Texture Synthesis

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

Texture

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

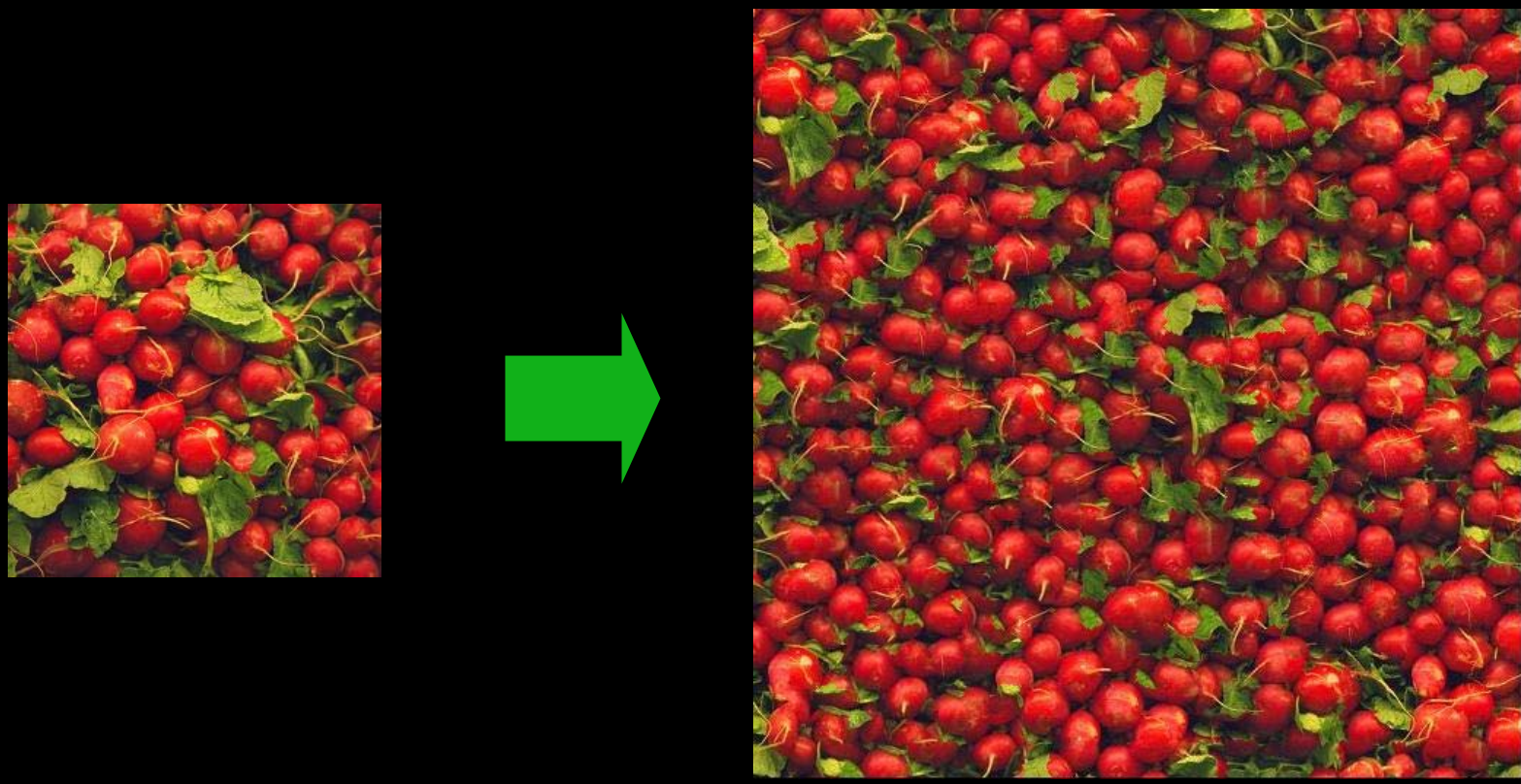
radishes

rocks

yogurt

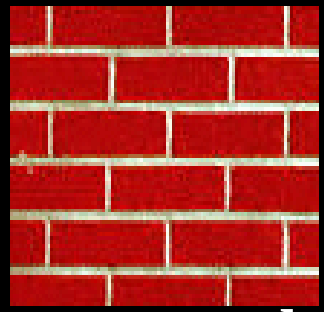
Texture Synthesis

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

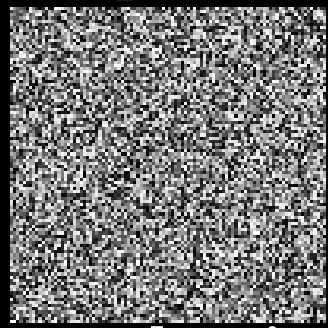


The Challenge

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



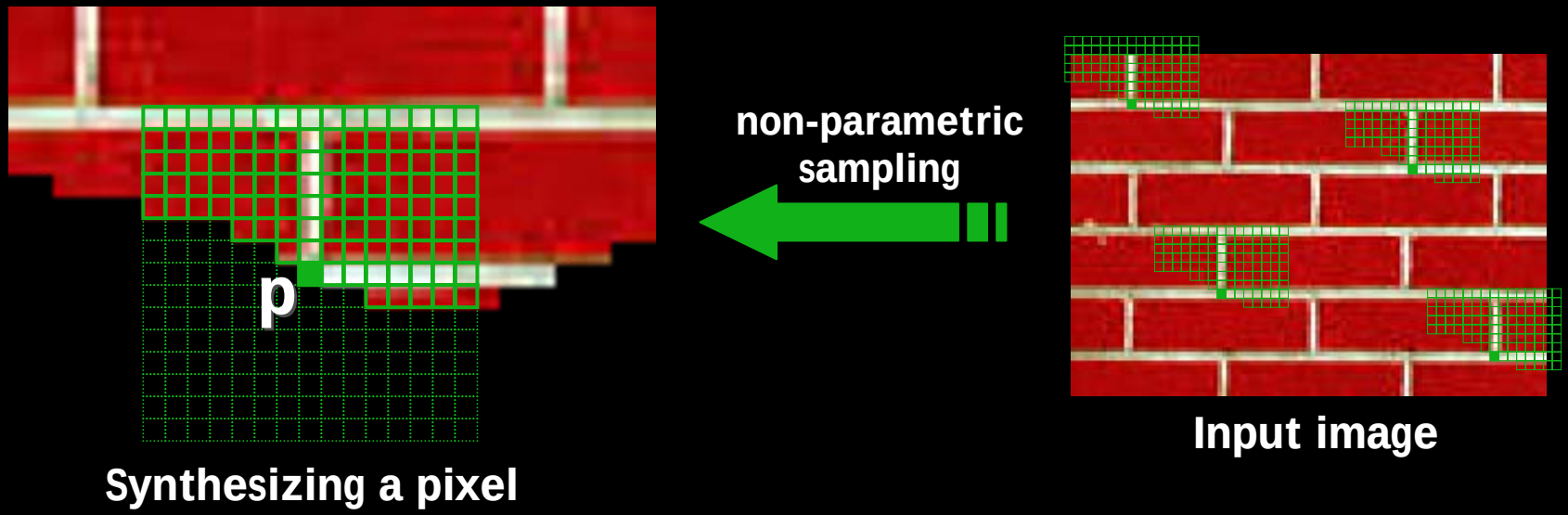
repeated



stochastic

Both?

Efros & Leung Algorithm

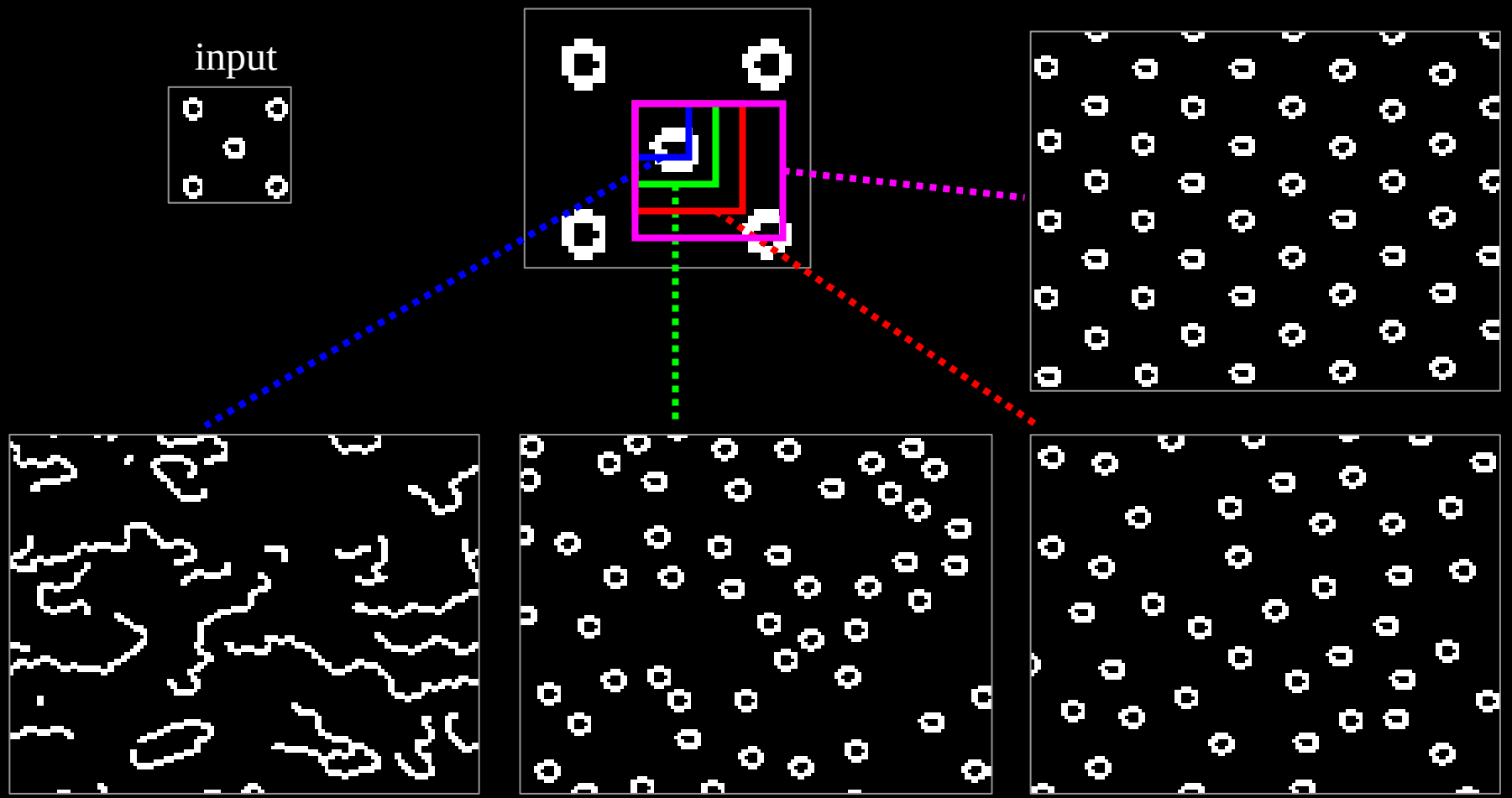


- Assuming Markov property, compute P(**p**|N(**p**))
  - Building explicit probability tables infeasible
  - Instead, we *search the input image* for all similar neighborhoods — that's our pdf for **p**
  - To sample from this pdf, just pick one match at random

