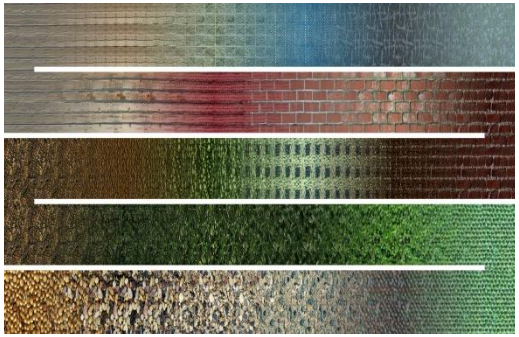
计算机视觉
Computer Vision
——Texture & Segmentation



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本节内容

- 纹理（Texture）
- 分割（Segmentation）

本节内容

- Mathematic Models
  - Markov Random Field
  - Gaussian mixture models
  - Kernel Density Estimation

- Mathematic Tools
  - K-mean
  - Mean shift
  - EM algorithm

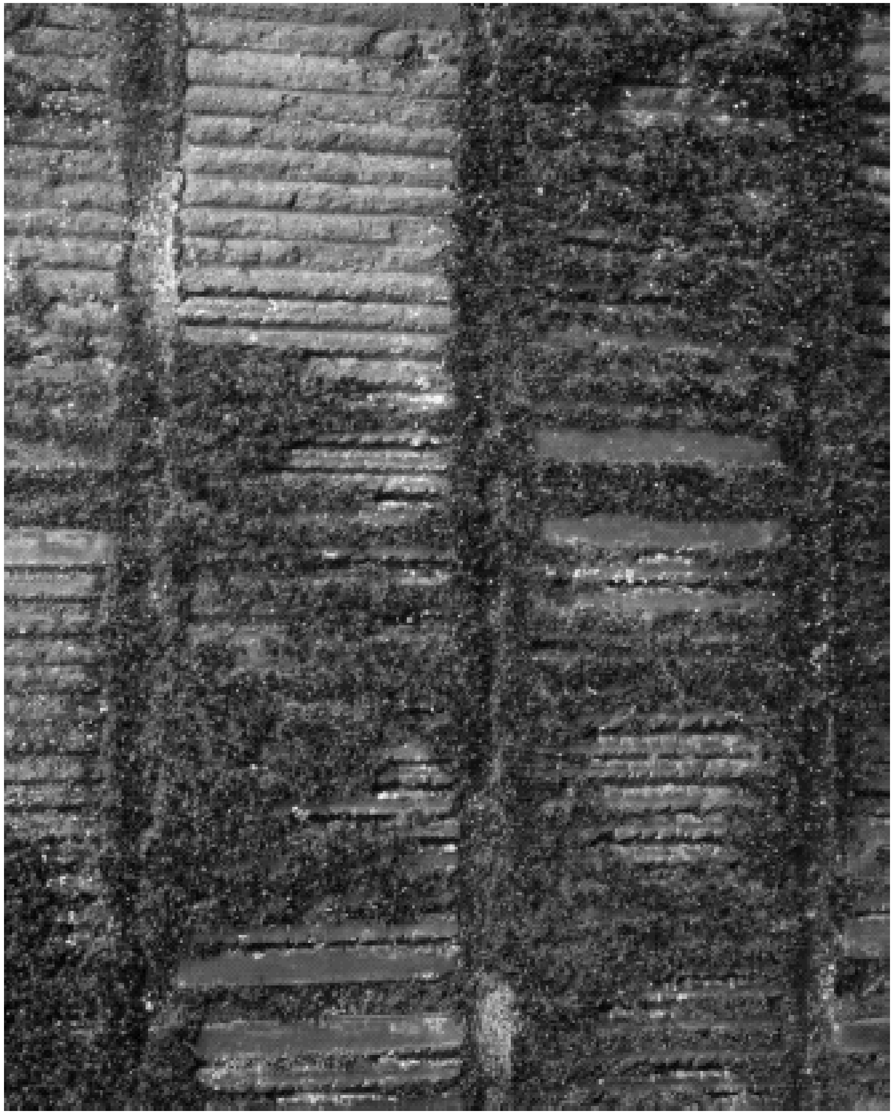
纹理

纹理

- What is Texture？
  - General definition
    - For texture mapping
    - Arbitrary images
  - Narrow definition
    - For (example-based) texture synthesis
    - Images with repetitive patterns

纹理

- Key issue: representing texture
  - Texture based matching
    - little is known
  - Texture segmentation
    - key issue: representing texture
  - Texture synthesis
    - useful; also gives some insight into quality of representation
  - Shape from texture
    - cover superficially



纹理

- Representing textures
  - Representation:
    - find the sub-elements, and represent their statistics
  - But what are the sub-elements, and how do we find them?
  - What statistics?
    - within reason, the more the merrier.

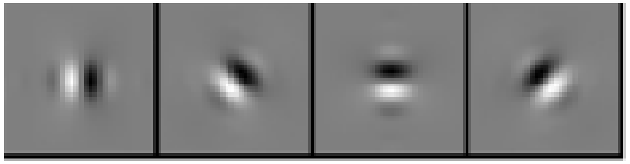
纹理

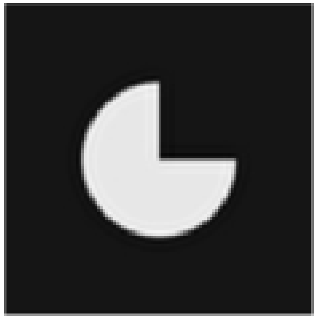
- Key issue: representing texture
  - Parametric representation
  - Non- parametric representation

