CS-184: Computer Graphics

Lecture #9: Texture and Other Maps

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Today

- Maps
  - Texture Mapping
  - Bump Mapping
  - Displacement Mapping
  - Shadow Maps
  - Environment Maps
- Compositing

Surface Detail

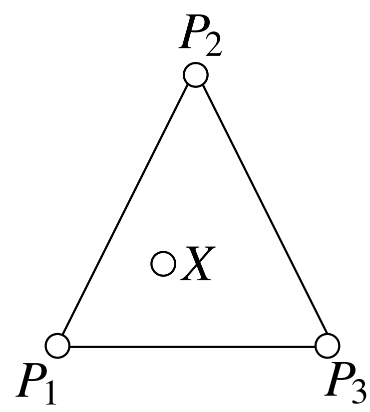
- The real world is complicated
- We can't explicitly model all the rich detail
- So, we come up with some "hacks"...

Texture Mapping

- The idea is to wrap a "texture" onto a surface
- To do this we need
  - A texture, usually just an image
  - A parameterization of the surface
  - A mapping from the surface parameterization to the texture coordinates

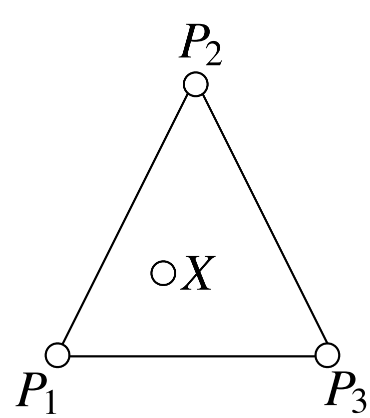
Barycentric Coordinates

- X can be expressed as
- $\alpha P_1 + \beta P_2 + \gamma P_3$
  where
  $\alpha + \beta + \gamma = 1$
  or, alternatively as
  $(1 - \alpha - \beta) P_1 + \alpha P_2 + \beta P_3$



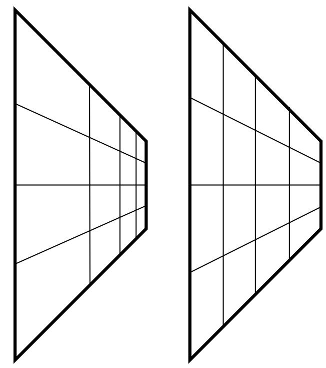
Barycentric Coordinates

- We can use barycentric coordinates to interpolate any quantity (color, texture coordinates, etc) stored at vertices, not just positions.



Bad Idea

- Simplest (and fastest) approach is to compute texture coordinates for polygon vertices and interpolate in screen space.
- This gives the image on the right.



7

Undoing Homogenization

- Let $P_i = (x_i, y_i, z_i, h_i)$ be the i^{th} point of some polygon, after projection, but before homogenization
- The homogenized point $S_i = P_i/h$ is the location of P_i on the screen.
- Let X be a point we wish to shade, we have its barycentric coordinates in screen space: $X = \sum_i b_i S_i$

8

Undoing Homogenization

- We know $S_i = P_i/h$
- We also know that there exist weights a_i, such that
- $X = (\sum_i a_i P_i)/(\sum_j a_j h_j)$
- Combining the above we have

$$\sum_i b_i S_i = X = (\sum_i a_i P_i)/(\sum_j a_j h_j)$$

$$\sum_i b_i (P_i/h_i) = (\sum_i a_i P_i)/(\sum_j a_j h_j)$$

9

Undoing Homogenization

$$b_i/h_i = a_i/(\sum_j a_j h_j) \qquad \forall i$$

$$b_i(\sum_j a_j h_j)/h_i = a_i \qquad \forall i$$

$$b_i(\sum_j a_j h_j)/h_i - a_i = 0 \qquad \forall i$$

- This is a linear system in a_i
- Unfortunately is is non-invertible, so...

