

ECE 595 / CS 491 / CS 591  
**Real-Time Rendering &  
Graphics Hardware**

Pradeep Sen  
Advanced Graphics Lab

Class 2  
January 22, 2007

### Announcements

- Webpage is up :  
▪ <http://www.ece.unm.edu/course/ece595>
- Project will be handed out on Wednesday  
(deadline will be extended to Feb 7)

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### Last time

- Introduction to the class
- Began to cover in detail the real-time rendering pipeline
  - Application
  - Vertex transformation
    - I want you to be able to derive transformations for rotation, scale, shear, & translation

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### Today

- Continue with the rendering pipeline
  - Transforming normals
  - Projections
  - Clipping
  - Viewport Transformation
  - Rasterization

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### Transforming normals

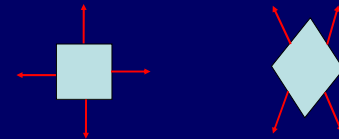
- If vertices are transformed by  $M$ , what should normals be transformed by?

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### Incorrect normal transformation

- Simply transform by  $M$ :  $Mn$



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### Correct normal transformation

- Derivation

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### What are normals used for?

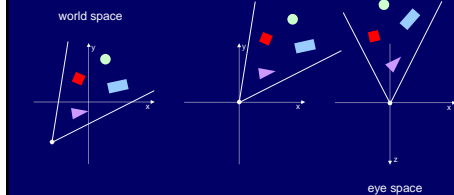


Lighting our world!

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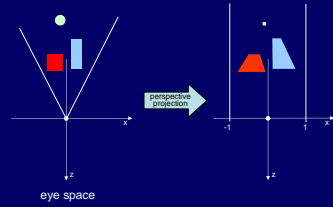
### So we have covered the view transformations...



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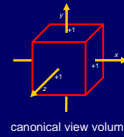
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## Perspective projection

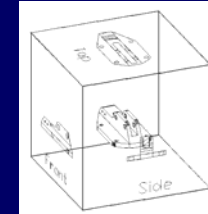


## Projection

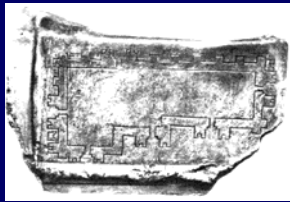
- Mapping a volume in eye space to the *canonical view volume*, defined by the axis-aligned cube with sides at  $\pm 1$



## Orthographic projection



## Orthographic projection



Map, Mesopotamia 2150BC

## Orthographic projection

- Derivation

## Perspective projection

- Orthographic projection did not depict the scene as perceived by an individual
- The Renaissance introduced a new way of thinking: the power of the individual
- Desire to represent the world as experienced by an individual, not an all-seeing god.
- Missing in much of the artwork that was not influenced by the Renaissance...

## Eastern art at the time of the Renaissance



Baburnama (1530)

## Development of perspective projection

- During the Renaissance, perspective projection came about as a way of representing the individual's view point

## Perspective projection



The Last Supper - Leonardo DaVinci (1495 - 1498)

### Perspective projection

- That's all good, but how do we use these in real-time rendering?
- Definition of the view frustum

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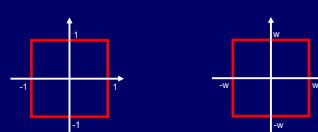
### Perspective projection

- Derivation of perspective projection matrices

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### Clipping

- Vertices have been projected to the canonical view volume



clipping can be done in either space

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### Clipping

- Inside view volume if:
  - $-w < x < w$
  - $-w < y < w$
  - $-w < z < w$  when  $0 < w$
  - $w < x < -w$
  - $w < y < -w$
  - $w < z < -w$  when  $w < 0$

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### Clipping

- Why do it early?
  - Saves a divide by w!

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### Clipping algorithm

- Naïve:
  - Do it while rasterizing!
  - Rasterize the entire triangle, reject the fragment if it is outside the window
  - This is essentially scissoring, which we will talk about later...
  - Works, but you waste a lot of time rasterizing fragments that don't end up in the screen

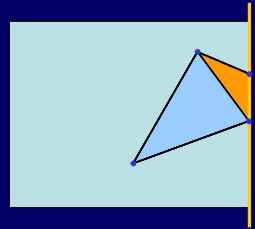
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### Clipping algorithm

- More sophisticated:
  - Variation of Sutherland-Hodgman polygon clipping algorithm
  - Clip triangle against each edge in turn to create new triangles.
  - Clip these against other edges...

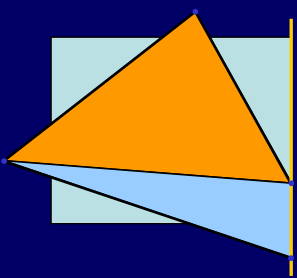
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### Triangle Clipping Algorithm



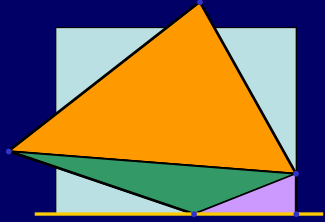
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### Triangle Clipping Algorithm

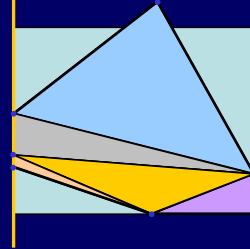


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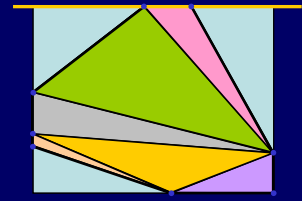
## Triangle Clipping Algorithm



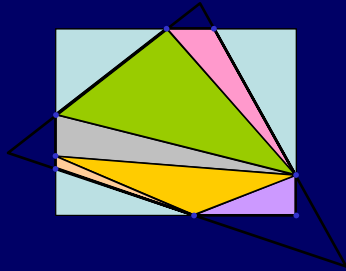
## Triangle Clipping Algorithm



## Triangle Clipping Algorithm



## Triangle Clipping Algorithm



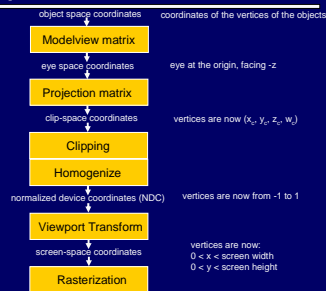
## Viewport transformation

- Take vertices that are -1 to 1 and map them to 0 to *screen width* and 0 to *screen height* for x and y respectively

## On to rasterization...

- The triangles are now ready for rasterization
- First let us review the different spaces we have looked at...

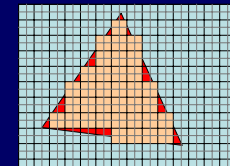
## Coordinate spaces



## Rasterization

- The goal of rasterization is to take the mathematical representation of a triangle, given by the vertices and determine which pixels should be lit on the screen

## Rasterization



## Rasterization

- There are two problems the rasterizer must solve:
  - Determine which pixels are “touched” by the triangle
  - Determine the value of interpolants at each of these vertices

## Bounding box algorithm

```
for (y = box.ymin; y < box.ymax; y++) {  
  for (x = box.xmin; x < box.xmax; x++) {  
    if (insideTriangle(x,y) {  
      generateFragment(x,y);  
    }  
  }  
}
```

## Reading

- End of chapter 3