Image

Image

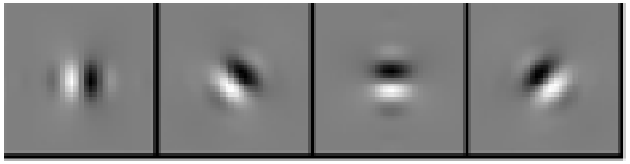
Filter Kernels



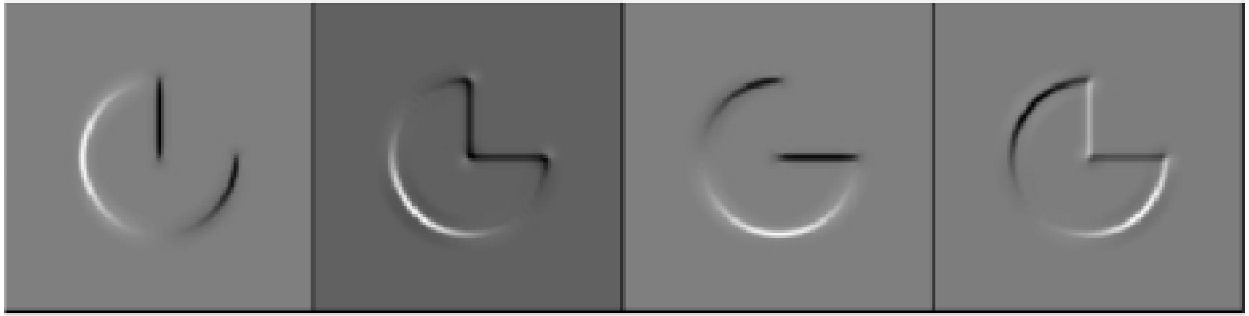


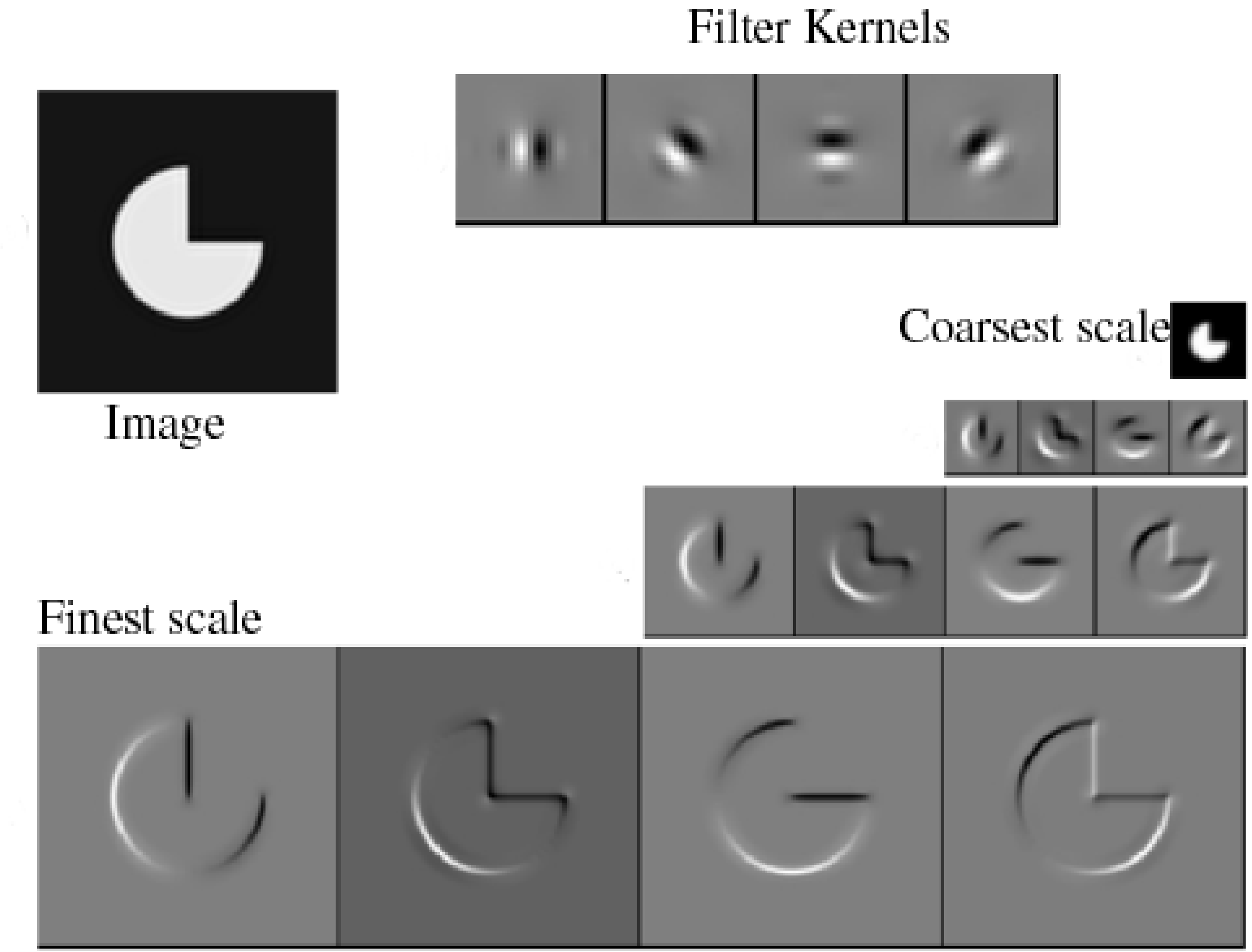
Image

Filter Kernels

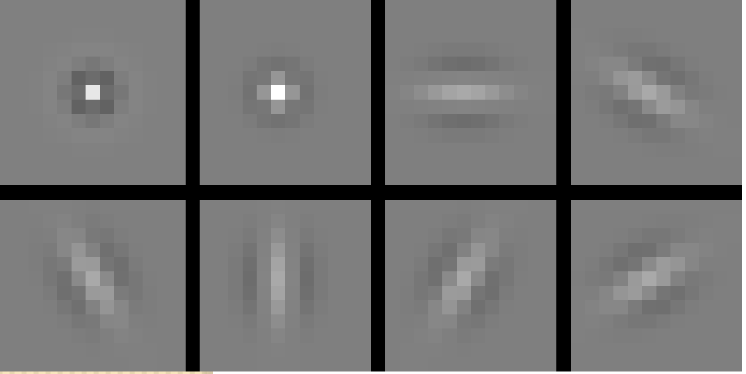


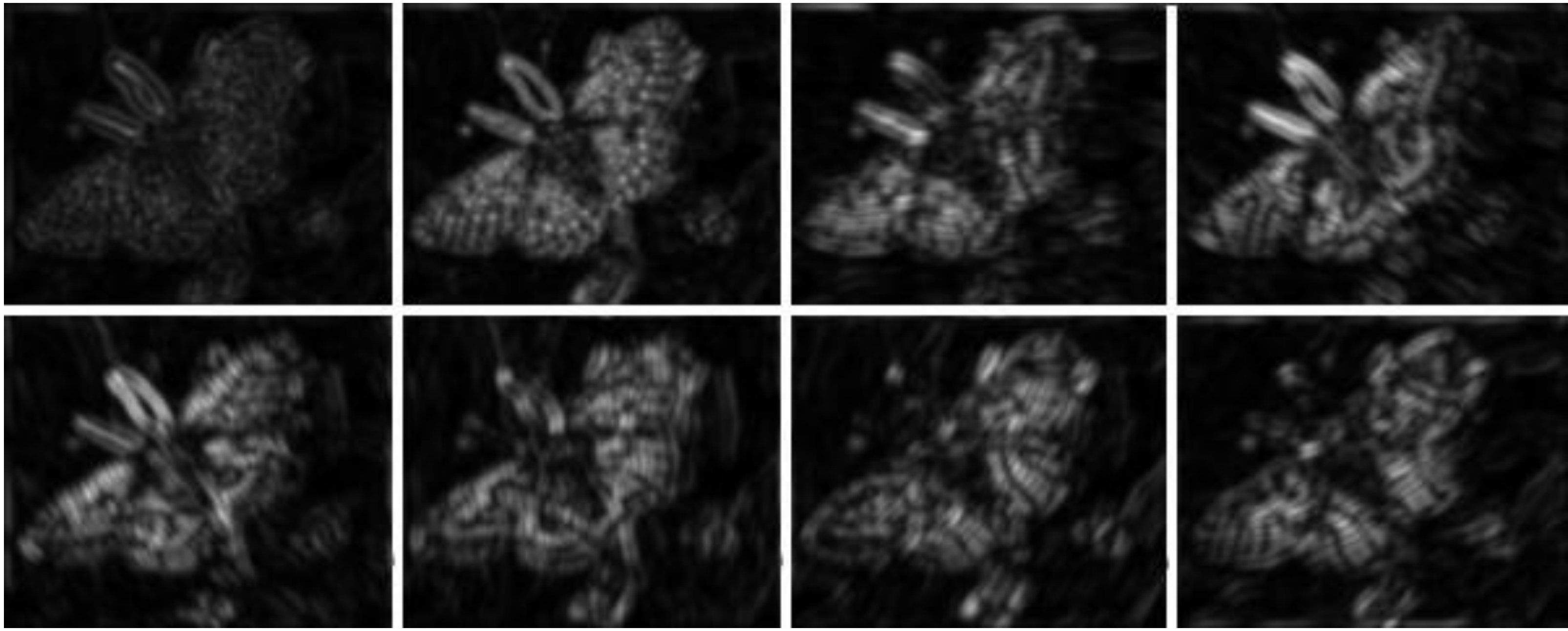
Finest scale

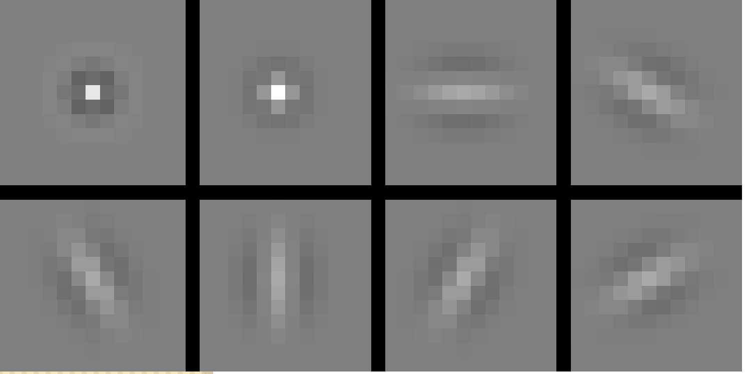


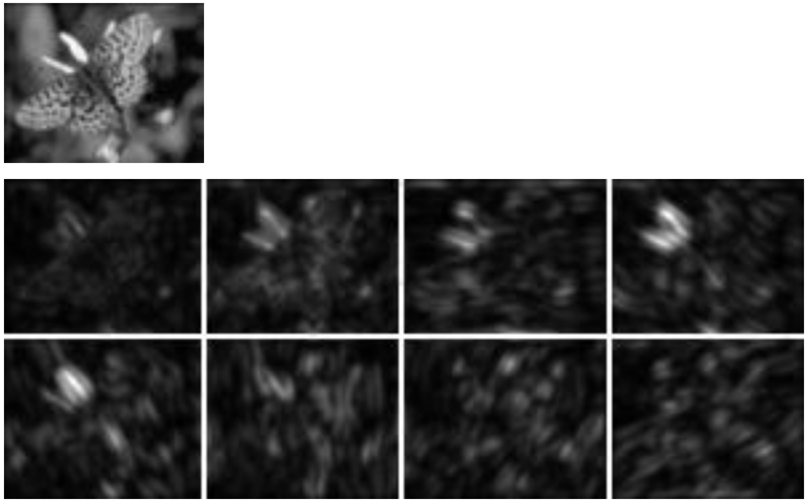


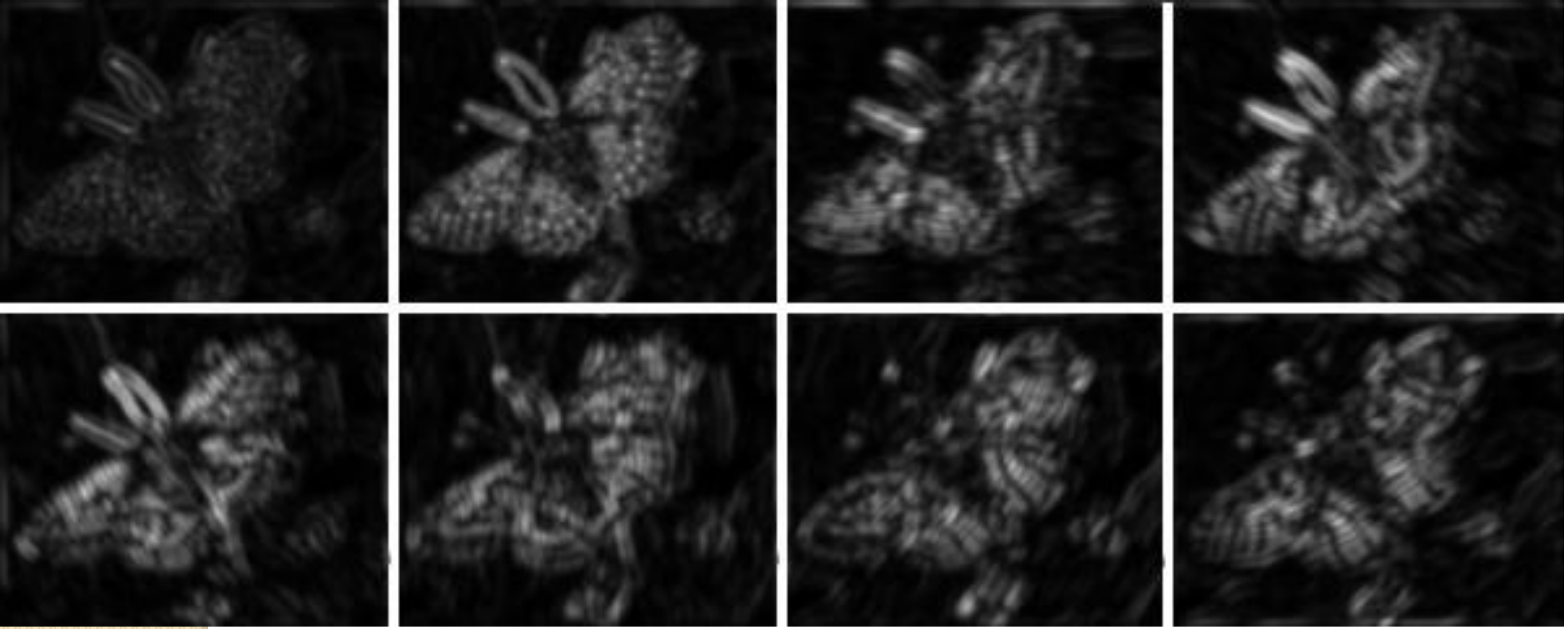
Reprinted from “Shiftable MultiScale Transforms,” by Simoncelli et al., IEEE Transactions on Information Theory, 1992, copyright 1992, IEEE

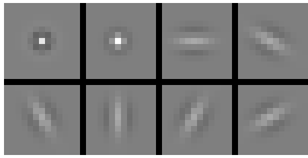


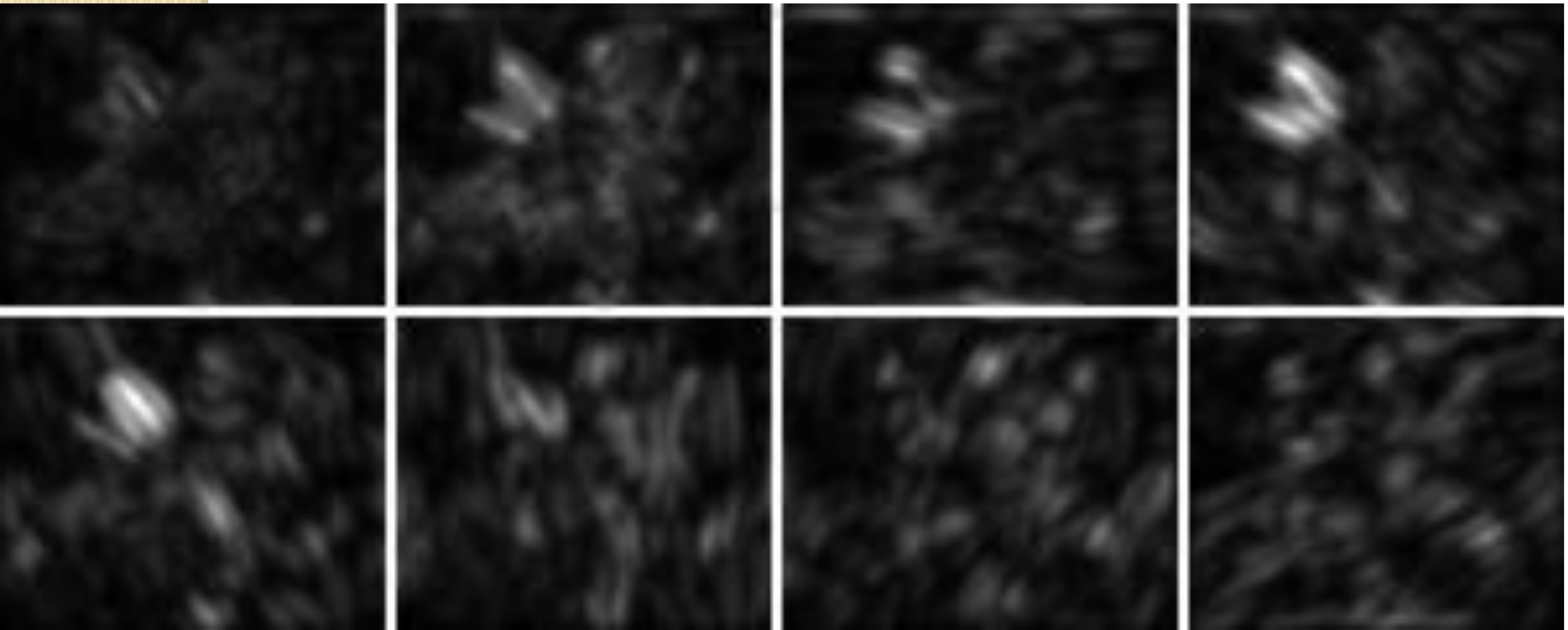












纹理

- Texture based matching
  - Texture Design Using a Simplicial Complex of Morphable Textures

[Matusik, et al 2005]

纹理

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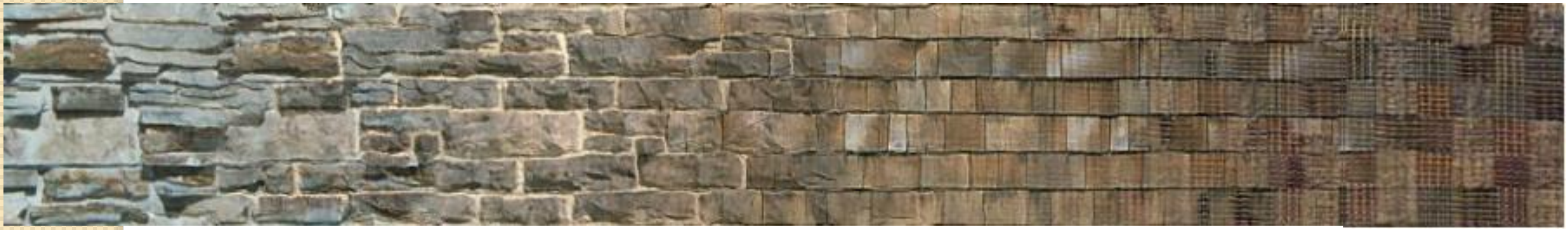

纹理

- Texture based matching
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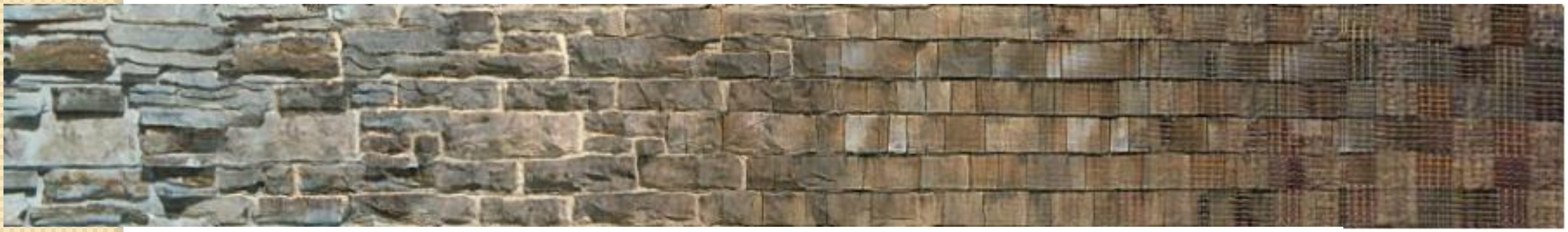
[Matusik, et al 2005]



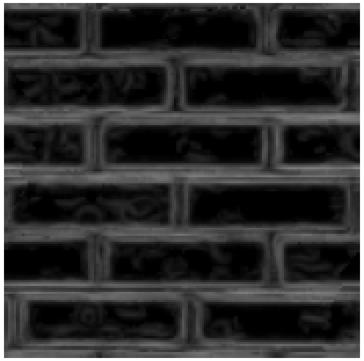
Find a space to interpolate a new texture from samples

纹理

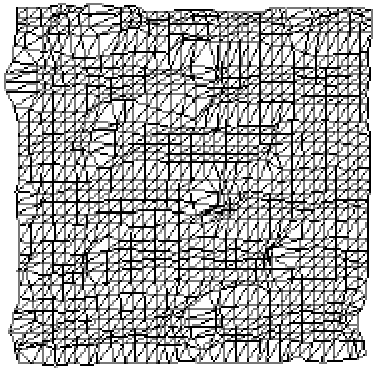
- Texture based matching
  - Texture Design Using a Simplicial Complex of Morphable Textures
    - Shape vector and a color vector.

