capabilities, i.e. ability to store and query data defined in a geometric space.

A spatial database allows storage and query of geometry objects defined in a geometric space. For instance, ability to query which objects are within a given distance of a point.

Some applications of spatial databases include map applications like Google maps or geo-location based mobile gaming like Pokemon Go.

Tree/Graph Structure:

This is a technique for representation of data .Tree is based on decision tree principal (classification). Graph is a non-linear data structure. Tree is a non-linear data structure. It is a collection of vertices/nodes and edges. It is a collection of nodes and edges. Graphs evolved from the field of mathematics. They are primarily used to describe a model that shows the route from one location to another location. A tree data structure, like a graph, is a collection of nodes. There is a root node. The node can then have children nodes. The children nodes can have their own children nodes called grandchildren nodes.

Text perceptual and cognitive foundation:

According to cognitive constructivism, perceptual processing involves inductive inference or intelligent problem solving. Perceptual processing operates beyond one's awareness, and attempts to construct the best description. According to cognitive constructivism, perceptual processing involves inductive inference or intelligent problem solving. Perceptual processing operates beyond one's awareness, and attempts to construct the best descrip-

Text perceptual and cognitive processes that are involved in the organization, interpretation and comprehension of graphics. The notational symbol system of graphics provides an unambiguous one-to-one relationship between each symbol and a referent in the content domain as well as relatively clear indications of the relations among symbols. Perceptual processes, operating on these symbols and inter-symbol relations, allow the viewer to detect, discriminate among and configure graphic symbols into patterns. Cognitive processes, to some extent influenced by the organization imposed by perception, operate iteratively on information organized by perception leading to the identification, interpretation and comprehension of what has been perceived. Studies that illustrate the operation of these processes are described. Research questions for future study are offered as a conclusion.

Evaluation in visualization:

Visualization or visualisation (see spelling differences) is any **technique** for creating images, diagrams, or animations to communicate a message. **Visualization** through visual imagery has been an effective way to communicate both abstract and concrete ideas since the dawn of humanity.

The first data and information visualization techniques and systems were developed and presented without a systematic evaluation; however, researchers have become, and are more and more, aware of the importance of evaluation. Evaluation is not only a means of improving techniques and applications, but it can also produce evidence of measurable benefits that will encourage adoption.

Visualization Application:

Educational visualization is using a simulation to create an image of something so it can be taught about. This is very useful when teaching about a topic that is difficult to otherwise see, for example, atomic structure, because atoms are far too small to be studied easily without expensive and difficult to use scientific equipment.

Information visualization concentrates on the use of computer-supported tools to explore large amount of abstract data. The term "information visualization" was originally coined by the User Interface Research Group at Xerox PARC and included Jock Mackinlay. Practical application of information visualization in computer programs involves selecting, transforming, and representing abstract data in a form that facilitates human interaction for exploration and understanding. Important aspects of information visualization are dynamics of visual representation and the interactivity. Strong techniques enable the user to modify the visualization in real-time, thus affording unparalleled perception of patterns and structural relations in the abstract data in question.

Knowledge visualization:

The use of visual representations to transfer knowledge between at least two persons aims to improve the transfer of knowledge by using computer and non-computer-based visualization methods complementarily. Thus properly designed visualization is an important part of not only data analysis but knowledge transfer process, too. Knowledge transfer may be significantly improved using hybrid designs as it enhances information density but may decrease clarity as well. For example, visualization of 3D scalar field may be implemented using iso-surfaces for field distribution and textures for the gradient of the field. Examples of such visual formats are sketches, diagrams, images, objects, interactive visualizations, information visualization applications, and imaginary visualizations as in stories. While information visualization concentrates on the use of computer-supported tools to derive new insights, knowledge visualization focuses on transferring insights and creating new knowledge in groups. Beyond the mere transfer of facts, knowledge visualization aims to further transfer insights, experiences, attitudes, values, expectations, perspectives, opinions, and predictions by using various complementary visualizations.

Product visualization:

Product visualization involves visualization software technology for the viewing and manipulation of 3D models, technical drawing and other related documentation of manufactured components and large assemblies of products. It is a key part of product lifecycle management. Product visualization software typically provides high levels of photorealism so that a product can be viewed before it is actually manufactured. This supports functions ranging from design and styling to sales and marketing. *Technical visualization* is an important aspect of product development. Originally technical drawings were made by hand, but with the rise of advanced computer graphics the drawing board has been replaced by computer-aided design (CAD). CAD-drawings and models have several advantages over hand-made drawings such as the possibility of 3-D modeling, rapid prototyping, and simulation.

Visual communication

Visual communication is the communication of ideas through the visual display of information. Primarily associated with two dimensional images, it includes: alphanumerics, art, signs, and electronic resources. Recent research in the field has focused on web design and graphically-oriented usability.

Visual analytics

Visual analytics focuses on human interaction with visualization systems as part of a larger process of data analysis. Visual analytics has been defined as "the science of analytical reasoning supported by the interactive visual interface".Its focus is on human information discourse (interaction) within massive, dynamically changing information spaces. Visual analytics research concentrates on support for perceptual and cognitive operations that enable users to detect the expected and discover the unexpected in complex information spaces.Technologies resulting from visual analytics find their application in almost all fields, but are being driven by critical needs (and funding) in biology and national security.

Animation

Principles:

- Persistence of vision
  - object seen by human eye remains mapped on retina for a brief time after viewing
  - display series of images rapidly and they blend together to create illusion of movement
  - requires at least 16 frames per second to look seamless
- Television: 30 frames per second

- Movies: displayed at 48 frames per second

Basic Animation Techniques

Traditional animation:

This includes the oldest techniques that were used by Disney and other entertainment brands in the earlier days. The idea is simple – you draw sequential images for each frame and show them in series to give an illusion of animation. It's just like those animation books that give an illusion when you flip the pages quickly.

- Cell animation (also called frame animation)
  - start with first and last image in motion (called *keyframes*)
  - draw images between keyframes (process called *tweening*) -- *small changes between images*
  - images are then *layered* onto background scene
  - images displayed rapidly
  - 15/second, 24/second, 30/second

2D Motion

This can refer to two things: traditional animations made from paper or other similar medium and vector-based animations made on computer. We will focus on the latter here. The idea is same as the traditional one. However, the only major difference is the lack of solid medium. You make all the drawings digitally on a computer and play those images to give an animation affect. So, it's comparatively easier and quicker than the traditional technique.

- Path-based Animation (vector animation)
  - Creates animated objects by following object's transition over a line or vector
  - Artist creates one drawing and a path
  - Computer program manipulates object by drawing frames as object travels over the path

3D Animations

3D movies are quite popular entertainment these days. This technique is quite similar to playing with puppets, but in a digital environment. The underlying process is quite technical, so let's just focus on the key principles. 3D animations combine the frames of 2D with modeling of characters. The computer prepares the images in a digital space and does all the calculations to make the objects move in the desired way. Generally, this is quite expensive style of animation and is seldom used.

- Computer animation
  - logic and procedural concepts are same as in cell animation *(keyframe, tweening, layering techniques)*
- Morphing
  - uses frames to create illusion of one object changing into another
  - more keypoints = smoother morph

Steps to create animation

1. Determine type of animation

2. Choose software

3. Create or select graphic to animate

4. Create color palette

5. Render (draw) graphic

6. Set display buffers for transformations

7. Generate basic design

8. Select and initialize palette

9. Create animation special effects

2D 3D Vector Visualisation

You can **visualize** a **vector field** by plotting **vectors** on a regular grid, by plotting a selection of streamlines, or by using a gradient color scheme to illustrate **vector** and streamline densities. You can also plot a **vector field** from a list of **vectors** as opposed to a mapping

Vector fields represent fluid flow (among many other things). They also offer a way to visualize functions whose input space and output space have the same dimension.

Vector notation: V=i+j+k

i is the unit vector in the x-direction

- j is the unit vector in the y direction
- k, is the unit vector in the z-direction

Methods used

1. Streamline: A **streamline** is a line that is tangent to the velocity **vector** at every point. **Streamlines** are traditionally used. in flow **visualizations** as they give the direction and orientation of the flow at each point along the line. In the. simplest case, we define a stationary 2D **vector field** as a map v : R.
2. Loopable animation
3. Generating a Random Velocity Field
4. Vector Glyphs : **Glyphs** are graphical objects that are used to represent information at points within a model.
5. **Non-spatial data** (also called attribute or characteristic **data**) is that information which is independent of all geometric considerations. o For example, a person's height, mass, and age are **non-spatial data** because they are independent of the person's location. It is necessary to create a communication channel that could quickly and efficiently transfer the information from the **data** to the user. By using visual elements like charts, graphs, and maps, **data visualisation** is an accessible way to see and understand trends, outliers, and patterns in **data**.

6. **A data set** consisting of two or more than two variables is referred to as **multivariate dataset**. It can be visualised with scatterplots, bar plots visualization techniques.and structured and unstructured techniques of graphs and trees.
7. **Perceptual issues** With the increase in the amount and dimensionality of scientific data collected, new approaches to the design of displays of such data have become essential. The designers of visual and auditory displays of scientific data seek to harness perceptual processes for data exploration. In these cases, even with good aesthetic qualities and good data, the graph will be confusing or misleading because of how people perceive and process what they are looking at. It is important to understand that these elements, while often found together, are distinct from one another.

8. **Congnitive Foundation:** The theoretical **cognitive** process of **visualization**. is directly related to creative visualisation. In relation to **cognition**, learning involves the internal (psychological) and external (physical) domains. Learning therefore involves processing of information as a way of interaction between these two domains. The cognitive aspect is different worldviews or frameworks serve as the foundation of understanding visual perception and cognition. Perception and cognition can be assumed as computations properties of interaction between active agents and lies in creataive tools for visualization.

