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







rocks



yogurt

Texture Synthesis

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

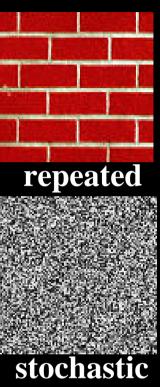






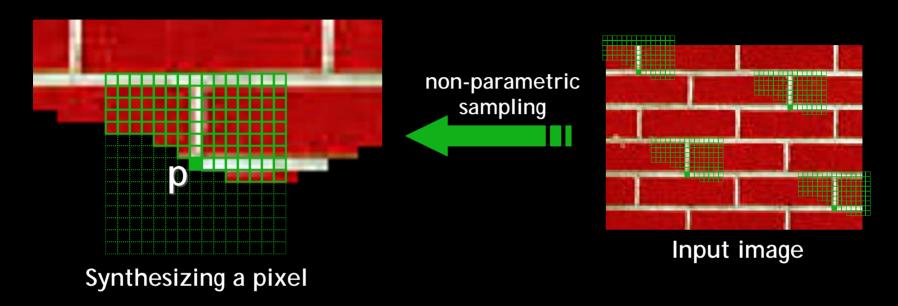
The Challenge

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





Efros & Leung Algorithm

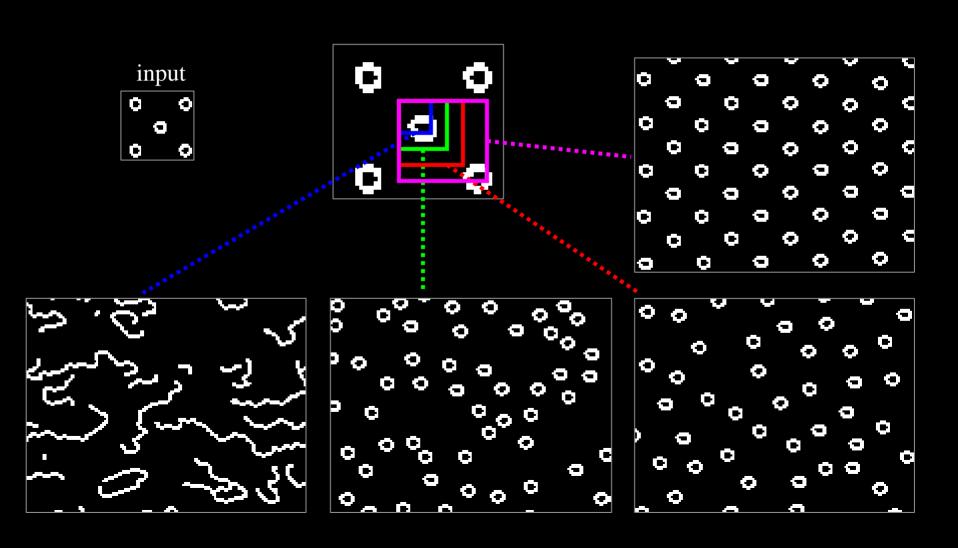


- Assuming Markov property, compute $P(\mathbf{p}|N(\mathbf{p}))$
 - Building explicit probability tables infeasible
 - Instead, we search the input image for all similar neighborhoods that's our pdf for p
 - To sample from this pdf, just pick one match at random

