Graphics Rendering Pipeline II

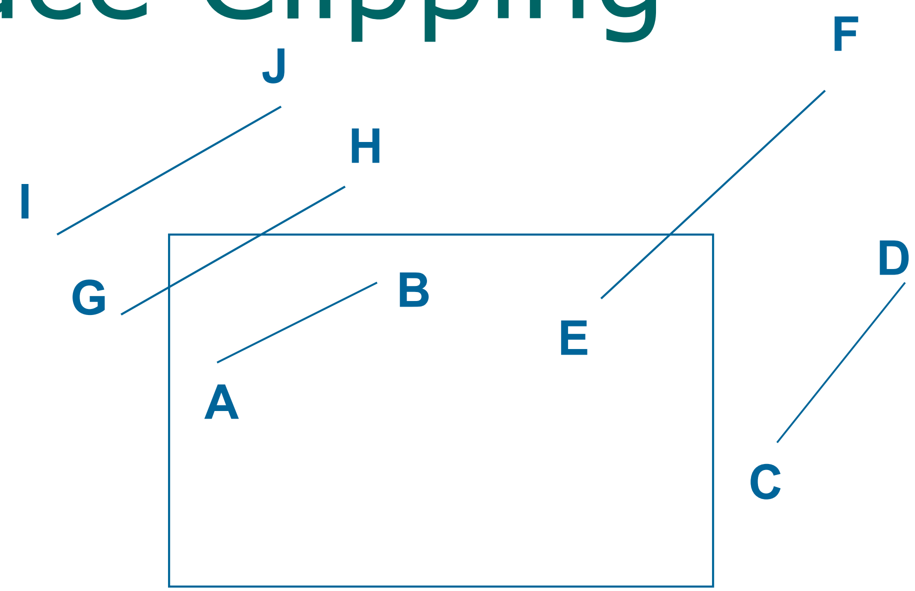
CS 211A

Clipping

- OpenGL does image space clipping
- Culling
  - Usually refers to object space
  - Done by the application programmer

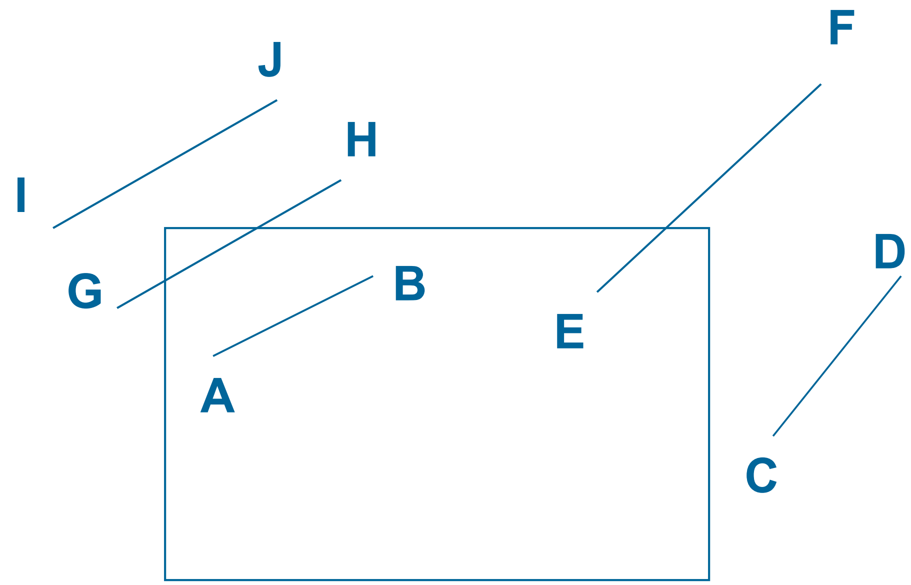
Image Space Clipping

- Accept AB
- Reject (Cull) CD
- Clip EF
  - One endpoint outside the window
- Clip GH
  - Both endpoints outside the window



