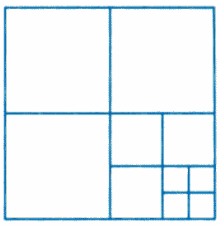
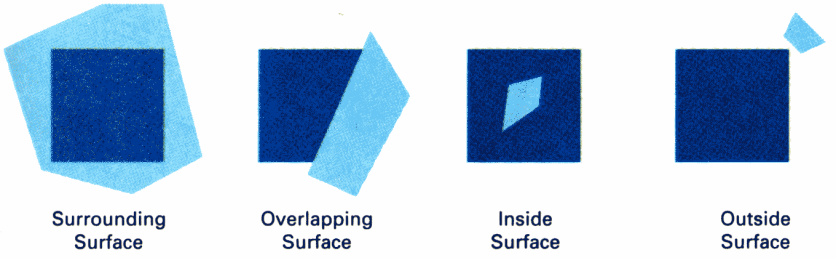
9.6 Area Subdivision Algorithms

The area-subdivision method takes advantage of area coherence in a scene by locating those view areas that represent part of a single surface.

The total viewing area is successively divided into smaller and smaller rectangles until each small area is simple, ie. it is a single pixel, or is covered wholly by a part of a single visible surface or no surface at all.



Dividing a square area into equal-sized quadrants at each step.



Possible relationships between polygon surfaces and a rectangular area.

The procedure to determine whether we should subdivide an area into smaller rectangle is:

1. We first classify each of the surfaces, according to their relations with the area:

Surrounding surface - a single surface completely encloses the area
Overlapping surface - a single surface that is partly inside and partly outside the area
Inside surface - a single surface that is completely inside the area
Outside surface - a single surface that is completely outside the area.

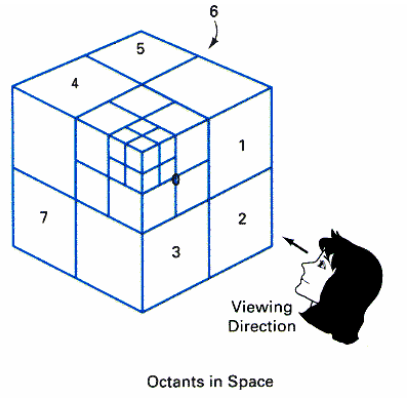
To improve the speed of classification, we can make use of the bounding rectangles of surfaces for early confirmation or rejection that the surfaces should be belong to that type.

2. Check the result from 1., that, if any of the following condition is true, then, no subdivision of this area is needed.

a. All surfaces are outside the area.
b. Only one surface is inside, overlapping or surrounding surface is in the area.
c. A surrounding surface obscures all other surfaces within the area boundaries.

For cases b and c, the color of the area can be determined from that single surface.

9.7 Octree Methods

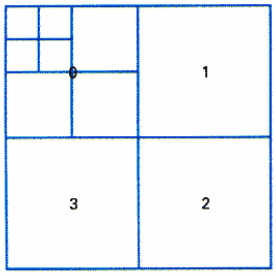


Octants in Space

In these methods, octree nodes are projected onto the viewing surface in a front-to-back order. Any surfaces toward the rear of the front octants (0,1,2,3) or in the back octants (4,5,6,7) may be hidden by the front surfaces.

With the numbering method (0,1,2,3,4,5,6,7), nodes representing octants 0,1,2,3 for the entire region are visited before the nodes representing octants 4,5,6,7. Similarly the nodes for the front four sub-octants of octant 0 are visited before the nodes for the four back sub-octants.

When a colour is encountered in an octree node, the corresponding pixel in the frame buffer is painted only if no previous color has been loaded into the same pixel position.



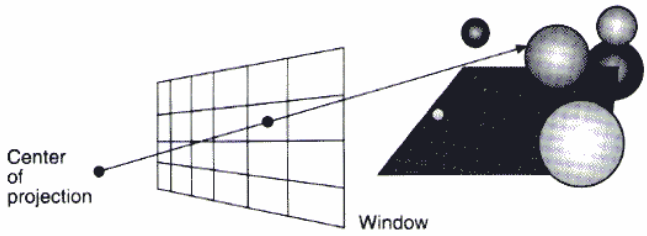
Quadrants for
the View Plane

In most cases, both a front and a back octant must be considered in determining the correct color values for a quadrant. But

- If the front octant is homogeneously filled with some color, we do not process the back octant.
- If the front is empty, it is necessary only to process the rear octant.
- If the front octant has heterogeneous regions, it has to be subdivided and the sub-octants are handled recursively.

9.8 Ray-Casting Method

The intensity of a pixel in an image is due to a ray of light, having been reflected from some objects in the scene, pierced through the centre of the pixel.



A ray is fired from the center of projection through each pixel to which the window maps, to determine the closest object intersected.

So, visibility of surfaces can be determined by tracing a ray of light from the centre of projection (viewer's eye) to objects in the scene. (backward-tracing).

⇨ Find out which objects the ray of light intersects.
⇨ Then, determine which one of these objects is closest to the viewer.
⇨ Then, set the pixel color to this object.

