Image Restoration using Multiresolution Texture Synthesis and Image Inpainting

CGI 2003

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Introduction : Motivation

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- Repairing damaged images
  - scratches on pictures or old films

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  - Images synthesized by IBR, etc.

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  - scratches on pictures or old films
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  - Images synthesized by IBR, etc.
- Delete unwanted objects on an image
  - subtitles, logos, microphones, ...

Intro: Repairing damages

Repairing damaged images

- scratches on pictures or old films

Photo from :
“Image Inpainting,”
M. Bertalmìo, et al.,
SIGGRAPH 2000.

http://www.ece.umn.edu/users/marcelo/restoration.html

Intro: Fill-in hole

Fill in missing part of images

- Images synthesized by IBR, etc.

White triangles:

- occlusions
- registration errors
- etc..

Intro : Delete objects

Delete unwanted objects on an image

- subtitles, logos, microphones, ...

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What are damaged pixels? / How to detect them?

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- Image sequences : Assuming temporal coherence
  - 3D Template matching, 3DMMF (3D multi-level median filter), 3D autoregressive model *(A.C. Kokaram, et al., "Detection of Missing Data in Image Sequences," 1995)*

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  - Unwanted object can not be detected automatically
- Here, we should manually specify restoration area

Image Restoration

- Solving PDE :
  - diffuses intensity from boundary pixels
  - can keep smoothness of image
  - can not reconstruct details
- Texture synthesis :
  - searches similar patterns and arranges them
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Question

Can we combine both advantages without including disadvantages?

PDE method

- Anisotropic diffusion
  - *M. Bertalmìo, et al., "Image Inpainting", SIGGRAPH 2000*
- Isotropic diffusion
  - *M. M. Oliveria, et al., "Fast Digital Image Inpainting,"VIIP 2001*
- Interpolating height field with bicubic B-spline surface

⇓

Assuming image height field continuity

PDE method : Example (1)

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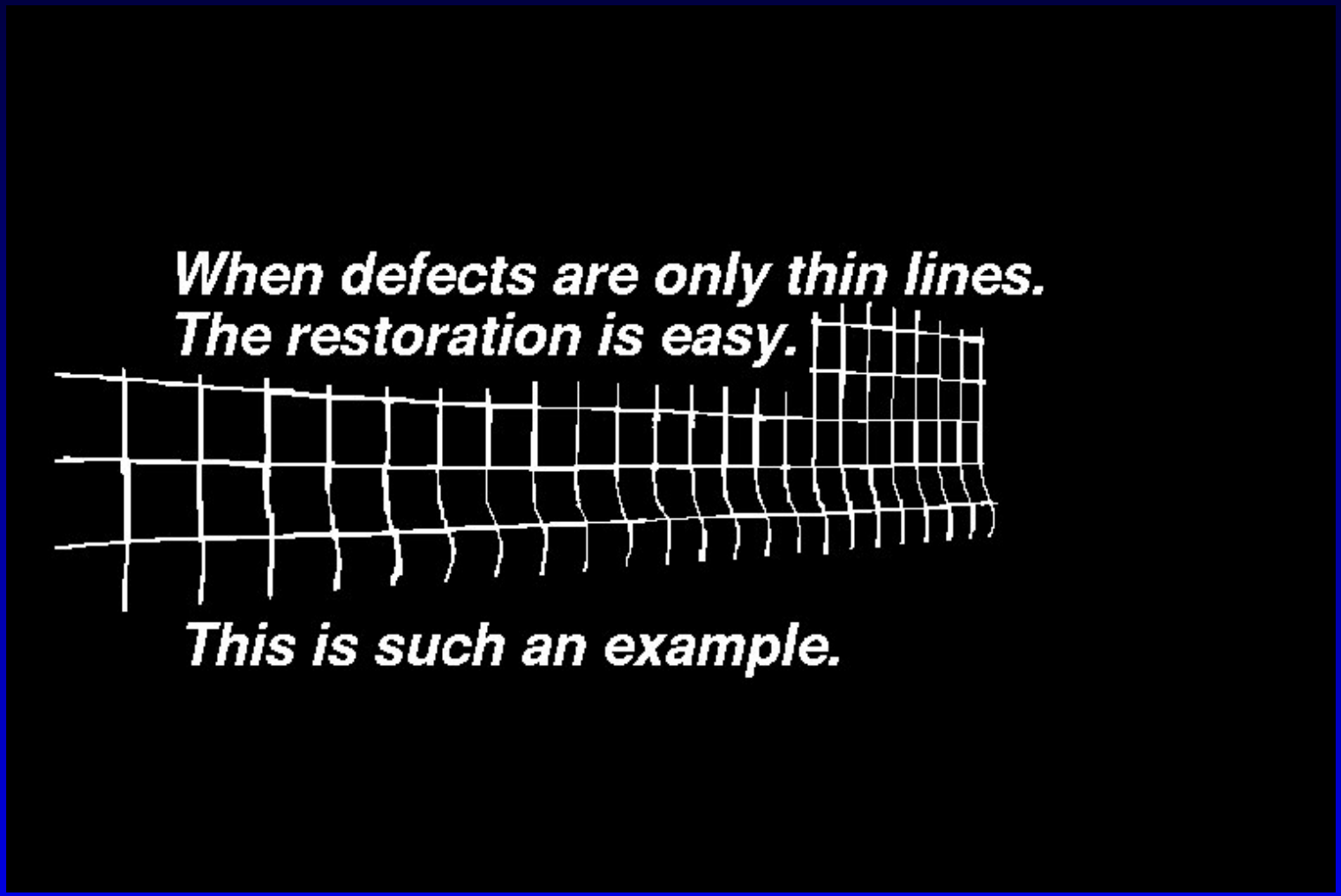
Input Image

