Data-driven methods: Video & Texture

15-463: Computational Photography
Alexei Efros, CMU, Spring 2010

Michel Gondry train video

http://youtube.com/watch?v=qUEs1BwVXGA

Weather Forecasting for Dummies™

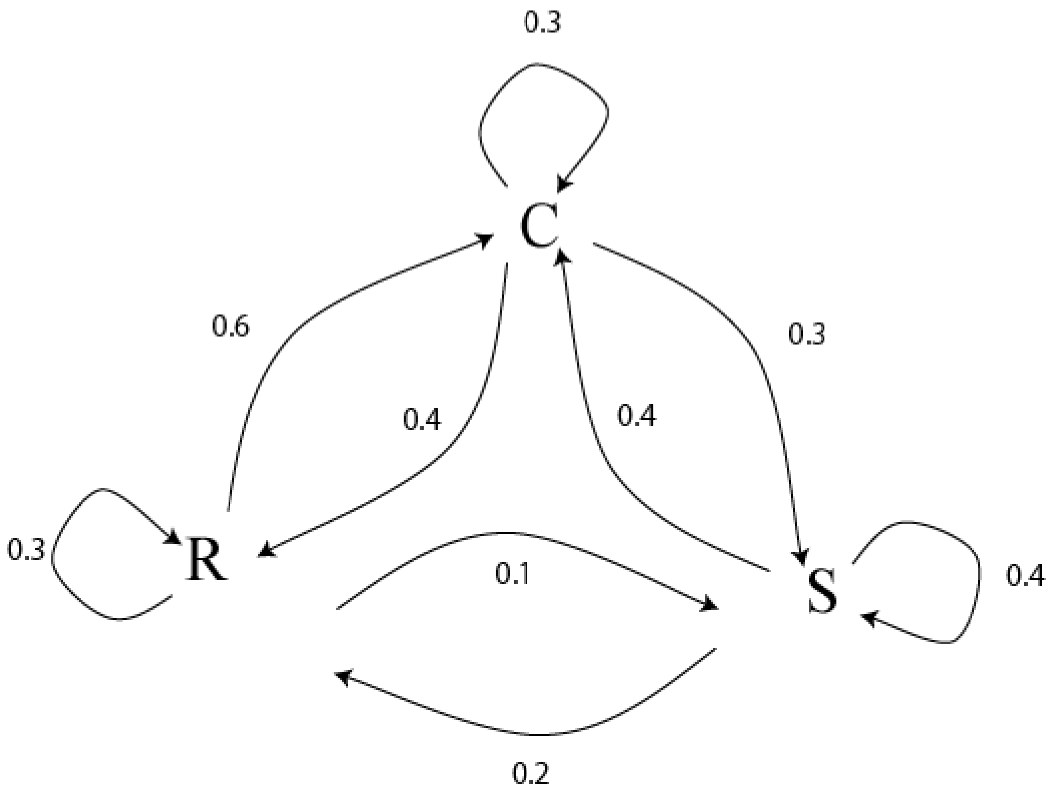
Let's predict weather:

- Given today's weather only, we want to know tomorrow's
- Suppose weather can only be {Sunny, Cloudy, Raining}

The "Weather Channel" algorithm:

- Over a long period of time, record:
  - How often S followed by R
  - How often S followed by S
  - Etc.
- Compute percentages for each state:
  - P(R|S), P(S|S), etc.
- Predict the state with highest probability!
- It's a Markov Chain

Markov Chain



$$\begin{pmatrix} 0.3 & 0.6 & 0.1 \\ 0.4 & 0.3 & 0.3 \\ 0.2 & 0.4 & 0.4 \end{pmatrix}$$

What if we know today and yesterday's weather?

Text Synthesis

[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"*

Video Textures

Arno Schödl

Richard Szeliski

David Salesin

Irfan Essa

Microsoft Research, Georgia Tech

Still photos

Video clips

Video textures

Problem statement

video clip

video texture

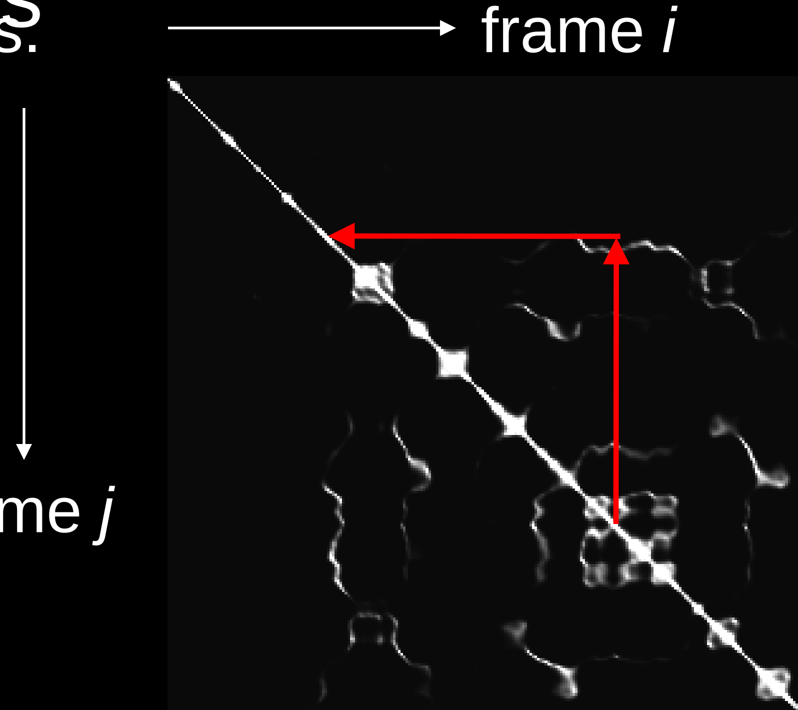
Our approach

- How do we find good transitions?

Finding good transitions

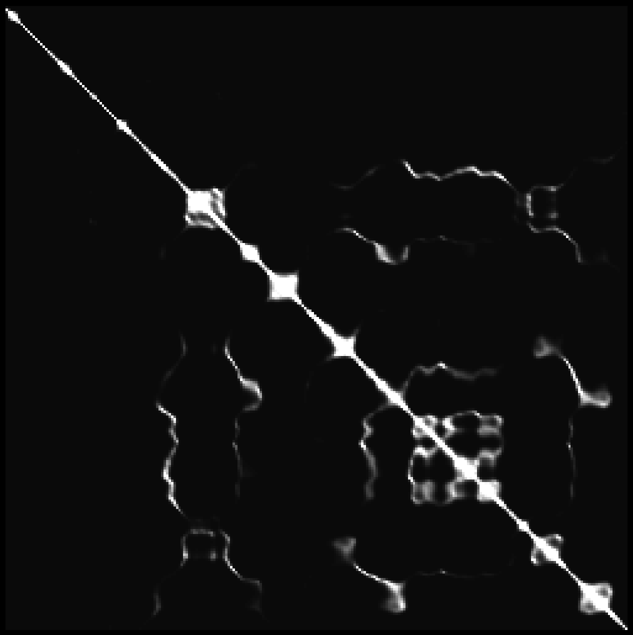
- Compute L_2 distance $D_{i,\,j}$ between all frames

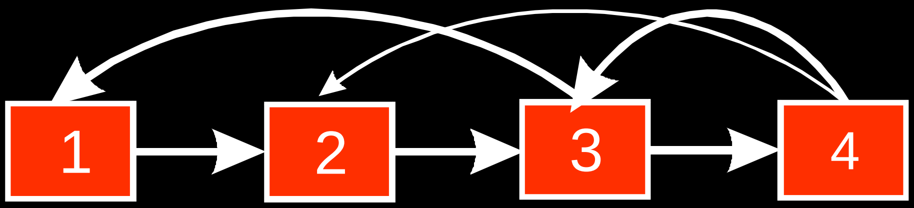
vs.



Similar frames make good transitions

Markov chain representation

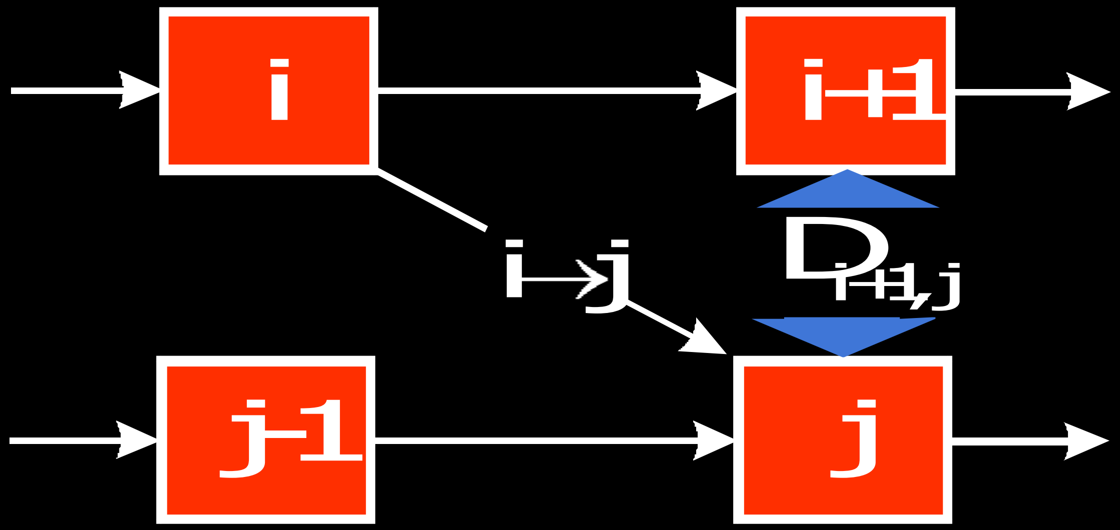




Similar frames make good transitions

Transition costs

- Transition from i to j if successor of i is similar to j
  - Cost function: $C_{i\rightarrow j} = D_{i+1,\, j}$
-



Transition probabilities

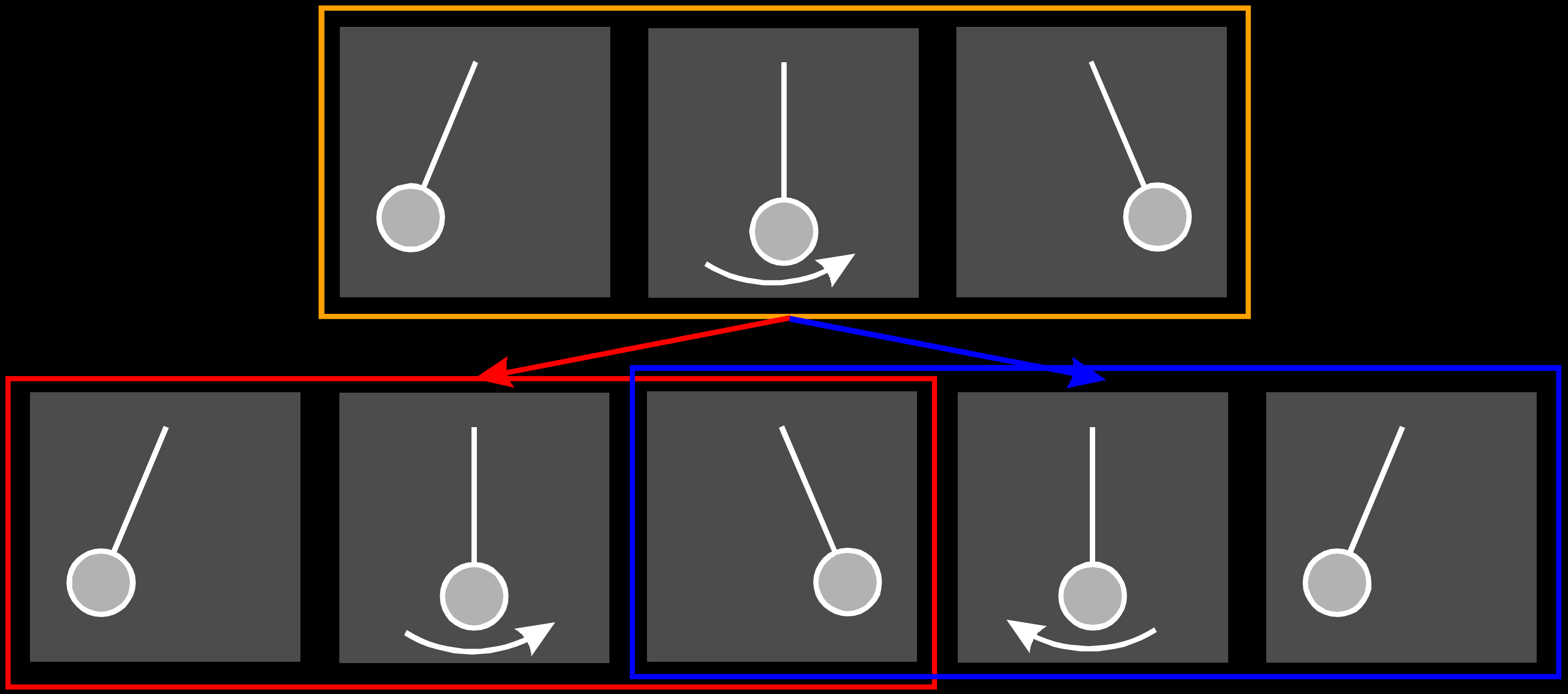
- Probability for transition $P_{i \to j}$ inversely related to cost:
  - $P_{i \to j} \sim \exp(-C_{i \to j} / \sigma^2)$

high σ

low σ

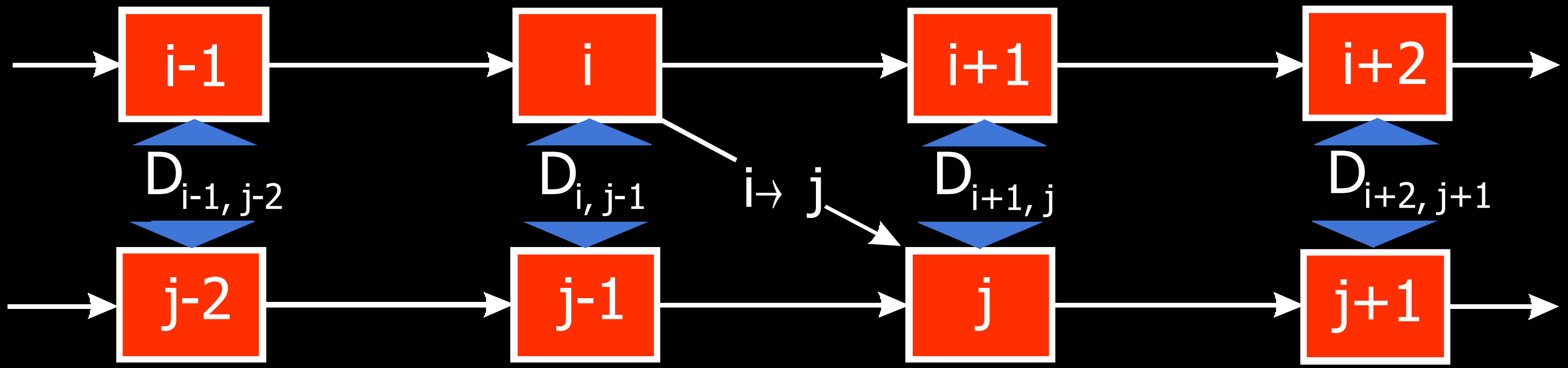
Preserving dynamics

Preserving dynamics



Preserving dynamics

- Cost for transition $i \to j$
  - $C_{i \to j} = \sum_{k=-N}^{N-1} w_k D_{i+k+1,\, j+k}$

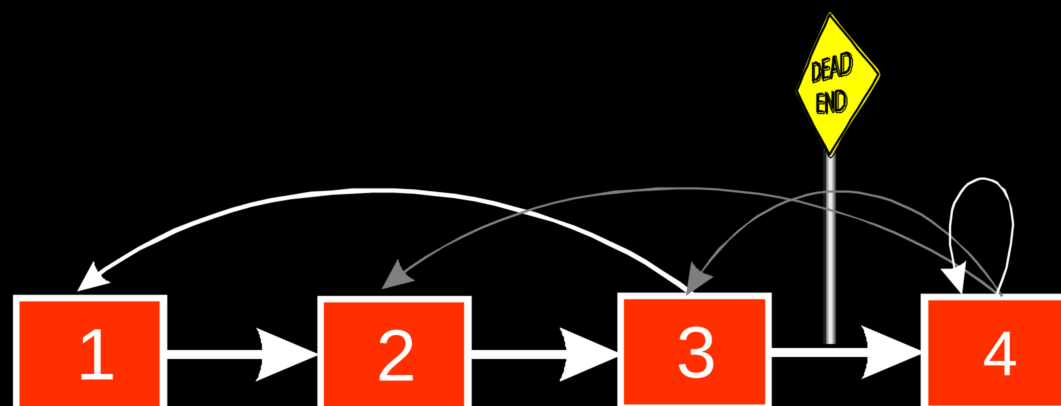


Preserving dynamics – effect

- Cost for transition $i \to j$
  - $$C_{i \to j} = \sum_{k=-N}^{N-1} w_k D_{i+k+1,\, j+k}$$

