SIGGRAPH 2001

Image Quilting for Texture Synthesis & Transfer

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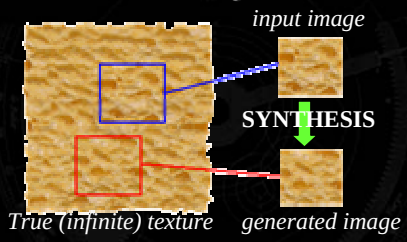
The Goal of Texture Synthesis



Given a finite sample of some texture, the goal is to synthesize other samples from that same texture

- The sample needs to be "large enough"

The Challenge

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


repeated


stochastic


Both?

Texture Synthesis for Graphics

Inspired by Texture Analysis and Psychophysics

- [Heeger & Bergen,'95]
- [DeBonet,'97]
- [Portilla & Simoncelli,'98]

...but didn't work well for structured textures

- [Efros & Leung,'99]
  - (originally proposed by [Garber,'81])

Efros & Leung '99

[Shannon,'48] proposed a way to generate English-looking text using N-grams:

- Assume a generalized Markov model
- Use a large text to compute prob. distributions of each letter given N-1 previous letters
- Starting from a seed repeatedly sample this Markov chain to generate new letters
- Also works for whole words

WE NEED TO EAT CAKE

Mark V. Shaney (Bell Labs)

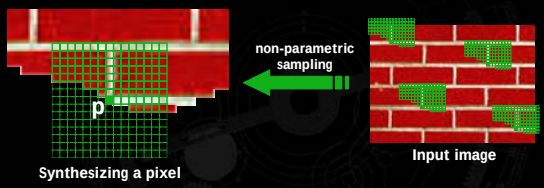
Results (using `alt.singles` corpus):

- *"As I've commented before, really relating to someone involves standing next to impossible."*
- *"One morning I shot an elephant in my arms and kissed him."*
- *"I spent an interesting evening recently with a grain of salt"*

Notice how well local structure is preserved!

- Now, instead of letters let's try pixels...

Efros & Leung ’99



Assuming Markov property, compute P(p|N(p))

- Building explicit probability tables infeasible
- Instead, let’s *search the input image* for all similar neighborhoods — that’s our histogram for **p**

To synthesize p, just pick one match at random

Efros & Leung ’99

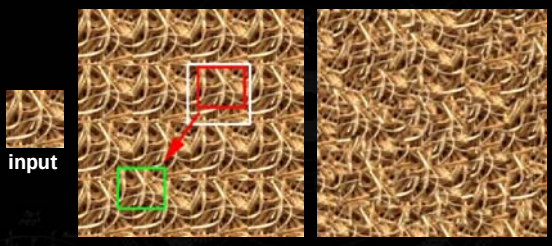
The algorithm

- Very simple
- Surprisingly good results
- Synthesis is easier than analysis!
- …but very slow

Optimizations and Improvements

- [Wei & Levoy,’00] (based on [Popat & Picard,’93])
- [Harrison,’01]
- [Ashikhmin,’01]

Chaos Mosaic [Xu, Guo & Shum, ‘00]



Process: 1) tile input image; 2) pick random blocks and place them in random locations 3) Smooth edges

Used in Lapped Textures [Praun et.al,’00]

Chaos Mosaic [Xu, Guo & Shum, ‘00]

Of course, doesn’t work for structured textures

Image Quilting

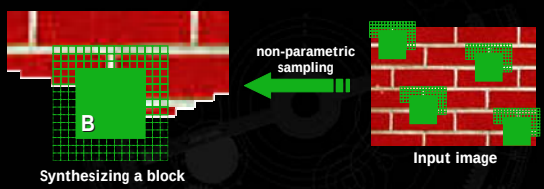
Idea:

- let’s combine random block placement of Chaos Mosaic with spatial constraints of Efros & Leung

Related Work (concurrent):

- Real-time patch-based sampling [Liang et.al. ’01]
- Image Analogies [Hertzmann et.al. ’01]

