

Texture Synthesis



© Darren Green (www.darrensworld.com)

15-463: Computational Photography
Alexei Efros, CMU, Fall 2005

Texture

- Texture depicts spatially repeating patterns
- Many natural phenomena are textures



radishes



rocks



yogurt

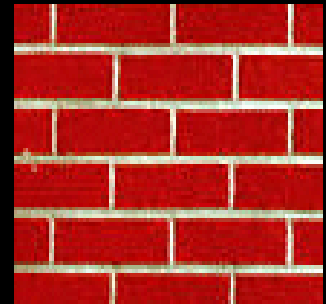
Texture Synthesis

- Goal of Texture Synthesis: create new samples of a given texture
- Many applications: virtual environments, hole-filling, texturing surfaces

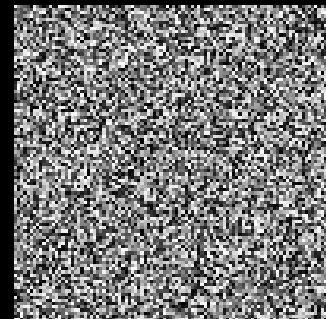


The Challenge

- Need to model the whole spectrum: from repeated to stochastic texture



repeated

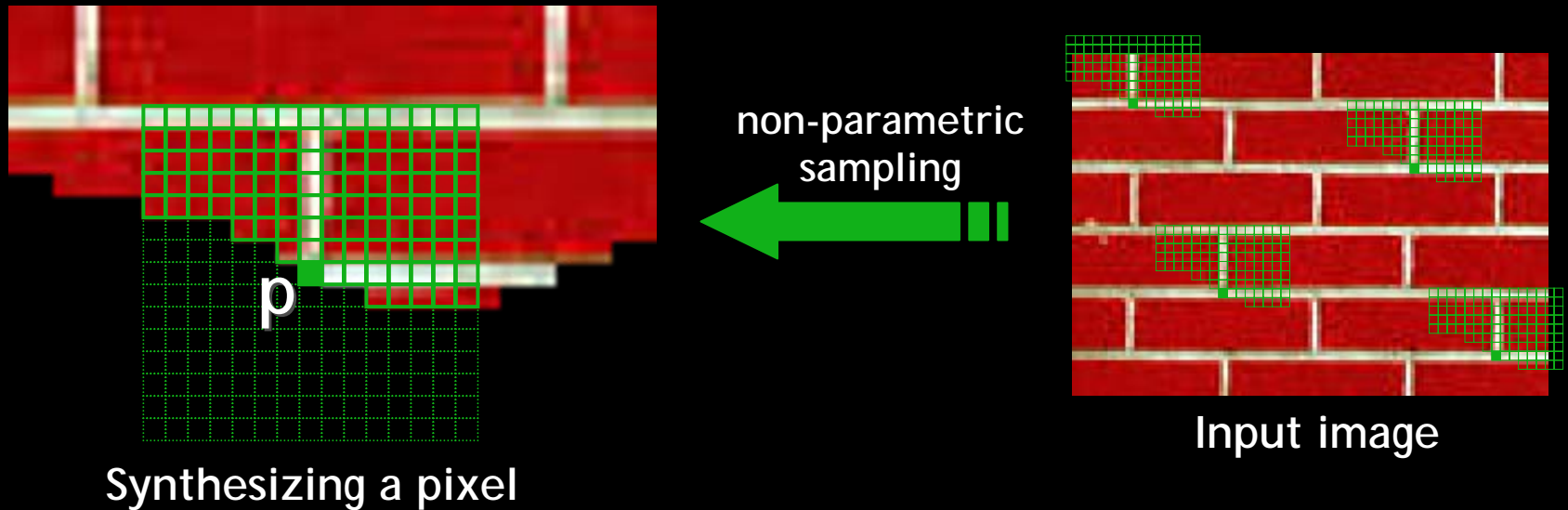


stochastic



Both?

Efros & Leung Algorithm

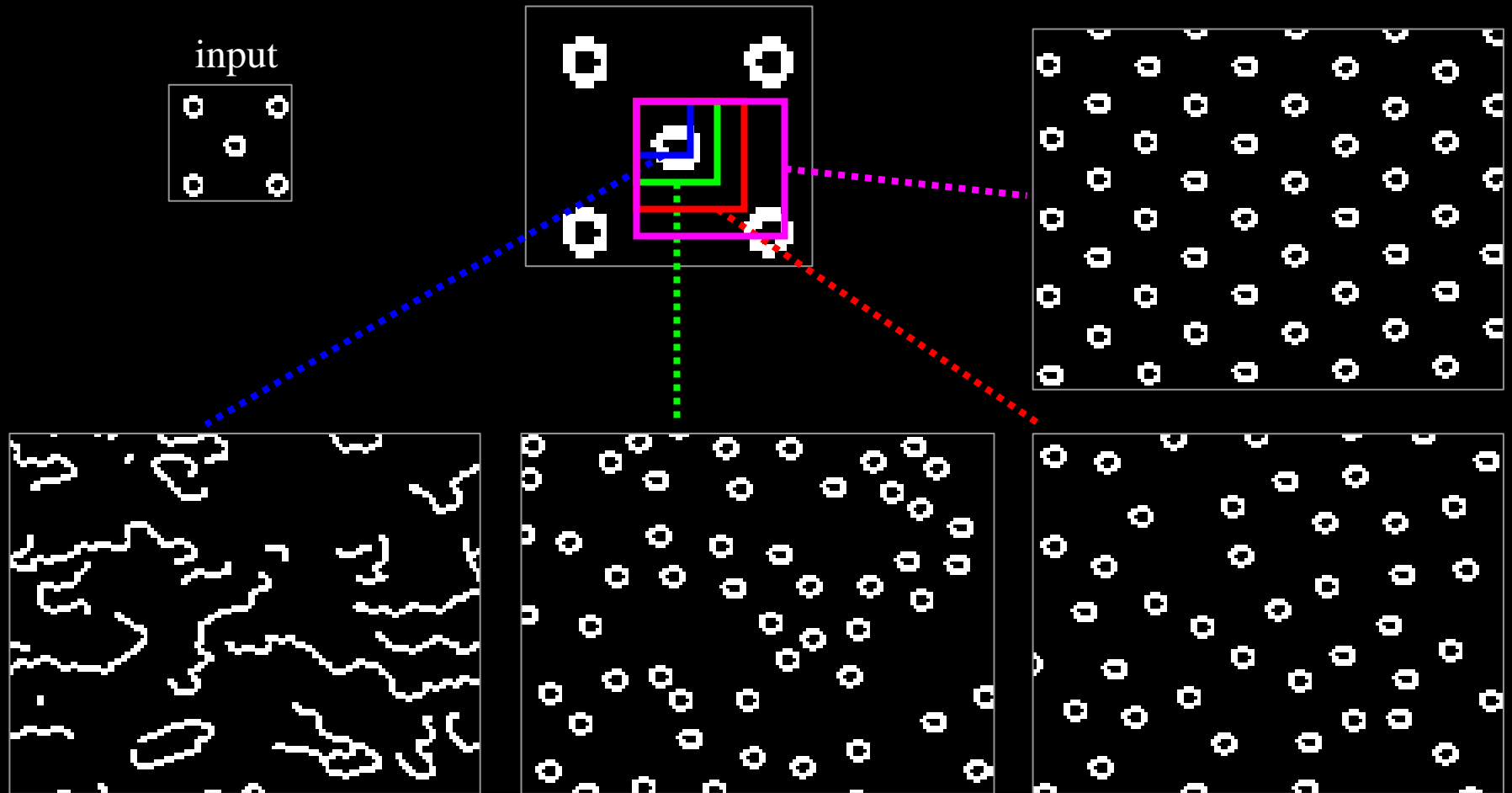


- Assuming Markov property, compute $P(\mathbf{p}|\mathbf{N}(\mathbf{p}))$
 - Building explicit probability tables infeasible
 - Instead, we *search the input image* for all similar neighborhoods — that's our pdf for \mathbf{p}
 - To sample from this pdf, just pick one match at random