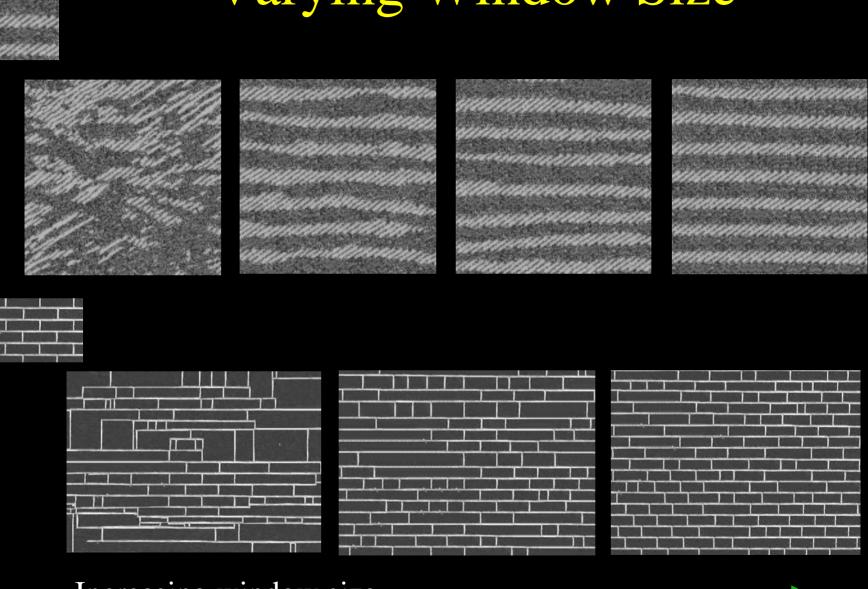
Some Details

- 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

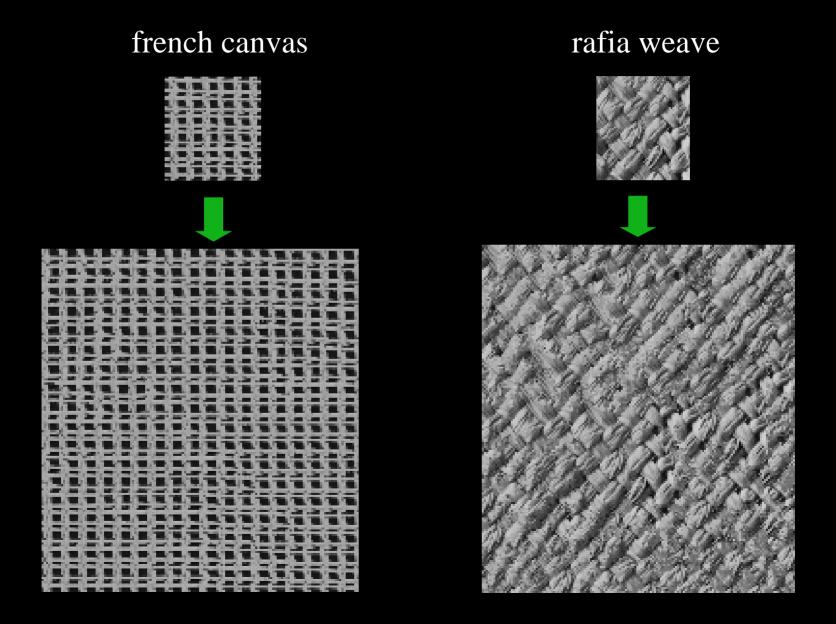


Varying Window Size

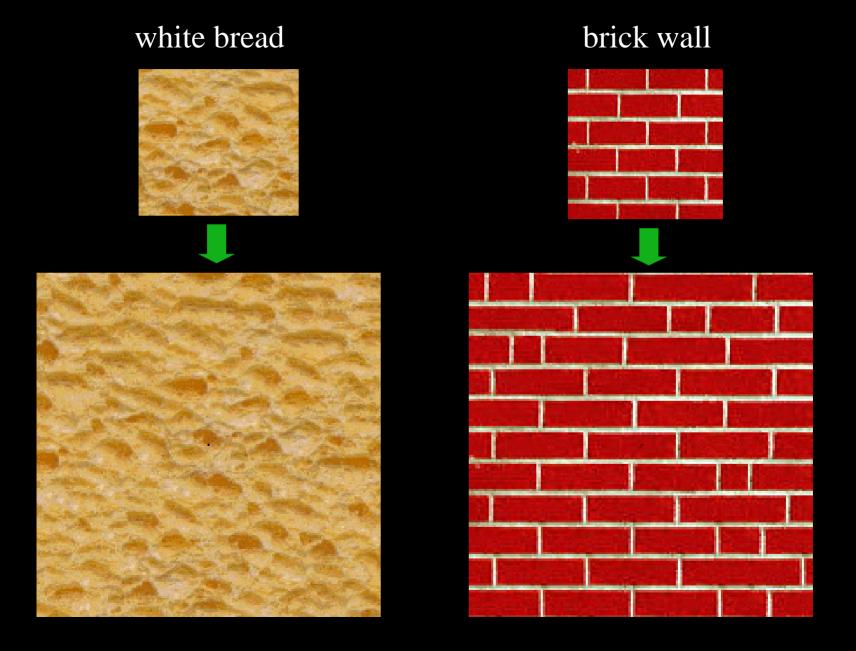


Increasing window size

Synthesis Results



More Results



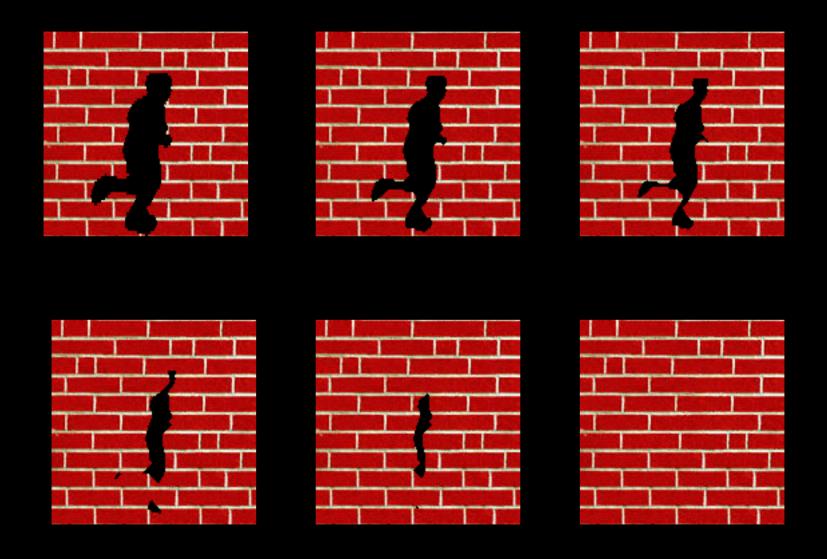
Homage to Shannon

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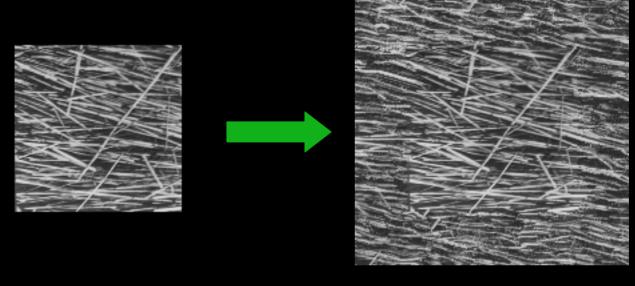
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Hole Filling



