Now Playing:

Big Bird
Eddie Floyd
from *The Complete Stax-Volt Singles Volume 1 (1959-1968)*
Released April 30, 1991

Polygon Drawing and Hidden Surface Removal

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COMP 575
October 9, 2007
Some slides and images courtesy Jeremy Wendt (2005) and Eric Bennett (2006)

Announcements

- Assignment 2 is due today
- Programming Assignment 2 will be out today
  - Demo/review in class on Thursday
  - Due Thursday after fall break (10/25)
- Late drop deadline (for undergrads) is next Monday (10/15)
  - Talk to me if you have any questions or concerns

Last Time

- Talked about the purpose of the rasterization step
- Discussed line drawing
  - Presented several algorithms
  - Finished up with Bresenham's algorithm
- Started on line anti-aliasing
  - Included a brief aside on filtering

Today

- Finish up line anti-aliasing
  - Ratio method
- Present several methods for polygon drawing
- Discuss hidden surface removal algorithms

Rasterization

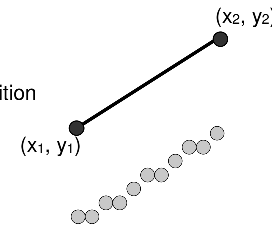
- In the rasterization step, geometry in device coordinates is converted into fragments in screen coordinates
- After this step, there are no longer any "polygons"

Rasterization

- All geometry that makes it to rasterization is within the normalized viewing region
- All the rasterizer cares about is (x, y)
  - z is only used for z-buffering later on
- Need to convert continuous (floating point) geometry to discrete (integer) pixels

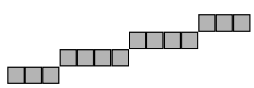
Line Drawing

- A classic part of the computer graphics curriculum
- Input:
  - Line segment definition
    - (x_1, y_1), (x_2, y_2)
- Output:
  - List of pixels



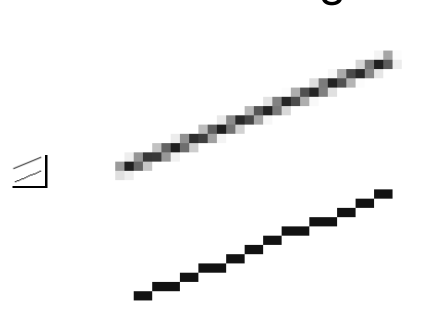
How Do They Look?

- So now we know how to draw lines
- But they don’t look very good:



- Why not?
- Aliasing

Antialiasing



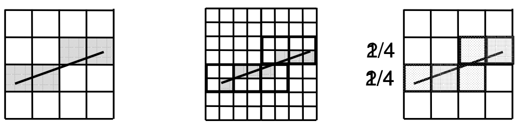
Antialiasing

- Essentially 2 techniques:
  1. Supersample then filter
     - We discussed a simple averaging filter
  2. Compute the fraction of a line that should be applied to a pixel
     - Ratio method

Antialiasing #1: Supersampling

- Technique:
  1. Create an image 2x (or 4x, or 8x) bigger than the real image
  2. Scale the line endpoints accordingly
  3. Draw the line as before
     - No change to line drawing algorithm
  4. Average each 2x2 (or 4x4, or 8x8) block into a single pixel

Antialiasing #1: Supersampling

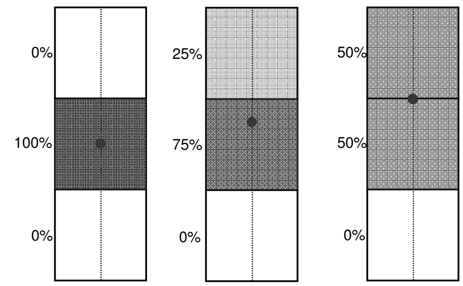


No antialiasing

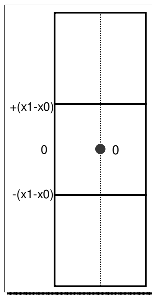
2x2 Supersampled

Downsampled to original size

Antialiasing #2: Ratios



Antialiasing #2: Ratios



$$\left(.5 * MAX\left(\frac{error}{x_1 - x_0}, 0\right)\right) RGB$$

$$\left(1.0 - .5 * abs\left(\frac{error}{x_1 - x_0}\right)\right) RGB$$

$$\left(.5 * MAX\left(\frac{-error}{x_1 - x_0}, 0\right)\right) RGB$$

Polygon Drawing

- After clipping, we know that the entire polygon is inside the viewing region
  - Makes the problem easier
- Need to determine which pixels are inside the polygon, and color those
  - Find edges, and fill in between them
  - Edges - Connected line segments
    - How to fill?