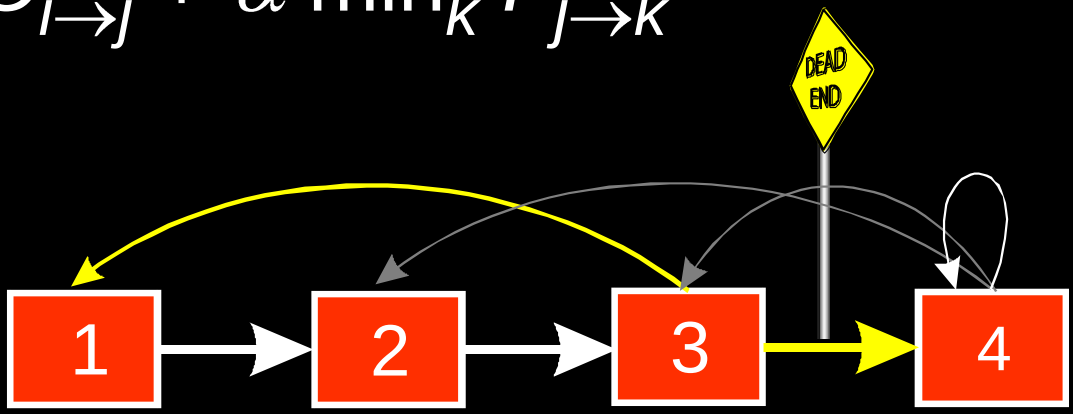
Dead ends

- No good transition at the end of sequence



Future cost

- Propagate future transition costs backward
- Iteratively compute new cost
  - $F_{i \to j} = C_{i \to j} + \alpha \min_k F_{j \to k}$



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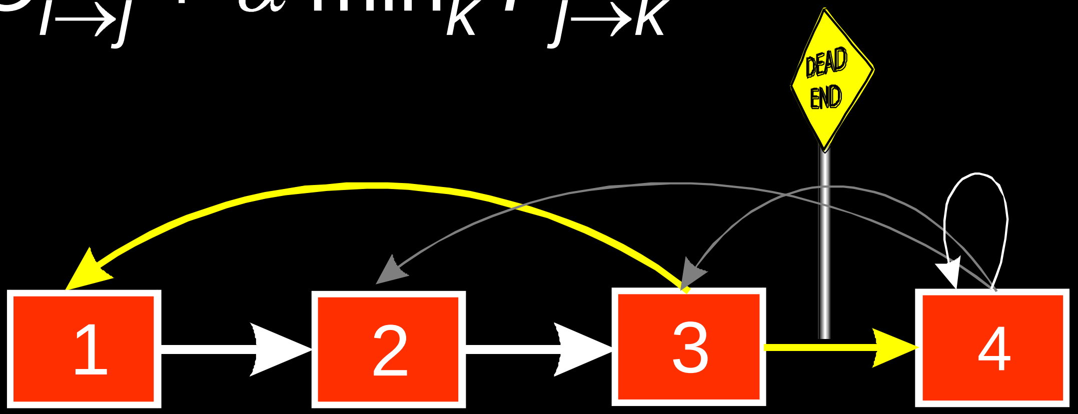

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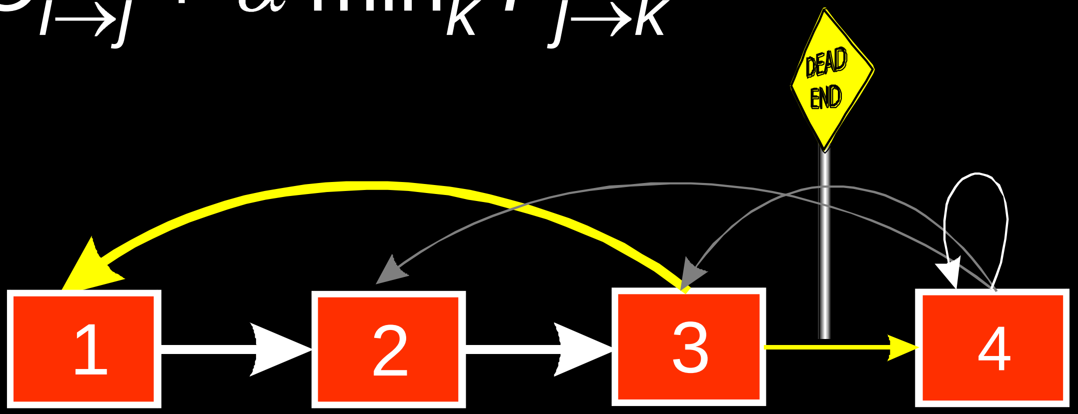

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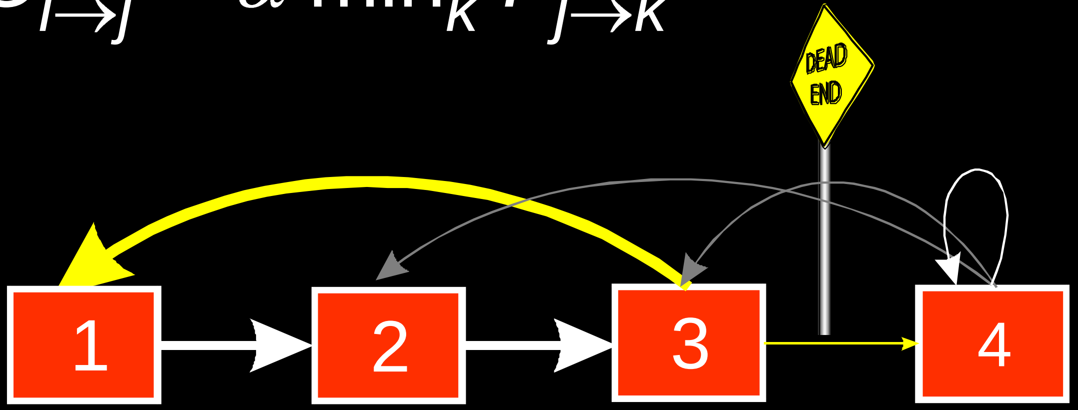
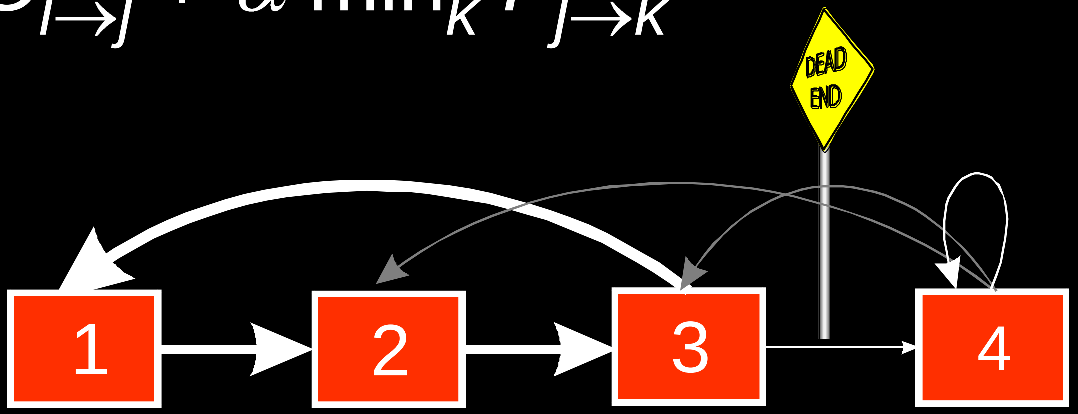


Future cost

- Propagate future transition costs backward
- Iteratively compute new cost
    - $F_{i \to j} = C_{i \to j} + \alpha \min_k F_{j \to k}$
- Q-learning



Future cost – effect

Finding good loops

- Alternative to random transitions
- Precompute set of loops up front

Video portrait

- Useful for web pages

Region-based analysis

- Divide video up into regions

- Generate a video texture for each region

Automatic region analysis

User-controlled video textures

slow variable fast

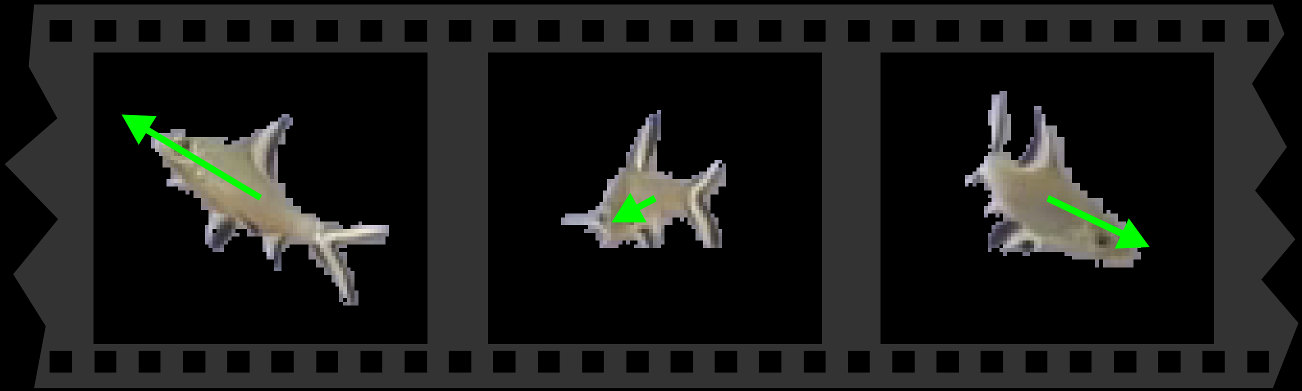
User selects target frame range

Video-based animation

- Like sprites computer games
- Extract sprites from real video
- Interactively control desired motion

Video sprite extraction

blue screen matting
and velocity estimation



Video sprite control

- Augmented transition cost:

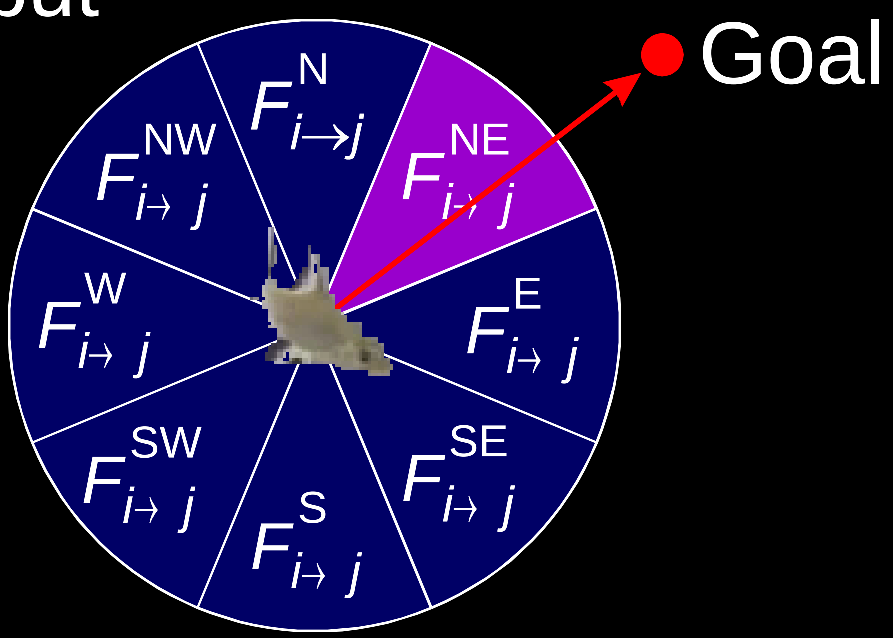
vector to mouse pointer

$$C^{\text{Animation}}_{i\to j} = \alpha \underbrace{C_{i\to j}}_{\text{Similarity term}} + \beta \underbrace{\text{angle}}_{\text{Control term}}$$

velocity vector

Video sprite control

- Need future cost computation
- Precompute future costs for a few angles.
- Switch between precomputed angles according to user input
- [GIT-GVU-00-11]



Interactive fish

Summary

- Video clips $\rightarrow$ video textures
  - define Markov process
  - preserve dynamics
  - avoid dead-ends
  - disguise visual discontinuities

Discussion

- Some things are relatively easy




Discussion

- Some are hard

“Amateur” by Lasse Gjertsen

http://www.youtube.com/watch?v=JzqumbhfxRo

Texture

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

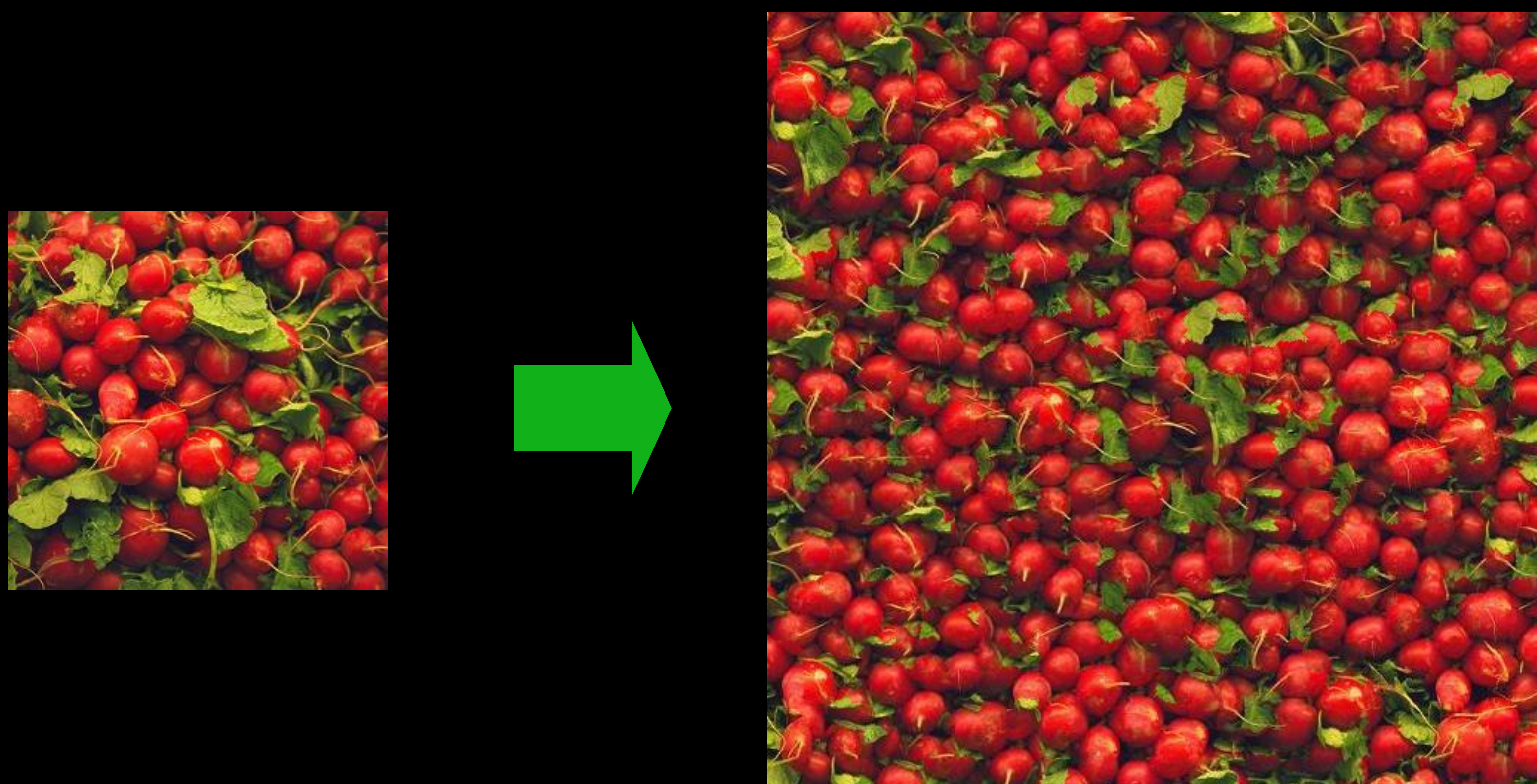
radishes

rocks

yogurt

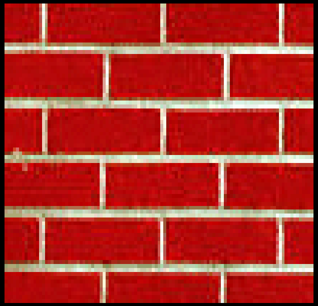
Texture Synthesis

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

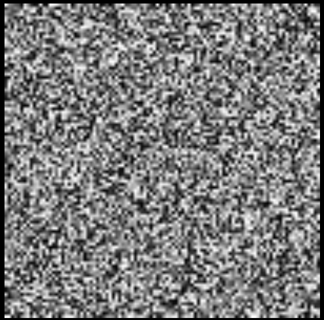


The Challenge

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



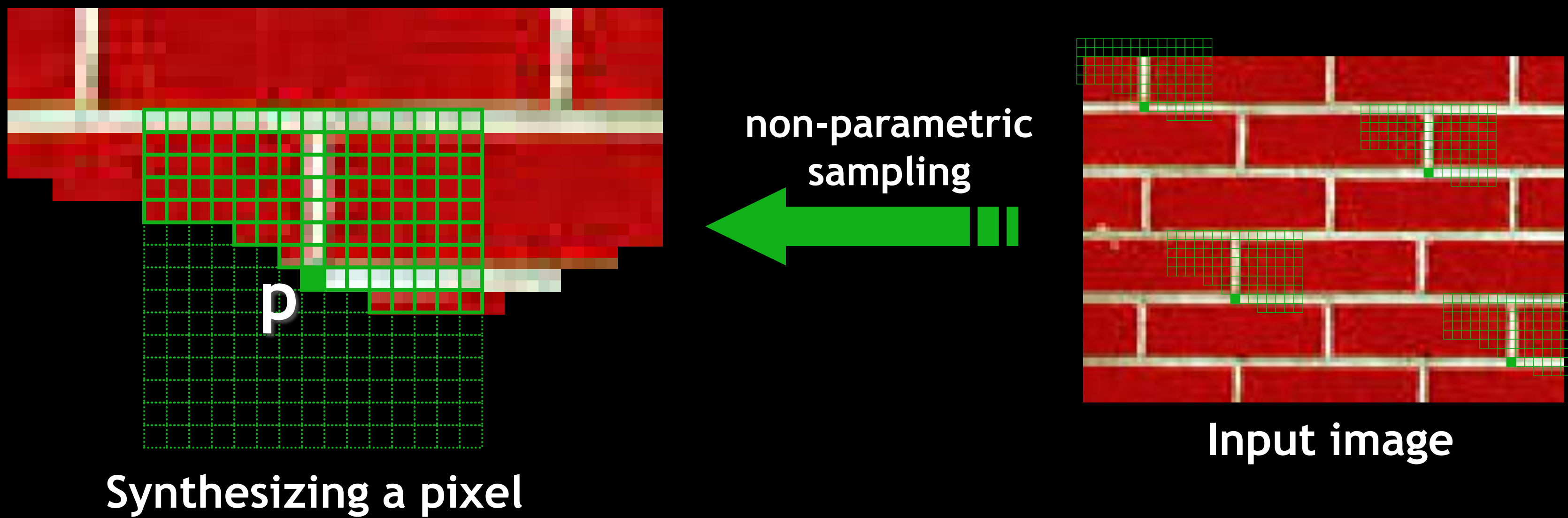
repeated



stochastic

Both?