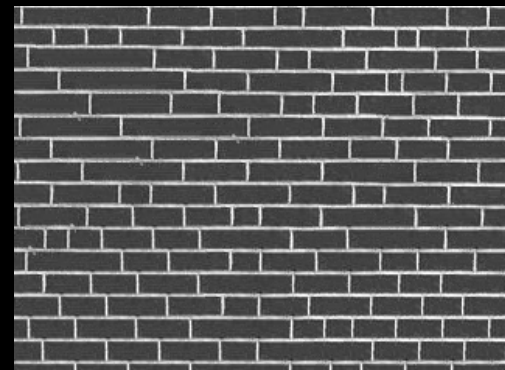
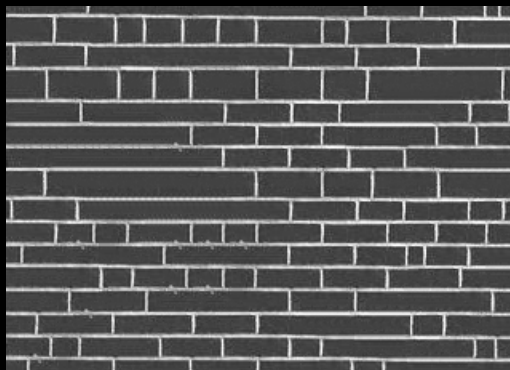
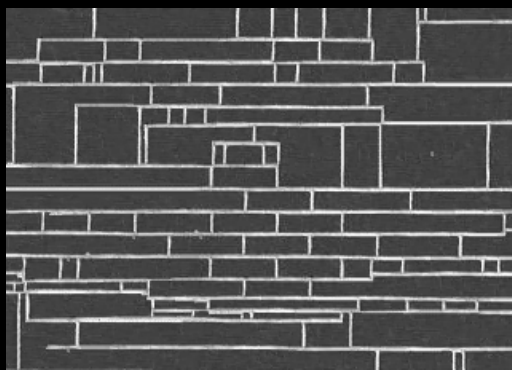
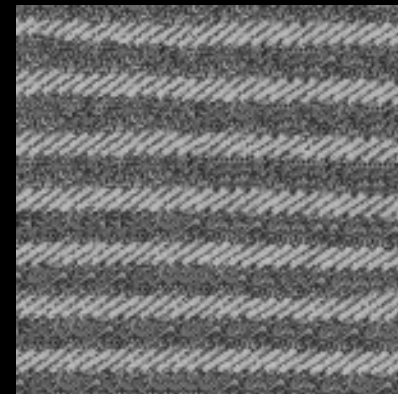
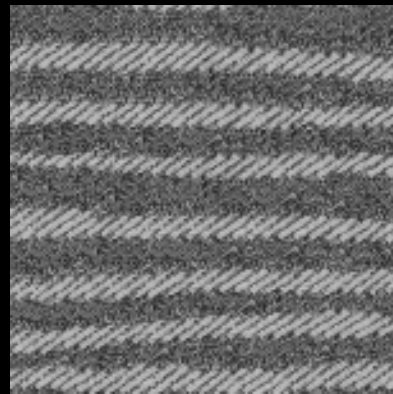
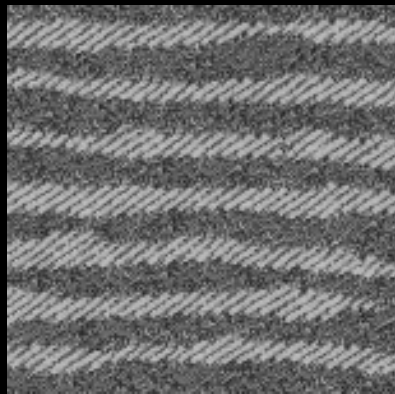
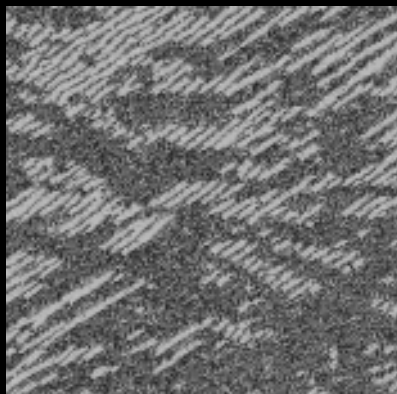
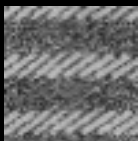
Some Details

- Growing is in “onion skin” order
 - Within each “layer”, pixels with most neighbors are synthesized first
 - If no close match can be found, the pixel is not synthesized until the end
- Using *Gaussian-weighted* SSD is very important
 - to make sure the new pixel agrees with its closest neighbors
 - Approximates reduction to a smaller neighborhood window if data is too sparse

Neighborhood Window



Varying Window Size

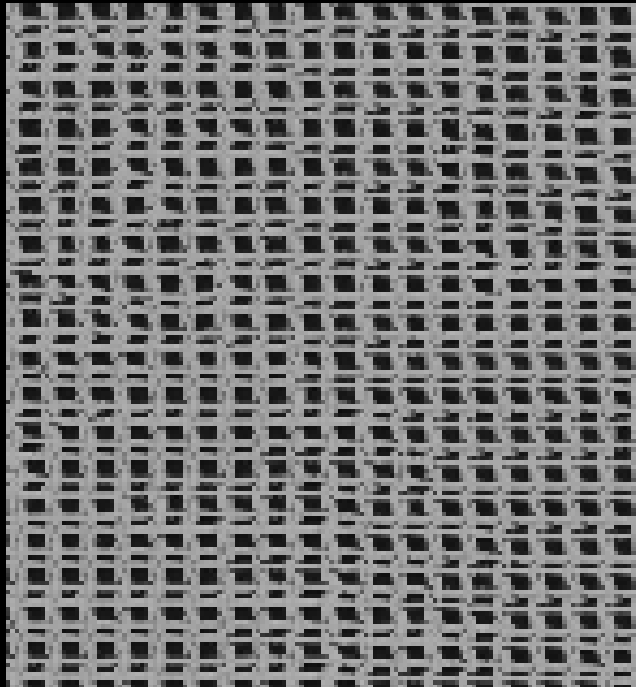
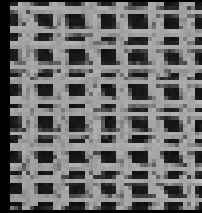


Increasing window size

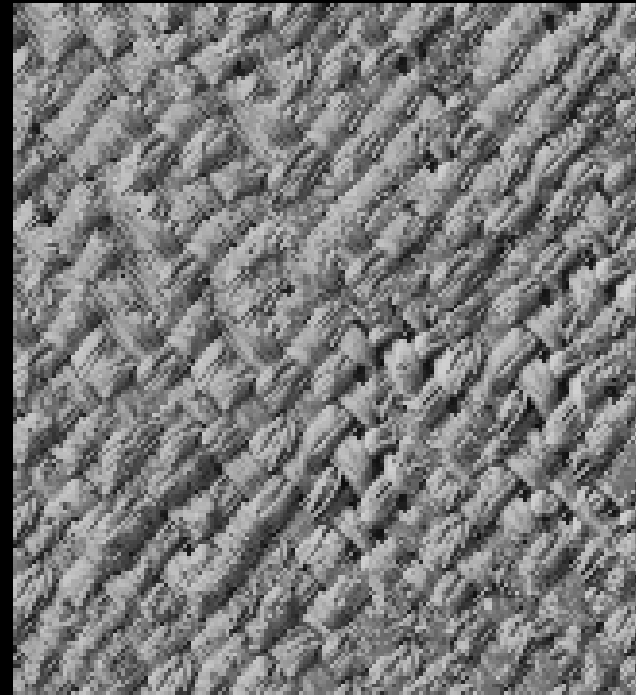


Synthesis Results

french canvas



rafia weave

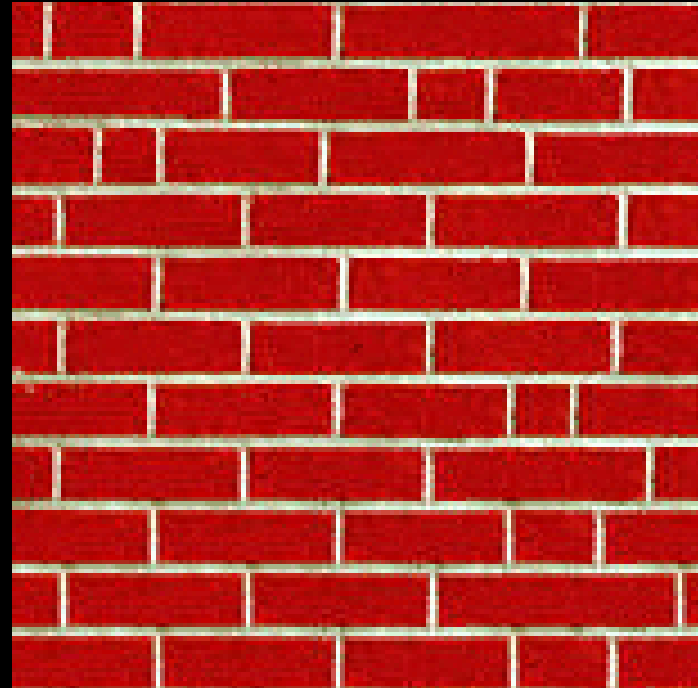
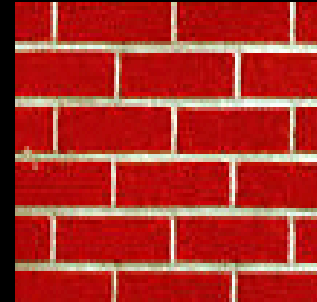