Extrapolation





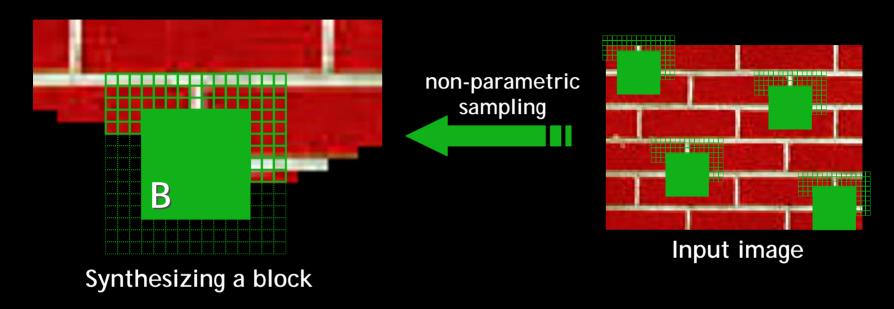




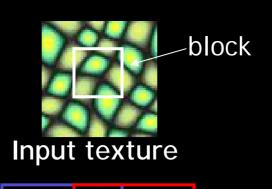
Summary

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

Image Quilting [Efros & Freeman]

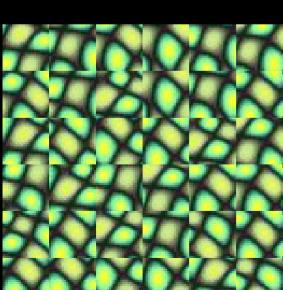


- Observation: neighbor pixels are highly correlated
- Idea: unit of synthesis = block
 - Exactly the same but now we want P(B|N(B))
 - Much faster: synthesize all pixels in a block at once
 - Not the same as multi-scale!



