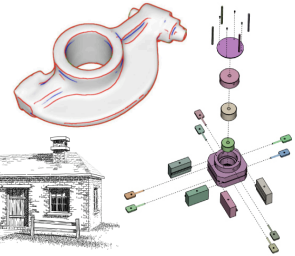
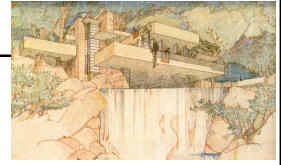


# Texture Synthesis

## Last Time?

- Architectural Rendering
- Reading for Today
- Line Drawing
- Pen & Ink / Hatching
- Technical Illustration
- Painterly Rendering



## Final Project Presentations

- Presenters:
  - Summarize prior work as necessary
  - Be technical: What were the challenges? How did you solve them?
  - Live demo / video / lots of images
  - Teams of 2: All should present & make it clear who did what
  - Practice! & time yourself!
- Rest of Class:
  - Attendance mandatory, start at 2pm sharp (please don't be late)
  - No laptops allowed during your classmates' presentations
  - Ask good questions (participation grade)
- Final Project Grade:
  - Report: 20 pts
  - Presentation: 10 pts (instructor: 5 pts, peer average: 5 pts)

## Final Presentation Schedule

Tues. April 21	Fri. April 24	Tues. April 28
1. Cody & David	1. Joseph & Atira	1. Yi Xiang
2. Jeff	2. Chris L. & Devin	2. Patrick
3. Josh & Jon Z.	3. Sean	3. Jon C.
4. Chris J. & Jarrett	4. Luke	4. Eric & Andrew
5. Jeremy	5. Abhishek & Taro	5. Justin & Mike "Z"
	6. Allan	6. Greg
		7. Corey

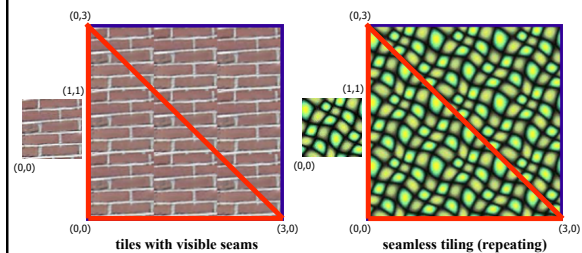
Total time (including setup & questions):  
14 min (individual), 24 min (team of 2)

## Today

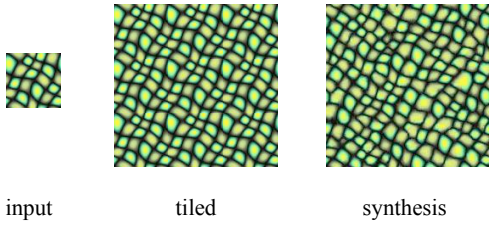
- Texture Tiling
- Texture Synthesis Challenge
- Markov Model
- Constrained Texture Synthesis
- Image Completion
- Wang Tiles for Texture Synthesis
- Volumetric Texture Synthesis

## Texture Tiling

- Specify a texture coordinate  $(u,v)$  at each vertex
- Canonical texture coordinates  $(0,0) \rightarrow (1,1)$



## Texture Synthesis Challenge



## Today

- Texture Tiling
- Texture Synthesis Challenge
- **Markov Model**
- Constrained Texture Synthesis
- Image Completion
- Wang Tiles for Texture Synthesis
- Volumetric Texture Synthesis

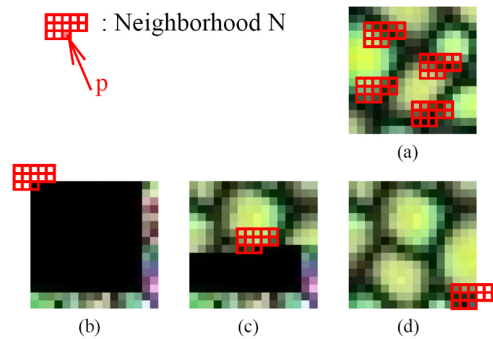
## Markov Random Field

- English words and sentences can be modeled as a Markov Random Field:

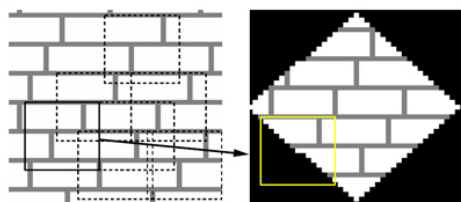
*"I spent an interesting evening recently with a grain of salt."*

## Template

"Fast Texture Synthesis using Tree-structured Vector Quantization", Wei & Levoy, SIGGRAPH 2000.