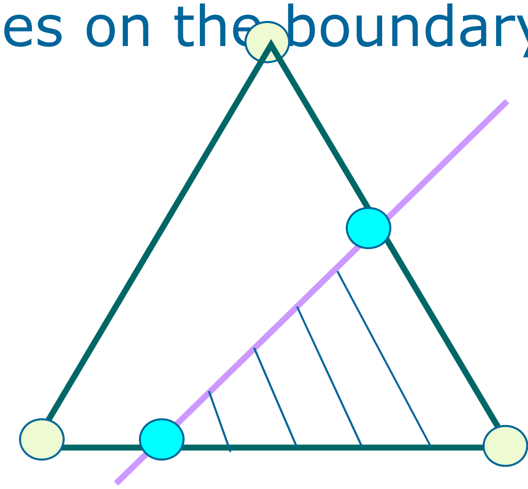
Efficiency

- How fast you can accept and reject?
- Do intersection computations minimally



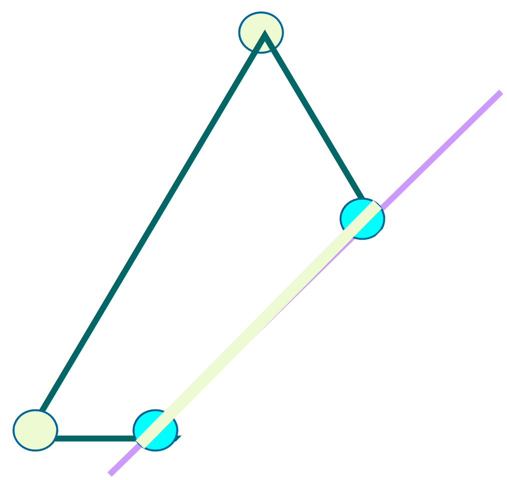
Clipping

- Removing the part of the polygon outside the view frustum
- If the polygon spans inside and outside the view frustum
  - – introduce new vertices on the boundary



Vertex Interpolation of Attributes

- For the new vertices introduced
  - compute all the attributes
  - Using interpolation of the attributes of all the original vertices



Clipping

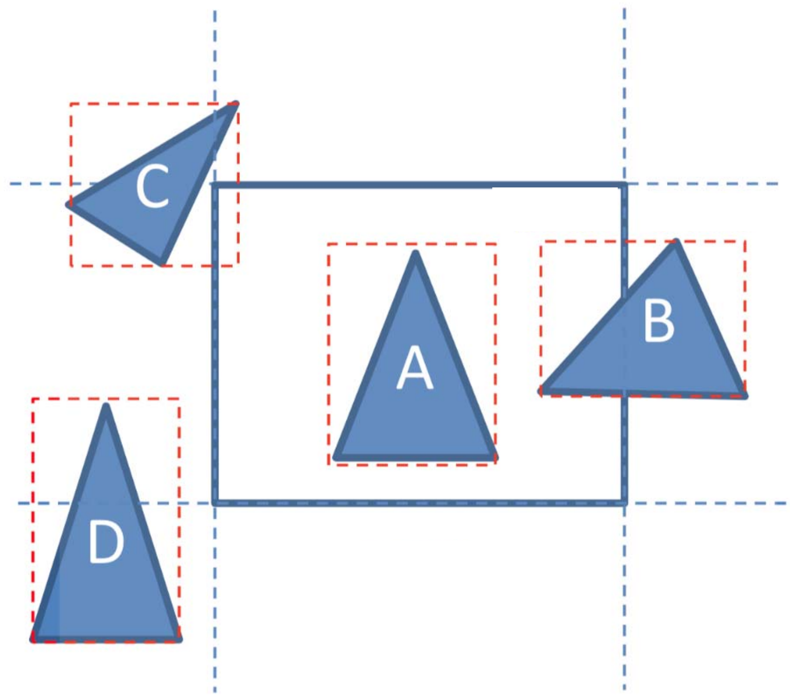
- Every triangle needs to go through the process of clipping
- Fast acceptance or rejection test for primitives completely inside or outside the window is critical
- Such test achieved in multiple ways
  - Using Bounding Boxes (Cohen Sutherland)
  - Using Logic Operations (Cohen Sutherland)
  - Using Integer Operations (Liang-Barsky)
  - Using Pipelining (Sutherland Hodgeman)

