Texture Synthesis

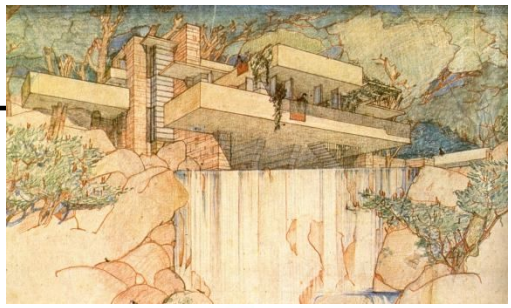
Eurythmy, Amkraut & Girard, 1989

Carlton Draught: Big Ad, 2006

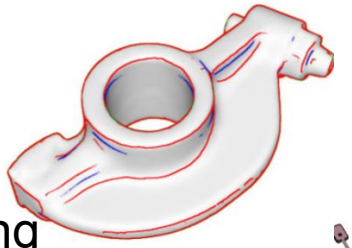
Uses Weta Digital's MASSIVE - first significant use in Lord of the Rings movies

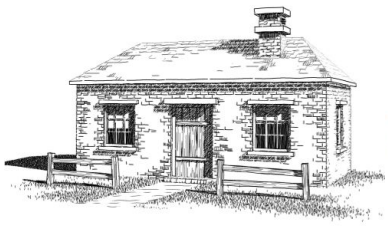
Finding Nemo, Fish School, 2009

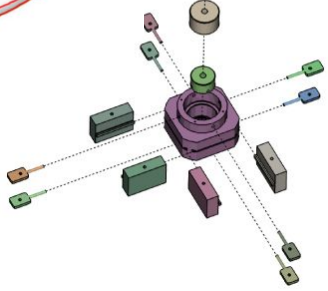
Last Time?



- Non-Photorealistic Rendering
  - Line Drawing
  - Pen & Ink / Hatching
  - Technical Illustration
  - Painterly Rendering
- Architectural Rendering







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Painterly Rendering

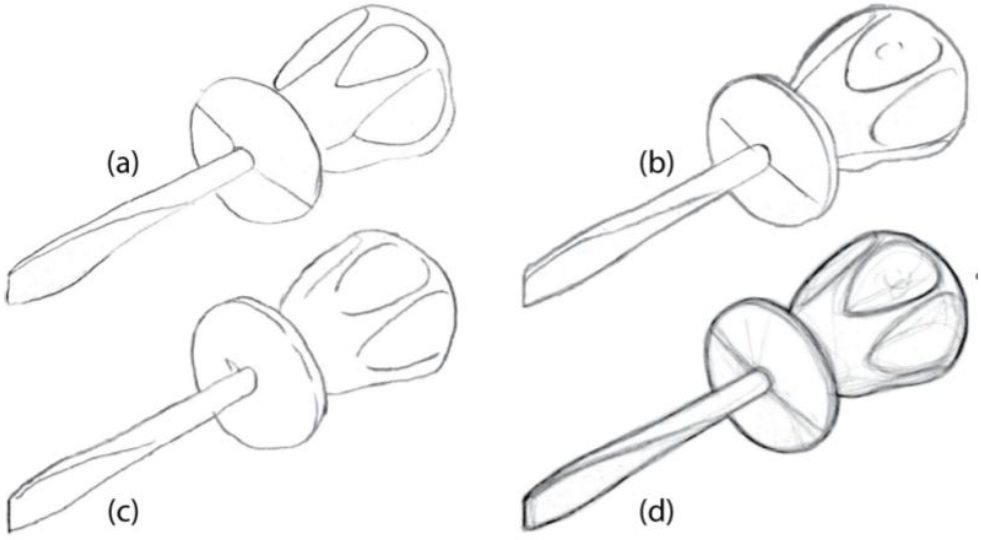
Painterly rendering with curved brush strokes of multiple sizes
Hertzmann SIGGRAPH 1998

Example-Based Brushes for Coherent Stylized Renderings

Zheng, Milliez, Gross, and Sumner, NPAR 2017

Figure 1: These 3D paintings are rendered in screen space using our method with calligraphy and watercolor styles. The paint stroke rendering is temporally coherent as the characters and camera are animated.

Where Do People Draw Lines?



Cole, Golovinskiy, Limpaecher, Stoddart Barros, Finkelstein, Funkhouser, & Rusinkiewicz, SIGGRAPH 2008

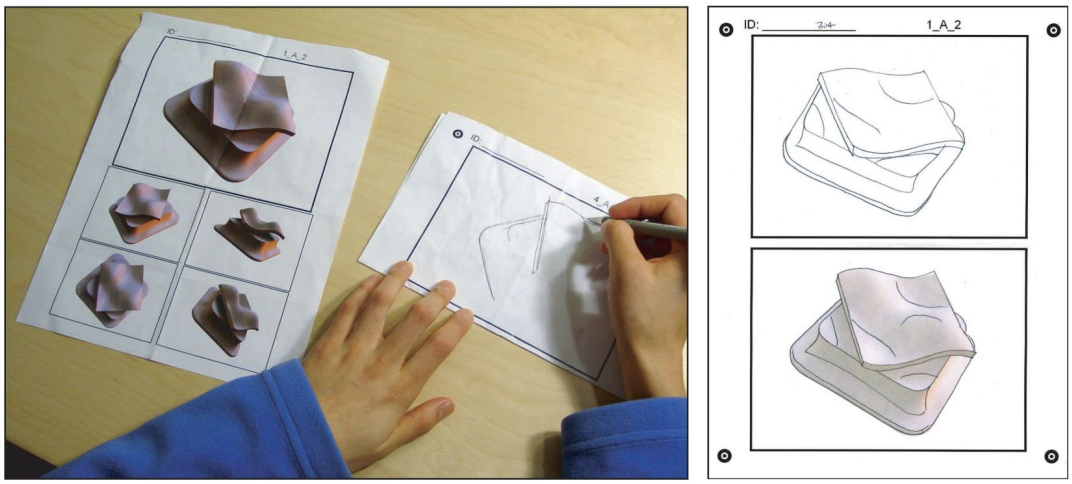
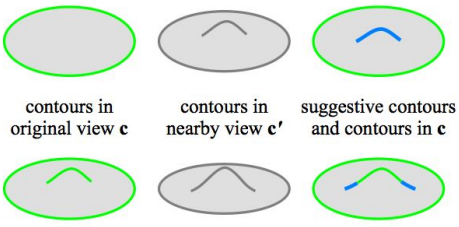


Figure 3: *Making a drawing.* With the drawing page folded in half, the artist makes a free-hand drawing while refering to the prompt page (left). The completed drawing page (right) contains a free-hand drawing and a registered drawing.