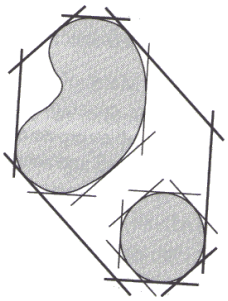
The ray-casting approach is an effective visibility-detection method for scenes with curved surfaces, particularly spheres.

Speeding up the intersection calculation in ray tracing

For 1024x1024 pixels image and 100 objects in the scene,
total number of object intersection calculations is about 100 millions.

1. Bounding Volume Approach

- Test for intersection of ray with the bounding volume of the object.
- Typical bounding volumes are sphere, ellipsoid, rectangular solid. The intersection calculation for these bounding volumes are usually faster than the displayed object.
- If ray does not intersect bounding volume, no further processing of the object is needed.
- Other bounding volumes include convex polygons formed by a set of planes.

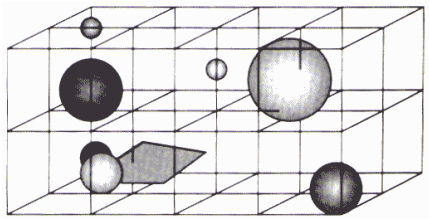


2. Using Hierarchies

- If a parent bounding volume does not intersect with a ray, all its children bounding volumes do not intersect with the ray and need not be processed
- Thus reduce the number of intersection calculations.

3. Space Partitioning Approach

- Partition the space into a regular grid of equal-size volumes.
- Each volume has associated with it a list of objects which are contained within or intersect the volume.
- Intersection calculation is only applied to those objects that are contained within the partition through which the ray passes.
- Objects lying within the partitions which do not intersect with the ray are not processed.



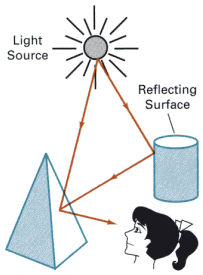
9.9 Summary and Comparison

The most appropriate algorithm to use depends on the scene

- depth-sort is particularly suited to scene with objects which are spread out along z-axis and/or with a small number of objects => rarely overlap in depth
- scan-line and area subdivision algorithms are suitable to scene where objects are spread out horizontally and/or scene with small number of objects (about several thousand surfaces).
- Z-buffer and subdivision algorithms perform best for scene with fewer than a few thousand surfaces.
- Octree is particularly good because it does not require any pre-sorting or intersection calculations.
- If parallel processing hardware is available, ray tracing would be a good choice (each processor handles a ray).

10 Surface Shading

A shading model is used in computer graphics to simulate the effects of light shining on a surface.

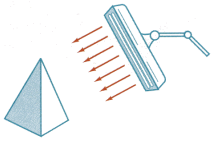


Point source

The intensity that we see on a surface is dependent upon
- The type of light sources.
- The surface characteristics (eg. Shining, matte, dull, and opaque or transparent).

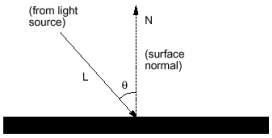
Types of illumination

A. Light emitting sources (eg. Light bulb, sun)
- When the light source is far away from the object => point source (eg. Sun)
- When the light source is large compared with the object => distributed light source (eg. Neon light)

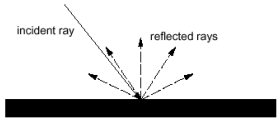

Distributed light source

B. Light reflecting sources (eg. Illuminated surface of an object, walls)
- 3 possible types of reflections ((1), (2), and (3)) to form the shading of a point on a surface.
  - Reflection of ambient light
    Multiple reflections of light from nearby objects => ambient light (or background light) -- (1)
    Ambient light has a uniform intensity in all directions. It causes a surface to be uniformly illuminated at any viewing position.
  - Reflection of point source light
    - A point source light emits directional light rays. Normally we consider light rays from a distant light source as being parallel (eg. Sun) and light rays from a close light source as being divergent (eg. Table lamp).
      - Two types of reflection of point source light:
        - Due to surface roughness => diffuse reflection -- (2)
        - Due to shinny surface => specular reflection -- (3)

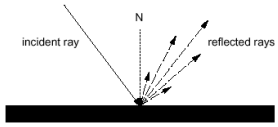
- When light is reflected (or refracted) from a surface, it does not reflect all light that enters the surface. Part of the energy will be absorbed by the surface. The reflection coefficient represents the amount of light reflected from an object's surface.
- The unit normal vector N represents the orientation of a surface.
- The unit vector L represents the direction of a light source at the surface.
- The angle of incident θ represents the angle between N and L.



- In diffuse reflection, we consider surfaces which reflect light with equal intensity in all directions. The amount of light energy that falls on a given area and hence the intensity of the reflection is proportional to the cosine of the angle of incident (ie. cos θ). This kind of surfaces are normally dull or matt.
- In specular reflection, we consider surfaces which reflect light with higher intensity at a particular direction. This kind of surfaces are normally shiny.

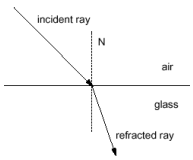


Diffuse Reflection



Specular Reflection

C. Light refraction
Refraction occurs when light travels through transparent or semi-transparent objects of different densities (for example, from air to glass).



Light Refraction