Evaluating data visualization system is difficult however some pattern based approach is required for evaluation. It can be broadly classified as

Quantitative evaluation focuses on collecting performance measurements, for example on time and errors, that can be analyzed using statistical methods. Qualitative evaluation, on the other hand, collects more in-depth and free-form data, such as observations, notes, transcripts, etc, and is often used for more exploratory or explanatory purposes.

The various patterns seen in visualisation are:

- Exploration: Patterns concerned with exploring the design space of the evaluation study. Are we using the right independent and dependent variables? Are we confident that the study is appropriate? Are we asking the right questions?

- Control: Mechanisms for controlling an evaluation study design to achieve high internal validity
- Generalization: Is this study grounded in real-world practices How trustworthy are these results?
- Validation: Finding the right balance, calibration, and parameters for an evaluation to save time, resources, and money. Are we testing the right thing in the right way?
- Presentation: Reporting the results of an evaluation correctly and economically. Are the results presented in a way where they can be easily understood?

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RAJIV GANDHI PROUDYOGIKI VISHWAVIDYALAYA, BHOPAL

New Scheme Based On AICTE Flexible Curricula

Computer Science and Engineering, VI-Semester

Departmental Elective - CS603 (B) Computer Graphics & Visualization

Topics Covered

Unit –V Multimedia :Basic of multimedia, application of Multimedia, Text-Types, Unicode Standard ,text Compression, Text file formats, Audio Components, Digital Audio, Digital Audio processing, Sound cards, Audio file formats ,Audio Processing software ,Video-Video color spaces, Digital Video, Digital Video processing, Video file formats. Animation: Uses of Animation, Principles of Animation, Computer based animation, 3D Animation, Animation file formats, Animation software, Special Effects in animation, Storyboarding for Animation, Compression: Lossless/Lossy Compression techniques, Image, Audio & Video Compression, MPEG Standards ,Multimedia Architecture, Multimedia databases

Multimedia : Multiple media – Combination of elements text, graphics, audio and video.

Multimedia is application of computer graphics where graphics or image is embedded with text element and audio element and can be animated to form video application.

Elements of Multimedia

The different types of information in a **multimedia** presentation, including text, images, audio, video and animations.

- Text
  - Hypertext
  - Documents
  - Fax

- Audio
  - MIDI
  - Digital Audio
- Graphics
  - GIS Maps
  - Fractals
- Video

Text

- It is a broad term for something that contains words to express something.
- Text is the most basic element of multimedia. This is a good choice of words could help convey the intended message to the users .
- Text is used in contents, menus, navigational buttons, subtitle of video.

Hypertext

When text is available as web site application it is called as hyper text. Hypertext is graph like strcture with components node and link. Hypertext refers to text within text and with link, user can move from one content to other. Content embedded into hypertext can be image, text, graphics and video.

Graphics

It is raster or vector image, scanned or created using image editor tool.It covers illustration, diagrams, pictures, satellite imagery

Animation

- The illusion of motion created by the consecutive display of images of static elements.
- In multimedia, animation is used to further enhance / enriched the experience of the user to further understand the information conveyed to them.

Video

- It is the technology of capturing, recording, processing, transmitting, and reconstructing moving pictures.
- Video is more towards photo realistic image sequence or live recording as in comparison to animation.

Audio

- It is produced by vibration, as perceived by the sense of hearing.
- In multimedia, audio could come in the form of speech, sound effects and also music score.
- In multimedia, audio is embedded in two forms
  - Digital Audio : Digital audio is sound that has been recorded in, or converted into, digital form.
  - MIDI: Musical Instrument Digital interface : This is sound file recorded by joining musical instrument with digital device(Computer), every musical instrument's sound is recorded when notation is played on the instruments and notation is recorded as data file. To play this file, same musical instrument with interface is required with same compatibility.

Applications of Multiledia

- Education and training
- Computer aided instruction
- Distance and interactive training
- Multimedia Encyclopedias Operations
- CAD/CAM
- Air traffic control
- On-line monitoring
- Multimedia security systems
- Video on demand

- Interactive TV
- Home shopping
- Remote home care
- Electronic album
- Remote consulting systems
- Video conferencing
- Multimedia documents
- Advertising

File Formats

FILE FORMAT: The specific format in which an file is saved. The format is identified by the three letter extension at the end of the file name. Every format has its own characteristics, advantages and disadvantages. By defining the file format it may be possible to determine the number of bits per pixel and additional information.

Graphics File Formats

The term "Graphics file" is used to refer to a computer file containing any sort of graphical, non-textual information: diagrams, charts, scanned-in images, files created by painting programs, and so on..

There are two main kinds of graphics file, **raster** (or **bitmapped**) and **vector**. Raster formats, which are more common, store information about individual pixels—the tiny picture elements that provide atoms of colour, like dabs of paint in a Pointillist painting. Vector formats, on the other hand, store information about the lines and curves that make up a drawing. Both make use of compression algorithms, which are methods of storing electronic information (of any sort) in a smaller space.

BMP (Bit-Map)

Can be recognized by the ".bmp" extension. It was developed by Microsoft Corporation, and provides a simple, efficient means of storing a wide variety of graphical data. BMP is the standard MS-Windows raster format (BMP files can be created with Windows' Paintbrush and used as "wallpaper" for the background when running Windows.) Transferring an image to the BMP format may result in some color shifts when BMP files are imported into Windows applications.

BMP-Windows-RGB format supports 1, 4, 8, 24 bits per pixel - not compressed.

GIF (Graphics Interchange Format)

Can be recognized by the ".gif" extension and is the most common format for graphical information on the Internet. The format was developed by CompuServe Incorporated in 1987 (the GIF87a format), and an improvement was made in 1989 (the GIF89a format). GIF files can only contain 256 colours, but the format is popular nonetheless for lower resolution image data: 256 colours is sufficient for many applications.

GIF uses a compression algorithm called LZW, (for Lempel-Ziv Welch, its developers), that works very well for line drawings and for files containing large areas of the same colour. LZW encoding has the further advantage that it requires only one pass, so images can be displayed while being decoded. This compression algorithm is the main reason this file format is so popular—not only are GIF files small relative to the amount of information they contain, but they can be displayed immediately. Further, GIF was designed to display reasonably on any form of display, showing any number of colours. This is a major benefit on the Internet where people use a wide variety of computer systems.

GIFs can have one colour selected as **transparent**, which means that pixels of that colour will appear the same as the pixels directly "behind" them on the screen. For example, if a Web page has a pink background and a "transparent GIF" is displayed on that page, the transparent pixels will appear pink, even if they show up as a different colour in a paint program.

GIFs may also be **interlaced**, which means that the rows of pixels making up the image are not displayed in sequential order from top to bottom. Instead, slices of the graphic are displayed throughout the image that are gradually built up during the decoding process. The effect on the screen is that of an entire image, though initially very blurry, that is gradually sharpened in a series of passes. This is in contrast to a non-interlaced image that begins to appear as a completely clear sliver at the top of the image, that drops like a curtain to the bottom. The advantage of interlacing is that it quickly provides an overview of what the picture looks like before going on to fill in the details.

GIF Files can range from monochrome to 256-color.

GIF - version 87a Non-Interlaced supports 1, 4, 8 bits per pixel.

GIF - version 87a Interlaced supports 1, 4, 8 bits per pixel.

GIF - version 89a Non-Interlaced supports 1, 4, 8 bits per pixel.

GIF - version 89a Interlaced supports 1, 4, 8 bits per pixel.

JPEG (Joint Photographic Experts Group)

This format can be recognized by the ".jpg" or ".jpeg" extension and is also quite popular on the Internet.

JPEG uses a "lossy" compression algorithm. **Lossy compression** means that some image data is thrown away in order to compress a file into a smaller file size—what you get out when you decompress is not exactly what you put in when you compressed it. While the loss of data may sound undesirable, there are several reasons why it can be used to advantage:

The lossy compression scheme was devised with the capabilities of the human eye in mind, so the main areas of information loss are in places where they are not typically noticed.

The person compressing the file has the option of specifying the degree of loss. The higher the degree, the smaller the compressed file and the faster it is to decode it, but the lower the image quality.

Allowing for loss means that the file can be compressed more than it would be otherwise—specifically, about 4 times as much as GIF, at standard settings.

However, it is not a good idea to open, save, and close a JPEG file repeatedly, since more information is lost every time. After a number of repetitions, the effect becomes noticeable.

Progressive JPEG works on the same principle as interlaced GIFs, providing a fast, low-quality image, and then filling in the details as more data arrive. Progressive JPEGs display faster than interlaced GIFs.

TIFF(Tagged-Image file Format)

Can be recognized by the ".tif" or ".tiff" extension, was designed to be powerful and flexible. It stores a very large amount of information about an image, and works well as an intermediary file format between scanners or paint programs and desktop publishing programs. One would scan or paint an image, save it as a TIFF file, import it into a desktop publishing program, and save it as another format. This actually works very well. The use of TIFF has been limited, however, since it is very complex. TIFF was developed in 1988 by Aldus Corporation, in cooperation with Microsoft Corporation. The Tagged Image File Format was primarily designed to become the standard format. In order to become the standard, the format was designed to handle just about any possibility. The result of this design provided the flexibility of an infinite number of possibilities for TIFF image can be saved.

As a result, no application at all can claim to support all TIFF variations. Some professional applications support many TIFF variations, but there will always be an obscure variation that will cause a problem for some application.

The TIFF format uses 6 different encoding routines. The TIFF format supports LZW method compression for image types. (This is the same compression used by the GIF format for indexed color) ***TIP:*** If an application is having a problem reading compressed TIFF files, try re-saving the file without compression.