More Results

white bread

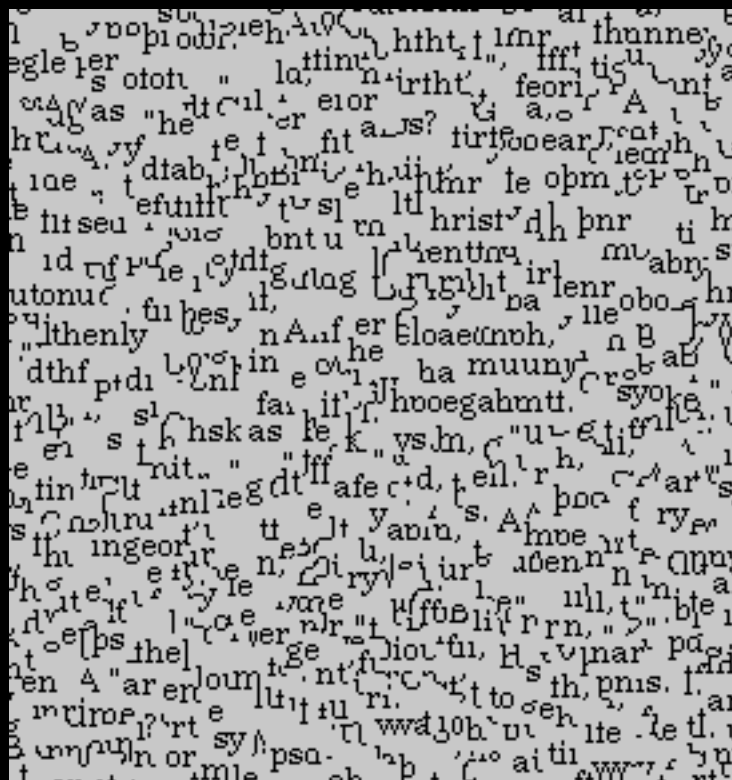


brick wall



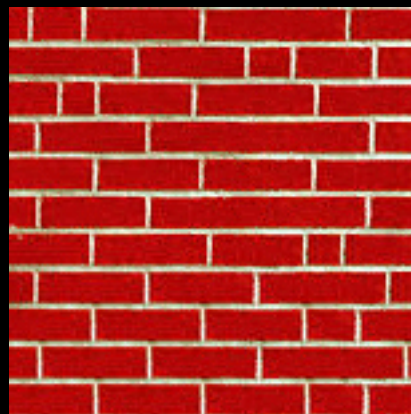
Homage to Shannon

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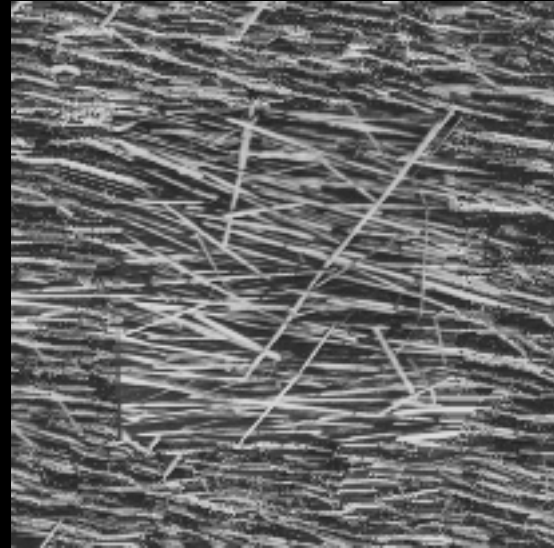
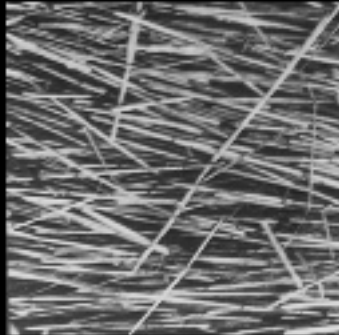


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Hole Filling



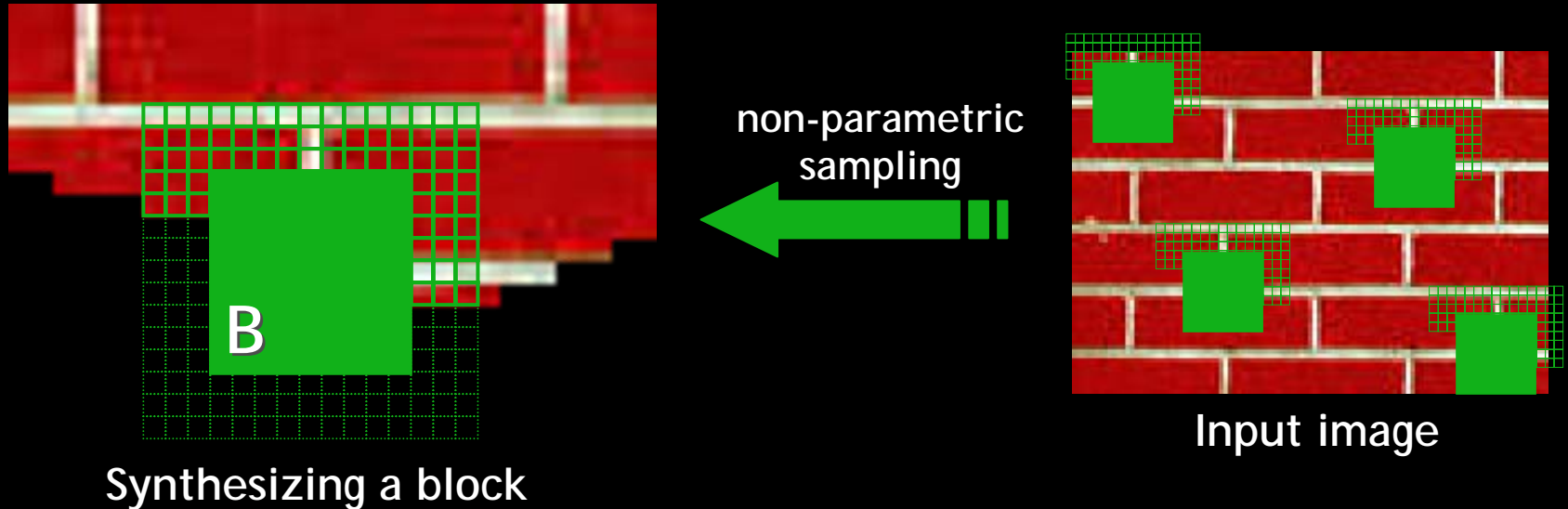
Extrapolation



Summary

- The Efros & Leung algorithm
 - Very simple
 - Surprisingly good results
 - Synthesis is easier than analysis!
 - ...but very slow

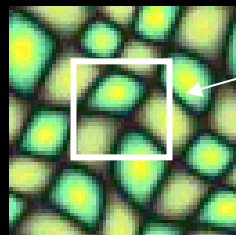
Image Quilting [Efros & Freeman]



- Observation: neighbor pixels are highly correlated

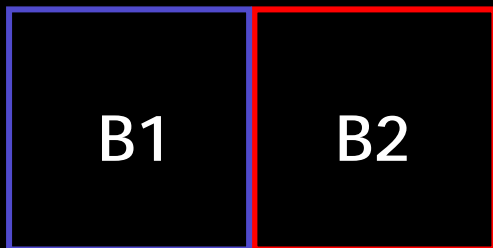
Idea: unit of synthesis = block

- Exactly the same but now we want $P(B | N(B))$
- Much faster: synthesize all pixels in a block at once
- Not the same as multi-scale!

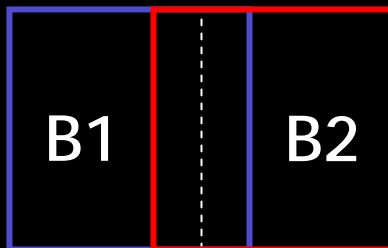


block

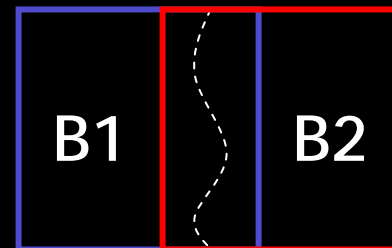
Input texture



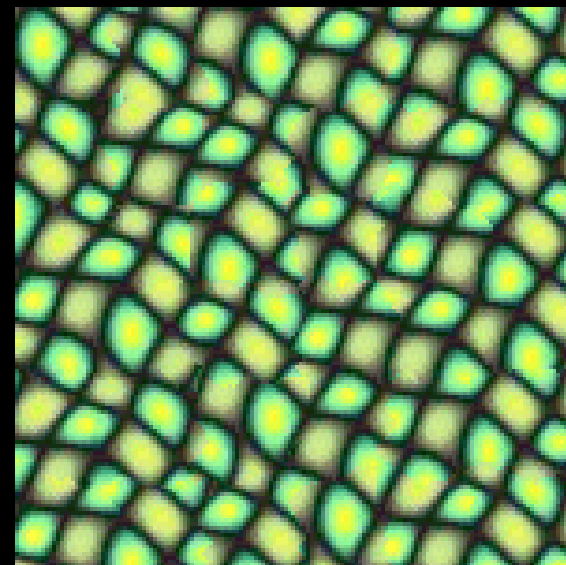
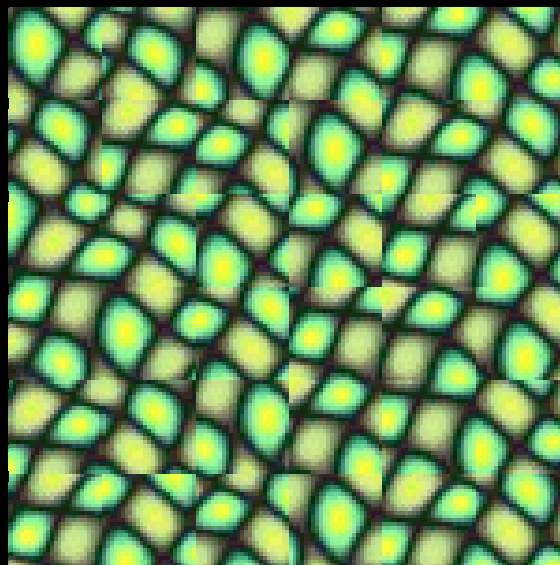
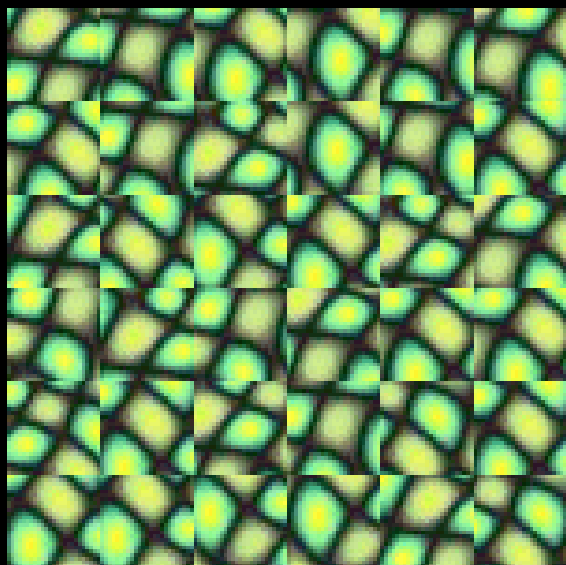
Random placement
of blocks