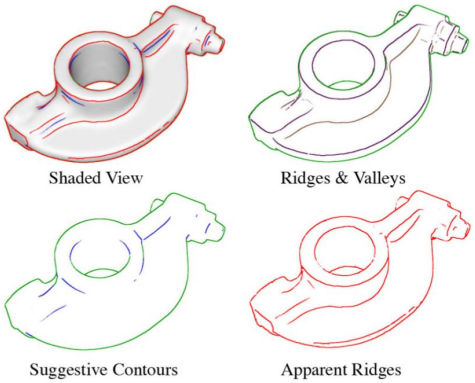
Cole, Golovinskiy, Limpaecher, Stoddart Barros, Finkelstein, Funkhouser, & Rusinkiewicz, SIGGRAPH 2008

Types of Edges in Line Drawings

- Silhouettes/Contours: where normal is perpendicular to the view direction
- Suggestive Contour: inflection points of the surface normal
- Ridges & Valleys: extremum of curvature
- Apparent Ridges: based on *view dependent* curvature



Suggestive Contours for Conveying Shape, DeCarlo et al., SIGGRAPH 2003



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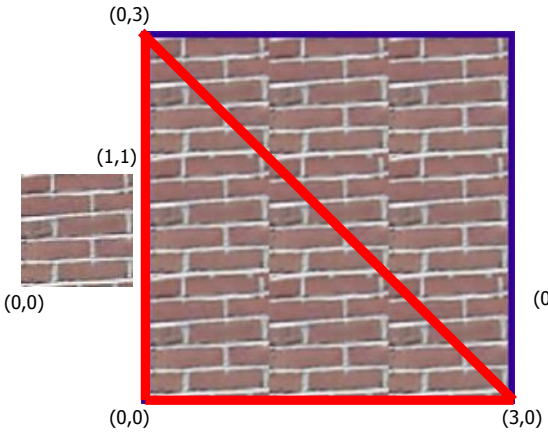
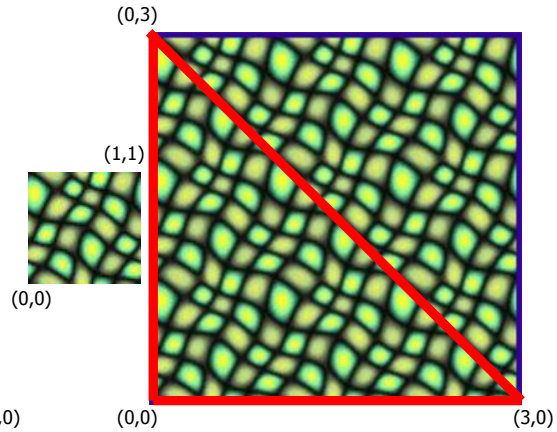
Texture Tiling

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

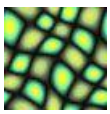


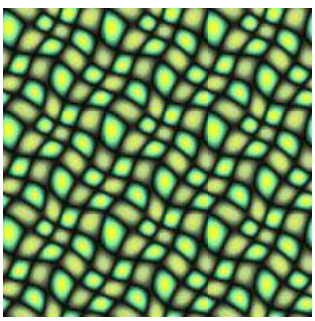
tiles with visible seams

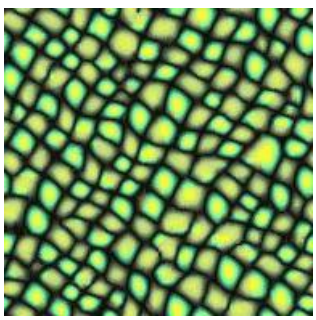


seamless tiling (repeating)

Texture Synthesis Challenge



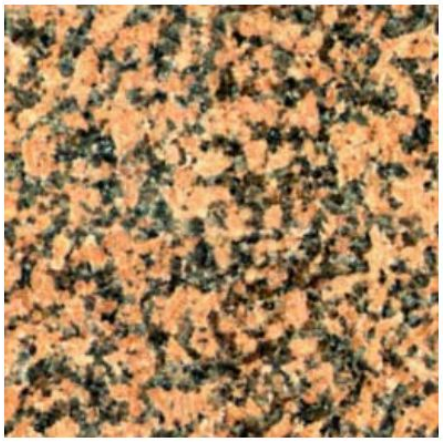




input tiled synthesis

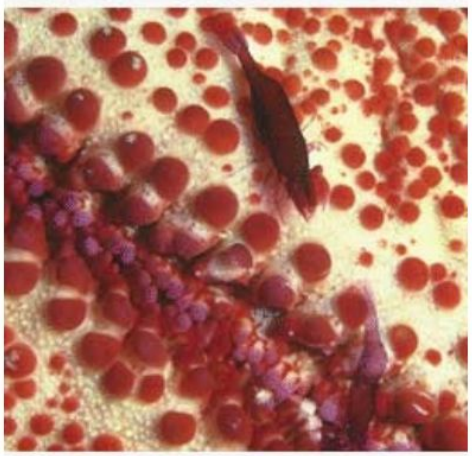
“Pyramid-Based Texture Analysis/Synthesis”, Heeger & Bergen, SIGGRAPH 1995

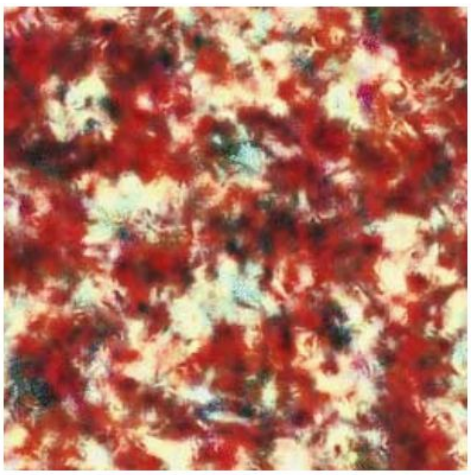
- Motivated by human texture perception
- Focused on stochastic textures
  (as opposed to deterministic/periodic textures)