EPSs (Encapsulated PostScript)

Uses a ".eps" extension and was also created by Adobe Systems. The Encapsulated PostScript file (EPS) format is supported by most illustration and page layout programs, and in most cases is the preferred format for these applications.

Note that this is also the only file format that supports transparent whites in Bitmap mode. EPS is a very complex interpreted language.

PDF(Portable Document File)

Denoted by a ".pdf" extension is yet another Adobe Systems product. The PDF, or Acrobat, format is currently used on the Web to deliver documents, though its use is much less than HTML. Its main advantage is that it requires no additional markup, as with HTML documents, before it can be made available online.

WPG(WordPerfect Graphic File)

WPG file format is used by WordPerfect. It first appeared with the release of WordPerfect 5.0, and with the release of version 5.1, the format was changed accordingly. It is advised to use the same format version as the version of WordPerfect in which the image will be used. These files can contain bitmaps, line art, and vector graphics. When using an application rather then WordPerfect for viewing a WPG file containing both bitmapped and vector elements, the vector elements will be discarded. Note that the WPG specification allows files of up to 256 colors, but WordPerfect itself would not read files of more than 16 colors !

WPG - version 5.0 format supports 1, 4, 8 bits per pixel.

WPG - version 5.1 format supports 1, 4, 8 bits per pixel.

WMF(Microsoft Windows Metafile)

These files may contain vector information such as lines circles... Only the bitmap data is extracted. May be 1, 4, 8 and 24 bit. The 4 and 8 bit images may be compressed using the Microsoft RLE compression as in BMP files.

PCX

This format, with a ".pcx" extension, is the oldest, most widely recognized graphic file format used for MS-DOS. It was developed in the early 1980s by ZSoft Corporation; the format has become outdated since the company dissolved.

PNG(Portable Network Graphics)

This format, pronounced “ping” and recognized by the ".png" extension. It is intended to supersede GIF, circumventing the legal difficulties involved with the compression algorithm used in that format, as well as adding useful features such as truecolor and error detection, and a faster version of interlacing. (GIF was recently involved in several lawsuits, the result of which was that people writing programs that create or display GIF files must license them.

This does not affect people who simply use the programs or GIF files, only people writing those programs. PNG, as an open standard, does not have this legal entanglement.) Originated by CompuServe to replace the gif file format. Uses the a Huffman coding variant. Supports 1,4,8,16,24, and 32 bit images. Also supports interlaced and transparency.

TGA(Truevision File Format)

The TGA format was developed by Truevision for their Targa and Vista products and is rarely seen nowadayss. Can be recognized by the ".tga" extension and is rarely seen nowadays, but it is still encountered in discussions on file formats.

PIC(Pictor)

PIC format files are generated and used by PICTOR, PC-Paint and GRASP and is the standard image file format for the Apple Macintosh.

IFF(Amiga Interchange File Format)

The Amiga Interchange File Format (IFF) is used to transfer documents to and from Commodore Amiga computers. The IFF file standard is extremely flexible, and allows all a few formats, not only images, including text to be stored inside an IFF file. IFF files can be exported from an Amiga to a PC.

ICO

Microsoft icon format. Contains a standard device independent bitmap. with a new header on top. Supports I and 4 bits uncompressed.

PSD

Adobe Photoshop format for storing 1, 8, 24 and 32 bit images. Can be compressed or uncompressed. Images may also be stored as CMYK data or RGB.

RAW

The Raw format is a flexible file format for transferring documents between different applications and computer platforms. Raw format consists of a stream of bytes describing the color information in the file. Each pixel is described in binary format, where 0 equals black and 255 equals white.

GIF and JPEG on the Web

The two most common graphics file formats on the World Wide Web are **GIF** and **JPEG**, and it is worth comparing the two directly.

GIF has the advantages of being “lossless”, having the option of transparency, and being good at compressing large areas of a single colour. JPEG has the advantages of greater compression in general, many more available colours (16 million, compared with GIF's 256), and being good at compressing images with many subtle distinctions, such as photographs.

Although JPEG is a lossy compression, it stores much more information than GIF to begin with, so real- world images still turn out much better when stored as JPEG images. GIF, on the other hand, is much better at storing anything with sharp lines, including text or any black-and-white image. GIF is also particularly good at grayscale images, since it can display an image of up to 256 grays without loss, which JPEG cannot.

In general, inline images on the Web are in GIF format, although JPEGs are also beginning to appear. Many browsers do recognize JPEG inline images, but not all. Thus, it is a good idea to use GIFs to ensure that all graphical Web browsers can display the images.

Sound File Formats

There are three parameters that are common to every sound file and affect the size of that file.

Sampling Rate: Most digital sound files save information as a long series of sound samples, in the same way a film saves moving pictures as a series of still images. The quality of a sound file can be increased by taking more of these samples in the same amount of time; that is, increasing the “sampling rate”. This has the effect, however, of increasing the file size.

Bits per Sample: Commonly, either 8 or 16 bits are used to represent each sample. Using 16 bits provides for much better quality, but produces files twice as large as 8-bit files.

Number of Channels: Because they work with two separate audio channels, stereo files are usually about twice the size of mono files. It is theoretically possible to record any number of channels, with a concomitant increase in file size. For example, a file intended to be played on a surround-sound system may record seven or more channels, and will thus be about seven times the size of a mono version of the same sound.

MIDI

The Musical Instrument Digital Interface system (MIDI) is designed to interconnect home computers, synthesizers, and so on with a standard interface. A MIDI file describes how each instrument in a synthesized band or orchestra plays—where "instrument" is defined fairly loosely and may refer to anything that makes a sound. MIDI files are often named with a ".mid" or ".midi" extension, and (because they store information in such a different manner from other sound files) are rarely found near other sound files.

Windows PCM waveform (.WAV)

All WAV formatted files follow the RIFF (Resource Information File Format) specification. Most of the special information is saved with the wave file in these formats. The standard Windows PCM waveform contains PCM coded data, which is pure uncompressed pulse code modulation formatted data.

Microsoft ADPCM waveform (.WAV)

Microsoft ADPCM compressed waveform forma consists of 4-bit per channel compressed data. Each 4-bit sample is expanded to 16-bits when loaded. For this reason, it is best to save 16-bit files in this format rather than 8-bit files as the quality will be much greater. In the end, the 16-bit data can still be quickly converted to 8-bit during playback on cards that don't support 16-bit.

IMA/DVI ADPCM waveform (.WAV)

This standard compresses 16-bit waves to 4-bit using a different (faster) method than Microsoft ADPCM, and has different distortion characteristics, which may be better, or worse, depending on the original sample being compressed. Again, it is better to save 16-bit audio in this format than 8-bit. This format allows for 3-bit compression as well at a slightly lower quality. Very few sound drivers support the 3-bit ADPCM, and we have found none that actually work properly.

CCITT mu-Law and A-Law waveforms (.WAV)

These formats compress original 16-bit audio down to 8 bits. The quality is somewhere between 8-bit and 16-bit. Thus, a-law and mu-law encoded waveforms have a higher s/n ration than 8-bit PCM, but at the price of a little more distortion that the original 16-bit audio. The quality is definitely higher than you would get with 4-bit ADPCM formats.

Soundblaster voice file format

The extension ".voc" is most commonly used by the Soundblaster sound card. This format only supports 8-bit audio, mono to 44.1 KHz, and stereo to 22 KHz.

MPEG Layer I & II & III (.MP2, .MP3)

The Motion Picture Experts Group audio file format gives the highest compression with the least amount of quality loss, but is also the slowest. In most cases, it takes longer to load or save an MPEG file than it does to play it. Layer 3 MPEG gives even higher quality. Only the sample rates of 48000, 44100, and 32000 are supported.

MOD

(Amiga SoundTracker) can be recognized by the ".mod" or ".nst" extensions and started out strictly for the Amiga, but is now used widely.

RealAudio 3.0 (.RA)

Use this format to create files for Progressive Networks's streaming audio servers and players.

Sun mLaw

With an ".au" extension, is most commonly used on NeXT and Sun computers. This is the most widely recognized sound format on the Internet, challenged only by the Windows-specific RIFF WAVE format. The most common use for the AU file format is for compressing 16-bit data to 8-bit mu-law data

AIFC (AIF with Compression) ".aif" or ".aiff" is most commonly used on Apple and SGI computers. It shares these extensions with uncompressed AIFF (Audio IFF) files, but this is transparent to the user. **NeXT snd** with the extension ".snd" is most commonly used on NeXT and Sun machines—watch out for this extension because it shares it with many others, like the one below. **Tandy snd** is yet another ".snd" format made for the Tandy computer, but it is associated with a particular program and so does not tend to be widely distributed.

Video File Format

AVI(Audio Video Interleaved)

Windows multimedia video format from Microsoft.

It interleaves standard waveform audio and digital video frames (bitmaps) to provide reduced animation at 15 fps at 160x120x8 resolution. Audio is 11,025Hz, 8-bit samples. It can have either one of the three video compression methods: Microsoft

Video 1, Microsoft RLE and Intel's Indeo.

MPEG

An image- compression scheme for full motion video proposed by the Motion Picture Experts Group, an ISO-sanctioned group. MPEG image scheme offers more compression than the JPEG scheme, which is largely for still images, because it takes advantage of the fact that full motion video is made up of many successive frames consisting of large areas that are not changed - like blue sky background. While JPEG, compresses each still frame in a video sequence as much as possible MPEG also performs "differencing," noting differences between consecutive frames. If two consecutive frames are identical, the second can be stored with the appropriate information. MPEG condenses moving images about three times more tightly than JPEG.