Efros & Leung Algorithm

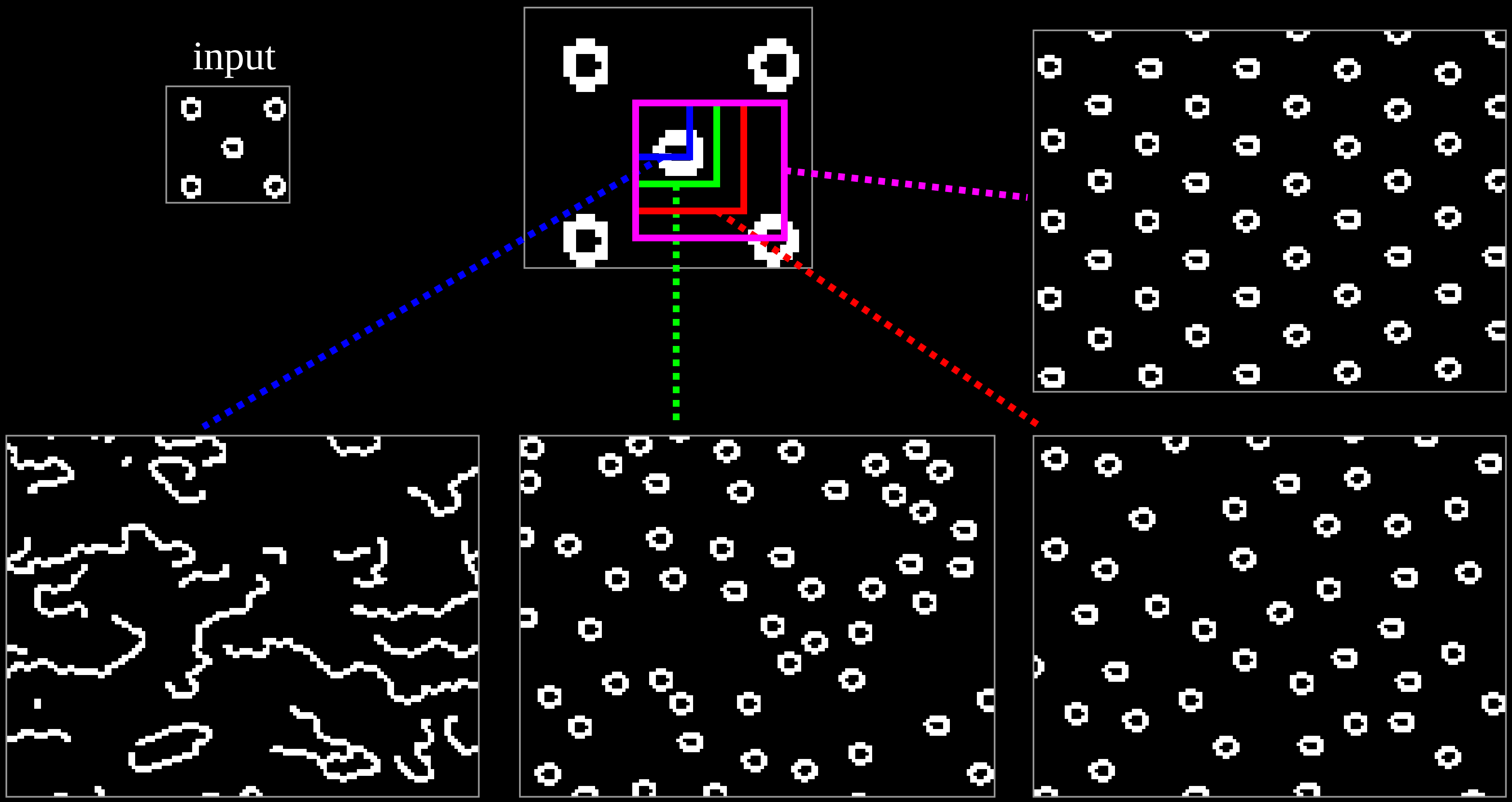


- Assuming Markov property, compute P(**p**|N(**p**))
  - Building explicit probability tables infeasible
  - Instead, we *search the input image* for all similar neighborhoods — that's our pdf for **p**
  - To sample from this pdf, just pick one match at random