“Pyramid-Based Texture Analysis/Synthesis”, Heeger & Bergen, SIGGRAPH 1995

- Focuses on matching the input histogram at different resolutions (frequencies)
- Failure example: *but is this really a “texture”?*





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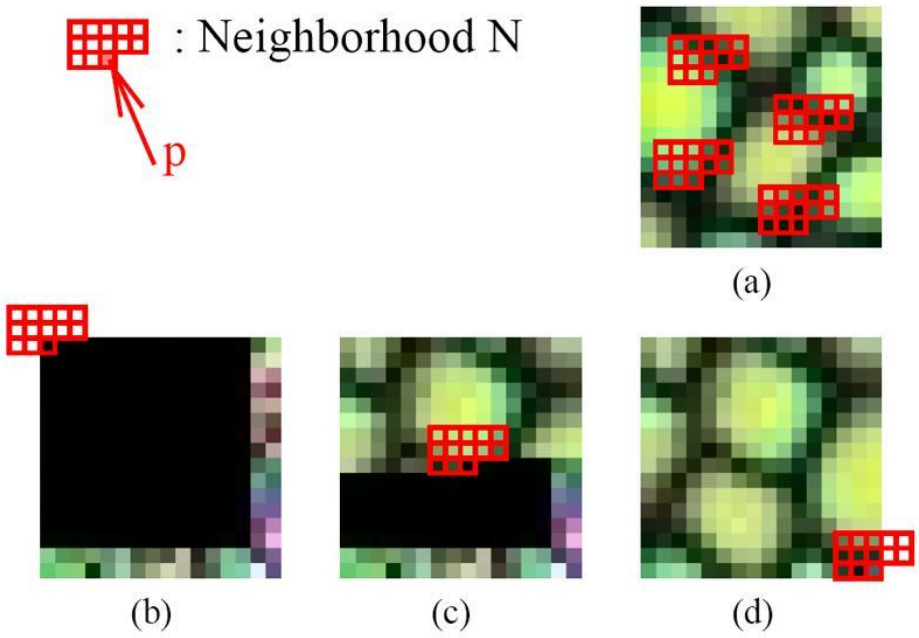
Markov Random Field

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

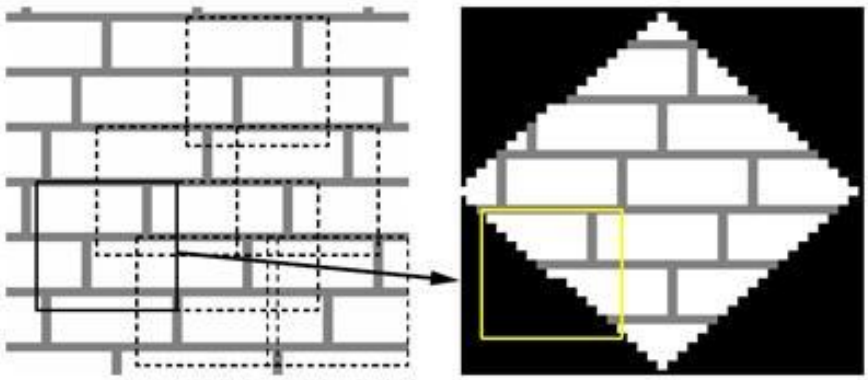
"I spent an interesting evening recently with a grain of salt."

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

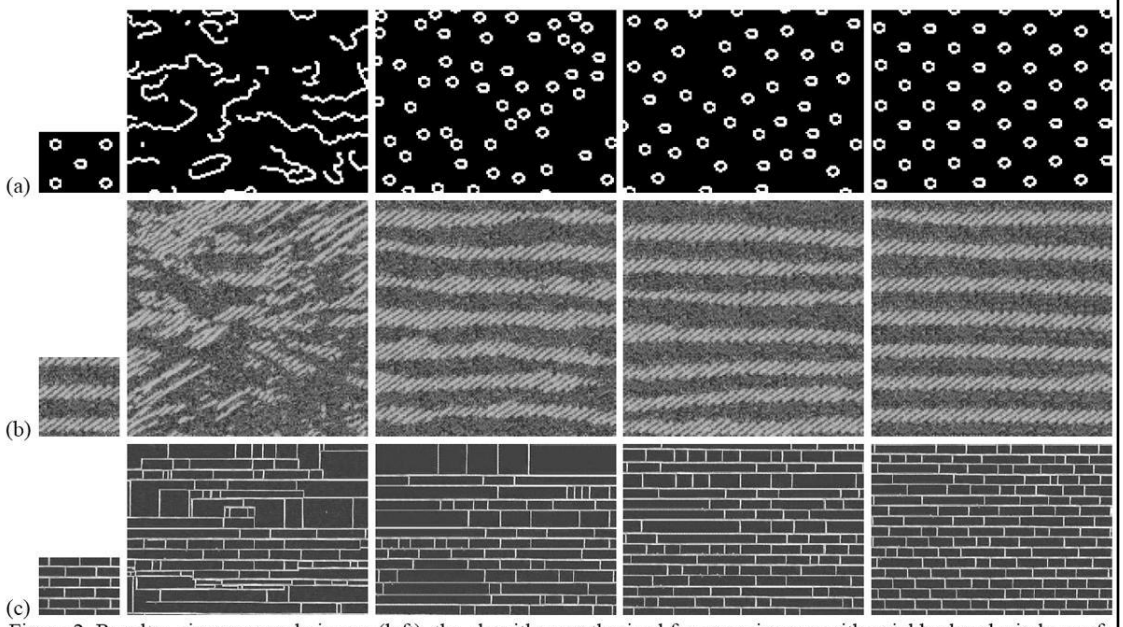
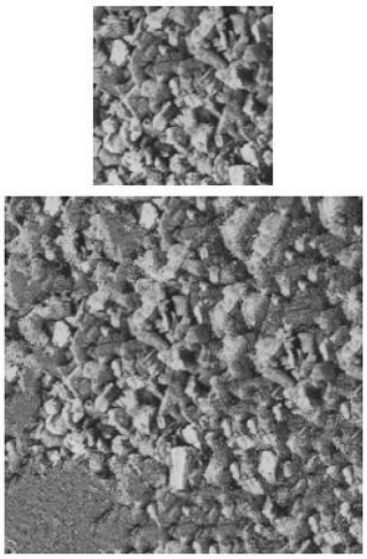


Figure 2. Results: given a sample image (left), the algorithm synthesized four new images with neighborhood windows of width 5, 11, 15, and 23 pixels respectively. Notice how perceptually intuitively the window size corresponds to the degree of randomness in the resulting textures. Input images are: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

Failure Examples



from Efros & Leung

from Wei & Levoy

Questions?

