Computer Graphics 14: Surface Detection Methods

Contents

Today we will start to take a look at visible surface detection techniques:

- Why surface detection?
- Back face detection
- Depth-buffer method
- A-buffer method
- Scan-line method
- Painter's method

Why?

We must determine what is visible within a scene from a chosen viewing position

For 3D worlds this is known as **visible surface detection** or **hidden surface elimination**

Two Main Approaches

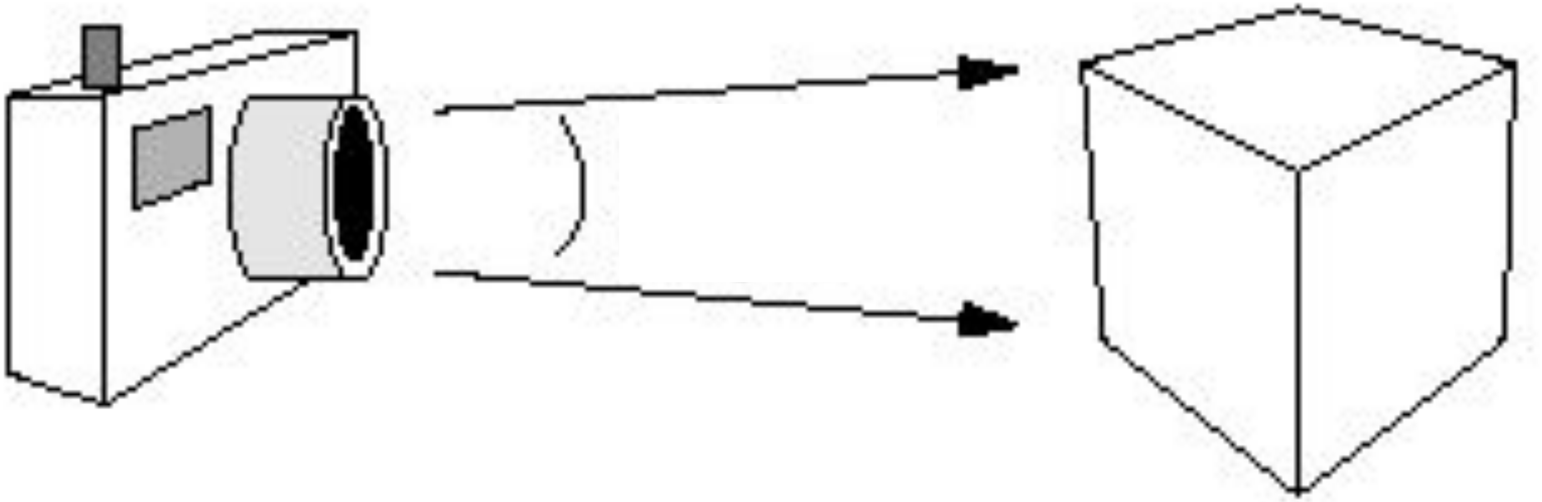
Visible surface detection algorithms are broadly classified as:

- **Object Space Methods:** Compares objects and parts of objects to each other within the scene definition to determine which surfaces are visible
- **Image Space Methods:** Visibility is decided point-by-point at each pixel position on the projection plane

Image space methods are by far the more common

Back-Face Detection

The simplest thing we can do is find the faces on the backs of polyhedra and discard them



Back-Face Detection (cont…)

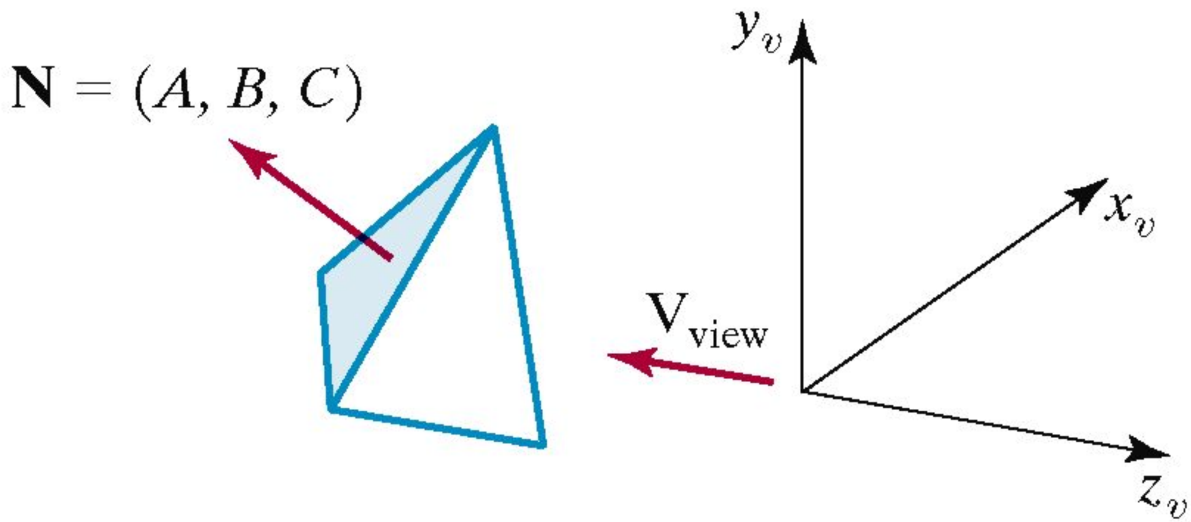
- We know from before that a point (x, y, z) is behind a polygon surface if:

$$Ax + By + Cz + D < 0$$

- where A, B, C & D are the plane parameters for the surface
- This can actually be made even easier if we organise things to suit ourselves
- Object space method

Back-Face Detection (cont…)

- Ensure we have a right handed system with the viewing direction along the negative z-axis
- Now we can simply say that if the z component of the polygon's normal is less than zero the surface cannot be seen

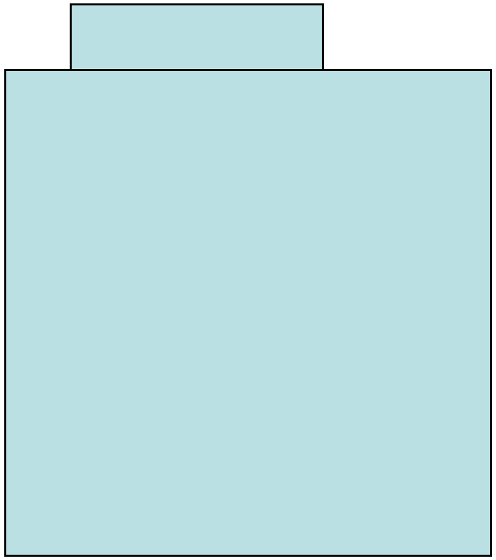


Back-Face Detection (cont…)

In general back-face detection can be expected to eliminate about half of the polygon surfaces in a scene from further visibility tests

More complicated surfaces though trouble us!

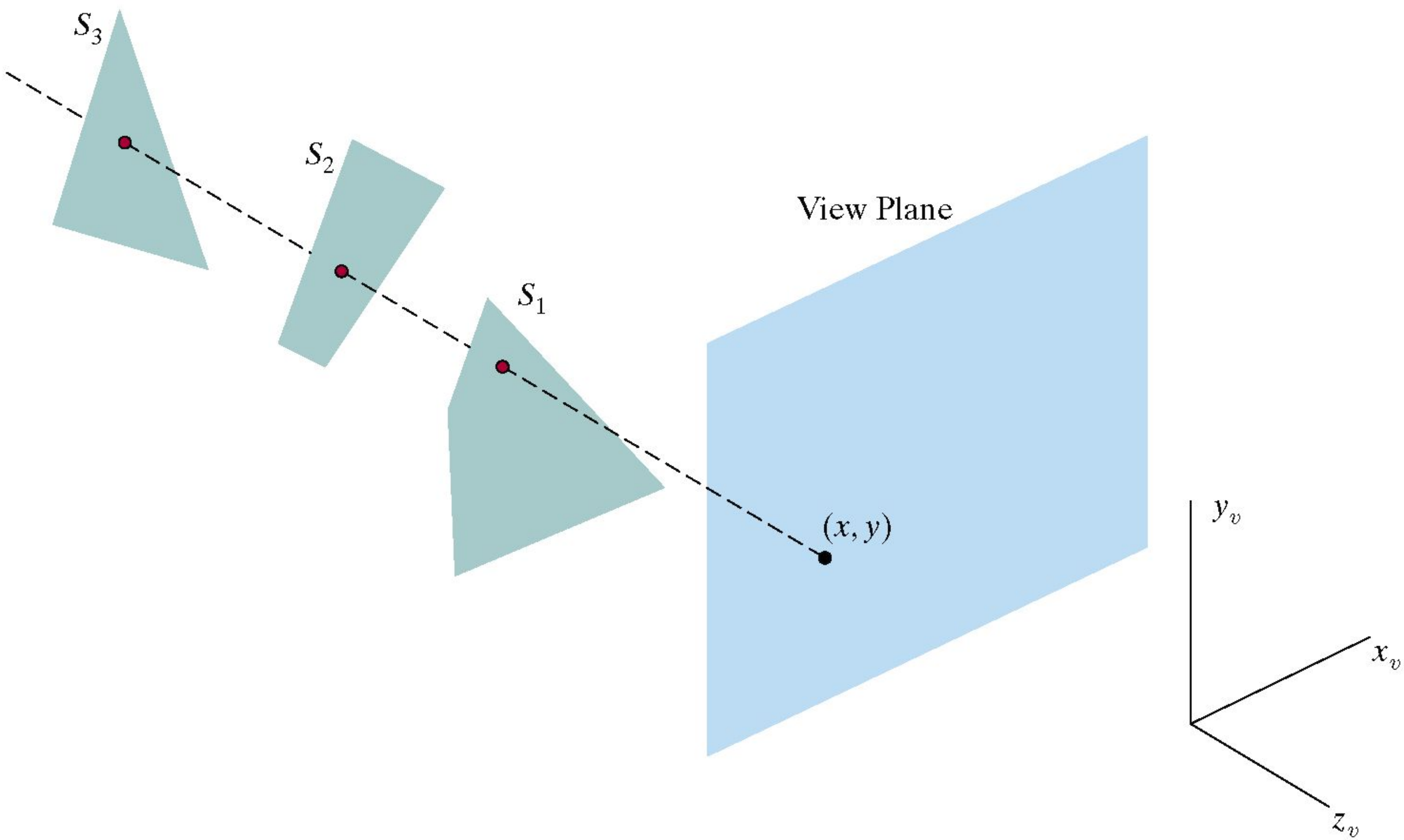
We need better techniques to handle these kind of situations