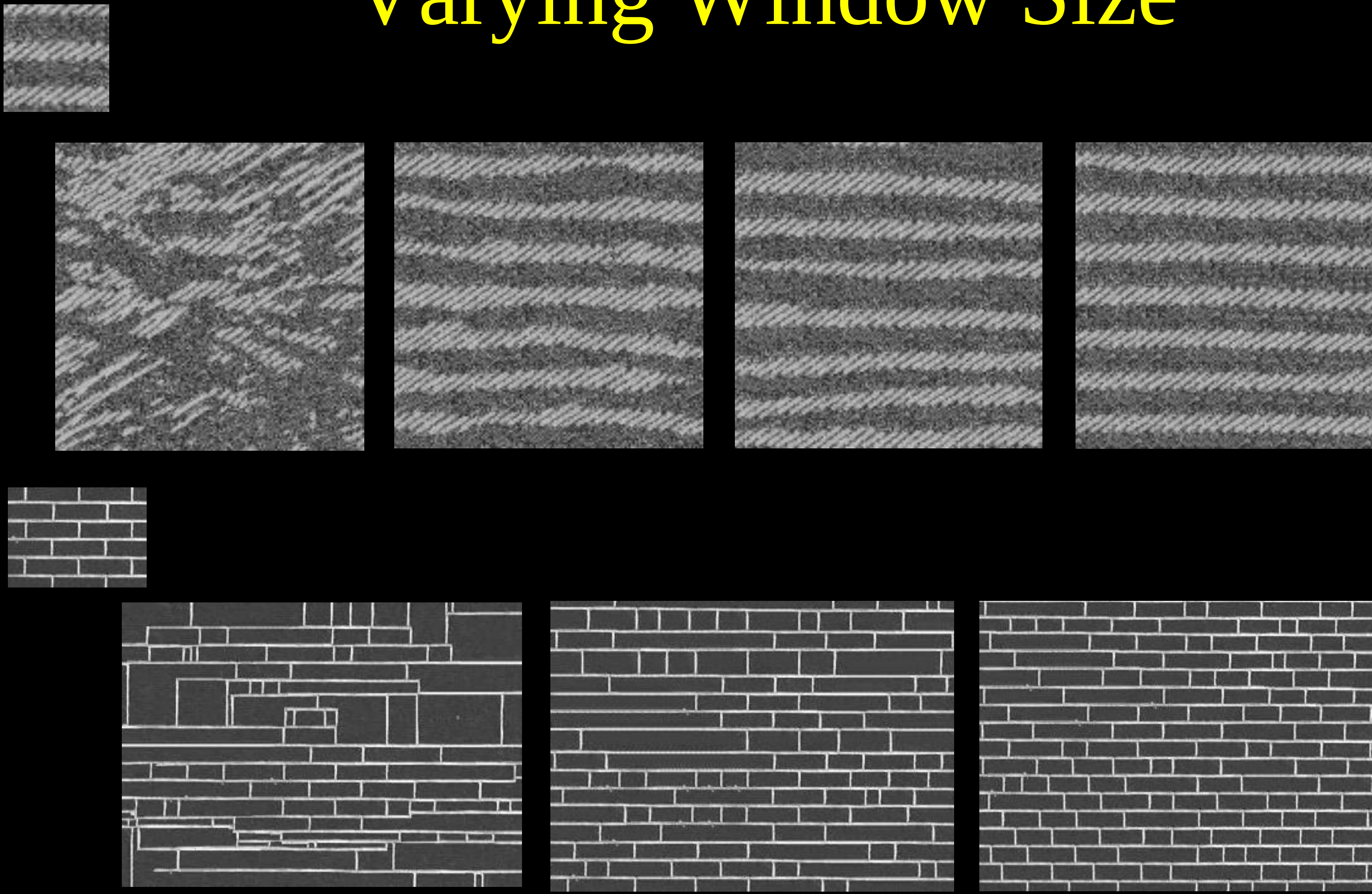
Some Details

- 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



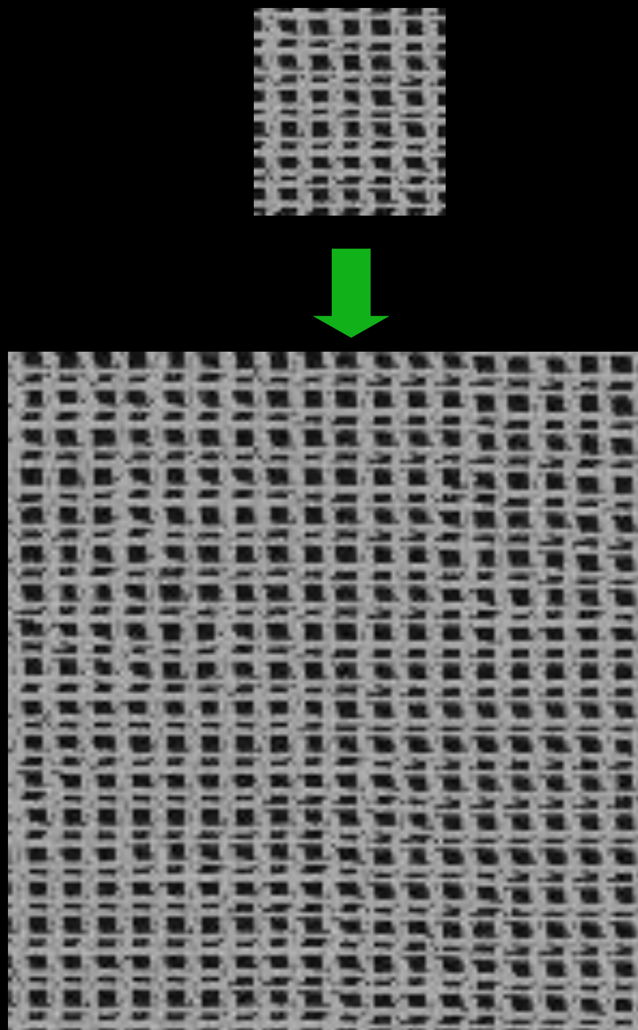
Varying Window Size



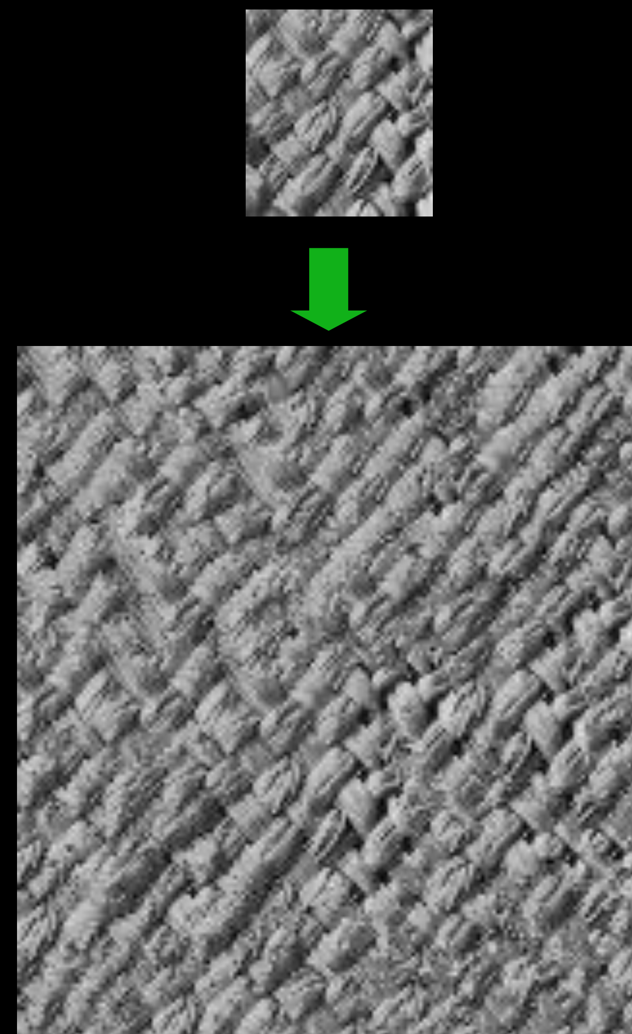
Increasing window size

Synthesis Results

french canvas

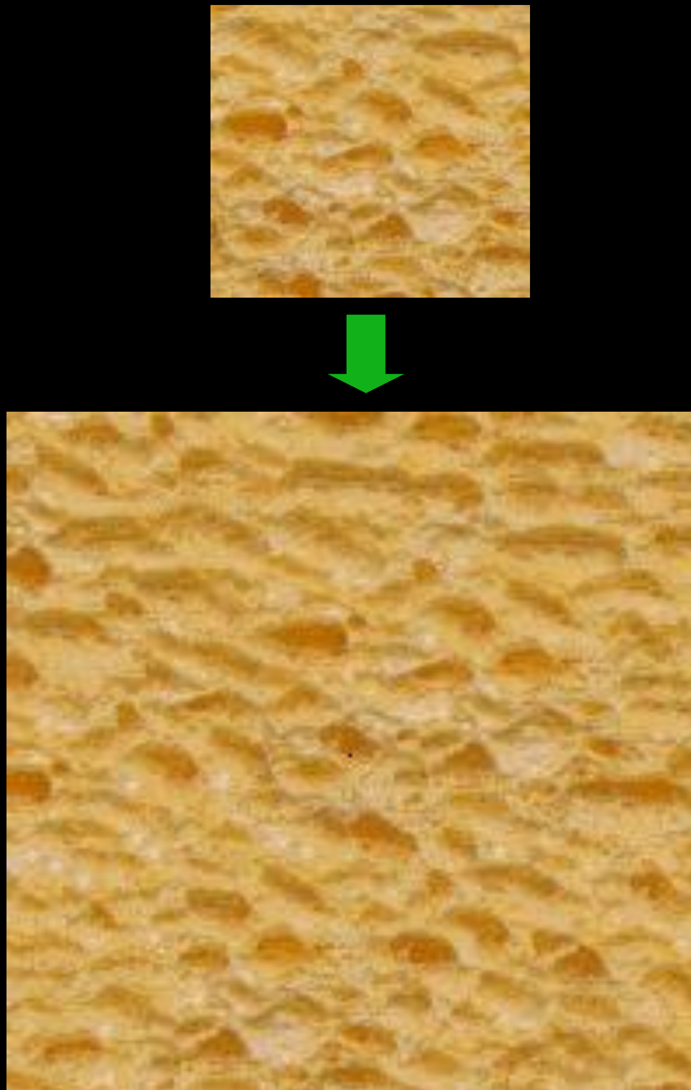


rafia weave

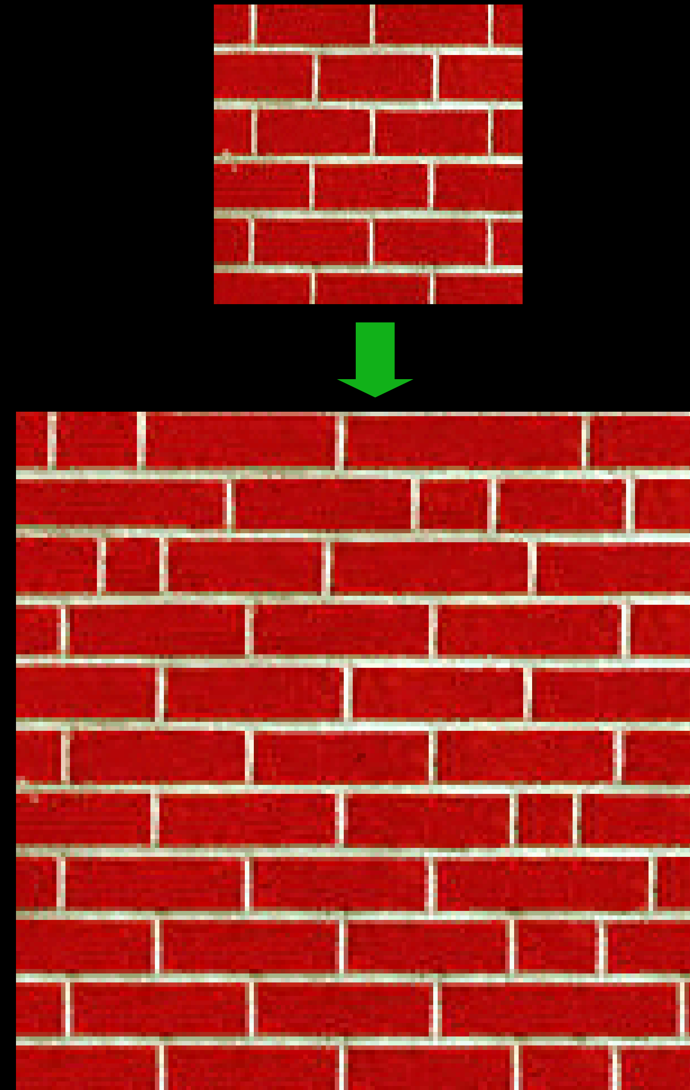


More Results

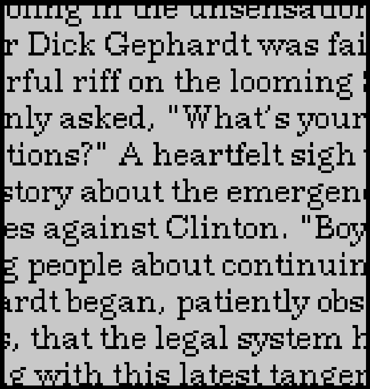
white bread

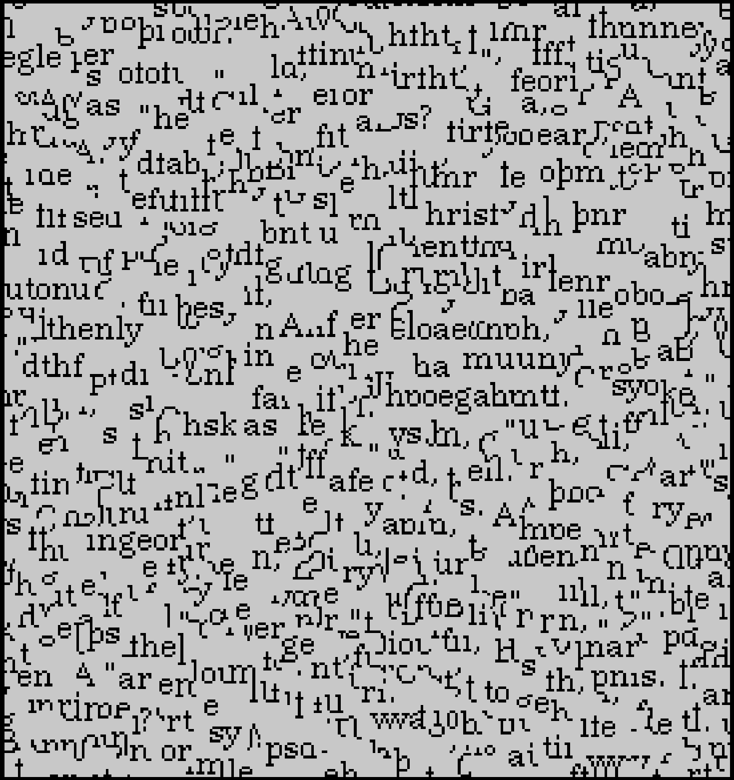


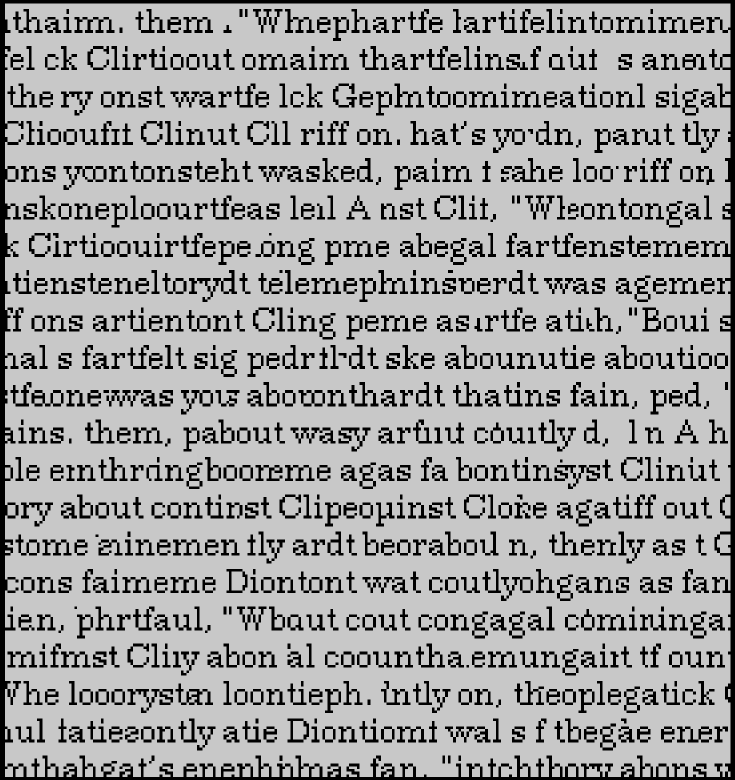
brick wall



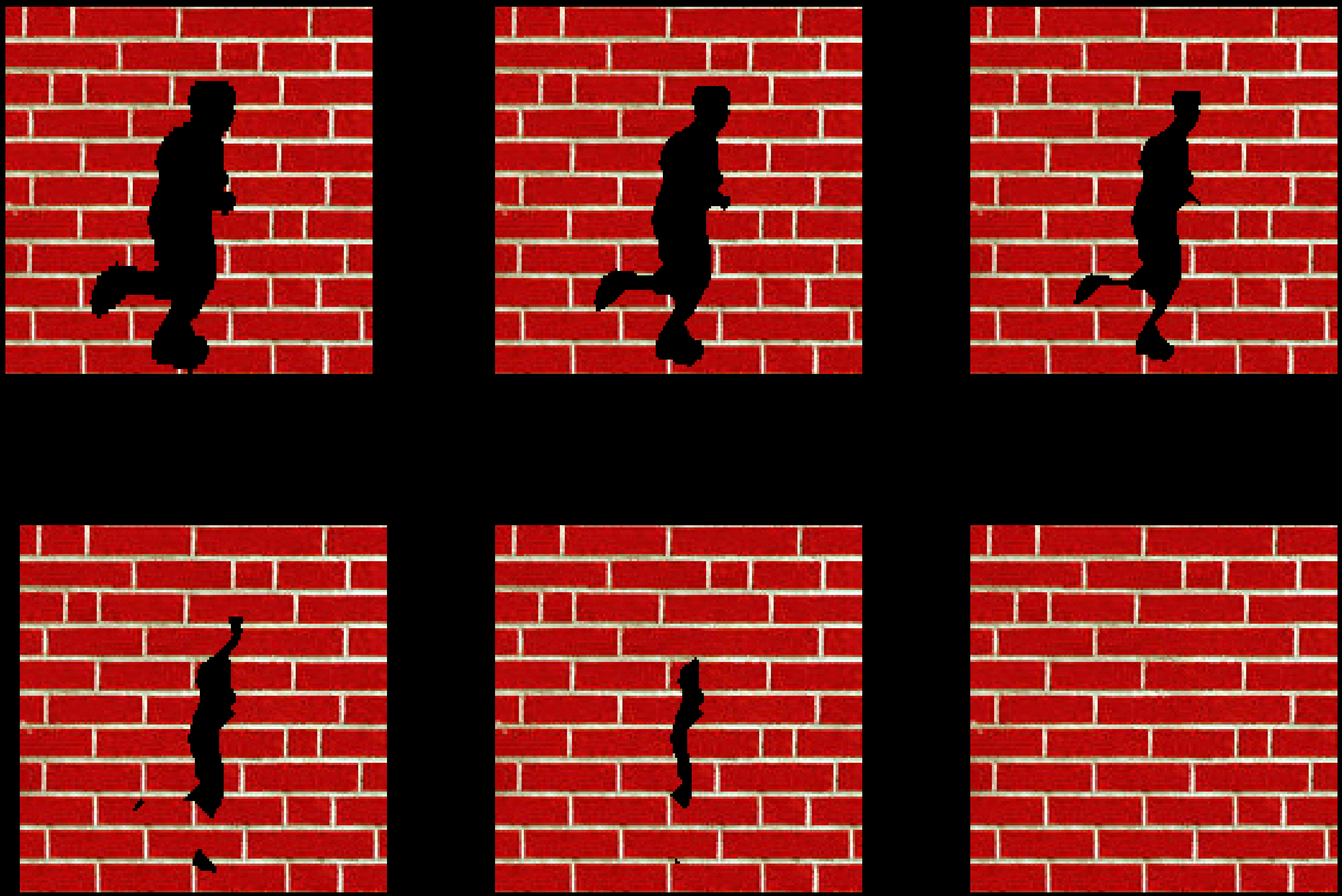
Homage to Shannon



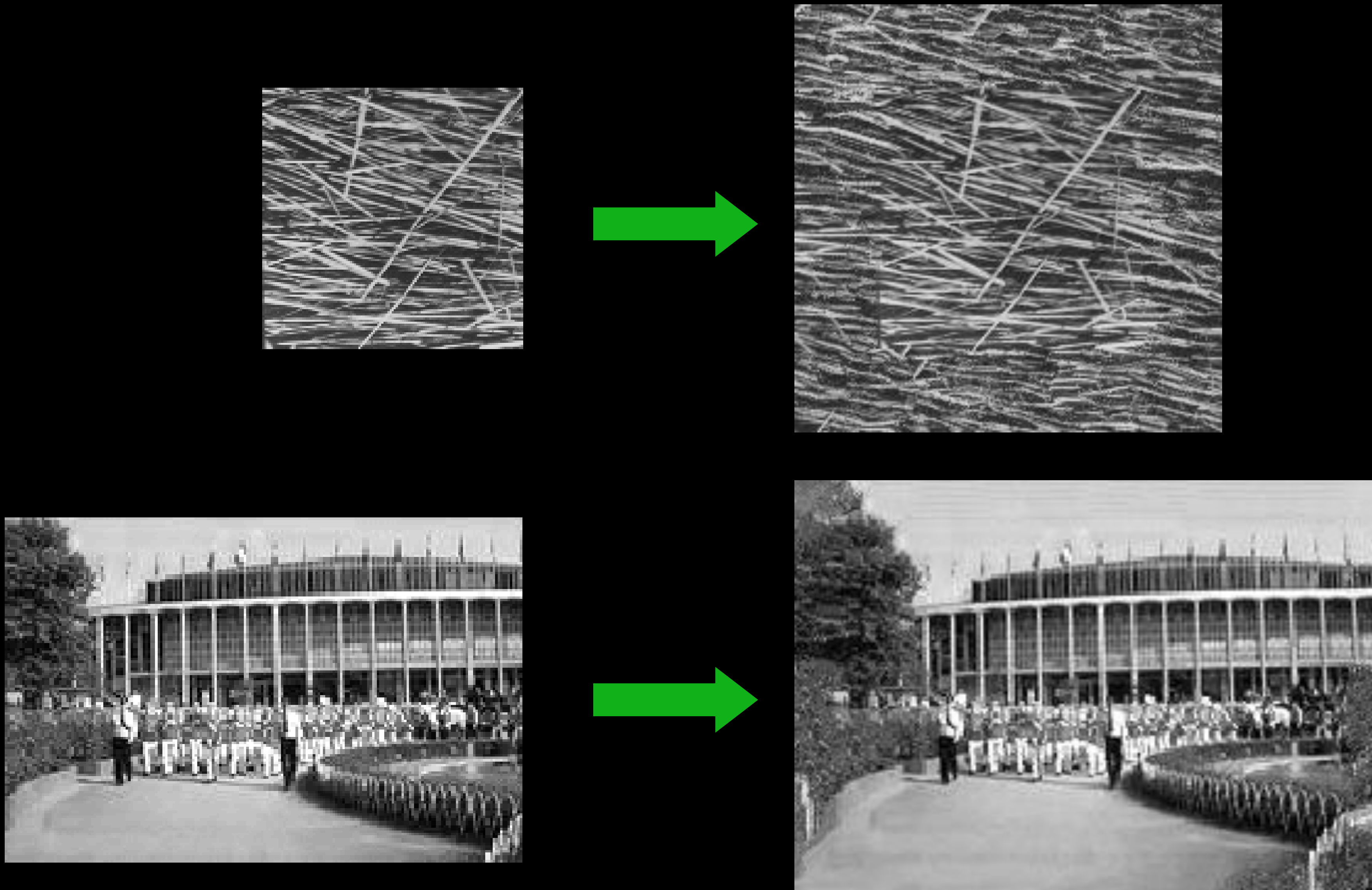




Hole Filling



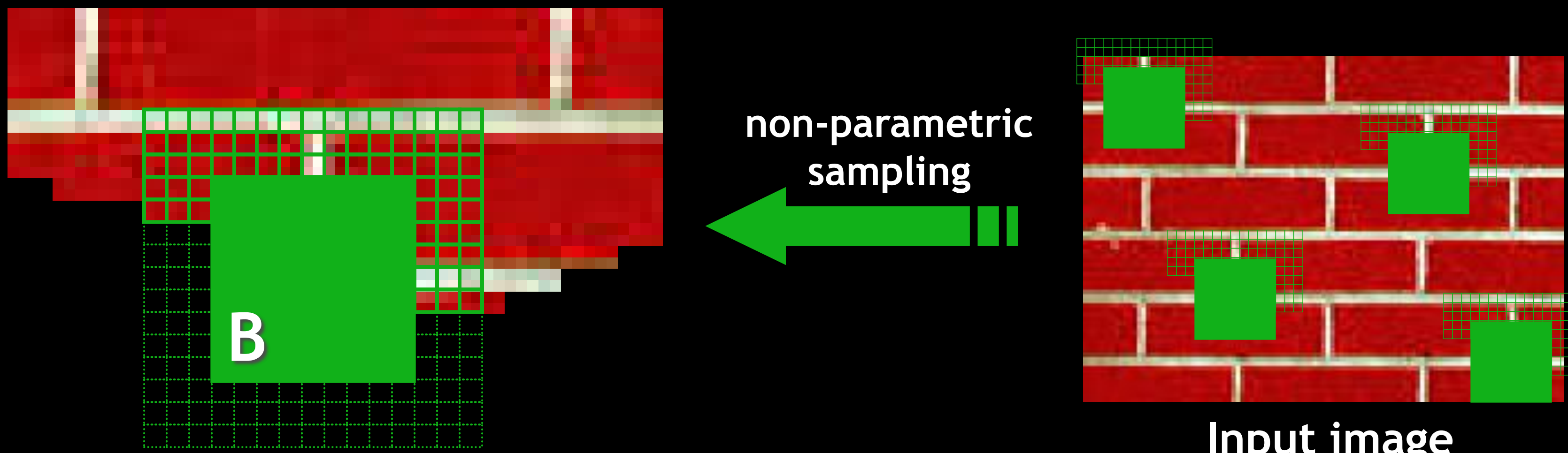
Extrapolation



Summary

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

Image Quilting [Efros & Freeman]



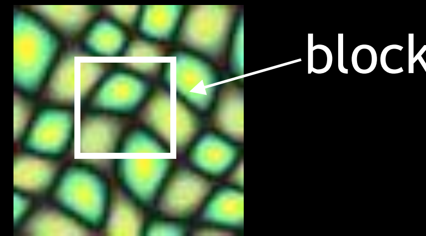
Synthesizing a block

Input image

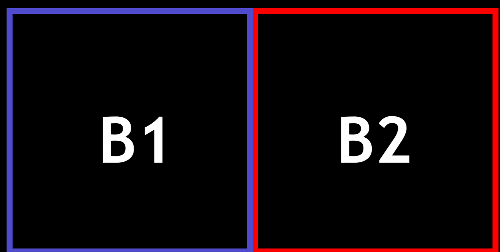
- Observation: neighbor pixels are highly correlated

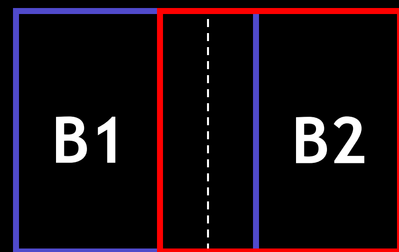
Idea: unit of synthesis = block

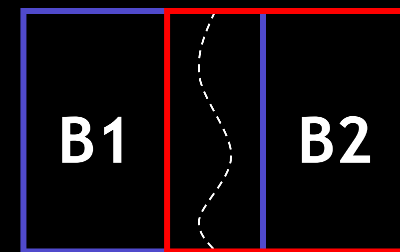
- Exactly the same but now we want P(**B**|N(**B**))
- Much faster: synthesize all pixels in a block at once
- Not the same as multi-scale!



