Rendering

Triangle Rasterization

CS 415: Game Development

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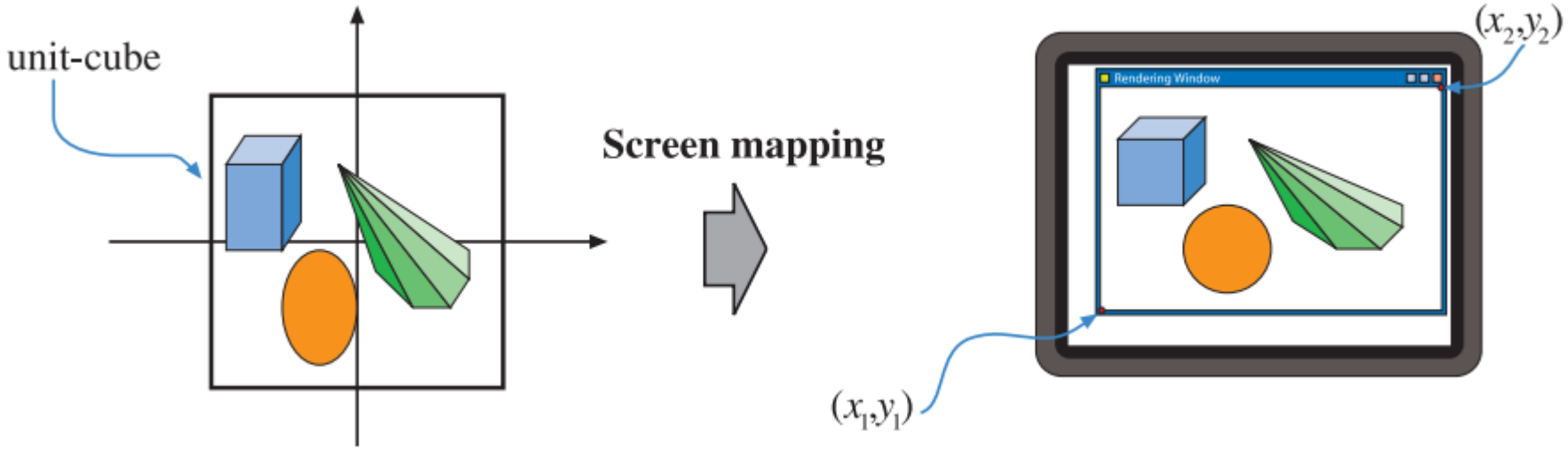
Rasterization and the Pipeline



- Rasterization happens after the viewport transformation
  - "screen mapping" = "viewport transformation"
- The vertex positions are now screen coordinates
- The z values for depth are also included

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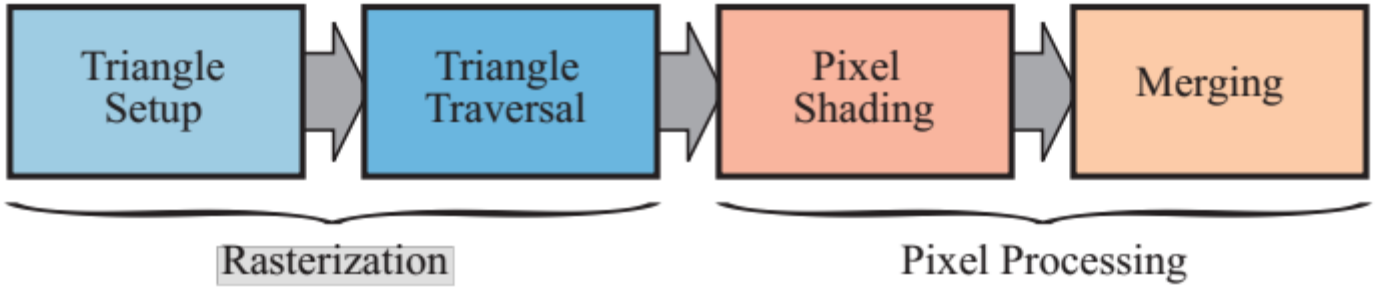
Triangle Rasterization



Triangle Setup

Edge equations and other data are computed.
This data may be used for triangle traversal, as well as for interpolation of other data.

Triangle Traversal

A fragment is generated for the part of the pixel that overlaps the triangle.
Data associated with each fragment is computed using interpolation.