PDE method : Example (1)

Mask Image



PDE method : Example (1)

Image with Mask

PDE method : Example (1)

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Fast Digital Image Inpainting : Gaussian diffusion

PDE method : Example (1)

Image Inpainting : Anisotropic diffusion

PDE method : Example (2)

Input Image

PDE method : Example (2)

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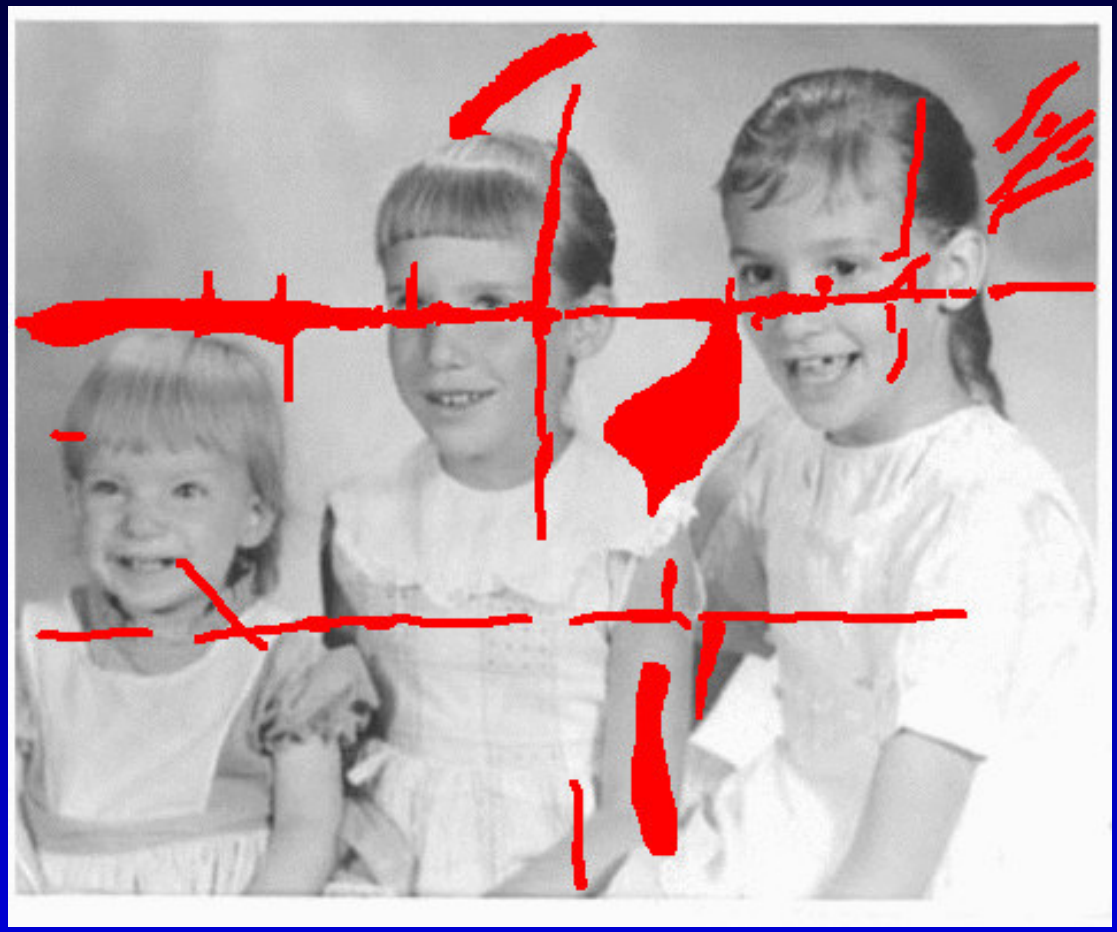