Depth-Buffer Method

- Compares surface depth values throughout a scene for each pixel position on the projection plane
- Usually applied to scenes only containing polygons
- As depth values can be computed easily, this tends to be very fast
- Also often called the z-buffer method
- Image space method

Depth-Buffer Method (cont…)



Depth-Buffer Algorithm

1. Initialise the depth buffer and frame buffer so that for all buffer positions (x, y)

   depthBuff(x, y) = 1.0

   frameBuff(x, y) = bgColour

Depth-Buffer Algorithm (cont…)

2. Process each polygon in a scene, one at a time
   - For each projected (x, y) pixel position of a polygon, calculate the depth z (if not already known)
   - If z < depthBuff(x, y), compute the surface colour at that position and set

     depthBuff(x, y) = z

     frameBuff(x, y) = surfColour(x, y)

   After all surfaces are processed depthBuff and frameBuff will store correct values

Calculating Depth

At any surface position the depth is calculated from the plane equation as:

$$z = \frac{-Ax - By - D}{C}$$

For any scan line adjacent x positions differ by ±1, as do adjacent y positions

$$z' = \frac{-A(x+1) - By - D}{C} \qquad z' = z - \frac{A}{C}$$

Iterative Calculations

- The depth-buffer algorithm proceeds by starting at the top vertex of the polygon
- Then we recursively calculate the x-coordinate values down a left edge of the polygon
- The x value for the beginning position on each scan line can be calculated from the previous one