QuickTime

Most major support QuickTime. Apple also provides a QuickTime for Windows version for Windows-based PCs.

Video Compression Standards

An uncompressed stream of video for creating a full-screen (640-by-480 pixels), 30 frames per second (fps), 24-bit color picture requires enough of disk space to match. Compression can reduce the massive video stream to manageable proportions.

Video compression and decompression can take place in hardware or software. The content provider may perform the compression, or the user may do it. Decompression takes place at the workstation. Software, decompression usually limits playing rates to less than 15fps. But 20fps 25fps, or even 30fps speeds are not impossible with the right client hardware, such as a fast graphics card and video bus. Hardware-based decompression supports rates of 30fps, but it requires a compression/decompression (codec) card.

MPEG is the most popular type of hardware decompression. It's used for distributing non-editable full-motion video. The current version, MPEG-1, requires up to 9MB per minute of storage. However, higher-quality video can be attained with 18MB of storage.

Digital Video Interactive (DVI) is another compression standard that usually uses hardware-assisted decompression. Its data rates and storage requirements are similar to those of MPEG.

The Joint Photographic Experts Group compression standard, or JPEG, is for compression of still frames. **M-JPEG** (Motion JPEG) takes JPEG into the video realm. M-JPEG requires hardware decompression. It's used for distributing full motion video in an editable format. Because its storage and transmission requirements are more than twice those of MPEG, it's not popular for networked applications.

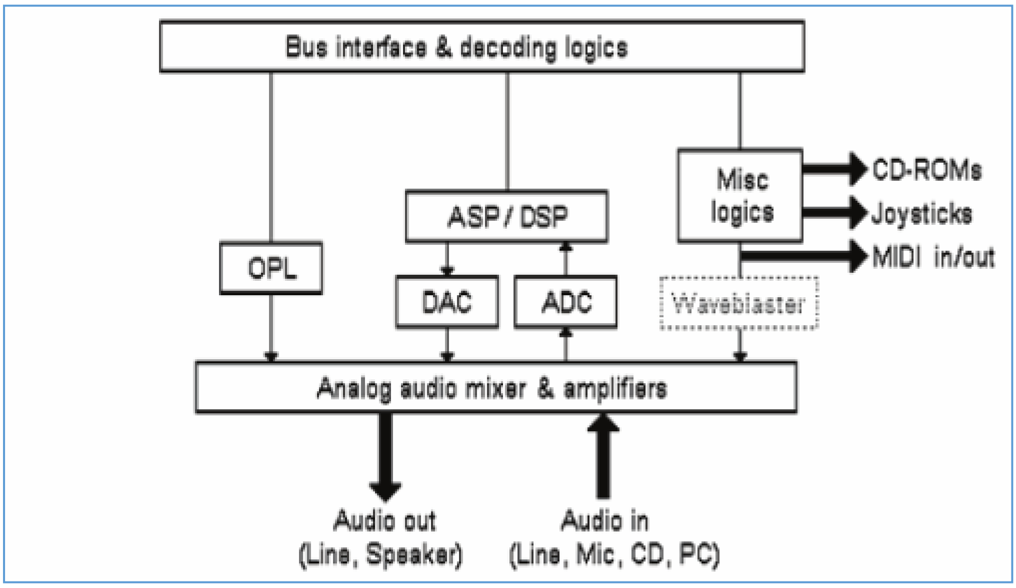
Audio-Video Interleaved (AVI) is not a compression type but a file format supported by Microsoft's Video for Windows.

Indeo, Intel's compression standard, is the most popular type of compression for video files in AVI format. Indeo uses software decompression. It requires 1.2Mbps bandwidth and 9MB per minute of storage.

Cinepak is the standard compression type for QuickTime, a multimedia environment for Macintoshes. Cinepak's requirements are similar to Indeo under AVI.

Audio Components

Sound Card



- It is the most basic element of a digital audio workstation.
- A sound card provides input jacks of microphones and external audio sources
- Converts sound from analog format to digital format and format its codec after recording
- Provides output jacks for headphones and external speakers
- Converts sound from digital to analog format when it is played
- Synthesizes MIDI sound samples

The standard of presentation of time for digital audio and video is SMPTE(Society of Motion Picture and Television Engineers)

The multitrack view allows you to record different sounds,musical instruments,or voices on separate tracks so that you can work with these units independently.

A track is a sequence of audio samples that can be played and edited as a separateunit.You can mix down the tracks,collapsing them all in to one unit. Often,different tracks are associated with different instruments or voices.

The most common technique to change an analog signal to digital data is called pulse code modulation (PCM). A PCM encoder has the following three processes:

a. Sampling
b. Quantization
c. Encoding

Which you are already knowing.

Digital Audio Processing

In case of Digital audio, Computer Plays the role of mixer and serves as recorder, editor, signal processor and synthesizer. Many hardware devices are embedded into software of digital mixer. There are analog-to-digital converter(ADC) and digital-to-analog converter (DAC) inside the digital mixer. The audio/MIDI interface connects the hardware with the computer. A mixer(mixing console) is used together inputs from microphones and instruments and dynamically adjust their amplitudes,equalize the frequency components,compress the dynamic range, apply special effects,and route the processed sound to outputs such as speakers.

Features of Digital Audio Processing Software

- The ability to import and save audio files in a variety of formats
- An interface(called transport controls)for recording and playing sound
- A wave form view that allows you to edit the wave,often down to the sample level
- Multitrack editors
- Audio restoration tools to remove hisses, clicks, pops,and background noise
- The ability to take input from or direct output to multiple channels
- Special effects such as reverb, panning, or flange
- Controls for equalizing and adjusting volume and dynamic range
- Frequency filters
- The ability to handle the MIDI format alongwith digital audio and to integrate the two types of data into one audio file
- the ability to record samples and add to the bank of MIDI patches and compression codec

Multimedia Architecture

Architecture for Multimedia Systems. The architecture of multimedia system may be described as a four-level hierarchy. In line with concepts developed in conventional layered systems such as the OSI,) each layer performs a specific function and supports the function performed in the layer above. The four-layers (lowest (bottom) layer first) of the architecture, known as the *RT architecture* (Real-time information handling), are:

1. **Network Subsystem (Layer 1)**

   This layer takes care of the functionalities for a possible connection through a network with a specified bandwidth and error probability as supported by the underlying technology. Takes care of Multimedia enabled hardware and peripherals.

2. **End-to-End QoS Control(Layer 2)**

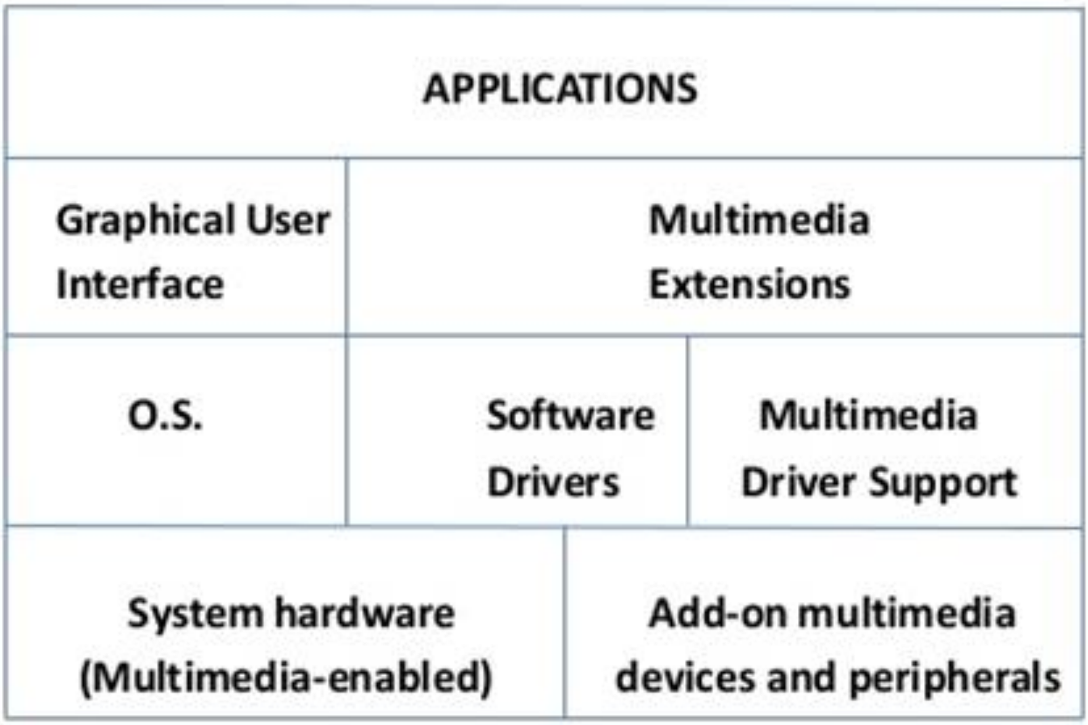
   This layer maintains the connection between the source and destination and can be conceptually viewed as a single connection for Quality of service along with support of OS, software drivers and Multimedia drivers.

3. **Media Management (layer 3)**

   This layer provides *generic* services to applications through GUI and MM extensions. A primary functions is synchronisation across the media elements.

4. **Application (Layer 4)**

   The direct interface with the user. The application wil also interface with the operating system, if required through underlying layer.



Types of multimedia

- **Linear :**
  - It is not interactive.
  - The user have no control over the content that is being showed to them.
- **NonLinear :**
  - It is interactive Users have control over the content that is being showed to them.
  - Users are given navigational control.

Interactive : When the user is given the option of controlling the elements

Hypermedia : A combination of hypertext, graphics, audio, video, (linked elements) and interactivity culminating in a complete, non-linear computer-based experience.