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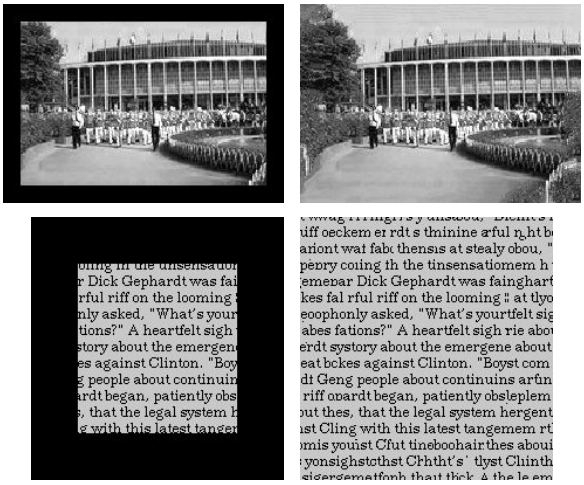
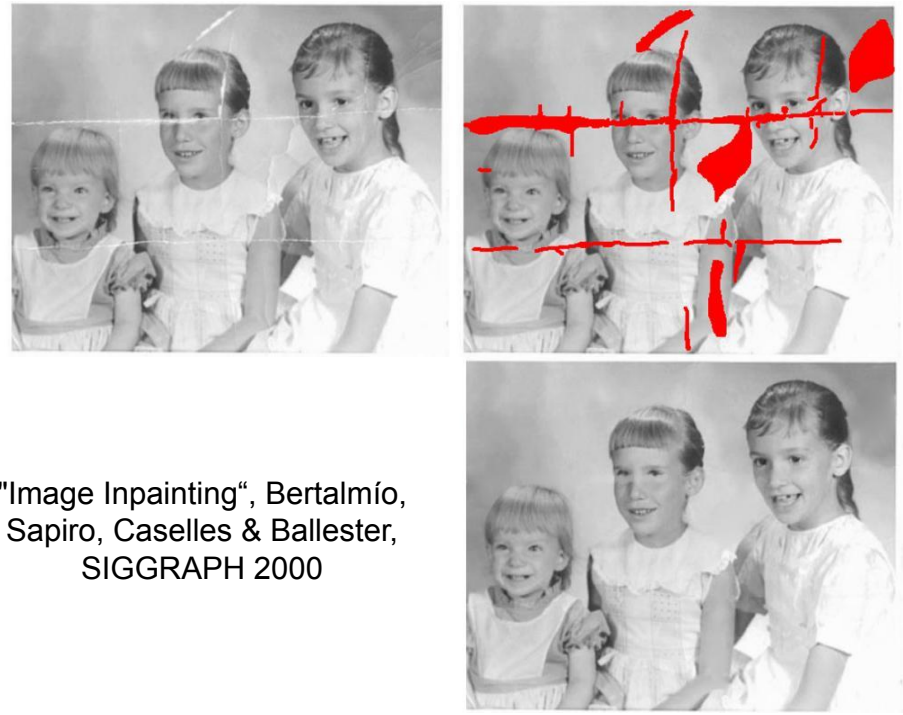
Constrained Texture Synthesis



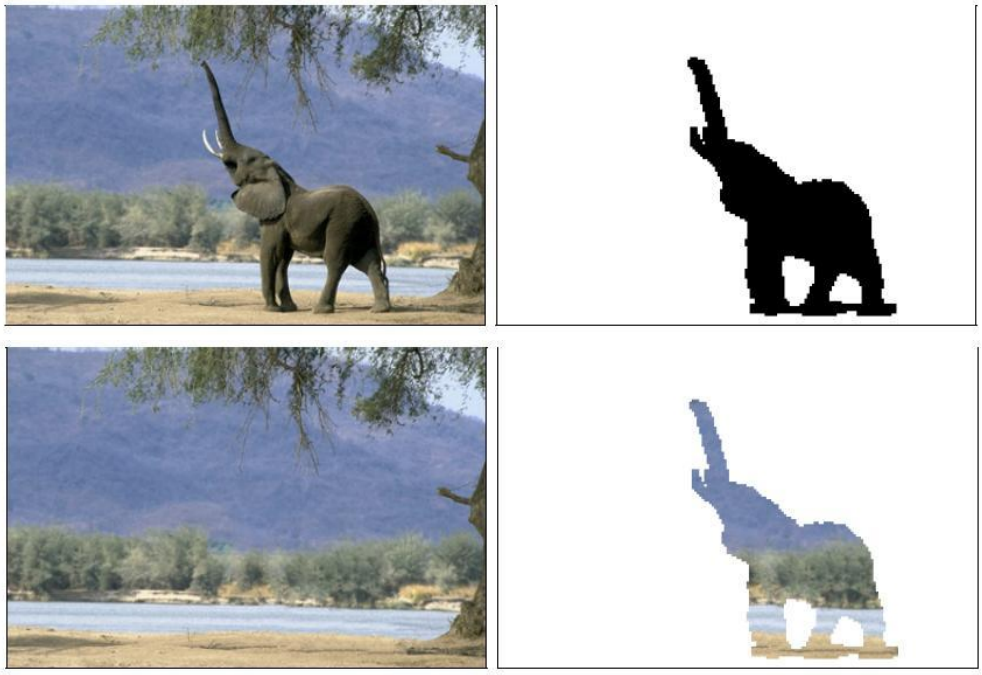
Examples from Efros & Leung
http://graphics.cs.cmu.edu/people/efros/research/EfrosLeung.html