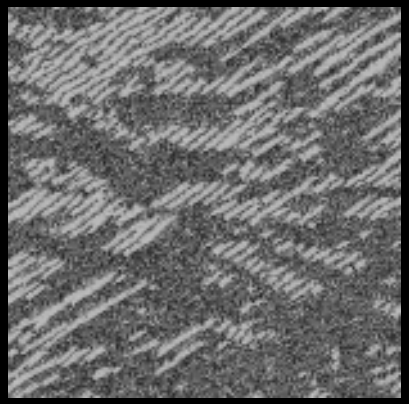
Some Details

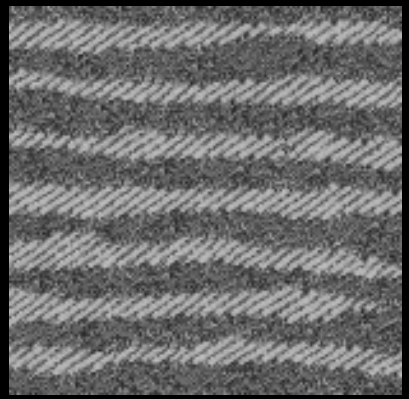
- Growing is in “onion skin” order
  - Within each “layer”, pixels with most neighbors are synthesized first
  - If no close match can be found, the pixel is not synthesized until the end
- Using *Gaussian-weighted* SSD is very important
  - to make sure the new pixel agrees with its closest neighbors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