Scan-Line Polygons

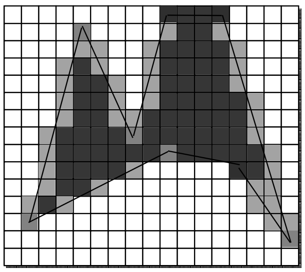
- Algorithm:
  1. Mark local minima and maxima
  2. Mark all distinct y values on edges
  3. For each scan line:
     1. Create pairs of edge pixels (going from left to right)
     2. Fill in between pairs

Scan-Line Polygons

- Difficulties:
  - Need to handle local maxima/minima correctly
    - Appear double in the edge pixel list
  - Need to handle overlapping pixels correctly
    - What to do if a pair of edge pixels map to the same pixel?
  - Need to handle horizontal lines correctly

Scan-Line Polygon Example

- Polygon Vertices
- Maxima / Minima
- Edge Pixels
- Scan Line Fill



Flood Fill

- 4-fill
  - Neighbor pixels are only up, down, left, or right from the current pixel
- 8-fill
  - Neighbor pixels are up, down, left, right, or diagonal

Flood Fill

- Algorithm:
  1. Draw all edges into some buffer
  2. Choose some “seed” position inside the area to be filled
  3. As long as you can
     1. “Flood out” from seed or colored pixels
        - 4-Fill, 8-Fill

Flood Fill Algorithm

Seed Position

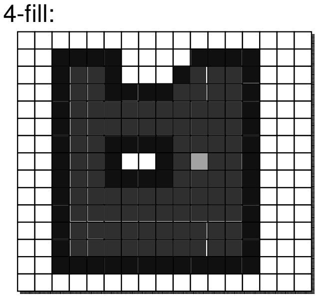
Edge “Color”

Fill “Color”

```
void boundaryFill4(int x, int y, int fill, int boundary)
{
   int curr;
   curr = getPixel(x, y);
   if ((current != boundary) && (current != fill))
   {
      setColor(fill);
      setPixel(x, y);
      boundaryFill4(x+1, y, fill, boundary);
      boundaryFill4(x-1, y, fill, boundary);
      boundaryFill4(x, y+1, fill, boundary);
      boundaryFill4(x, y-1, fill, boundary);
   }
}
```

Flood Fill Example

- 4-fill:



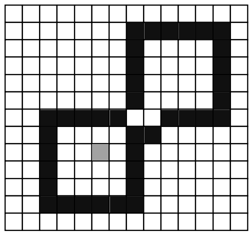
- Edge Pixels
- Seed
- Filled Pixels

Difficulties with Flood-Fill

- Have to worry about stack depth
  - How deep can you go?
- How do you choose the start point?
- Which buffer is used?

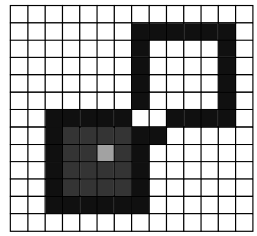
Difficulties with Flood Fill

- What happens in this case?

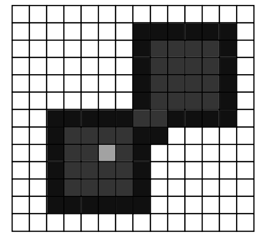


Difficulties with Flood Fill

4 Fill:



8 Fill:



Which to Use?

- Scan-line is generally used for rasterization
- Flood-fill is generally used in applications responding to user input, like MS Paint

Done with Polygon Drawing

- Need to identify and mark the extents of the polygon, then fill in between them
- We discussed 2 algorithms:
  - Scan-Line
  - Flood Fill
- Any questions?

Continuing Down the Pipeline...