Image Inpainting

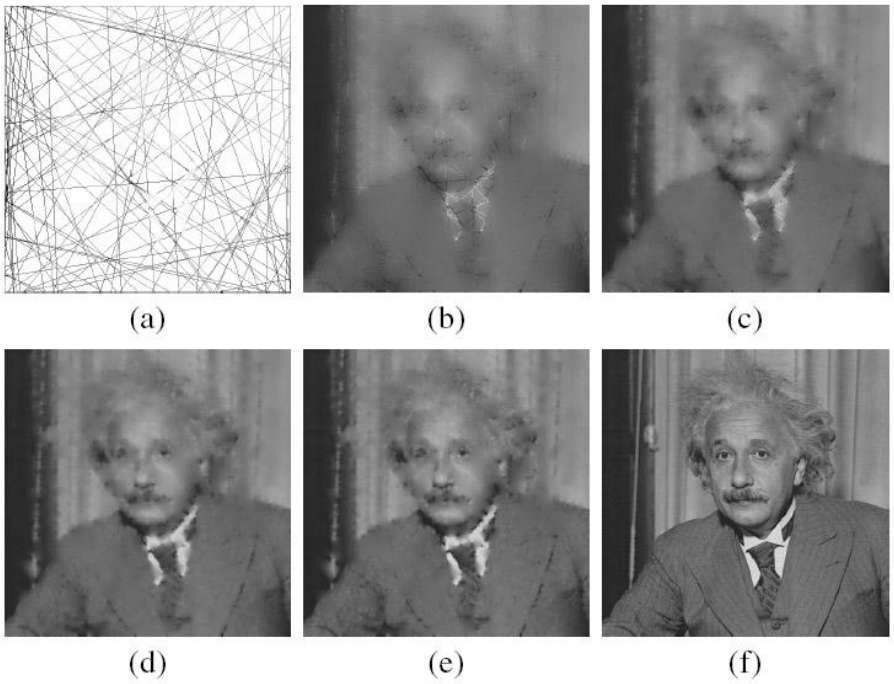


"Image Inpainting“, Bertalmío, Sapiro, Caselles & Ballester, SIGGRAPH 2000

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

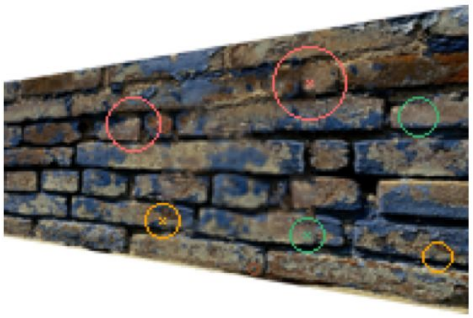


“Fragment-based image completion”,
Drori, Cohen-Or, Yeshurun, SIGGRAPH 2003

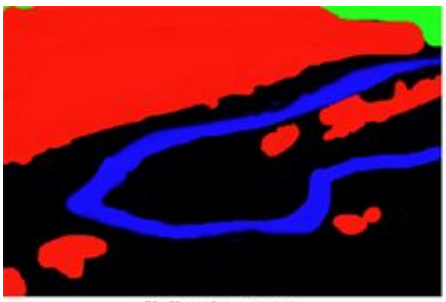


“Fragment-based image completion”, Drori, Cohen-Or, Yeshurun, SIGGRAPH 2003

- Coarse to fine completion
- Confidence & traversal order
- Search for best match over different scales, rotations, & resolutions (texture frequency)
- Compositing fragments

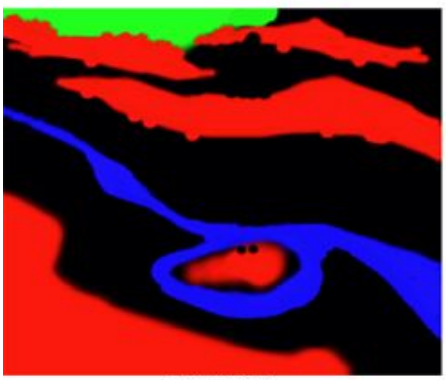


"Image Analogies", Hertzmann et al., *SIGGRAPH 2001*



Unfiltered source (A)

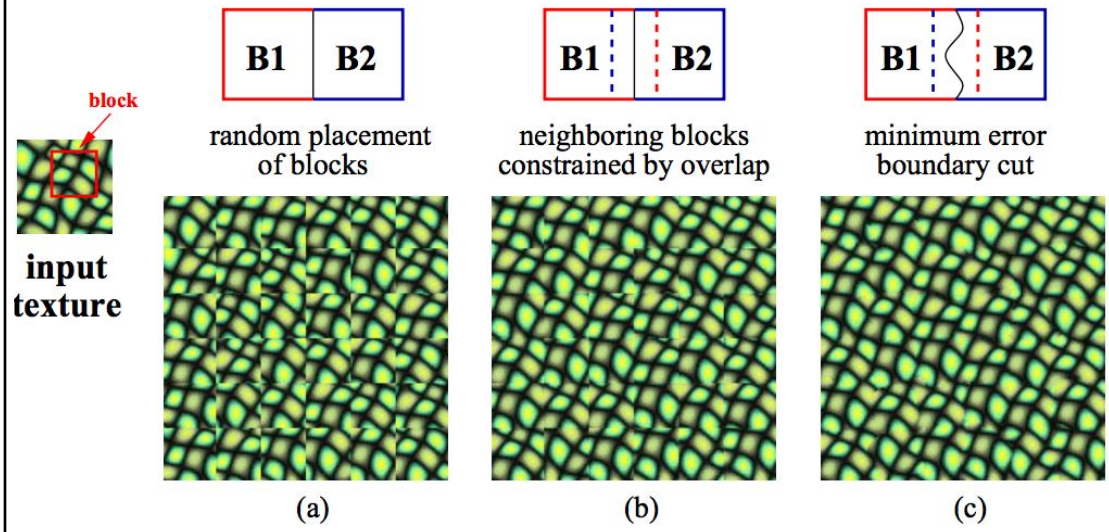
Filtered source (A')