PDE method : Example (2)

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Image Inpainting : Anisotropic diffusion

PDE method : Hard case

Input Image

PDE method : Hard case

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PDE method : Pros & Cons

PDE based methods

- Advantages :

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    $\rightarrow$ Anisotropic diffusion tries to reconstruct high frequency part, but it is limited

Texture synthesis (1)

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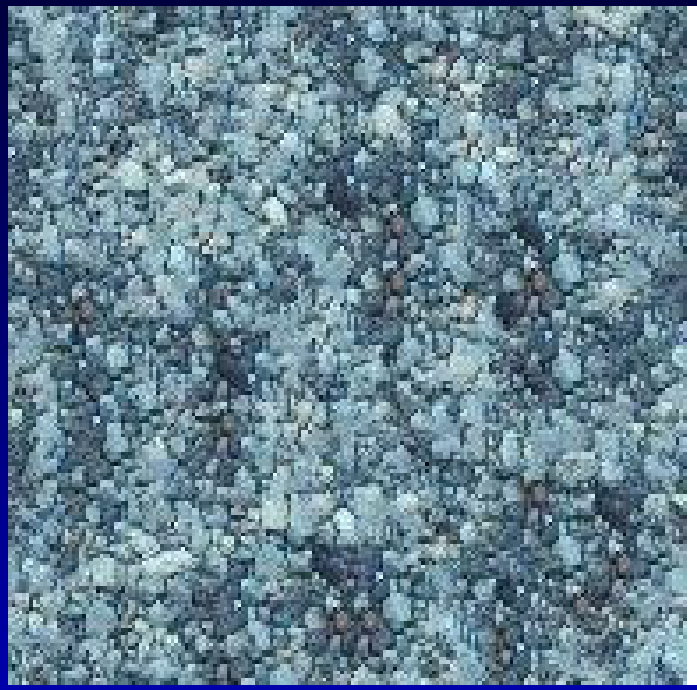
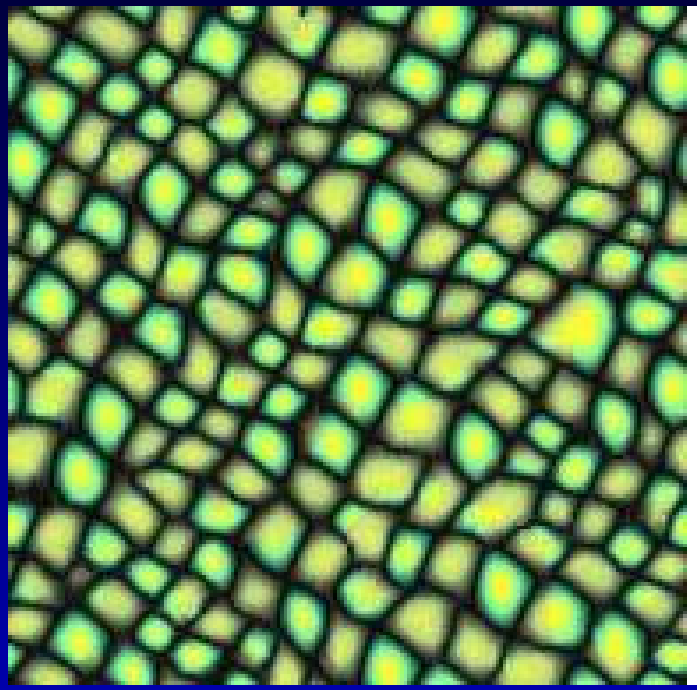
What is a texture?