Spatial Subdivision

- Can be used for both image space and object space culling
- Based on bounding boxes or volumes

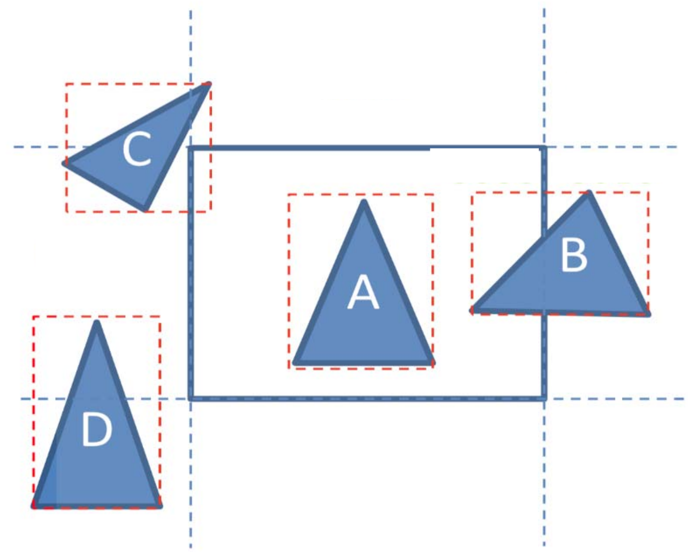
Using Bounding Boxes

- Compute axis aligned bounding box of each triangle
- See if it is inside or outside
- Testing achieved easily



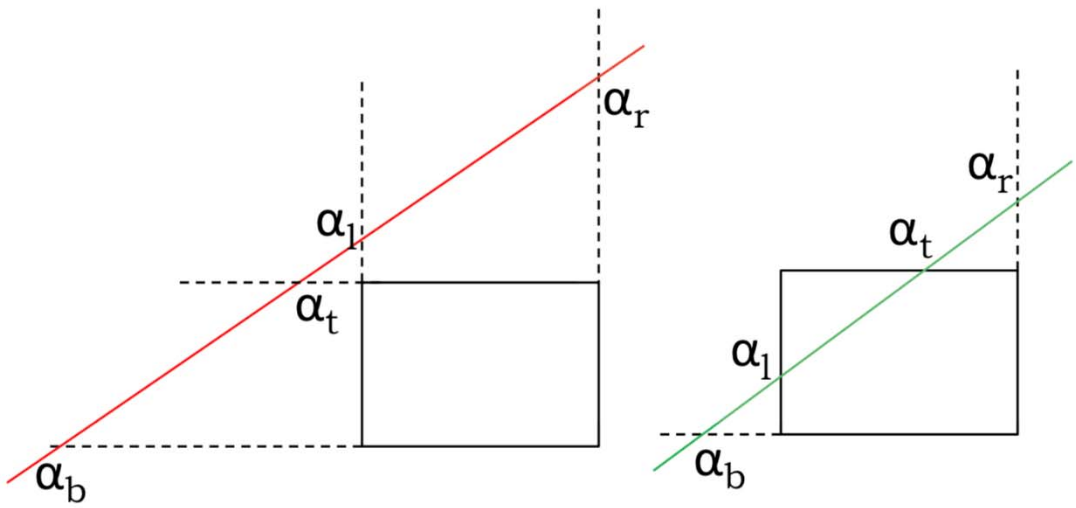
Using Logic Operations

- Divide the 2D image plane into regions
- Assign binary codes to the regions
- Have four bits, $b_1b_2b_3b_4$ associated with each projected vertex (x, y) such that
  - $b_1 = y<t_w$
  - $b_2 = y>b_w$
  - $b_3 = x>r_w$
  - $b_4 = x<l_w$