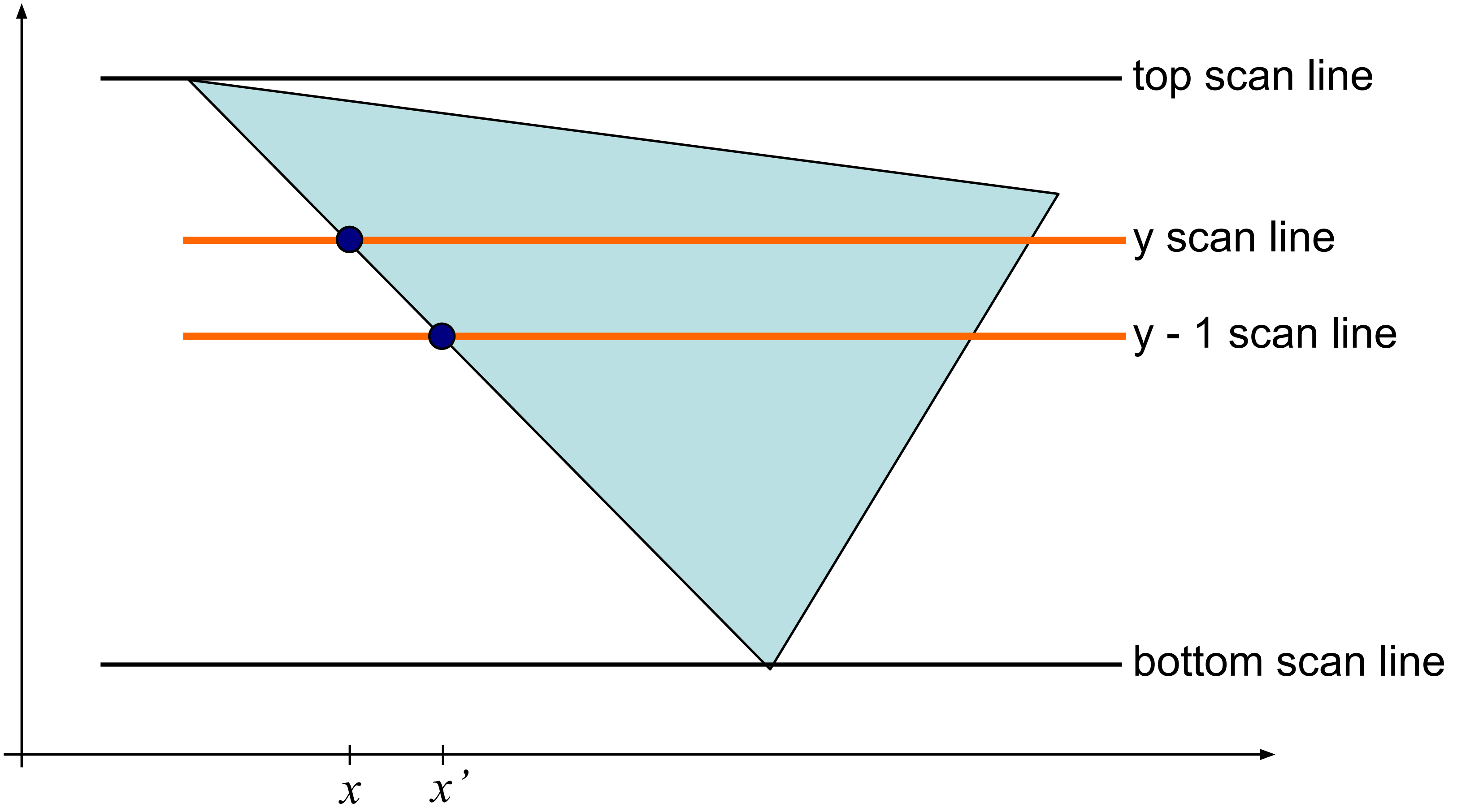
$$x' = x - \frac{1}{m}$$ where m is the slope

Iterative Calculations (cont…)

Depth values along the edge being considered are calculated using

$$z' = z - \frac{A/m + B}{C}$$

Iterative Calculations (cont…)



A-Buffer Method

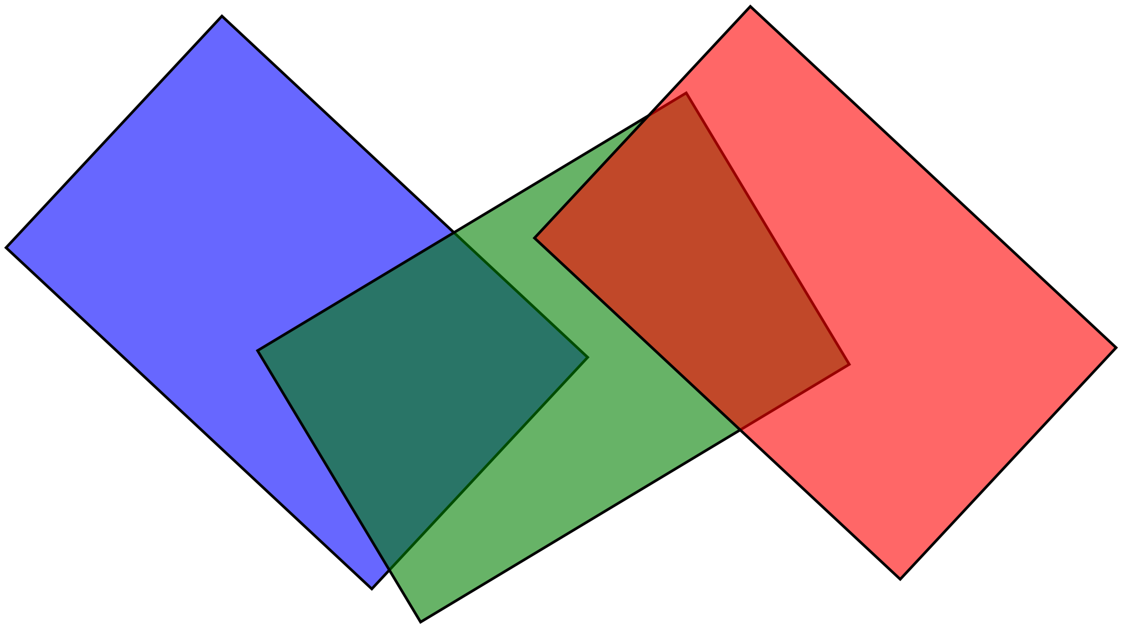
The A-buffer method is an extension of the depth-buffer method