纹理

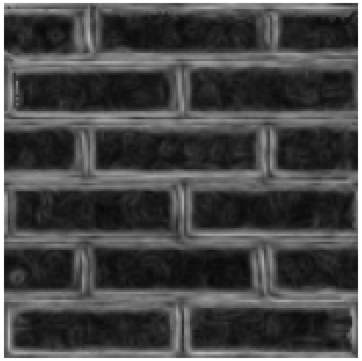
- Texture based matching
  - Texture Design Using a Simplicial Complex of Morphable Textures
    - Shape vector and a color vector.
    - Color is given by the map I : R2 → R3
    - Shape is represented by A warp vector fields W :R2→R2



Feature map F_0



Warp W_{01}

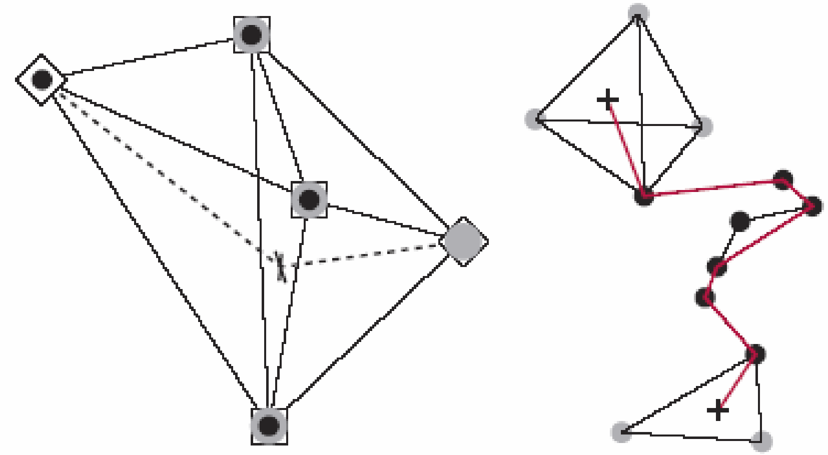


Feature map F_1

纹理

- Texture based matching
  - Texture Design Using a Simplicial Complex of Morphable Textures

[Matusik, et al 2005]



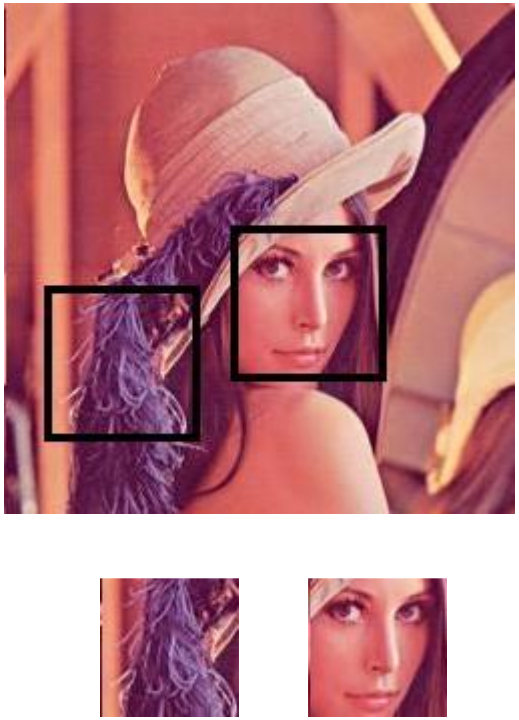
$$\hat{I}(x,y) = \sum_{i=0}^{n-1} c_i I_i \left((x,y) + \sum_{j\neq i} \left(w_j W_{ij}(x,y)\right)^{-1} \right),$$

纹理

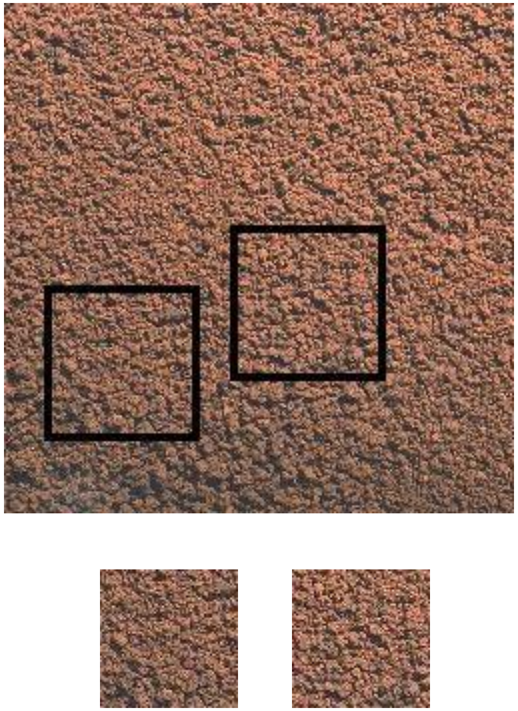
- Texture based matching
  - Texture Design Using a Simplicial Complex of Morphable Textures

纹理

- Non-parameteric Texture Model
  - Local and stationary (Markov Random Field)



non-texture



texture

Markov Property

- Formal definition
  - Let $X=\{X_n\}_{n=0\ldots N}$ be a sequence of random variables taking values $s_k \in N$ Iff $P(X_m=s_m|X_0=s_0,\ldots,X_{m-1}=s_{m-1}) = P(X_m=s_m| X_{m-1}=s_{m-1})$ then the X fulfills Markov property
- Informal definition
  - The future is independent of the past given the present.

Markov Random Field

- Markov Chain
  - Informal definition
    - The future is independent of the past given the present.
  - Formal definition
    - Let **X**=$\{X_n\}_{n=0\ldots N}$ be a sequence of random variables taking values

      $s_k \in N$ Iff $P(X_m=s_m|X_0=s_0,\ldots,X_{m-1}=s_{m-1}) = P(X_m=s_m| X_{m-1}=s_{m-1})$

    then the X fulfills Markov property

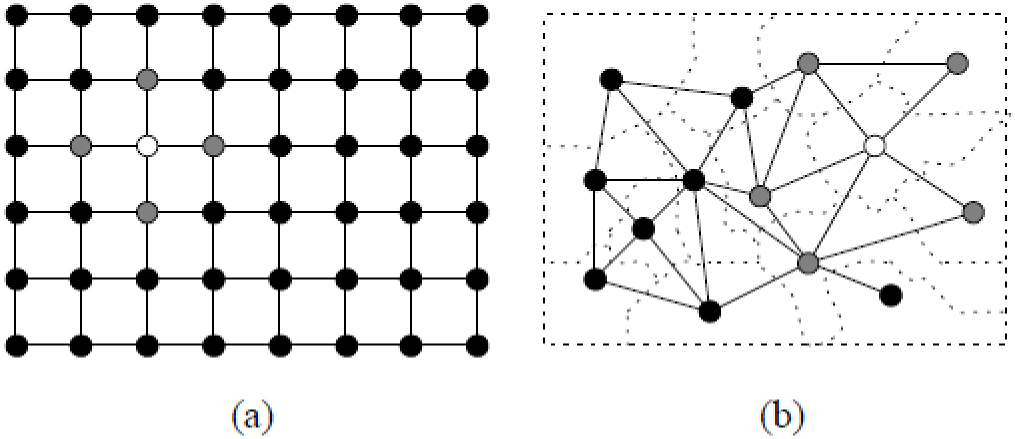
Markov Random Field

- Markov Chain
  - Markov chain theory developed around 1900.
  - Hidden Markov Models developed in late 1960's.
  - Used in speech recognition in 1960-70.

Andrei Andreyevich Markov

Markov Random Field

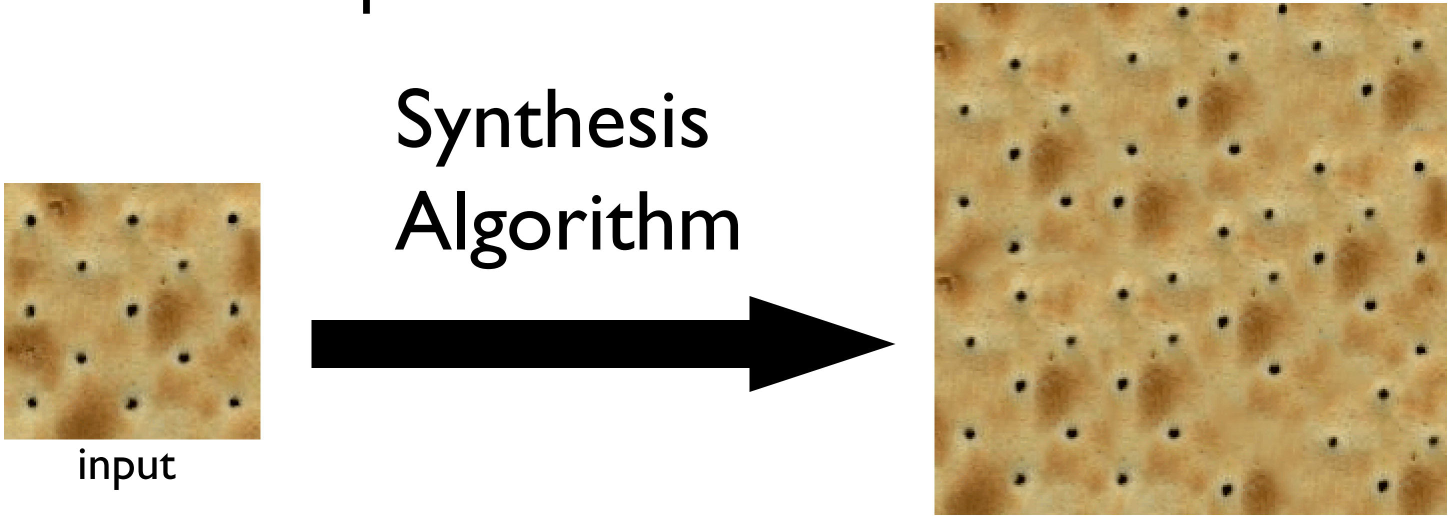
- Markov Random Field



(a) (b)

纹理

- Texture synthesis
  - Produce an arbitrarily large output with similar look
  - General Input – needs to satisfy certain assumptions