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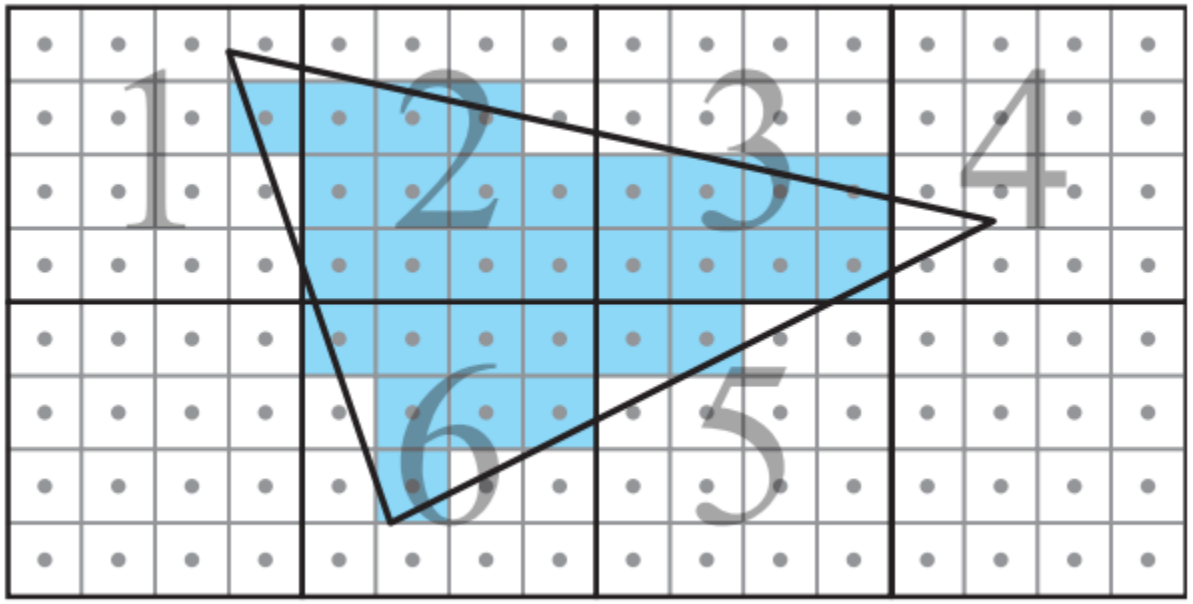
Tiled Rasterization



Pixels are grouped into tiles (4x4 in this example)

Tile processing has greater memory coherence than scanline

For example, texel data is cached more effectively

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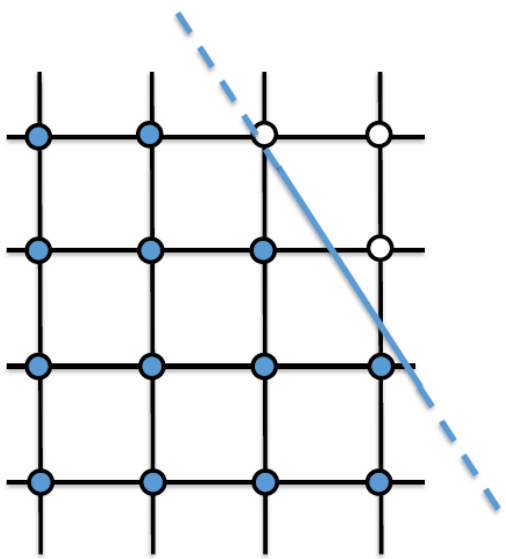
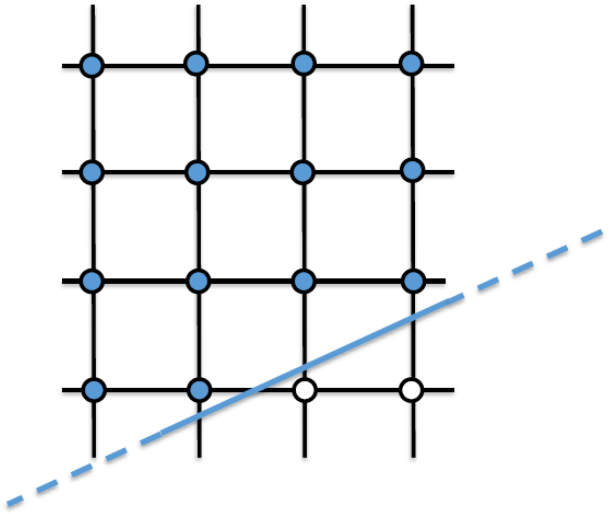
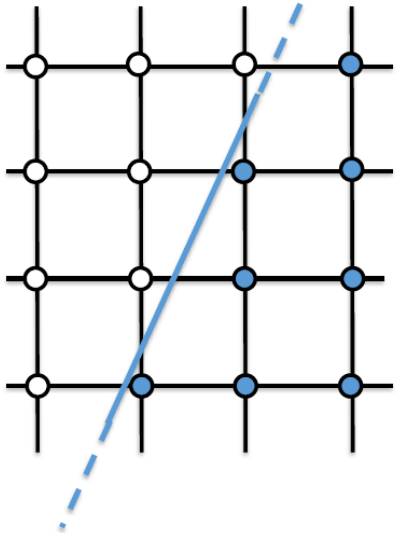
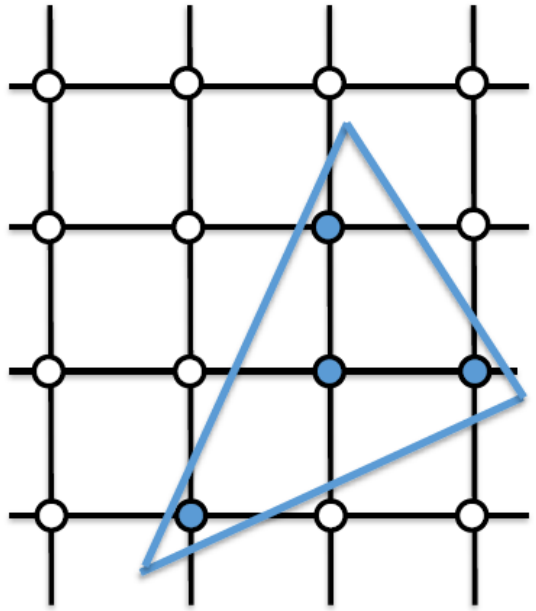
Basic Idea