The A-buffer method is visibility detection method developed at Lucasfilm Studios for the rendering system REYES (**R**enders **E**verything **Y**ou **E**ver **S**aw)

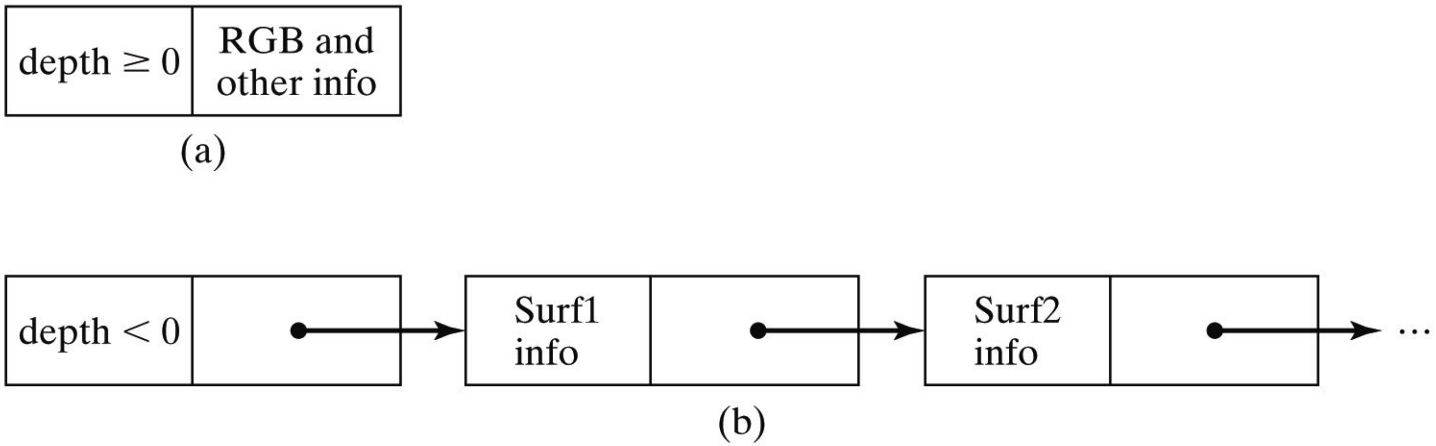
A-Buffer Method (cont…)

The A-buffer expands on the depth buffer method to allow transparencies

The key data structure in the A-buffer is the *accumulation buffer*



A-Buffer Method (cont…)



If depth is >= 0, then the surface data field stores the depth of that pixel position as before

If depth < 0 then the data filed stores a pointer to a linked list of surface data

A-Buffer Method (cont…)

- Surface information in the A-buffer includes:
  - RGB intensity components
  - Opacity parameter
  - Depth
  - Percent of area coverage
  - Surface identifier
  - Other surface rendering parameters
- The algorithm proceeds just like the depth buffer algorithm
- The depth and opacity values are used to determine the final colour of a pixel

Scan-Line Method

- An image space method for identifying visible surfaces
- Computes and compares depth values along the various scan-lines for a scene

Scan-Line Method (cont…)

Two important tables are maintained:
- The edge table
- The surface facet table

The edge table contains:
- Coordinate end points of reach line in the scene
- The inverse slope of each line
- Pointers into the surface facet table to connect edges to surfaces

Scan-Line Method (cont…)

The surface facet tables contains:

- The plane coefficients
- Surface material properties
- Other surface data
- Maybe pointers into the edge table