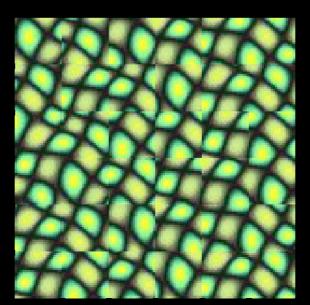
B1 B2

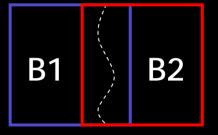
Random placement of blocks



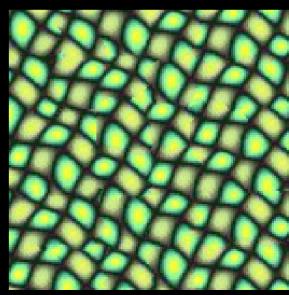
B1 B2

Neighboring blocks constrained by overlap

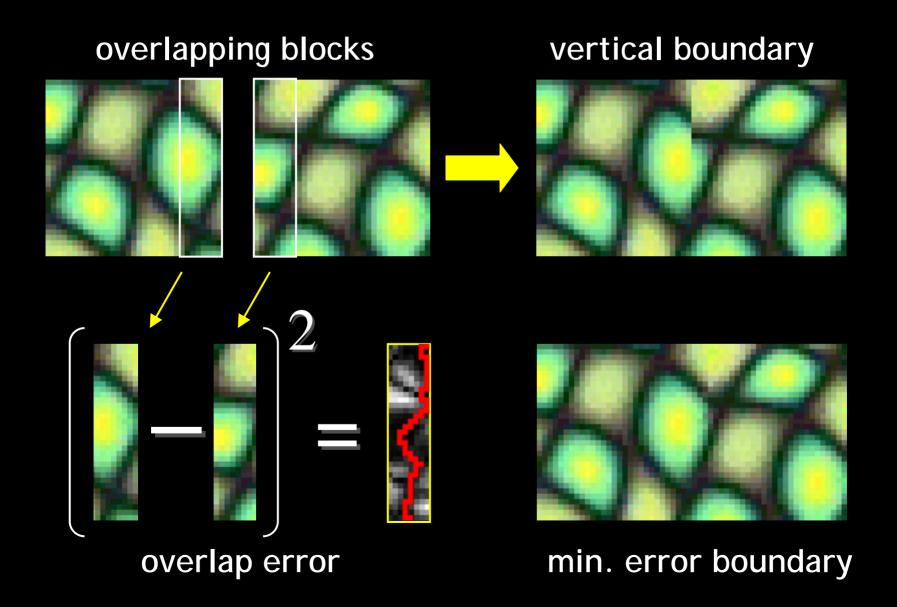




Minimal error boundary cut



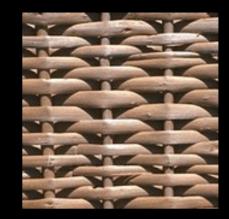
Minimal error boundary



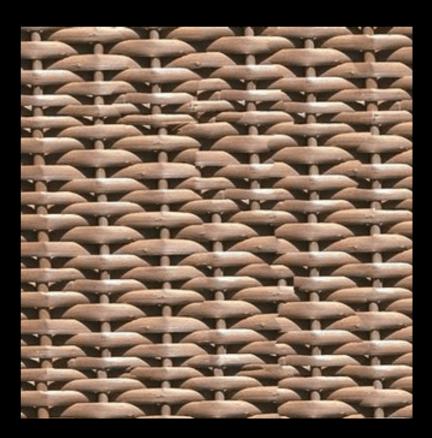