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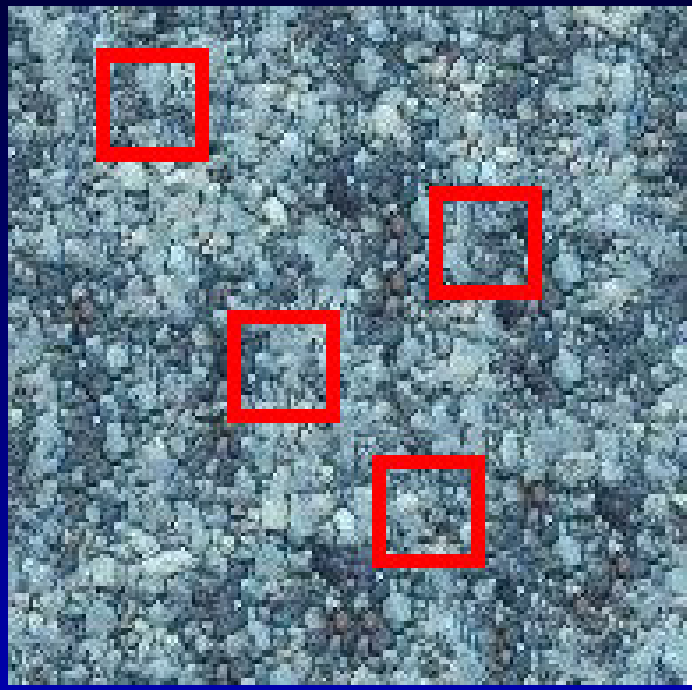