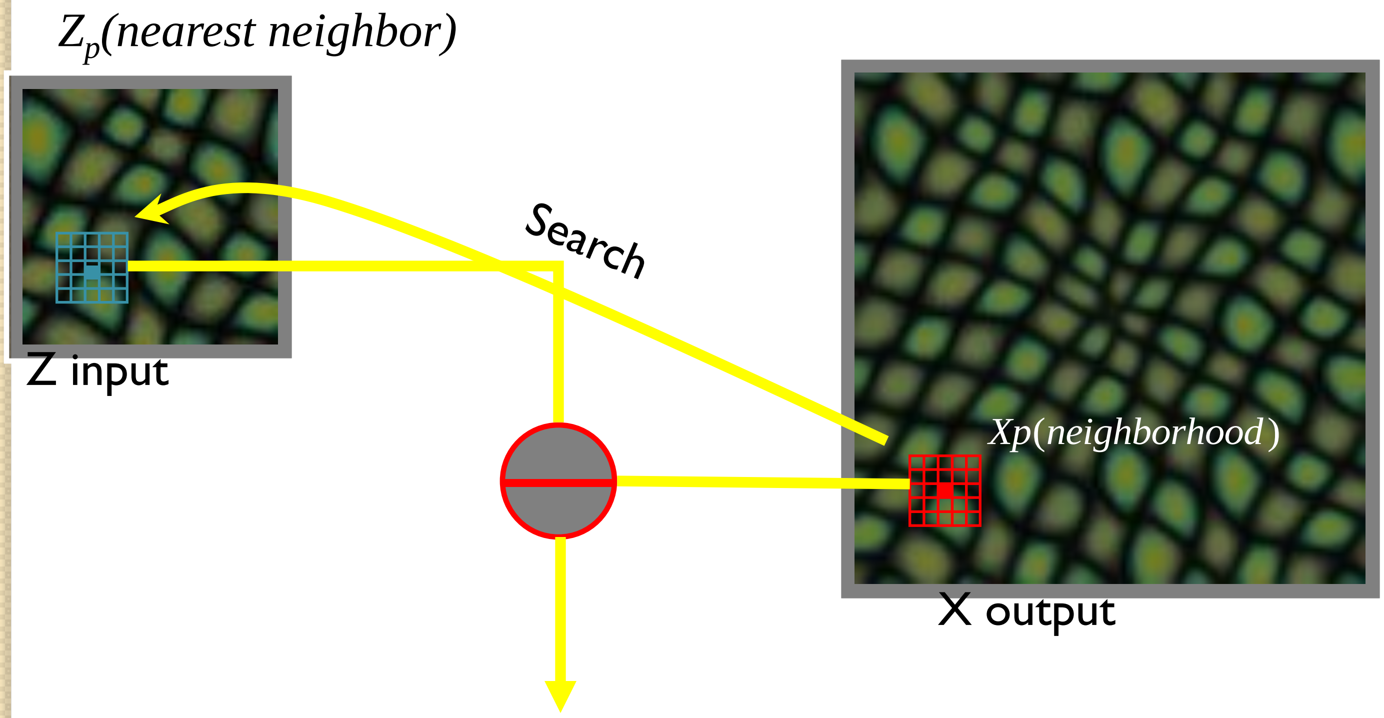
Synthesis Algorithm

input

output

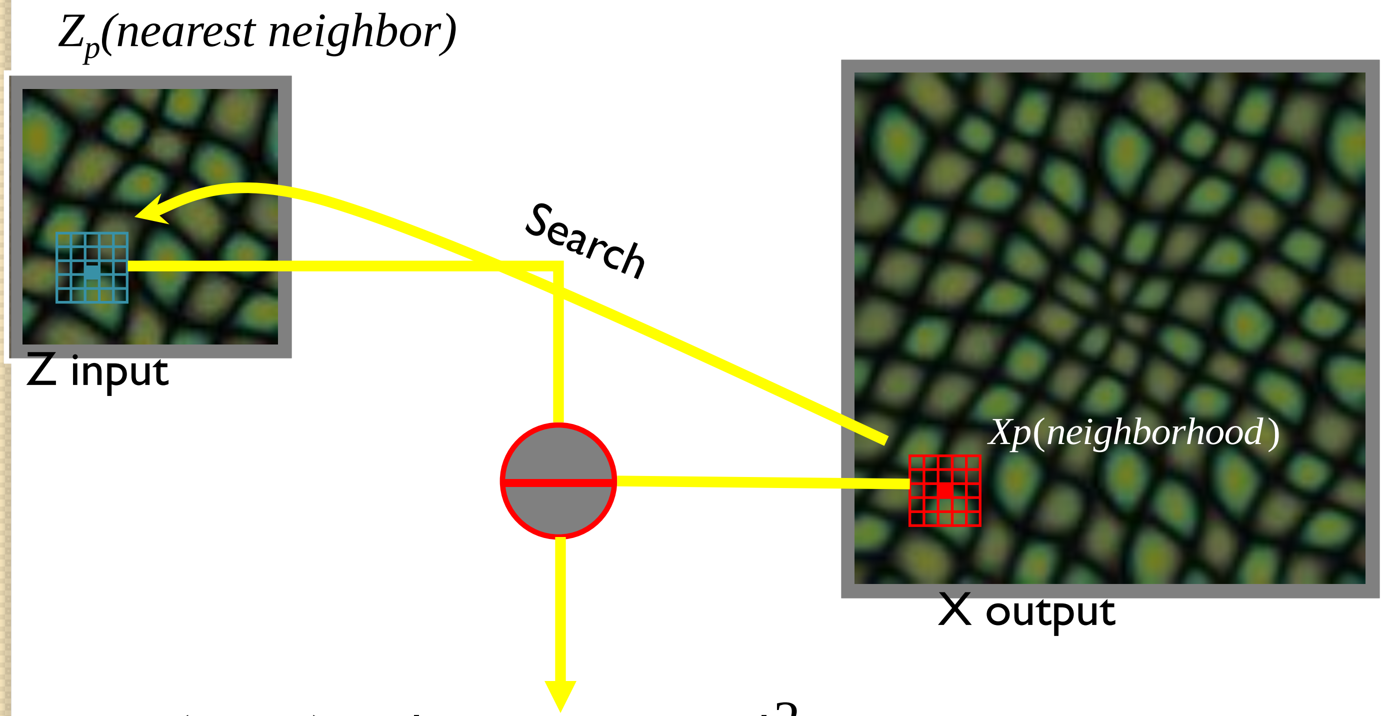
纹理

- Texture synthesis
  - Ensure local neighborhood similarity



纹理

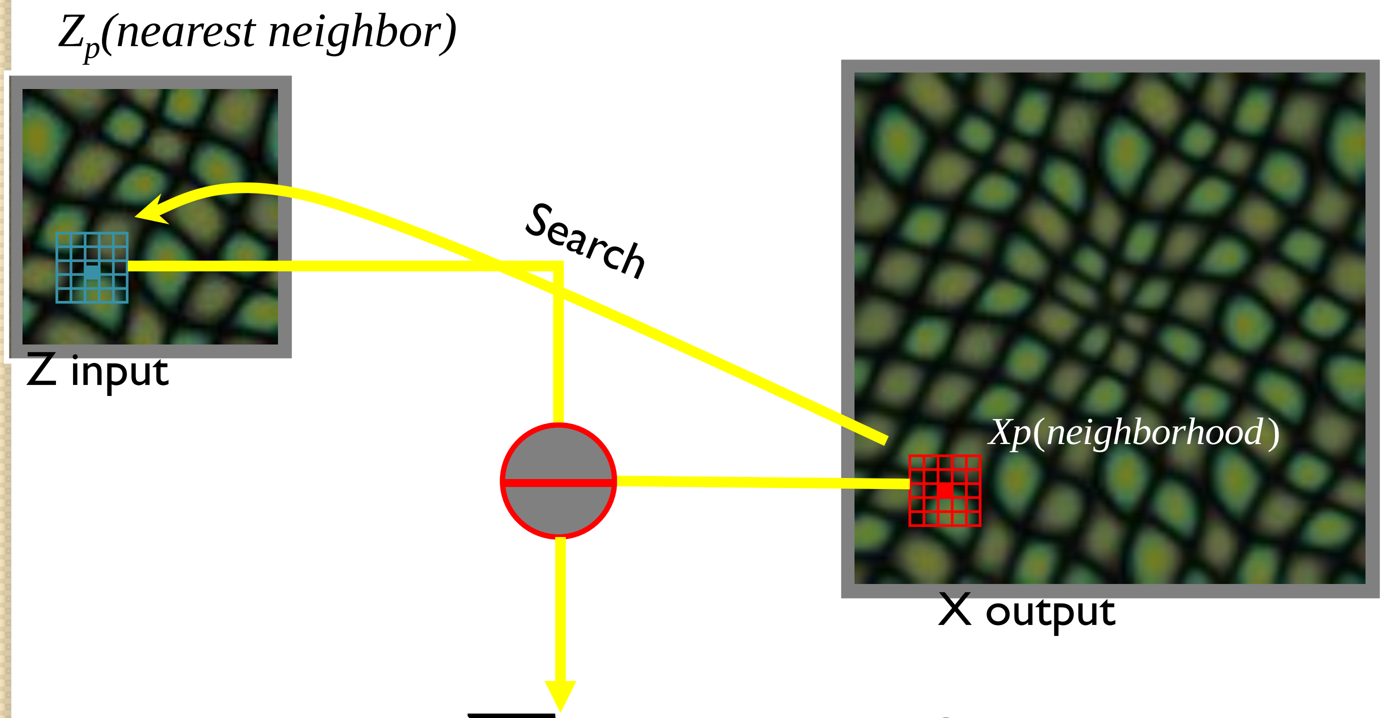
- Texture synthesis
  - Ensure local neighborhood similarity



$$E(X_p) = |X_p - Z_p|^2$$

纹理

- Texture synthesis
  - Ensure local neighborhood similarity



Z_p(nearest neighbor)

Search

Z input

Xp(neighborhood)

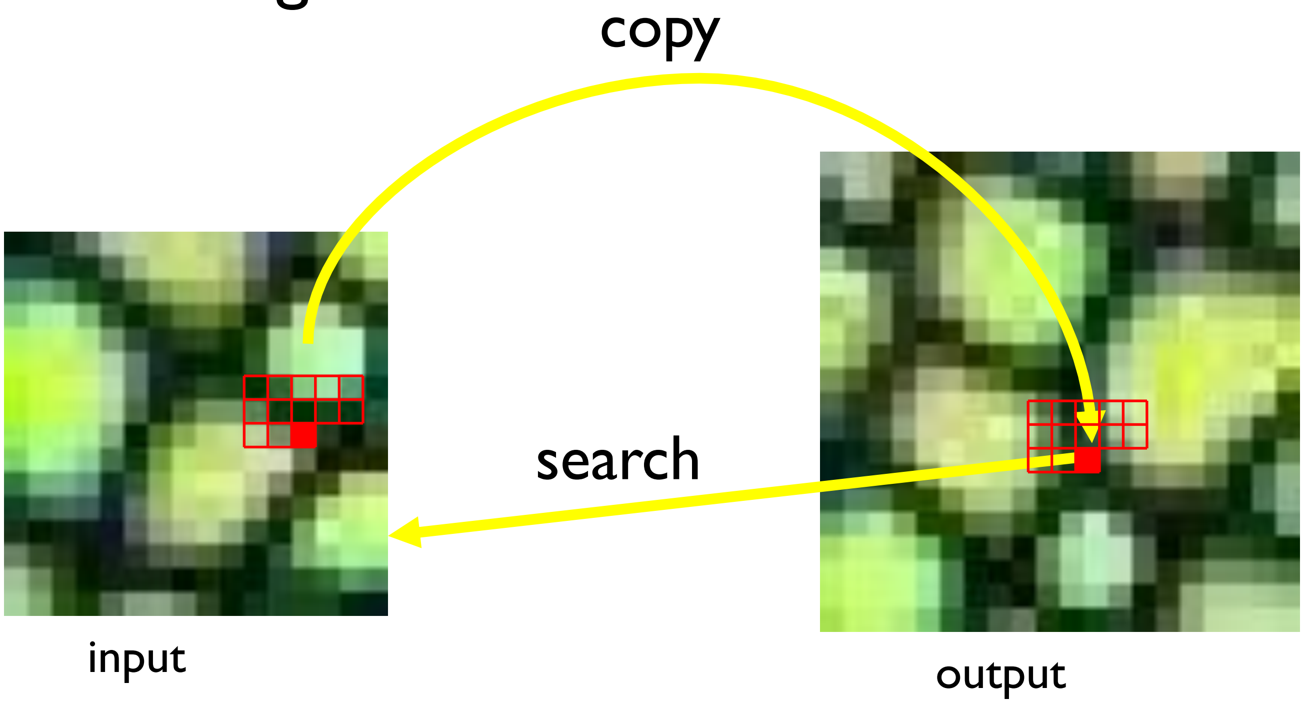
X output

$$E(X) = \sum_{p \in X'} | X_p - Z_p |^2$$

纹理

[Wei & Levoy 2000]

- Texture synthesis-Pixel-based Algorithm
  - Basic Idea - notice the use of fixed neighborhoods



copy

search

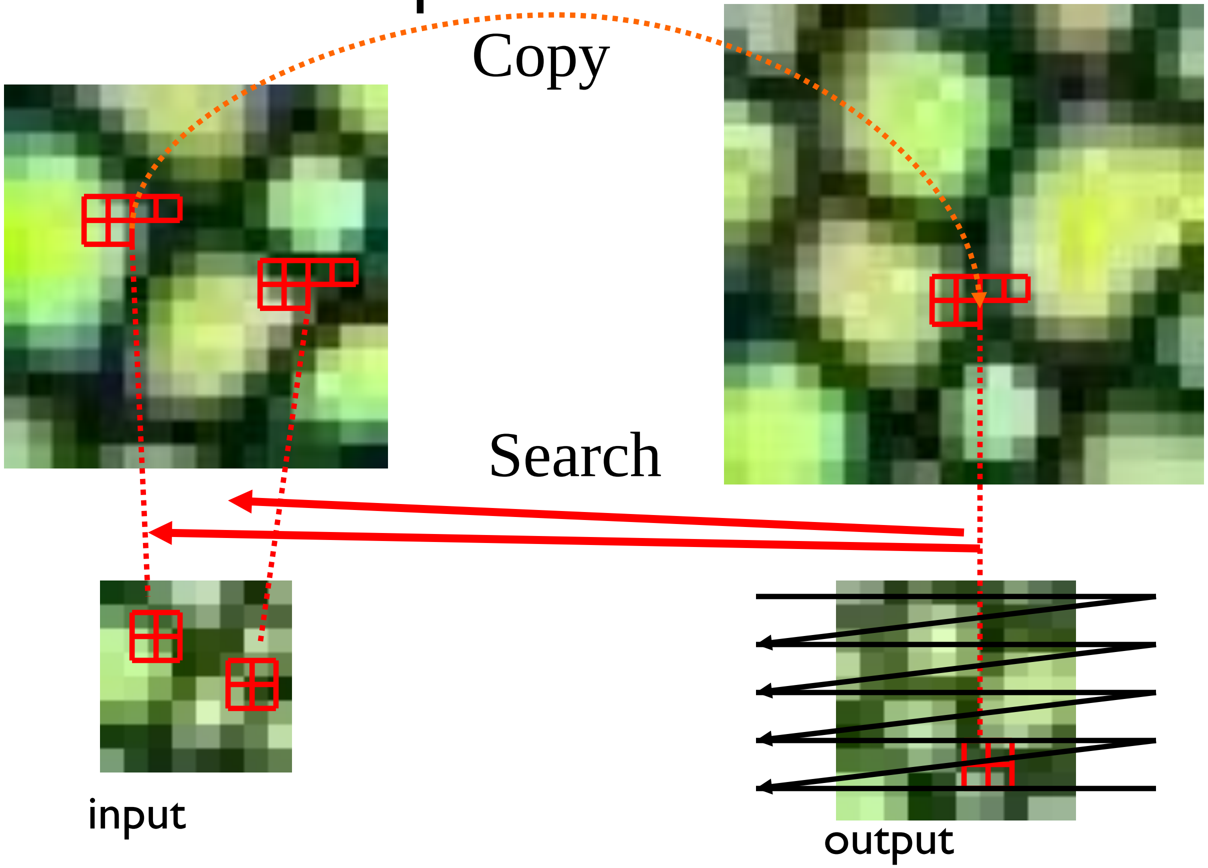
input

output

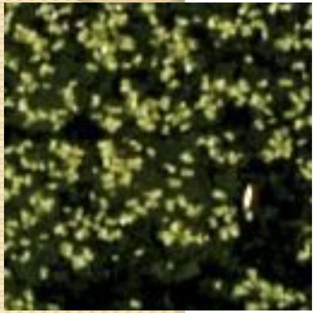
纹理

[Wei & Levoy 2000]

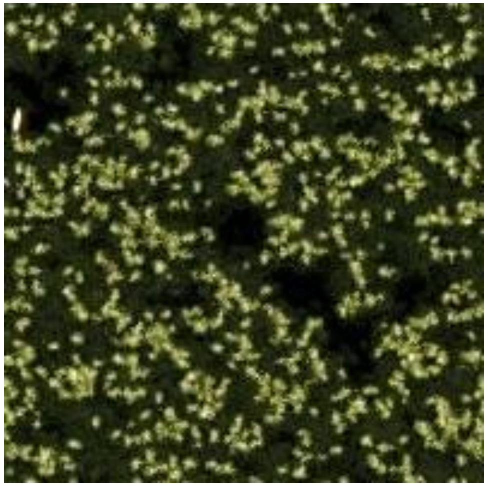
- Texture synthesis-Pixel-based Algorithm
  - Use multiple resolutions