10

Undoing Homogenization

- we add

$$\sum_i a_i = 1 \quad \sum_i b_i = 1$$

- now its solvable and the solution is:
-
$$a_1 = \frac{h_2 h_3 b_1}{h_2 h_3 b_1 + h_1 h_3 b_2 + h_1 h_2 b_3}$$
-
- similar formulas exist for a_2 and a_3

Bump/Displacement Mapping

- Texture mapping changes a surface's reflectance, but that can't give us a realistic orange
- For this we can use bump or displacement mapping

Bump Mapping

- The idea is to perturb the surface normals
- If the bump map is an array of vectors, just add the bump vectors to the surface normals
- If the bump map is an array of scalars (desired displacements along the normal direction), then the new normal is

  $n' = n + b_u(n \times P_v) - b_v(n \times P_u)$

13

Displacement Mapping

- Actually perturb the location of the surface, usually along the normal direction, by scalar values given in the displacement map
- This is usually done by moving the vertices of a polygonal mesh

14

Bumps vs. Displacements

- Bumps do not cast shadows or change the silhouette, they do produce specular effects
- Displacements actually change the geometry
- Displacement maps only look good on high resolution models
- Bottom line: bumps are cheaper, displacements look better

Shadow Maps

- Key insight: If we render the scene from the point of view of the light source, the lit surfaces will be visible and the unlit surfaces will by hidden
- We render the scene from the point of view of the light source
- Store the z values in a “depth shadow map”

Shadow Maps

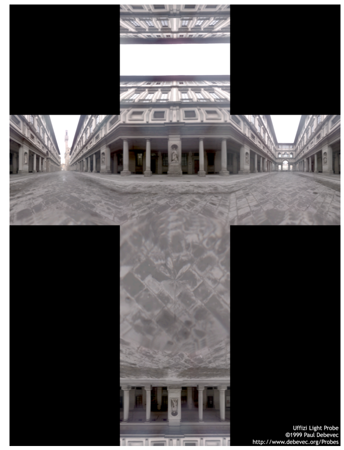
- For each polygon
  - Render the polygon from the camera
  - Render the polygon from the light
  - Compare the z value from the light with the one in the depth shadow map
    - If they match, the polygon is lit
    - Otherwise it is in shadow

Environment Maps

- Fake reflections
- Assumes the environment is very far away
- Depends on the location of the camera
- Usually stored in a spherical table or a cube map

Environment Maps

- Remove the reflective object from the scene
- Render the scene six times with the eye at the center of the removed object
- Render the scene, using reflection vectors to index the cube map



Compositing

- Sometimes scenes are too complex to render all at once
- Different parts of a scene often do not interact
- Need a way to render pieces separately and put them back together later

Alpha Channels

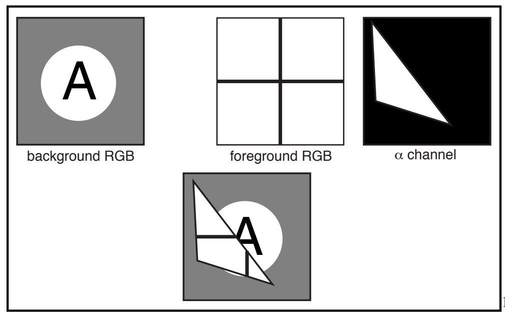
- Alpha channel stores opacity
- Primary operation is "over"
- Pre-multiplied alpha allows the use of the same rules for all 4 channels

Normal Alpha Channel

$$\mathbf{c} = \alpha \mathbf{c}_f + (1-\alpha)\mathbf{c}_b$$

Pre-multiplied Alpha Channel

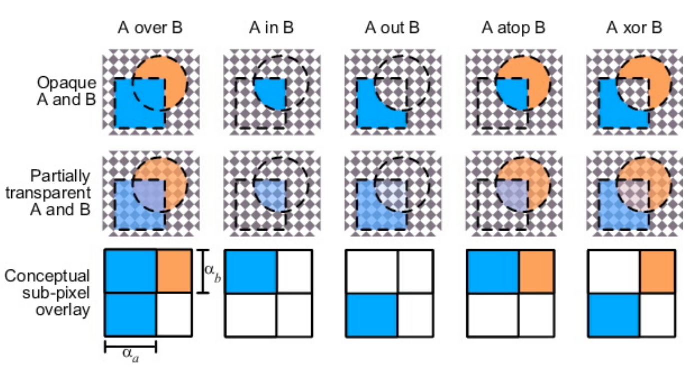
$$\mathbf{c} = \mathbf{c}_f + (1-\alpha)\mathbf{c}_b$$



Alpha Channel

- Other Operations

$$\mathbf{c} = F\mathbf{c}_f + G\mathbf{c}_g$$



Operation	F	G
Over	1	$1-\alpha_f$
Inside	α_g	0
Outside	$1-\alpha_g$	0
Atop	α_g	$1-\alpha_f$
Xor	$1-\alpha_g$	$1-\alpha_f$
Clear	0	0
Set	1	0

22

Suggested Reading

- Fundamentals of Computer Graphics by Pete Shirley
  - Chapters 10, 3.4

23