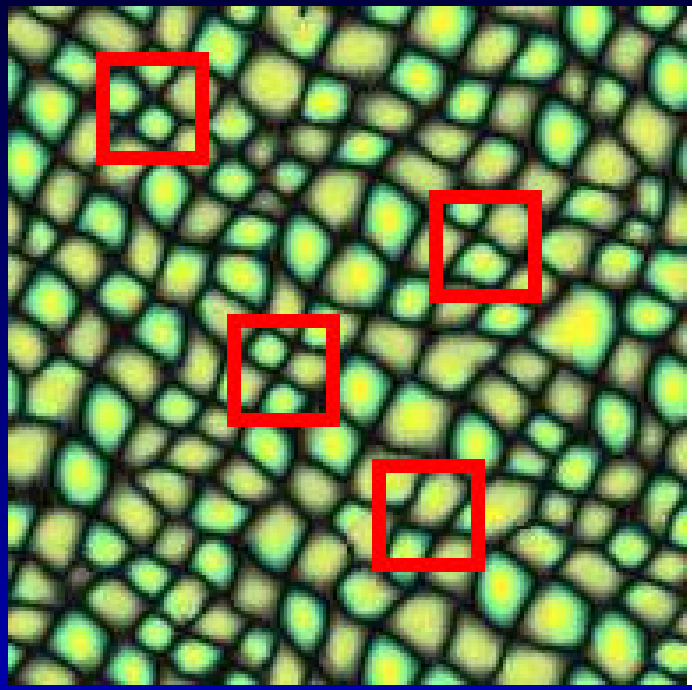

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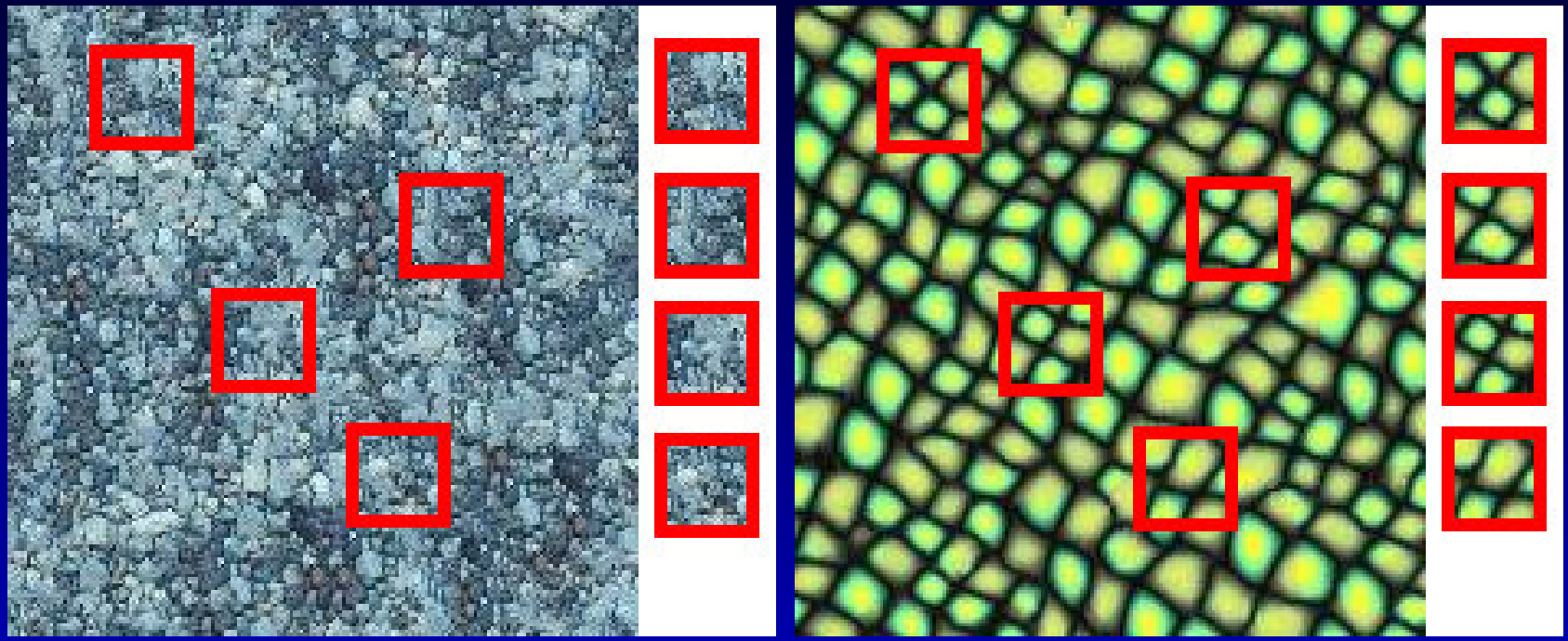
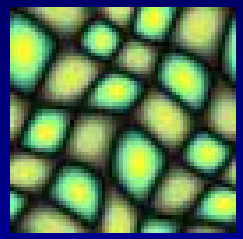


Texture: An image that exhibits spatial homogeneity

Texture synthesis (2)

Using spatial homogeneity for synthesis



Input

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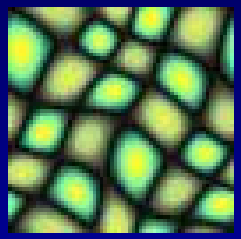
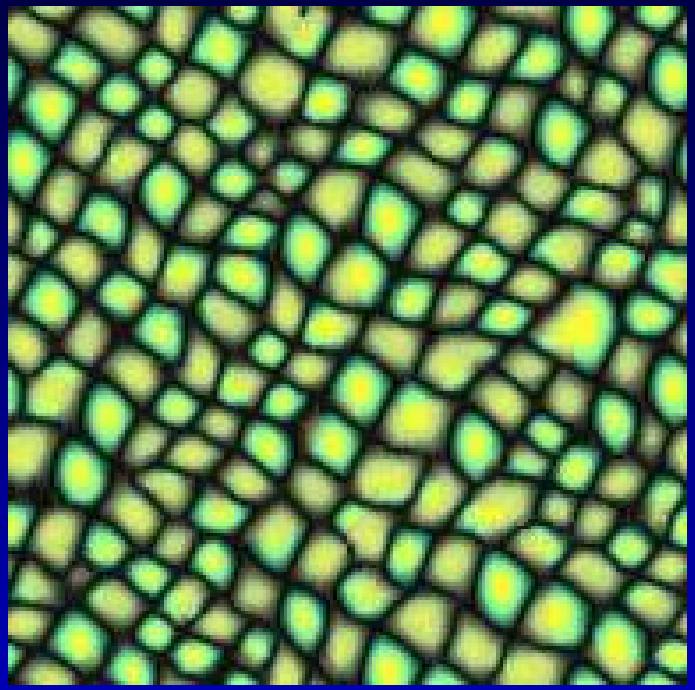