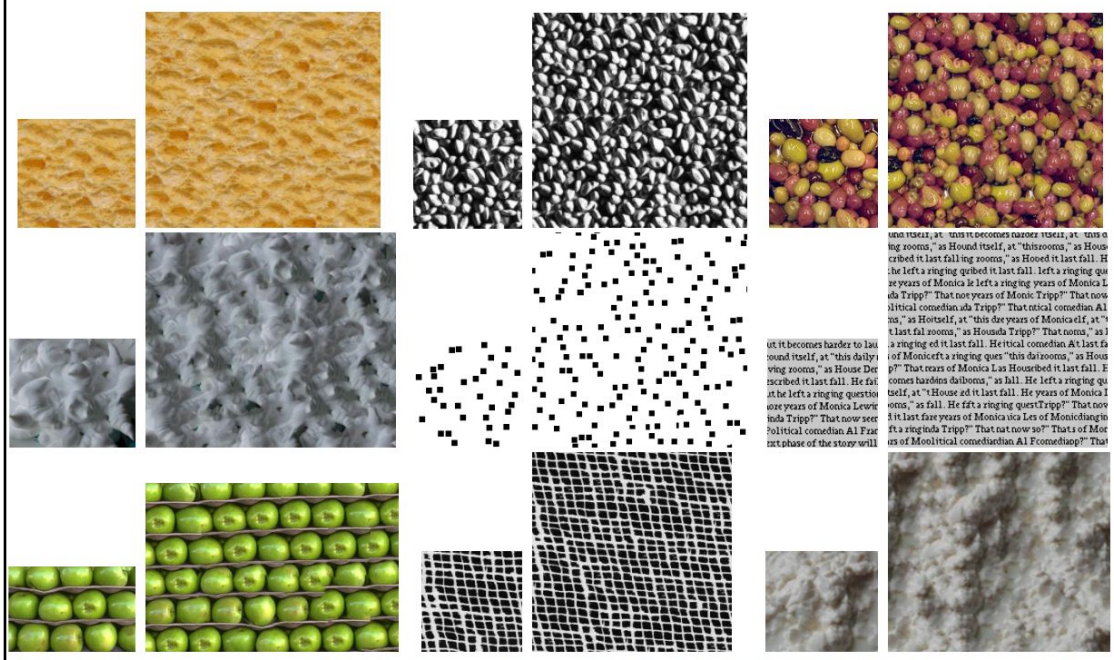
Unfiltered (B)

Filtered (B')

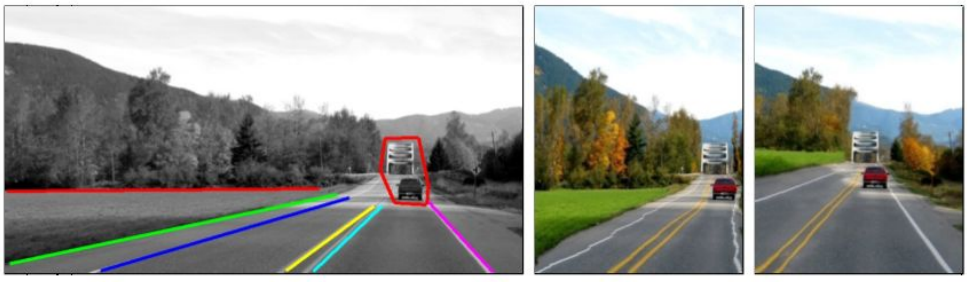
“Image Quilting for Texture Synthesis and Transfer”, Efros & Freeman, SIGGRAPH 2001



“Image Quilting for Texture Synthesis and Transfer”, Efros & Freeman, SIGGRAPH 2001



"PatchMatch: A Randomized Correspondence Algorithm for Structural Image Editing", Barnes, Shechtman, Finkelstein, & Goldman, SIGGRAPH 2009



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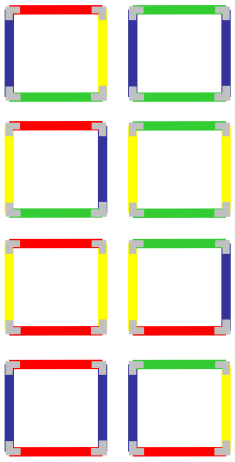
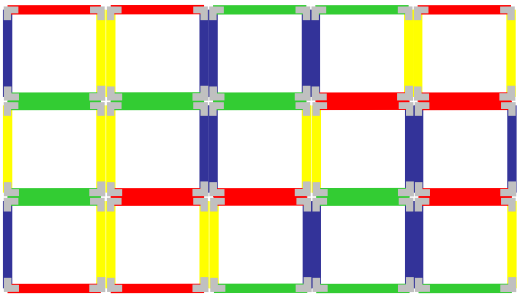
Wang Tiles





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

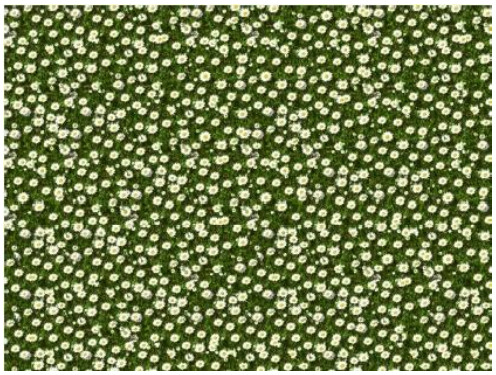
"Wang Tiles for Image and Texture Generation",
Cohen, Shade, Hiller, Deussen, SIGGRAPH 2003

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

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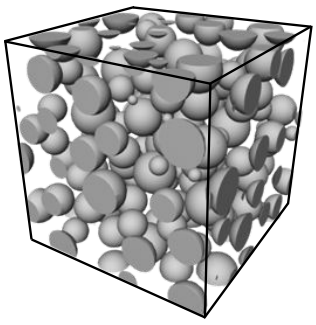
Recovering Sphere Distributions