Neighboring blocks
constrained by overlap

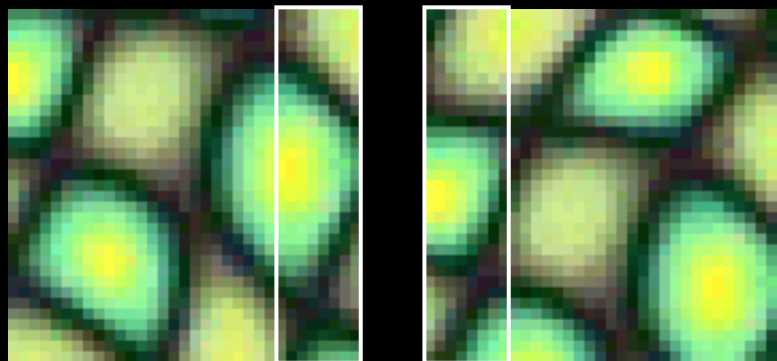


Minimal error
boundary cut

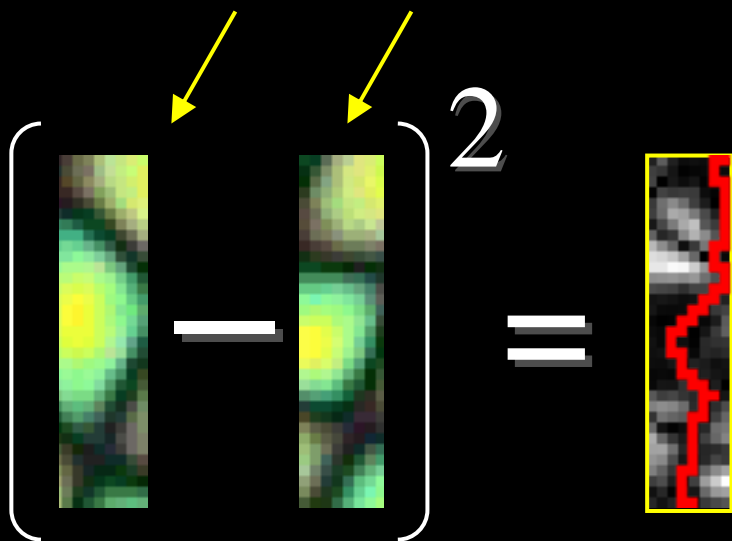
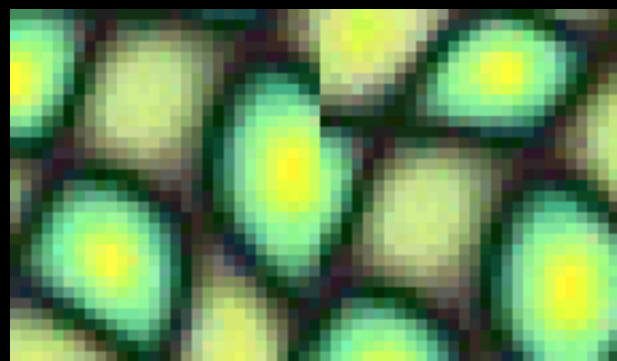


Minimal error boundary

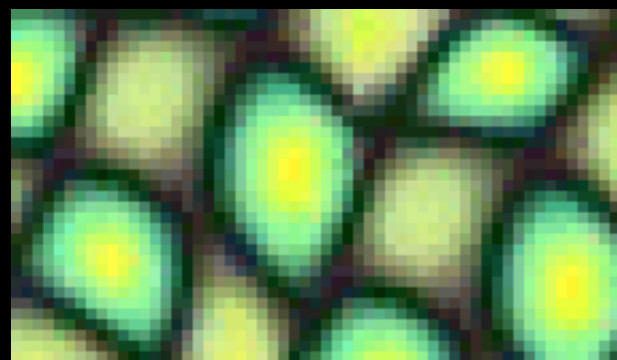
overlapping blocks



vertical boundary



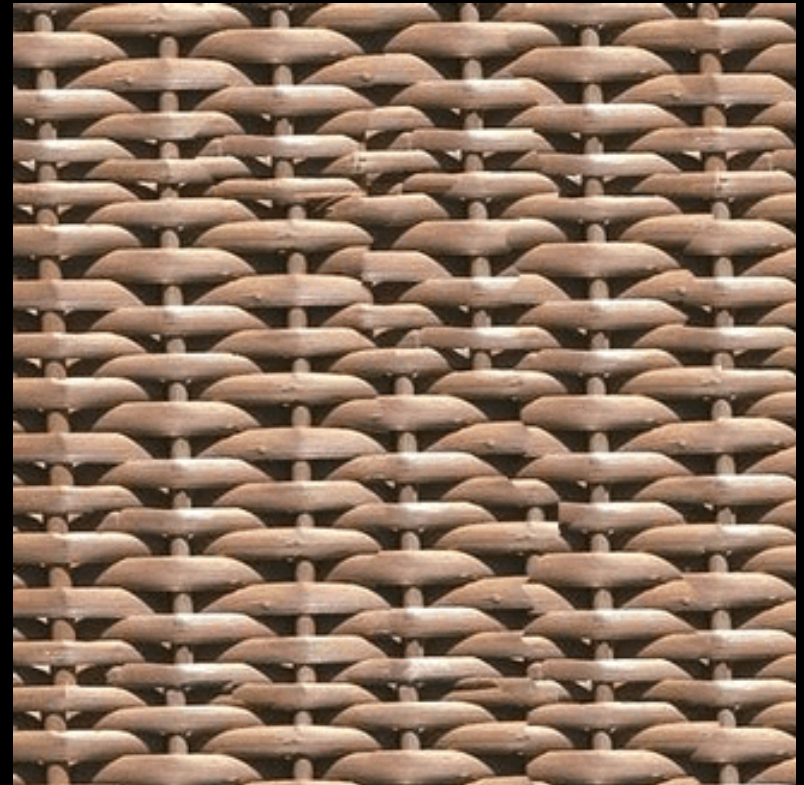
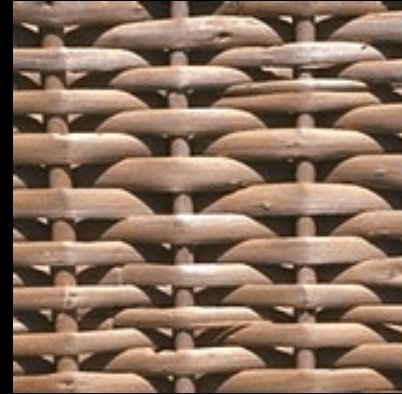
overlap error