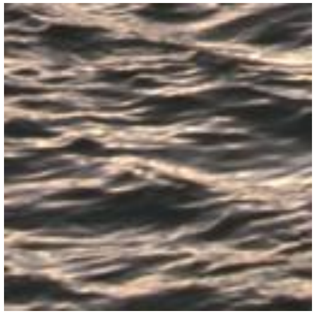


Pixel-based Algorithm Results

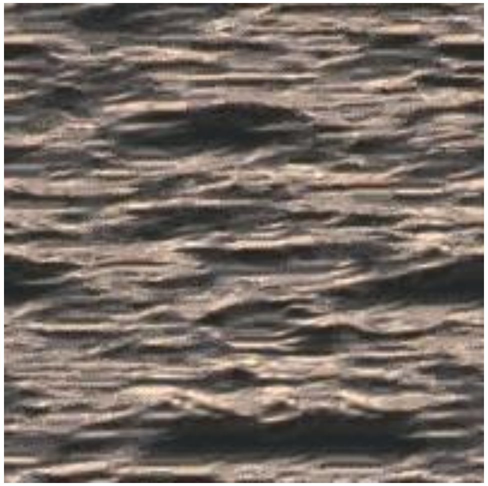


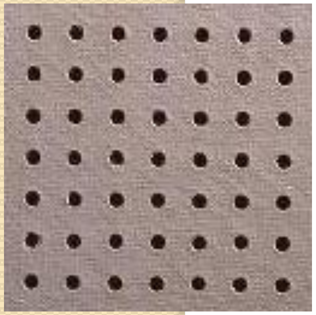
Random



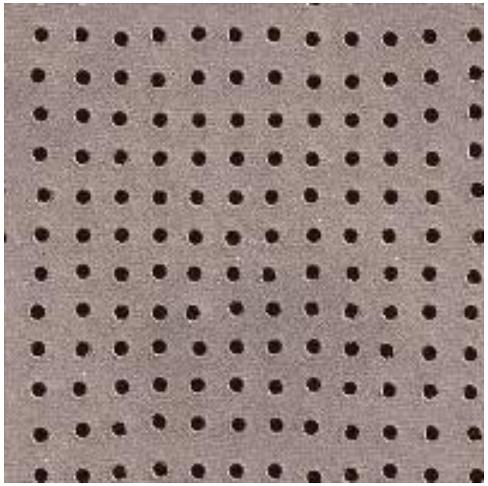


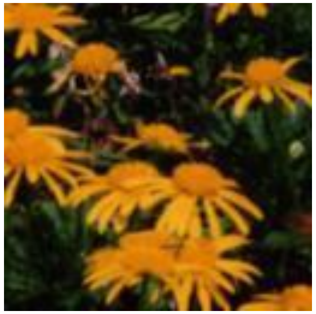
Oriented



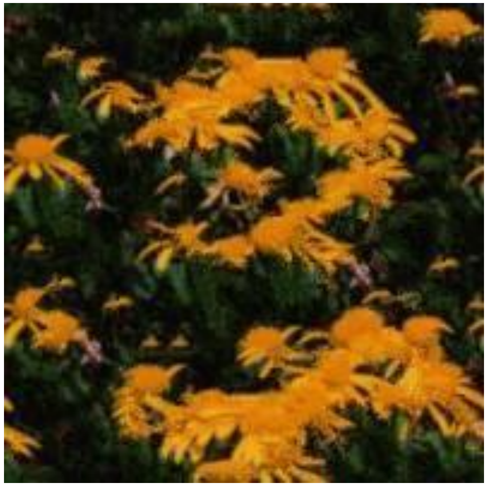


Regular

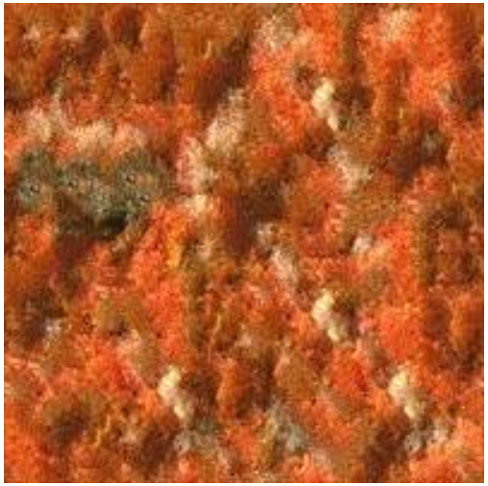


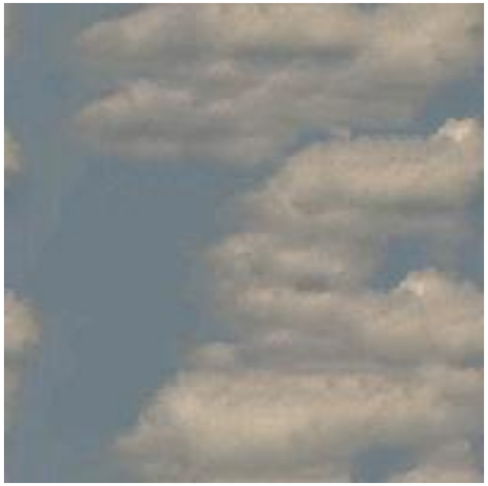


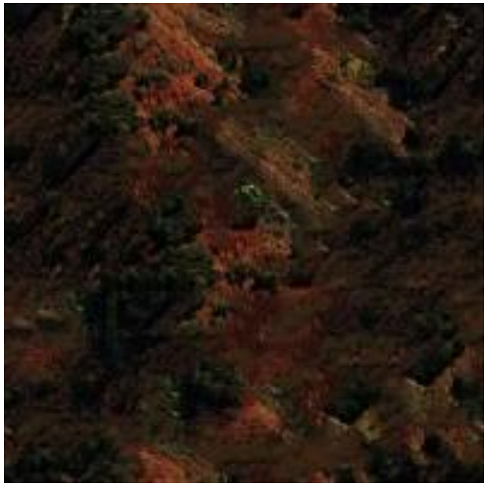
Semi-regular

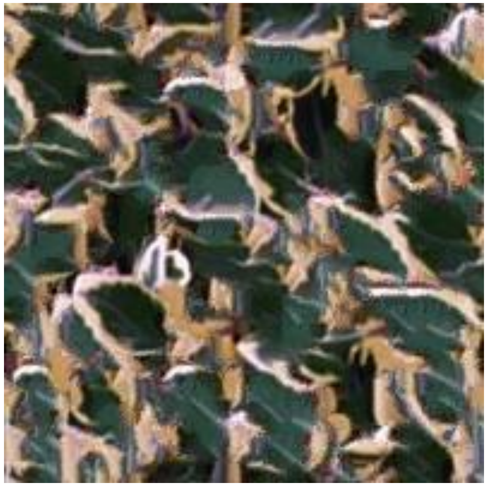


Pixel-based Algorithm Results









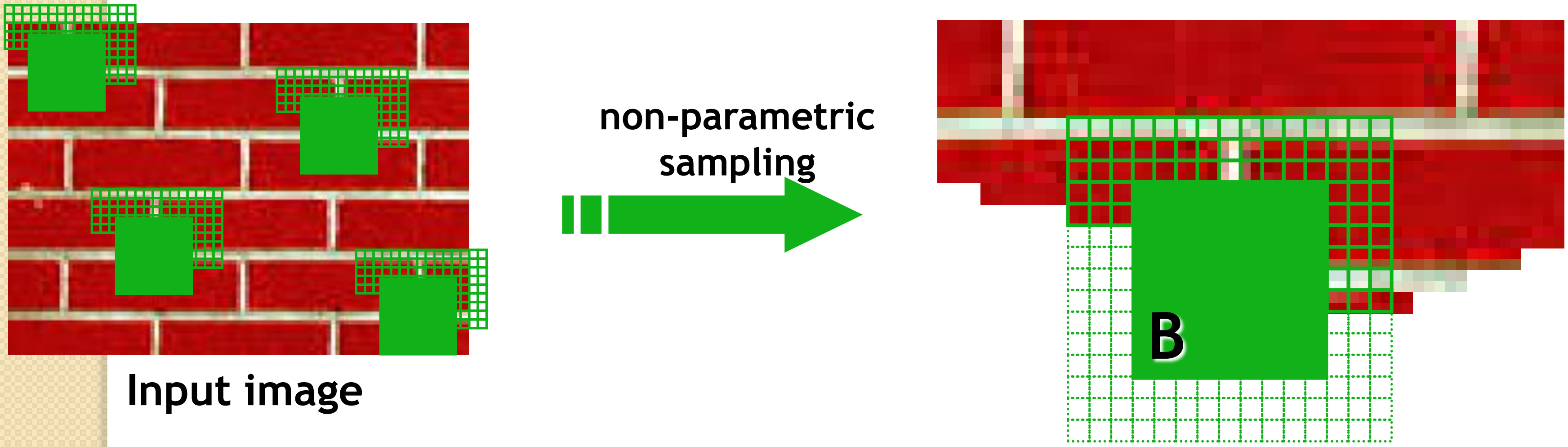
纹理

- Texture synthesis
  - Patch-based

纹理

[Efros & Freeman 2001]

- Texture synthesis-Patch-based Algorithm
  - Synthesis in unit of patches instead of pixels



Input image

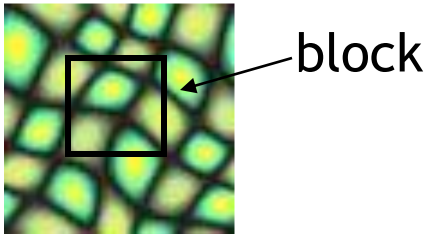
non-parametric sampling

Synthesizing a block

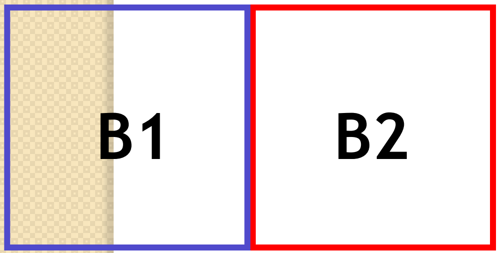
纹理

[Kwatra et al 2004]

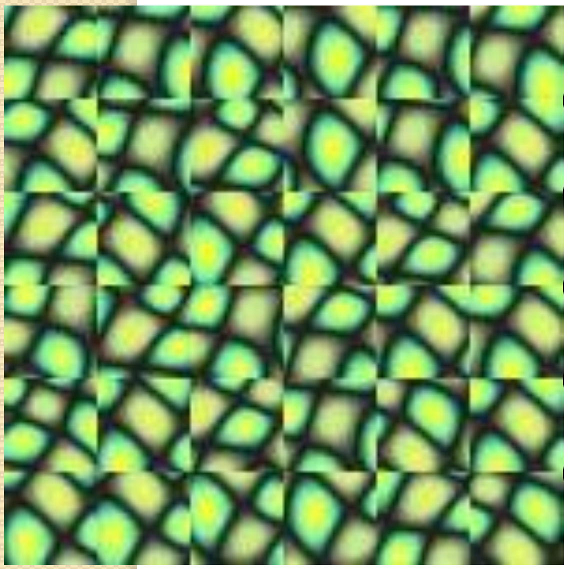
- Texture synthesis-Patch-based Algorithm
  - Use graph cut rather than dynamic programming for finding path