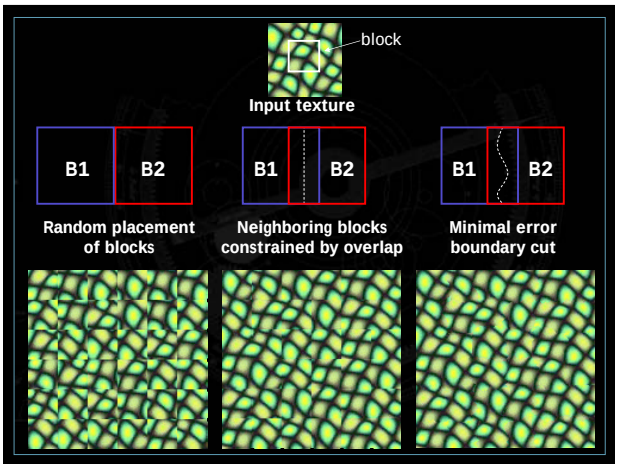
Efros & Leung ’99 extended



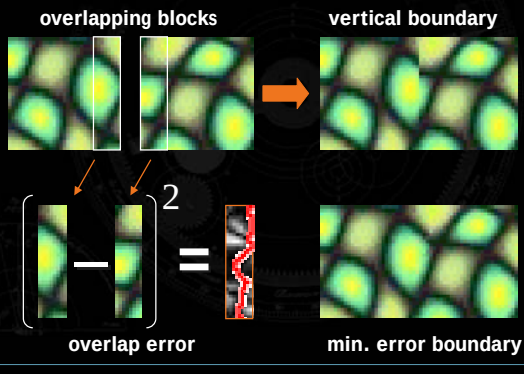
Observation: neighbor pixels are highly correlated

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!



Minimal error boundary



Our Philosophy

The "Corrupt Professor's Algorithm":

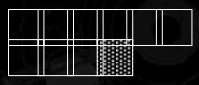
- Plagiarize as much of the source image as you can
- Then try to cover up the evidence

Rationale:

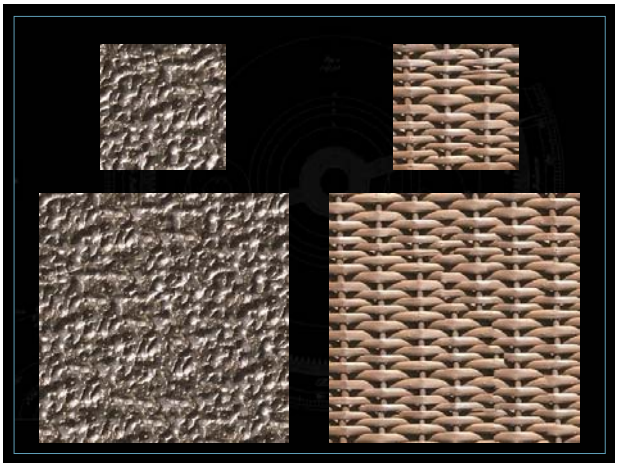
- Texture blocks are by definition correct samples of texture so problem only connecting them together