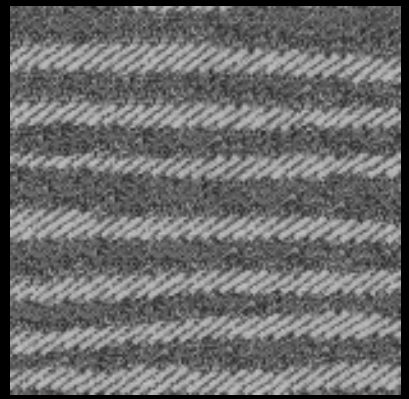
Neighborhood Window

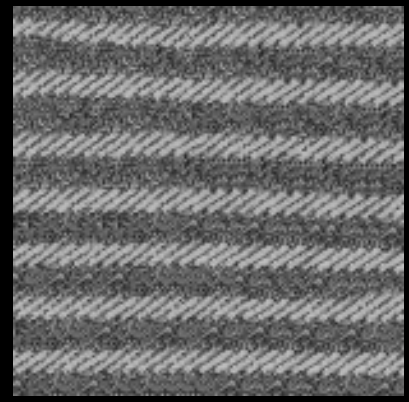


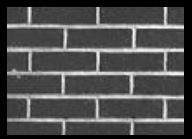
Varying Window Size

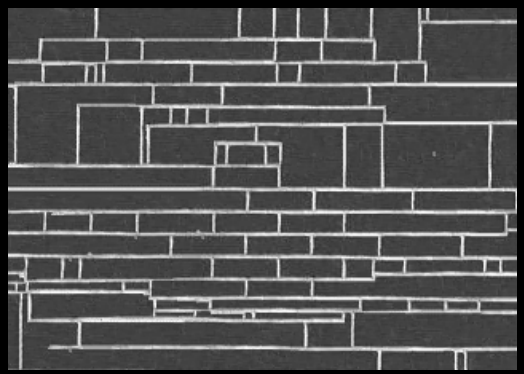


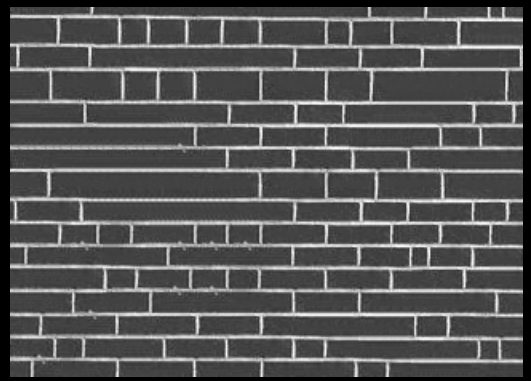


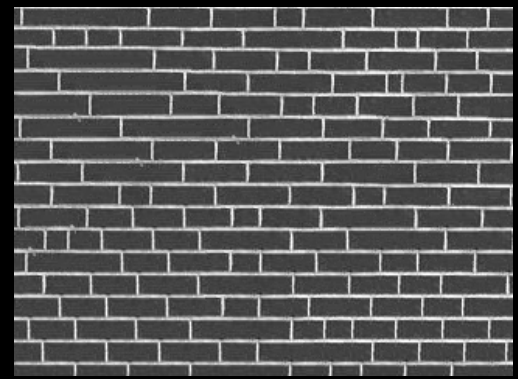








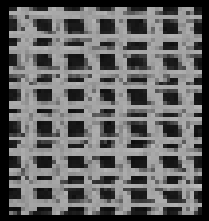


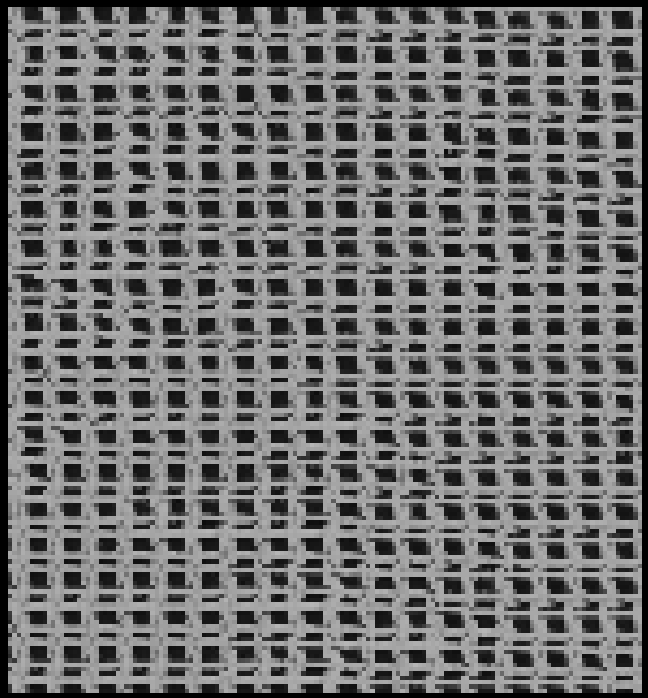


Increasing window size

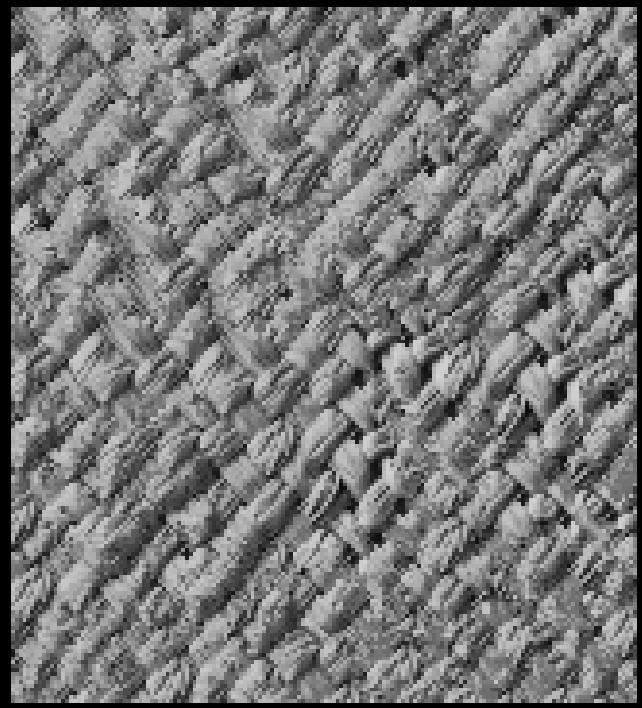
Synthesis Results

french canvas



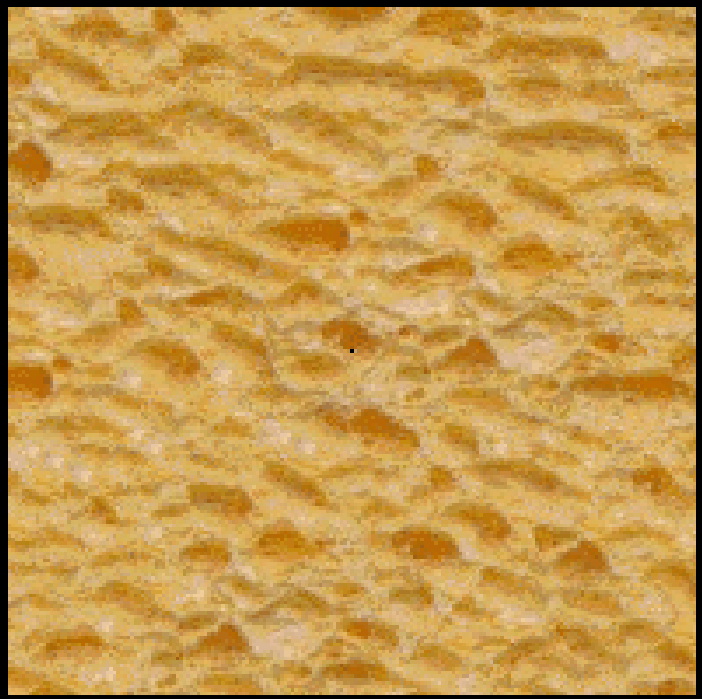


rafia weave

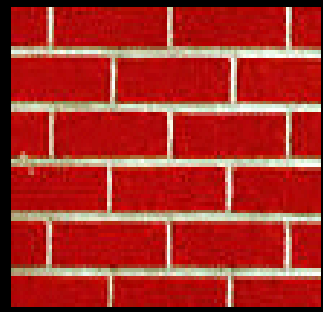


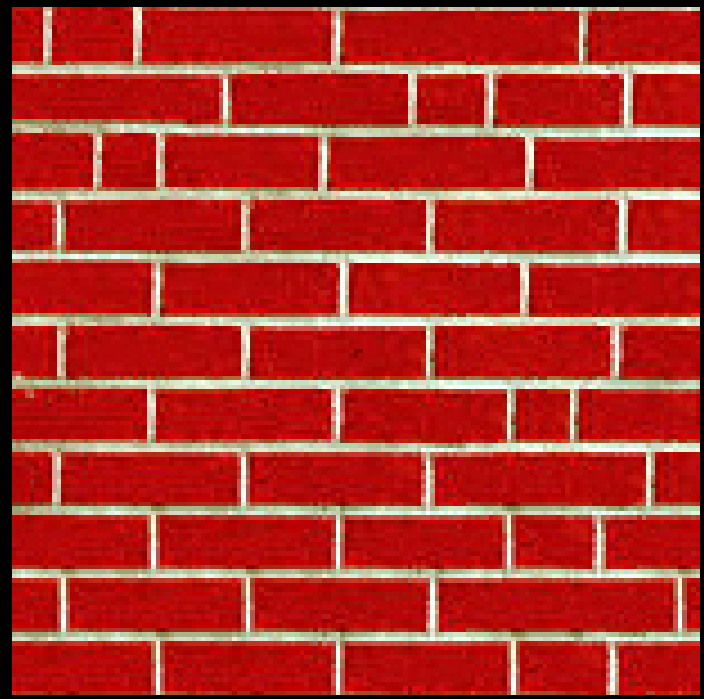
More Results

white bread

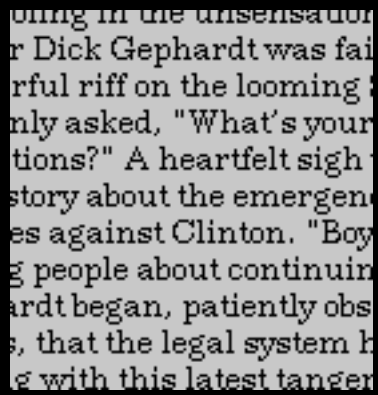


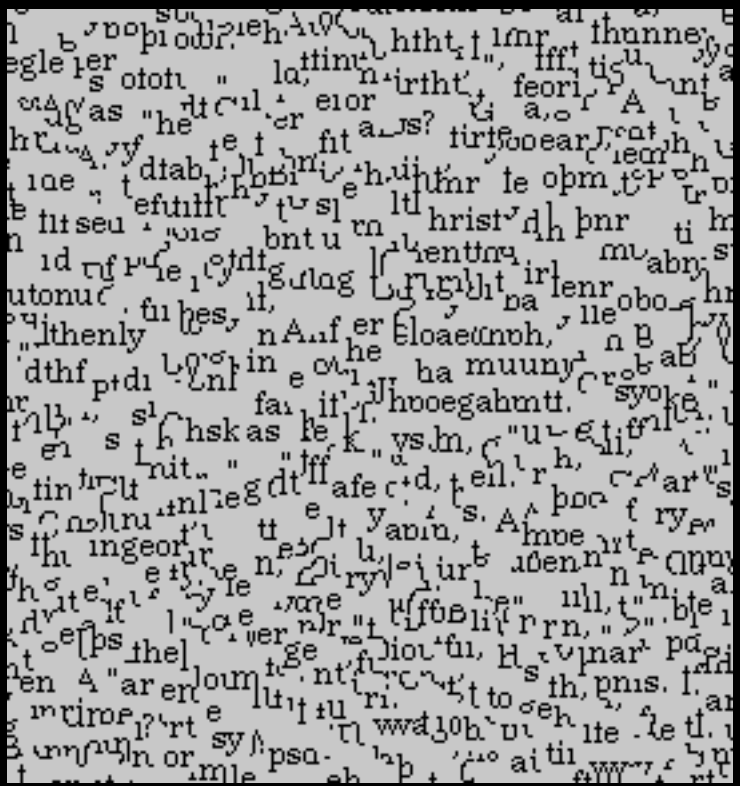
brick wall

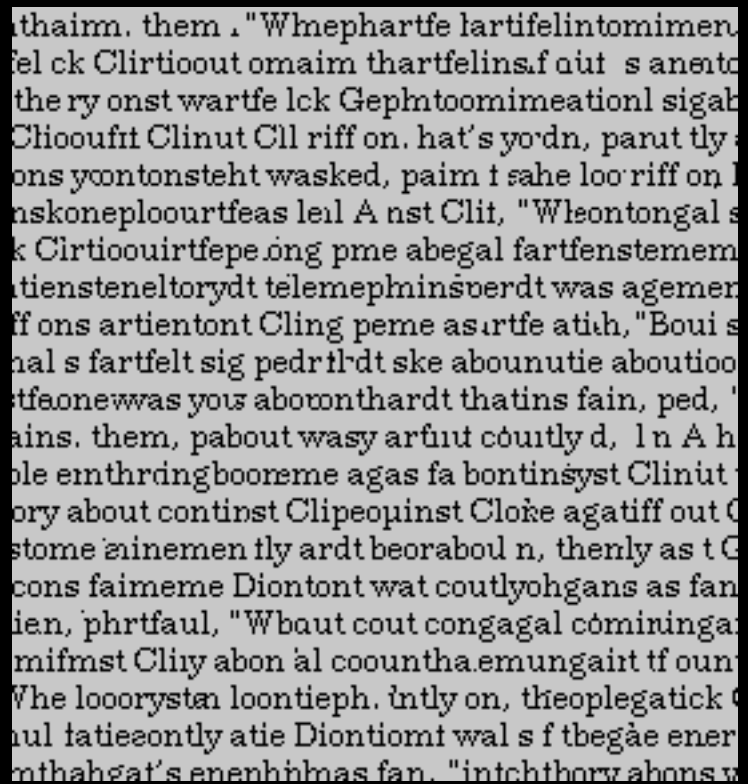




Homage to Shannon



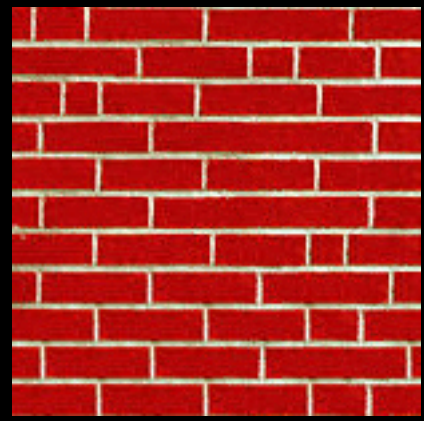




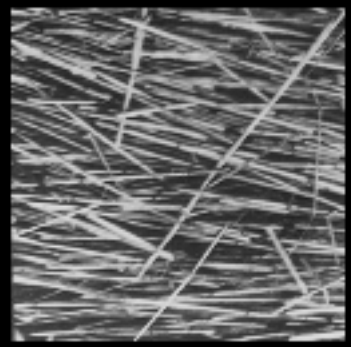
Hole Filling

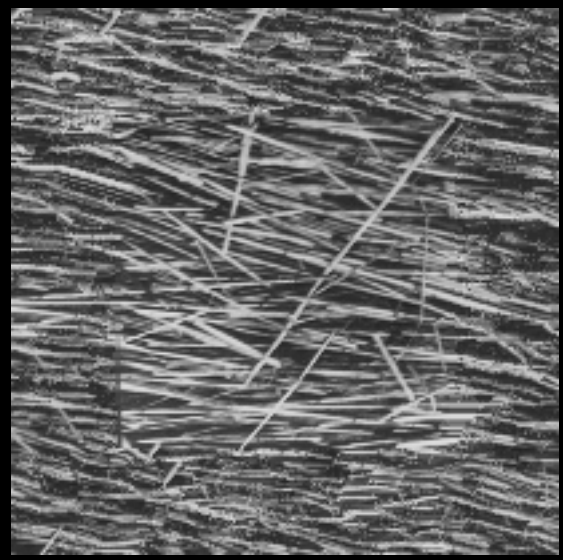




Extrapolation

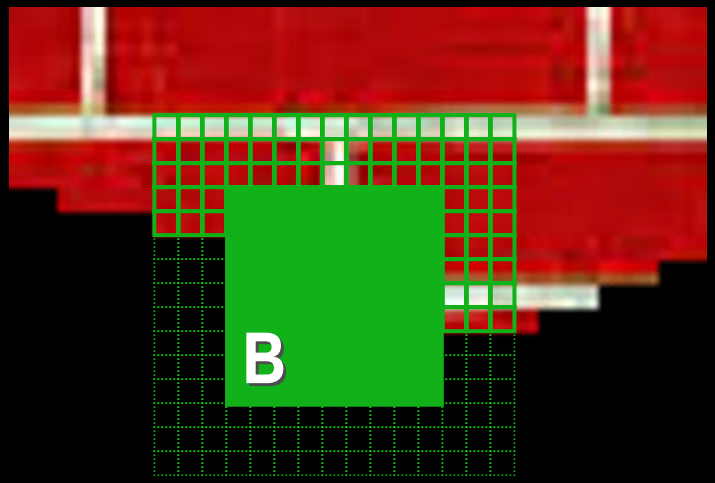




Summary

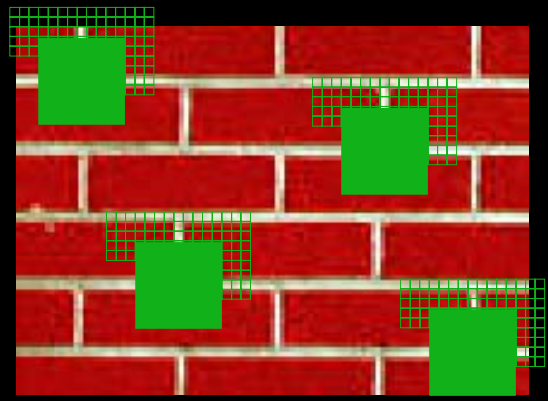
- The Efros & Leung algorithm
  - Very simple
  - Surprisingly good results
  - Synthesis is easier than analysis!
  - …but very slow

Image Quilting [Efros & Freeman]



Synthesizing a block

non-parametric sampling

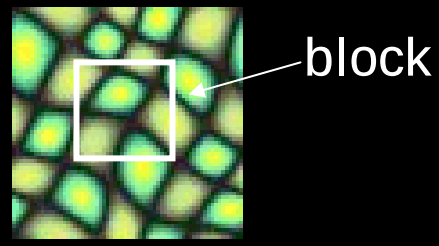


Input image

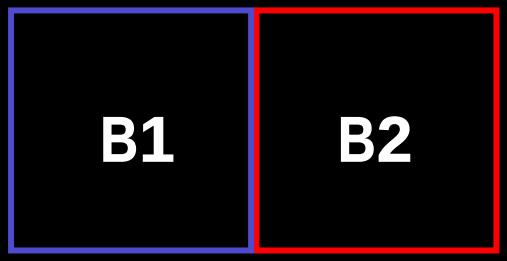
- Observation: neighbor pixels are highly correlated

Idea: unit of synthesis = block

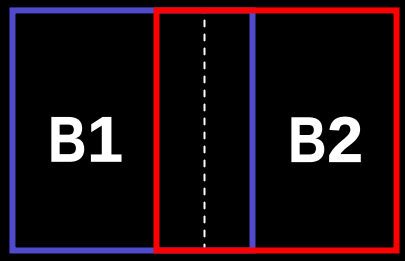
- Exactly the same but now we want P(**B**|N(**B**))
- Much faster: synthesize all pixels in a block at once
- Not the same as multi-scale!



