# Data-driven methods: Video & Texture

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CS194: Intro to Computer Vision & Comp. Photography
Alexei Efros, UC Berkeley, Fall 2020

Michel Gondry train video

http://www.youtube.com/watch?v=0S43IwBF0uM

# Class Choice award!

# Weather Forecasting for Dummies™

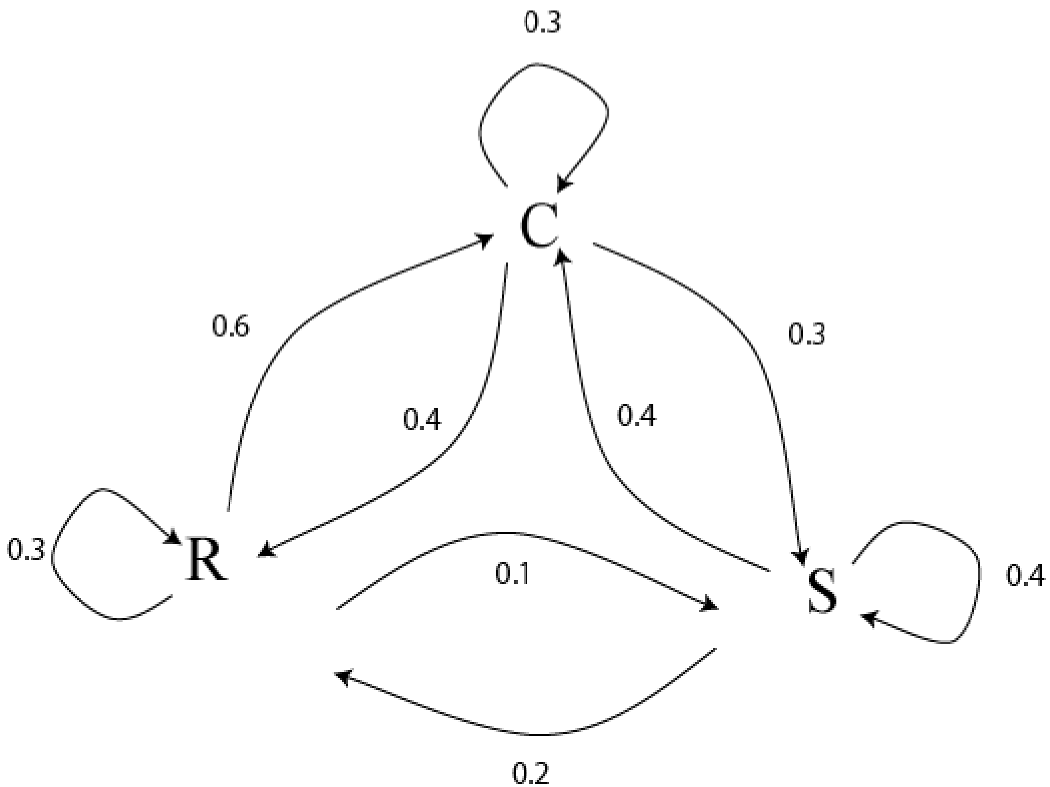
Let's predict weather:

- 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

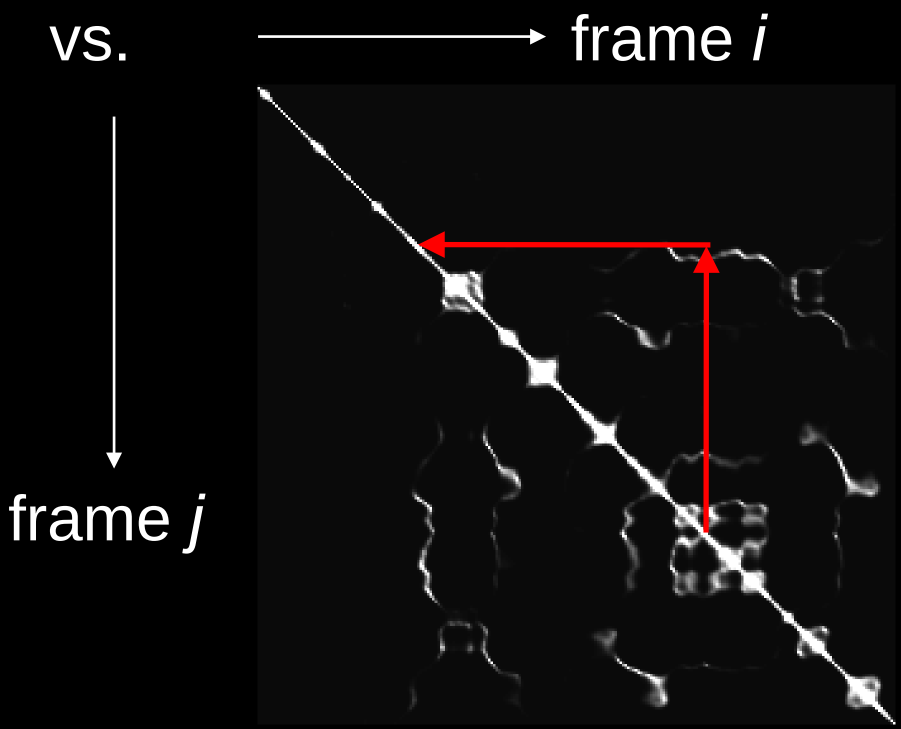
video texture

# Our approach

- How do we find good transitions?

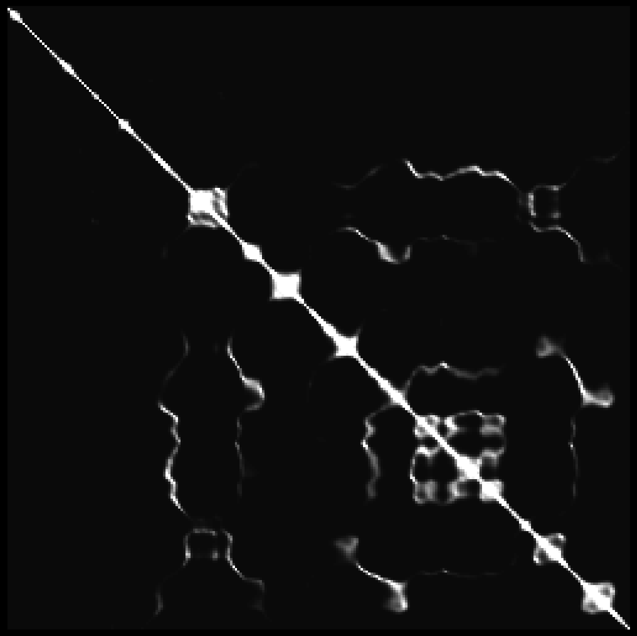
# Finding good transitions

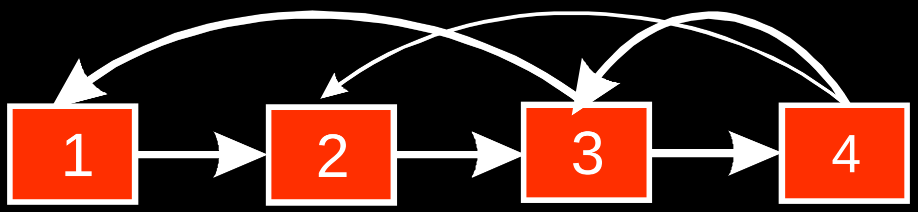
- Compute $L_2$ distance $D_{i,\,j}$ between all frames




Similar frames make good transitions

# Markov chain representation

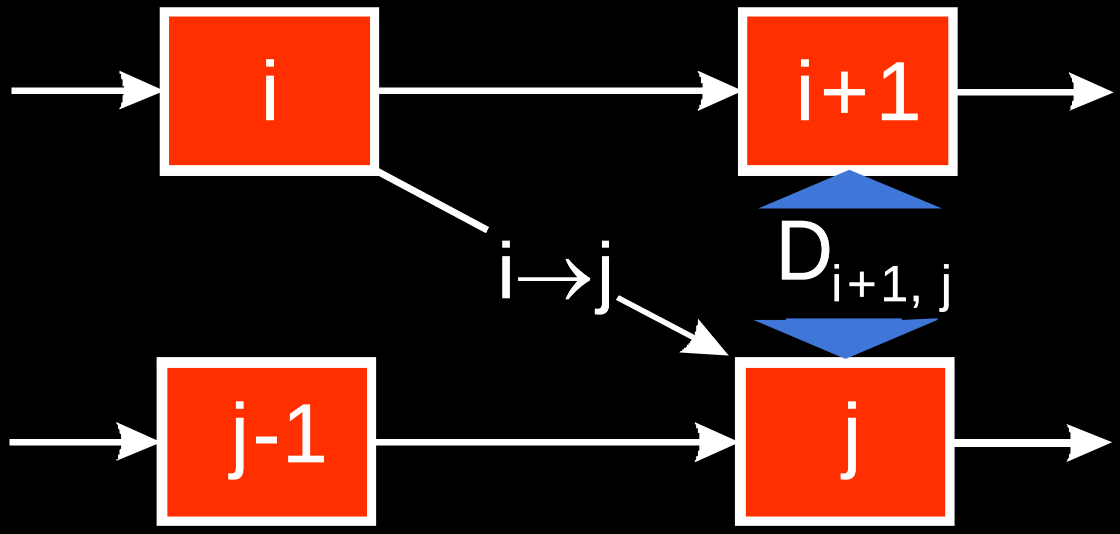





Similar frames make good transitions

# Transition costs

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



# Transition probabilities

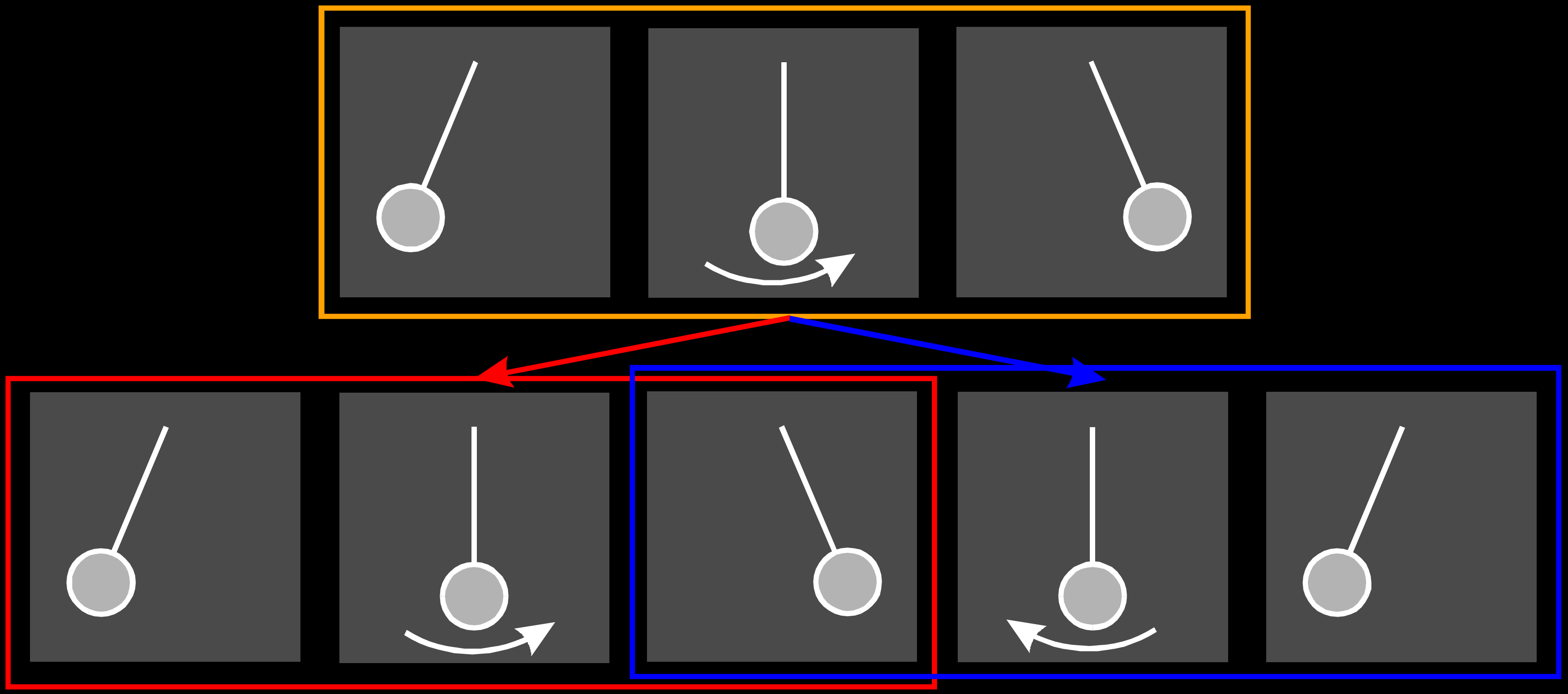
- Probability for transition $P_{i \to j}$ inversely related to cost:
  - $P_{i \to j} \sim \exp\left( - C_{i \to j} / \sigma^2 \right)$