Input

$\Rightarrow$



Output

Texture synthesis: Classification

- Procedure based
  - Fractal, Cellular textures (Fleischer 1995), Reaction diffusion (Turk 1991)

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- Statistics analysis and synthesis
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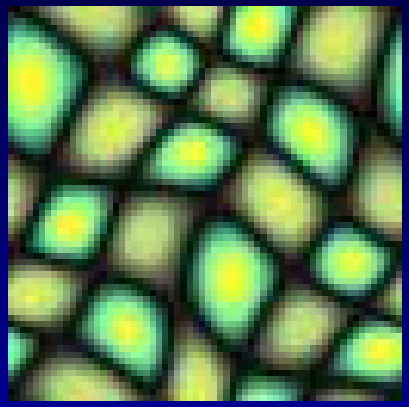
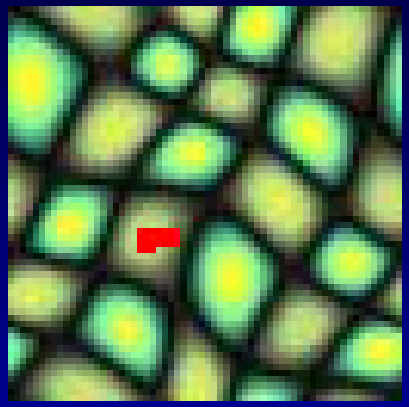
  - Texture Mixing and Texture Movie Synthesis Using Statistical Learning (Bar-Joseph 2001)
- Non-parametric Sampling
  - Texture Synthesis by Non-parametric Sampling (Efros 1999)
  - Fast Texture Synthesis Using Tree-Structured Vector Quantization (Wei 2000)

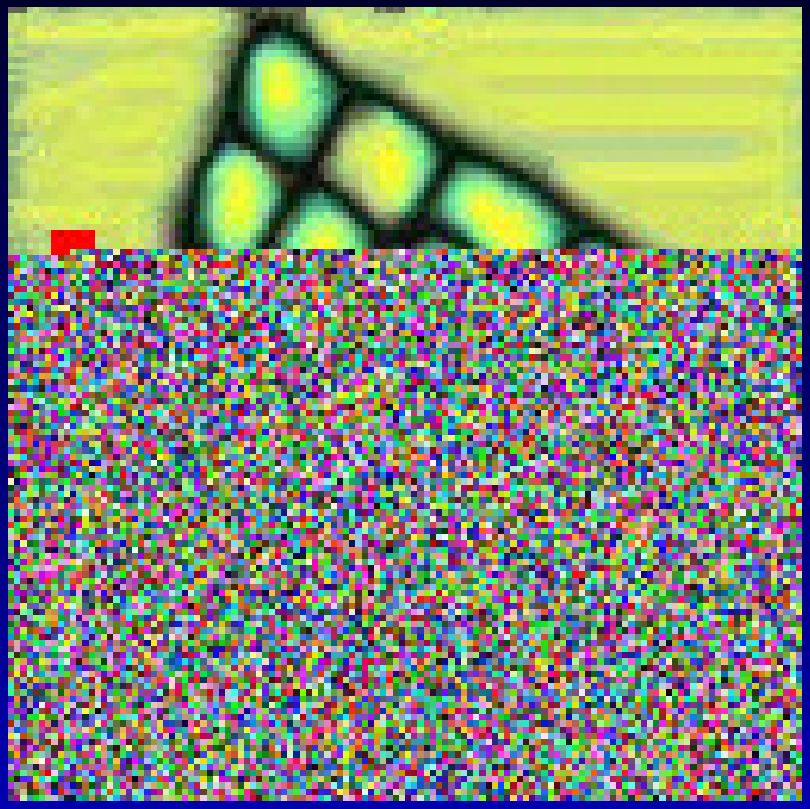
Non-parametric Sampling (1)