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

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

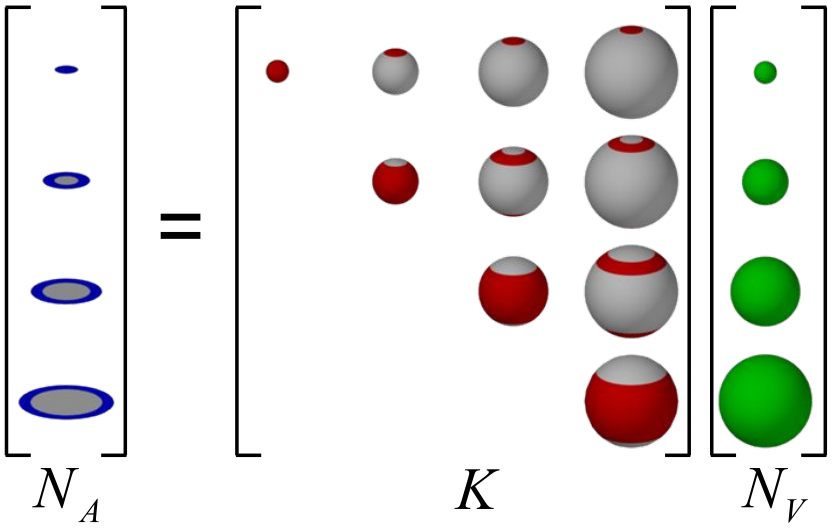
$\overline{H}$ = Mean caliper particle diameter

The fundamental relationship of stereology:

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

Slide from Rob Jagnow

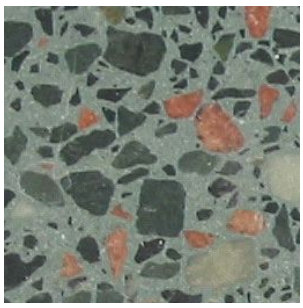
Recovering Sphere Distributions



Slide from Rob Jagnow

Profile Statistics

Segment input image to obtain profile densities N_A.



Input

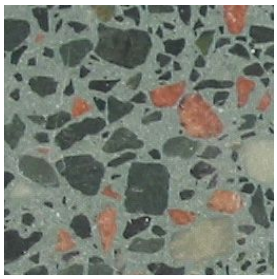
Segmentation

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



Input

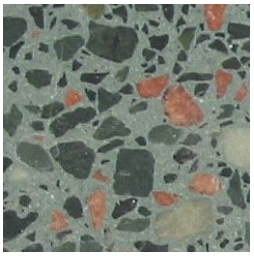
Mean Colors

Synthetic Volume

Slide from Rob Jagnow

Recovering Noise

How can we replicate the noisy appearance of the input?