high $\sigma$

low $\sigma$

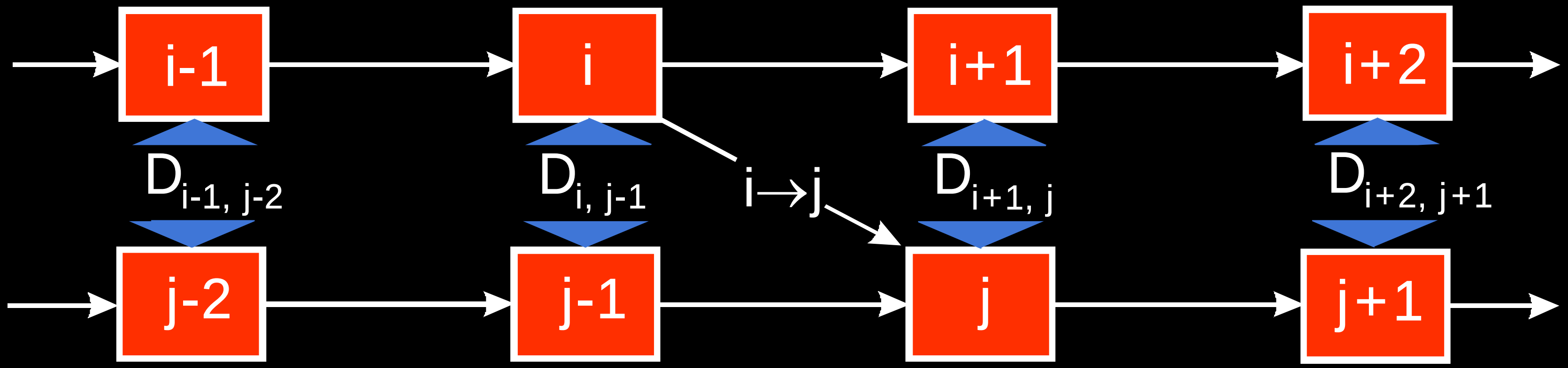
# Preserving dynamics

# Preserving dynamics



# Preserving dynamics

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

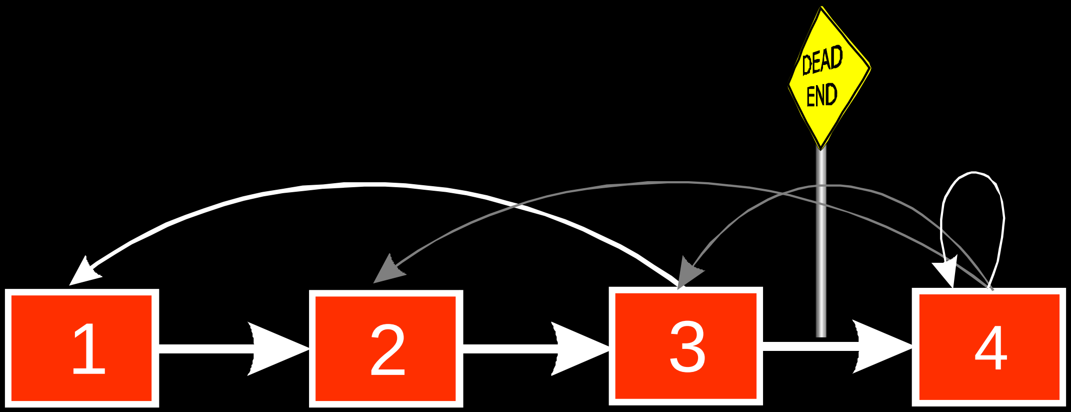


# Preserving dynamics – effect

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

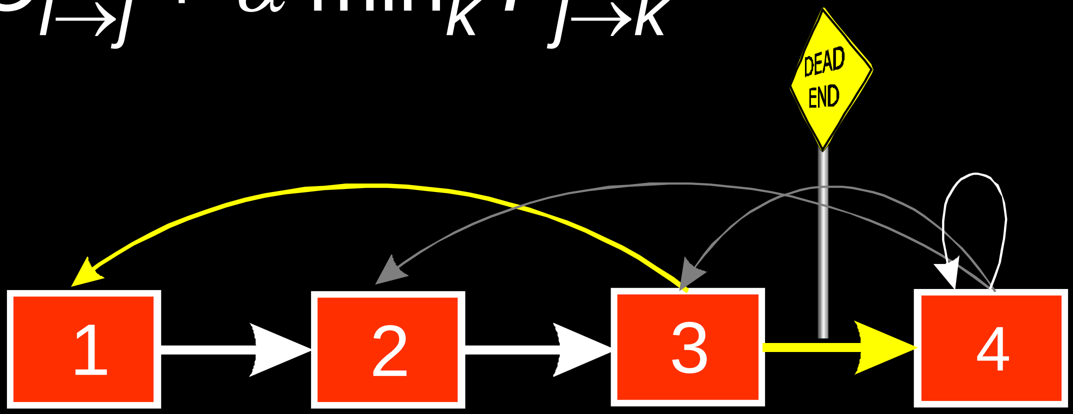
# Dead ends

- 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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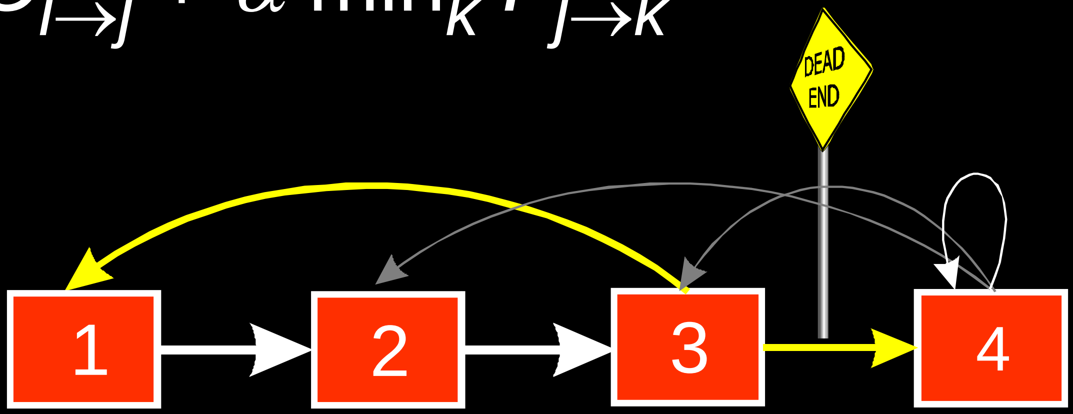

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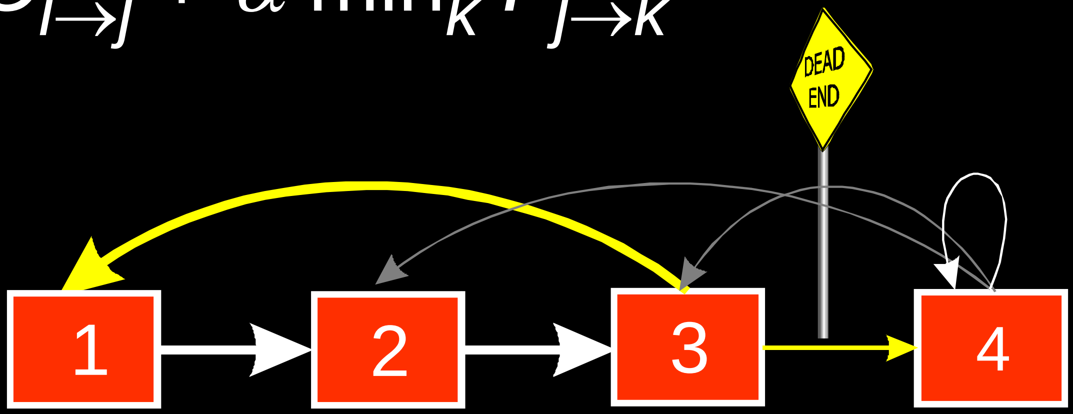

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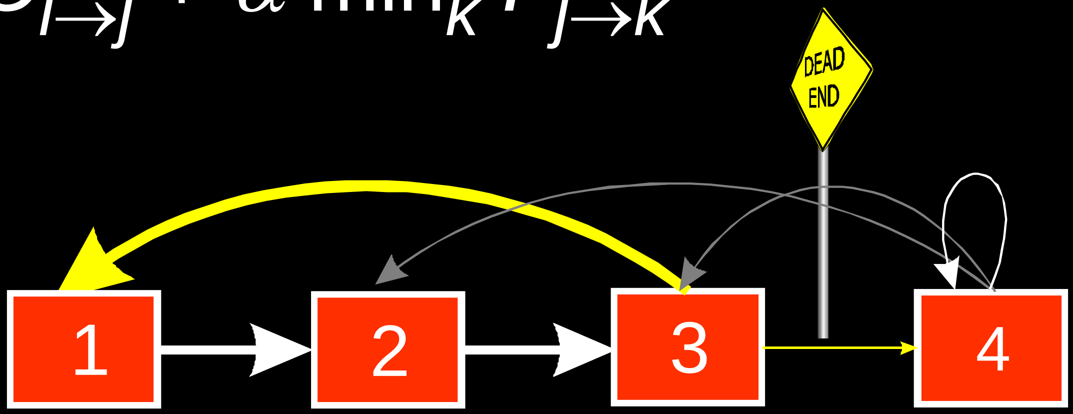
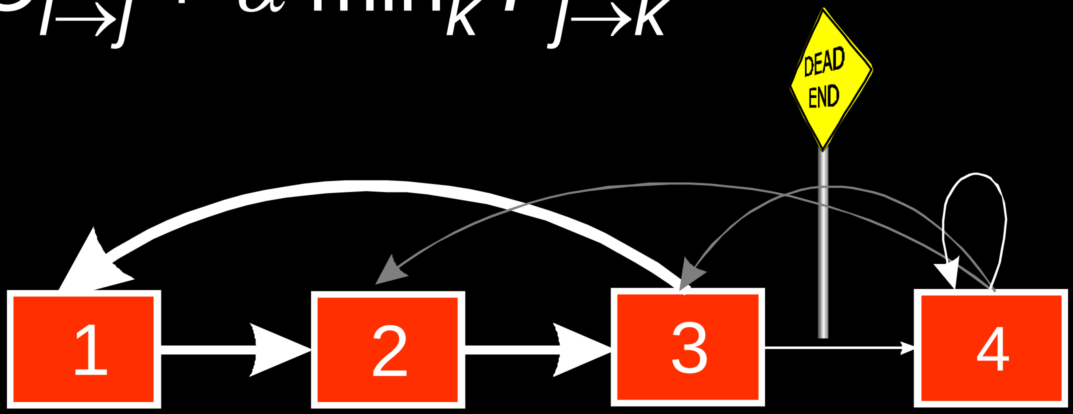


# Future cost

- 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



# Final result

# Finding good loops

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

# Video portrait

- c.f. Harry Potter

# Region-based analysis

- Divide video up into regions

- Generate a video texture for each region

# User-controlled video textures

slow variable fast

User selects target frame range

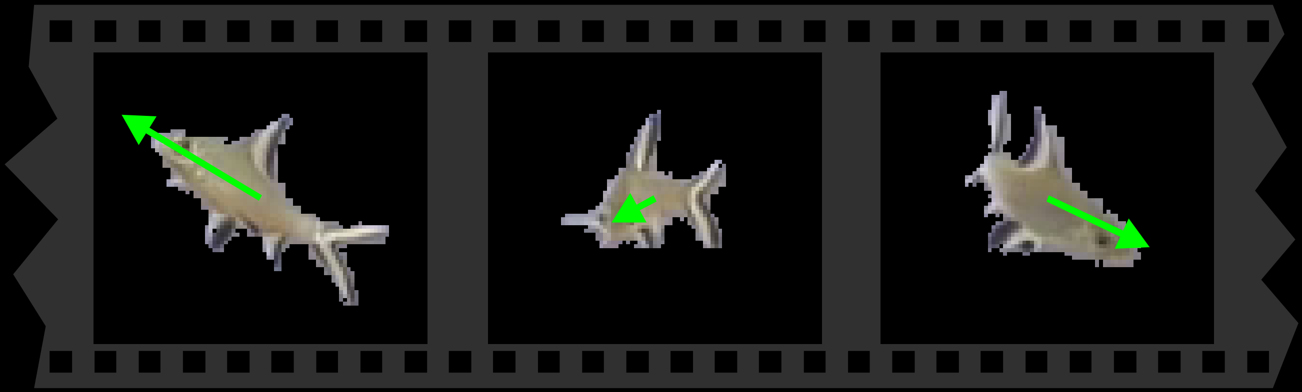
# Video-based animation

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




# Video sprite extraction

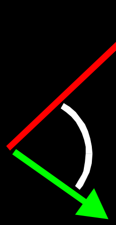
blue screen matting
and velocity estimation



# Video sprite control

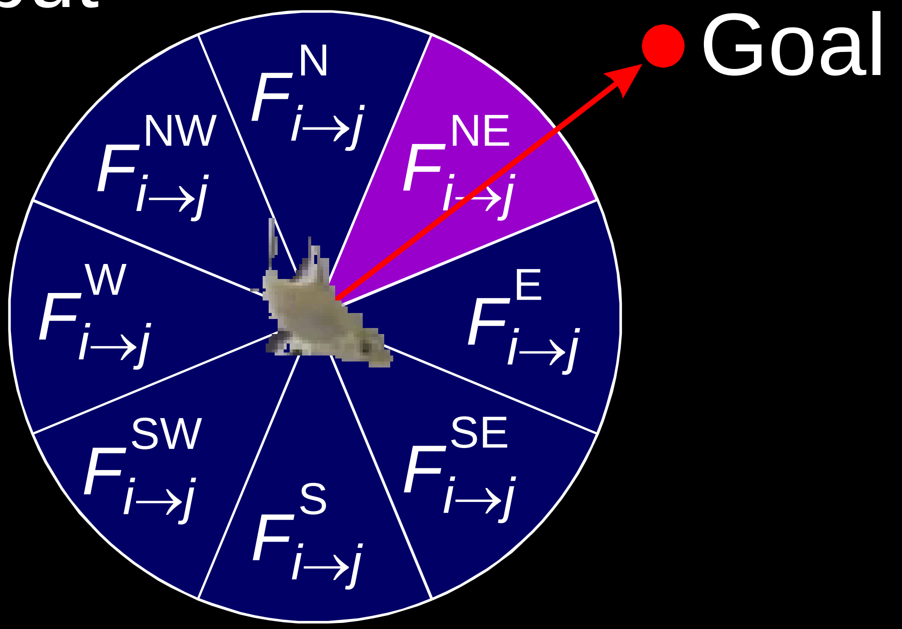
- Augmented transition cost:

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



# 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]

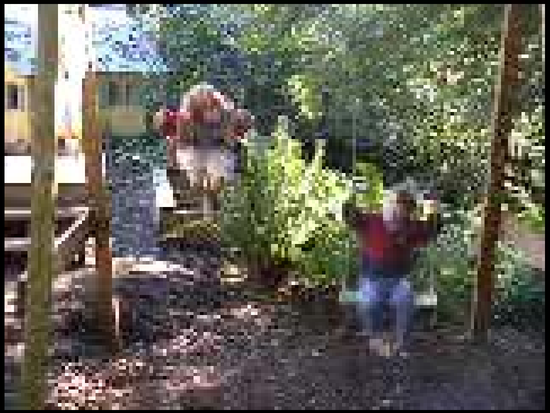


# Interactive fish

# Summary / Discussion

- Some things are relatively easy






# Discussion

- Some are hard

# “Amateur” by Lasse Gjertsen

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

similar idea:

http://www.youtube.com/watch?v=MsBMG-p1HDM&feature=share&list=PLFFD733D0FF425290

# Hyperlapse Videos

https://www.youtube.com/watch?v=Wt_Y04xn84M

# “Do As I Do” (ICCV 2003)

https://youtu.be/UMJcpLIAwKg

Efros, Berg, Mori, Malik, “Recognizing Action at a Distance”, ICCV **2003**

# Texture

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

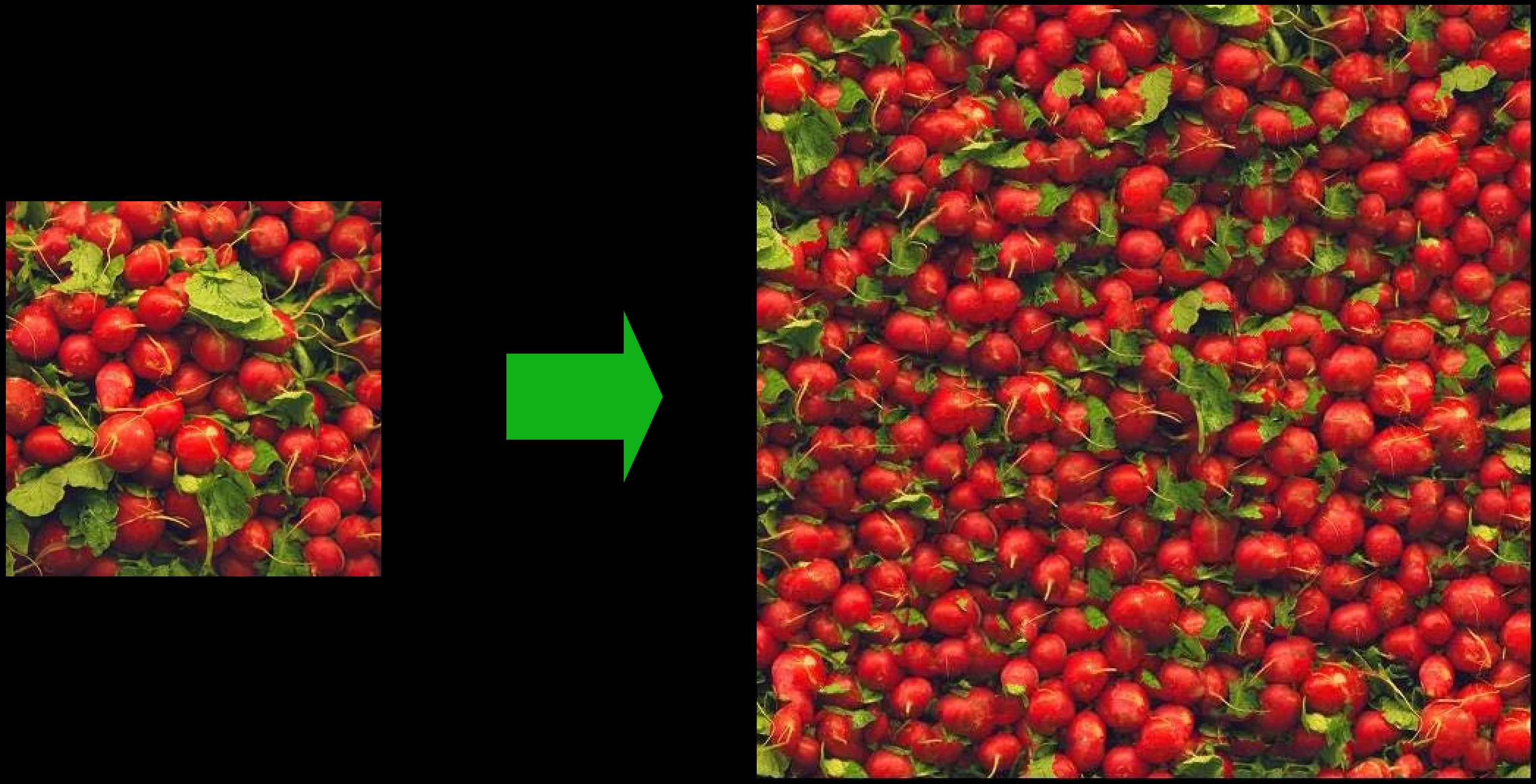
radishes

rocks

yogurt

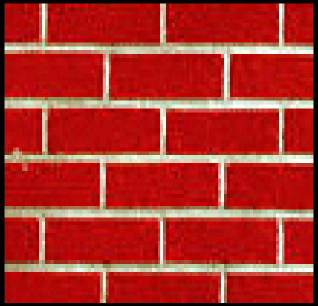
# Texture Synthesis

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

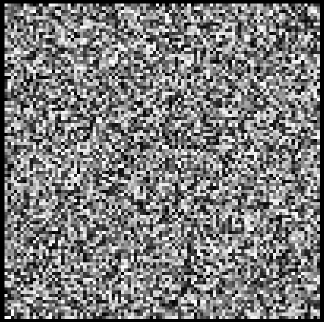


# The Challenge

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



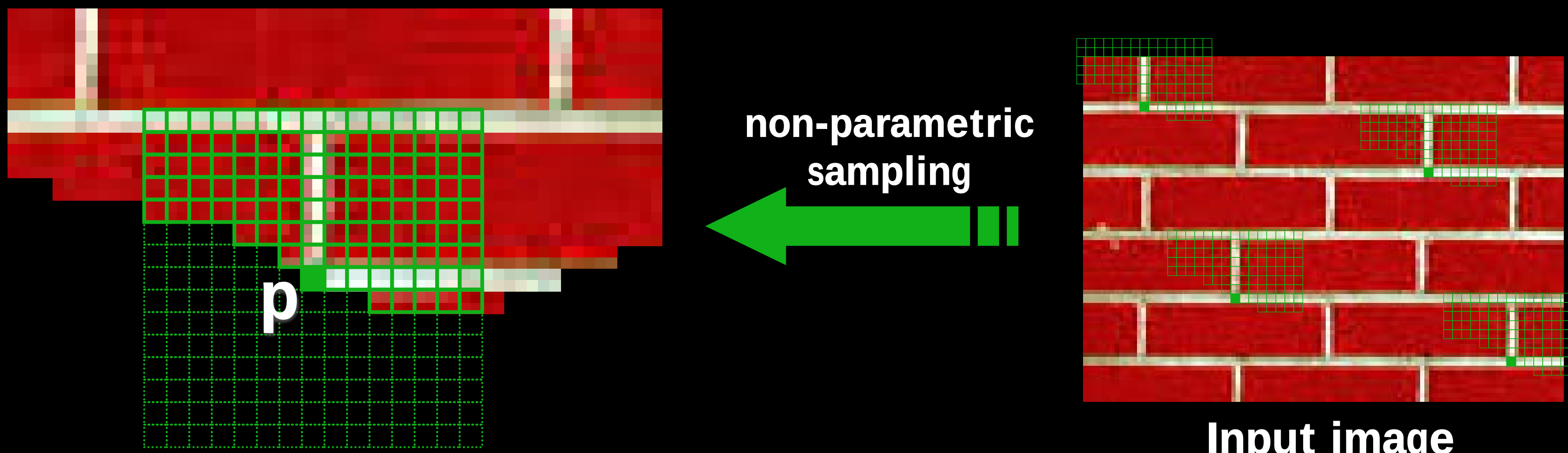
**repeated**



**stochastic**

**Both?**

# Efros & Leung Algorithm




Synthesizing a pixel

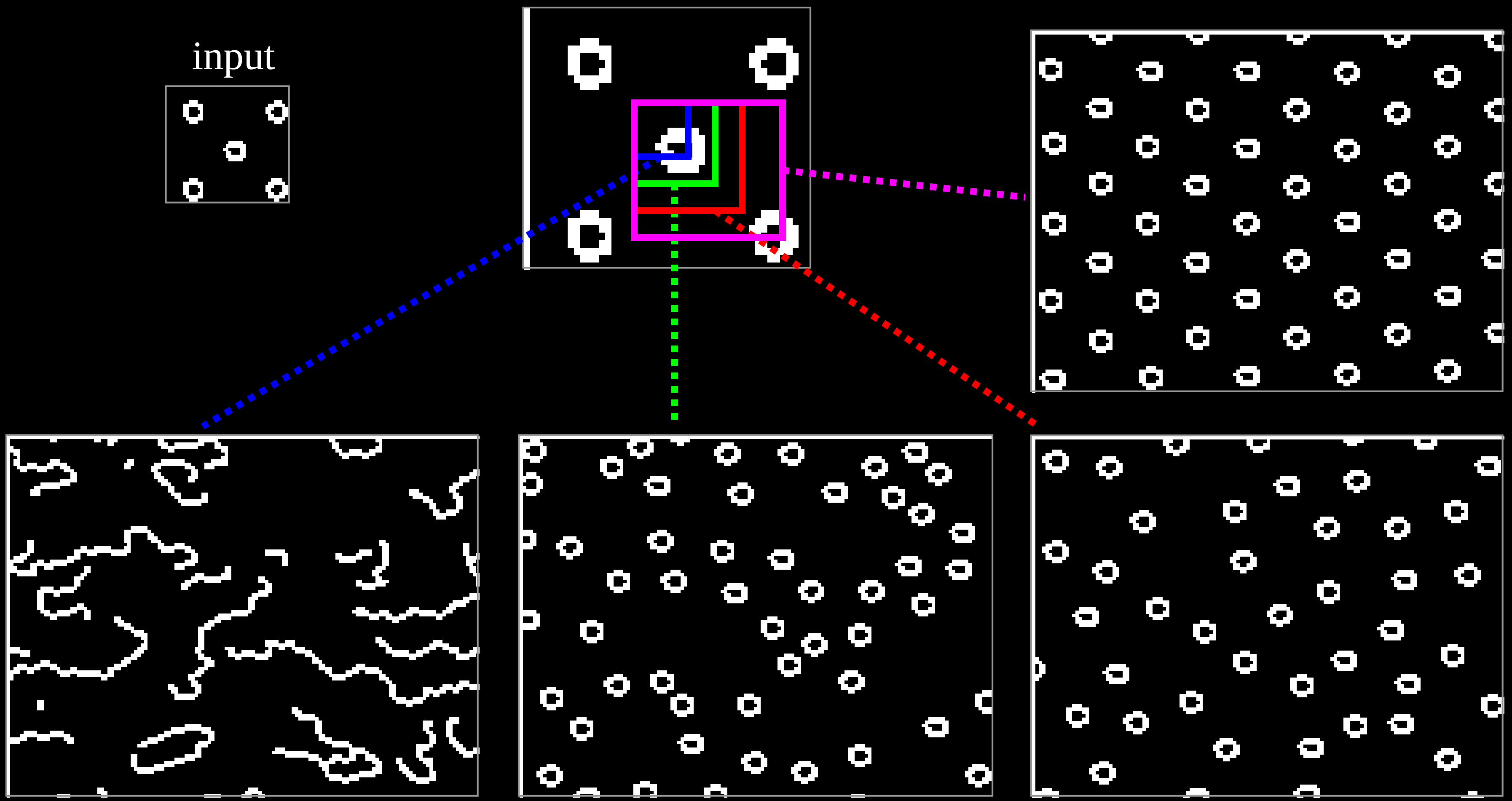
Input image

- 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

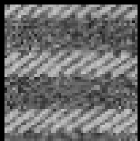
# Some Details

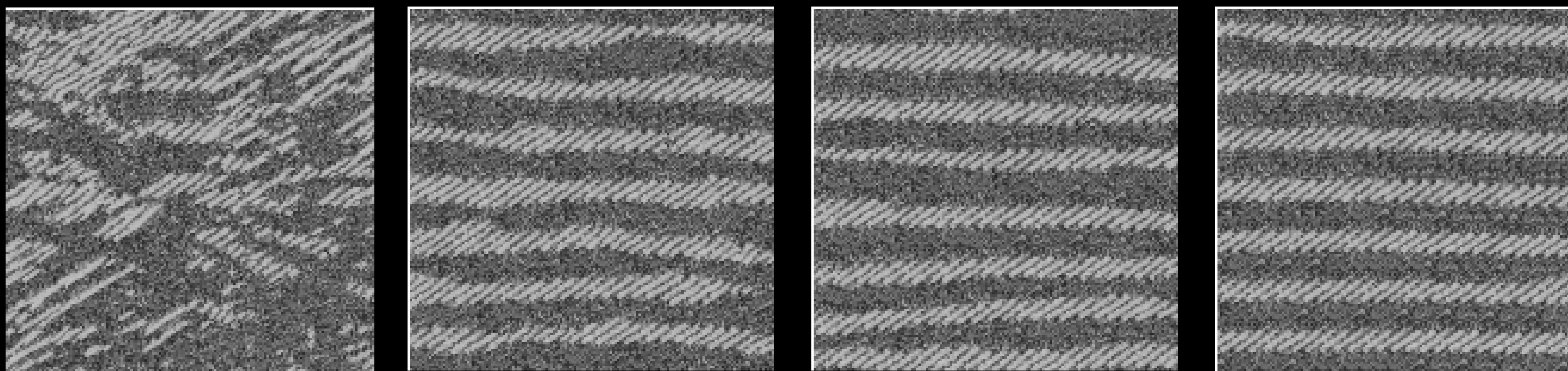
- Growing is in “onion skin” order
  - Within each “layer”, pixels with most neighbors are synthesized first
  - If no close match can be found, the pixel is not synthesized until the end
- Using *Gaussian-weighted* SSD is very important
  - to make sure the new pixel agrees with its closest neighbors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