Initialize target image with random color pixels

Non-parametric Sampling (1)





Search similar kernel (red shape) on seed image
transfer a pixel

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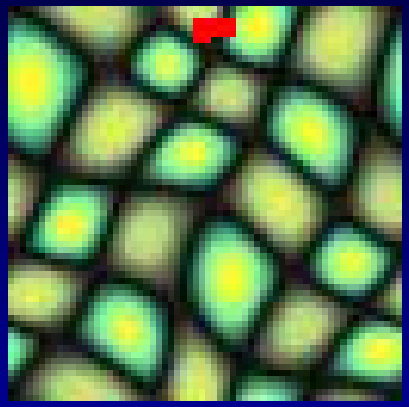

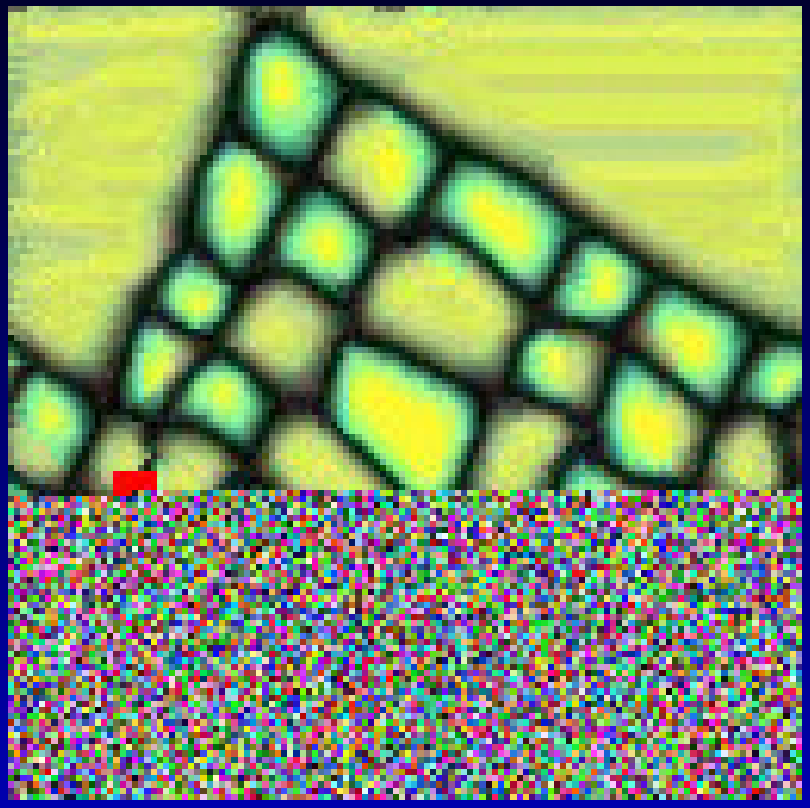

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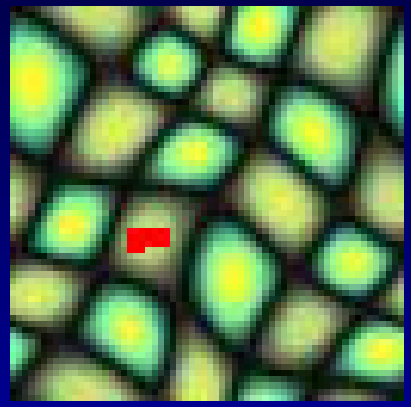

