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Texture Mapping

CPSC 314

Texture Mapping

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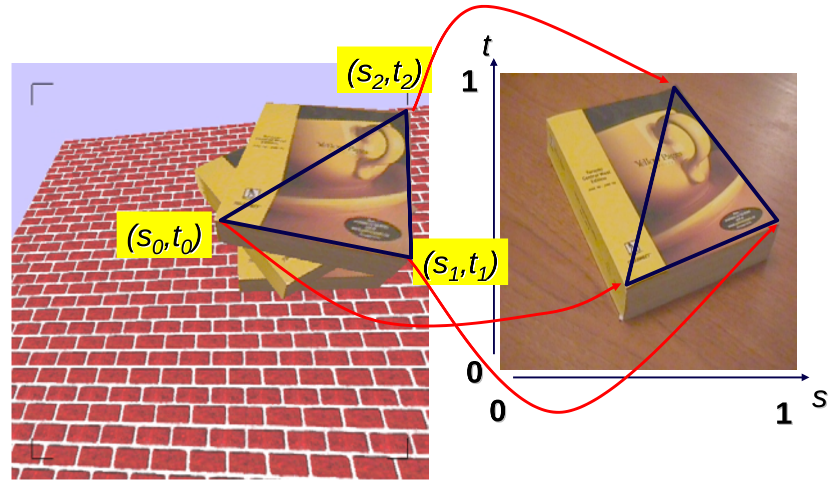

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- images attached to geometry
- “texels”: texture elements
- adds visual detail, substitute for geometric detail

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Texture Coordinates

- generation at vertices
  - *specified by programmer or artist*

    ```
    glTexCoord2f(s,t)
    glVertexf(x,y,z)
    ```
  - *generate as a function of vertex coords*

    ```
    glTexGeni(), glTexGenfv()
    ```
    $s = a*x + b*y + c*z + d*h$
- interpolated across triangle (like R,G,B,Z)

  (well, not quite...)

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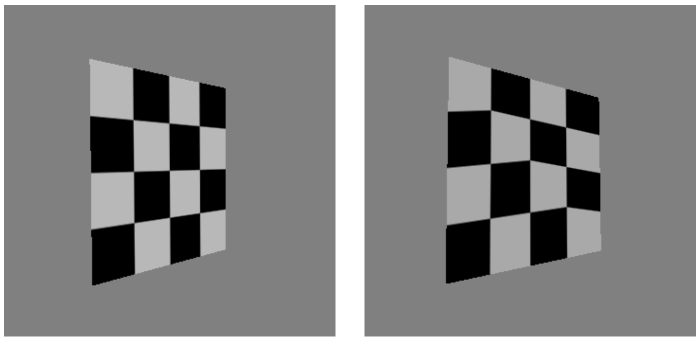
Texture Coordinate Interpolation

- perspective foreshortening problem
- also problematic for colour interpolation, etc.



Texture Coordinate Interpolation

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Perspective Correct Interpolation

- α, β, γ :
  Barycentric coordinates of a point $\mathbf{P}$ in a triangle
- s_0, s_1, s_2 : texture coordinates
- w_0, w_1, w_2 : homog coordinates

$$s = \frac{\alpha \cdot s_0 / w_0 + \beta \cdot s_1 / w_1 + \gamma \cdot s_2 / w_2}{\alpha / w_0 + \beta / w_1 + \gamma / w_2}$$

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Texture Coordinate Interpolation

$$P' = \begin{bmatrix} E & 0 & A & 0 \\ 0 & F & B & 0 \\ 0 & 0 & C & D \\ 0 & 0 & -1 & 0 \end{bmatrix} P$$

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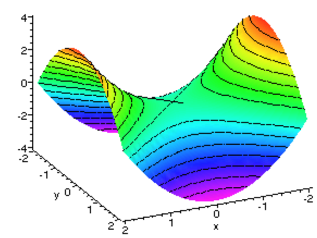
Textures of other dimensions

- 1D: represent isovalues
  - *e.g.: contour lines, temp, ...*

    ```
    glTexCoord1f(s)
    ```



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Textures of other dimensions

- 3D: solid textures
  - *e.g.: wood grain, medical data, ...*

    `glTexCoord3f(s,t,r)`
- 4D: 3D + time, projecting textures

    `glTexCoord3f(s,t,r,q)`

Texture Coordinate Transformations

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Motivation:

- Change scale, orientation of texture on an object

Approach:

- *texture matrix stack*
- 4x4 matrix stack
- transforms specified (or generated) tex coords

```
glMatrixMode( GL_TEXTURE );
glLoadIdentity();
…
```


Texture Coordinate Transformations

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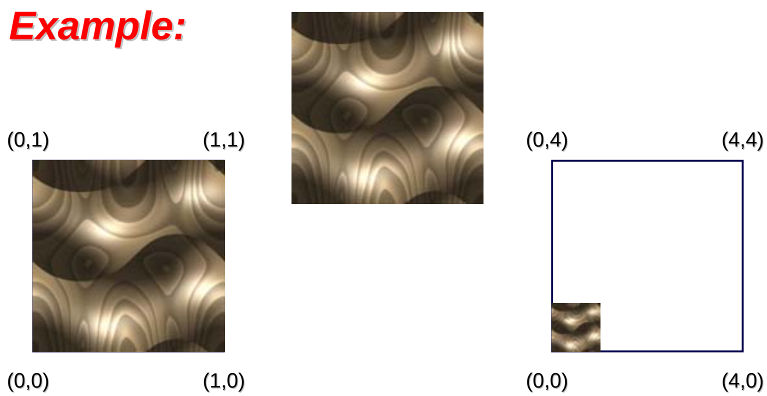
Example:



glScalef(4.0, 4.0, ?);