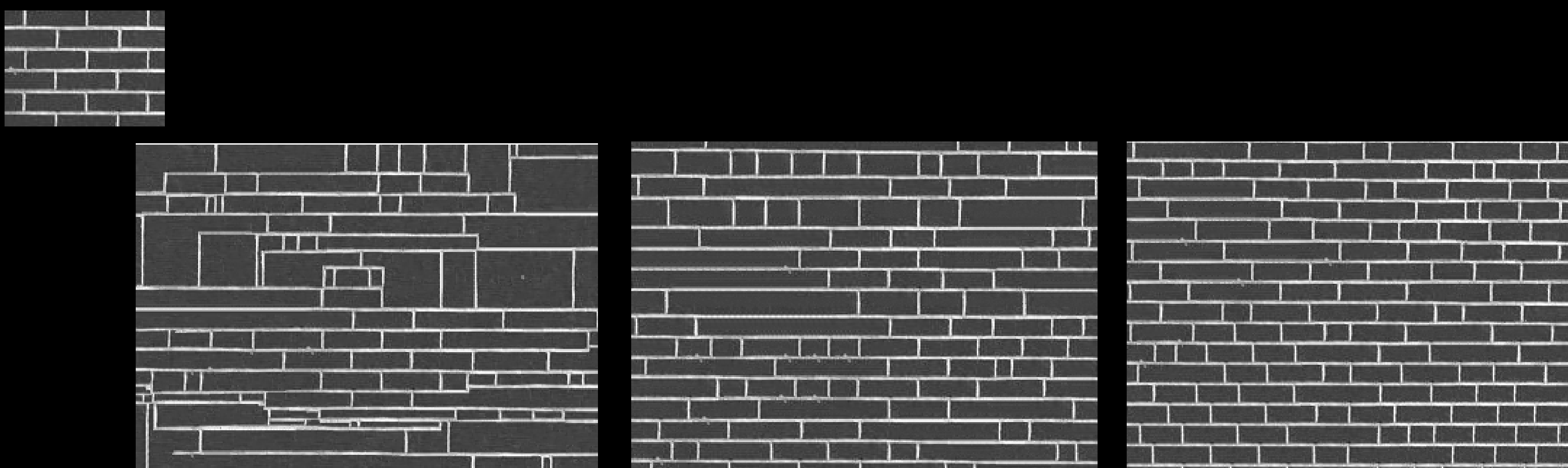
# Neighborhood Window



# Varying Window Size



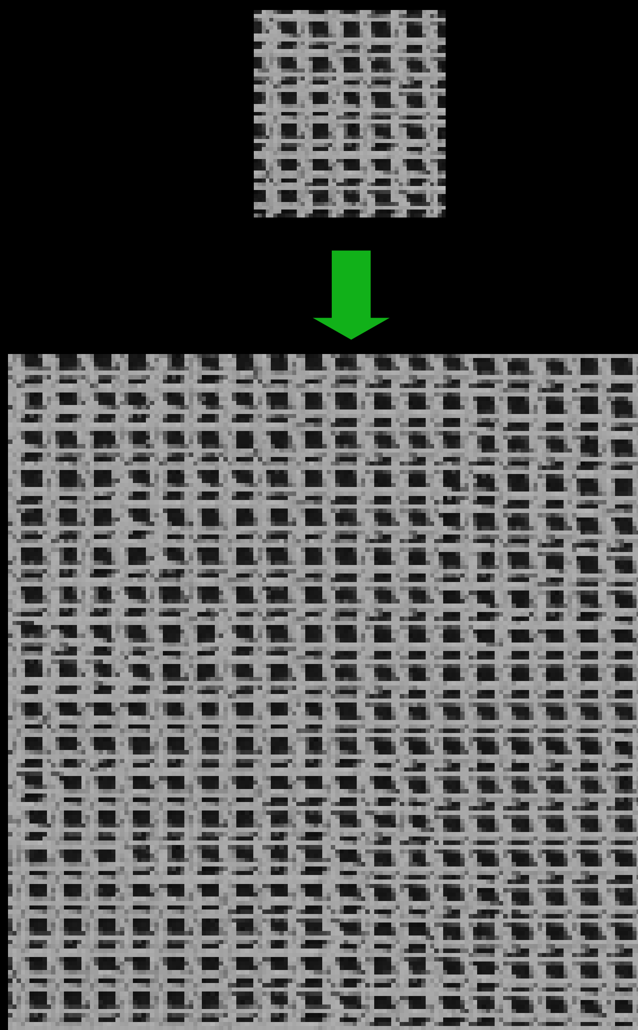




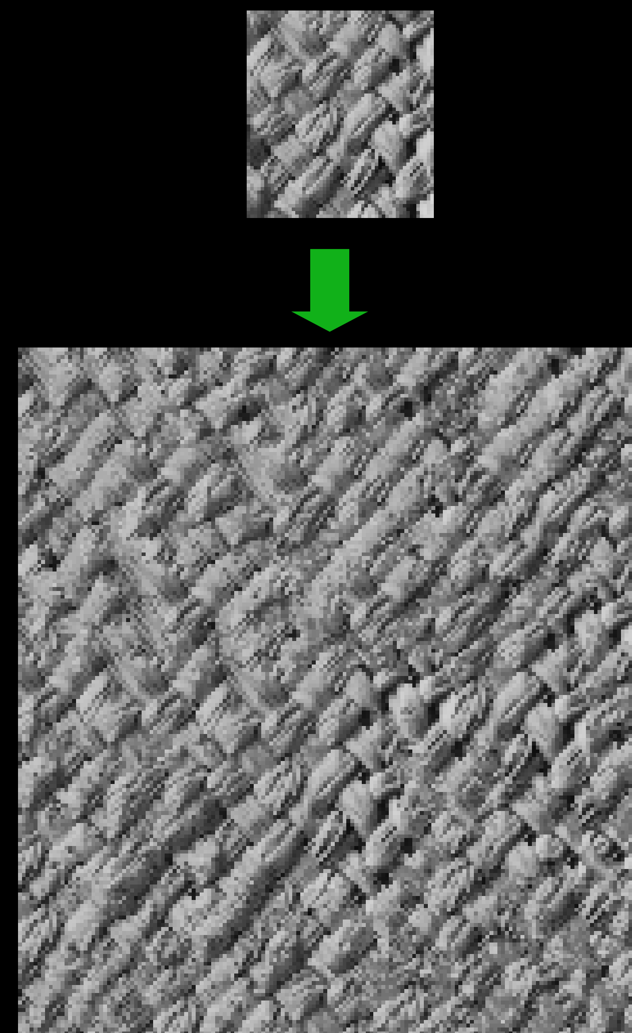
Increasing window size

# Synthesis Results

french canvas

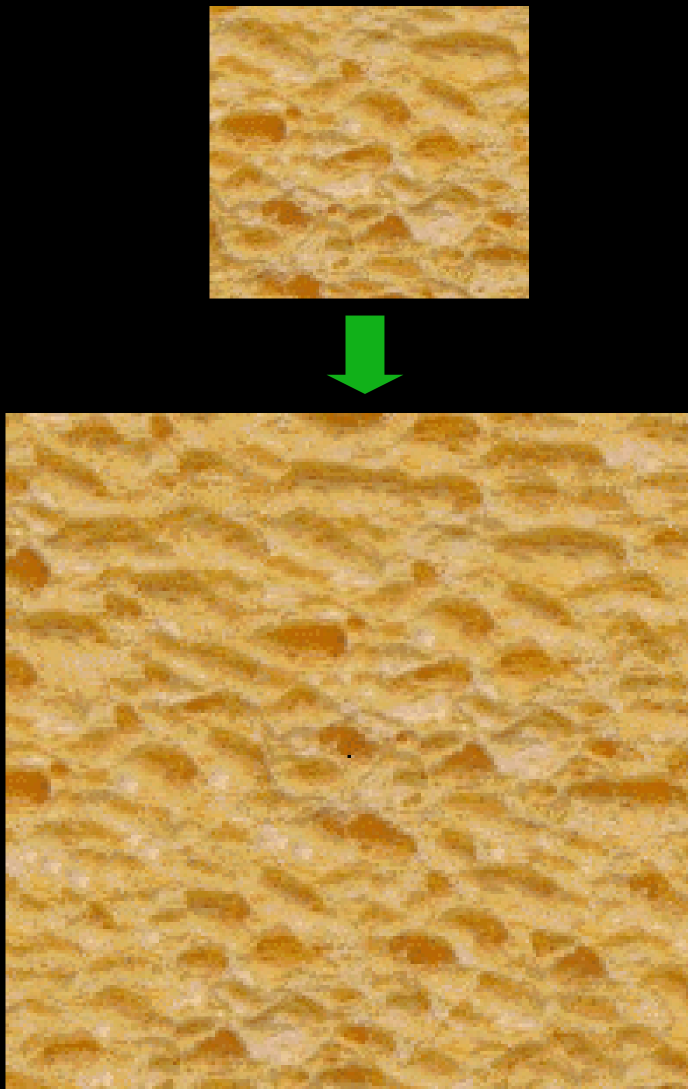


rafia weave

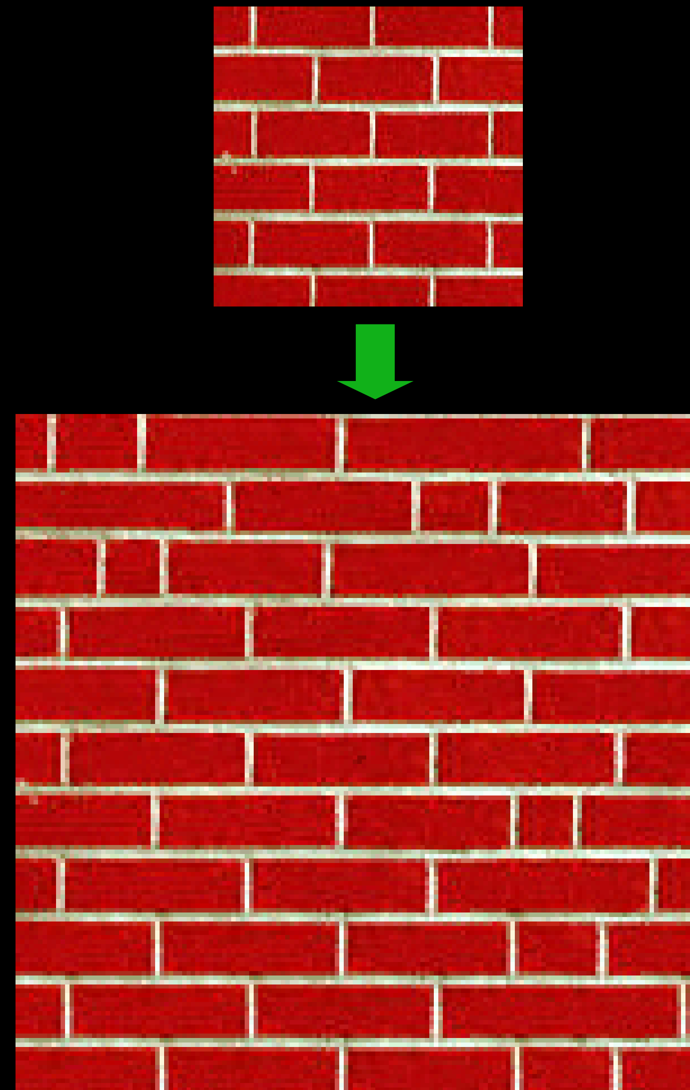


# More Results

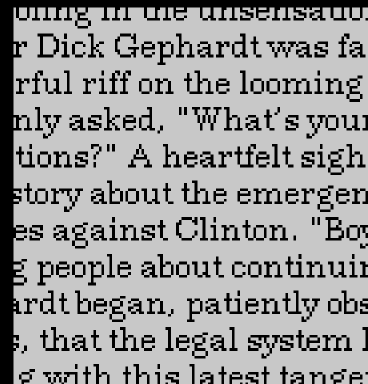
white bread

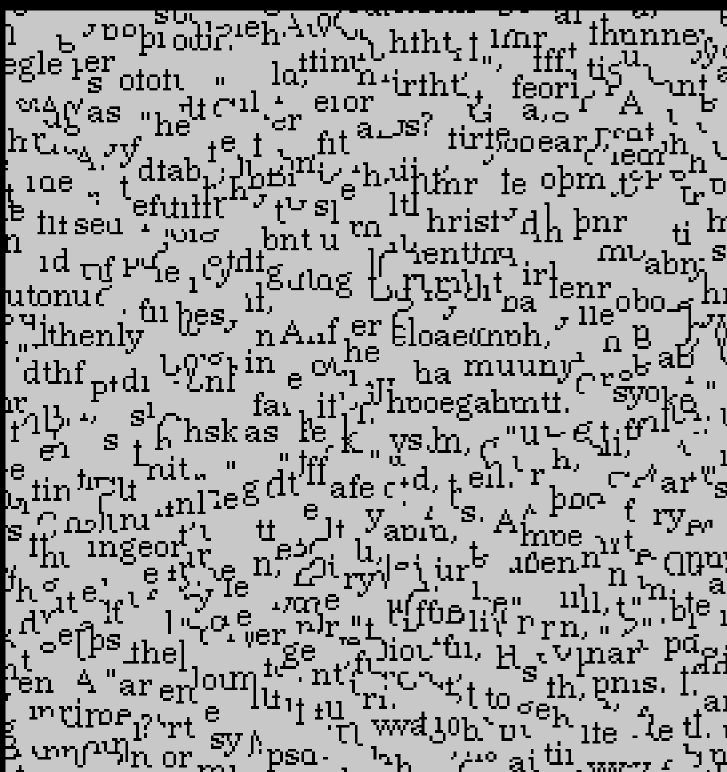


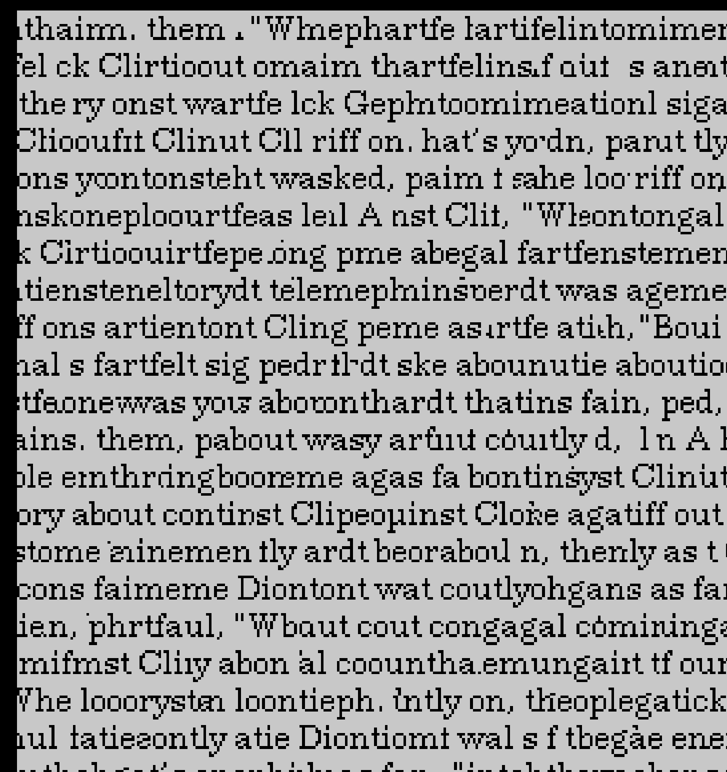
brick wall



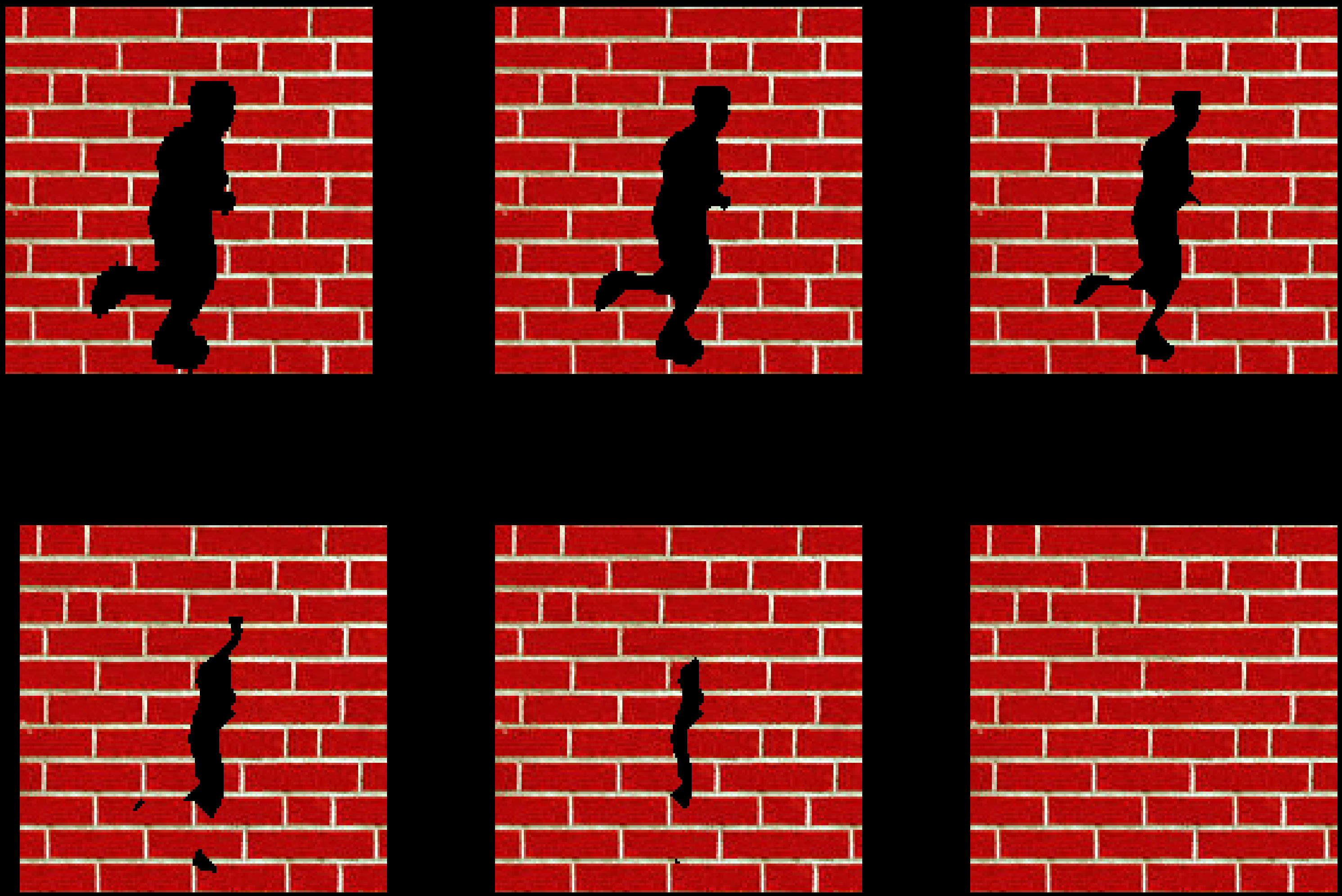
# Homage to Shannon



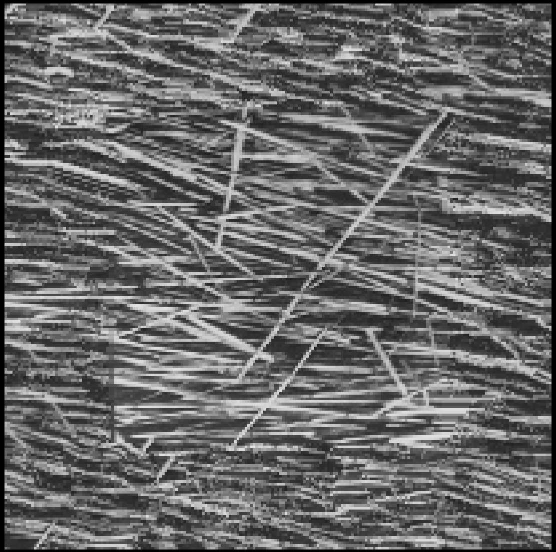