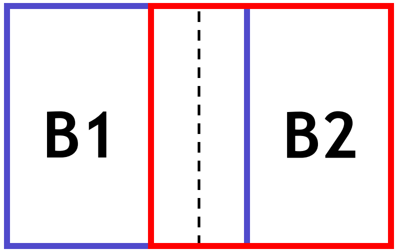


Input texture

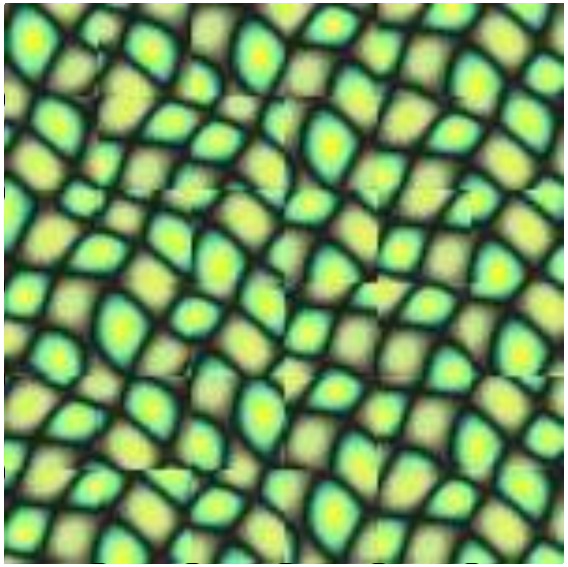


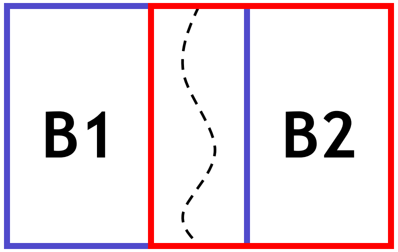
Random placement of blocks



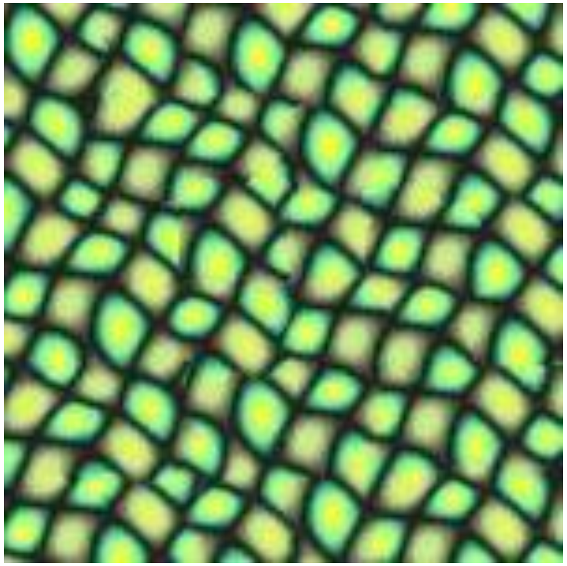


Neighboring blocks constrained by overlap





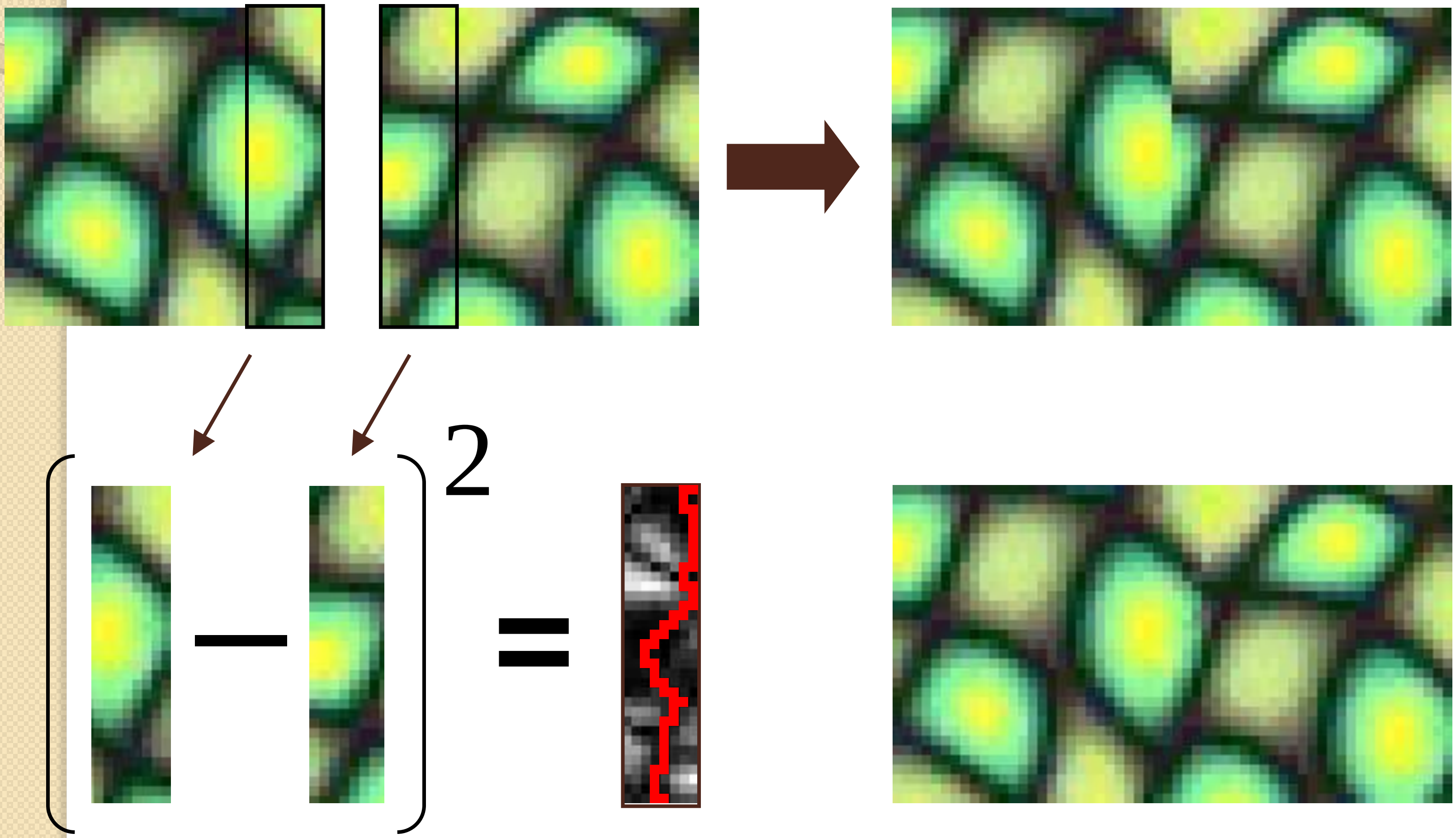
Minimal error boundary cut



Minimal error boundary

overlapping blocks

vertical boundary

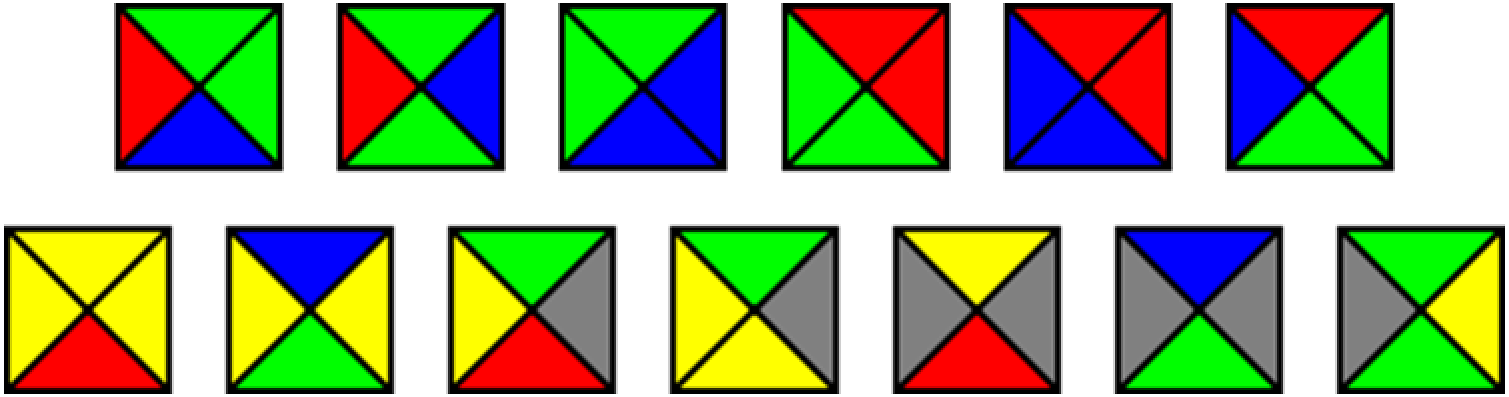


overlap error

min. error boundary

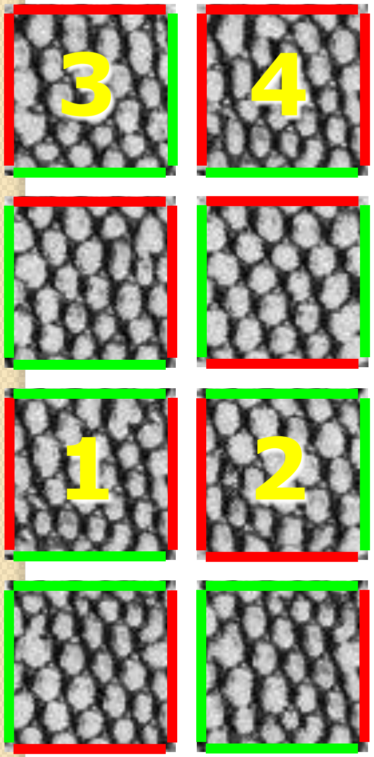
纹理

- Texture synthesis-Patch-based Algorithm
  - Wang Tiles(王浩)[Cohen et al 2003]



纹理

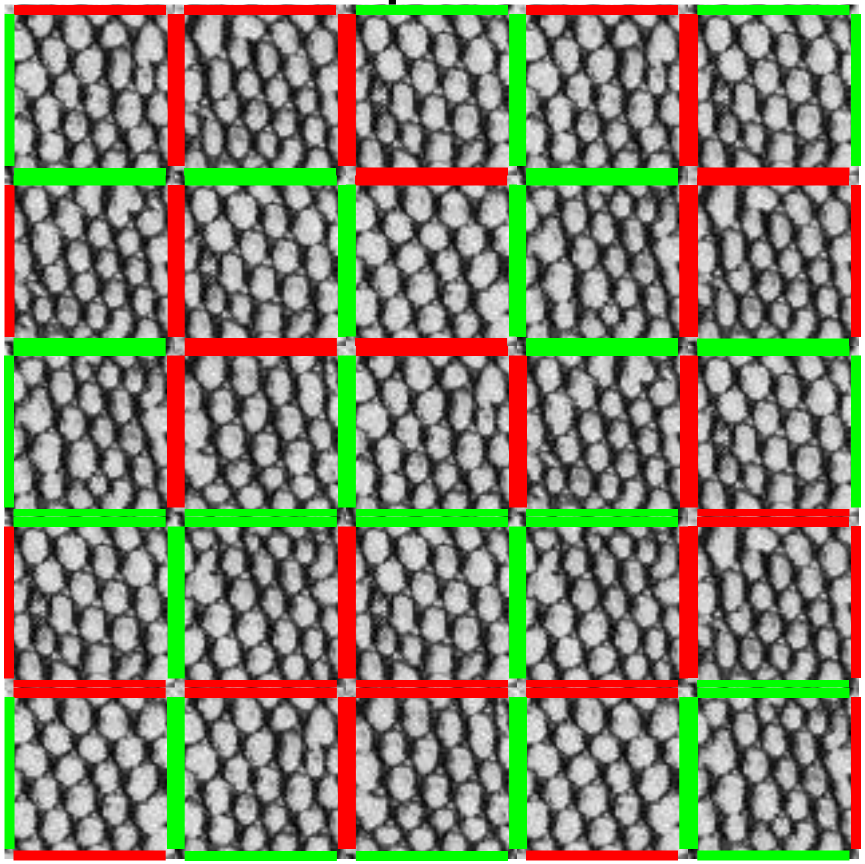
- Texture synthesis-Patch-based Algorithm
  - Wang Tiles[Cohen et al 2003]



Input tiles

continuous pattern across identical edge color

tiling



adjacent tiles share identical edge color

纹理

- Video Texture synthesis

纹理

- Video Texture synthesis
  - Video clip

纹理

- Video Texture synthesis
  - Video clip → Video Texture

纹理

- Video Texture synthesis

A sequence of random variables

{ADEABEDADBCAD}

A sequence of random variables

{BDACBDCACDBCADCBADCA}

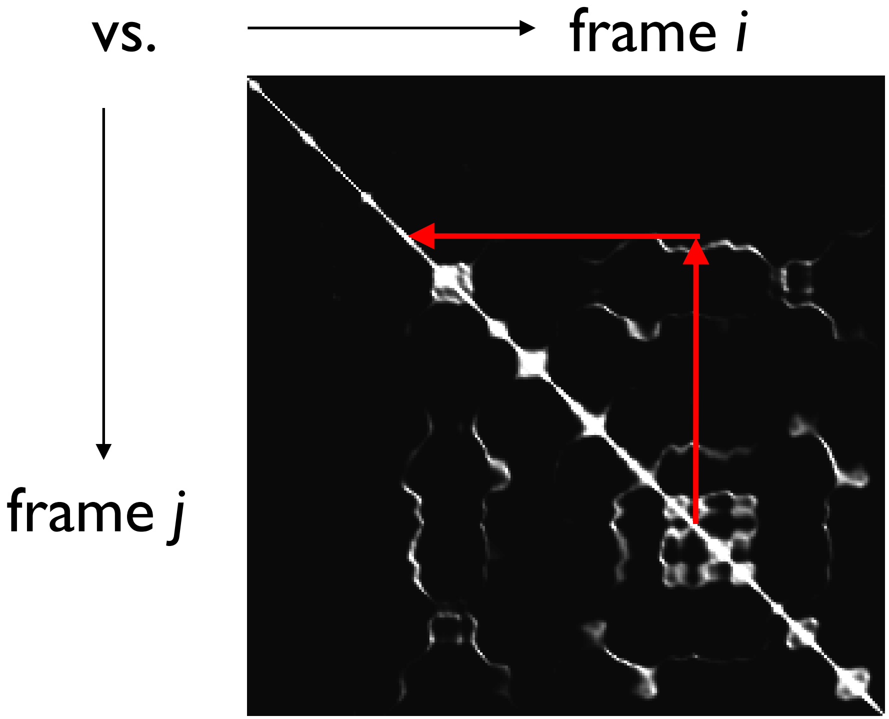
Markov chain

纹理

- Video Texture synthesis
  - Approach

纹理

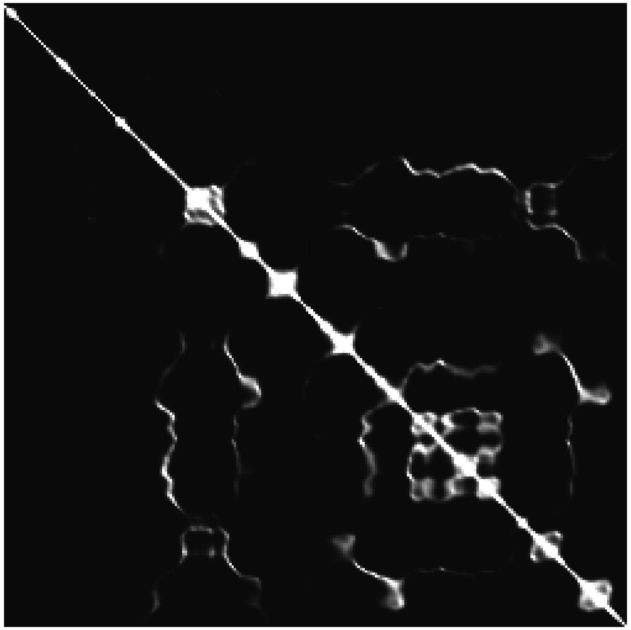
- Video Texture synthesis
  - Compute L_2 distance $D_{i,\,j}$ between all frames