Multimedia Database(MMDB)

Multimedia database is the collection of interrelated multimedia data that includes text, graphics (sketches, drawings), images, animations, video, audio etc and have vast amounts of multisource multimedia data. The framework that manages different types of multimedia data which can be stored, delivered and utilized in different ways is known as multimedia database management system. There are three classes of the multimedia database which includes static media, dynamic media and dimensional media.

Content of Multimedia Database management system:

1. **Media data** – The actual data representing an object.
2. **Media format data** – Information such as sampling rate, resolution, encoding scheme etc. about the format of the media data after it goes through the acquisition, processing and encoding phase.
3. **Media keyword data** – Keywords description relating to the generation of data. It is also known as content descriptive data. Example: date, time and place of recording.
4. **Media feature data** – Content dependent data such as the distribution of colors, kinds of texture and different shapes present in data

Application of Multimedia based on Multimedia databases

1. **Repository applications** – A Large amount of multimedia data as well as meta-data (Media format date, Media keyword data, Media feature data) that is stored for retrieval purpose, e.g., Repository of satellite images, engineering drawings, radiology scanned pictures.
2. **Presentation applications** – They involve delivery of multimedia data subject to temporal constraint. Optimal viewing or listening requires DBMS to deliver data at certain rate offering the quality of service above a certain threshold. Here data is processed as it is delivered. Example: Annotating of video and audio data, real-time editing analysis.

3. **Collaborative work using multimedia information** – It involves executing a complex task by merging drawings, changing notifications. Example: Intelligent healthcare network.
4. **For ex.**
    1. Digital libraries
    2. News-on-demnad
    3. Video-on-demand
    4. Music database
    5. GIS

Case studies : Oracle Intermedia, Jasmine – OODB- number of built in classes for multimedia data

Storage Requirement and Data Structures

MMDB stores data for all multimedia elements text, graphics, audio and video. So for versatile data it required some additional data fields as compared to traditional relational or OO database. It is a framework that manages different data potentially as array of media sources.

The data fields are as follows:

- Long bit and byte string
- BLOBS – Binary Large Objects
- Paths and references : Links to media files where media files are kept in drive folder or web server folder
- Content retrieval capabilities : query processing is typical in this case, so search by contents must be there , either there will be tagging of the elements
- Meta data – aspects of media data keyword data, features data for indices

Data fields with media can be classified as :

- Static media: time-independent – text and images
- Dynamic media: time dependent- audio and video
- 3d games and CAD –dimensional media - line diagrams, virtual environments

Examples

- RDBMS supports with BLOB: BFILE 4GB file system for storing multimedia data
- CLOB: single-byte character- 8 bits as character storage to store long characters
- NCLOB- fixed width and varying width multi-byte character where text and subtitle of audio file can be stored

Characteristics

- Corresponding storage media
- Descriptive search methods
- View specific and simultaneous data
- Management of large amounts of data
- Real time data transfer
- Large transactions

Requirements of MMDB

- Data Integration
- Data in dependence
- Concurrency control
- Persistence
- Privacy
- Recovery
- Query control
- MMDB storage and Data structures
- Querying- search db by contents

Animation Principles

- Squash and stretch.: It is best described with a bouncing ball, which appears stretched when falling and squashed when it hits the ground.
- Anticipation.: anticipation is used to prepare for the main action of an animated scene.
- Staging: The essence of staging is keeping focus on what is relevant, eliminating unnecessary detail, and avoiding any confusion.
- Straight ahead action and pose to pose. draws out a scene frame by frame from beginning to end (*"straight ahead action*")or starts with a few key frames, and then fills in the intervals (from "*pose to pose*")
- Follow through and overlapping action. *"Follow through"* relates to parts of the subject that continue to move with inertia after a completed action.
- Slow in and slow out. Your animation will look realistic if more drawings are added to the beginning and end of an action, emphasizing gradual speed up and slow down, and fewer in the middle.
- Arc. follow curved paths rather than straight lines.
- Secondary action Supporting the main action with secondary one adds more dimension to the character animation and gives a scene more life.
- Timing Referring to the number of drawings or frames for a given action
- Exaggeration exaggeration is especially useful and livening for animation.
- Solid drawing : an object following the rules of perspective in three-dimensional space
- Appeal: appeal reflects compelling attractiveness or charm that can inspire devotion in others.

Animation Effects

- In-Between - tweening by adding incremental sprites between ending and starting sprites
- Step recording - record sprite position in one frame, move ahead to next frame and record new sprite position
- Real-time recording - use mouse to establish sprite path and record this movement. Record at slow rate and speed up when playing

    - Cast to time - create cast member, slightly modify it creating new cast member until sequence of still images created
    - Space to time - position cast member in different positions in different channels and then move from multiple channels to single channel
    - Paste special relative - automatically position sequence of frames on stage where last sequence ended
- Onion skinning -- allows creation of new images by tracing over existing image. Allows editing of animated sequences using other cast members for reference
- Trail effect -- previous image not completely erased when next image appears on screen
- Film loop -- cast member that consists of a series of animated frames set up to play over and over
- Warp, skew, perspective -- edit cast member to change a variety of aspects of the cast member (see cathiewarp.exe in LabMaterials)
- Filtering -- plug-in image editors that apply effects to bitmapped images (ex. Can install Photoshop effects)
- Color cycling -- change the palette used over the course of several frames in the animation. Excellent for representing flowing, spinning, or pulsing objects

Digital Video

- Video is an excellent tool for delivering multimedia.
- Video places the highest performance demand on computer and its memory and storage.
- Digital video has replaced analog as the method of choice for making and delivering video for multimedia
- Digital video device produces excellent finished products at a fraction of the cost of analog.
- Digital video eliminates the image-degrading analog-to-digital conversion.

Many digital video sources exist, but getting the rights can be difficult, time-consuming, and expensive.

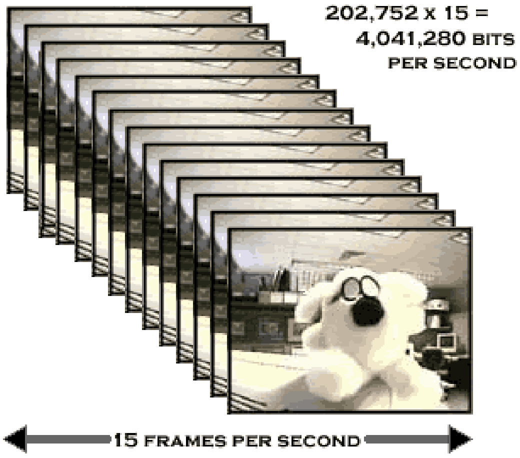
How video works

- Light reflected from an object through the camera's lens is converted into electronic signal by charge-coupled device (CCD).
- This electronic signal contains three channels of color information and synchronization pulses (sync).
- Several video standards exist that deal with the amount of separation between the components of the signal.
- Digital video is the digitisation of analogue video signals into numerical format
- It creates the illusion of full motion by displaying a rapid sequence of changing images on a display device.
- Conversion from analogue to digital format requires the use on an ADC (Analogue to Digital Converter)
- A Digital to Analogue Converter (DAC) can be used to output digital video on analogue equipment
- Video clip stored on any mass-storage device can be played back on a computer's monitor without special hardware.
- Setting up a production environment for making digital video, requires some hardware specifications. Some specifications include computer with FireWire connection and cables, fast processor, plenty of RAM, fast and big hard disk.

Digitizing Video

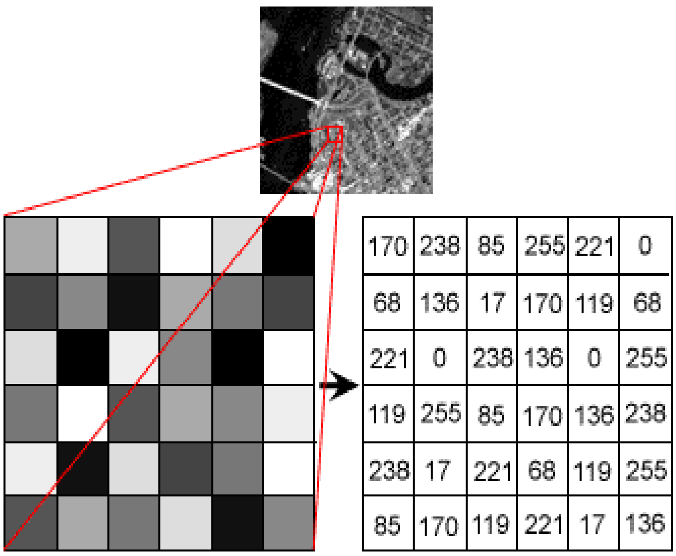
- Digital video is often used to capture content from movies and television to be used in multimedia.
- A video source (video camera ,VCR, TV or videodisc) is connected to a video capture card in a computer.
- As the video source is played, the analog signal is sent to the video card and converted into a digital file (including sound from the video).
  - file size in digitized video which included
    - frame rate
    - image size
    - color depth.
    -

- Frame Rate
  - animation is an illusion caused by the rapid display of still images.
  - television and movies play at 30 fps but acceptable playback can be achieved with 15 fps.



2. **Image Size**
   - A standard full screen resolution is 640x480 pixels but to safe storing space a video with 320x240 for a computer display is still acceptable.
   - New high-definition televisions (HDTV) are capable of resolutions up to *1920×1080p60*,
     - 1920 pixels per scan line by 1080 scan lines, progressive, at 60 frames per second.

3. **Color Depth**
   - The quality of video is dependent on the color quality (related to the number of colors) for each bitmap in the frame sequence.



Broadcast Video Standards

National Television Standards Committee (NTSC):

- These standards define a method for encoding information into electronic signal that creates a television picture.
- It has screen resolution of 525 horizontal scan lines and a scan rate of 30 frames per second.