# Hole Filling



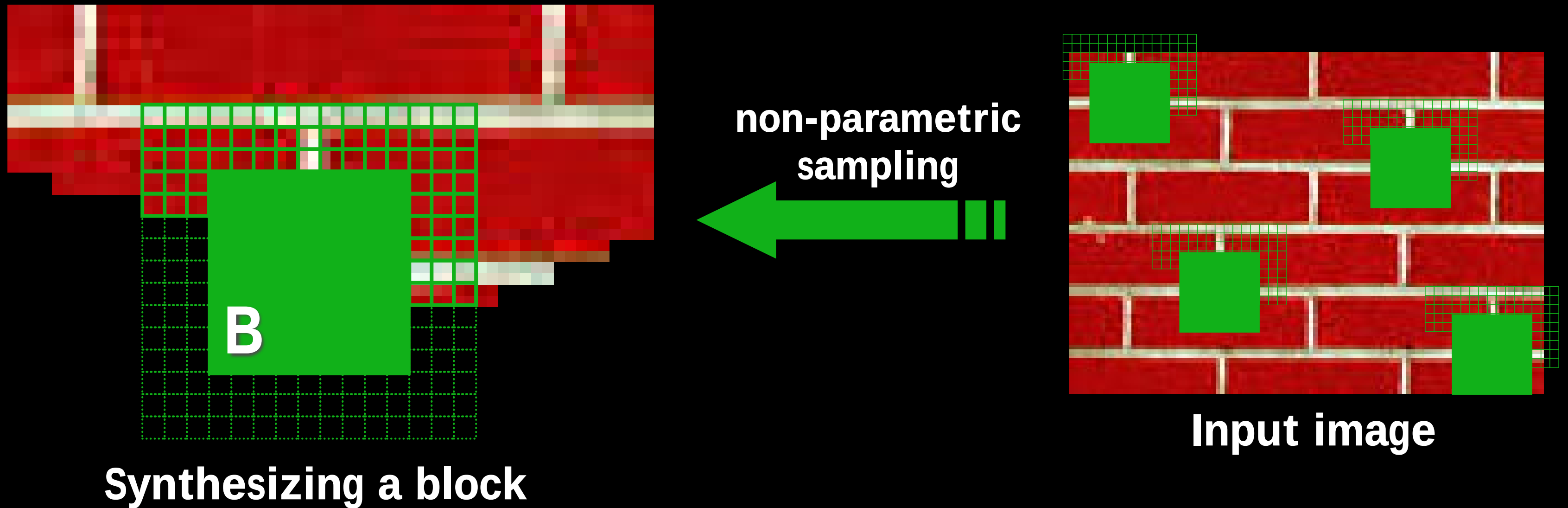
# Extrapolation



# Summary

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

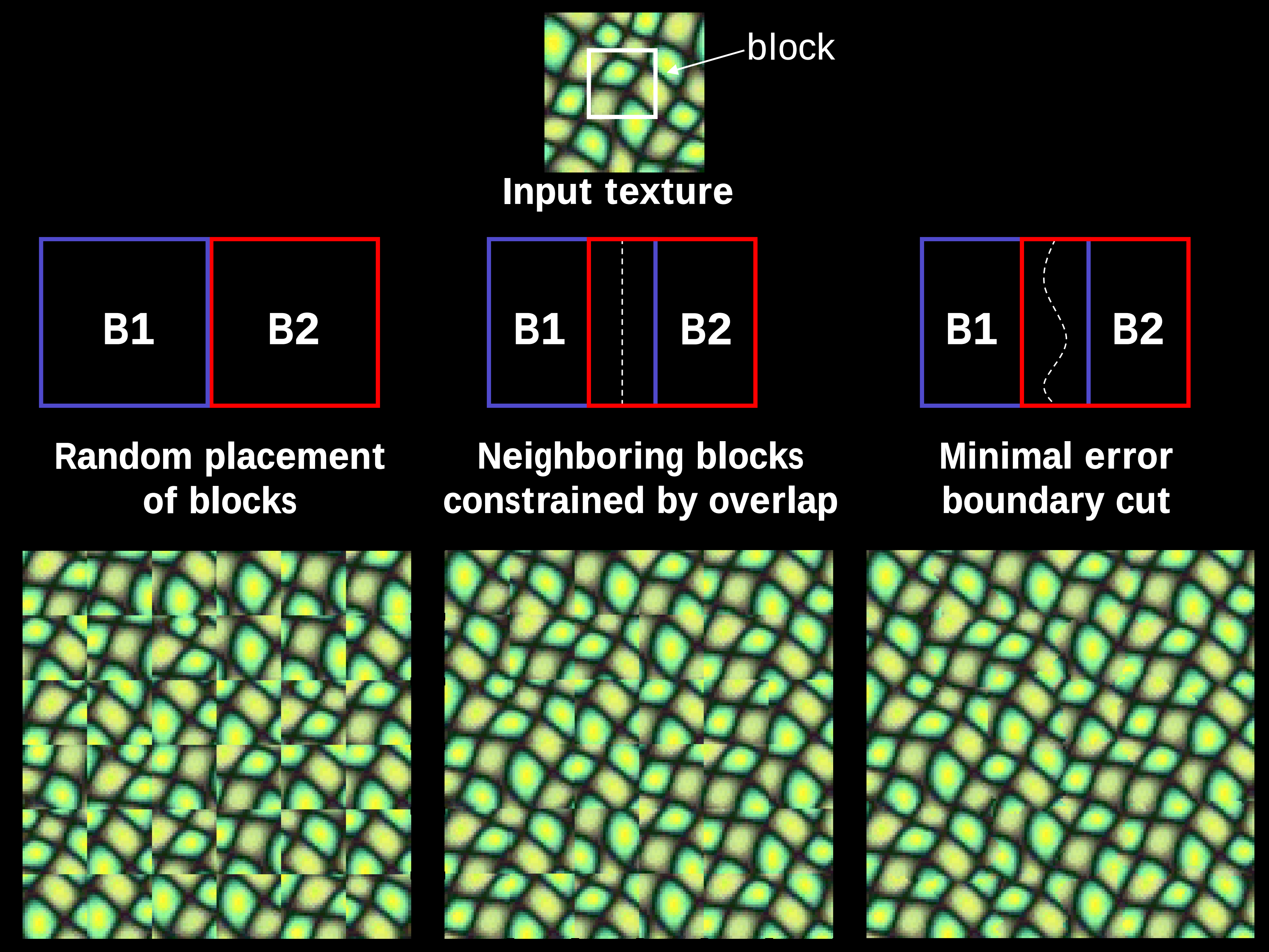
# Image Quilting [Efros & Freeman]



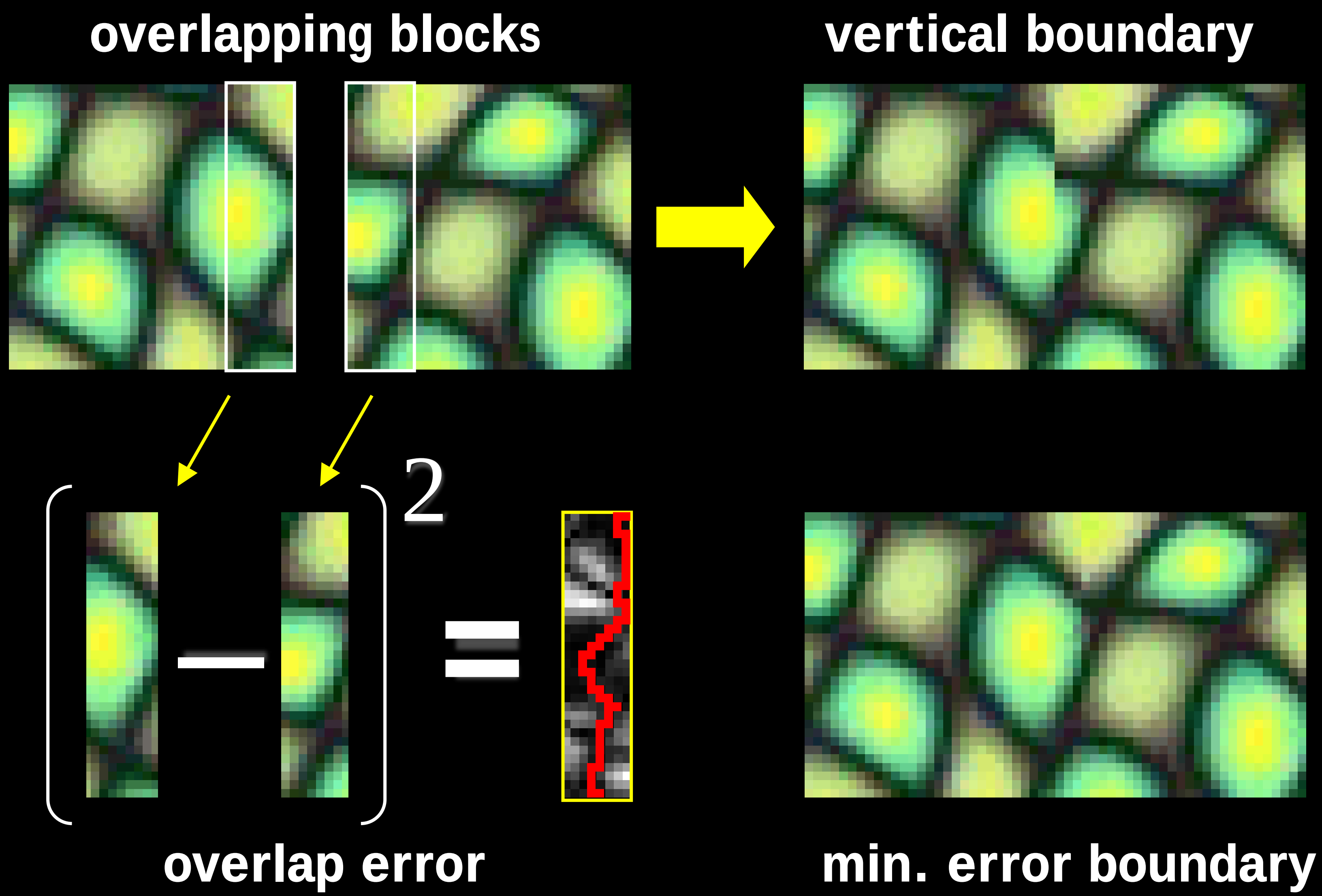

- Observation: neighbor pixels are highly correlated

**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!

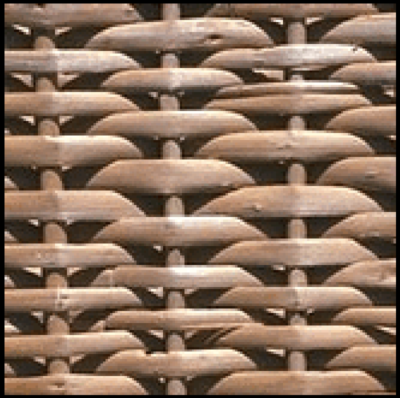

block
Input texture
B1
B2
Random placement of blocks
B1
B2
Neighboring blocks constrained by overlap
B1
B2
Minimal error boundary cut