Input texture



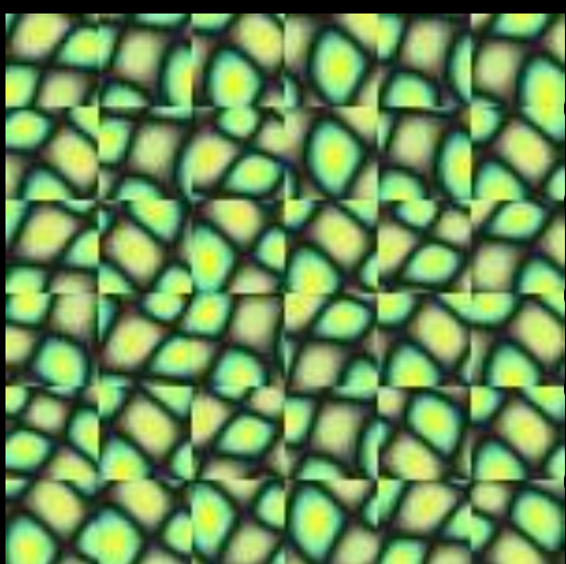


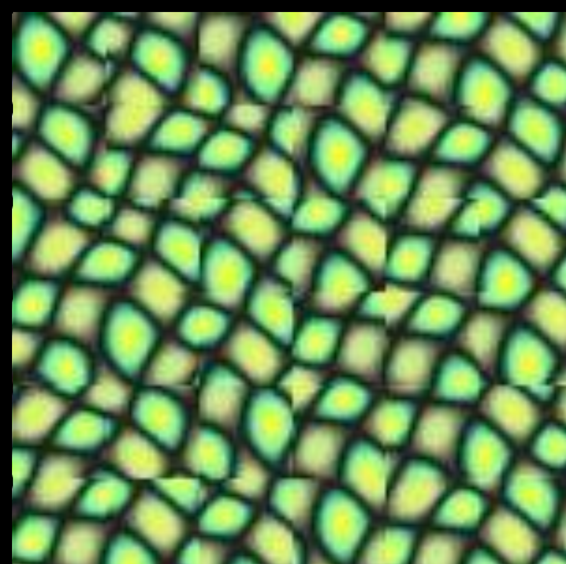


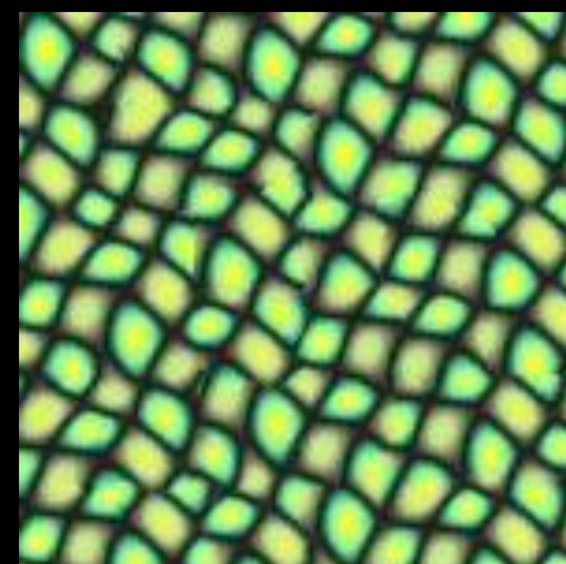
Random placement of blocks

Neighboring blocks constrained by overlap

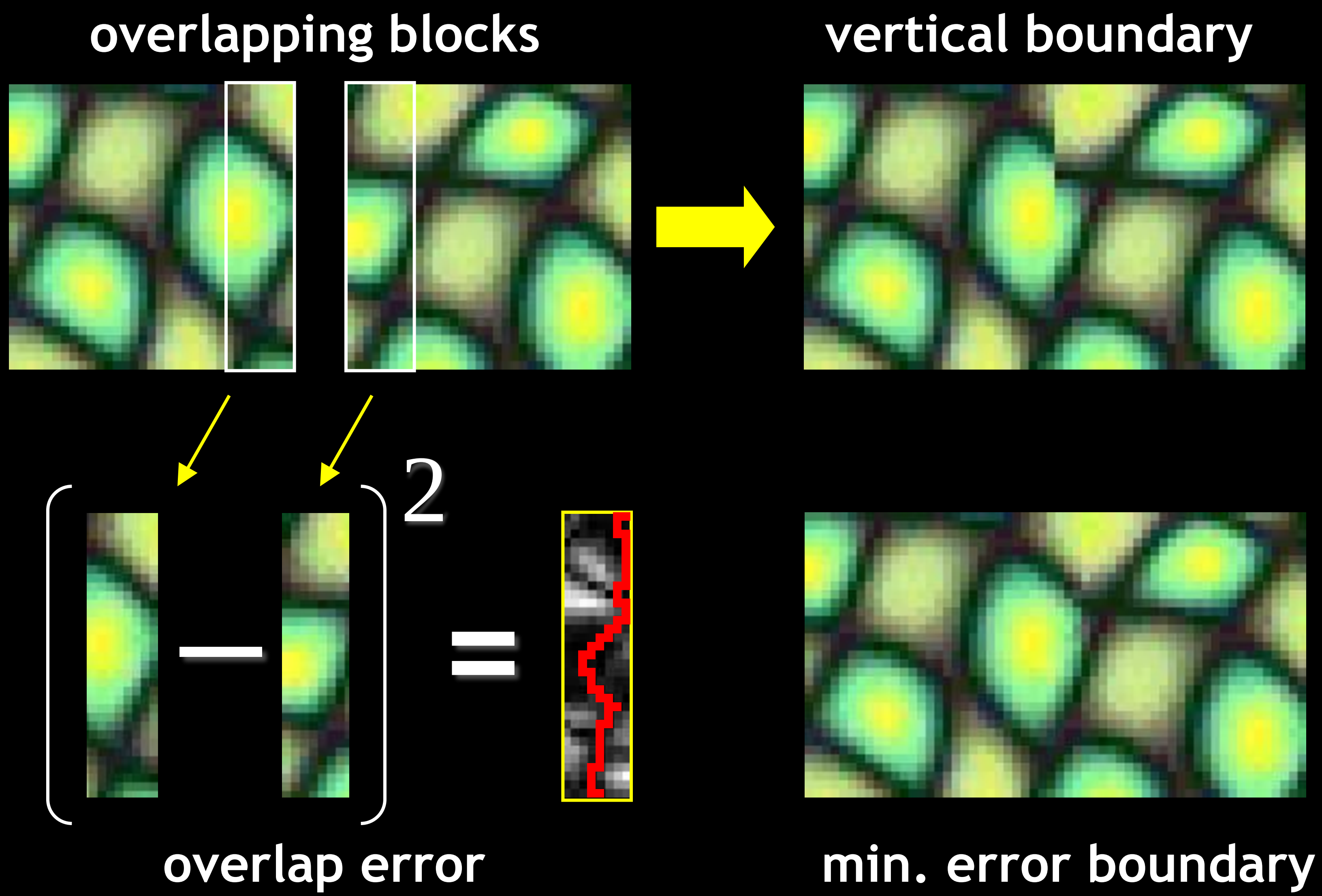
Minimal error boundary cut







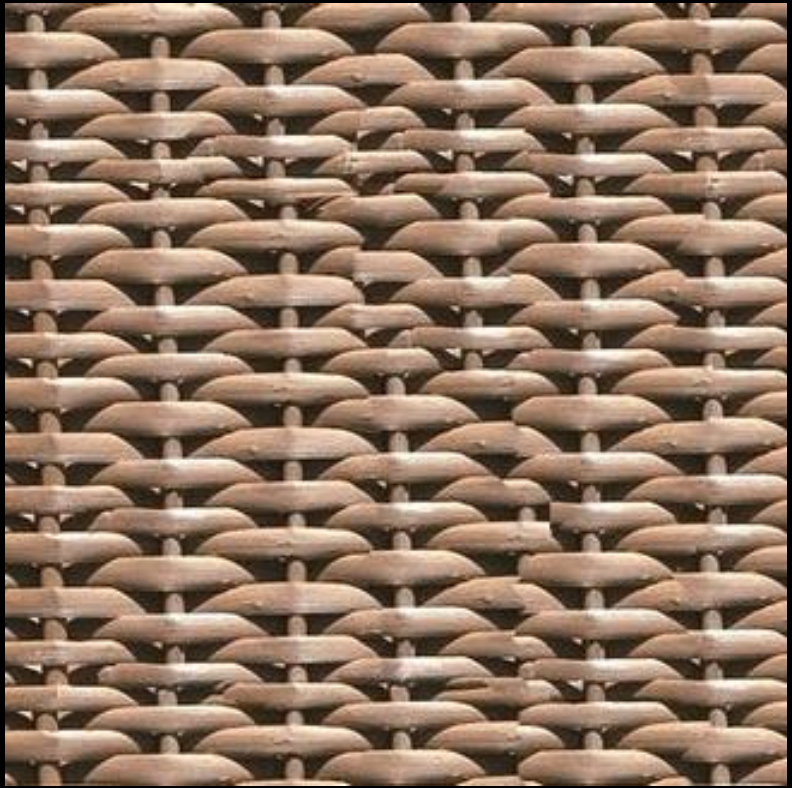
Minimal error boundary

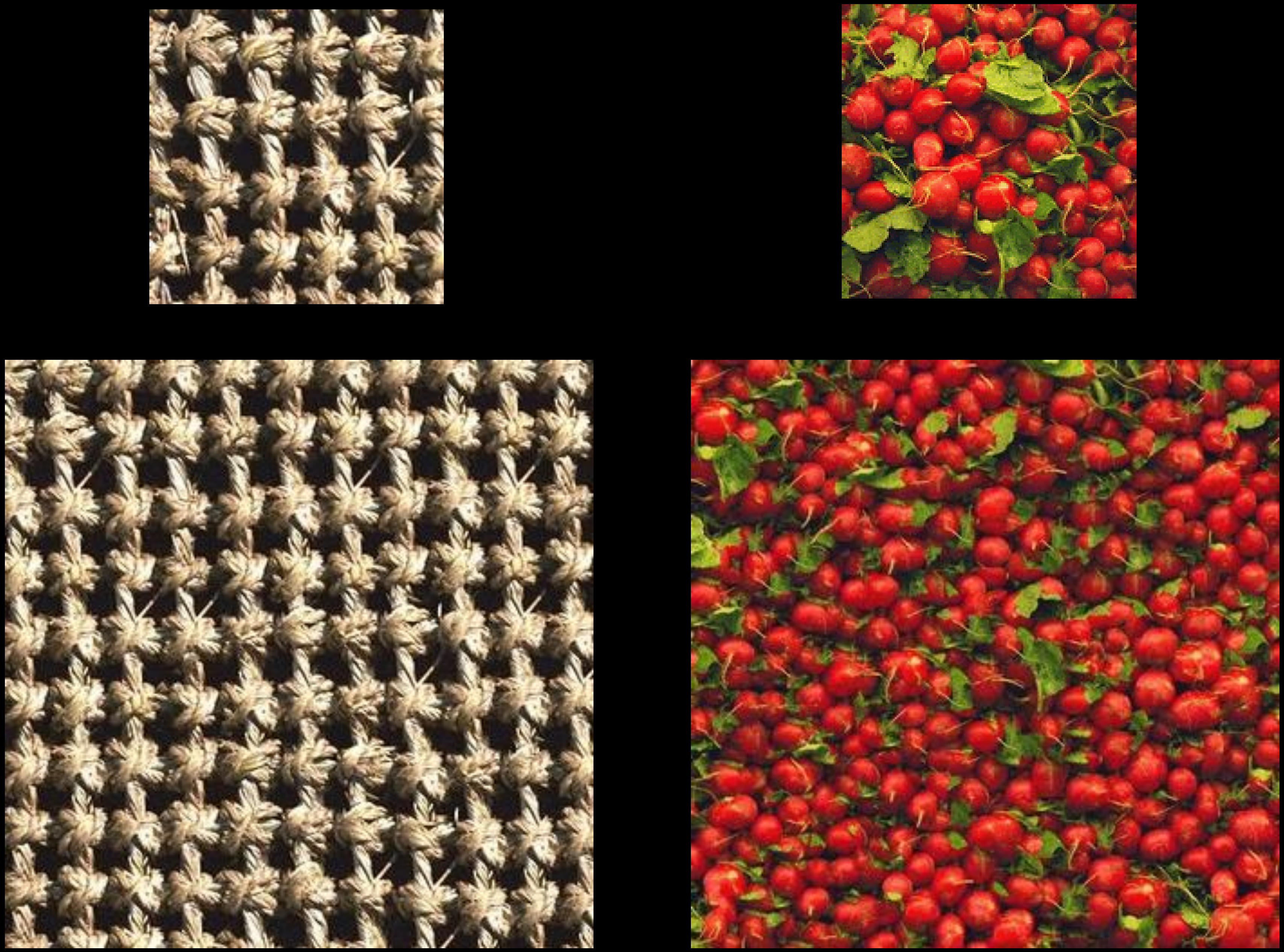


Our Philosophy

- 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





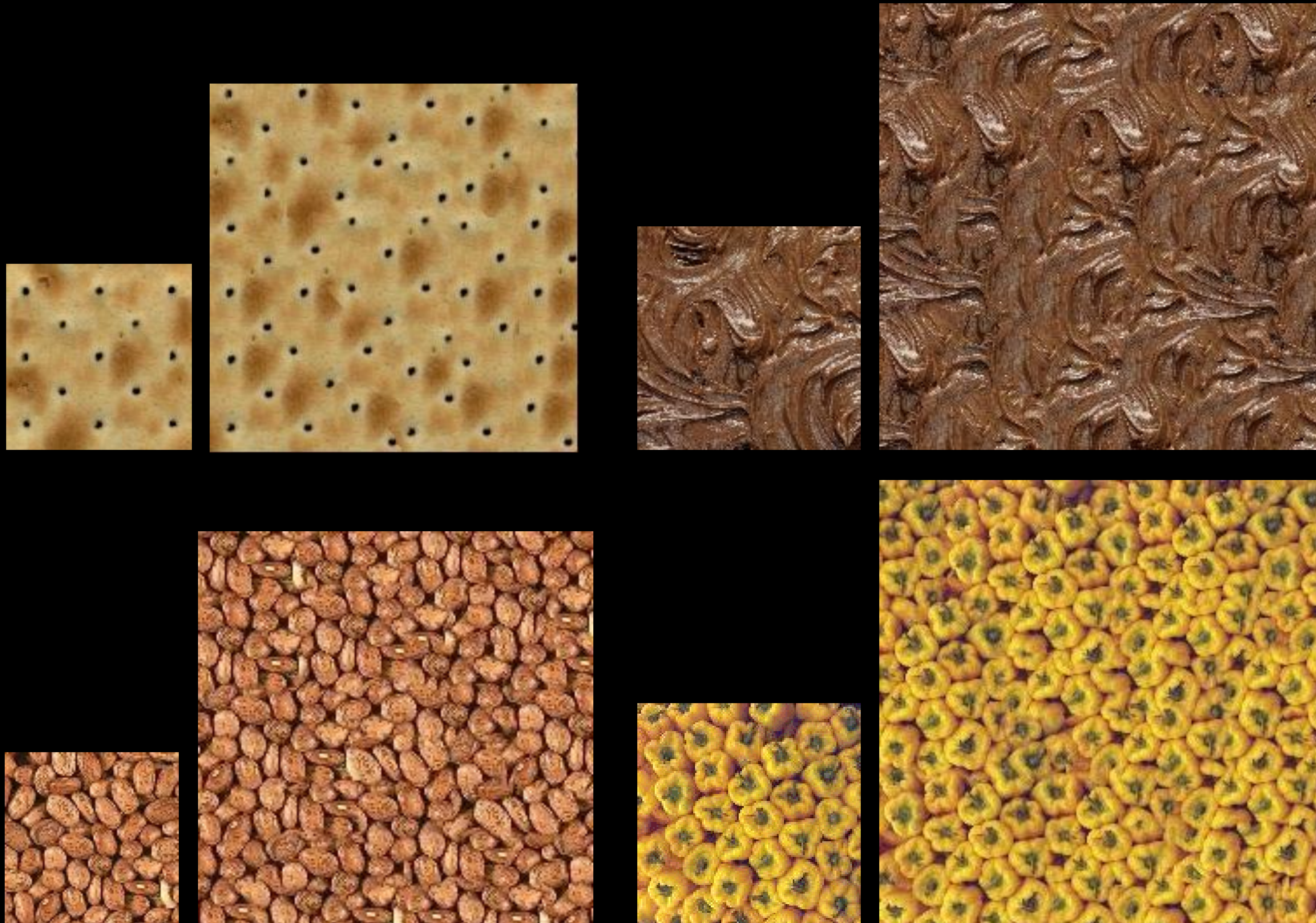




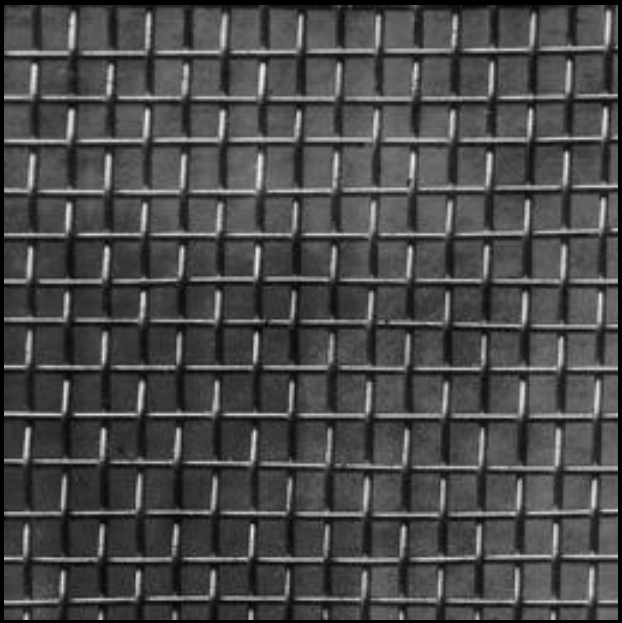
College Inn


College Inn

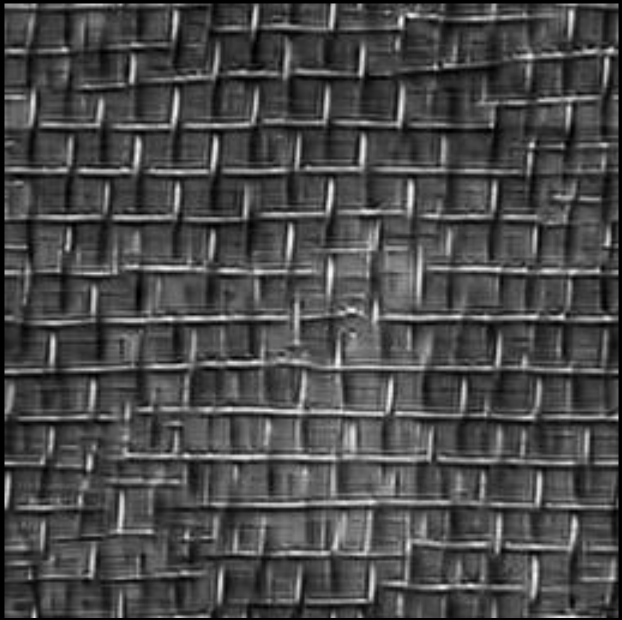


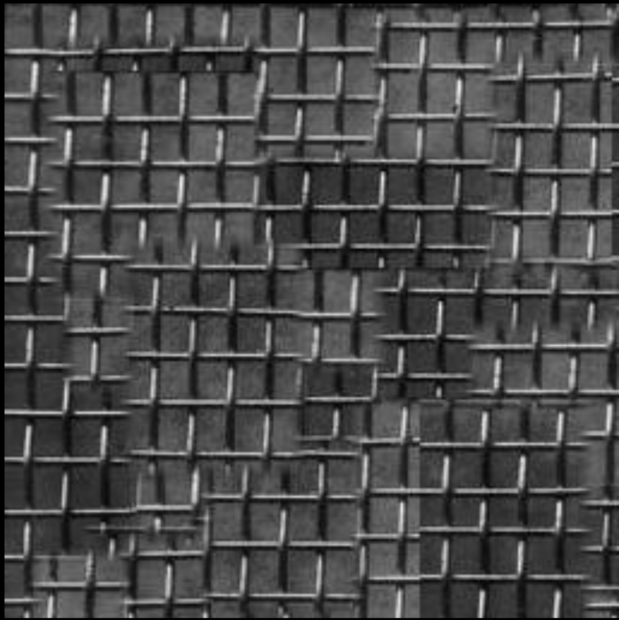
Failures
(Chernobyl Harvest)