Phase Alternate Line (PAL) and Sequential Color and Memory (SECAM):

- PAL has a screen resolution of 625 horizontal lines and a scan rate of 25 frames per second.
- SECAM has a screen resolution of 625 horizontal lines and is a 50 Hz system.
- SECAM differs from NTSC and PAL color systems in its basic technology and broadcast method.

Advanced Television Systems Committee (ATSC) Digital Television (DTV):

- This digital standard provides TV stations with sufficient bandwidth to present four or five Standard Television (STV) signals or one High Definition TV (HDTV) signal.
- This standard allows for transmission of data to computers and for new Advanced TV (ATV) interactive services.

Digital Video Recording and Editing

- **Linear**
  - It plays end to end in one direction, usually pertains to videotape editing specifically the editing of linear tape segments into one final master tape.
- **Non-linear**
  - Refers to the editing of disk-based digital video.
  - The software provides an on screen map of what the final video sequences should look like incorporating the edits, splices, special effects, transitions and sound tracks.

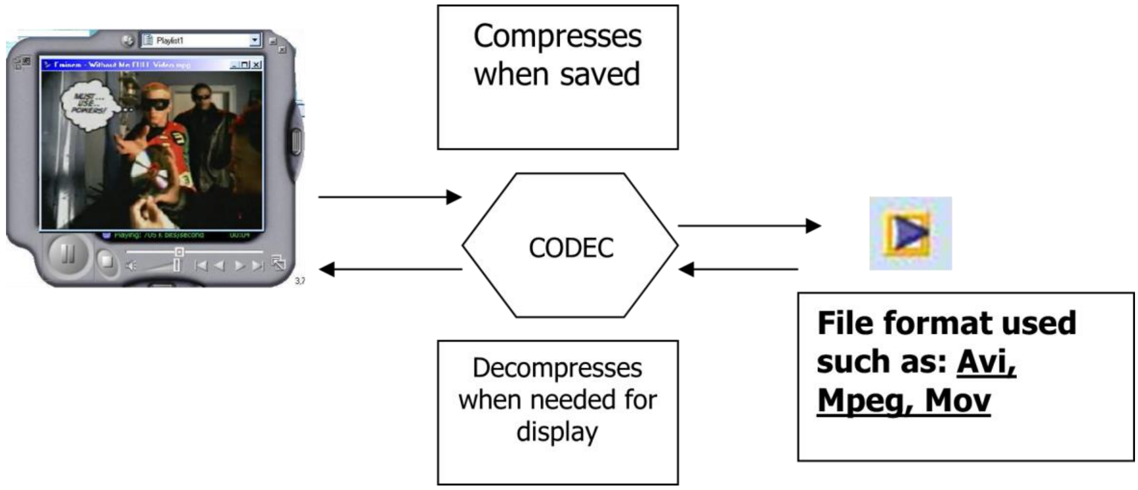
- **Transitions**
    - Such as fading, wiping, splatters, scrolling, stipple and many more are available by simply dragging and dropping that transition between the two video clips.
- **Superimposing**
    - The ability to superimpose one clip over another is a valuable technique.
    - The technique of green screening is identical except that the color green is used for the screen and later digitally removed.
    - The blue screen and green screen superimposing are just two of the superimposing technique available.

Digital Video Compression

- Digital video compression schemes or codecs is the algorithm used to compress (code) a video for delivery.
- The codec then decodes the compressed video in real-time for fast playback.
- Streaming audio and video starts playback as soon as enough data has transferred to the user's computer to sustain this playback.
- The video compression/decompression programs are used so that video can fit on a single CD and the speed of transferring video from a CD to the computer can be increased.
- Let us say that a sequence of 25fps video is about 25MB.
- CD-ROM transfer rate is calculated as follows:
    - 1X= 150KB per second
    - 10X=1.5 MB per second
    - 100X= 15 MB per second

File formats supporting compression

- Microsoft's AVI format
- QuickTime
- MPEG
- Div-X
- Wmv (Windows Media Video**)**

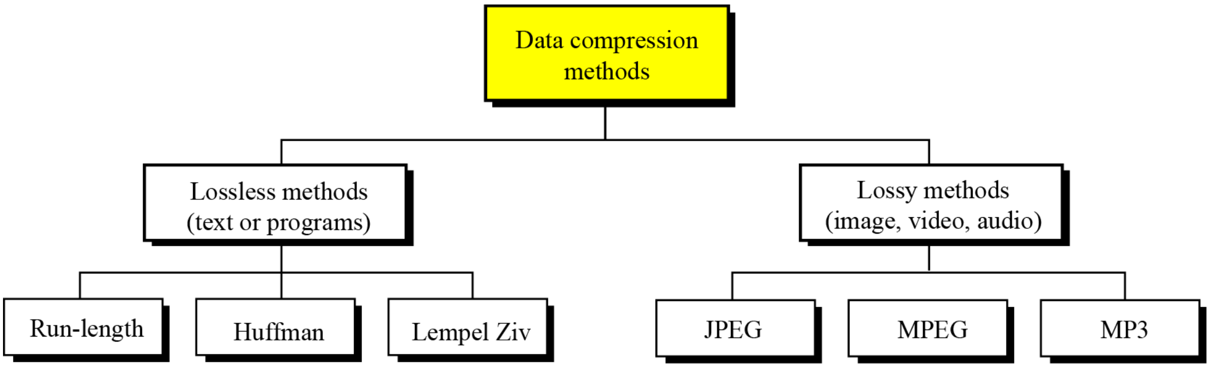


- **Two types of COMPRESSION:**
  - Lossless compression
    - Preserves the exact image throughout the compression and decompression process. E.g: text images is to identify repeating words and assign them a code.
  - Lossy compression
    - Eliminates some of the data in the image and therefore provides greater compression ratios than lossless compression.
- **Two types of CODEC (lossy):**
  - Spatial compression
    - a digital compression of video data that compresses the size of the video file by compressing the image data of each frame
    - Compression is done by removing redundancy from data in the same frame.
  - Temporal compression
    - a digital compression of video data that uses similarities of sequential frames over time to determine and store only the image data that differs from frame to frame.
    - Compression is done by removing similarity between successive video frames

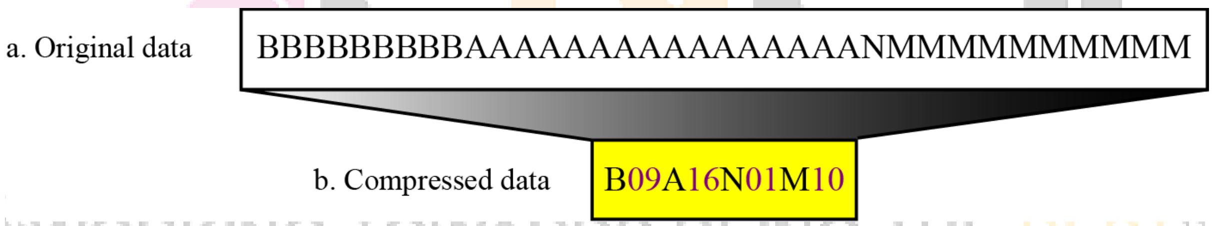
Examples : Standards have been established for compression programs, including JPEG (Joint Photographic Experts Group) and MPEG (Motion Picture Experts Group).

Data Compression

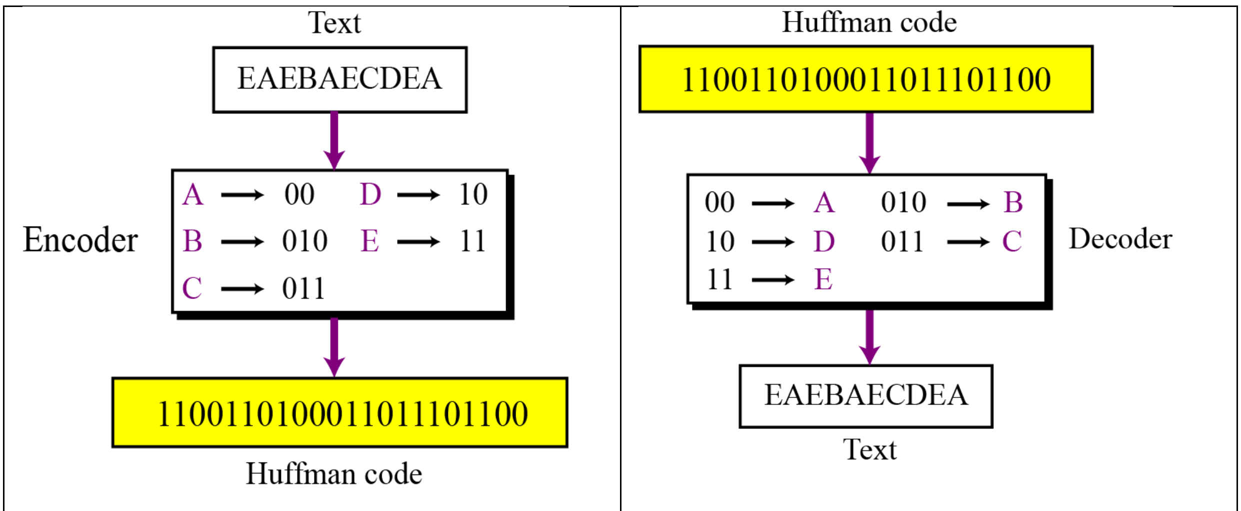
implies sending or storing a smaller number of bits. Although many methods are used for this purpose, in general these methods can be divided into two broad categories: lossless and lossy methods. For multimedia it is applicable for all the elements text, image, audio and video