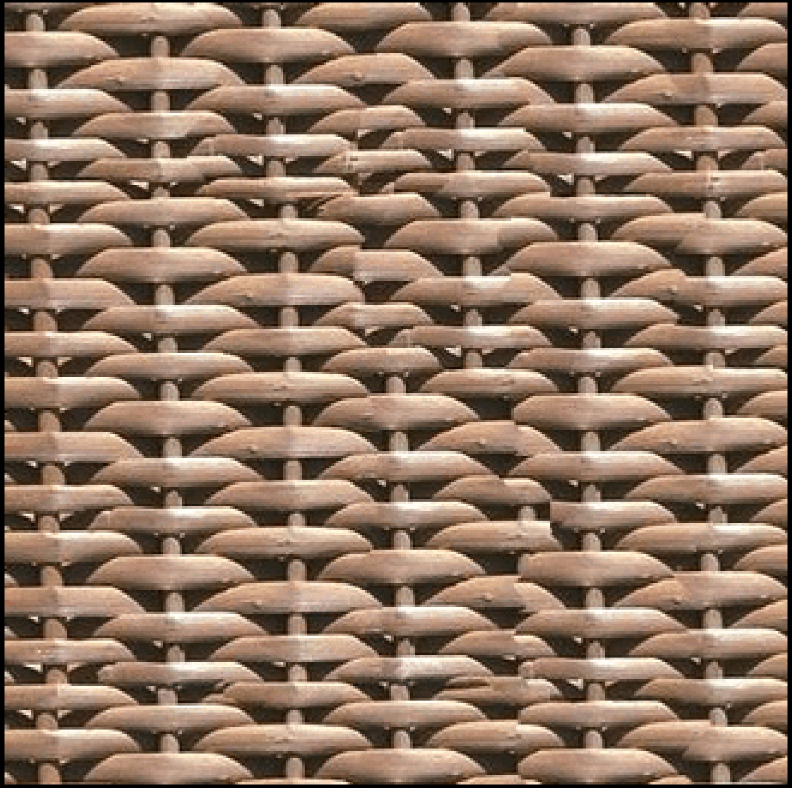
# Minimal error boundary

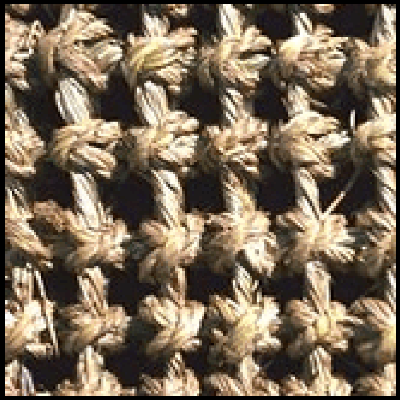


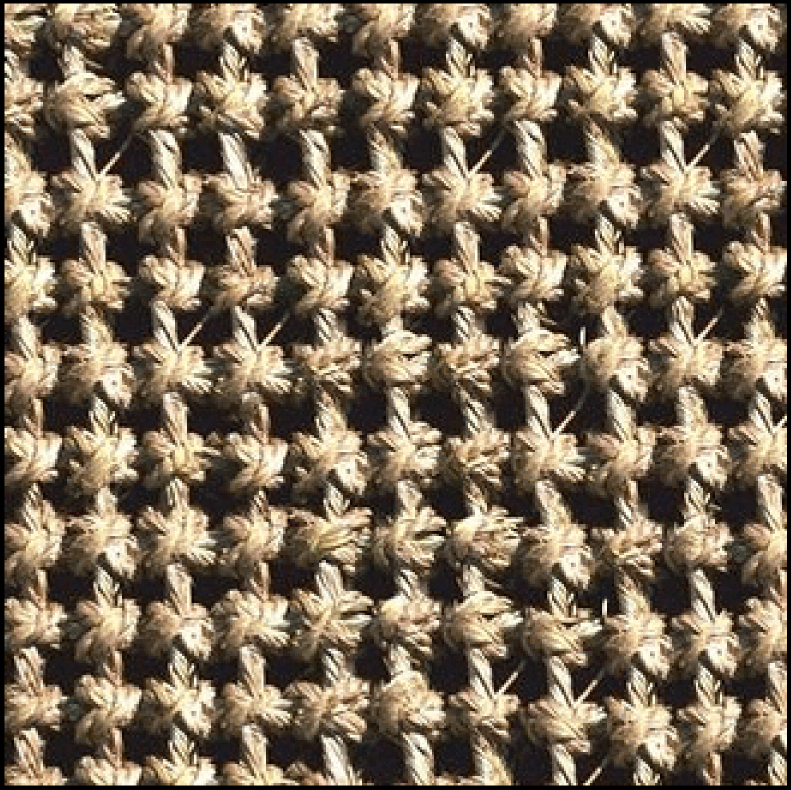
# Our Philosophy

- 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





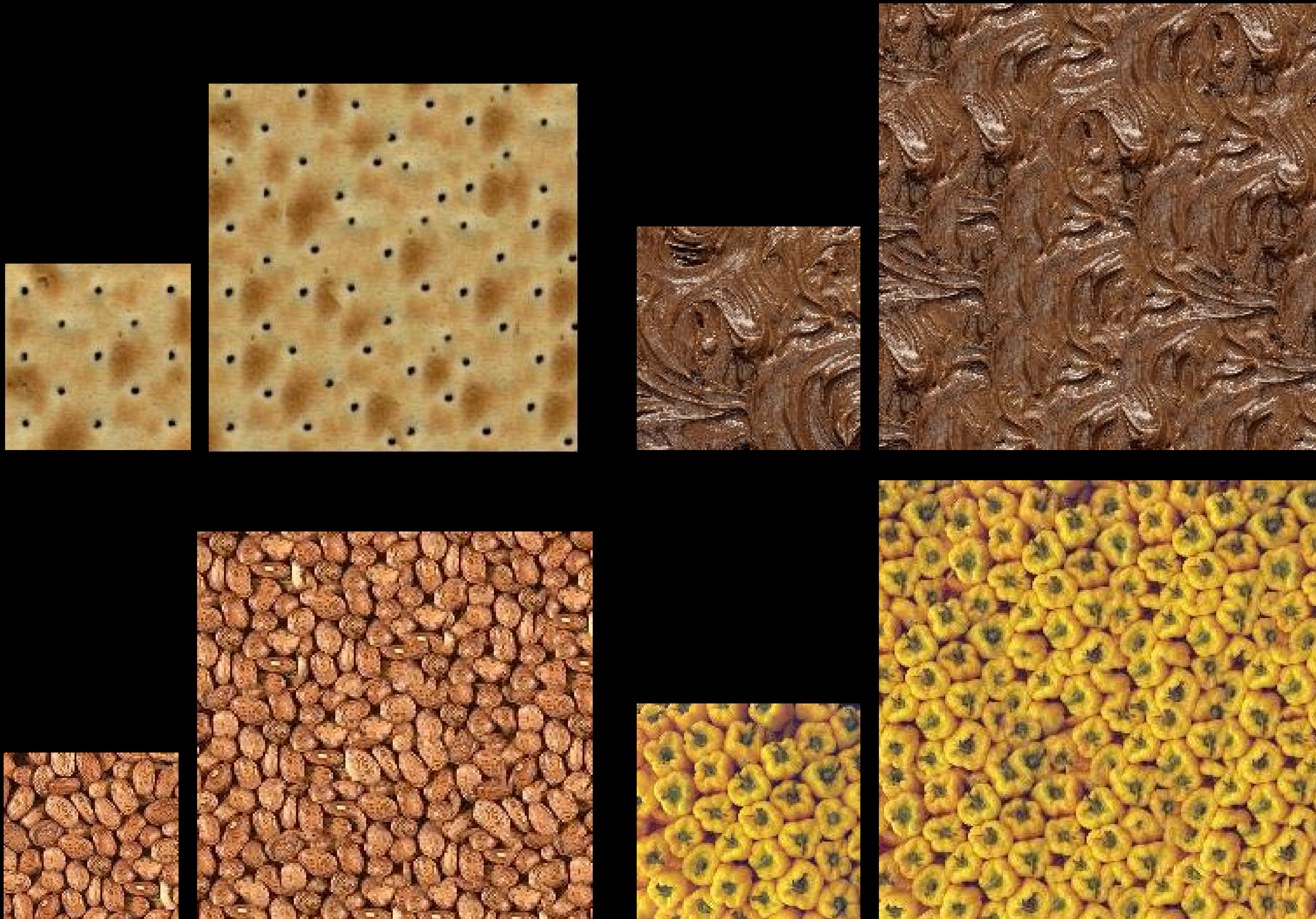




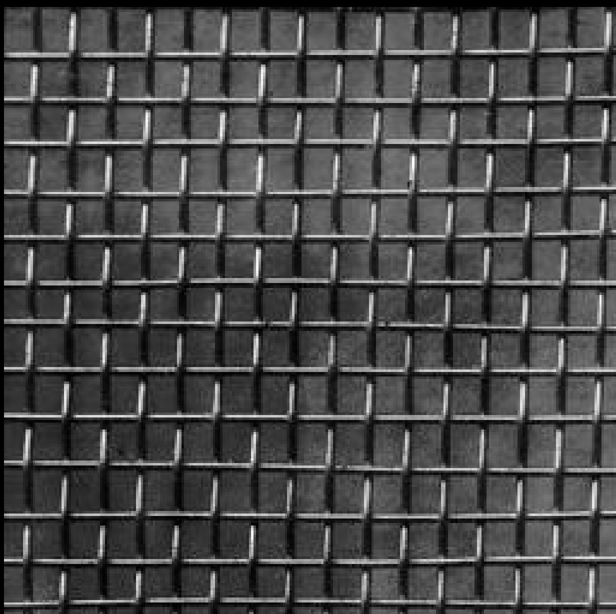

College Inn
Chicken Broth


College Inn
Chicken Broth

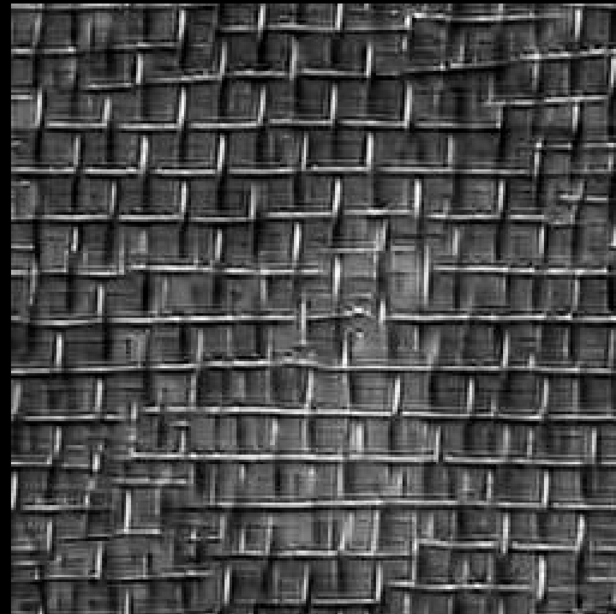


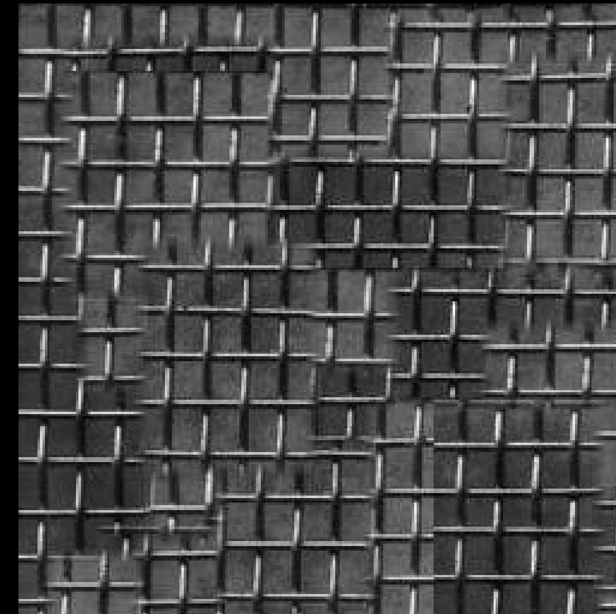
# Failures
## (Chernobyl Harvest)



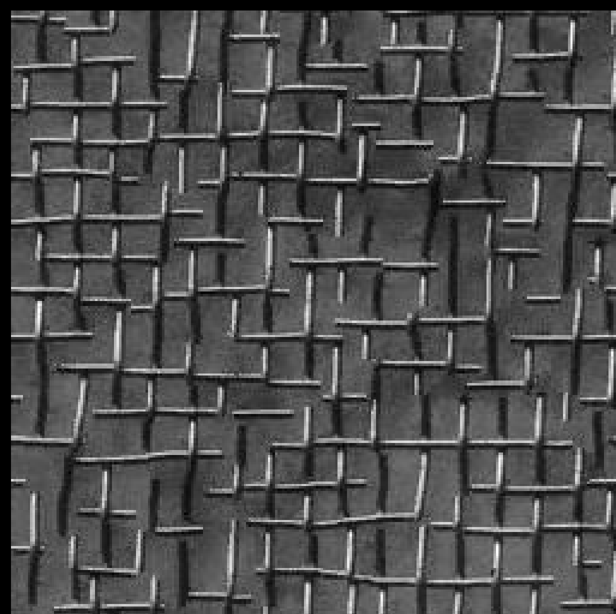
input image



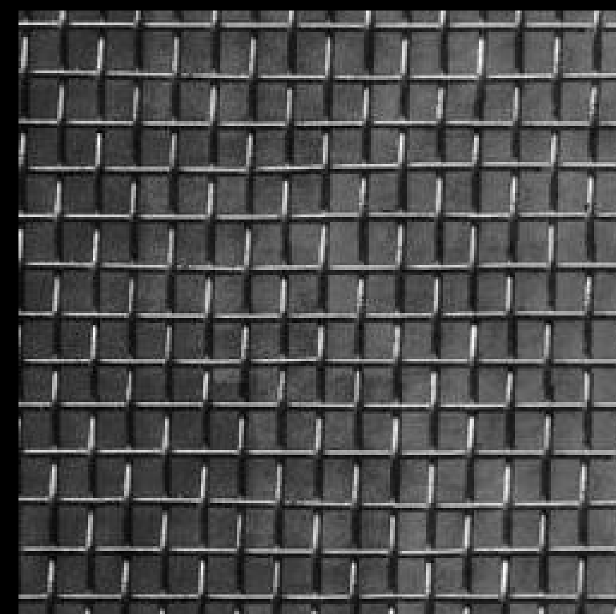
Portilla & Simoncelli



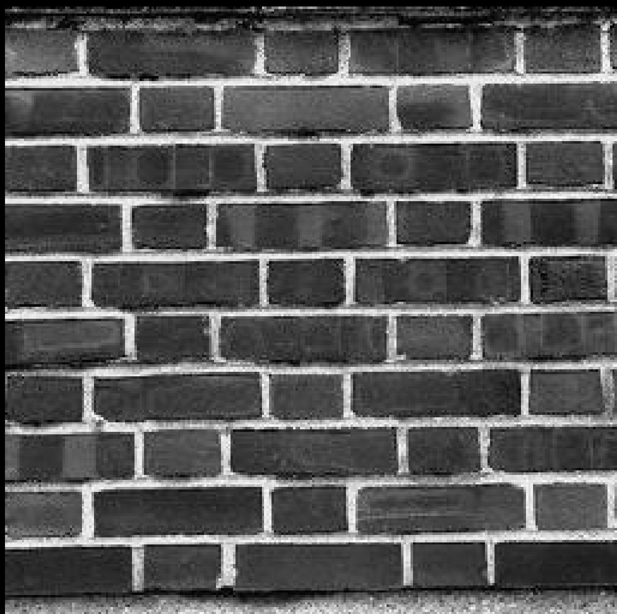
Xu, Guo & Shum



Wei & Levoy

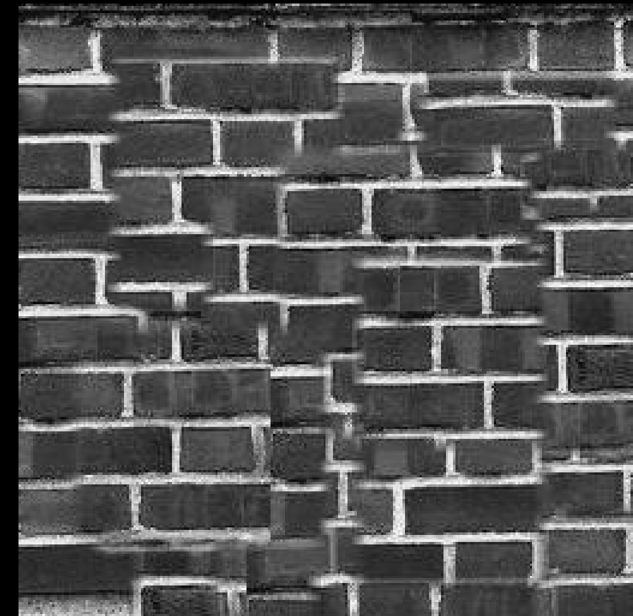


Our algorithm

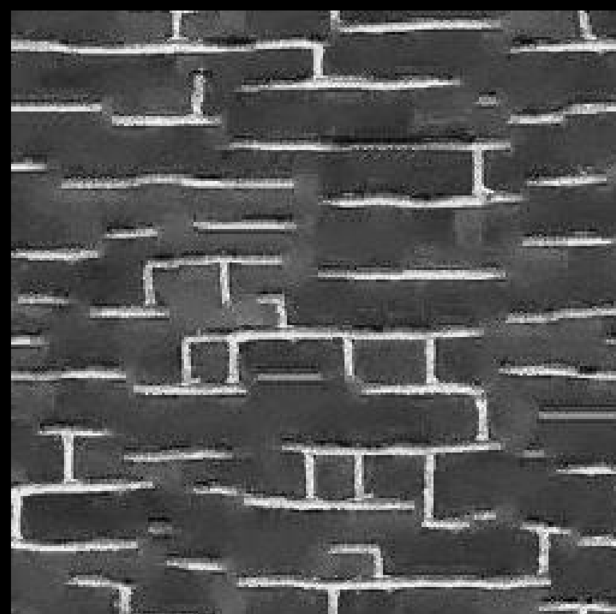


input image

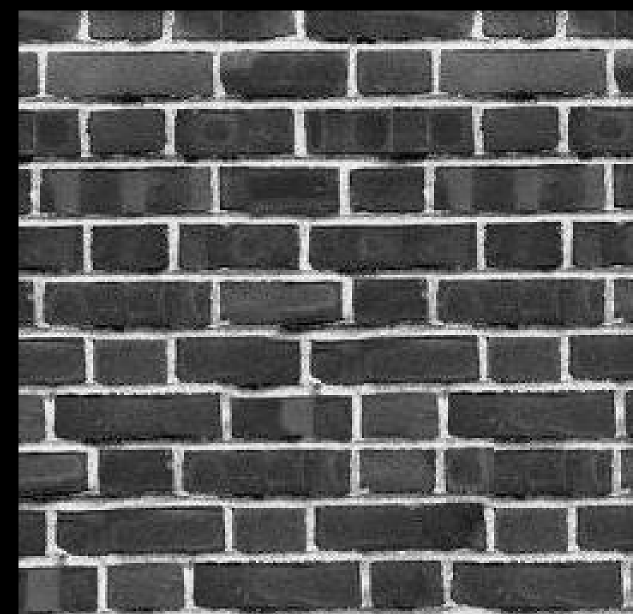
Portilla & Simoncelli



Xu, Guo & Shum



Wei & Levoy



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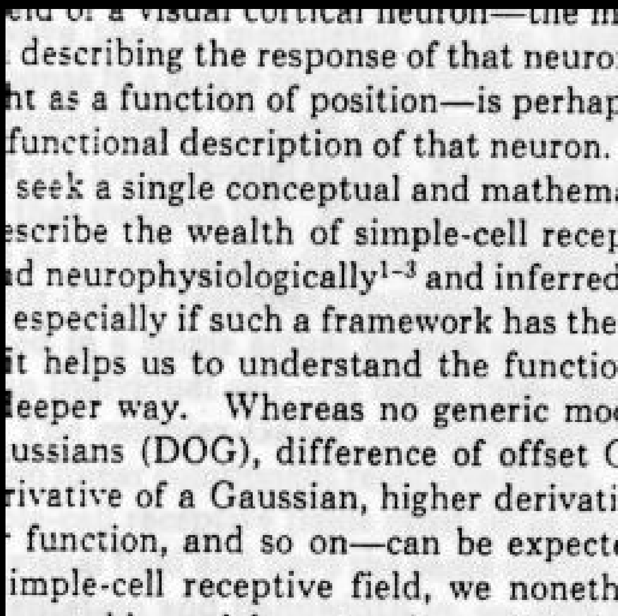

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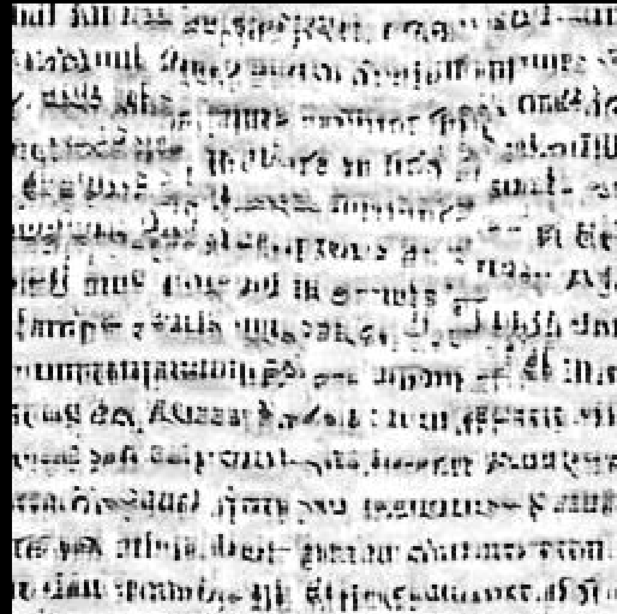
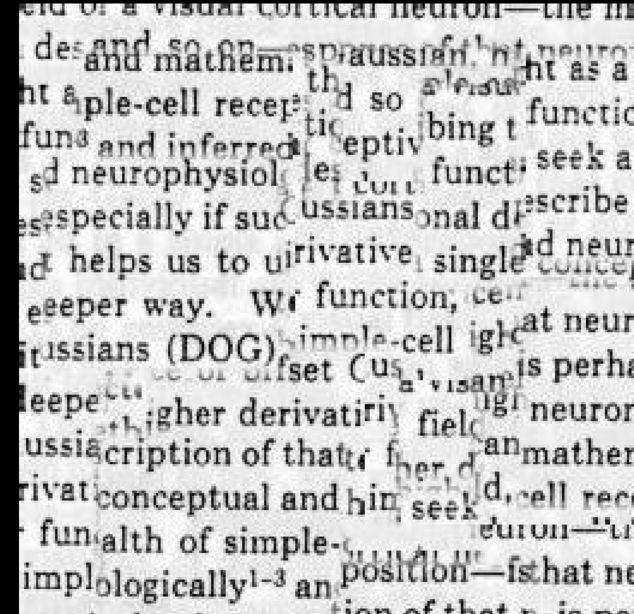