Our Philosophy

- 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



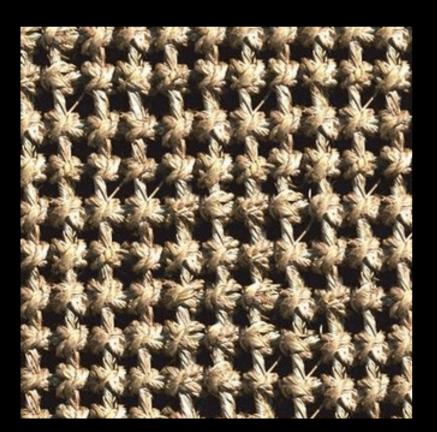




























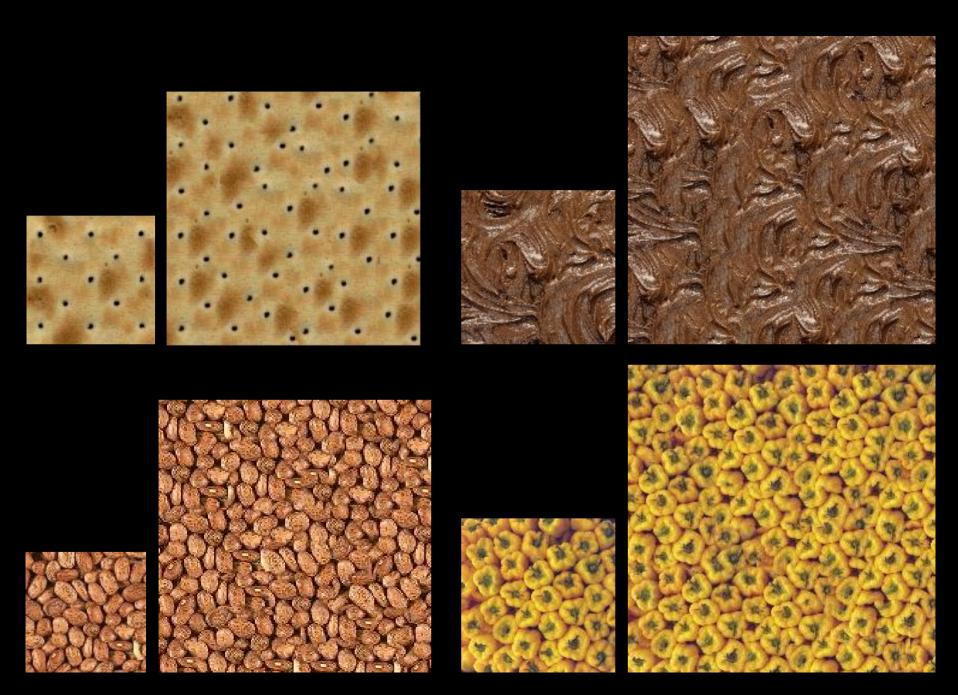












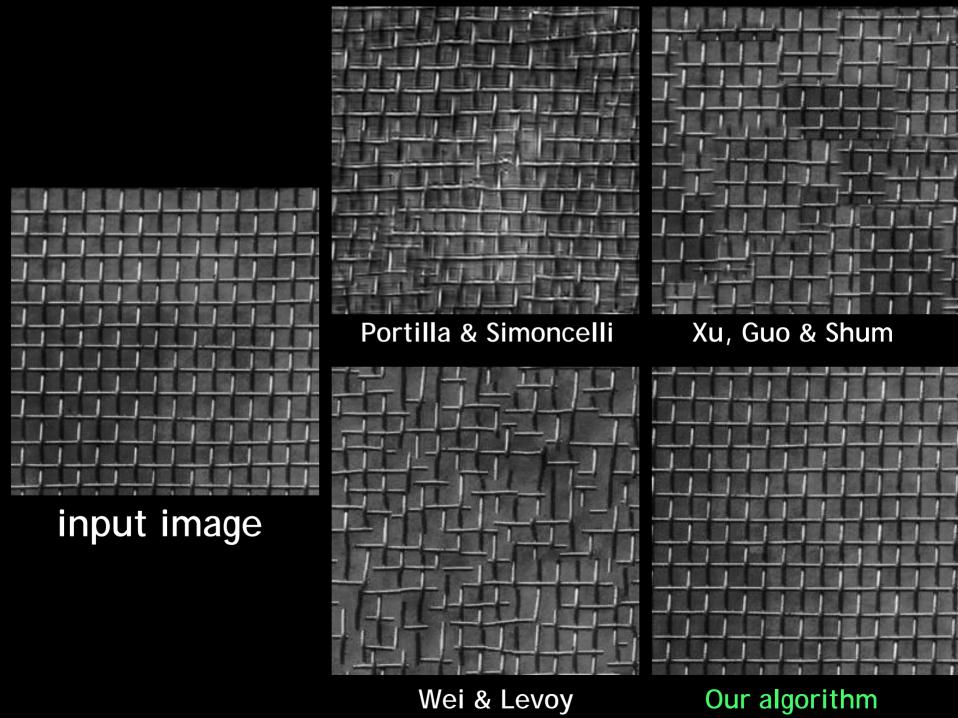


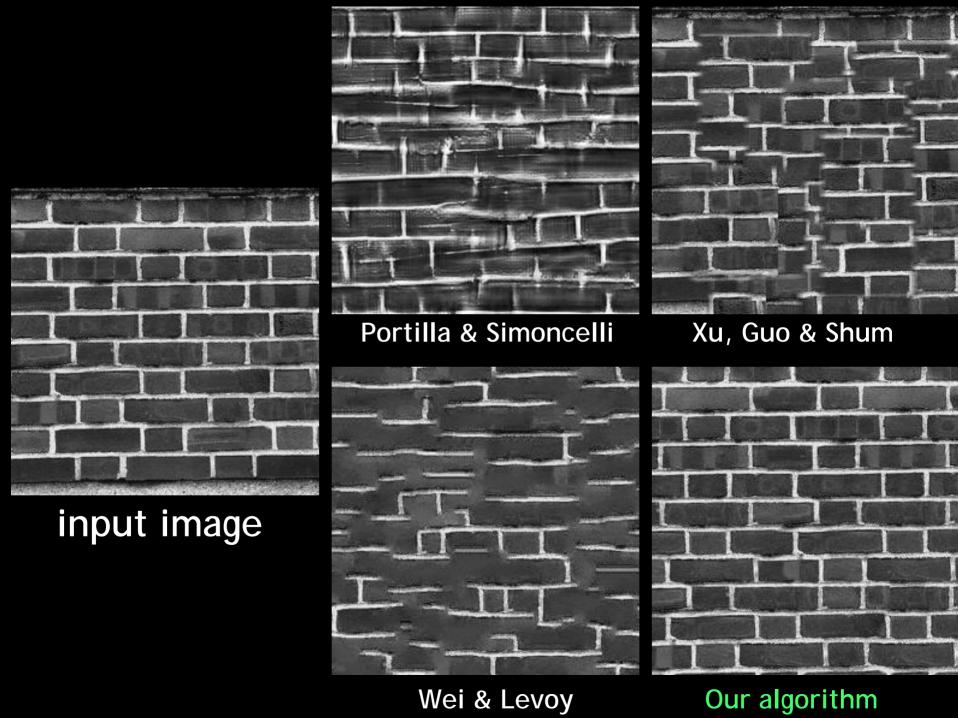
Failures (Chernobyl Harvest)











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Xu, Guo & Shum