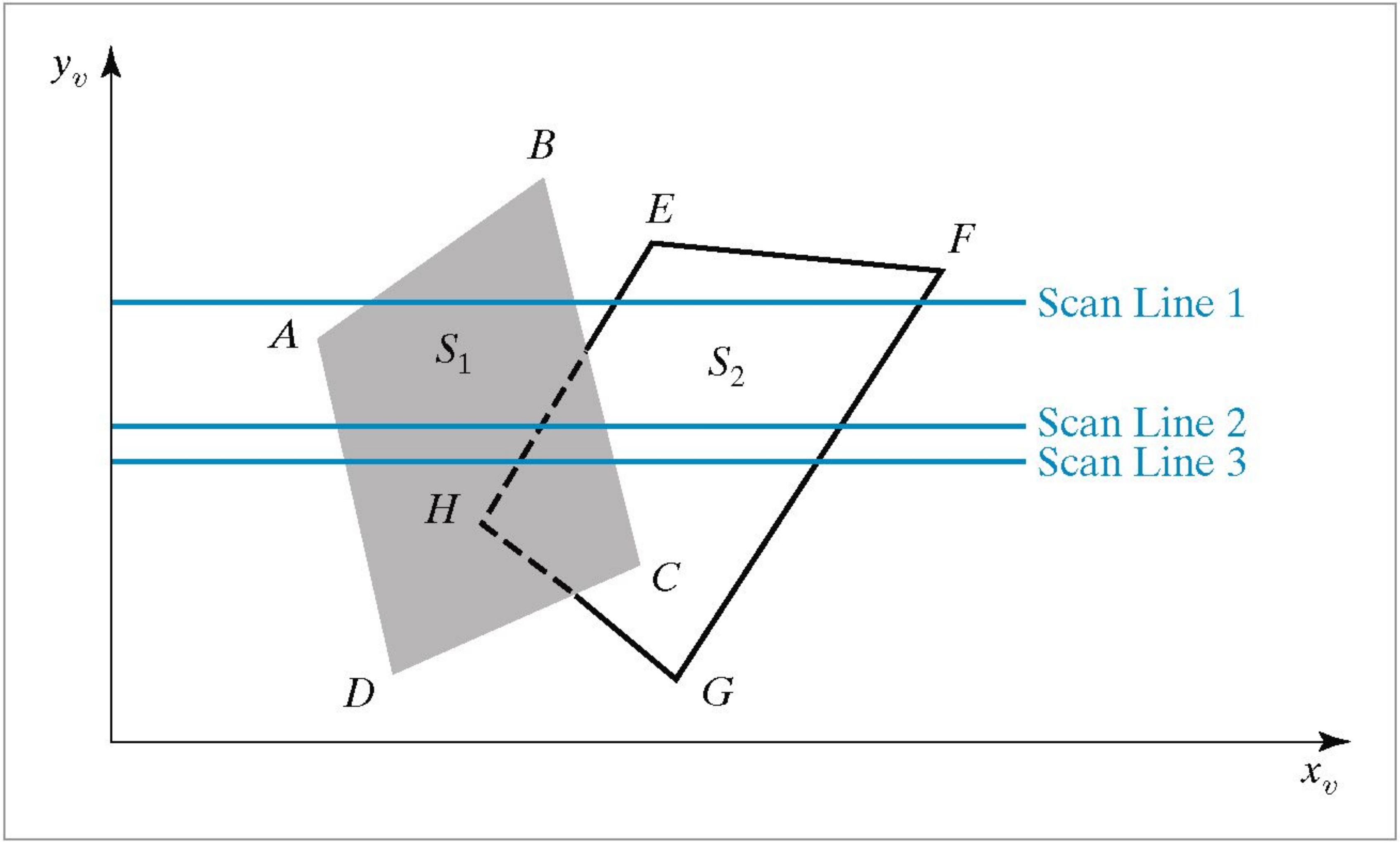
Scan-Line Method (cont…)

- To facilitate the search for surfaces crossing a given scan-line an active list of edges is formed for each scan-line as it is processed
- The active list stores only those edges that cross the scan-line in order of increasing x
- Also a flag is set for each surface to indicate whether a position along a scan-line is either inside or outside the surface

Scan-Line Method (cont…)