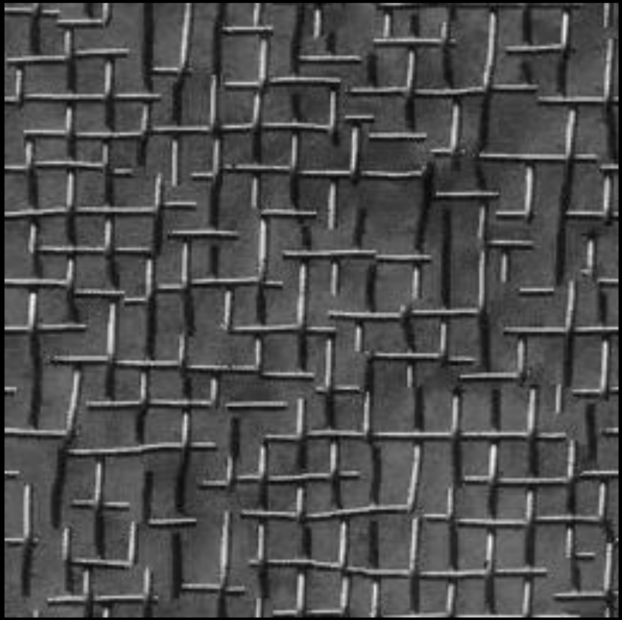
input image



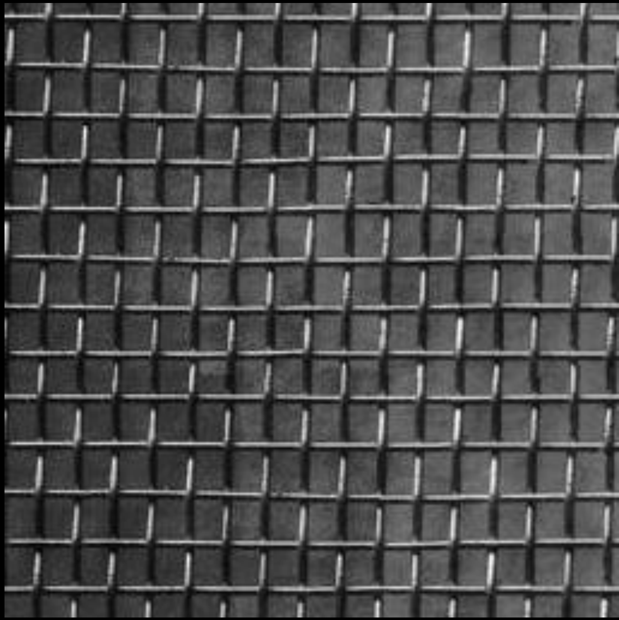
Portilla & Simoncelli



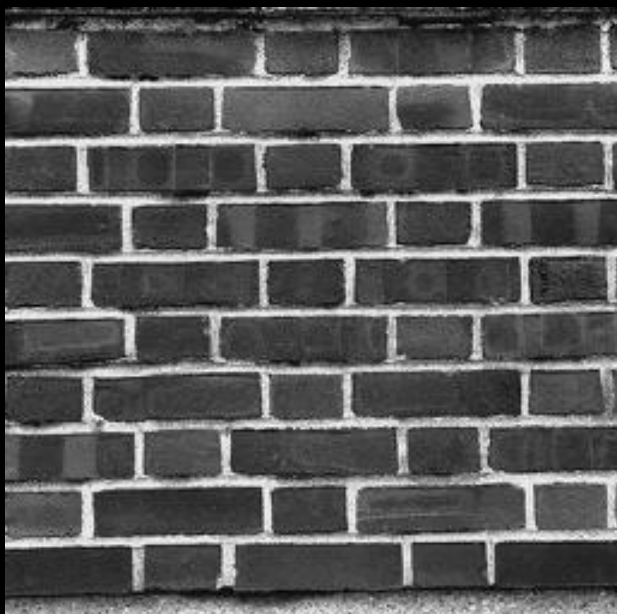
Xu, Guo & Shum



Wei & Levoy

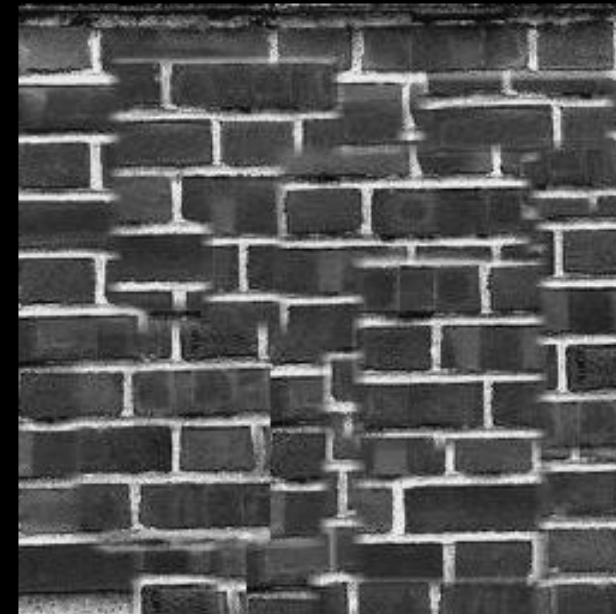


Our algorithm



input image

Portilla & Simoncelli



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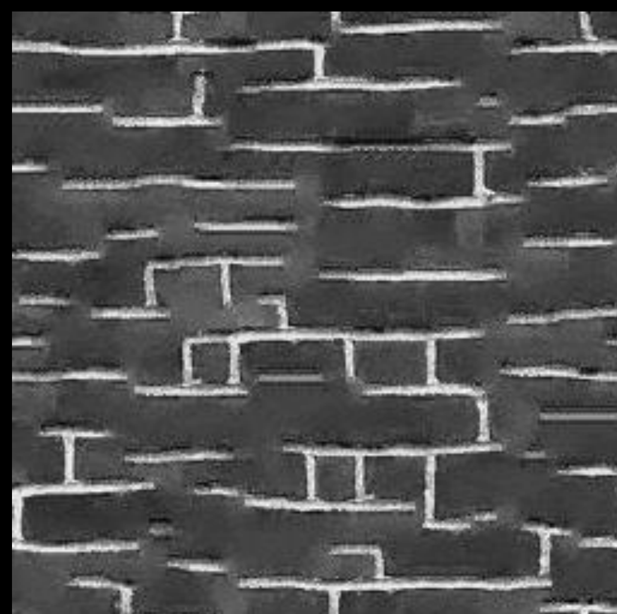
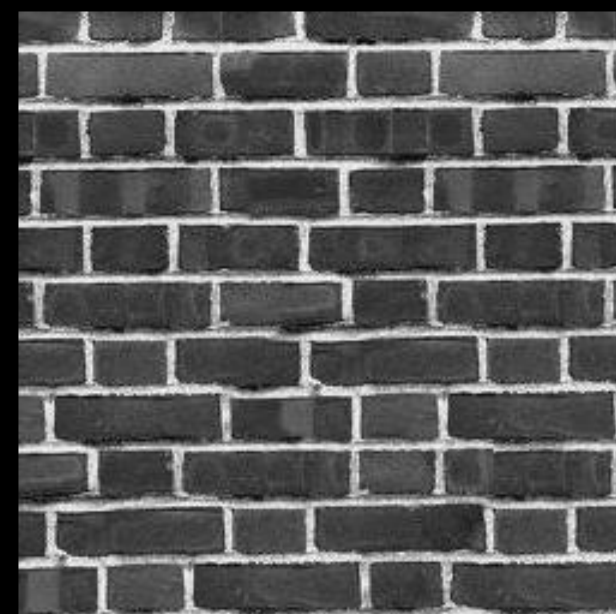


Wei & Levoy



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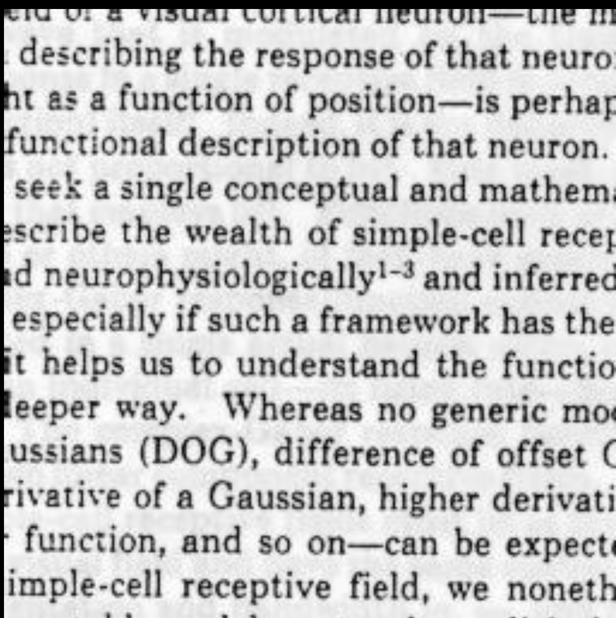

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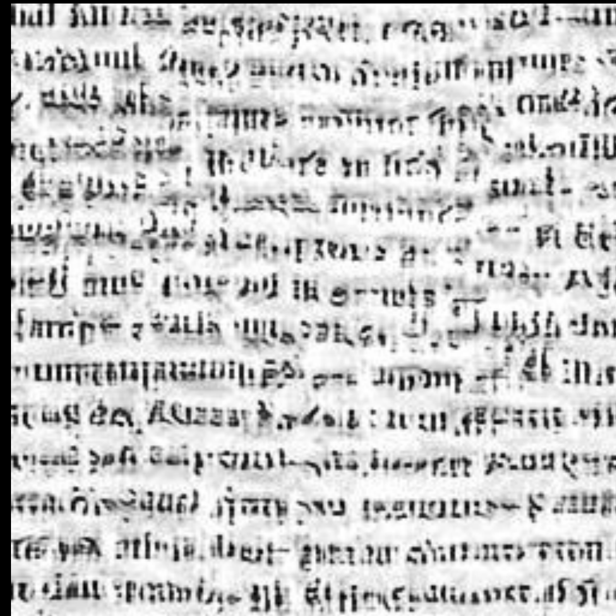
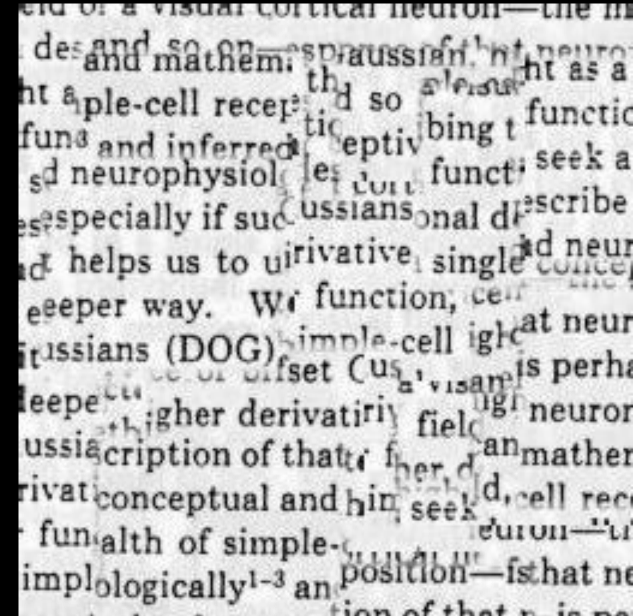
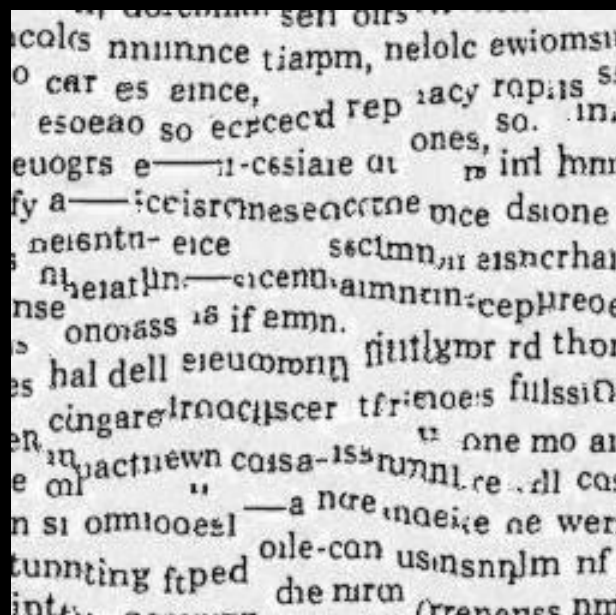