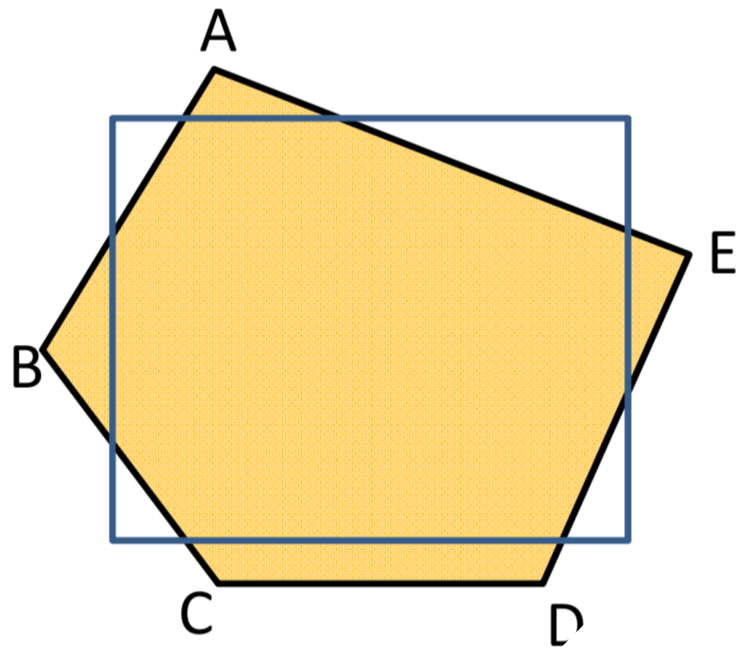
Using Integer Operations

- Intersection of the primitives that are not trivially accepted/rejected with the window boundaries have to be computed
  - first find the window boundary that intersects the primitive
  - finc



Using Pipelining

- Four stages of clipping against left, top, right and bottom edges of the window

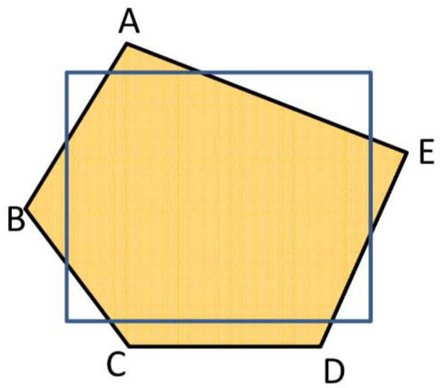


Using Pipelining

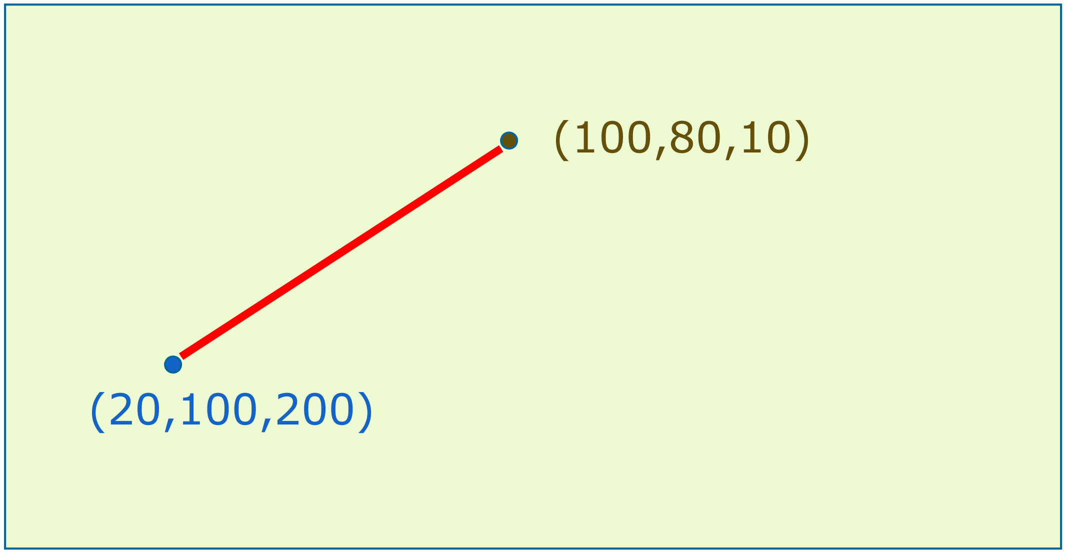
- Sutherland-Hodgeman method
- 1. If first vertex is IN output the same, or else nothing