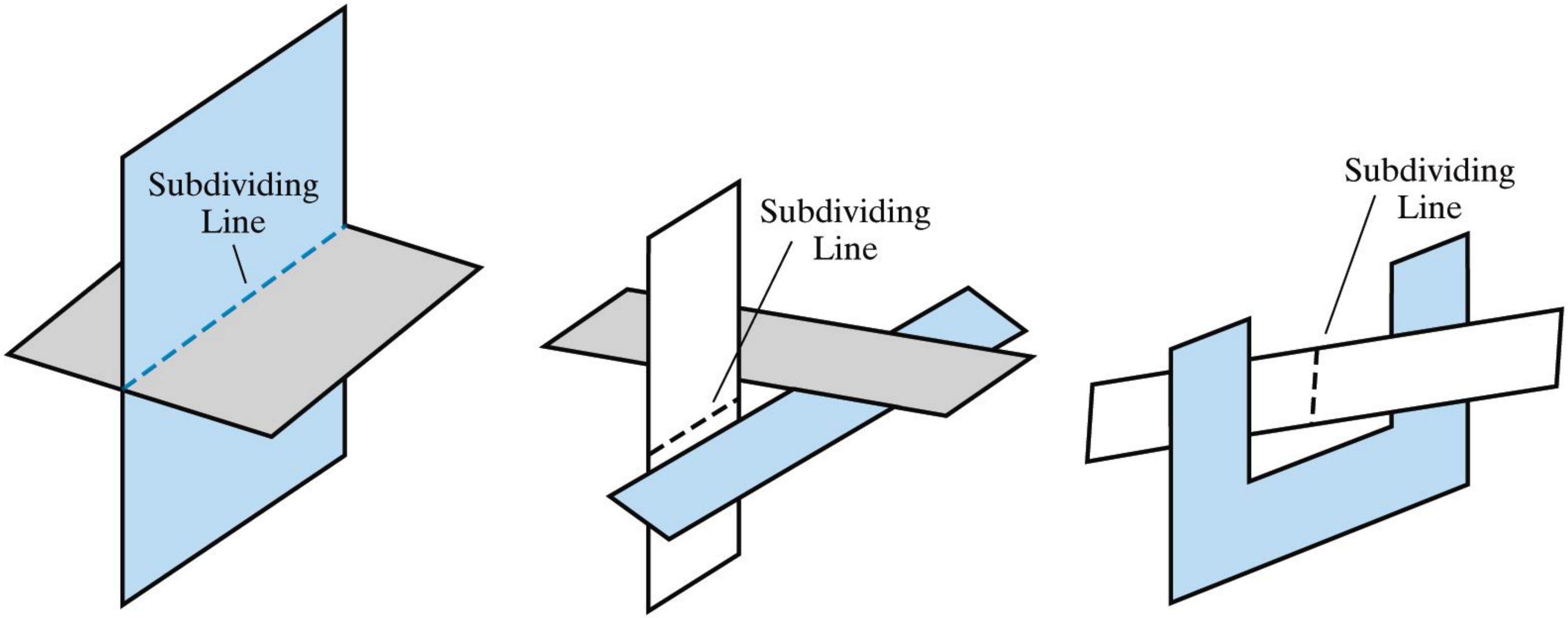
- Pixel positions across each scan-line are processed from left to right
- At the left intersection with a surface the surface flag is turned on
- At the right intersection point the flag is turned off
- We only need to perform depth calculations when more than one surface has its flag turned on at a certain scan-line position

Scan Line Method Example



Scan-Line Method Limitations

- The scan-line method runs into trouble when surfaces cut through each other or otherwise cyclically overlap
- Such surfaces need to be divided



Depth-Sorting Method

A visible surface detection method that uses both image-space and object-space operations

Basically, the following two operations are performed

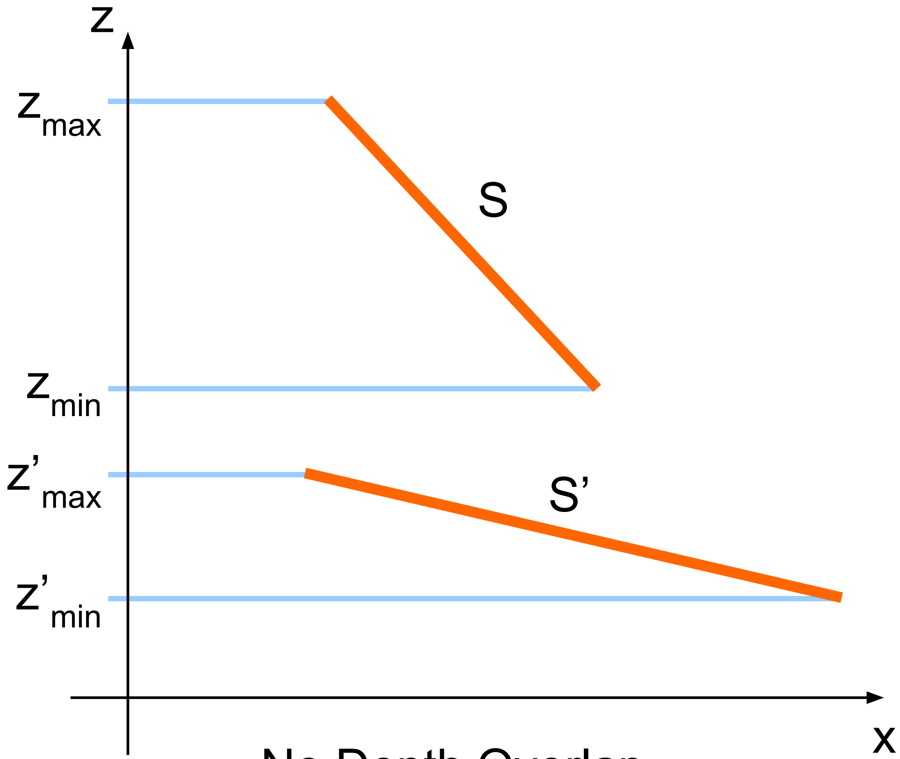
- Surfaces are sorted in order of decreasing depth
- Surfaces are scan-converted in order, starting with the surface of greatest depth