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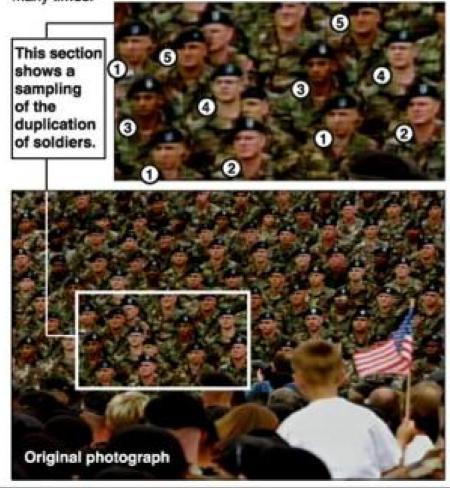
Wei & Levoy

Our algorithm

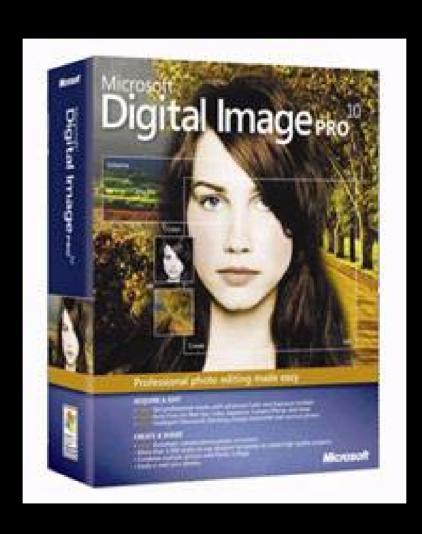
Political Texture Synthesis!

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.



MS Digital Image Pro (DEMO)



Fill Order



• In what order should we fill the pixels?