  2. Loop through the rest of the vertices testing transitions.
  - (a) If IN-TO-OUT, output intersection with edge
  - (b) If IN-TO-IN, output the vertex
  - (c) If OUT-TO-IN, output intersection with edge and the vertex
  - (d) If OUT-TO-OUT, output nothing

Sutherland-Hodgeman method

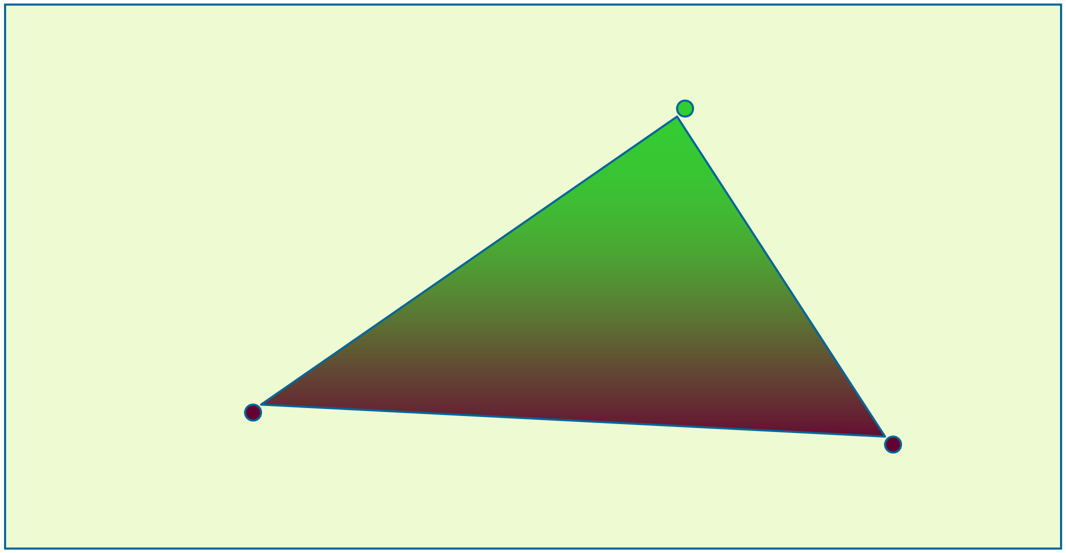


Scan Conversion



- Which pixels to color?
- What color to put for each pixel?

Scan Conversion



- Which pixels to color?
- What color to put for each pixel?