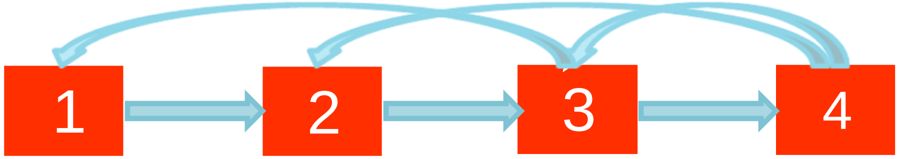


Similar frames make good transitions

Markov chain representation

- Video Texture synthesis
  - Markov chain representation





Similar frames make good transitions

纹理

- Video Texture synthesis
  - Lengthen / shorten video without affecting speed

shorter

original

longer

纹理

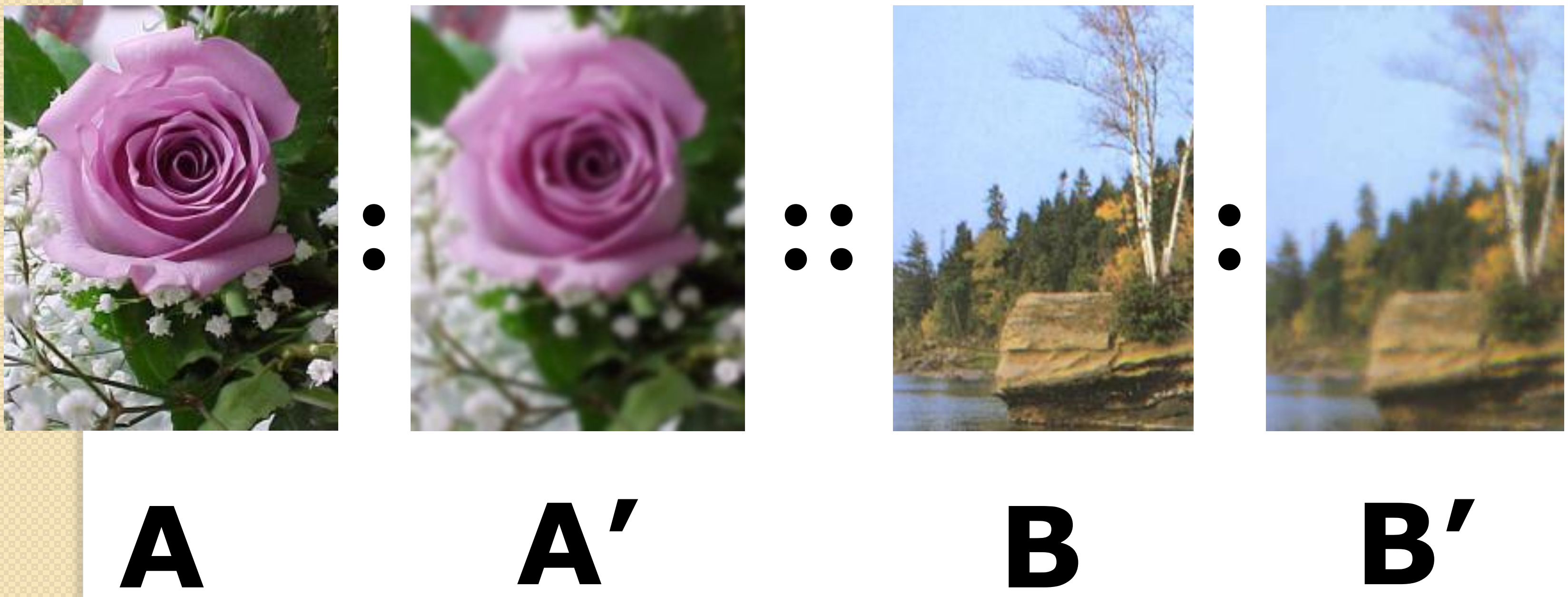
- Video Texture synthesis

纹理

- Image analogies

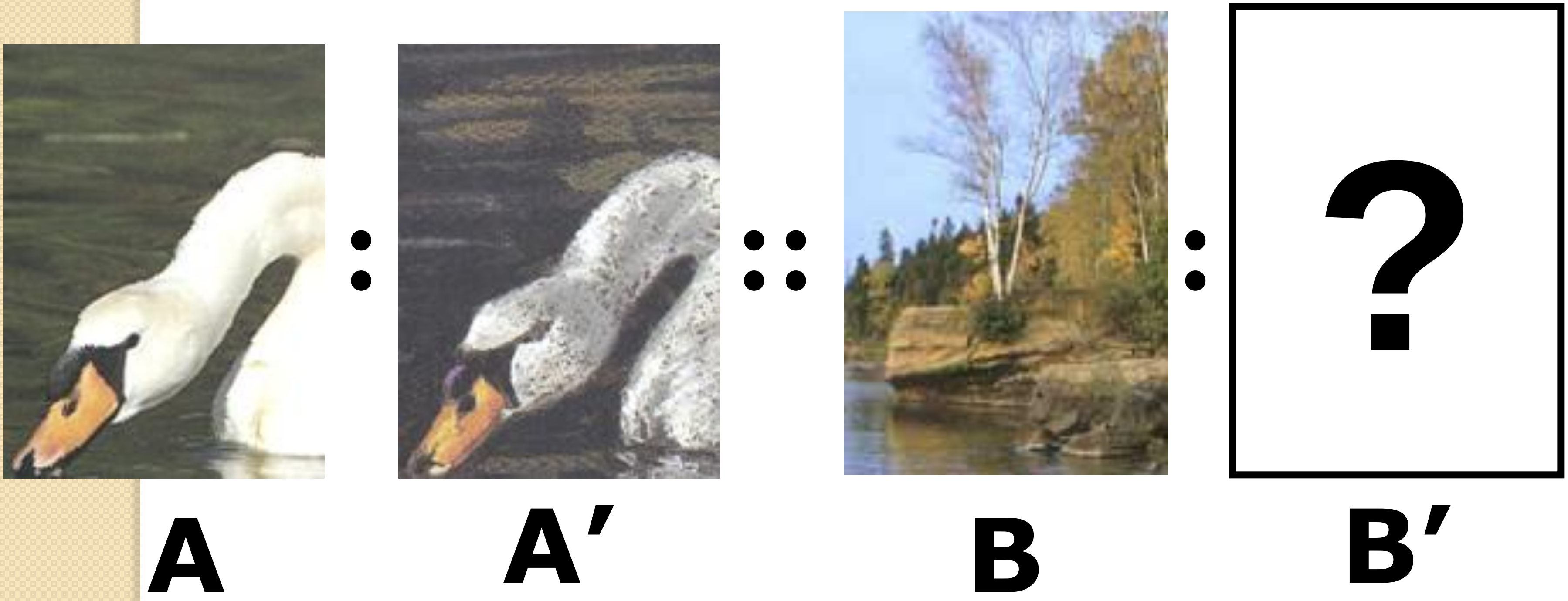
纹理

- Image analogies
  - Simple Blur



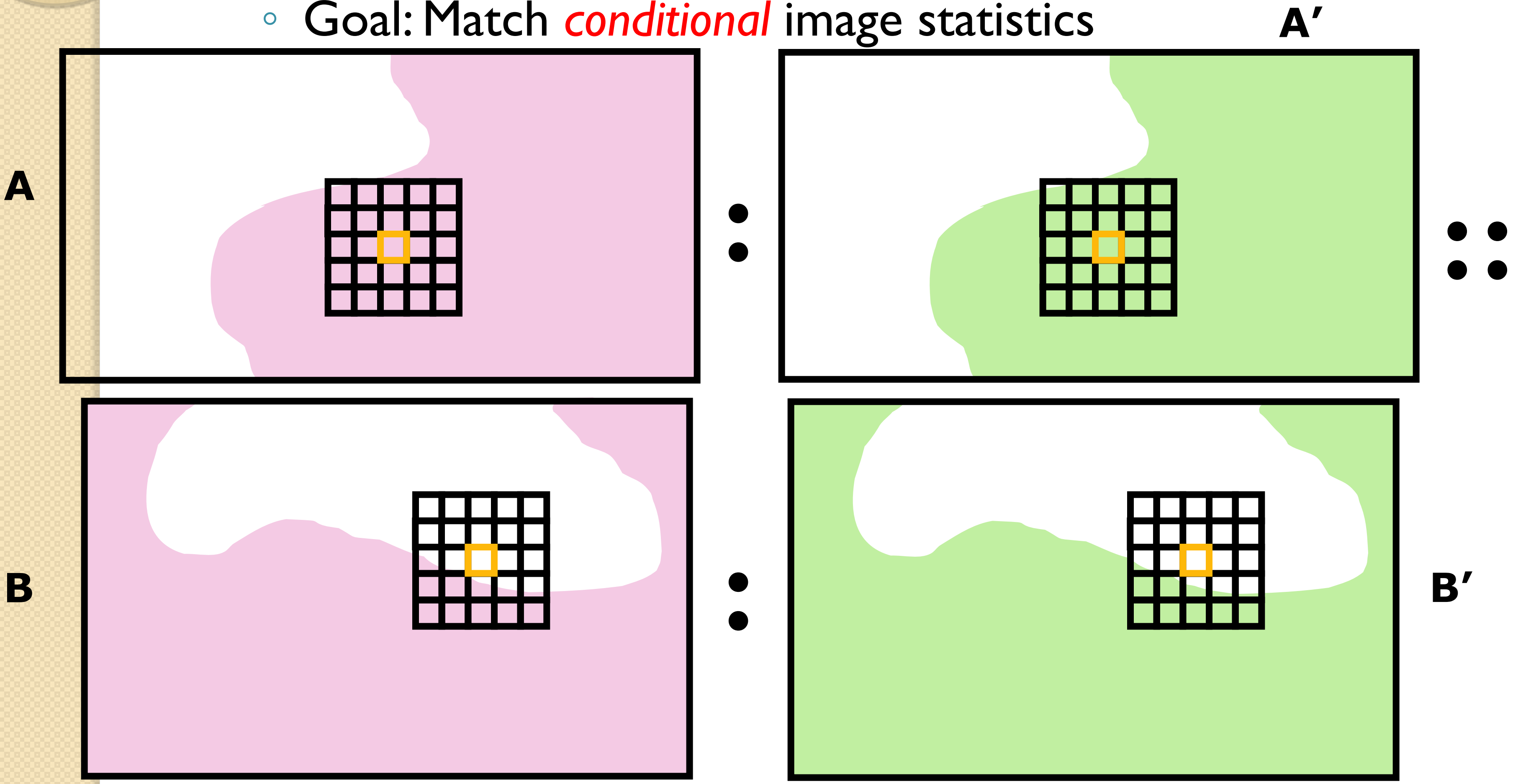
纹理

- Image analogies
  - Artistic Styles



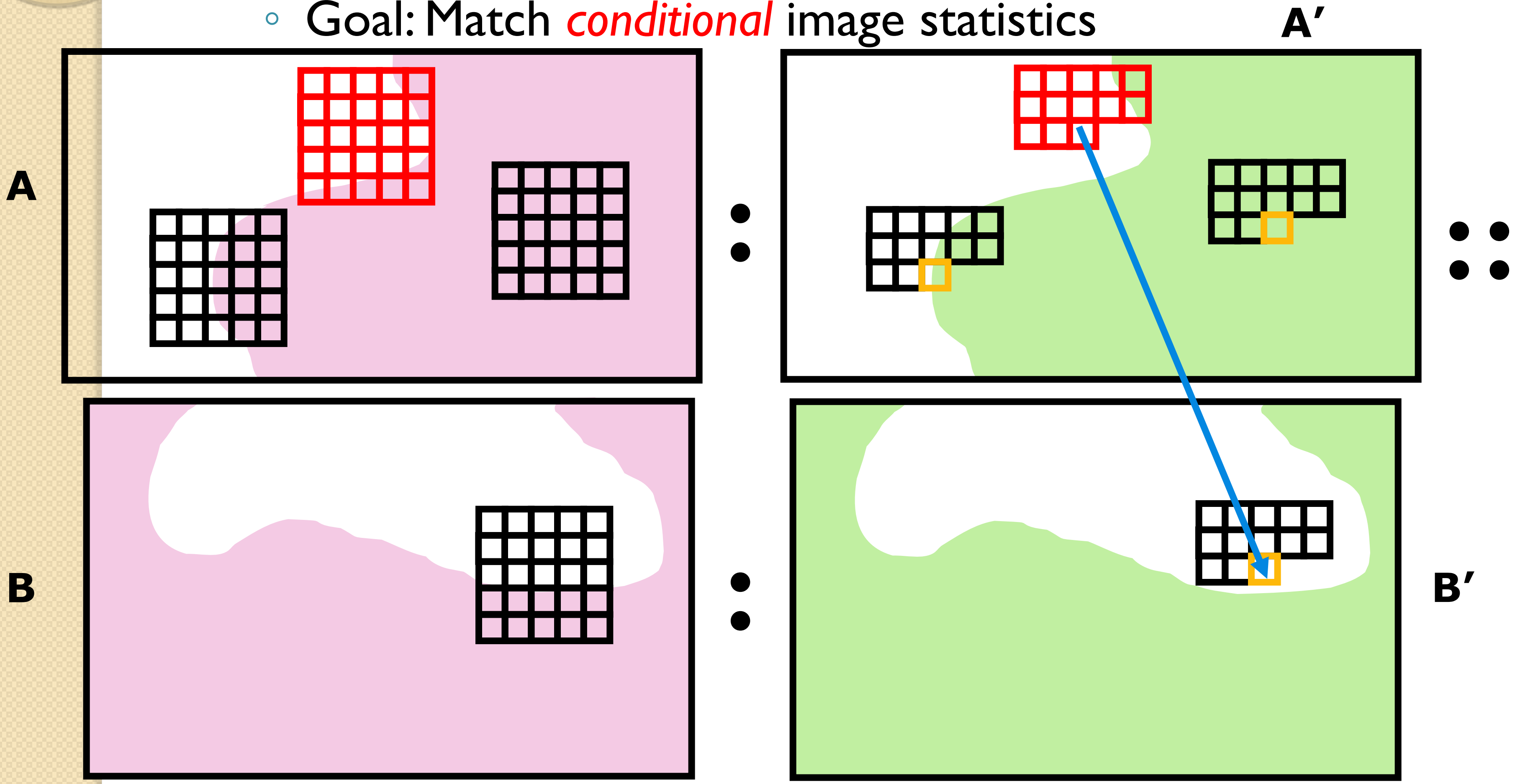
纹理

- Image analogies
  - Goal: Match *conditional* image statistics



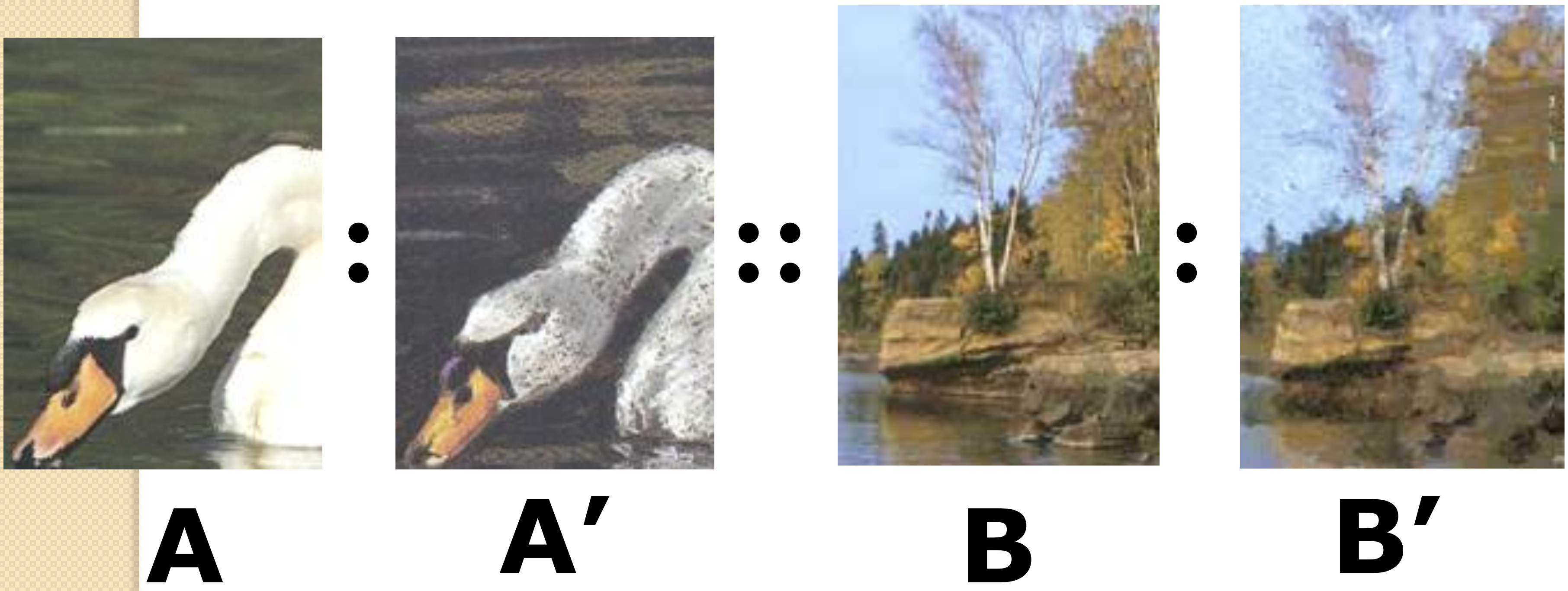
纹理

- Image analogies
  - Goal: Match *conditional* image statistics

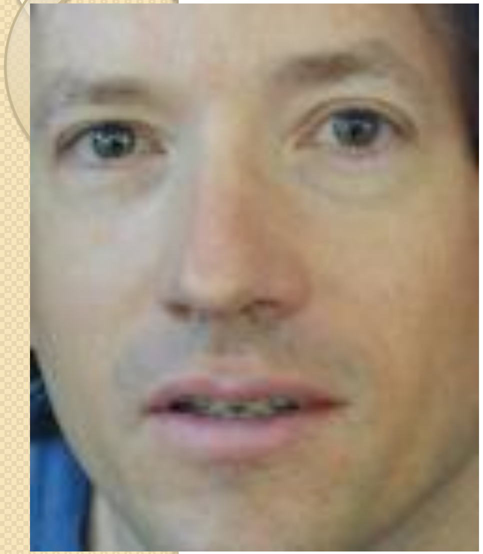


纹理

- Image analogies
  - Artistic Styles



Efros & Freeman 2001
Target Color



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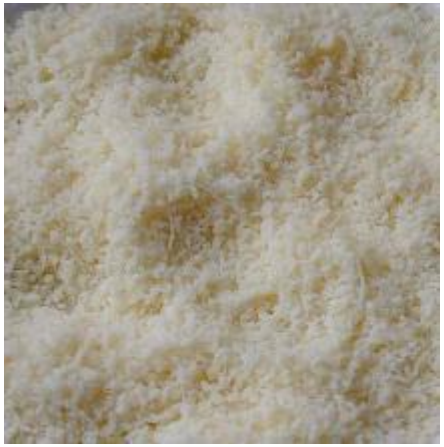

parmesan

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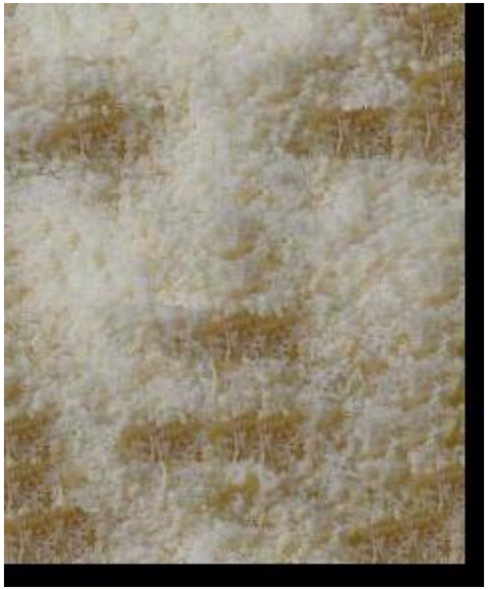