## Alternate Synthesis Order



"Texture Synthesis by Non-parametric Sampling",  
Efros & Leung, ICCV 1999

## Neighborhood Size

Image from Efros & Leung

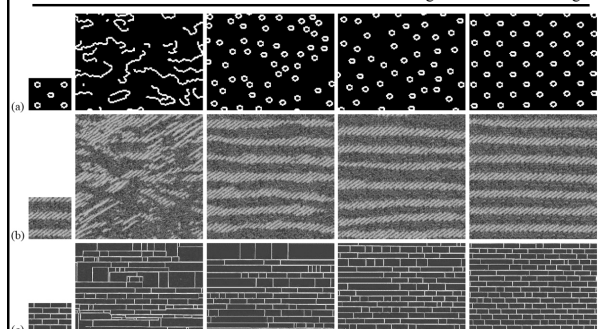
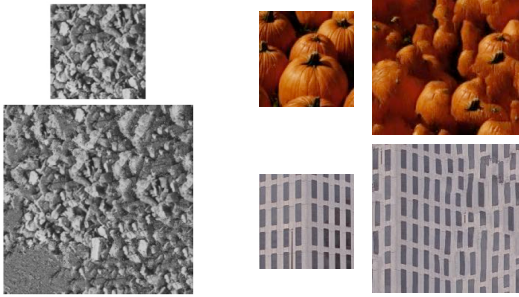


Figure 2. Results: given a sample image (left), the algorithm synthesized four new images with neighborhood windows of width 5, 11, 15, and 23 pixels respectively. Notice how perceptually intuitively the window size corresponds to the degree of randomness in the resulting textures. Input images are: (a) synthetic rings, (b) Brodatz texture D11, (c) brick wall.

## Failure Examples



from Efros & Leung



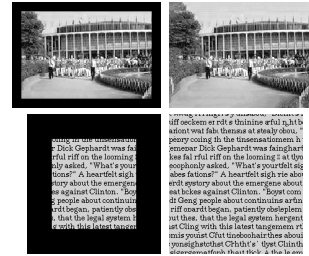
from Wei & Levoy

## Questions?

## Today

- Texture Tiling
- Texture Synthesis Challenge
- Markov Model
- **Constrained Texture Synthesis**
- **Image Completion**
- Wang Tiles for Texture Synthesis
- Volumetric Texture Synthesis

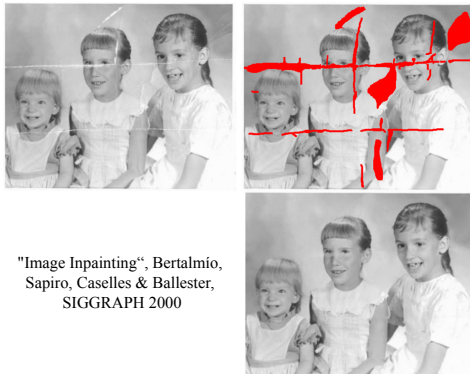
## Constrained Texture Synthesis



Examples from Efros & Leung

<http://graphics.cs.cmu.edu/people/efros/research/EfrosLeung.html>

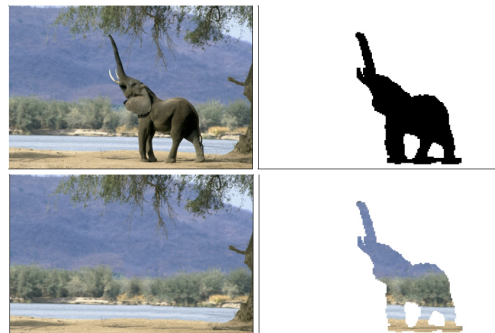
## Image Inpainting



"Image Inpainting", Bertalmio, Sapiro, Caselles & Ballester, SIGGRAPH 2000

## Image Completion

"Fragment-based image completion",  
Drori, Cohen-Or, Yeshurun,  
SIGGRAPH 2003



## Image Completion

"Fragment-based image completion",  
Drori, Cohen-Or, Yeshurun,  
SIGGRAPH 2003

(a) (b) (c)  
(d) (e) (f)

## Reading For Today:

Unfiltered source (A) Filtered source (A')  
Unfiltered (B) Filtered (B')

"Image Analogies", Hertzmann et al., SIGGRAPH 2001

## Today

- Texture Tiling
- Texture Synthesis Challenge
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## Wang Tiles

Align tiles to match edge color to create non-periodic tilings

"Wang Tiles for Image and Texture Generation",  
Cohen, Shade, Hiller, Deussen, SIGGRAPH 2003

## Wang Tile Texture Synthesis

- As a precomputation, fill the tiles with texture
- Then create infinite amounts of non-periodic texture!