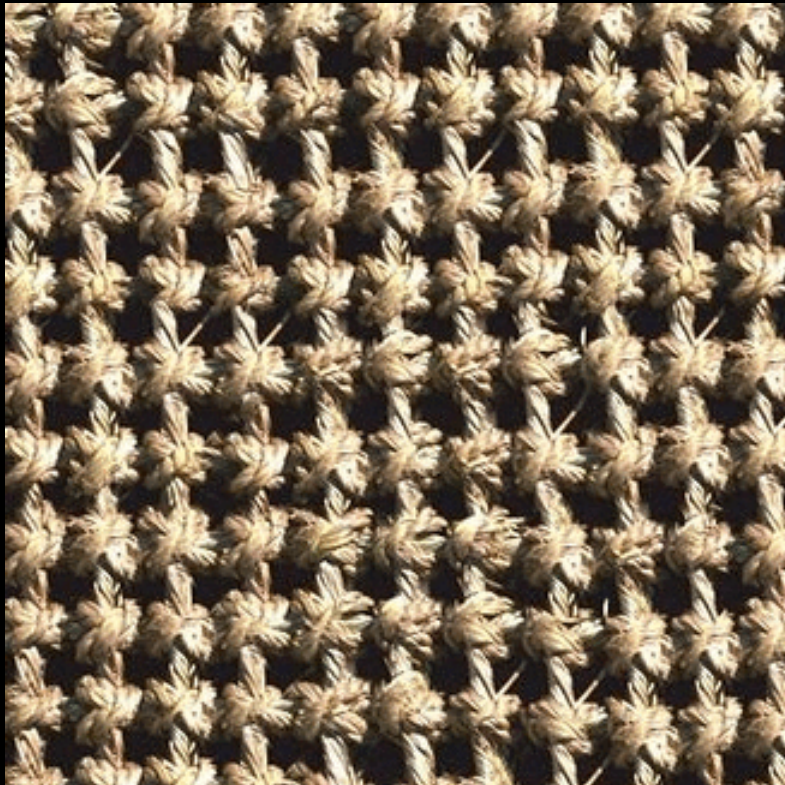


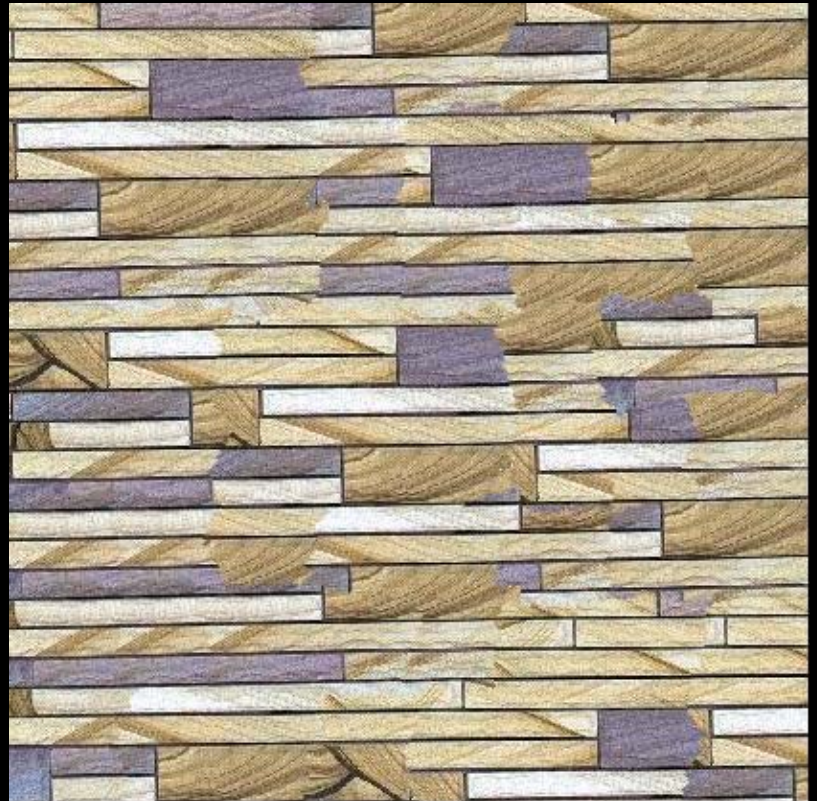
min. error boundary

Our Philosophy

- The “Corrupt Professor’s Algorithm”:
 - Plagiarize as much of the source image as you can
 - Then try to cover up the evidence
- Rationale:
 - Texture blocks are by definition correct samples of texture so problem only connecting them together

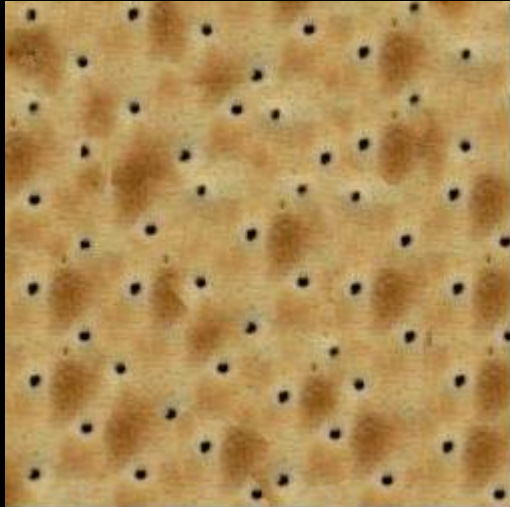
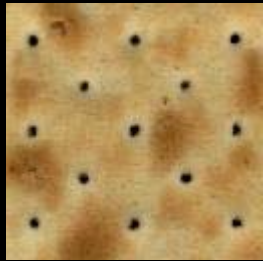






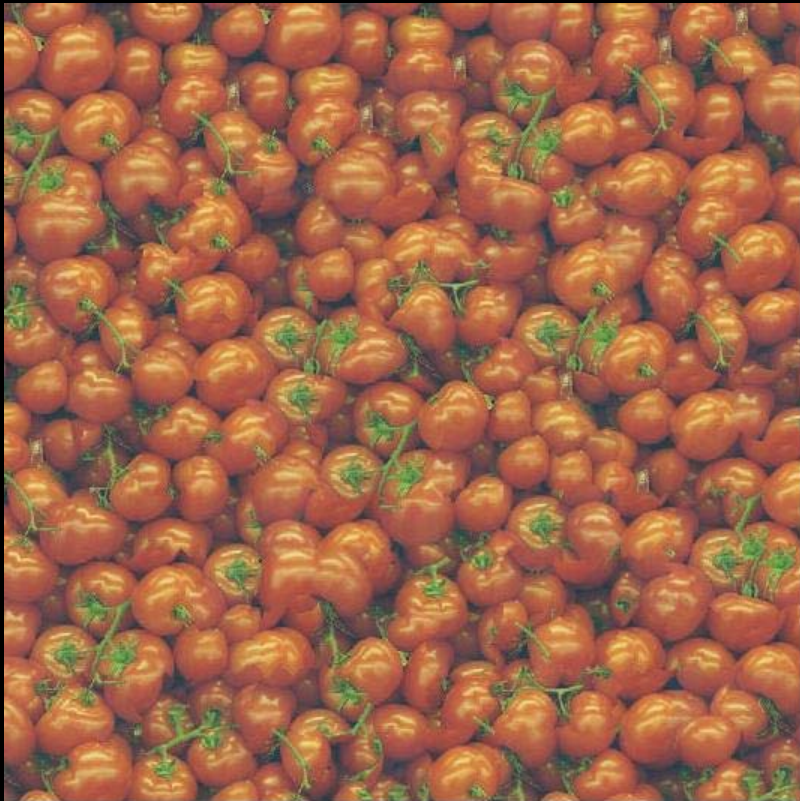


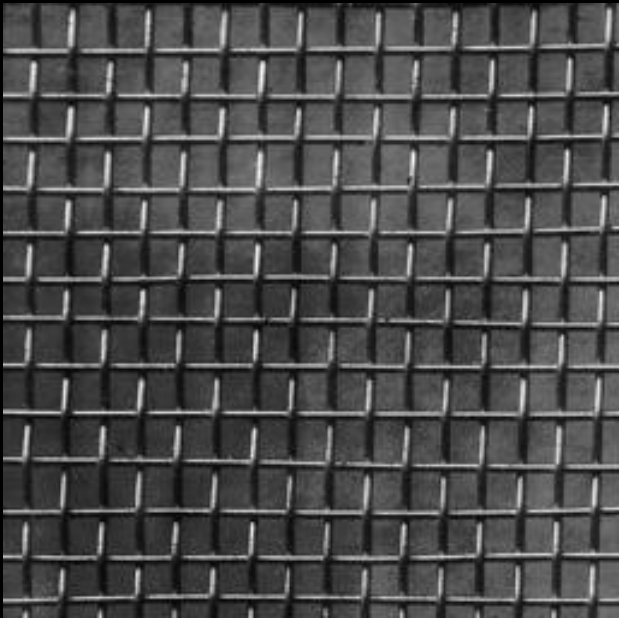




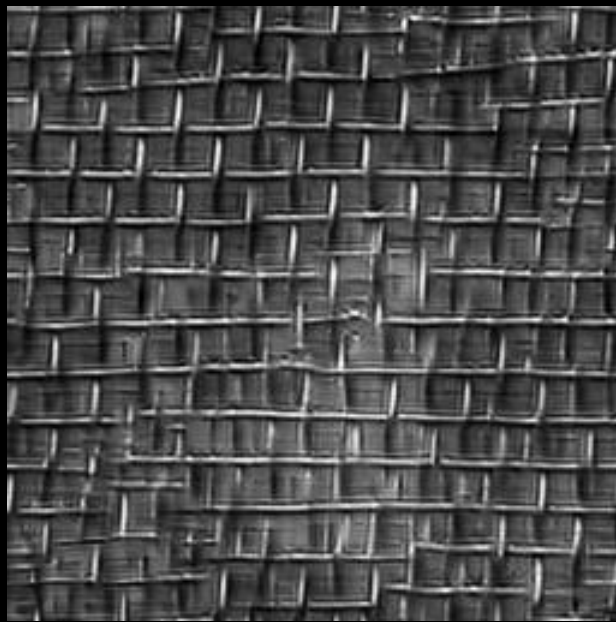


Failures (Chernobyl Harvest)