The depth-sorting method is often also known as the **painter's method**

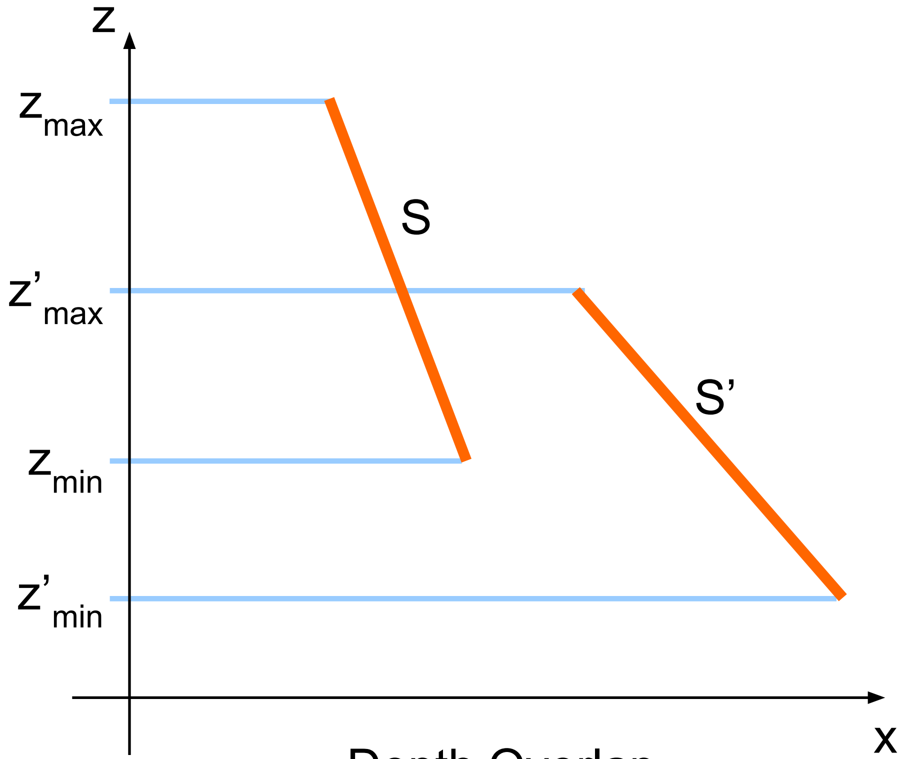
Depth-Sorting Method (cont…)

- First, assume that we are viewing along the z direction
- All surfaces in the scene are ordered according to the smallest z value on each surface
- The surface S at the end of the list is then compared against all other surfaces to see if there are any depth overlaps
- If no overlaps occur then the surface is scan converted as before and the process repeats with the next surface

Depth Overlapping



No Depth Overlap



Depth Overlap

Depth-Sorting Method (cont…)

When there is depth overlap, we make the following tests:

- The bounding rectangles for the two surfaces do no overlap
- Surface S is completely behind the overlapping surface relative to the viewing position
- The overlapping surface is completely in front of S realtive to the viewing position
- The boundary edge projections of the two surfaces onto the view plane do not overlap

Depth-Sorting Method (cont…)

- The tests are performed in the order listed and as soon as one is true we move on to the next surface
- If all tests fail then we swap the orders of the surfaces

Summary

We need to make sure that we only draw visible surfaces when rendering scenes

There are a number of techniques for doing this such as

- Back face detection
- Depth-buffer method
- A-buffer method
- Scan-line method
- Painter’s method