Input texture sample Automatically generated set of Wang tiles Synthesized textures using Wang tiling

"Wang Tiles for Image and Texture Generation",  
Cohen, Shade, Hiller, Deussen, SIGGRAPH 2003

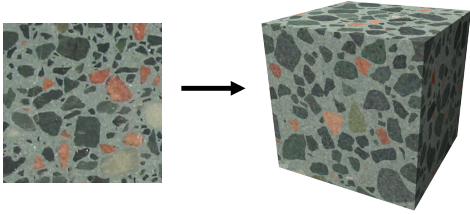
## Today

- Texture Tiling
- Texture Synthesis Challenge
- Markov Model
- Constrained Texture Synthesis
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## Objective

"Stereological Techniques for Solid Textures"  
Jagnow, Dorsey, & Rushmeier, SIGGRAPH 2004

Given a 2D slice through an aggregate material,  
create a 3D volume with a comparable appearance.



Slide from Rob Jagnow

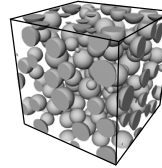
## Recovering Sphere Distributions



$N_A$  = Profile density  
(number of circles per unit area)

$N_V$  = Particle density  
(number of spheres per unit volume)

$\bar{H}$  = Mean caliper particle diameter

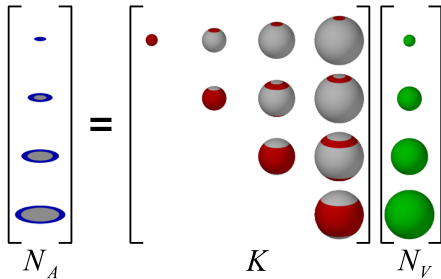


The fundamental relationship  
of stereology:

$$N_A = \bar{H}N_V$$

Slide from Rob Jagnow

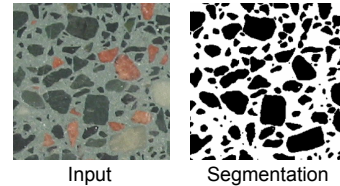
## Recovering Sphere Distributions



Slide from Rob Jagnow

## Profile Statistics

Segment input image to obtain profile densities  $N_A$ .



Input

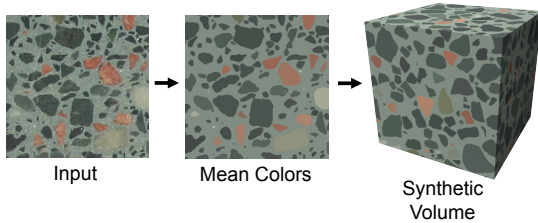
Segmentation

Bin profiles according to their area,  $\sqrt{A/A_{\max}}$

Slide from Rob Jagnow

## Recovering Color

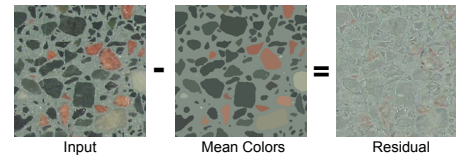
Select mean particle colors from  
segmented regions in the input image



Slide from Rob Jagnow

## Recovering Noise

How can we replicate the noisy appearance of the input?



Input

Mean Colors

Residual

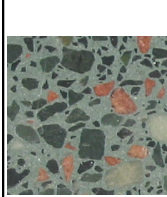
The noise residual is less  
structured and responds well to  
Heeger & Bergen's method



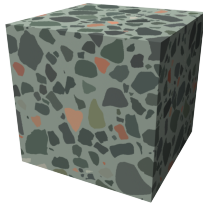
Synthesized Residual

Slide from Rob Jagnow

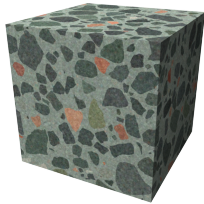
## Putting It All Together



Input



Synthetic volume  
without noise



Synthetic volume  
with noise

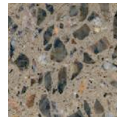
Slide from Rob Jagnow

## Results

Input



Result



Slide from Rob Jagnow