Which pixels

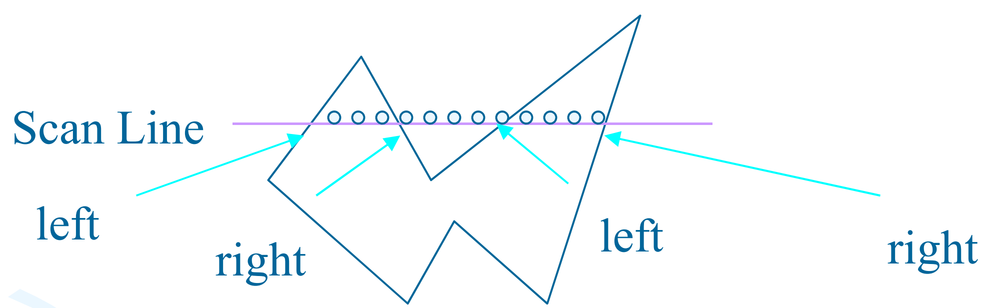
- Efficient Data Structures
- Integer Operations are preferred
- Hardware adaptability
- Line
  - Bresenham's
- Polygon
  - Using an edge table and active edge table data structure

How to color them?

- Linear interpolation
- Find the coefficients from the marked pixels
  - Screen space interpolation
- Use these linear coefficients to find a weighted combination of color
- Is screen space interpolation correct?
  - Not really, but we are not sensitive to it

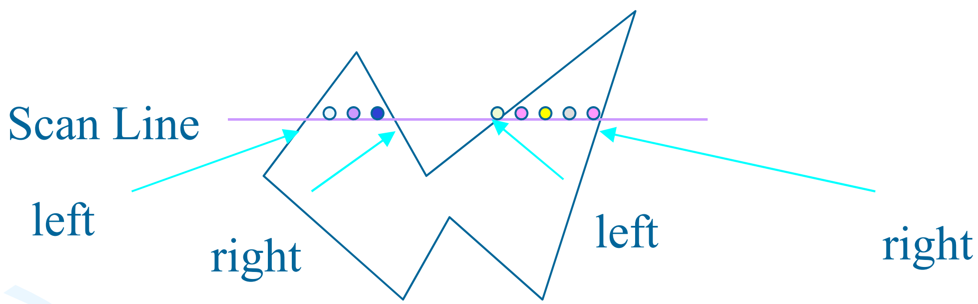
Rasterization

- Process of generating pixels in the scan (horizontal) line order (top to bottom, left to right).
  - Which pixels are in the polygon



Pixel Interpolation of Attributes

- Interpolate the colors and other attributes at pixels from the attributes of the left and right extent of the scan line on the polygon edge.
- Also in scan line order



Hidden Surface Removal

- Z buffer (size of the framebuffer)
- Initialize
- Store z when projecting vertices
- During scan conversion
  - Interpolate 1/z
  - If depth is smaller than existing value
    - Set new depth
    - Color pixel