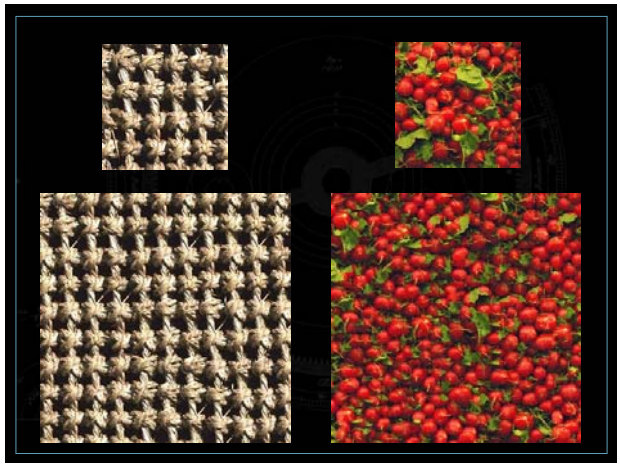
Algorithm

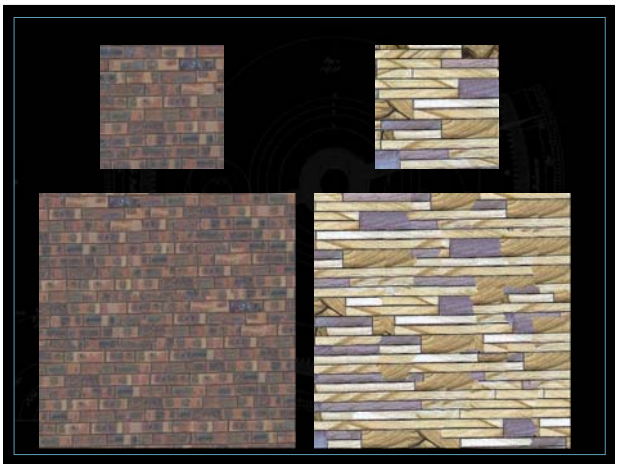
- Pick size of block and size of overlap
- Synthesize blocks in raster order

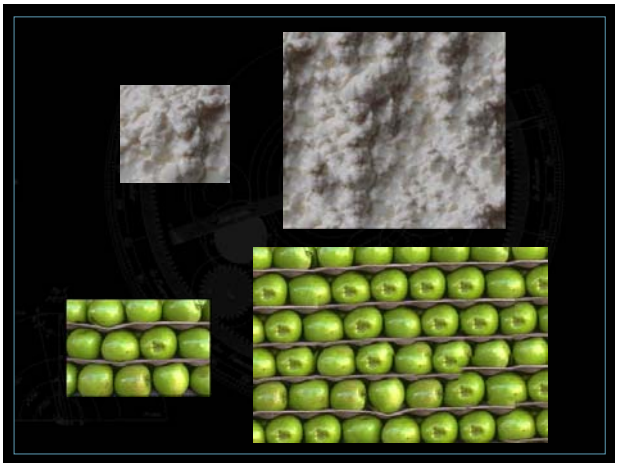


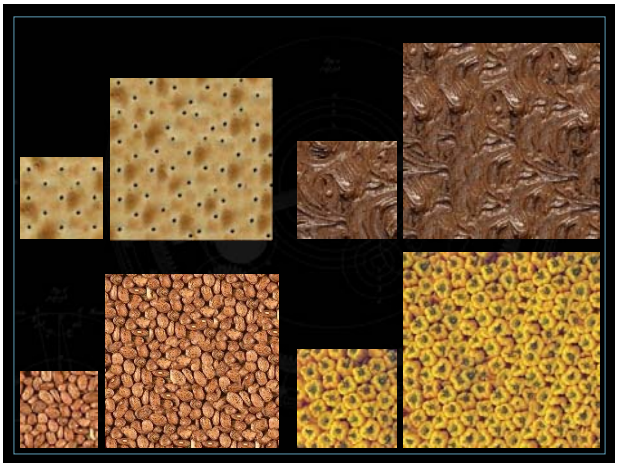
- Search input texture for block that satisfies overlap constraints (above and left)
  - Easy to optimize using NN search [Liang et.al., '01]
- Paste new block into resulting texture
  - use dynamic programming to compute minimal error boundary cut

