# Procedural Modeling

Last Time?

- Modern Graphics Hardware
- Cg Programming Language
- Gouraud Shading vs. Phong Normal Interpolation
- Bump, Displacement, & Environment Mapping
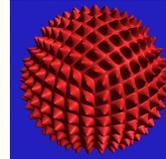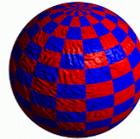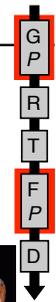
Final Project Progress Reports

- What do you plan to show for your progress report next week Thursday?

- Each teammate should make a post outlining their contributions thus far
- Post image(s), e.g., bloopers
- Post revised task list

Today

- Texture Mapping
- Common Texture Coordinate Mappings
- Solid Texture
- Procedural Textures
- Perlin Noise
- Procedural Modeling
- L-Systems

Texture Mapping
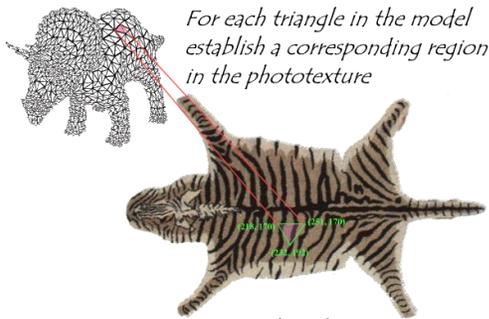
For each triangle in the model establish a corresponding region in the phototexture

During rasterization interpolate the coordinate indices into the texture map

Texture Mapping Difficulties

- Tedious to specify texture coordinates
- Acquiring textures is surprisingly difficult
  - Photographs have projective distortions
  - Variations in reflectance and illumination
  - Tiling problems
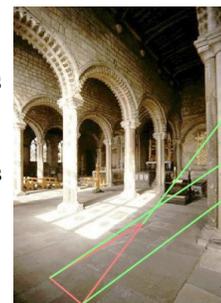
Can't do this!

You can get around this problem for planar surfaces if you specify 4 points...

Common Texture Coordinate Mappings

- Orthogonal
- Cylindrical
- Spherical
- Perspective Projection
- Texture Chart
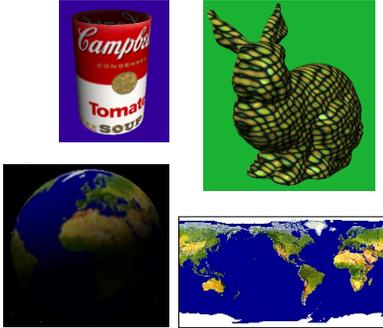
Projective Textures

- Use the texture like a slide projector
- No need to specify texture coordinates explicitly
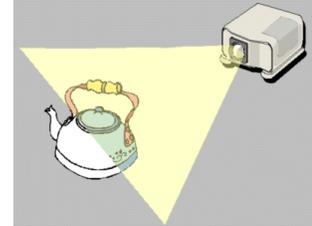
Projective Texture Example

- Modeling from photographs
- Using input photos as textures

Original photograph with marked edges   Recovered model   Model edges projected onto photograph   Synthetic rendering
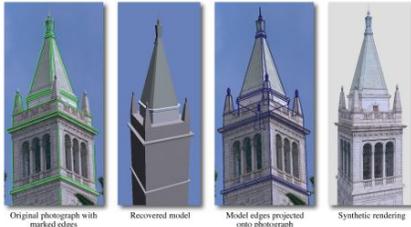
Figure from Debevec, Taylor & Malik
http://www.debevec.org/Research

Texture Chart

- Pack triangles into a single image
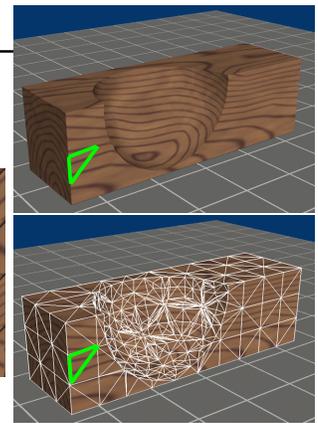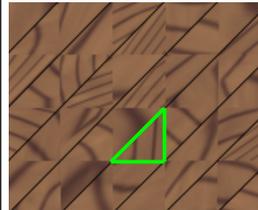
Questions?