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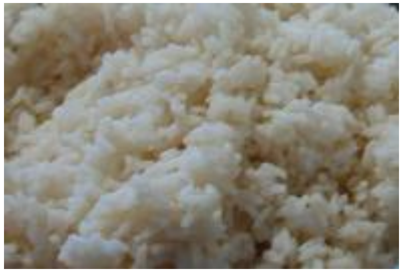

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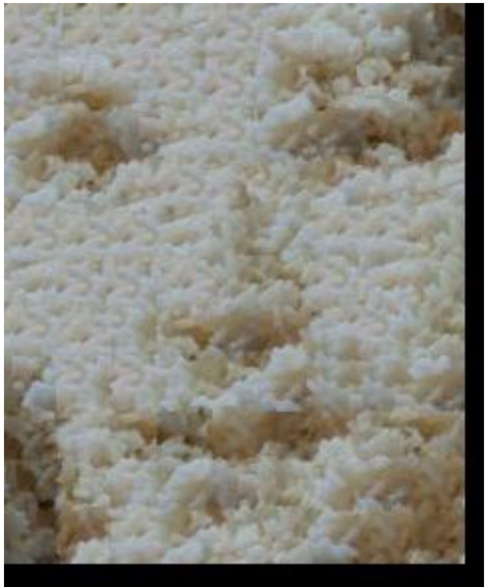

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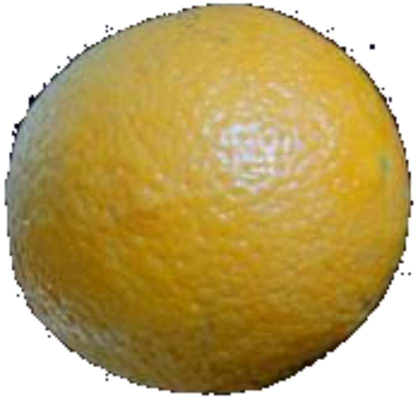

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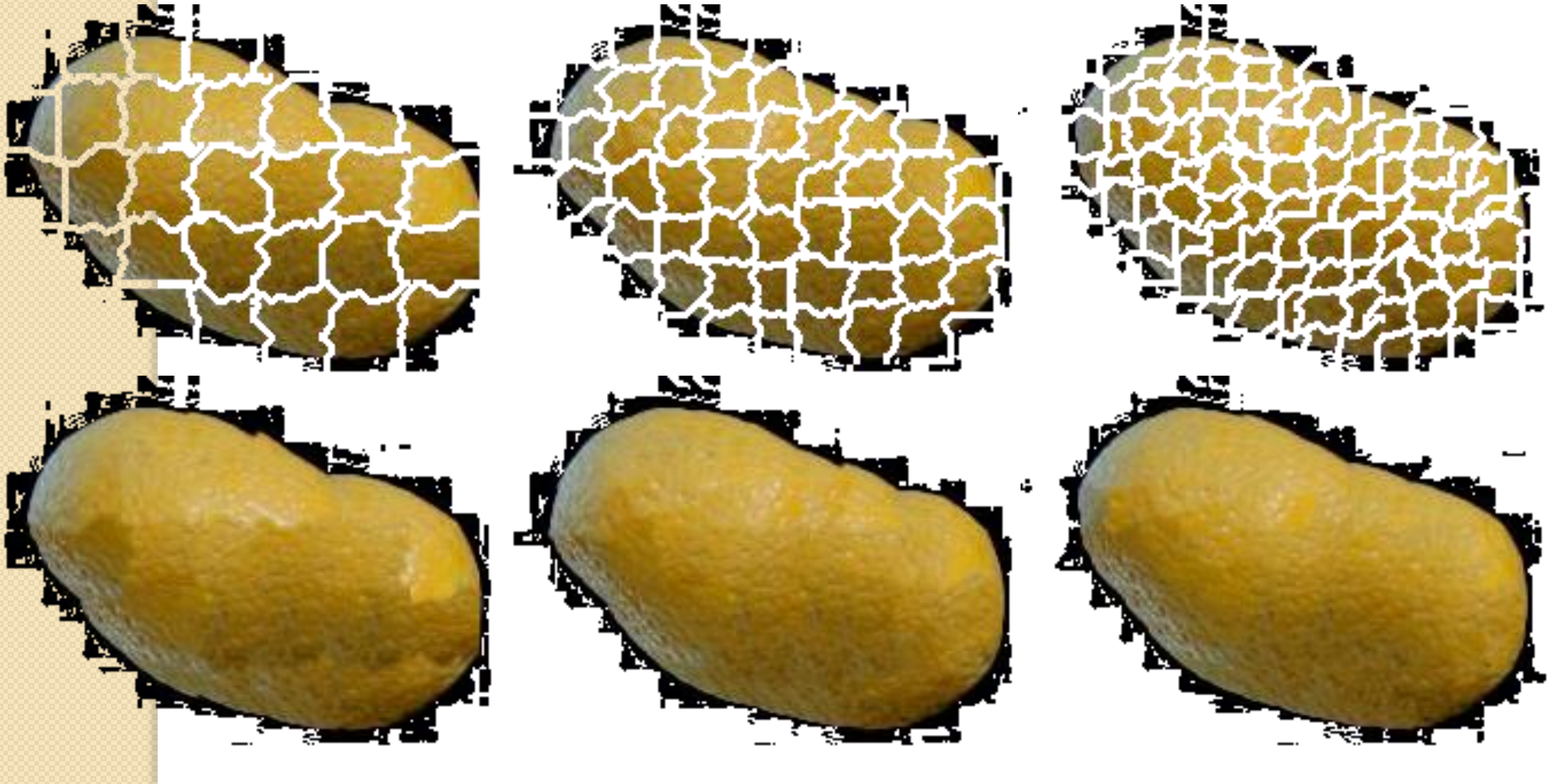

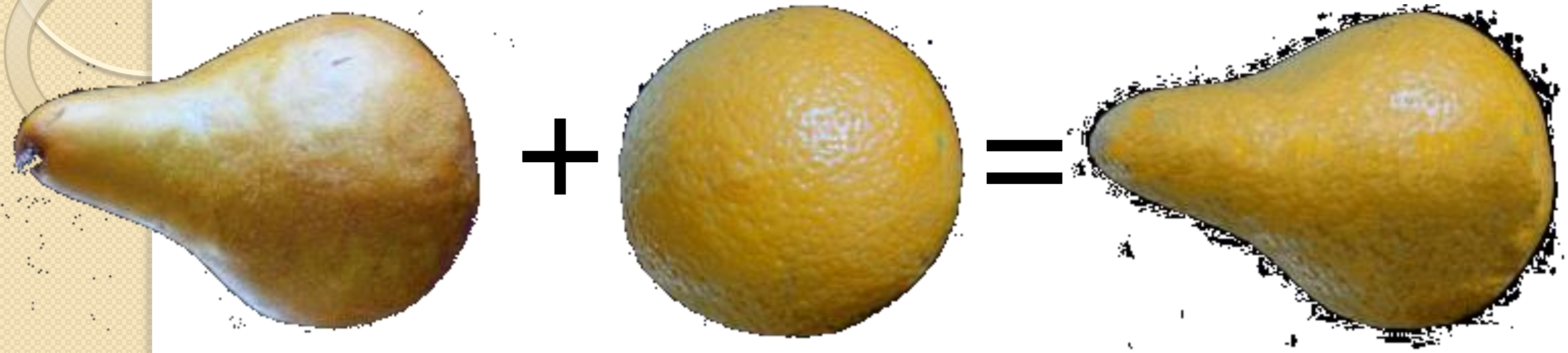

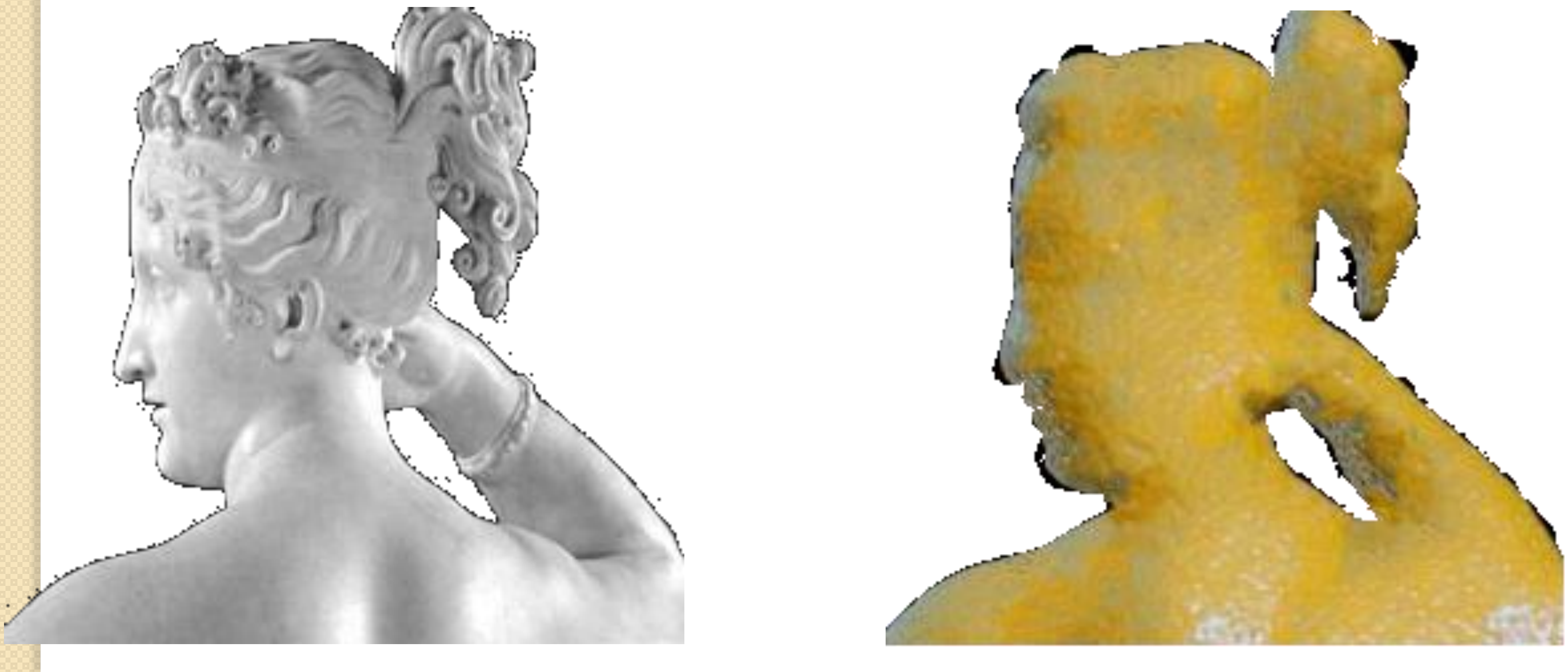

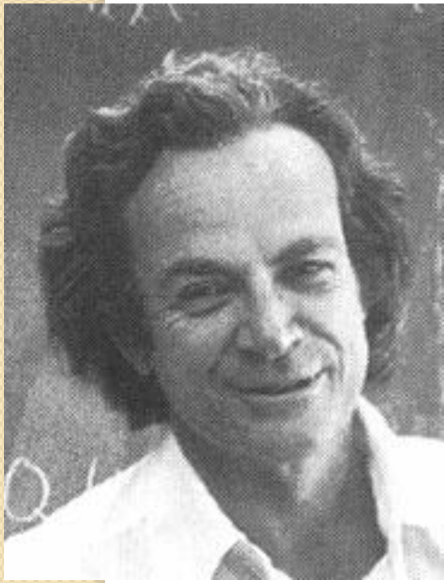

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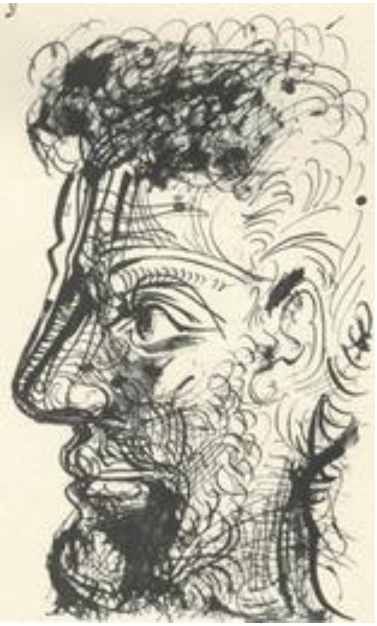

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