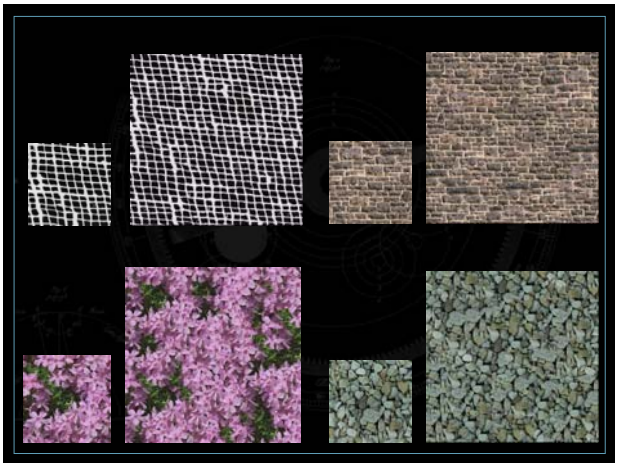










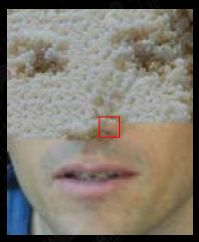



Failures
(Chernobyl
Harvest)

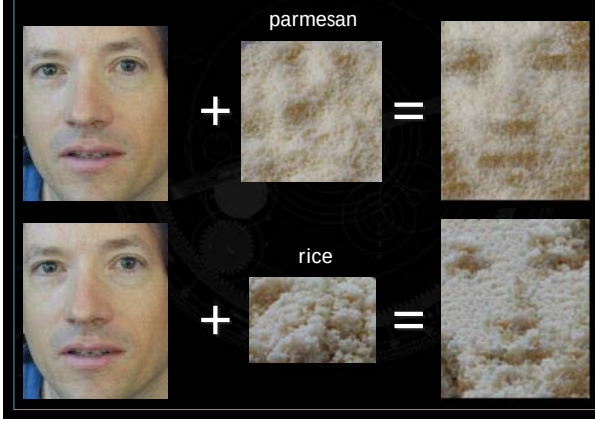
Texture Transfer

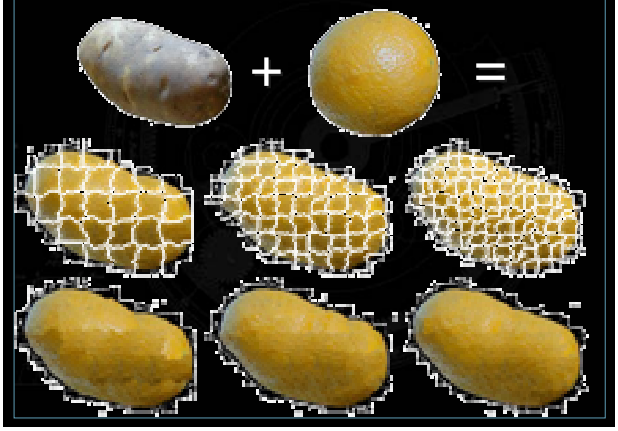
Take the texture from one object and "paint" it onto another object

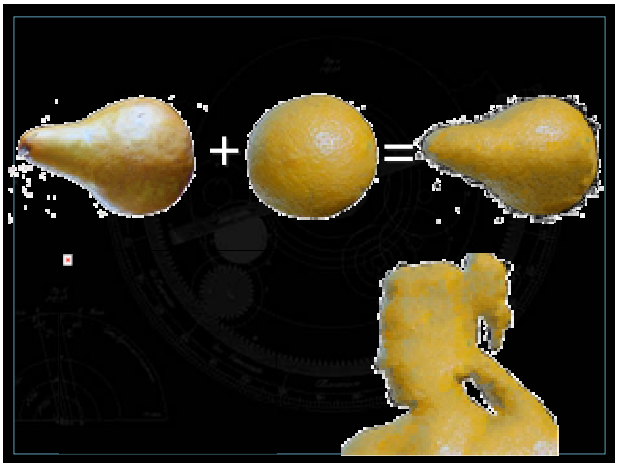
- This requires separating texture and shape
- That's HARD, but we can cheat
- Assume we can capture shape by boundary and rough shading