- At this point (the end of rasterization), we've converted all our graphics primitives to fragments
  - Basically, single pixels
- Now what we have to do is figure out which of these fragments make it to the screen
  - Backface culling
  - Depth culling

Hidden Surface Removal

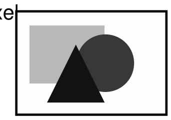
- Alternatively, visible surface detection
  - Need to determine which surfaces are visible to the user, and cull the rest
    - This came up briefly when we were talking about materials
- Some algorithms work on *polygons*, in the vertex processing stage
- Some algorithms work on *fragments*, in the fragment processing stage (*i.e.* this stage)

Backface Culling

- Where?
  - Object space
- When?
  - After transformation but before clipping
- What?
  - If **normal • toViewer** < 0, discard face
    - That is, if the polygon face is facing away from the viewer, throw it out

Backface Culling

- So what does this buy us?
  - Up to 50% fewer polygons to clip/rasterize
- Is this all we have to do?
  - No.
    - Can still have 2 (or more) front faces that map to the same screen pixel
    - Which actually gets drawn?



Depth Culling

- Can happen here (fragment processing)
  - z-buffering
- Can happen before rasterization
  - Painter's algorithm

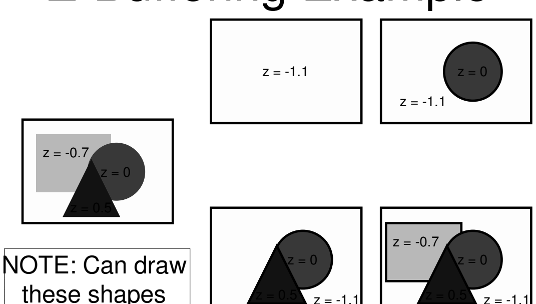
Z-Buffering

- Where?
  - Fragment space
- When?
  - Immediately after rasterization
- How?
  - Basically, remember how far away polygons are, and only keep the ones that are in front

Z-Buffering

- Need to maintain z for all fragments
  - Why we project to a volume instead of a plane
- Maintain a separate depth buffer, the same size and resolution of the color buffer
  - Initialize this buffer to z=-1.1 (all z is in [-1, 1])
- As each fragment comes down the pipe, test fragment.z > depth[s][t]
  - If true, the fragment is in front of whatever was there before, so set color[s][t]=frag.color and depth[s][t]=frag.z

Z-Buffering Example



NOTE: Can draw these shapes in any order

Z-Buffering

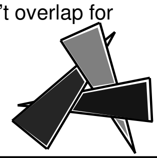
- Advantages:
  - Always works. The nearest object always determines the color of a pixel
  - Easy to understand / Easy to code
  - Does not require any global knowledge about the scene
- Disadvantages:
  - Expensive with memory
    - Needs a whole extra buffer
    - Not really a problem anymore

Painter's Algorithm

- Really a class of algorithms
  - Somehow sort the objects by distance from the viewer
  - Draw objects in order from farthest to nearest
    - The *entire* object
  - Nearer objects will "overwrite" farther ones

Painter's Algorithm

- Does anyone see a problem with this?
  - Objects can have a *range* of depth, not just a single value
  - Need to make sure they don't overlap for this algorithm to work



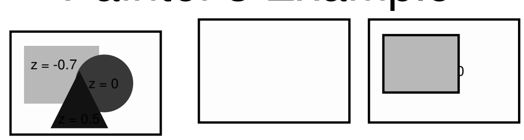
Painter's Algorithm

1. Sort all objects' z_{min} and z_{max}
2. If an object is uninterrupted (its z_{min} and z_{max} are adjacent in the sorted list), it is fine
3. If 2 objects DO overlap
   1. Check if they overlap in x
      - If not, they are fine
   2. Check if they overlap in y
      - If not, they are fine
      - If yes, need to split one

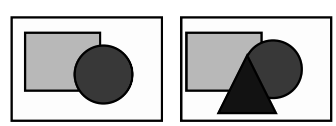
Painter's Algorithm

- The splitting step is the tough one
  - Need to find a plane to split one polygon by so that each new polygon is entirely in front of or entirely behind the other
    - Polygons may actually intersect, so then need to split each polygon by the other
- After splitting, you can resort the list and should be fine

Painter's Example



Sort by depth:
Green rect
Red circle
Blue tri



Next Time

- More fragment processing
  - Texture mapping
- Demo/discussion of programming assignment 2
- Written assignment 2 handed back