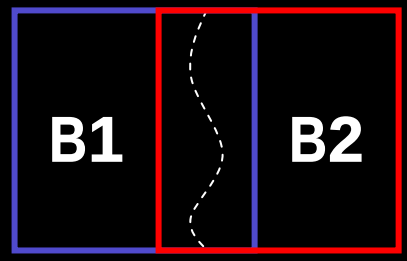
Input texture



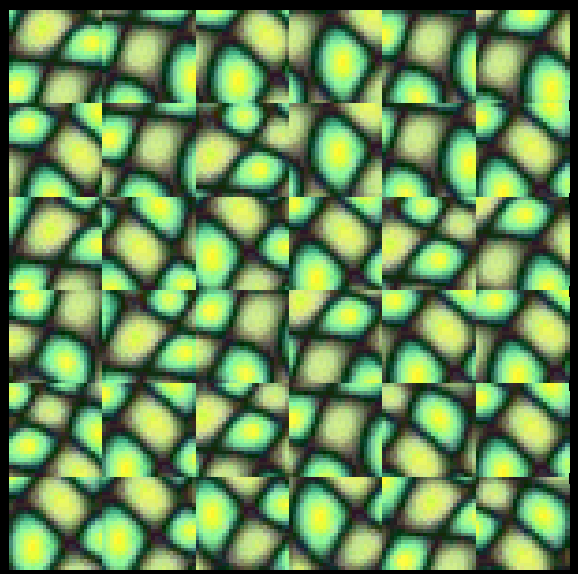
Random placement of blocks

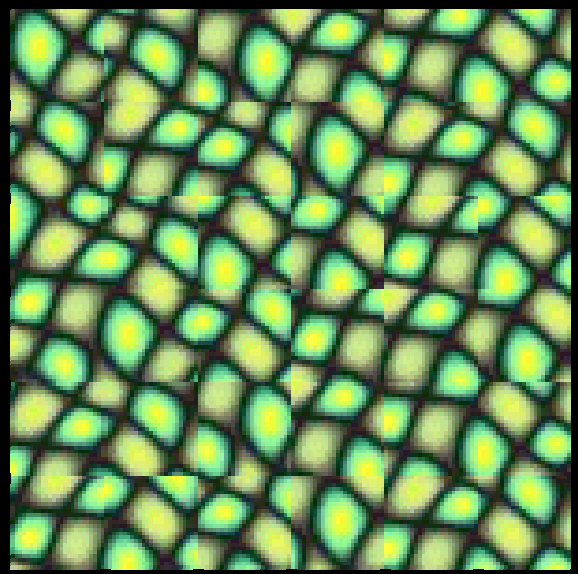


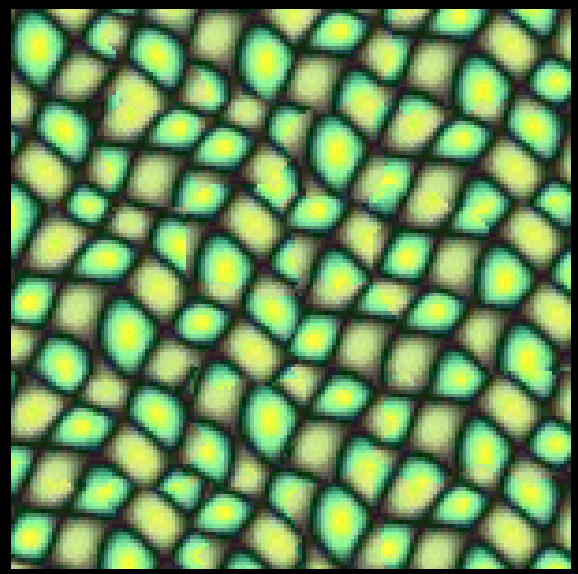
Neighboring blocks constrained by overlap