Portilla & Simoncelli



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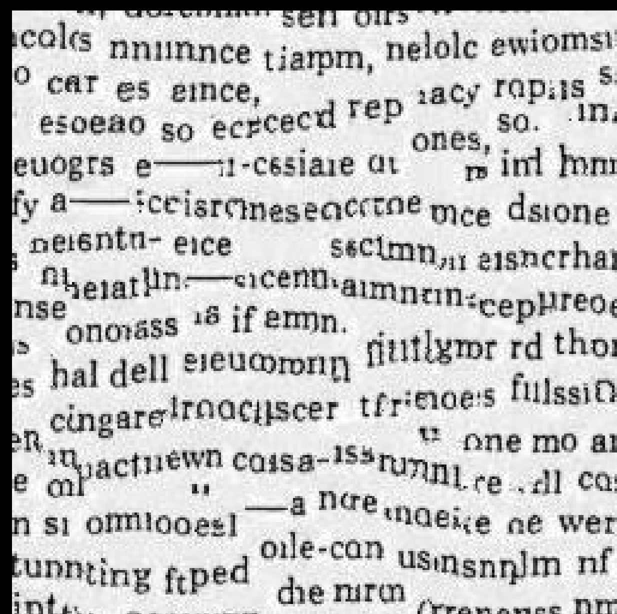
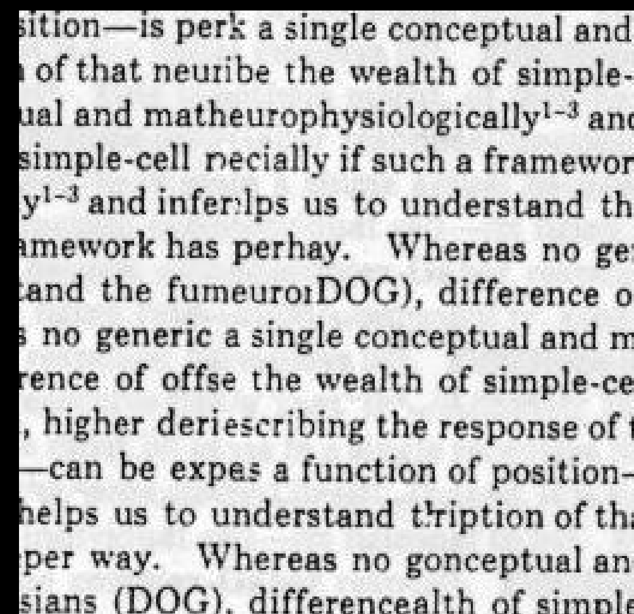


Wei & Levoy



Our algorithm

# Application: Texture Transfer

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

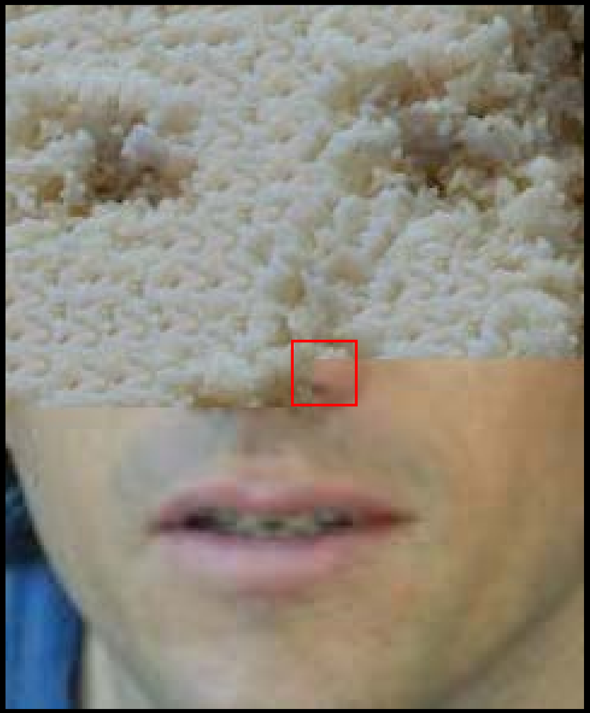
# Texture Transfer

Constraint

Texture sample

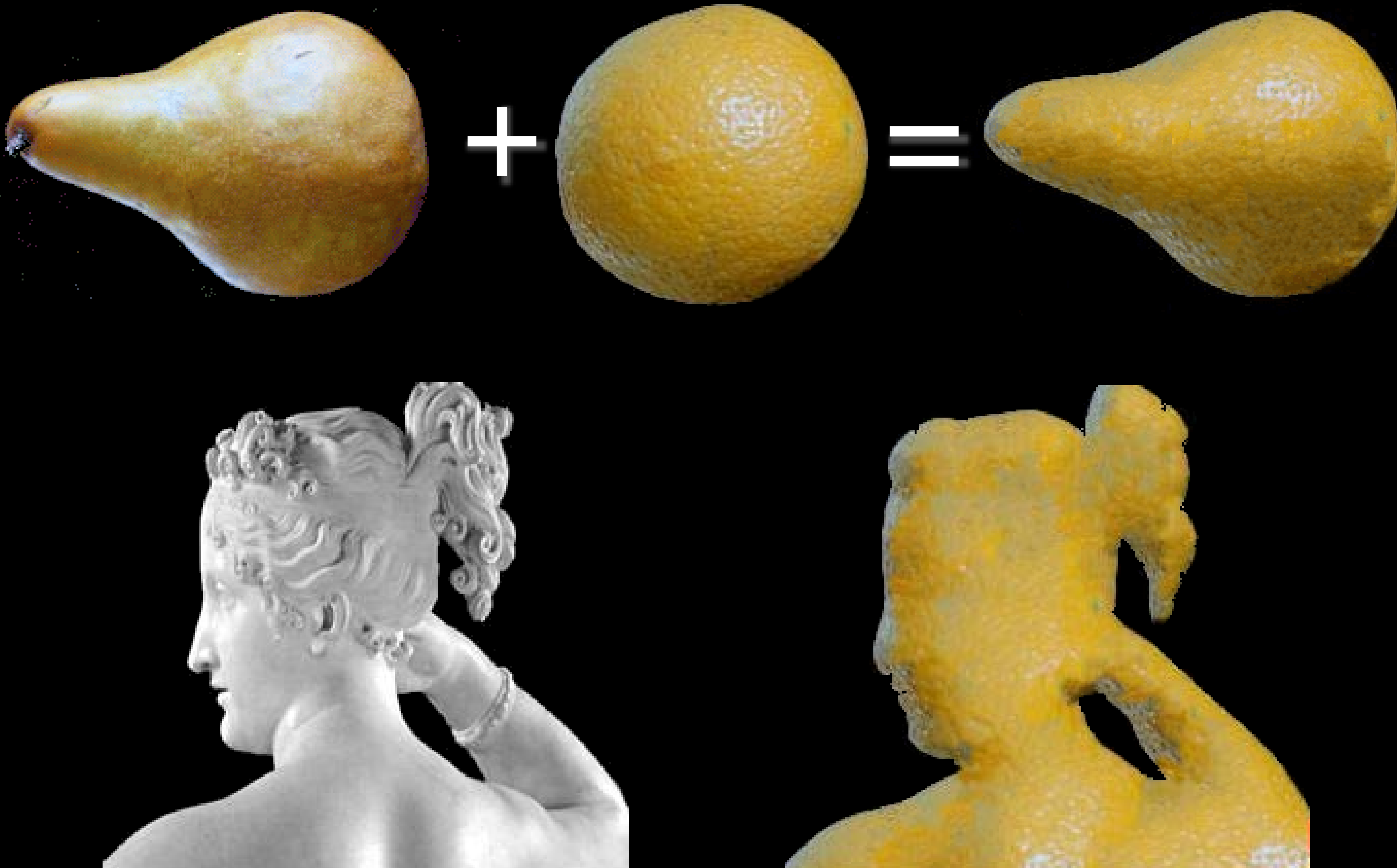
# Texture Transfer

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

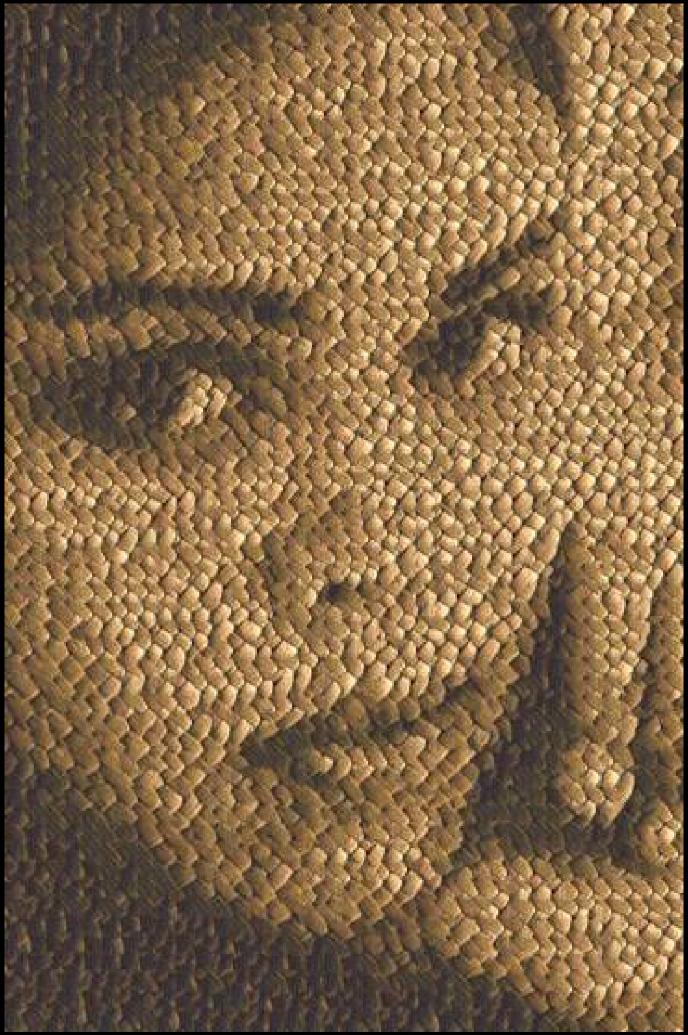


Same as texture synthesis, except an additional constraint:

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

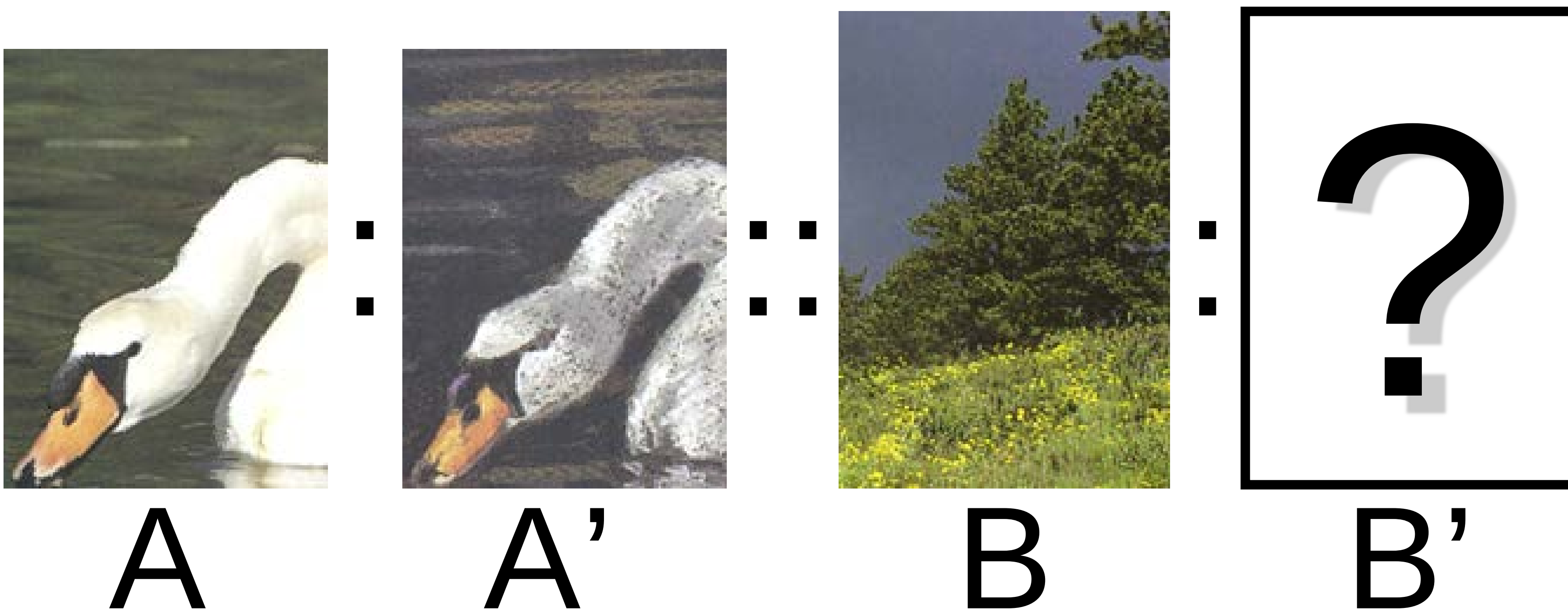
A’

B

B’