Final Drawing

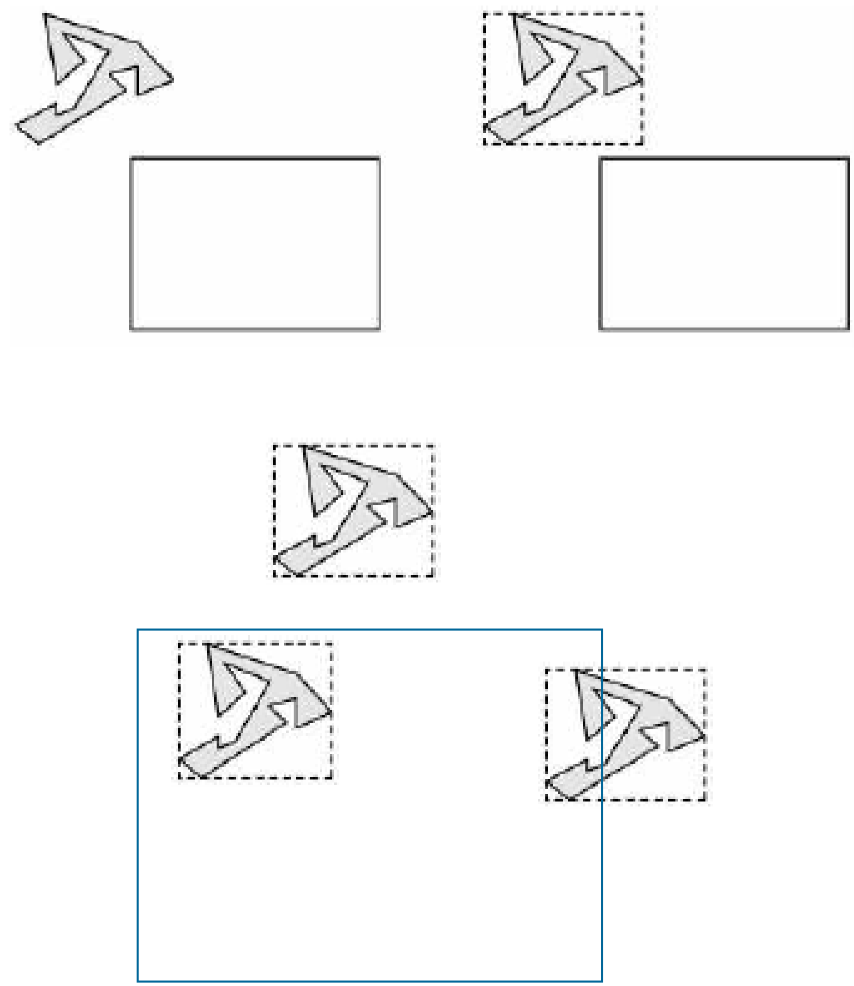
```
Transform all vertices;
Clear frame buffer;
Clear depth buffer;
for i=1:n triangles
   for all pixels (xs,ys) in the triangle
      pixelz = 1/z interpolated from vertex;
      if (pixelz < depthbuffer[xs][ys])
         framebuffer[xs][ys]= color interpolated
           from vertex attributes;
      endif;
   endfor;
endfor;
```

Two Efficiency Measures

- Spatial Subdivision
- Hidden Surface Removal

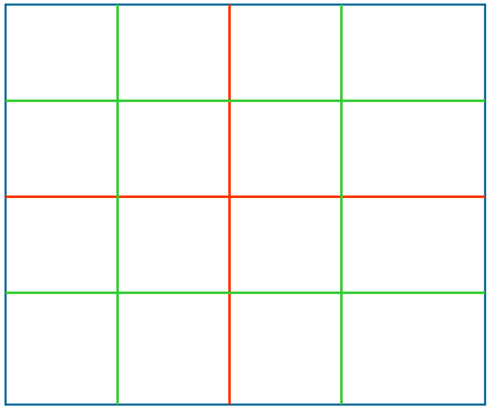
Bounding Boxes and Volumes

- Polygon clipping is overkill if entire polygon outside the window
- Maintain a bounding box
  - Axis-aligned
- Can be a big savings
- Can be easily extended to 3D
  - For volumes in object-space



Hierarchical Spatial Subdivision (2D)

- Quadtree
  - Each node corresponds to a BB
  - It holds the indices of all primitives in that box
  - Divide each box into four equal sized box
    - Four children per node
    - Can be computed from BB of parent
    - BB stored only at root



Hierarchical Spatial Subdivision (2D)

- Tree building
- Culling the Model
  - Depth first traversal of nodes
  - If BB inside the view frustum
    - Draw all triangles
  - If BB outside the view frustum
    - Draw nothing
  - If BB intersects the view frustum
    - Go through the children recursively
  - Creates tree cuts

Extending to 3D

- Cubes instead of boxes
- Octree
  - Eight children
  - Divide in three directions
- Note that may not be optimal
  - Boxes may not be the tightest fit
  - Can have another tree with smaller depth
- Very efficient
  - Since child BB computation is trivial

Back Face Culling

- Do not want to render back facing polygons
- If the normal is pointed towards the viewer
  - $-90 \leq \theta \leq 90$
  - $\cos(\theta) \geq 0$
  - $n.v \geq 0$
- Viewing in -z
  - Culled if normal has negative z