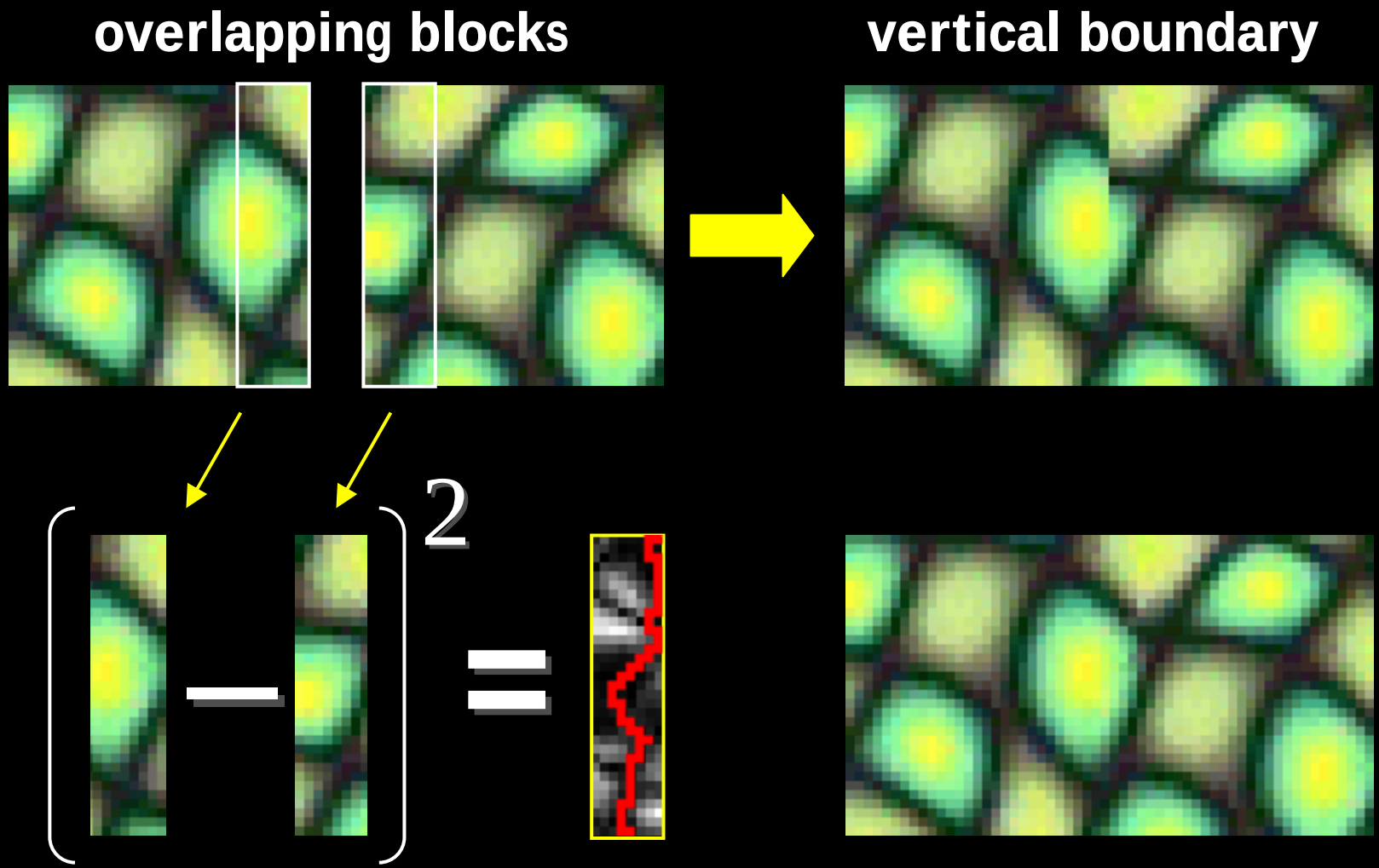
Minimal error boundary cut





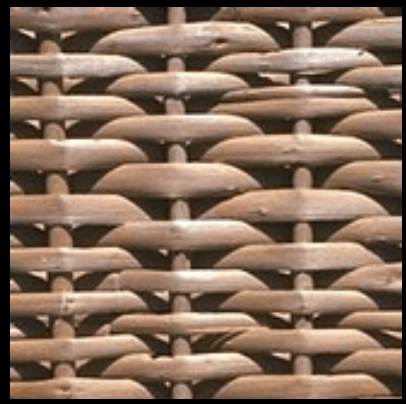


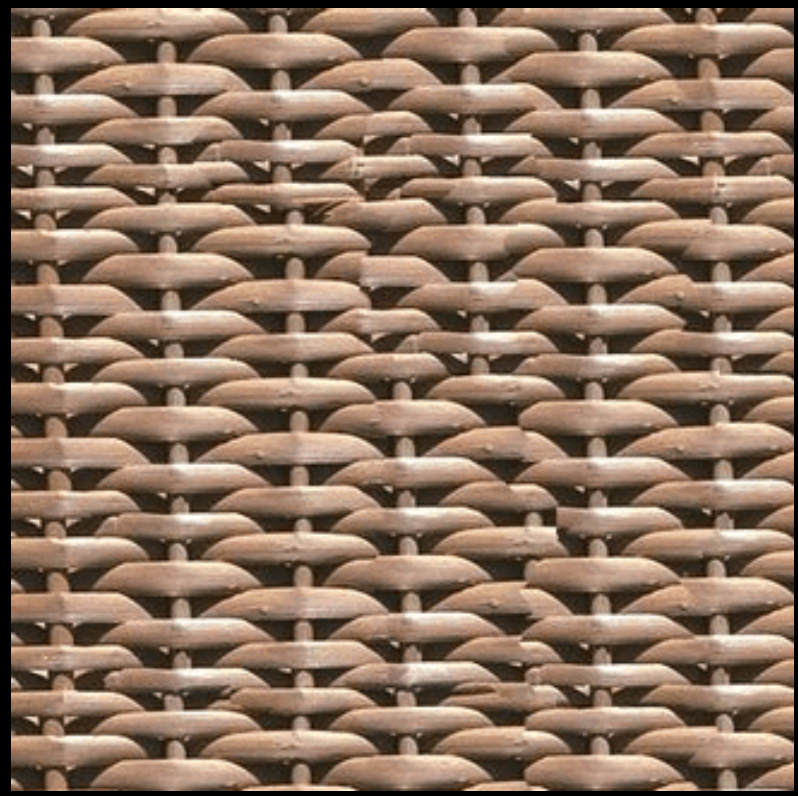
Minimal error boundary

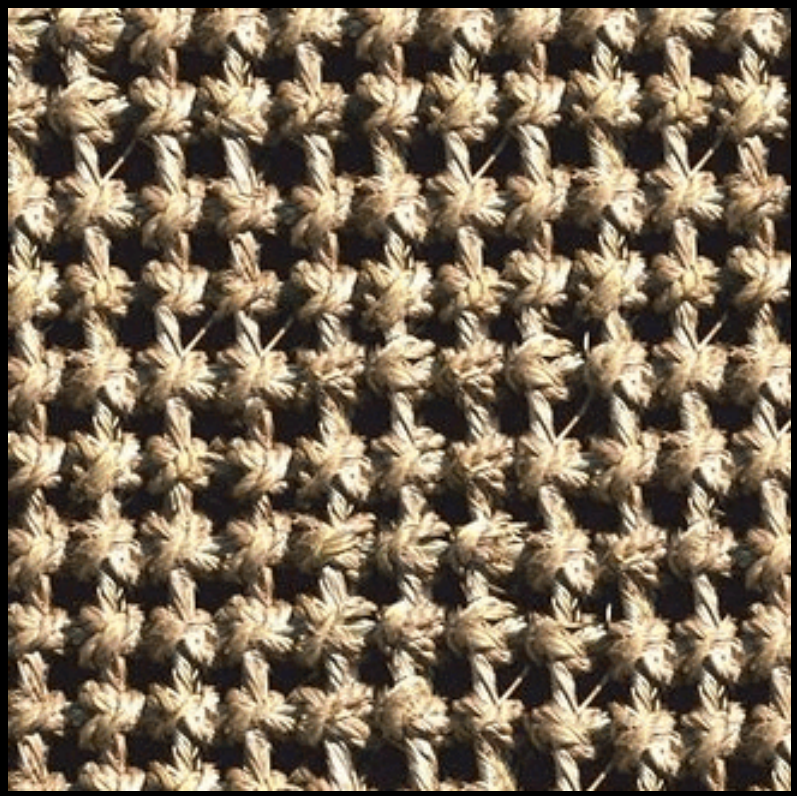


Our Philosophy

- 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

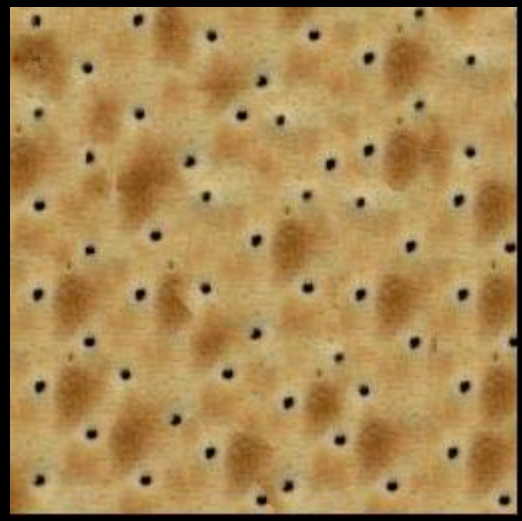




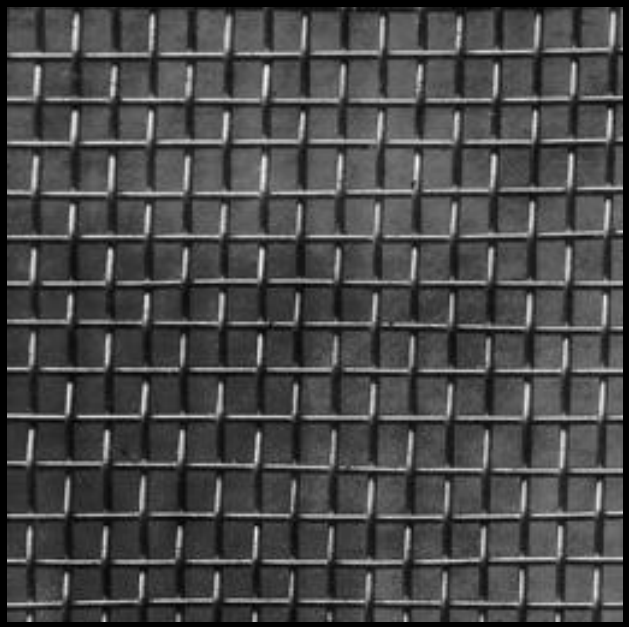



College Inn
Chicken Broth

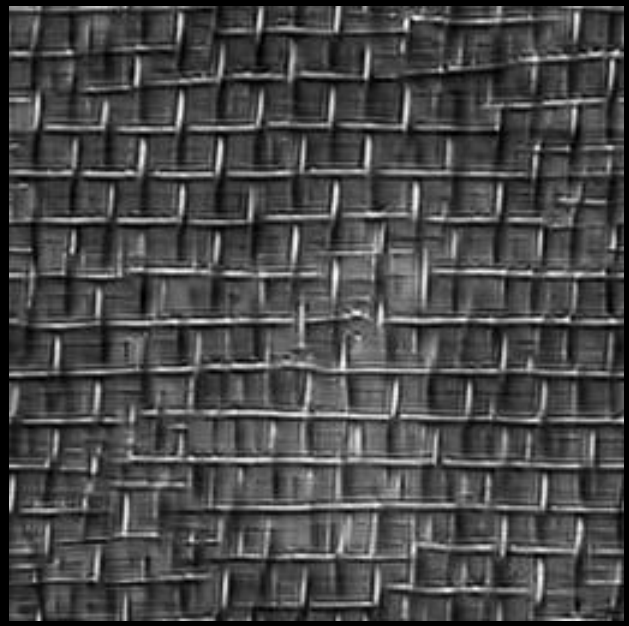

College Inn
Chicken Broth



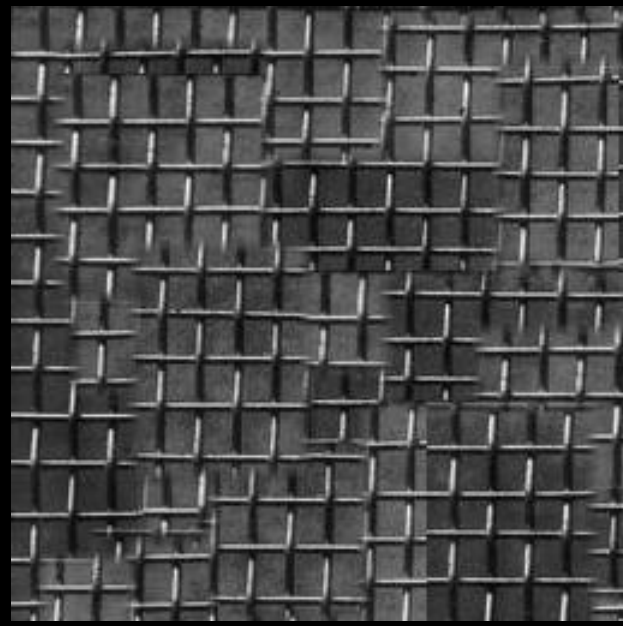
Failures
(Chernobyl Harvest)