Run-length encoding is probably the simplest method of compression



Huffman coding assigns shorter codes to symbols that occur more frequently and longer codes to those that occur less frequently**.**

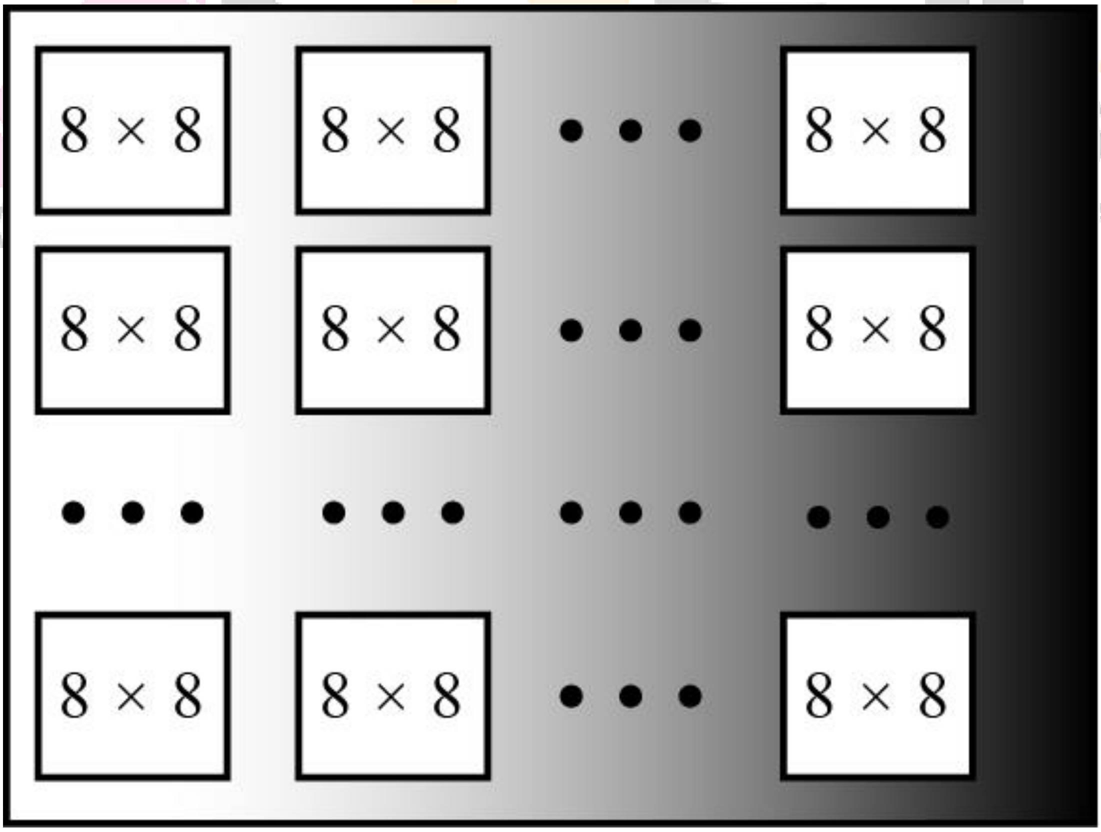


Encoding	**Decoding**

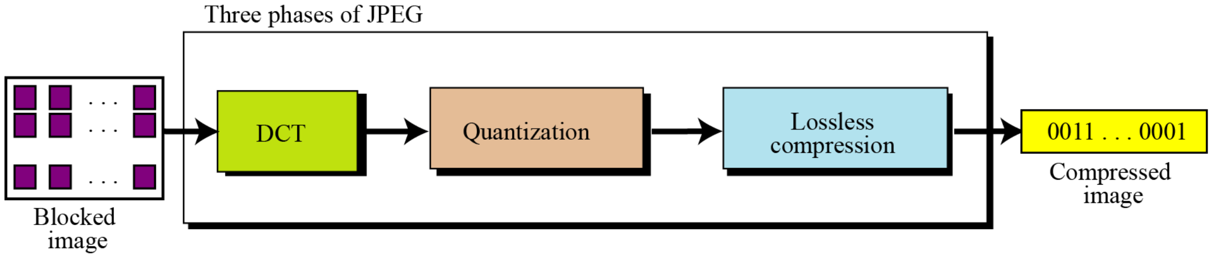
JPEG(Spatial Compression)

- JPEG compression identifies these area and stores them as blocks of pixels instead of pixel by pixel reducing the amount of information needed to store the image.
- These program reduce the file size of graphic images by eliminating redundant information.
- The changes in the image from frame to frame.
- Key frames are identified every few frames the changes that occur from key frame.
- Provide greater compression ratios than JPEG.
- Initially, it requires extra hardware for multimedia.

In JPEG, a grayscale picture is divided into blocks of 8 × 8 pixel blocks to decrease the number of calculations because, as we will see shortly, the number of mathematical operations for each picture is the square of the number of units.

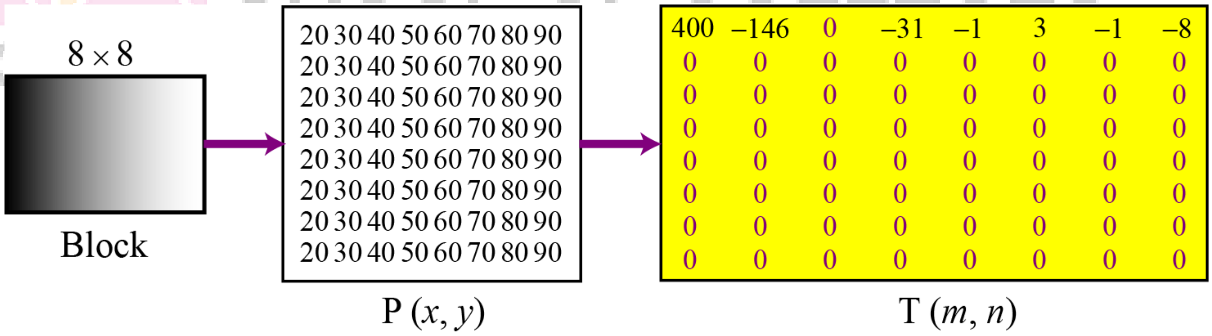


The whole idea of JPEG is to change the picture into a linear (vector) set of numbers that reveals the redundancies. The redundancies (lack of changes) can then be removed using one of the lossless compression methods we studied previously. A simplified version of the process is shown in Figure.



Discrete Cosine Transformation(DCT)

In this step, each block of 64 pixels goes through a transformation called the discrete cosine transform (DCT). The transformation changes the 64 values so that the relative relationships between pixels are kept but the redundancies are revealed. The formula is given in Appendix G. P(x, y) defines one value in the block, while T(m, n) defines the value in the transformed block.

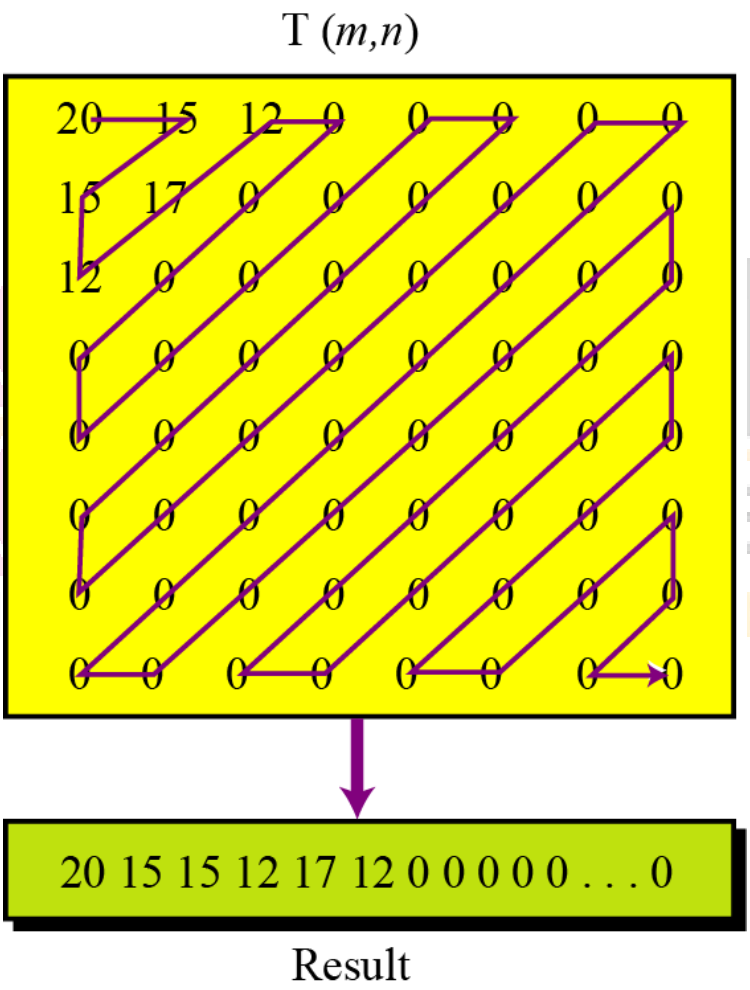


Quantization

After the T table is created, the values are quantized to reduce the number of bits needed for encoding. Quantization divides the number of bits by a constant and then drops the fraction. This reduces the required number of bits even more. In most implementations, a quantizing table (8 by 8) defines how to quantize each value. The divisor depends on the position of the value in the T table. This is done to optimize the number of bits and the number of 0s for each particular application.