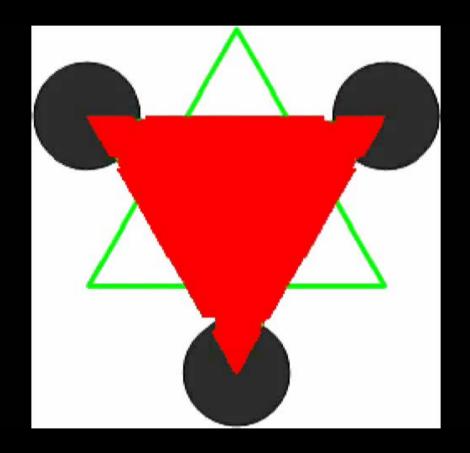
Fill Order



- 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



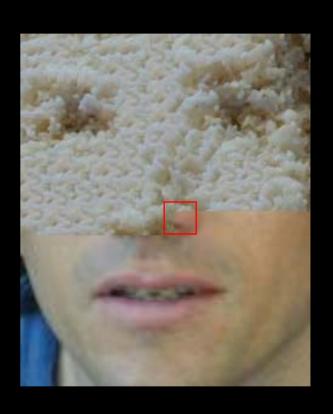


Texture sample

Texture Transfer

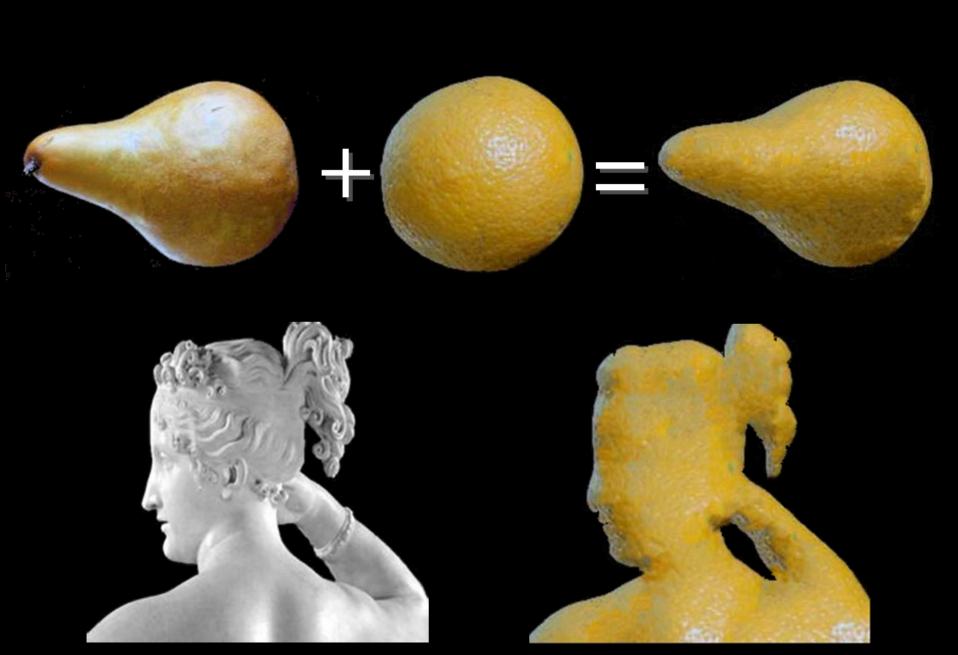
 Take the texture from one image and "paint" it onto another object





Same as texture synthesis, except an additional constraint:

- 1. Consistency of texture
- 2. Similarity to the image being "explained"







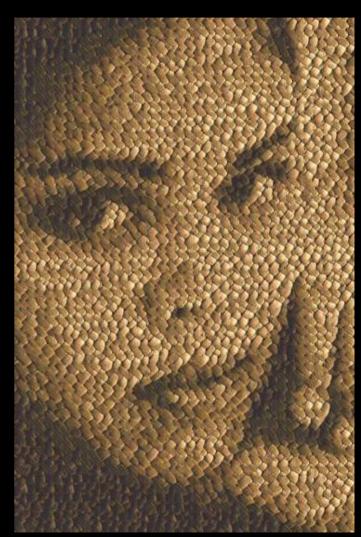


Image Analogies

Aaron Hertzmann^{1,2}

Chuck Jacobs²

Nuria Oliver²

Brian Curless³

David Salesin^{2,3}

¹New York University

²Microsoft Research

³University of Washington

Image Analogies



A



A'



B



В'



Blur Filter



Unfiltered source (A)



Filtered source (A')



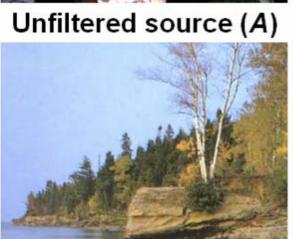
Unfiltered target (B)