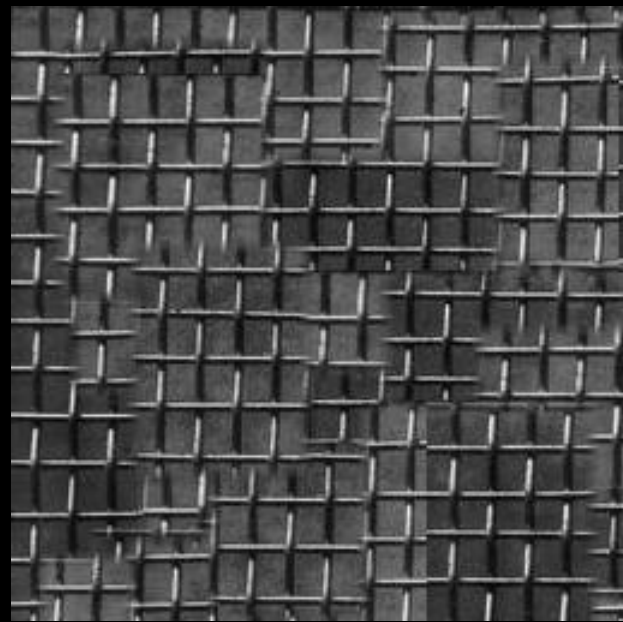




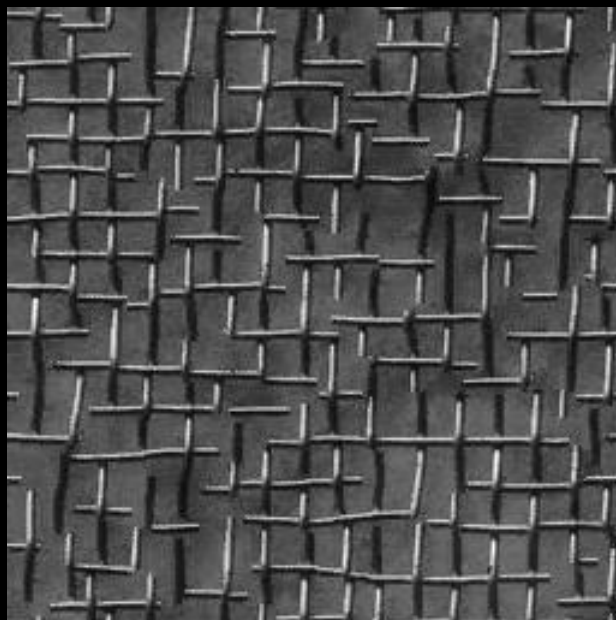
input image



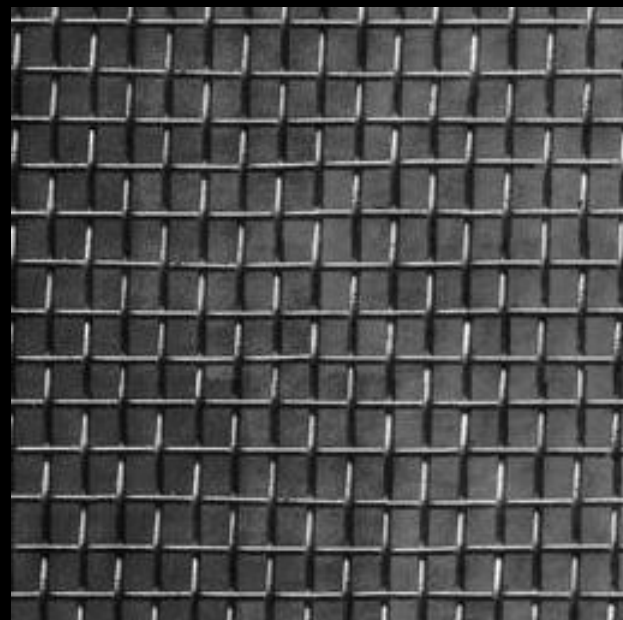
Portilla & Simoncelli



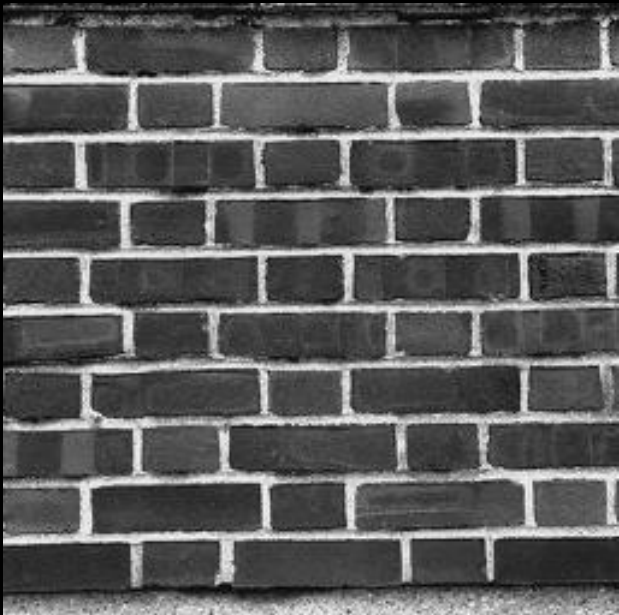
Xu, Guo & Shum



Wei & Levoy



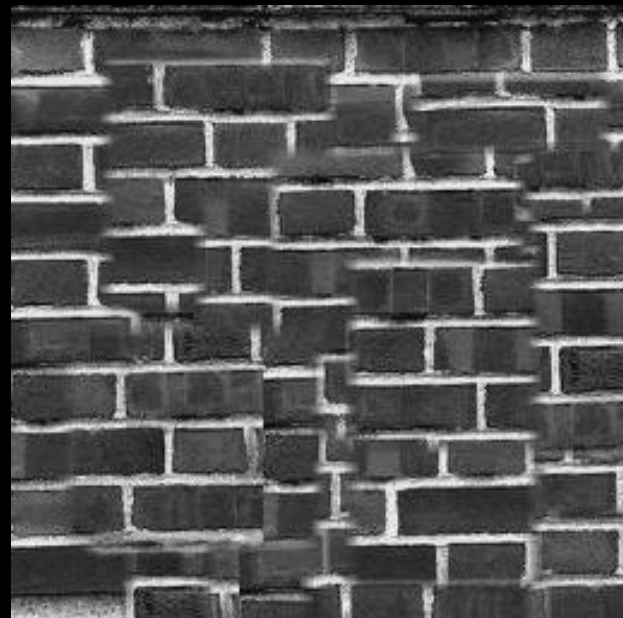
Our algorithm



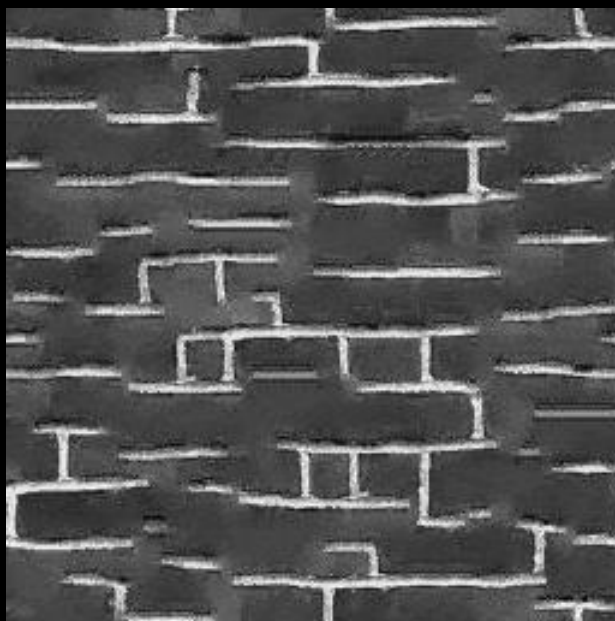
input image



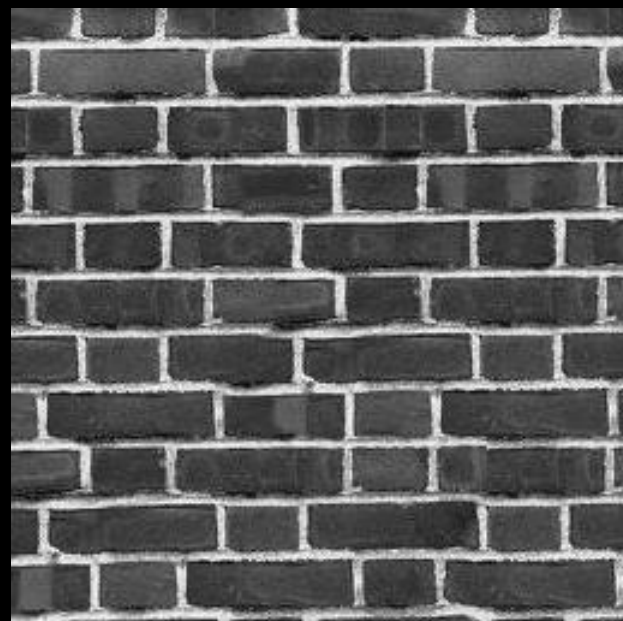
Portilla & Simoncelli



Xu, Guo & Shum



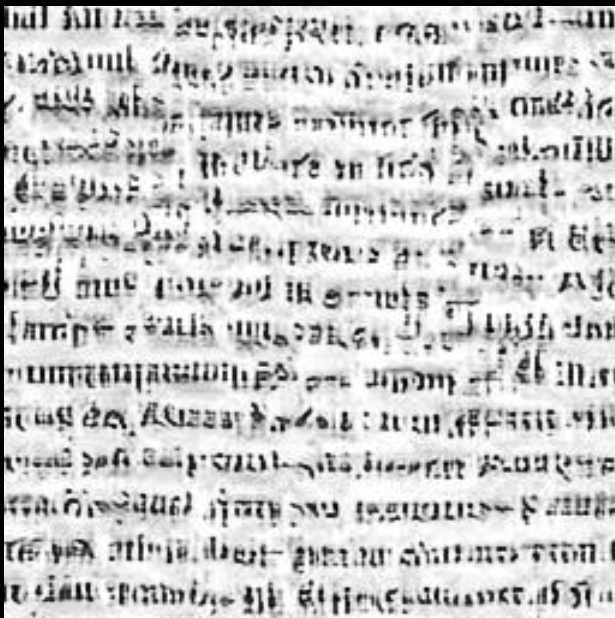
Wei & Levoy



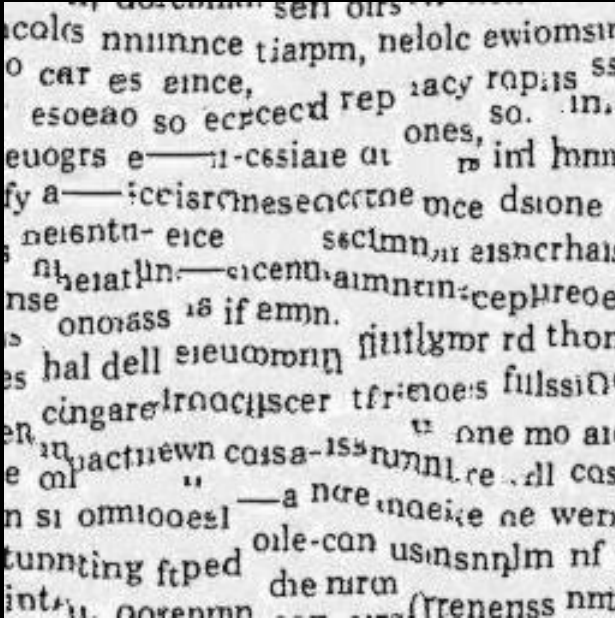
Our algorithm

end of a visual cortical neuron—the
describing the response of that neuro
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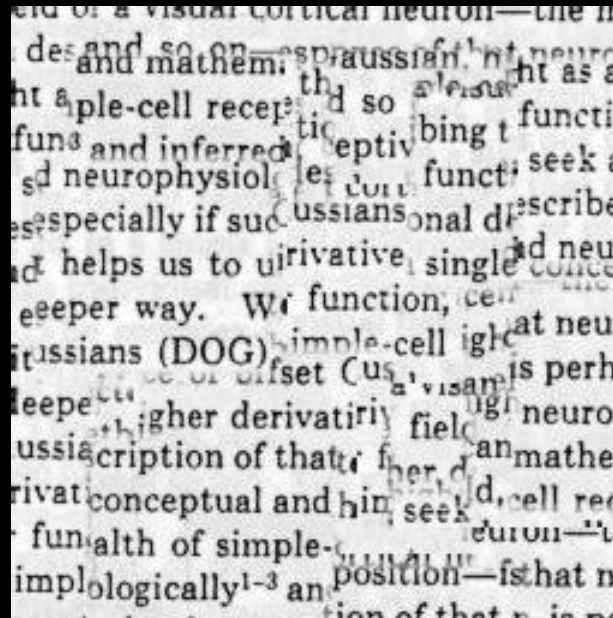