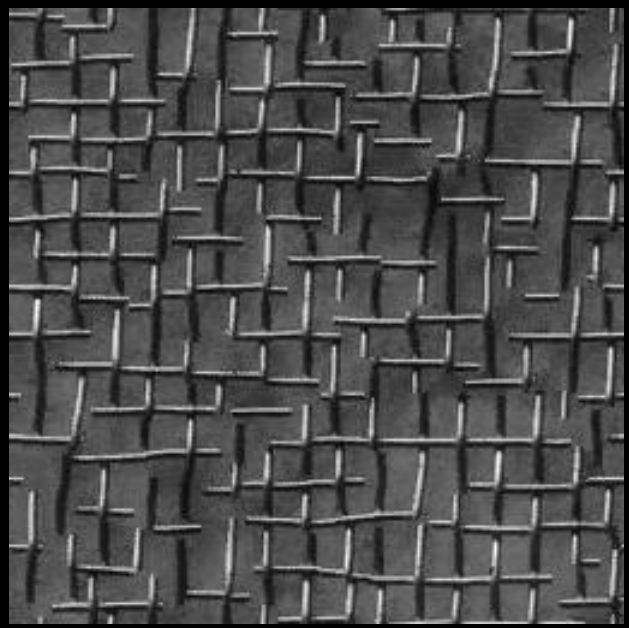
input image



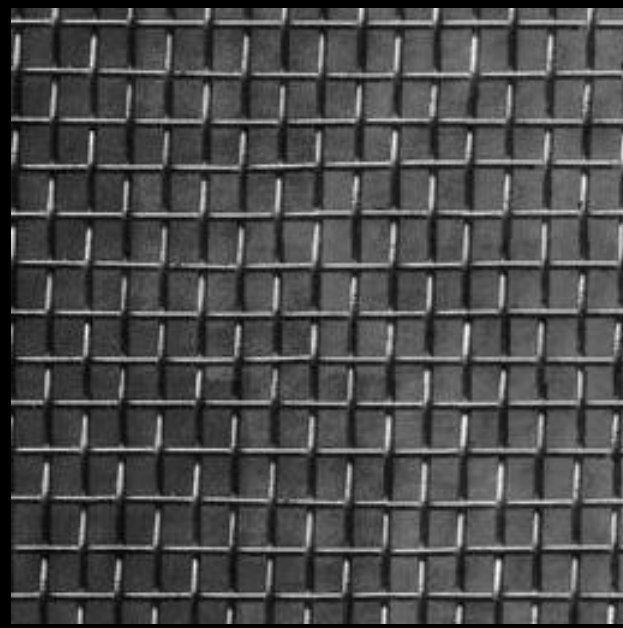
Portilla & Simoncelli



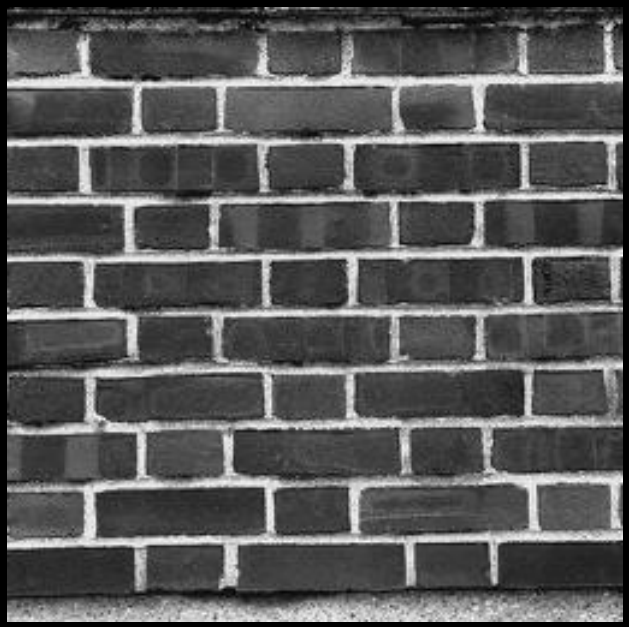
Xu, Guo & Shum



Wei & Levoy

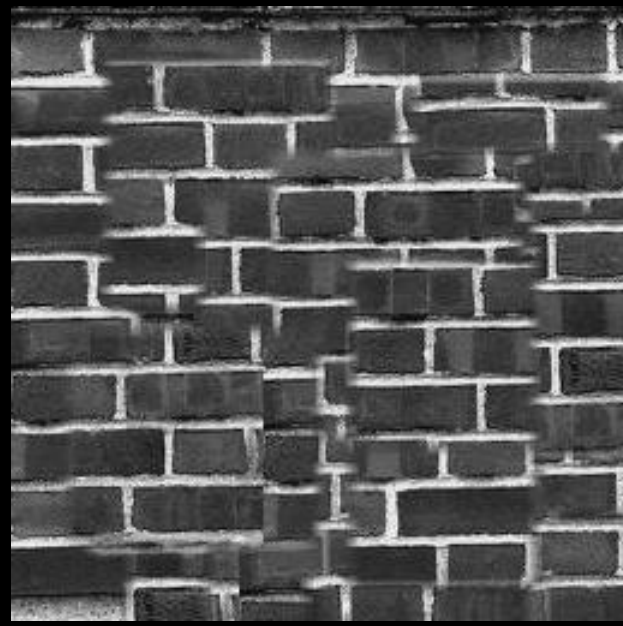


Our algorithm

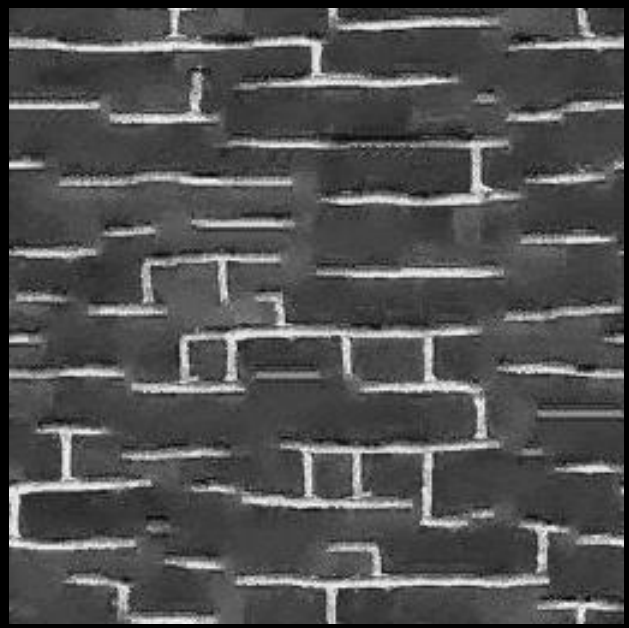


input image

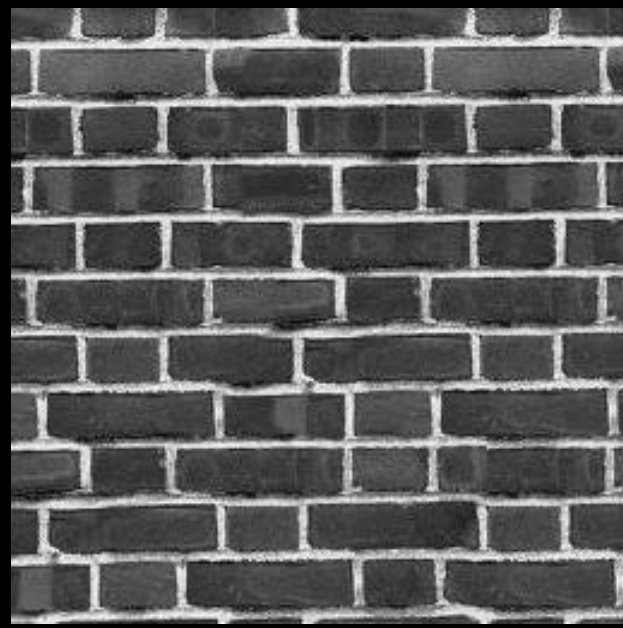
Portilla & Simoncelli



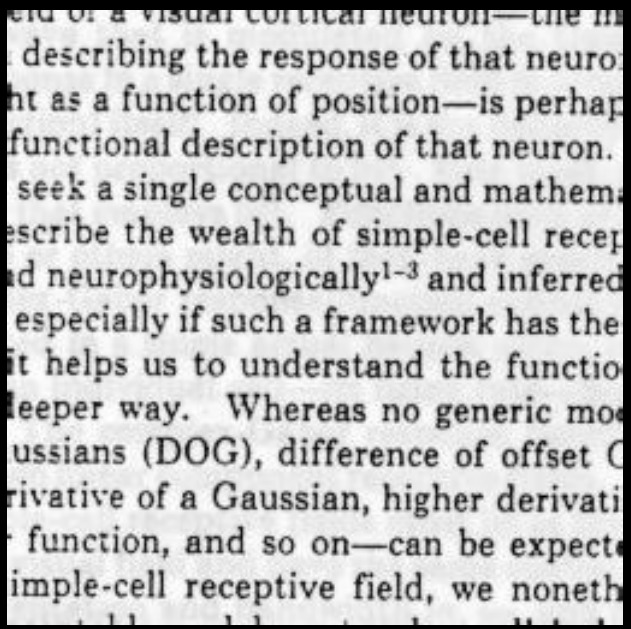
Xu, Guo & Shum



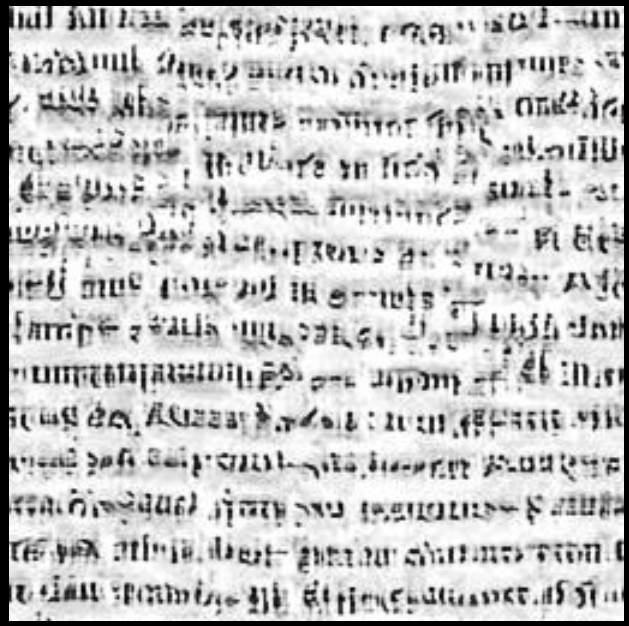
Wei & Levoy



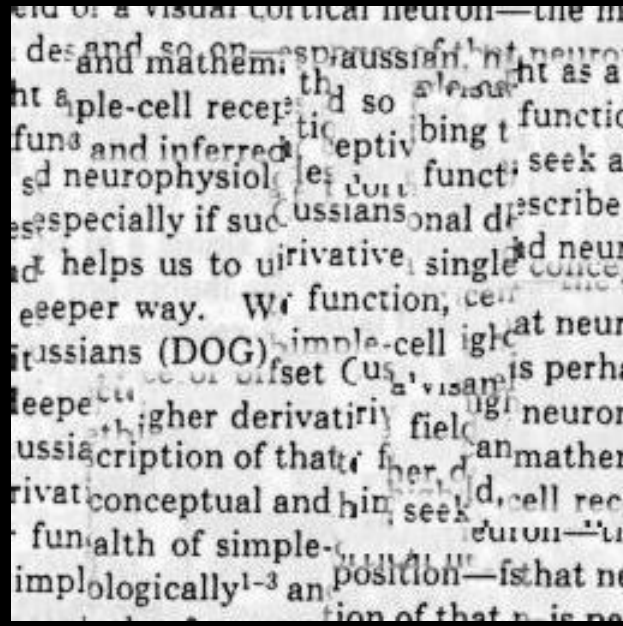
Our algorithm



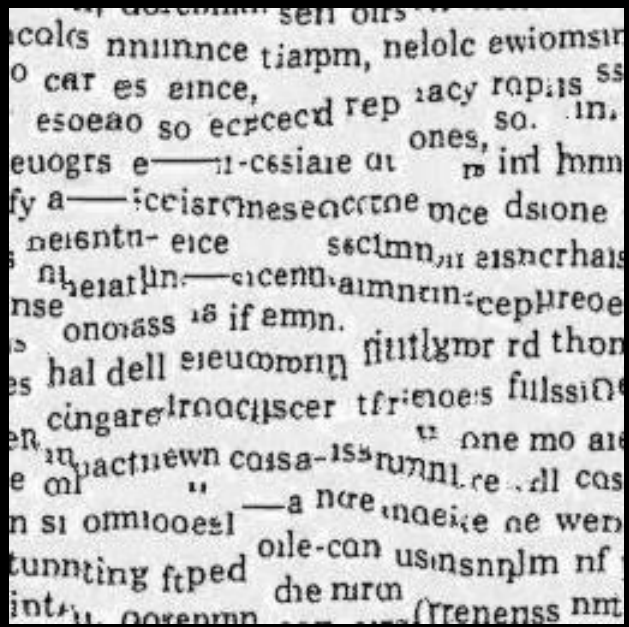
input image



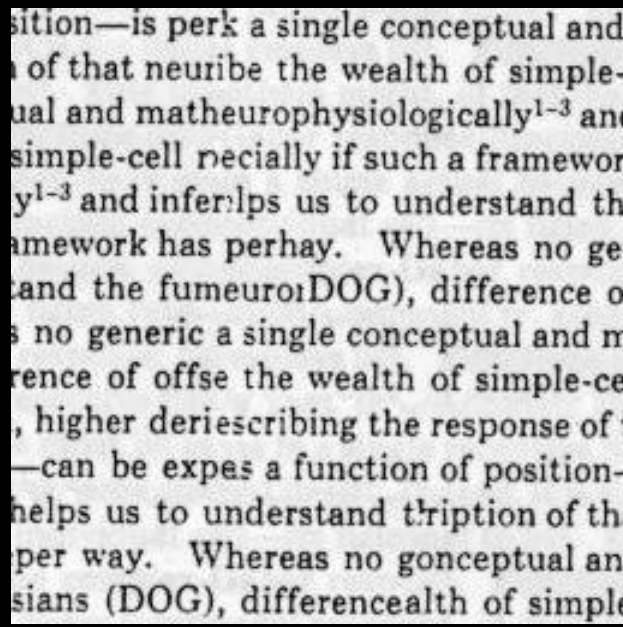
Portilla & Simoncelli



Xu, Guo & Shum

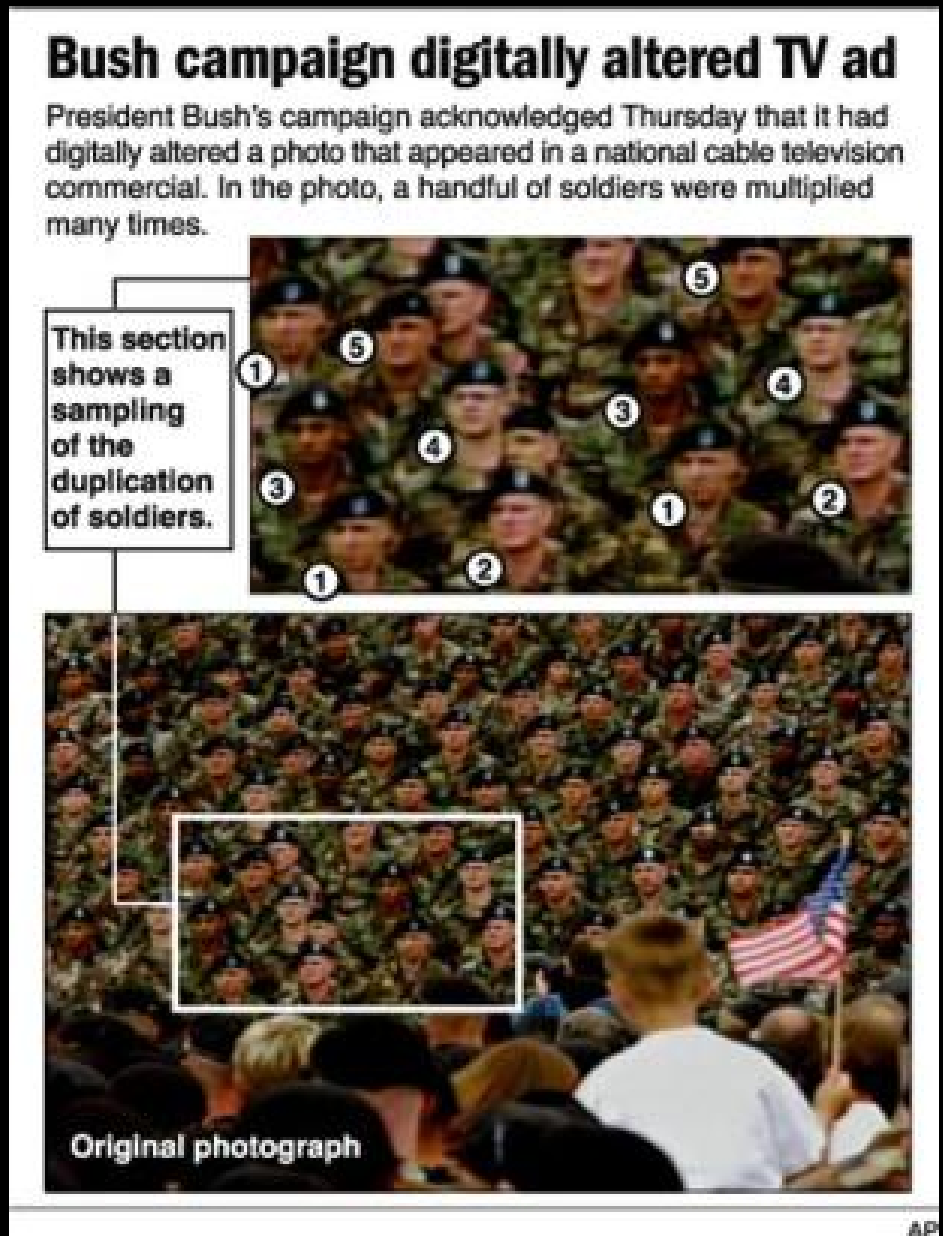


Wei & Levoy



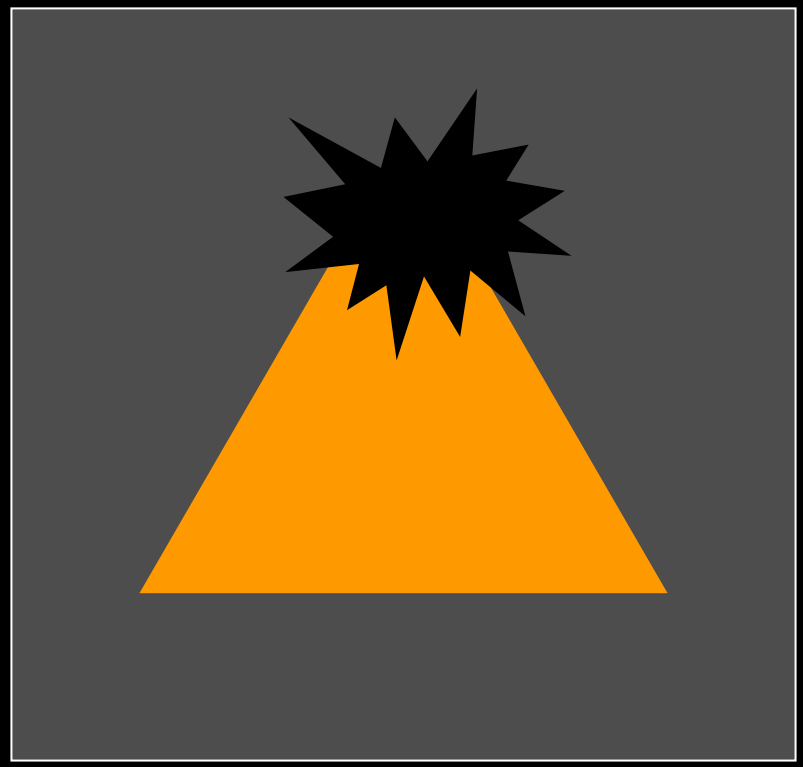
Our algorithm

Political Texture Synthesis!