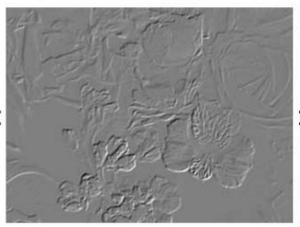
Filtered target (B')

Edge Filter

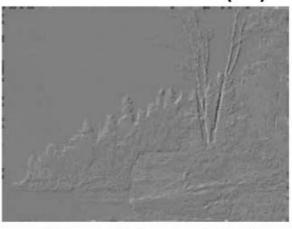




Unfiltered target (B)

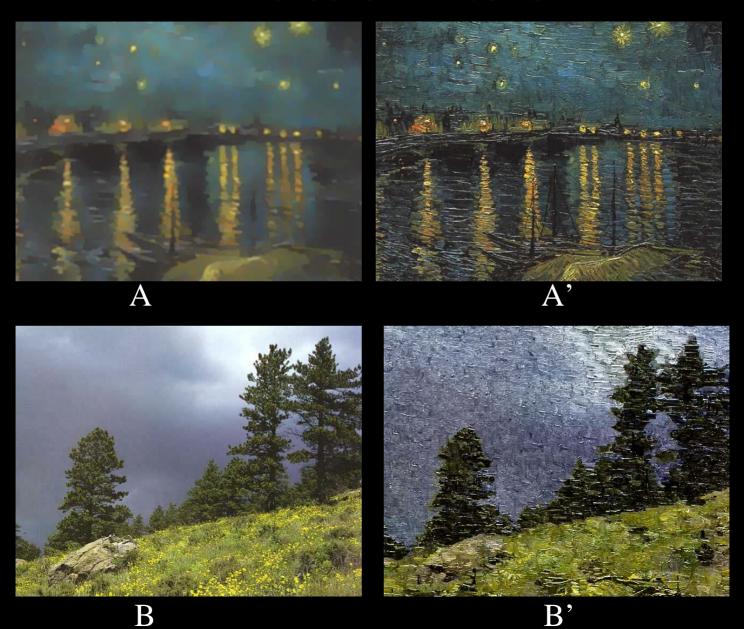


Filtered source (A')



Filtered target (B')

Artistic Filters



Colorization



Unfiltered source (A)



Filtered source (A')

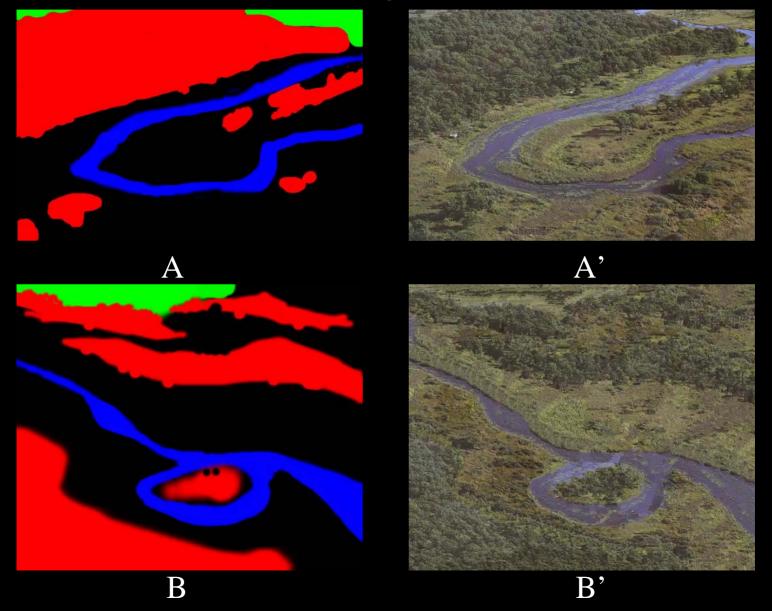


Unfiltered target (B)



Filtered target (B')

Texture-by-numbers



Super-resolution





A

Super-resolution (result!)





B'

Video Matching [Sand & Teller, 2004]



Motion Magnification

Ce Liu Antonio Torralba William T. Freeman Frédo Durand Edward H. Adelson

Computer Science and Artificial Intelligence Laboratory

Massachusetts Institute of Technology