input image



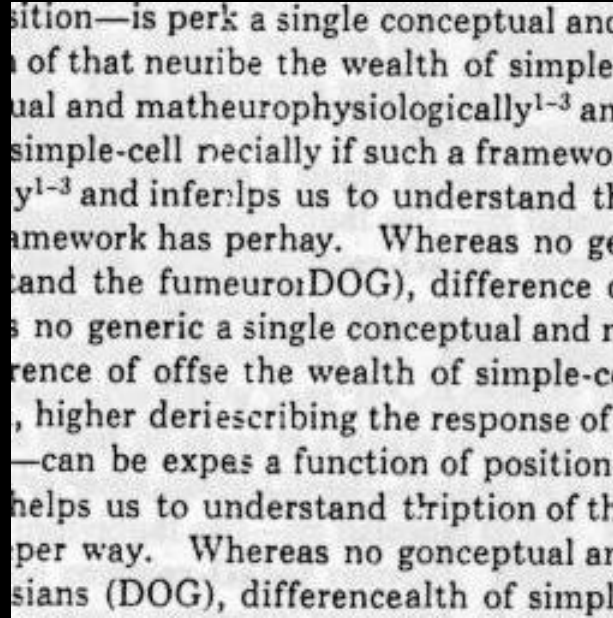
Portilla & Simoncelli



Wei & Levoy



Xu, Guo & Shum



Our algorithm

Political Texture Synthesis!

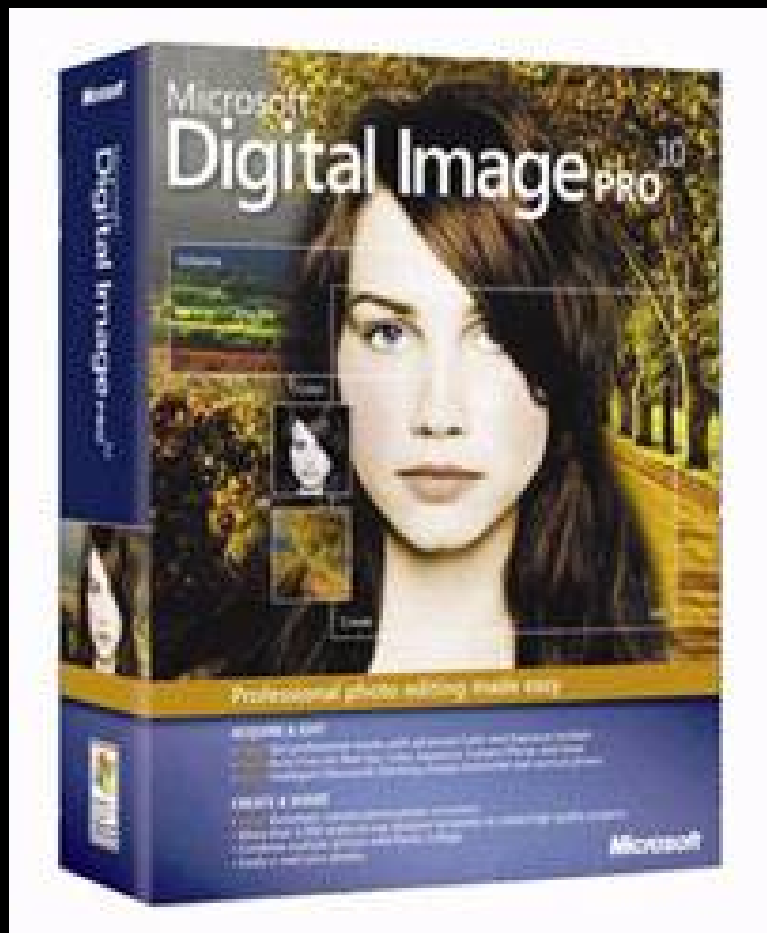
Bush campaign digitally altered TV ad

President Bush's campaign acknowledged Thursday that it had digitally altered a photo that appeared in a national cable television commercial. In the photo, a handful of soldiers were multiplied many times.

This section shows a sampling of the duplication of soldiers.



MS Digital Image Pro (DEMO)



Fill Order



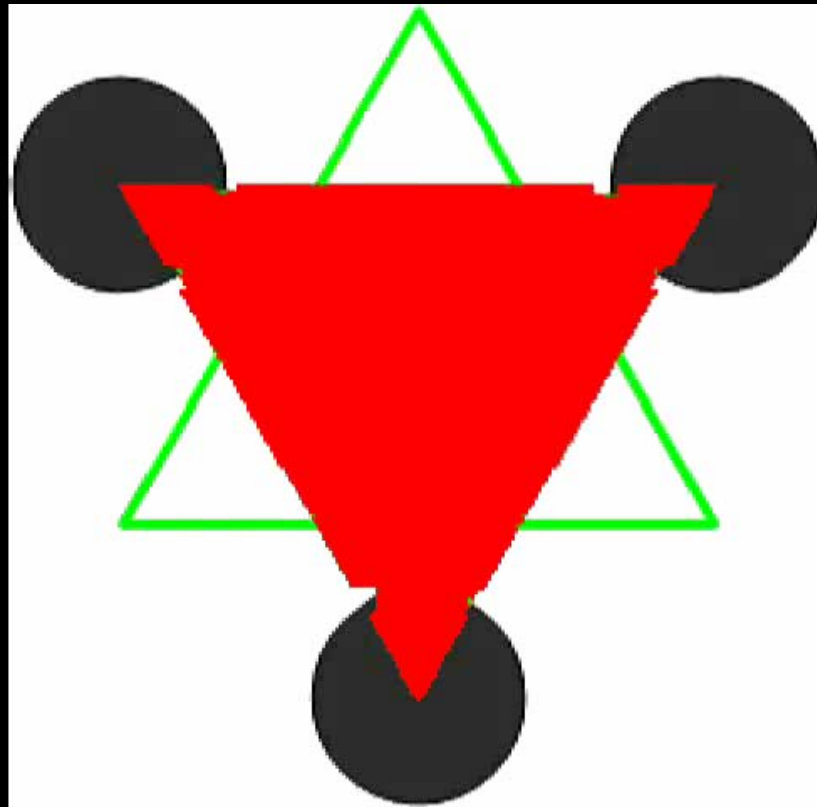
- In what order should we fill the pixels?