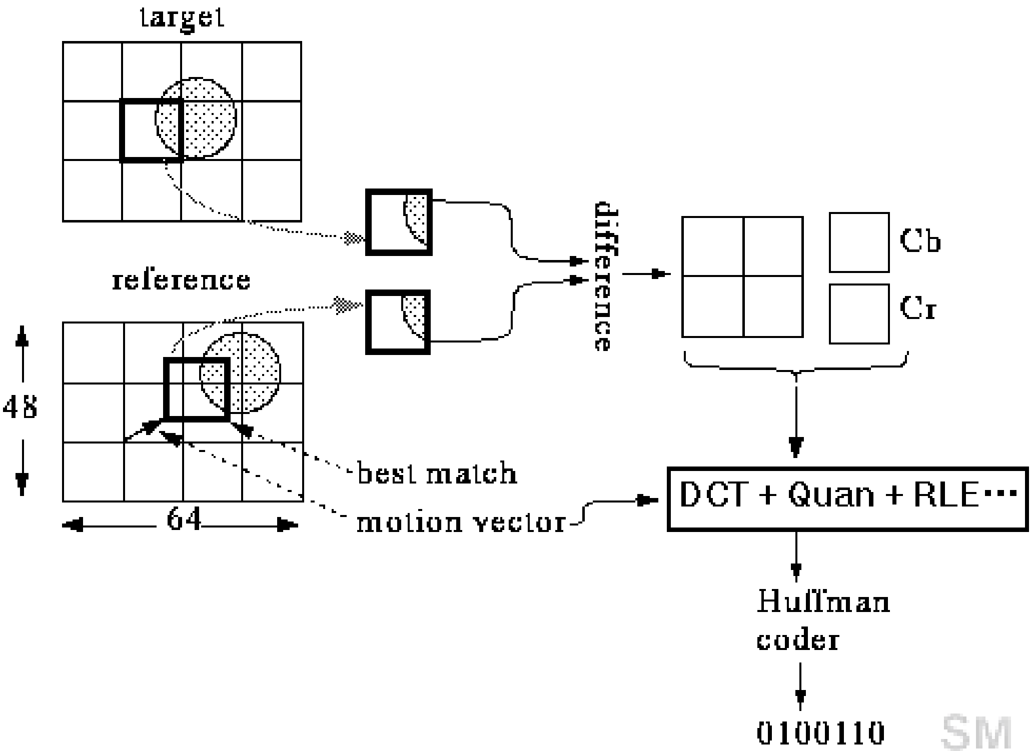
After quantization the values are read from the table, and redundant 0s are removed. However, to cluster the 0s together, the process reads the table diagonally in a zigzag fashion rather than row by row or column by column. The reason is that if the picture does not have fine changes, the bottom right corner of the T table is all 0s.

JPEG usually uses run-length encoding at the compression phase to compress the bit pattern resulting from the zigzag linearization.

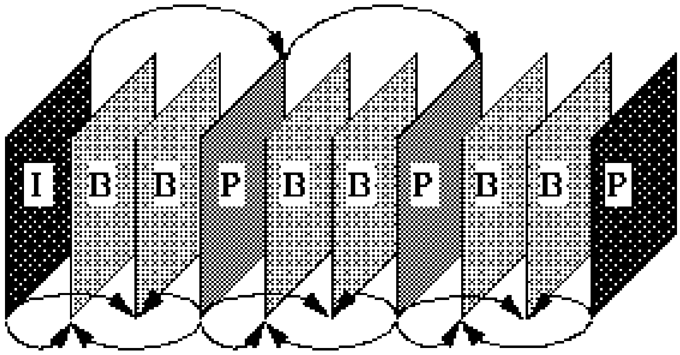


MPEG Compression

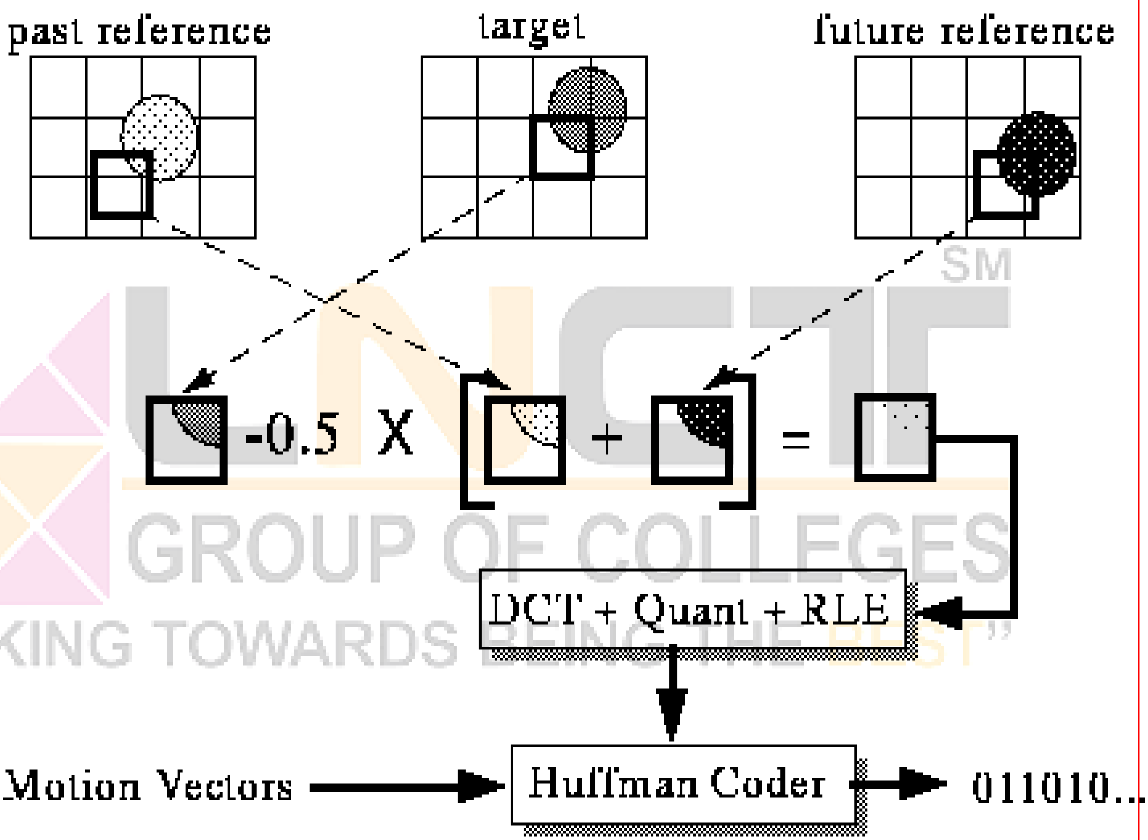
- MPEG is a real-time video compression algorithm.
- MPEG-4 includes numerous multimedia capabilities and is a preferred standard.
- MPEG-7 (or Multimedia Content Description Interface) integrates information about motion video elements with their use.
- The color depth below 256 colors is poorer-quality image.
- The frame rate to below 15 fps causes a noticeable and distracting jerkiness that unacceptable.
- Changing the *image size* and *compressing* the file therefore become primary ways of reducing file size.
- JPEG compression exploits the spatial redundancy in image data through DCT
- For video data, each frame can be compressed using JPEG and a compression ratio of 20:1 can be achieved. Can it be do more ?
- Consecutive frames are very similar. If we encode the first frame and encode where each region moves to in the second frame, we obtain a prediction of the second frame. Only the residual needs to be encoded.
- This is similar to predictive coding that exploits the temporal redundancy in video data
- Suppose the first frame is encoded already using JPEG, what is the best way of encode frame 2 ?
    - JPEG
    - Motion prediction
        - For motion prediction to work, we need to record the motion of every pixel. This can be done more efficiently using image blocks called "Macroblocks"
        - The predicted macroblock and the actual image block are compared and the difference is encoded



- Previous frame is called "reference" frame
- Current frame is called "target" frame
- The target frame is divided into 16x16 macroblocks
- For each macroblock, its best match in the reference frame is computed, the 2D motion vector and the image prediction error are recorded
- Prediction error: DCT+Quantization+RLE+Huffman
- Motion vector: Quantization+entropy coding
- Different match measures and methods can be used for finding the best match for each macroblock either Mean absolute difference or mean squared difference
- MPEG encodes video frames using the following pattern
  - I-frame: Intraframe
  - P-frame: Interframe
  - B-frame: Bi-directional frame, search for macroblocks both in I-frame and P-frame
  - So B frames are decoded after next P frame is decoded



- Images in video are best predicted by both previous and following images, especially for occluded areas



Audio Compression

Audio compression can be used for speech or music. For speech we need to compress a 64 kHz digitized signal, while for music we need to compress a 1.411 MHz signal. Two categories of techniques are used for audio compression: predictive encoding and perceptual encoding**.**

Predictive Encoding

In predictive encoding, the differences between samples are encoded instead of encoding all the sampled values. This type of compression is normally used for speech. Several standards have been defined such as GSM (13 kbps), G.729 (8 kbps), and G.723.3 (6.4 or 5.3 kbps).

Perceptual Encoding:MP3

The most common compression technique used to create CD-quality audio is based on the perceptual encoding technique. This type of audio needs at least 1.411 Mbps, which cannot be sent over the Internet without compression. MP3 (MPEG audio layer 3) uses this technique**.**

Bibliography and References

- Donald Hearn and M.P. Becker “Computer Graphics” Pearson Pub.
- Schaum’s series “ Computer Graphics” TMH
- Theories in Information Visualization: What, Why and How, Zhicheng Liu* and John Stask Visualisation research papers
- Parekh “Principles of Multimedia” Tata McGraw Hill
- Andleigh, Thakral , “Multimedia System Design “ PHI Learning
- Tay Vaughan, “Multimedia: Making it works”, TMH
- Web resources geeksforgeeks.org/ CMU universities