Texture Coordinate Transformations

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Projective Transformations

- can do projective transformations
- tex coord (s,t,r,q) : q $\longleftrightarrow$ h

Texture Coordinate Transformations

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Example:

Brabec and Heidrich

Texture Lookup

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Issue:

- What happens to fragments with s or t outside the interval $[0\ldots1]$?

Multiple choices:

- Take only fractional part of texture coordinates
  - *Cyclic repetition of texture to tile whole surface*

    glTexParameteri(…, GL_TEXTURE_WRAP_S, GL_REPEAT)
- Clamp every component to range $[0\ldots1]$
  - *Re-use color values from border of texture image*

    glTexParameteri(…, GL_TEXTURE_WRAP_S, GL_CLAMP)

Reconstruction

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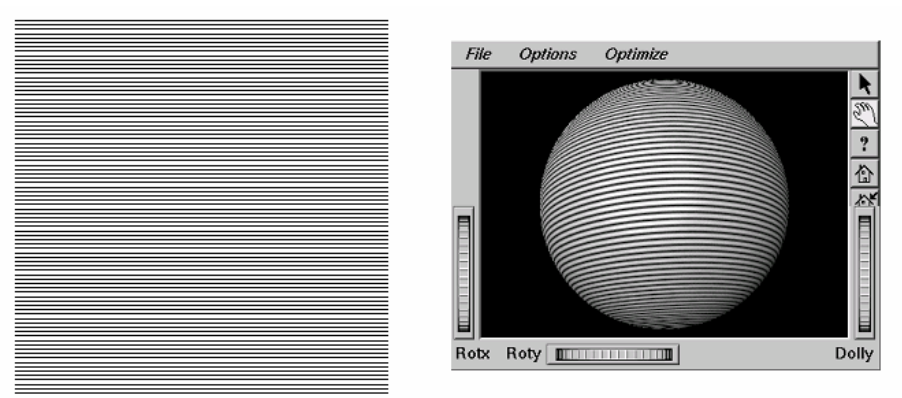

(image courtesy of Kiriakos Kutulakos, U Rochester)

Reconstruction

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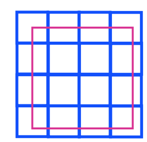
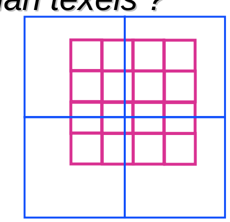
- How to deal with:
  - *pixels that are much larger than texels ? (apply filtering, “averaging”)*



  - *pixels that are much smaller than texels ?* (interpolate)



MIP-mapping

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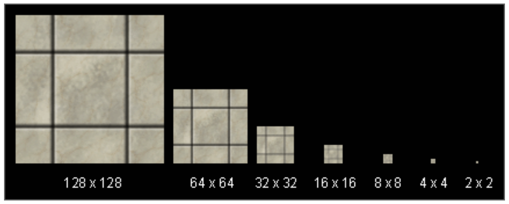
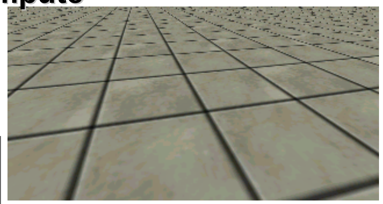
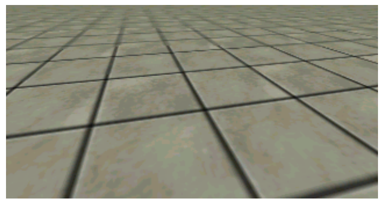
Use an “image pyramid” to precompute averaged versions of the texture





Without MIP-mapping



With MIP-mapping

MIP mapping

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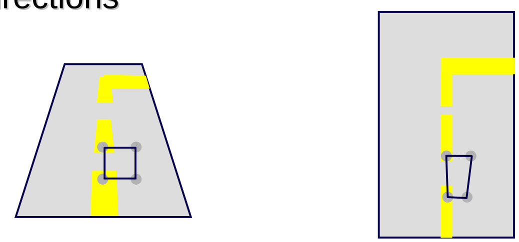
Problem:

- A MIP-map level selects the same minification factor for both the s and the t direction (isotropic filtering)
- In reality, perspective foreshortening (amongst other reasons) can cause different scaling factors for the two directions



MIP mapping

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Which resolution to choose:

- MIP-mapping: take resolution corresponding to the smaller of the sampling rates for s and t
  - *Avoids aliasing in one direction at cost of blurring in the other direction*
- Better: anisotropic texture filtering
  - *Also uses MIP-map hierarchy*
  - *Choose larger of sampling rates to select MIP-map level*
  - *Then use more samples for that level to avoid aliasing*
  - *Maximum anisotropy (ratio between s and t sampling rate) usually limited (e.g. 4 or 8)*