Fill Order



- In what order should we fill the pixels?
 - choose pixels that have more neighbors filled
 - choose pixels that are continuations of lines/curves/edges

Exemplar-based Inpainting demo



<http://research.microsoft.com/vision/cambridge/i3l/patchworks.htm>

Application: Texture Transfer

- Try to explain one object with bits and pieces of another object:



Texture Transfer



Constraint

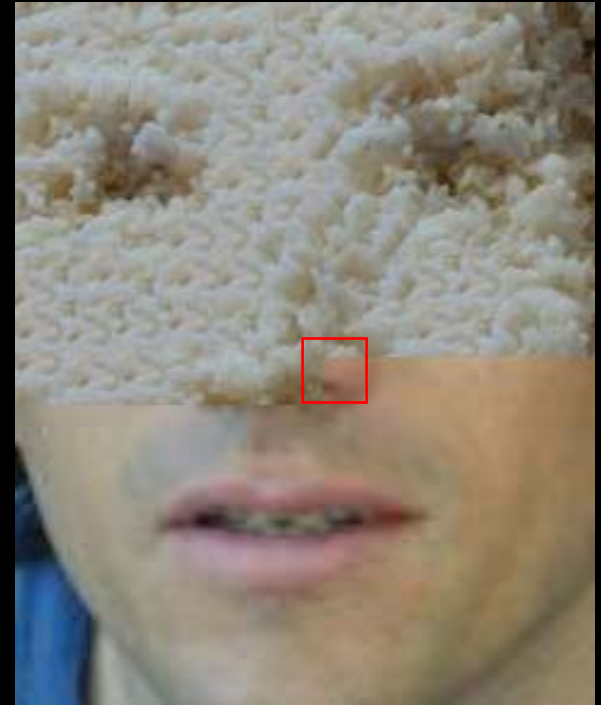


Texture sample



Texture Transfer

- Take the texture from one image and “paint” it onto another object



Same as texture synthesis, except an additional constraint:

1. Consistency of texture
2. Similarity to the image being “explained”



+



=



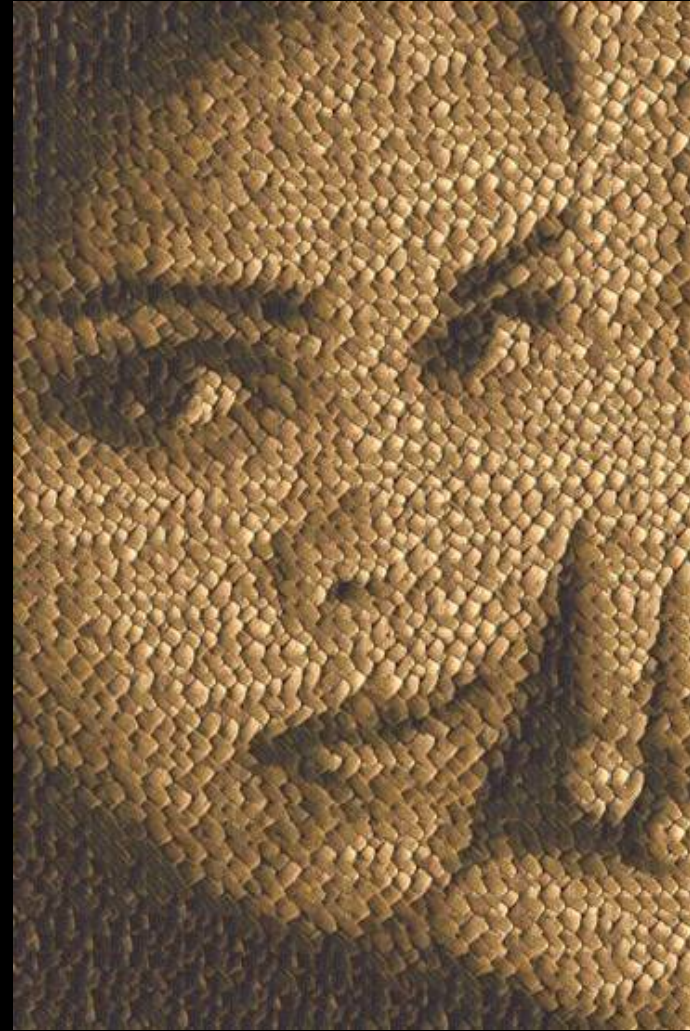


Image Analogies

Aaron Hertzmann^{1,2}

Chuck Jacobs²

Nuria Oliver²

Brian Curless³

David Salesin^{2,3}

¹New York University

²Microsoft Research

³University of Washington

Image Analogies



A



A'



B



B'



Blur Filter



Unfiltered source (A)



Filtered source (A')



Unfiltered target (B)

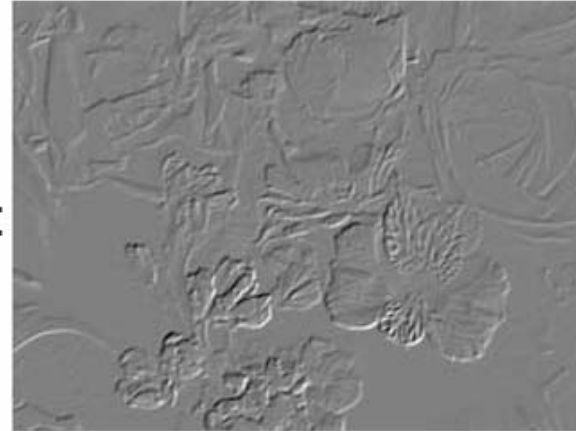


Filtered target (B')

Edge Filter



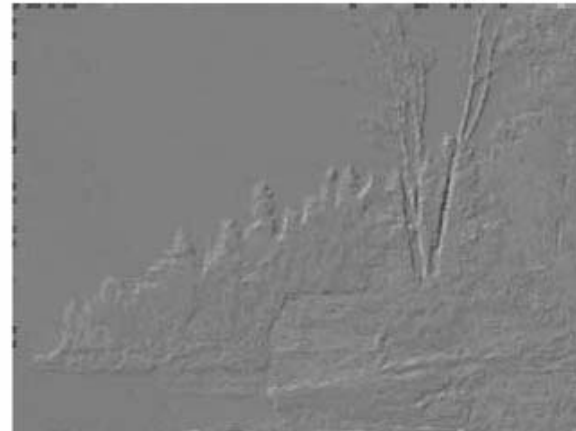
Unfiltered source (A)



Filtered source (A')



Unfiltered target (B)



Filtered target (B')

:
::

Artistic Filters



A



A'



B



B'

Colorization



Unfiltered source (A)



Filtered source (A')



Unfiltered target (B)



Filtered target (B')

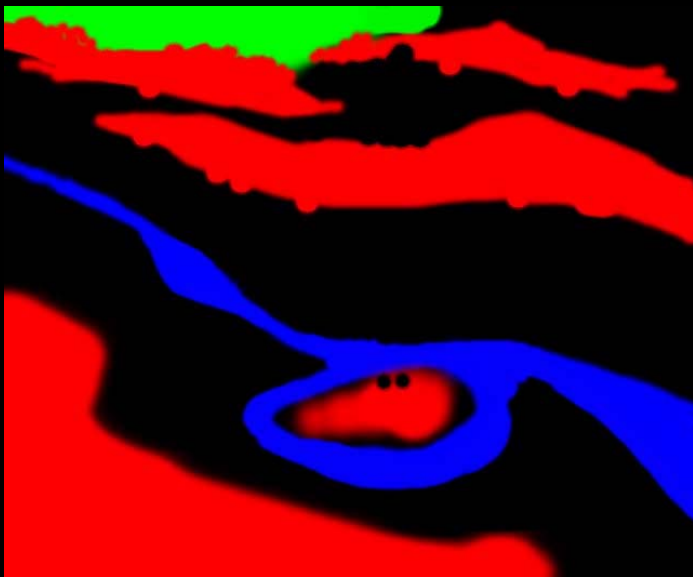
Texture-by-numbers



A



A'



B



B'

Super-resolution



A



A'

Super-resolution (result!)



B



B'

Video Matching [Sand & Teller, 2004]



SIGGRAPH2005

Motion Magnification

Ce Liu Antonio Torralba William T. Freeman

Frédo Durand Edward H. Adelson

Computer Science and Artificial Intelligence Laboratory

Massachusetts Institute of Technology