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Texture Map vs. Solid Texture
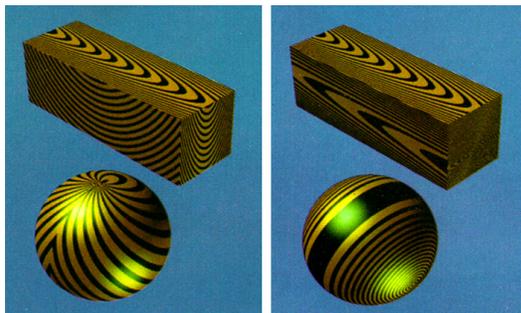
"Solid Texturing of Complex Surfaces",
Peachey, SIGGRAPH 1985

Procedural Textures

$f(x,y,z) \rightarrow$ color
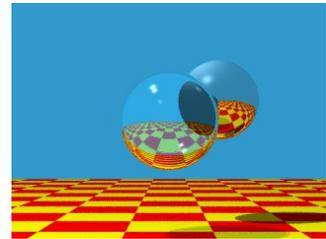
Image by Turner Whitted

Procedural Textures

- Advantages:
  - easy to implement in ray tracer
  - more compact than texture maps (especially for solid textures)
  - infinite resolution

- Disadvantages
  - non-intuitive
  - difficult to match existing texture
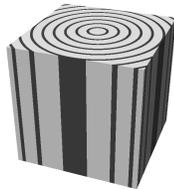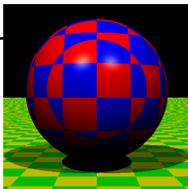
Readings for Today:

- Ken Perlin, "An Image Synthesizer", SIGGRAPH 1985 & "Improving Noise", SIGGRAPH 2002

Perlin Noise

- Properties:
  - Looks "random", but is deterministic (always returns the same answer for a specific coordinate)
  - Small memory footprint & fast to compute
  - Known amplitude & frequency
  - Smooth interpolation when zoomed in
- Can be combined/layered:
  - Add multiple noise functions w/ different frequencies and amplitudes
  - Simple arithmetic operations (thresholding, sine waves, etc.)
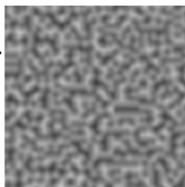
Cellular Textures
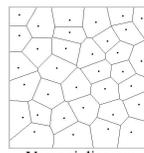
Voronoi diagram
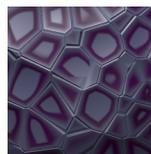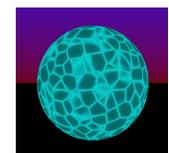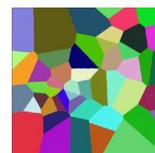
"A Cellular Texture Basis Function", Worley, SIGGRAPH 1996

www.worley.com
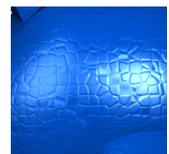
## Questions?
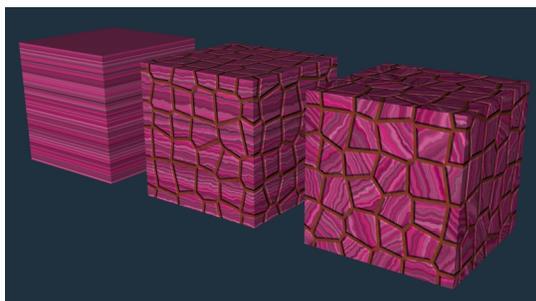
Image by Justin Legakis

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Procedural Displacement Mapping