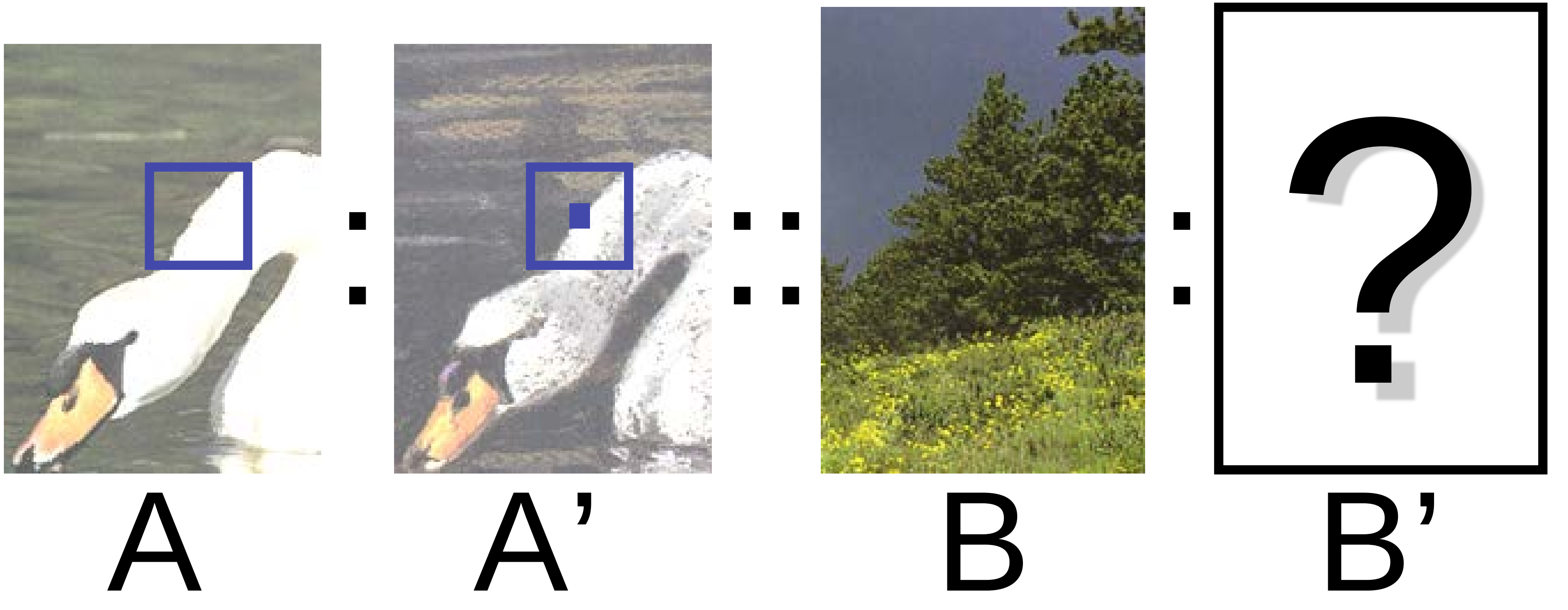
# Image Analogies

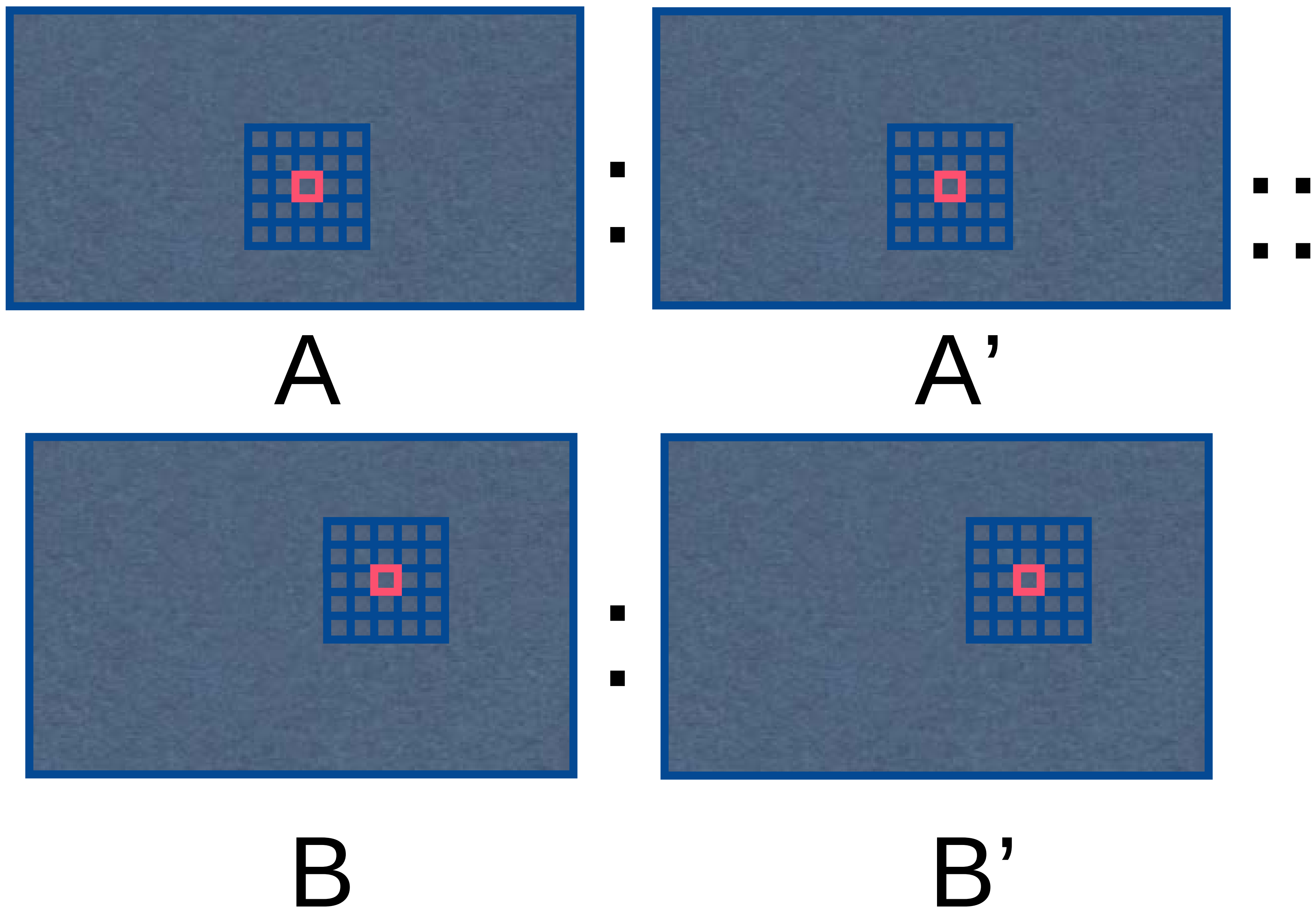
Goal: Process an image by example

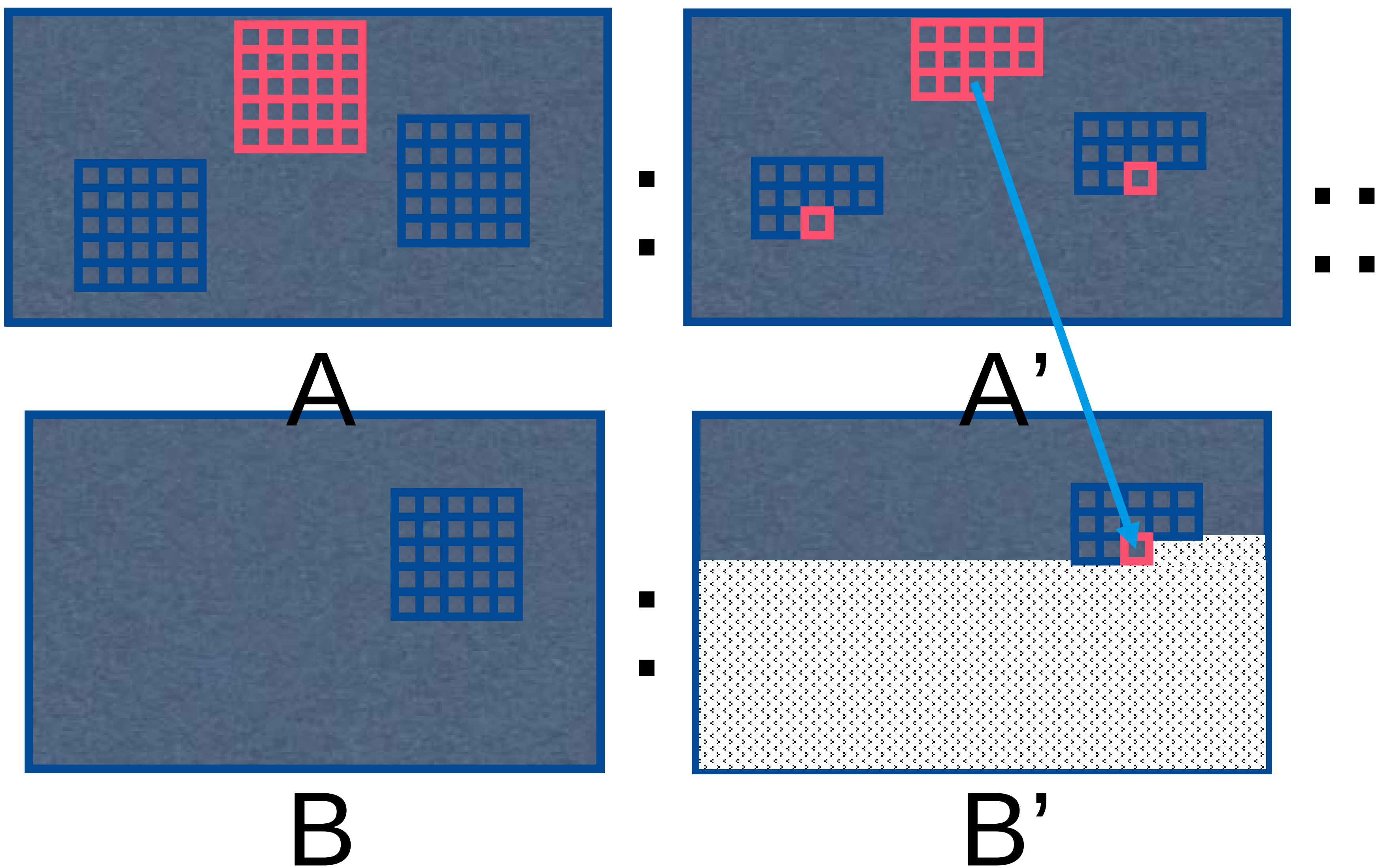



Hertzmann et al. SIGGRAPH 2001

# Non-parametric sampling




A
A'
B
B'


A
A’
B
B’

# Blur Filter

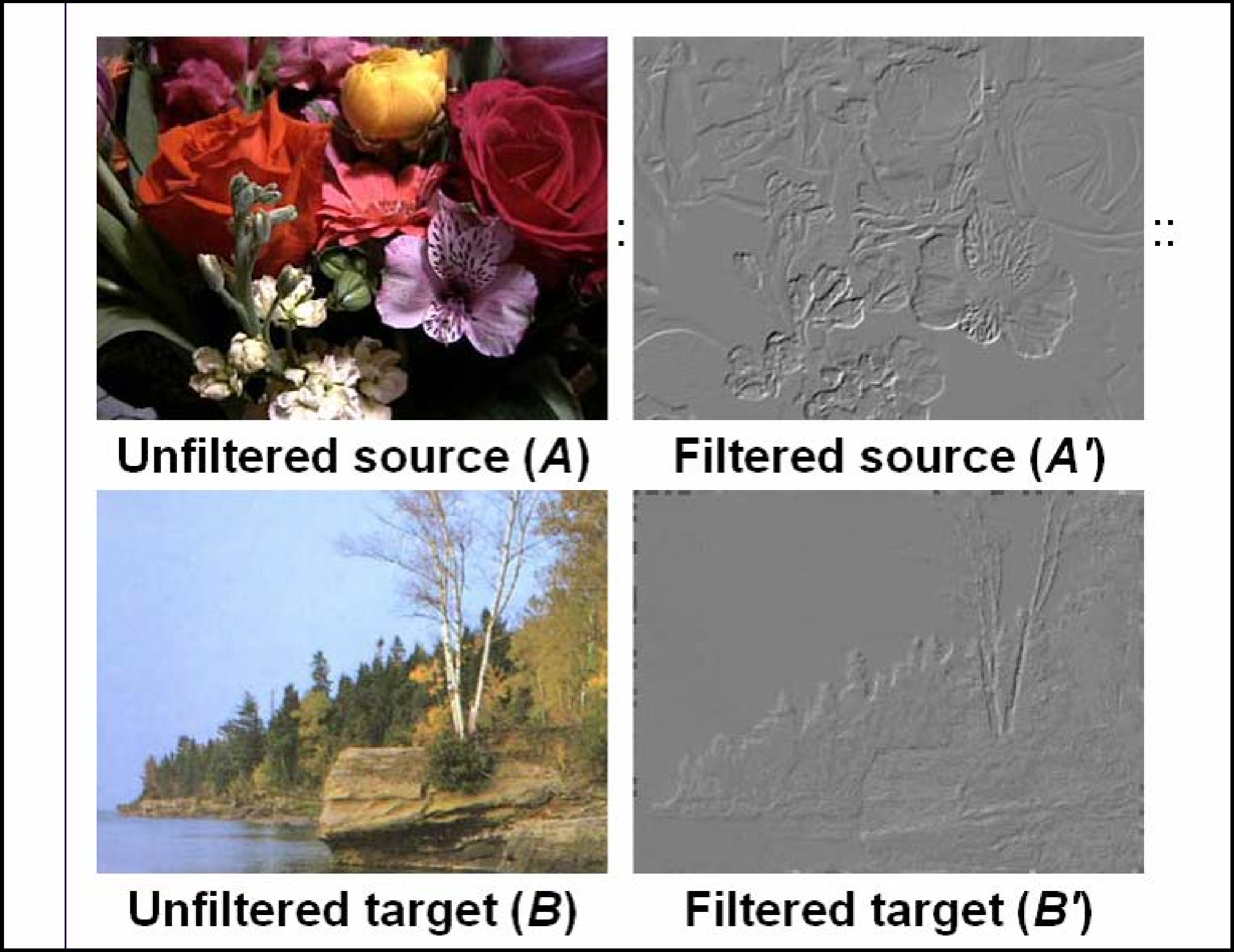
**Unfiltered source** ($A$)

**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

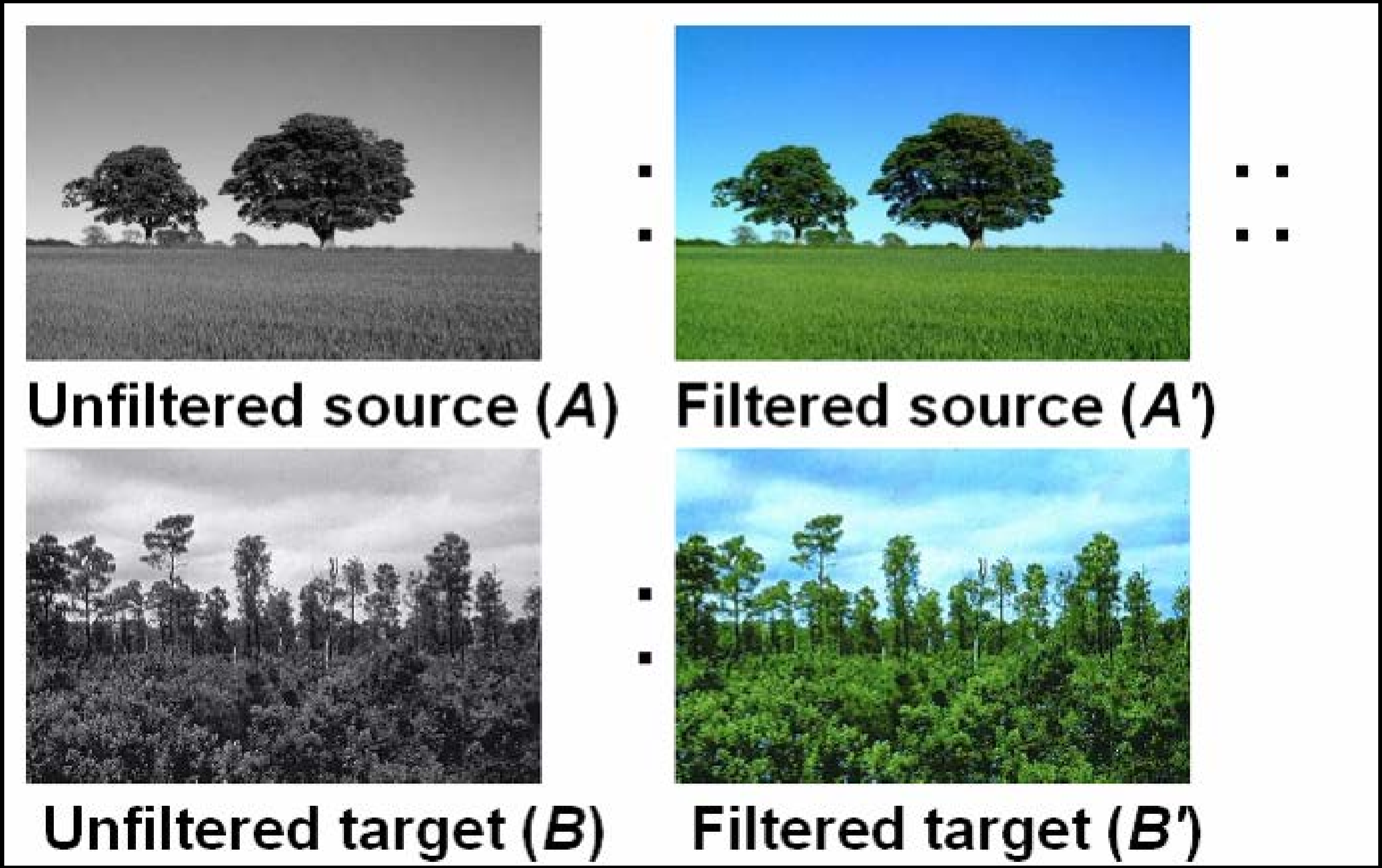
A

A’

B

B’

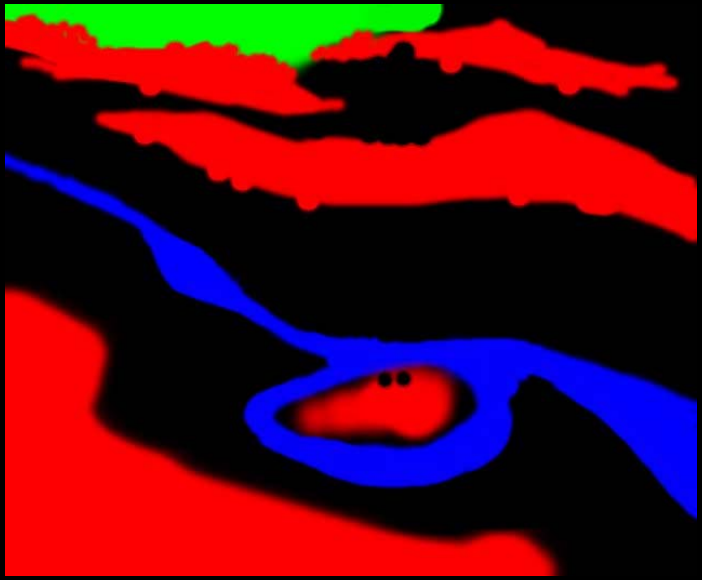
# Colorization



# Texture-by-numbers

A

A’



B

B’

# Super-resolution

A

A’

# Super-resolution (result!)

B

B’