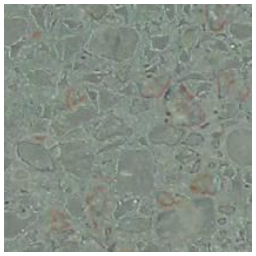


Input

-

Mean Colors

=



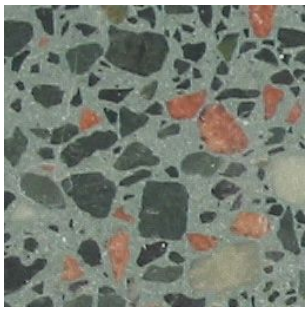
Residual

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

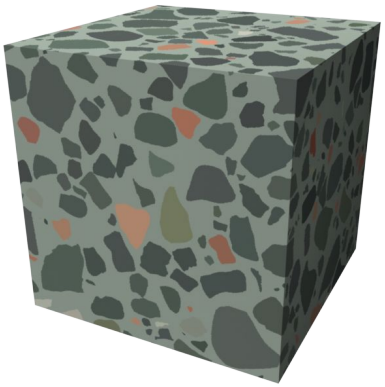
Synthesized Residual

Slide from Rob Jagnow

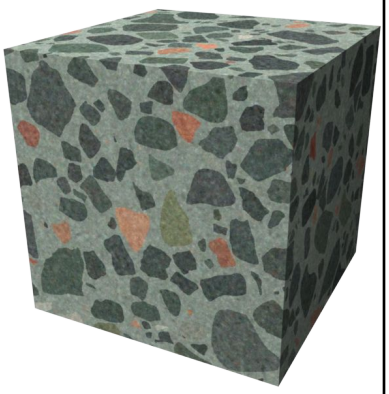
Putting It All Together



Input



Synthetic volume
without noise



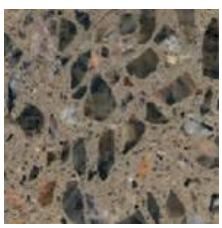
Synthetic volume
with noise

Slide from Rob Jagnow

Results

Input

Result



Slide from Rob Jagnow

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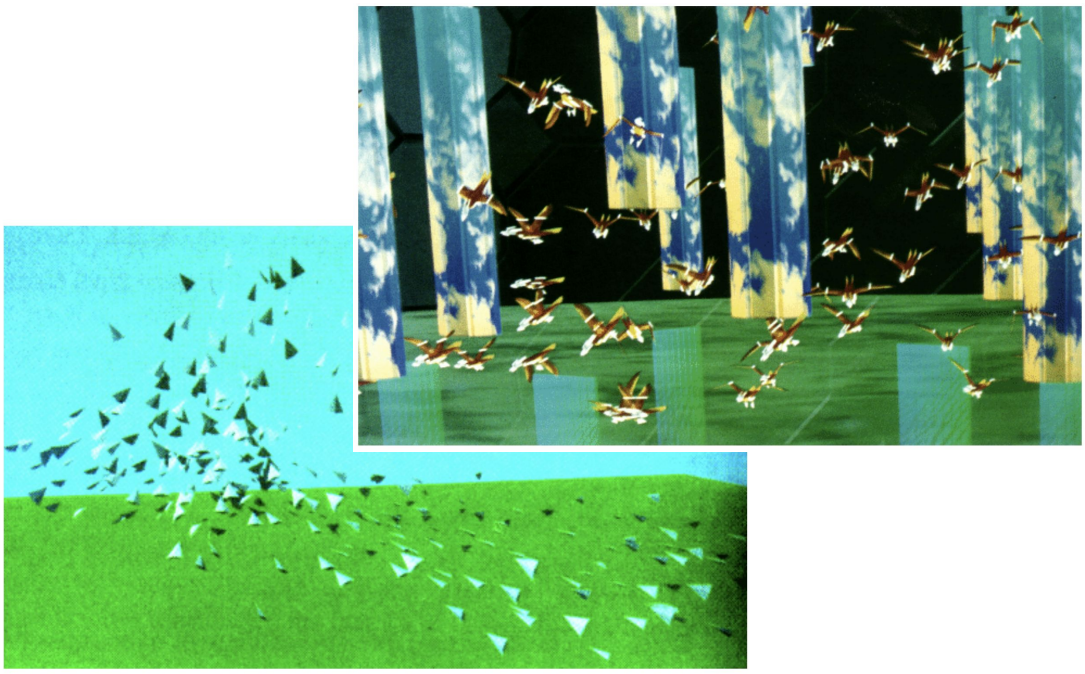
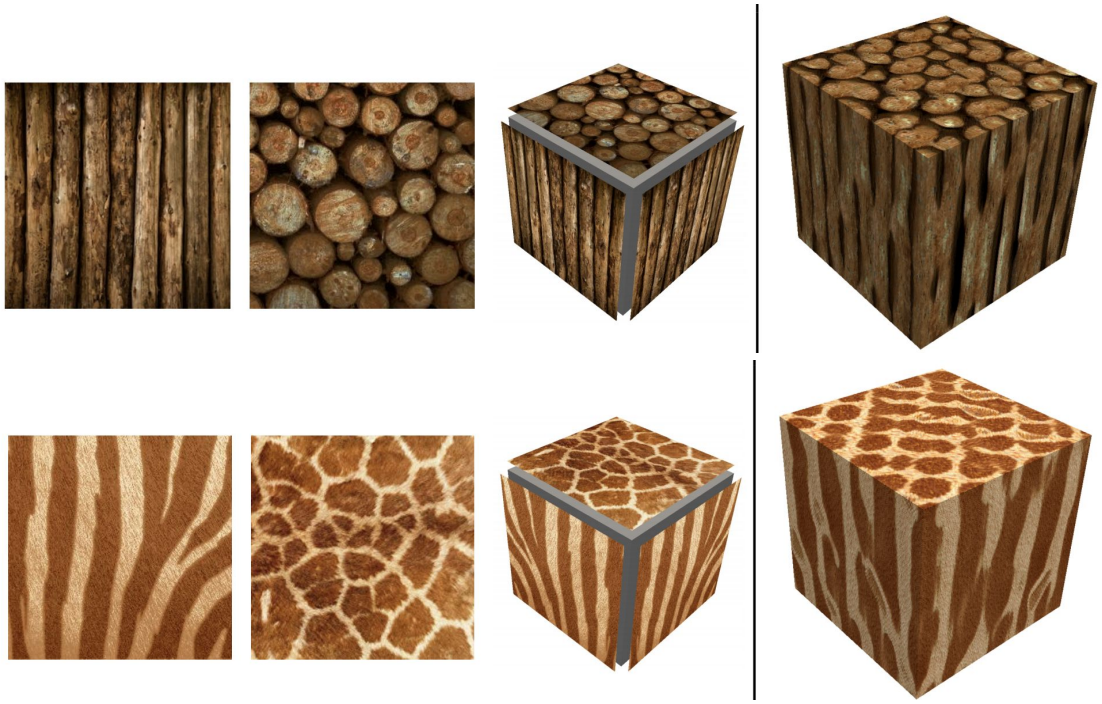
"Flocks, Herds, and Schools: A Distributed Behavioral Model", Craig W. Reynolds, SIGGRAPH 1987



“On Demand Solid Texture Synthesis Using Deep 3D Networks”, Gutierrez, Rabin, Galerne, and Hurtut, 2019



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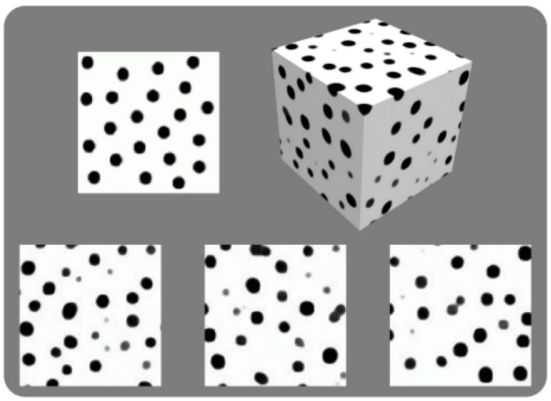
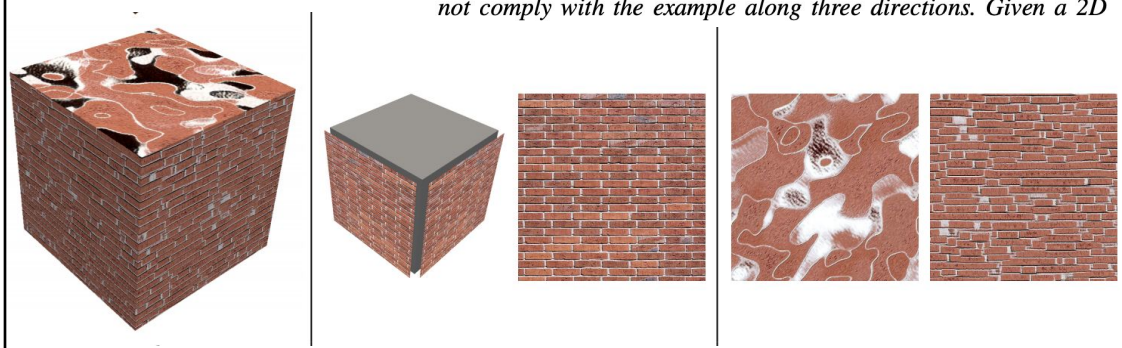


Figure 8: *Illustration of a solid texture whose cross sections cannot comply with the example along three directions. Given a 2D*



“Interactive Digital Photomontage”, Agarwala, Dontcheva, Agrawala, Drucker, Colburn, Curless, Salesin, & Cohen SIGGRAPH 2004