Find which pixels lie on positive side of the three line equations









How can you test which side of a line a pixel falls on?

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Edge Functions

Suppose the vertices of the triangle are p_0 p_1 and p_2

For each triangle edge compute a function

$$\mathbf{n} \cdot ((x, y) - \mathbf{p}) = 0$$

n is a normal vector pointing to inside of the triangle

p is a point on the line formed by the edge

Example: Edge Functions

$$\mathbf{n} \cdot ((x, y) - \mathbf{p}) = 0$$

Edge vector is $p_1 - p_0$

Normal is $p_1 - p_0$ rotated 90 degrees counterclockwise:

$$\mathbf{n}_2 = (-(p_{1y} - p_{0y}), p_{1x} - p_{0x})$$

n_2 points to the inside of the triangle

inserting n_2 and p_0 into the edge function we have

$$\begin{aligned} e_2(x, y) &= -(p_{1y} - p_{0y})(x - p_{0x}) + (p_{1x} - p_{0x})(y - p_{0y}) \\ &= -(p_{1y} - p_{0y})x + (p_{1x} - p_{0x})y + (p_{1y} - p_{0y})p_{0x} - (p_{1x} - p_{0x})p_{0y} \\ &= a_2 x + b_2 y + c_2. \end{aligned}$$

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Optimizations

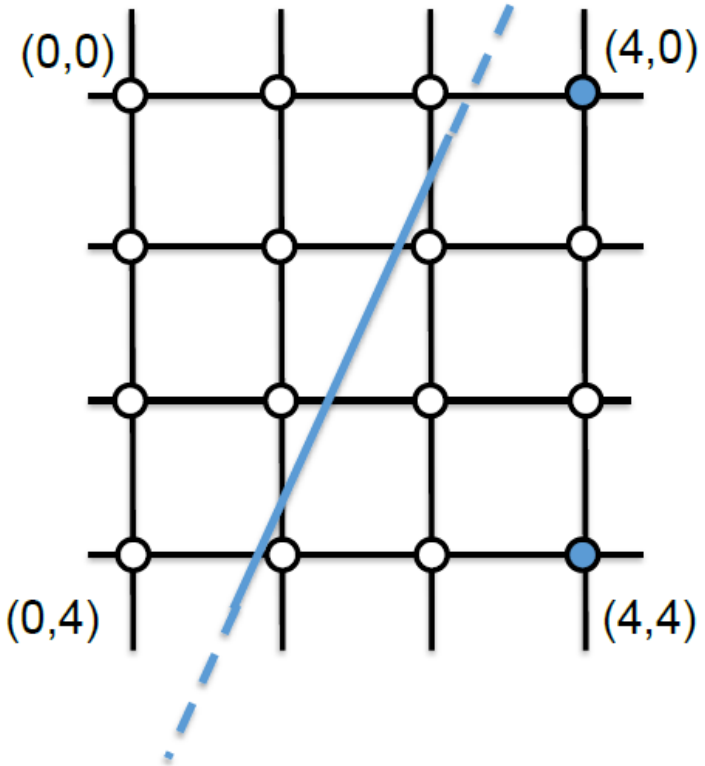
- Can use fixed point screen space coordinates (integer arithmetic)
- Can do incremental updates to edge functions when testing pixels
  - Example: Suppose we test tested a pixel center at (x,y)
    Then, to test pixel center at (x+1,y) we have

$$e(x+1,y) = a(x+1) + by + c = a + ax + by + c = a + e(x,y)$$

Optimizations

Can quickly check if an entire tile lies outside triangle

- If all corners of tile outside triangle → tile is outside
- If all corners of tile inside → tile is inside
- Otherwise, an edge passes through the tile