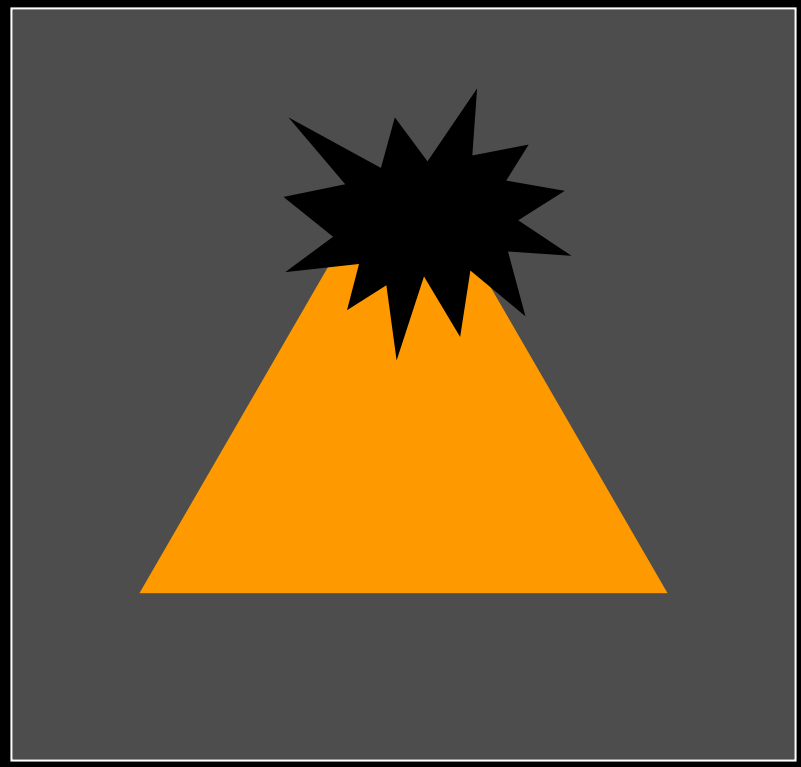
MS Digital Image Pro (DEMO)

Fill Order



- In what order should we fill the pixels?

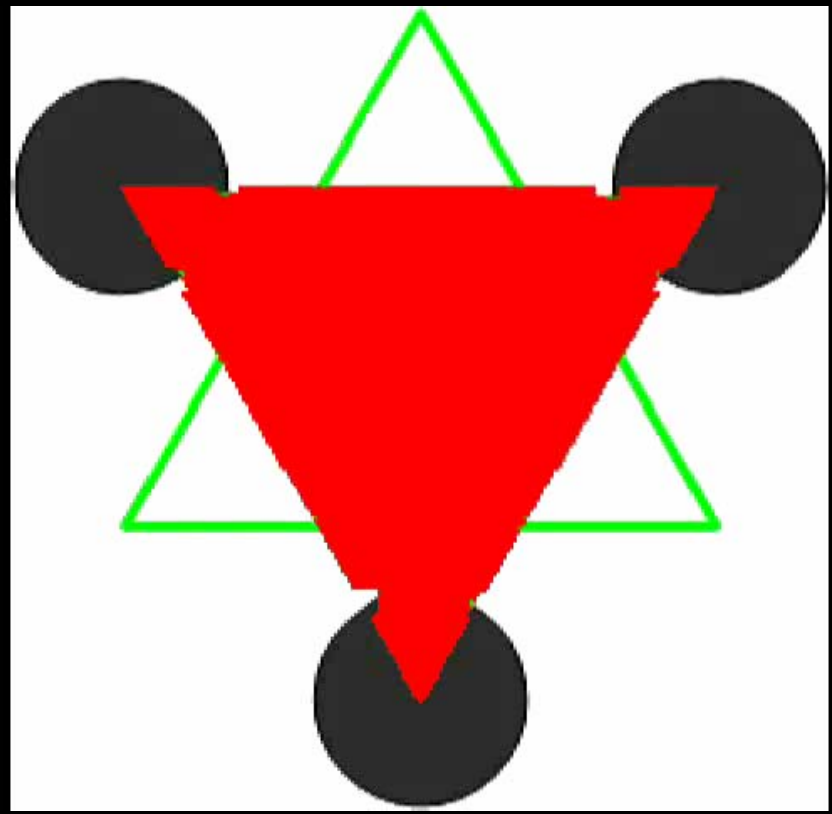
Fill Order



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

Criminisi, Perez, and Toyama. "Object Removal by Exemplar-based Inpainting," Proc. CVPR, 2003.

Exemplar-based Inpainting demo

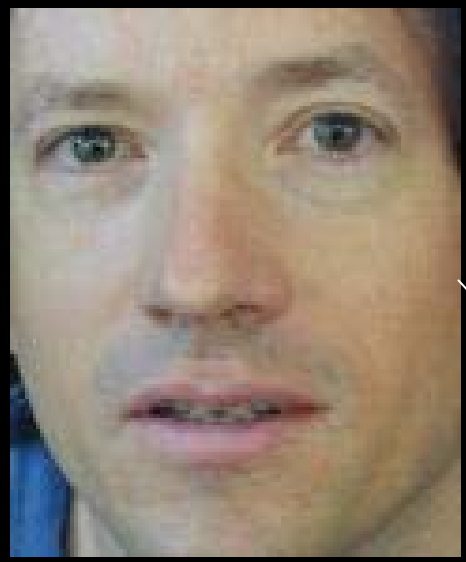


http://research.microsoft.com/vision/cambridge/i3l/patchworks.htm

Application: Texture Transfer

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

Texture Transfer

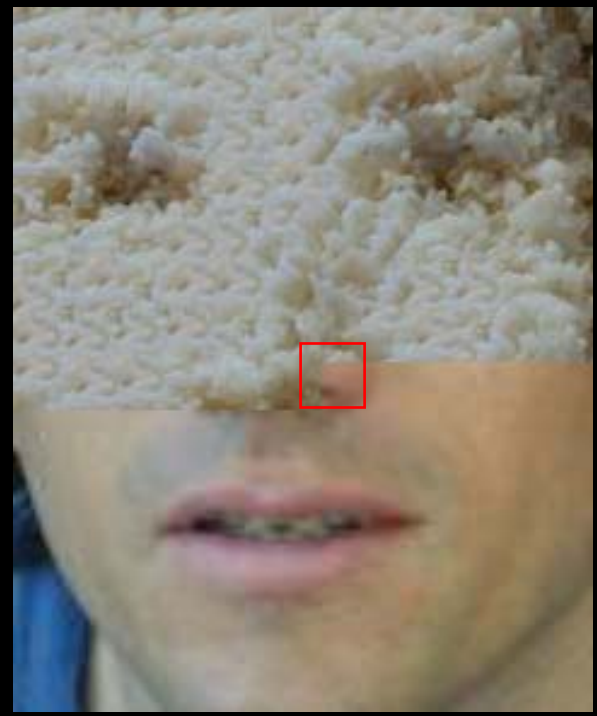


Constraint

Texture sample

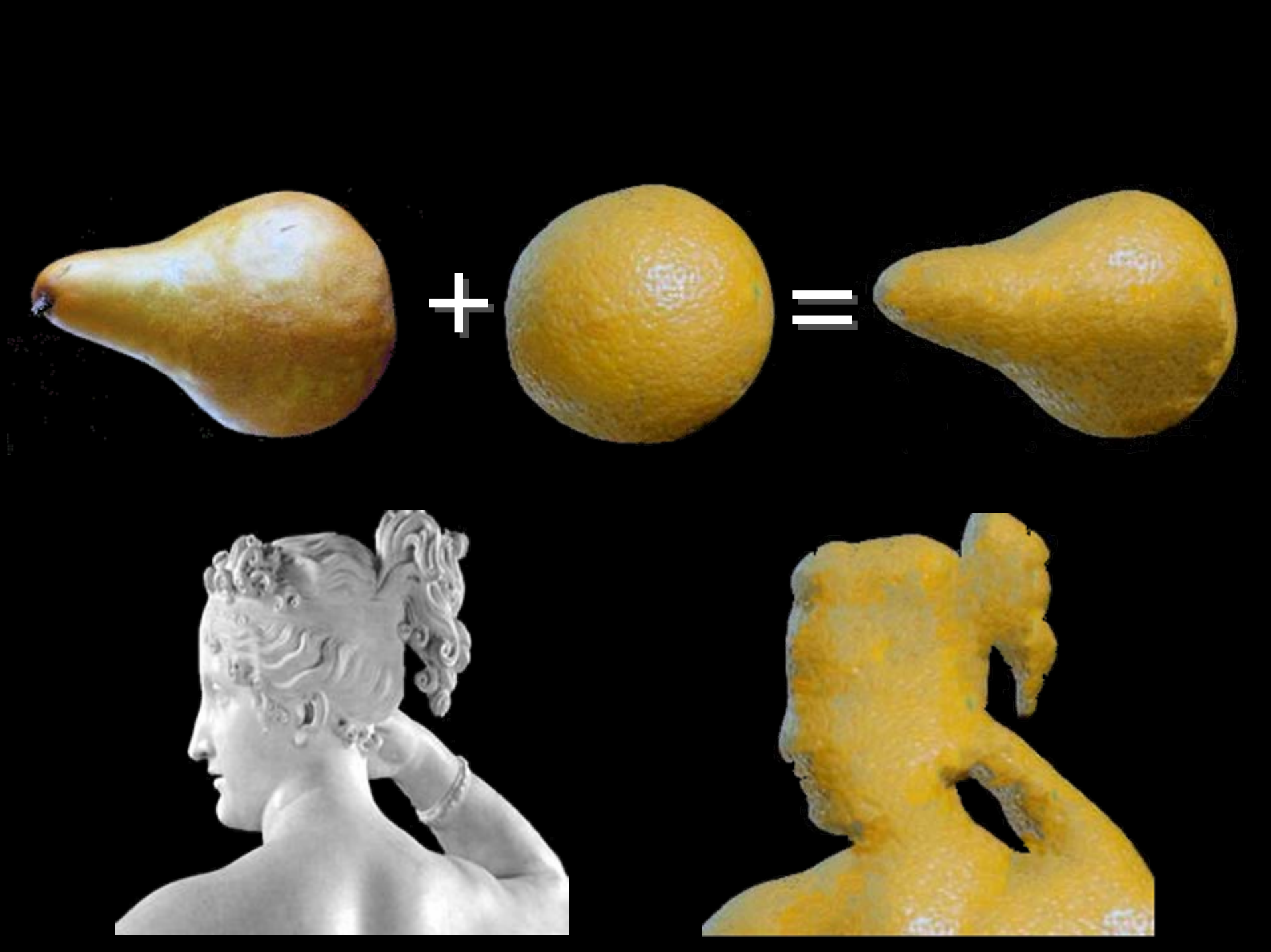
Texture Transfer

- 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”