Ken Musgrave
www.kenmusgrave.com

L-Systems

alphabet: {a,b}
initiator: a
production rules:
  a -> b
  b -> ba

generations:
  a
  b
  ba
  bab
  babba
  bababab
  babbababbabba
  babbababbabbababbabab
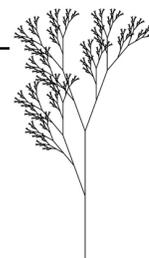
d
$n=7, \delta=20°$
X
$X \rightarrow F[+X]F[-X]+X$
$F \rightarrow FF$
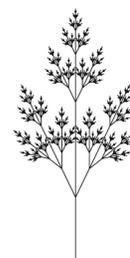
e
$n=7, \delta=25.7°$
X
$X \rightarrow F[+X][-X]FX$
$F \rightarrow FF$

Prusinkiewicz & Lindenmayer,
The Algorithmic Beauty of Plants, 1990
http://algorithmicbotany.org/

L-Systems
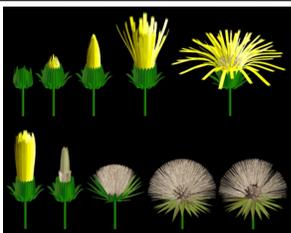
Animation of Plant Development
Prusinkiewicz et al.,
SIGGRAPH 1993

Prusinkiewicz & Lindenmayer,
The Algorithmic Beauty of Plants, 1990
http://algorithmicbotany.org/

Cellular Texturing for Architecture
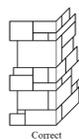
Correct   Incorrect
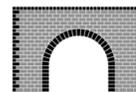
"Feature-Based Cellular Texturing for Architectural Models", Legakis, Dorsey, & Gortler, SIGGRAPH 2001
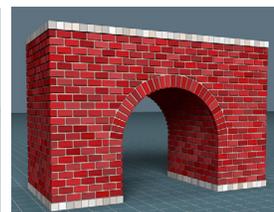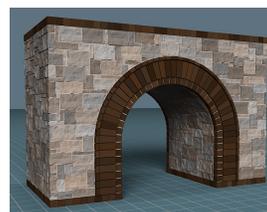
L-Systems for Cities

"Procedural Modeling of Cities",
Parish & Müller, SIGGRAPH 2001
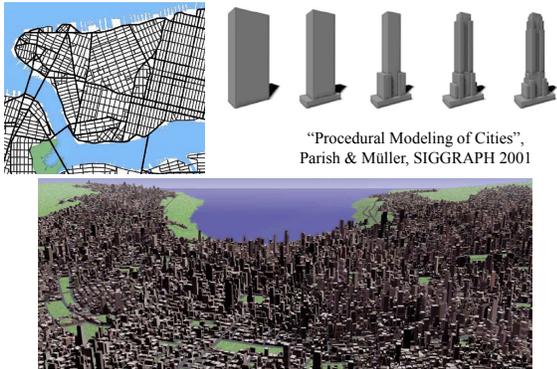
Procedural Modeling of Buildings

- "Procedural Modeling of Buildings", Mueller, Wonka, Haegler, Ulmer & Van Gool, SIGGRAPH 2006

Image-based Procedural Modeling of Facades

- Mueller, Zeng, Wonka, & Van Gool, SIGGRAPH 2007
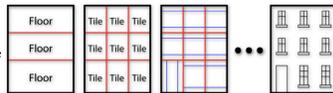
Input Photograph

Reconstructed 3D Geometry

Questions?
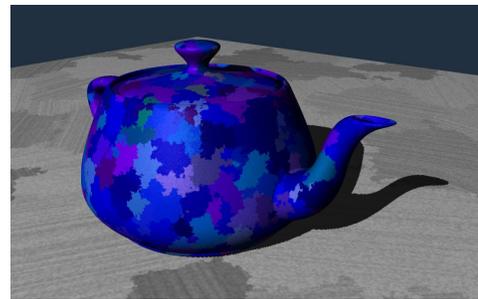
Image by Justin Legakis

Reading for Friday:

- "Artistic Tessellations by Growing Curves", Li & Mould, Non-Photorealistic Animation and Rendering (NPAR) 2011