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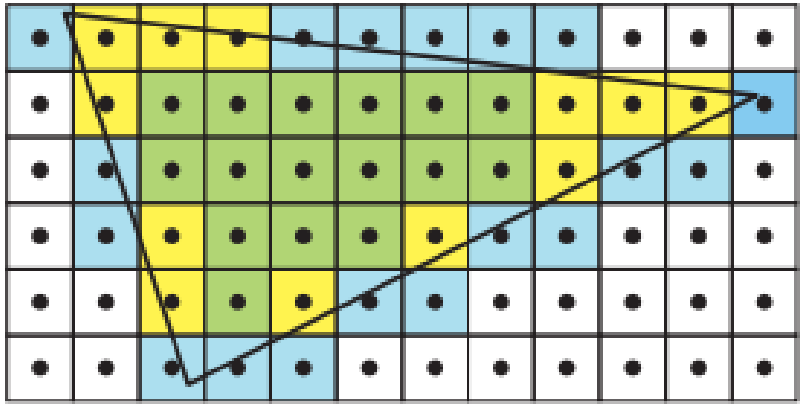
Conservative Rasterization



Outer Conservative Rasterization: all colored pixels (any pixel partially or fully in triangle)
Inner Conservative Rasterization: green pixels (pixels fully inside triangle)

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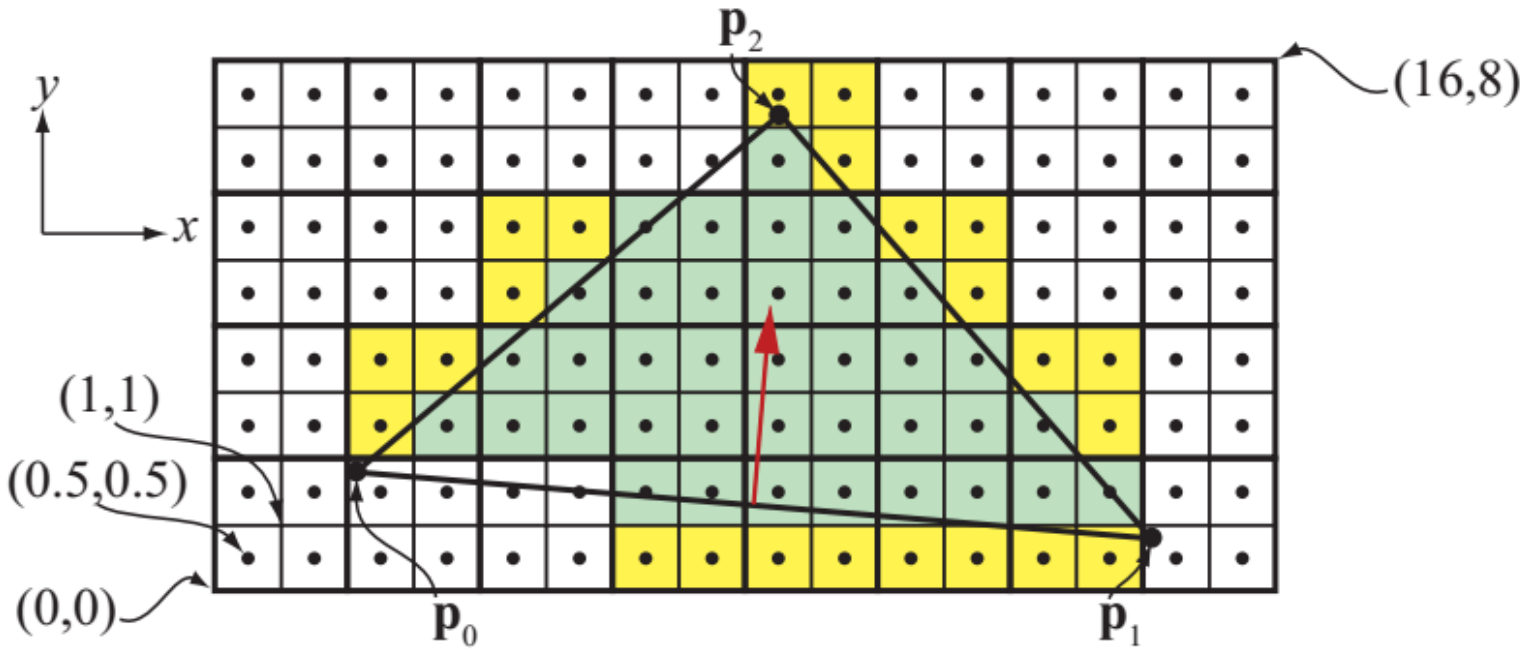
Triangle Rasterization



- Fragments grouped into quads for texturing and other operations
- Yellow fragments are “helper fragments”

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