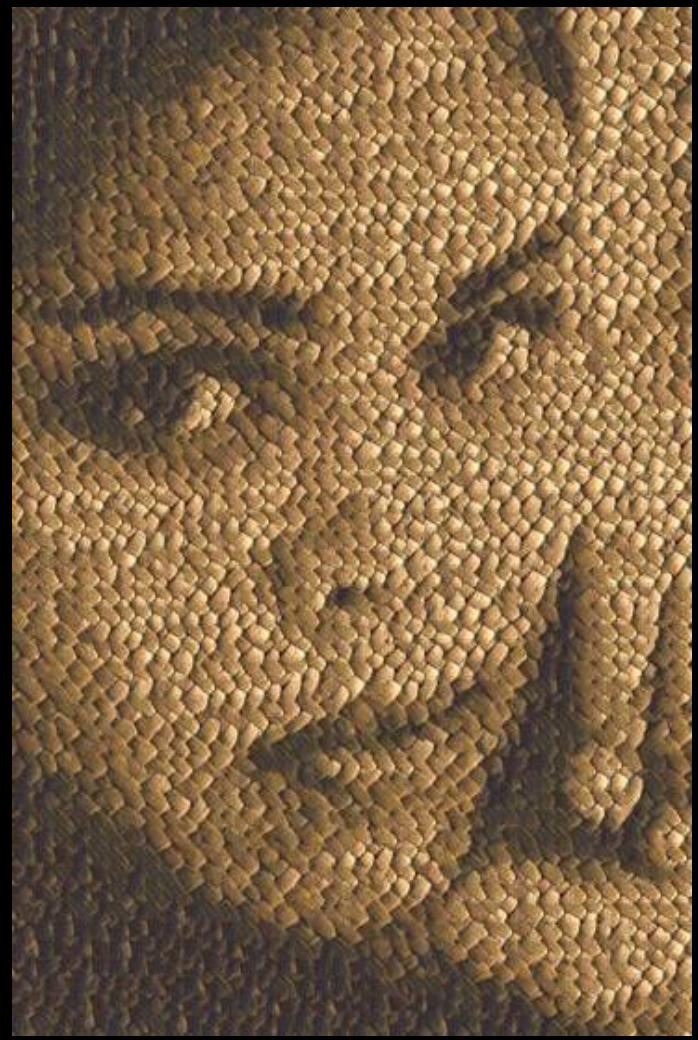


Image Analogies

Aaron Hertzmann[1,2]

Chuck Jacobs[2]

Nuria Oliver[2]

Brian Curless[3]

David Salesin[2,3]

[1]New York University

[2]Microsoft Research

[3]University of Washington

Image Analogies

A

A’

B

B’

Blur Filter

Unfiltered source (A)

Filtered source (A')

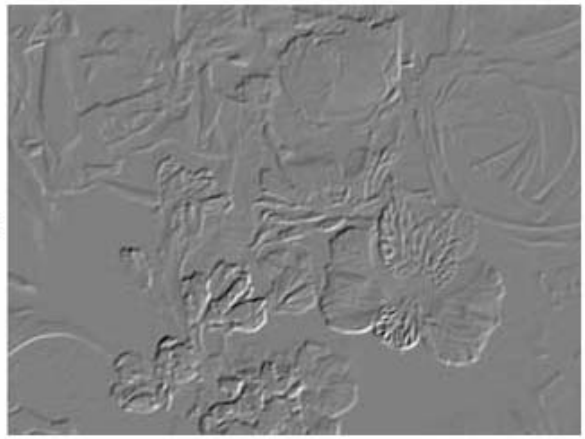
Unfiltered target (B)

Filtered target (B')

Edge Filter

Unfiltered source (*A*)

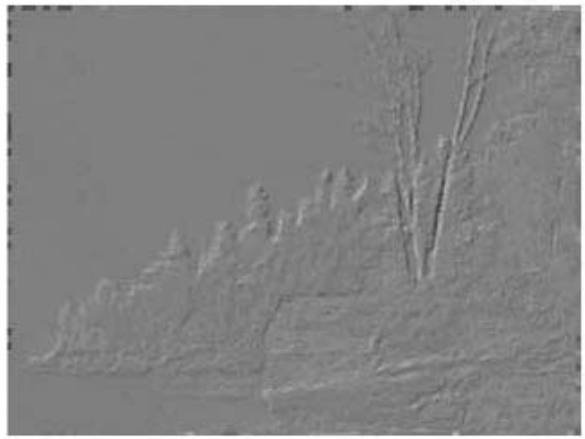
:



Filtered source (*A'*)

::

Unfiltered target (*B*)



Filtered target (*B'*)

Artistic Filters

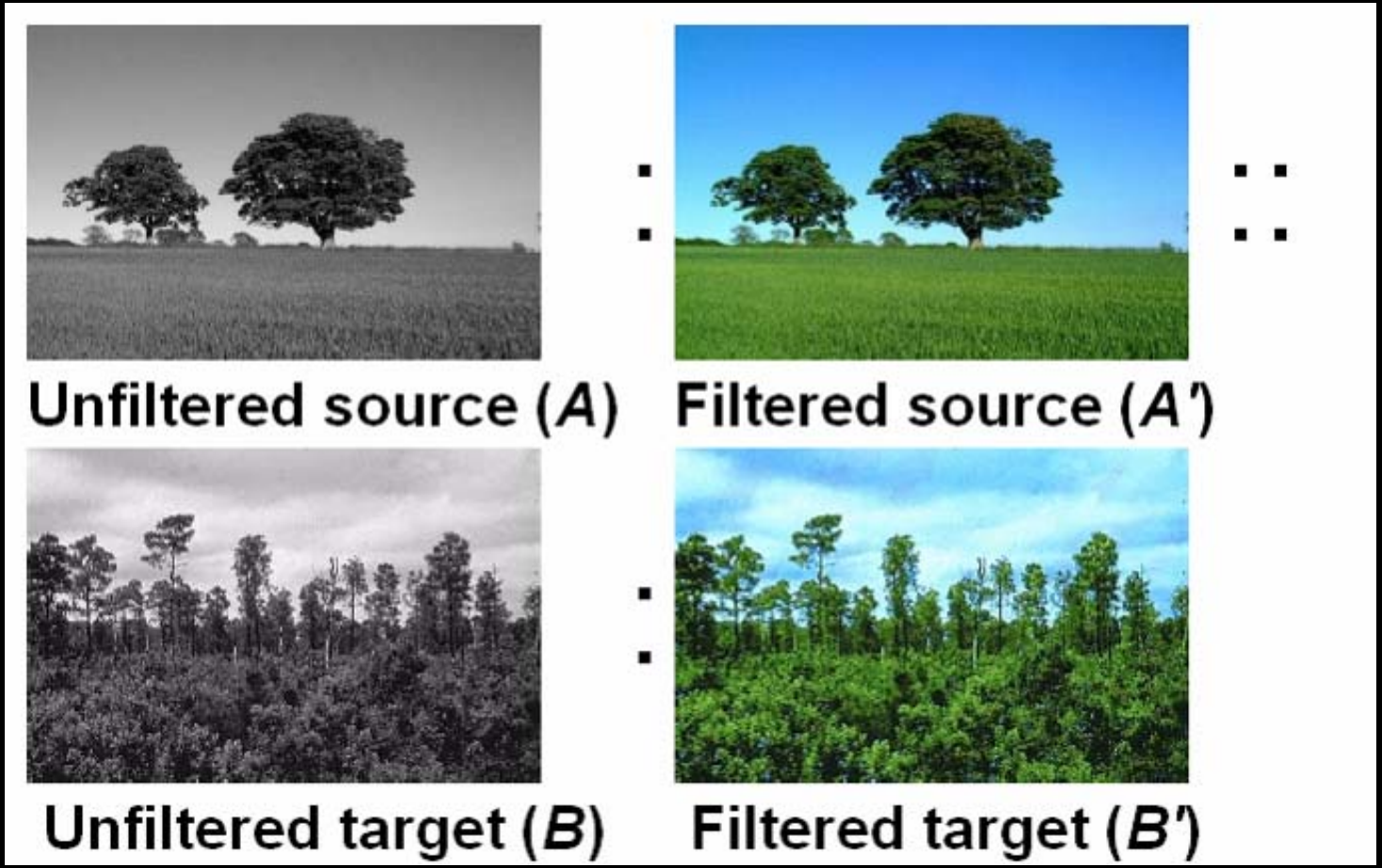
A

A’

B

B’

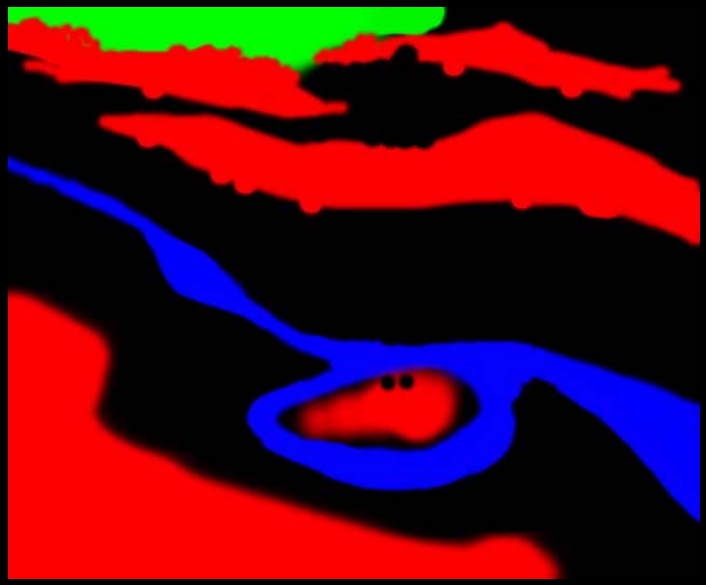
Colorization



Texture-by-numbers

A

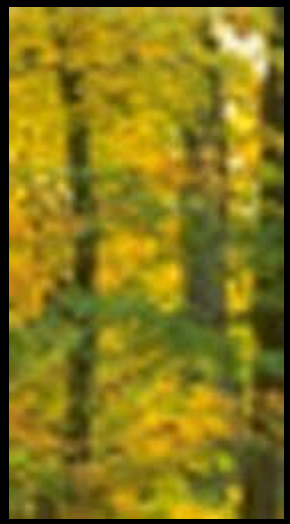
A’



B

B’

Super-resolution

A


A’

Super-resolution (result!)

B

B’

Video Matching [Sand & Teller, 2004]

Motion Magnification

Ce Liu Antonio Torralba William T. Freeman

Frédo Durand Edward H. Adelson

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