Portilla & Simoncelli



Xu, Guo & Shum



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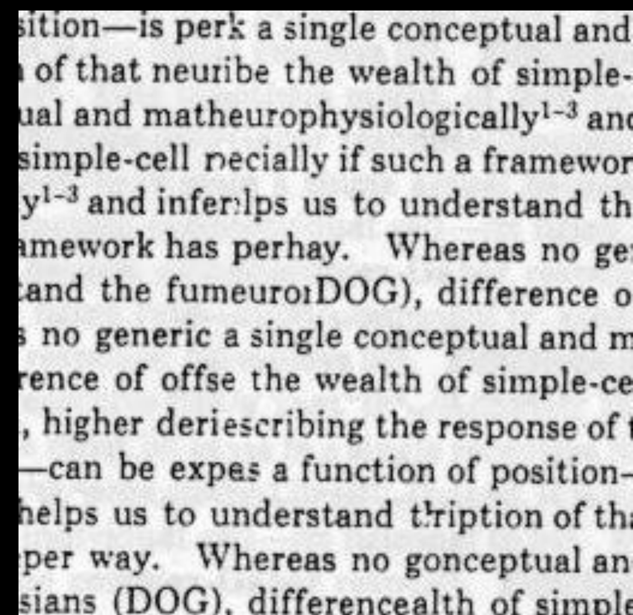
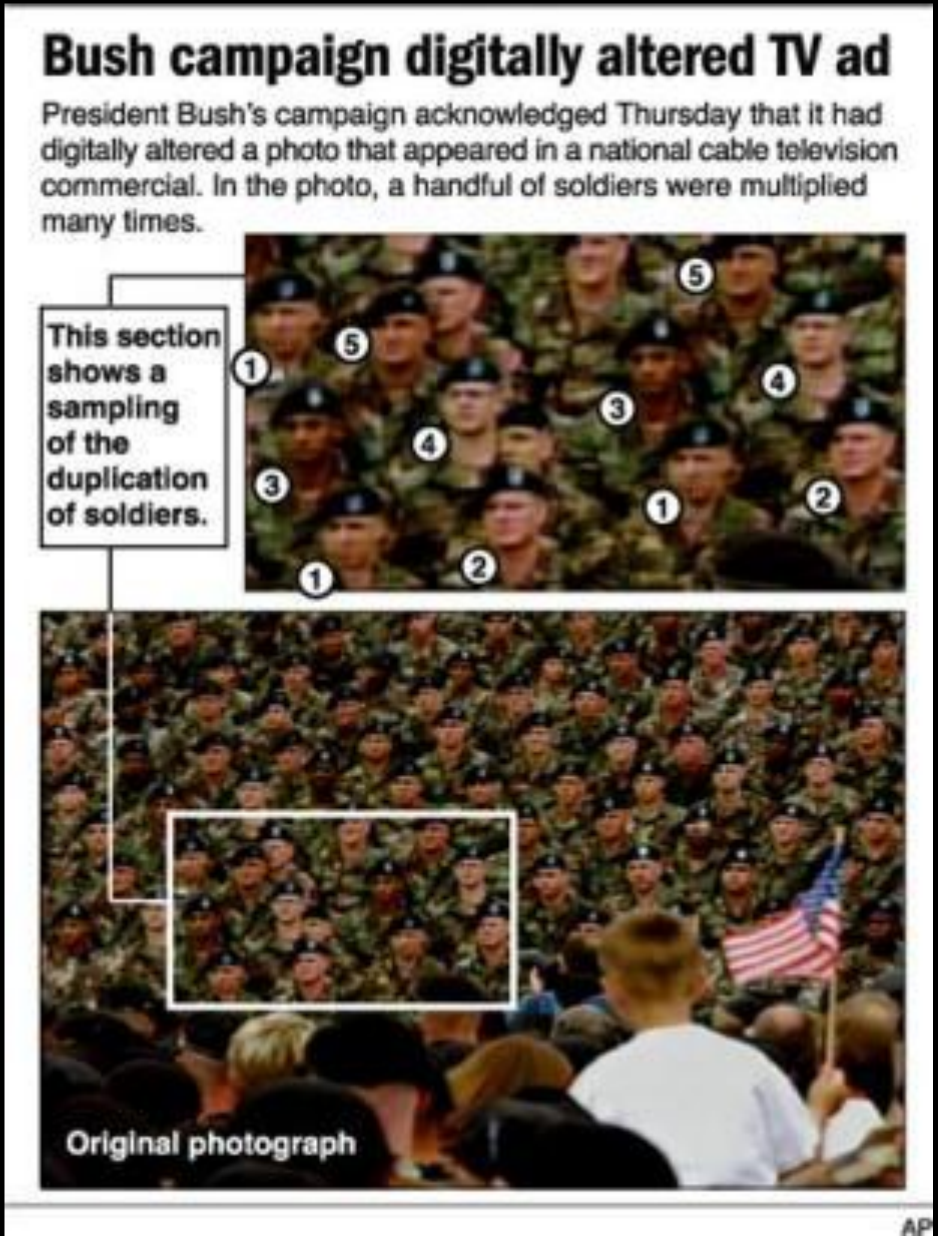
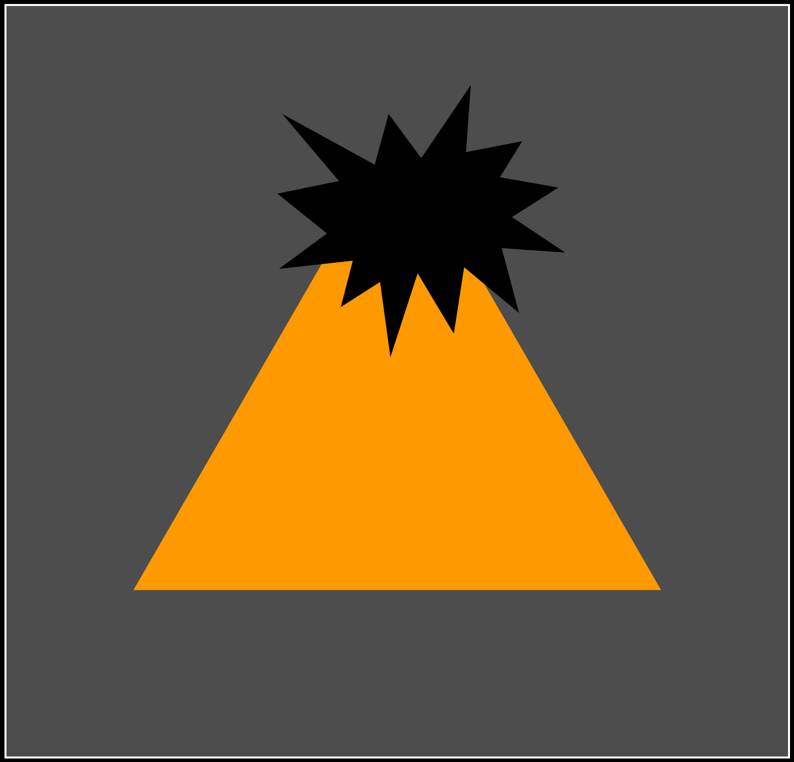


Our algorithm

Political Texture Synthesis!

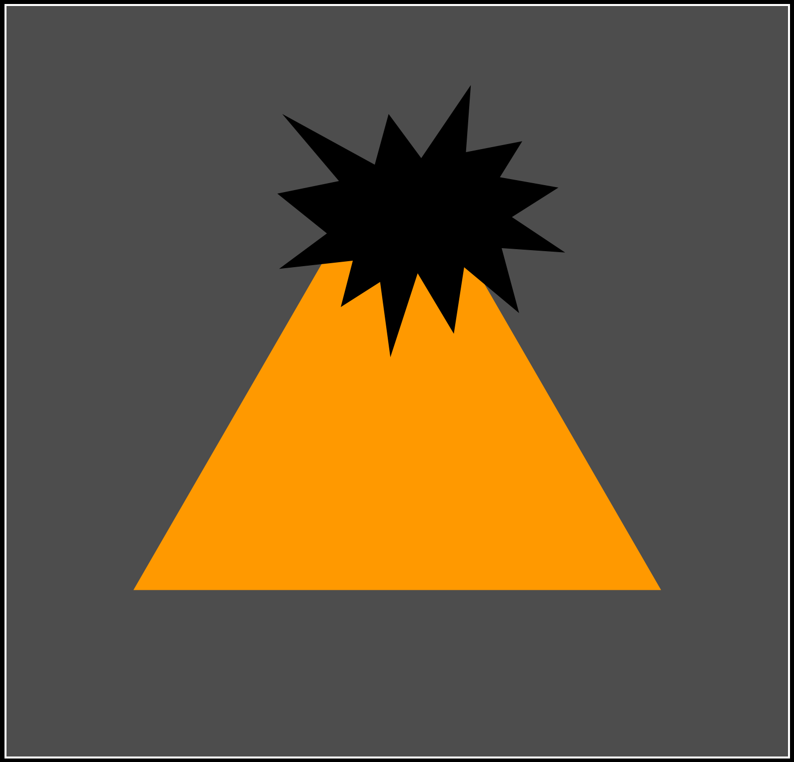


Fill Order



- In what order should we fill the pixels?

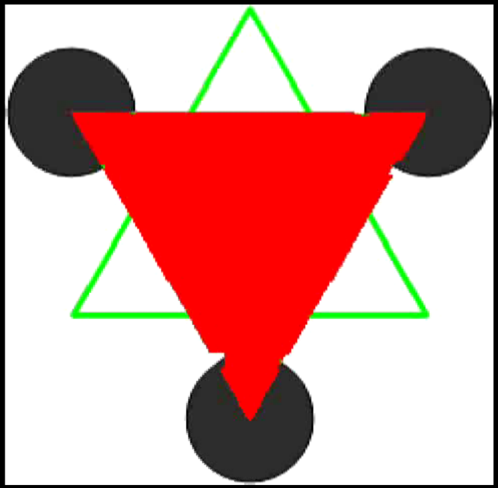
Fill Order



- 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

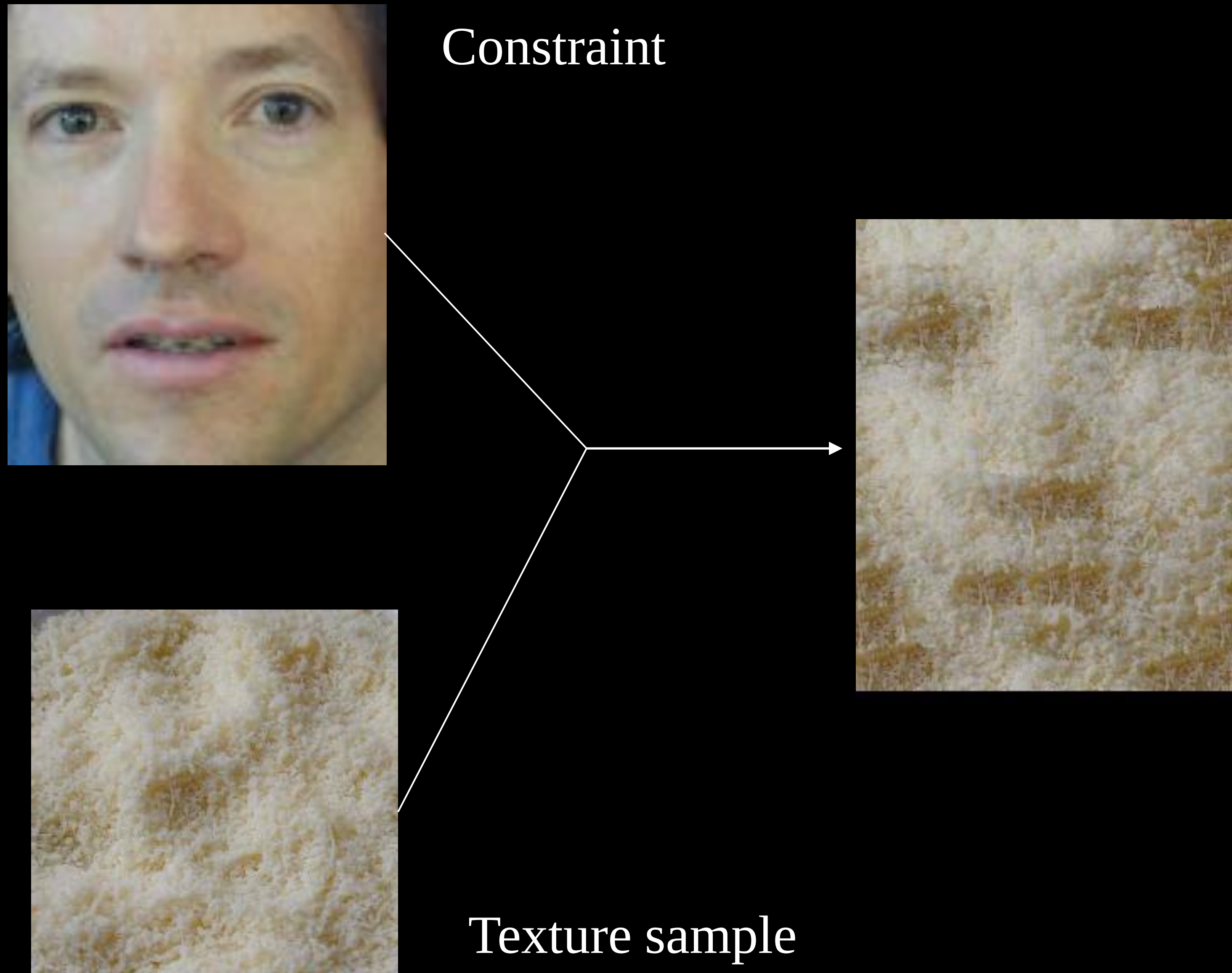
Application: Texture Transfer

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

+

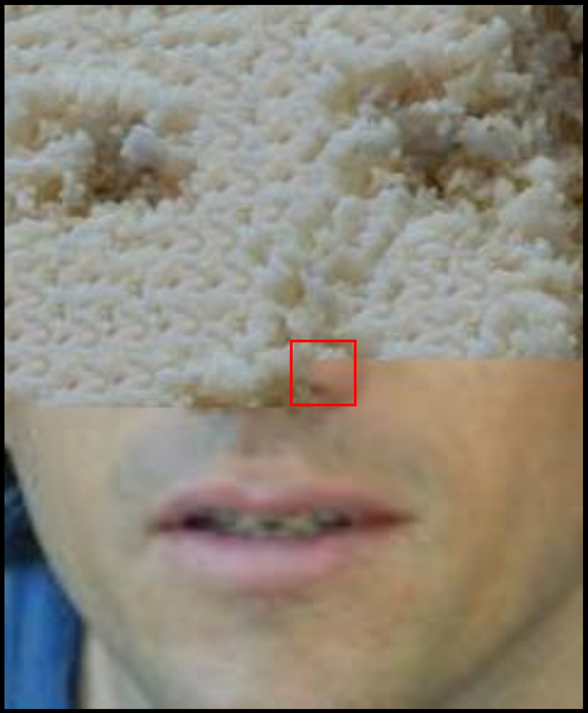
=

Texture Transfer



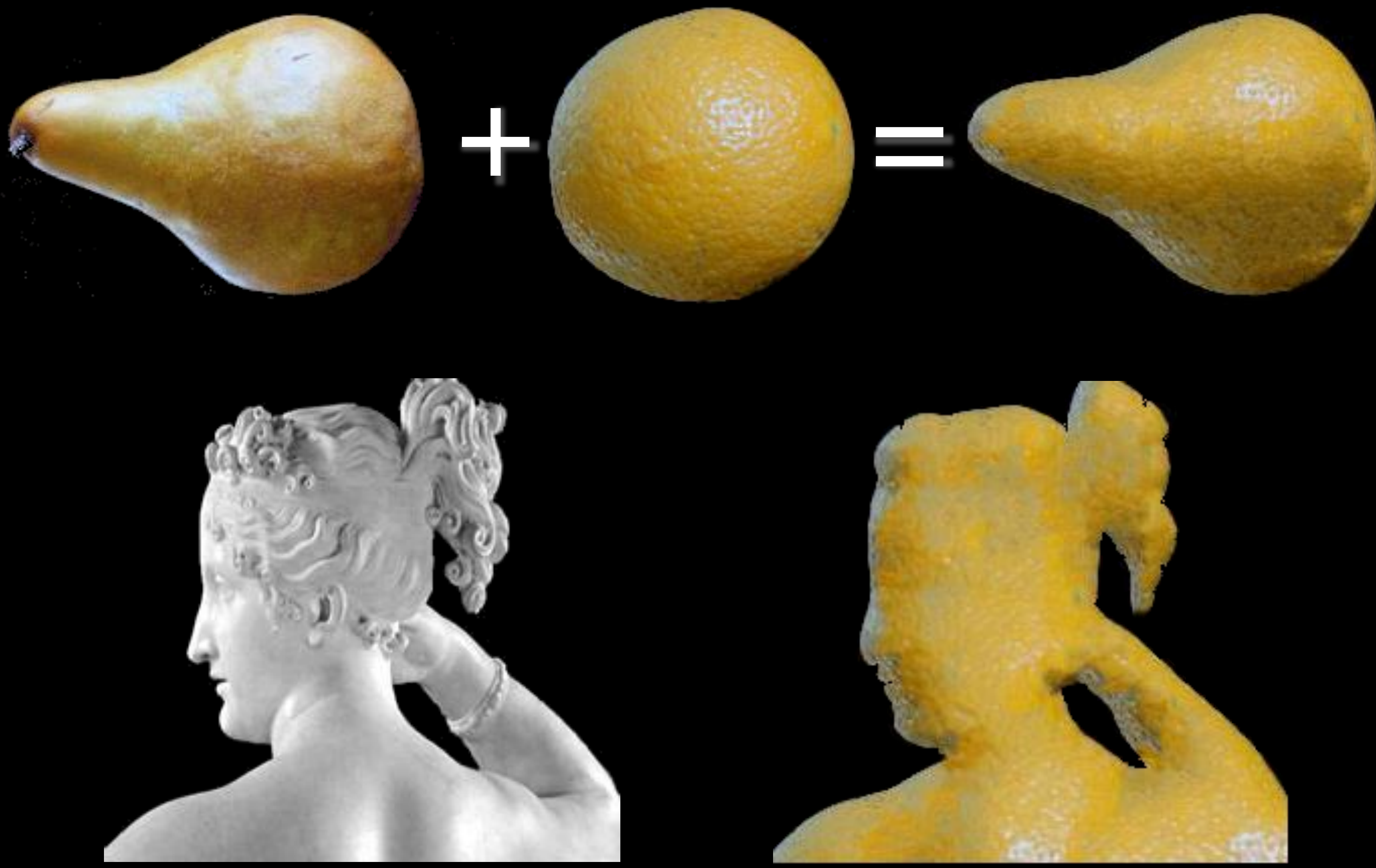
Texture Transfer

- 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”