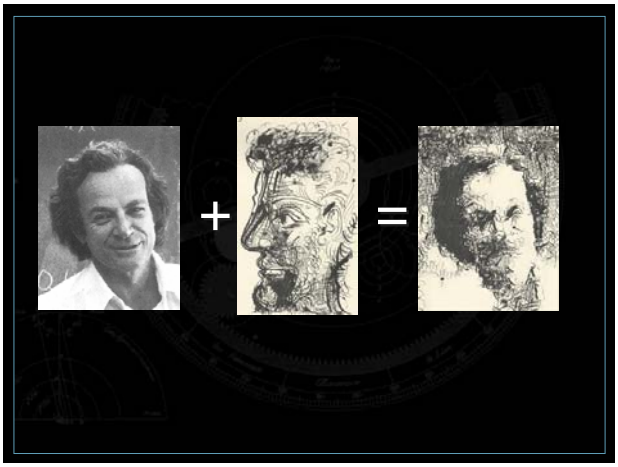


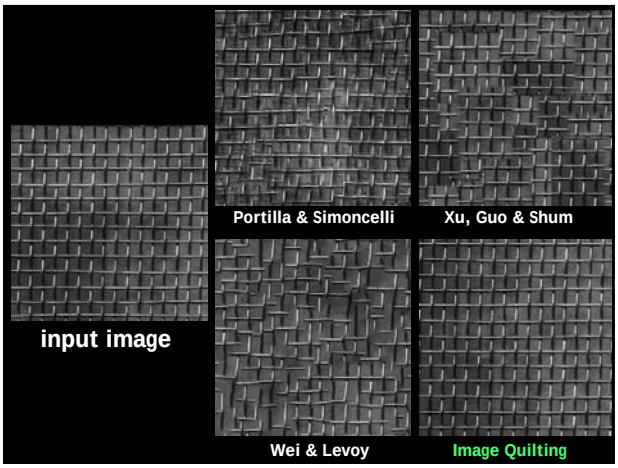
Then, just add another constraint when sampling: similarity to underlying image at that spot

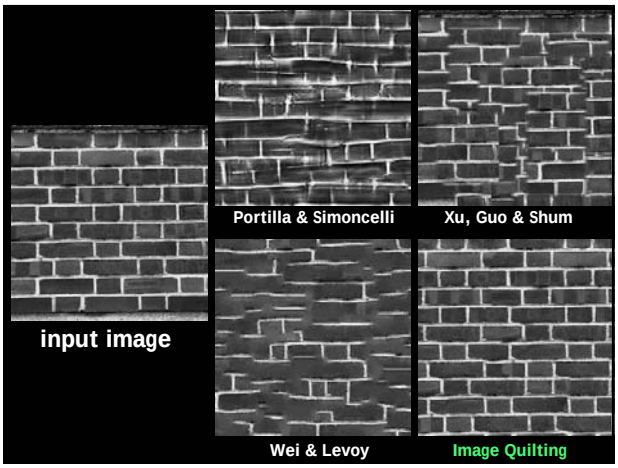


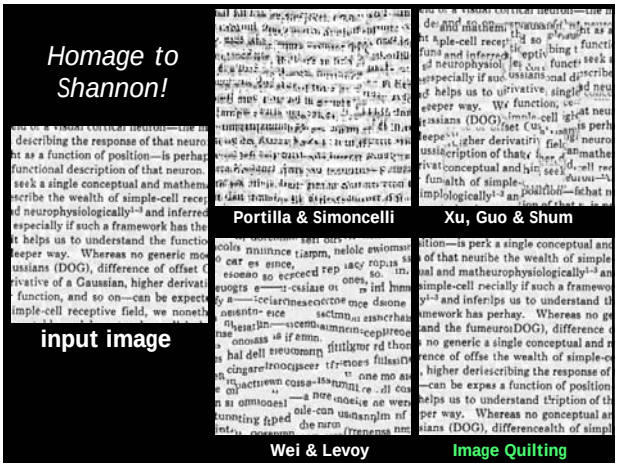












Conclusion

Quilt together patches of input image

- randomly (texture synthesis)
- constrained (texture transfer)

Image Quilting

- No filters, no multi-scale, no one-pixel-at-a-time!
- fast and very simple
- Results are not bad