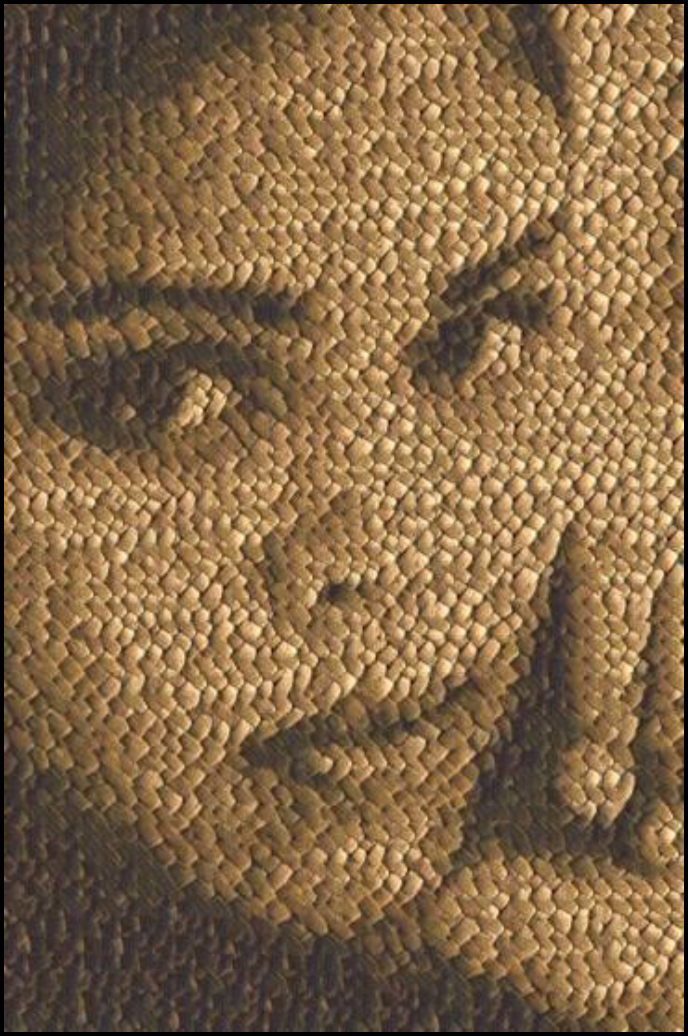


Image Analogies

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

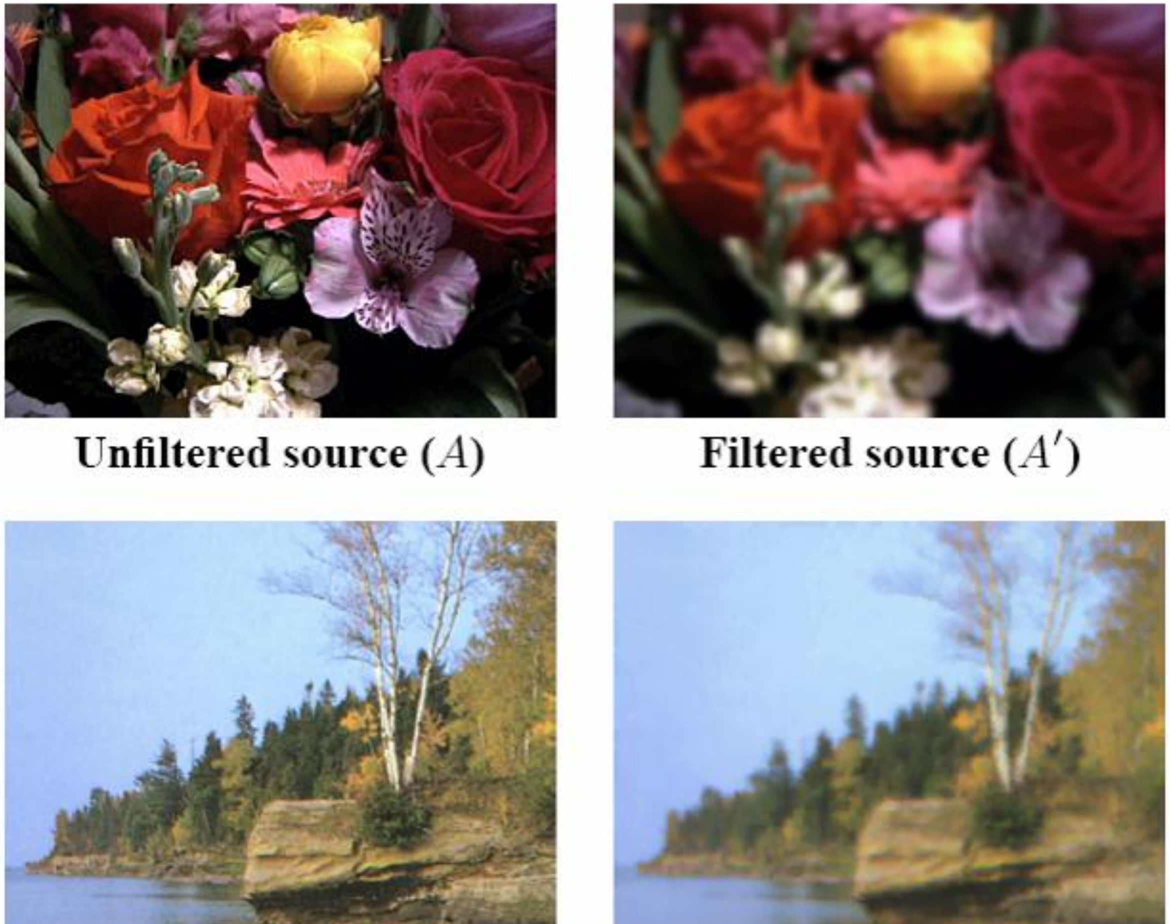
A

A’

B

B’

Blur Filter



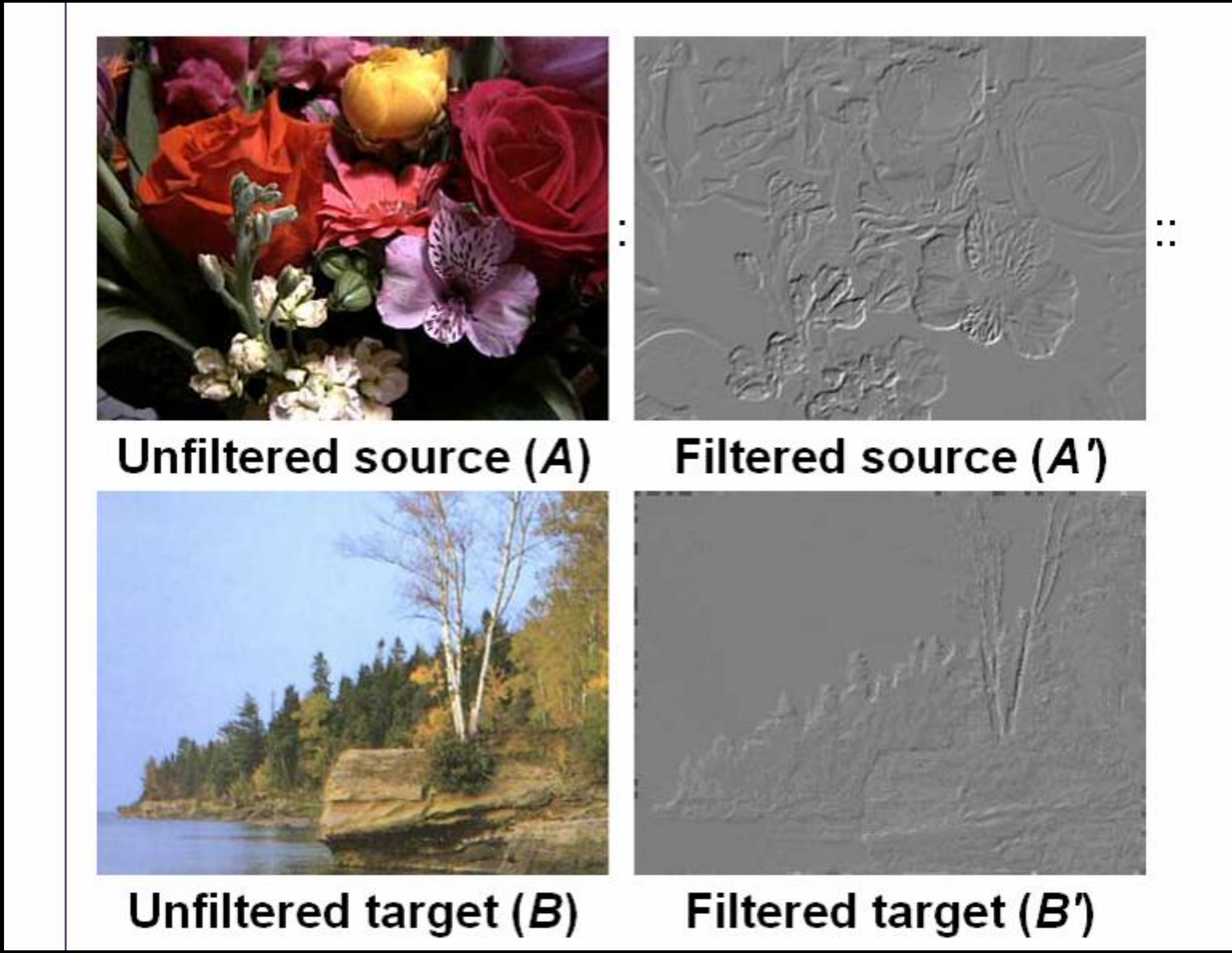
Unfiltered source (A)

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

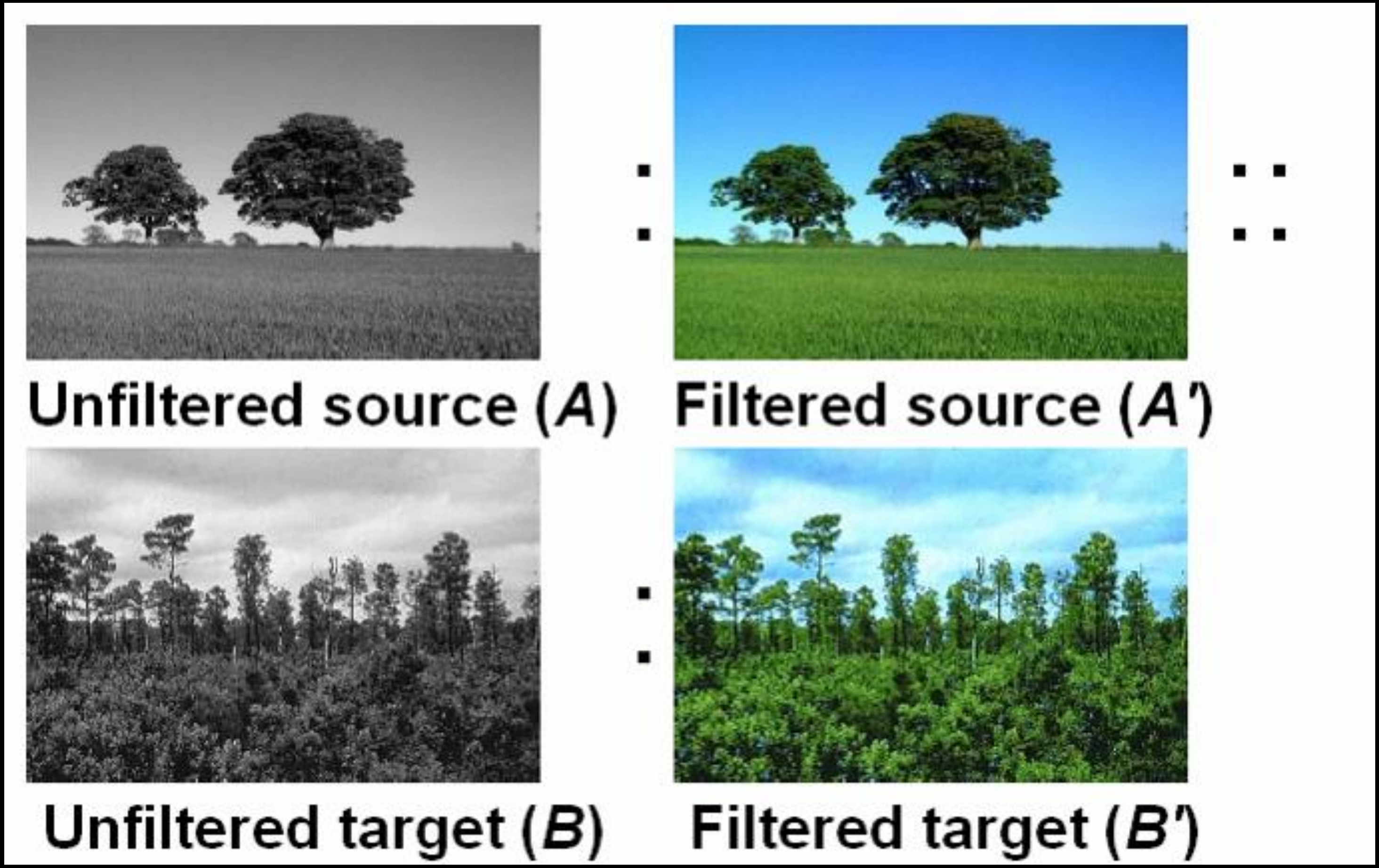
A

A’

B

B’

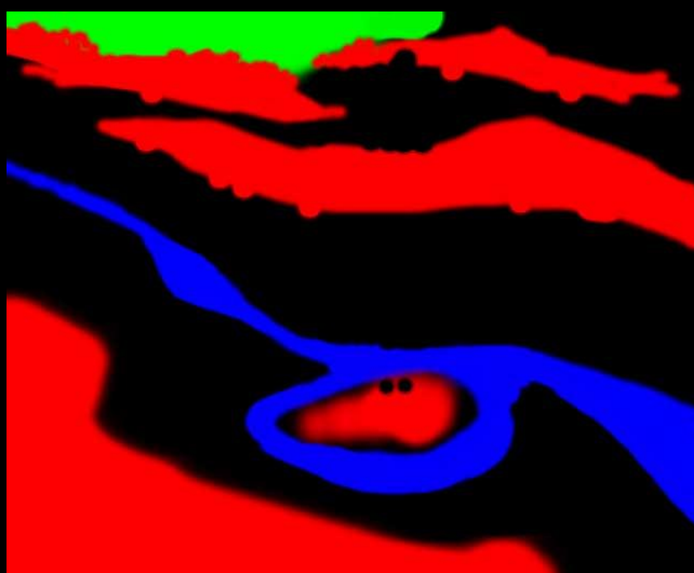
Colorization



Texture-by-numbers

A

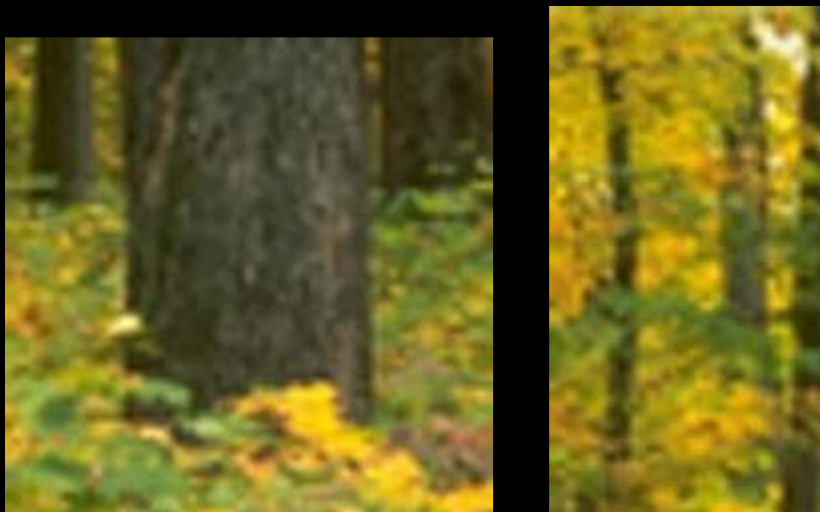
A’



B

B’

Super-resolution



A

A’

Super-resolution (result!)

B

B’