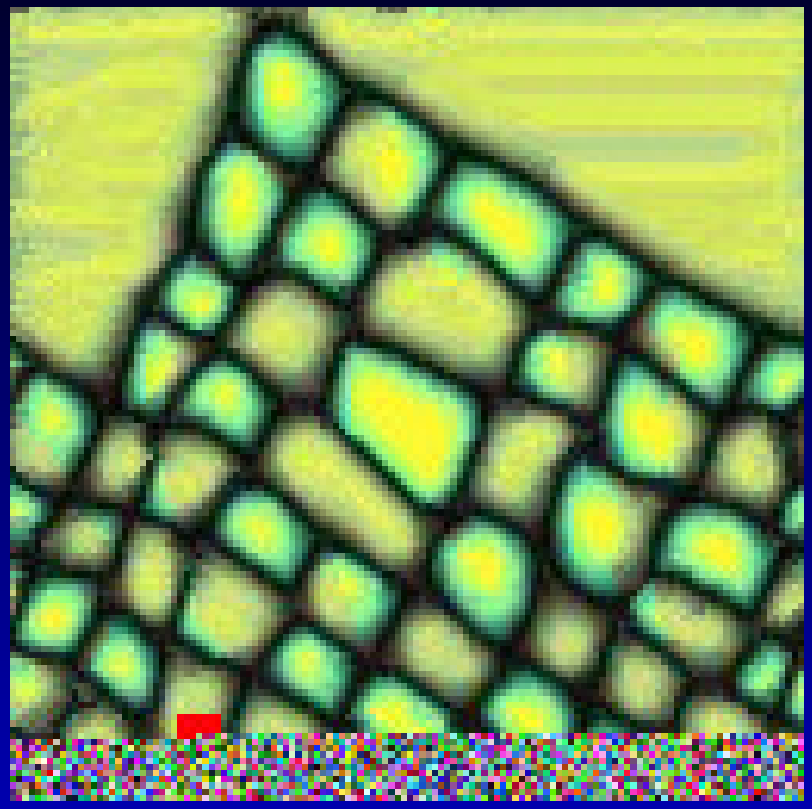

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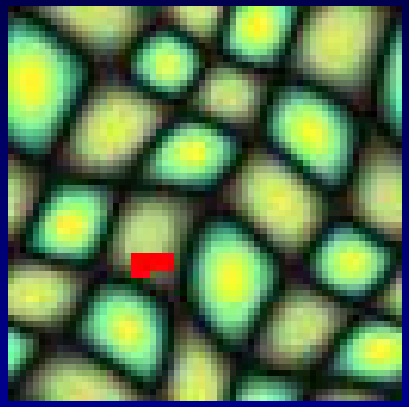

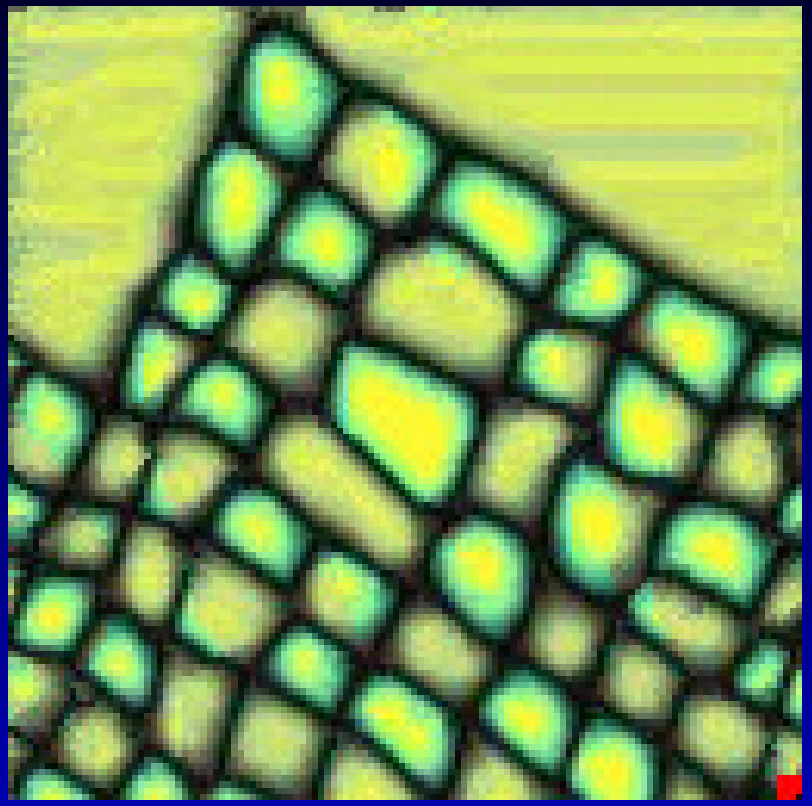

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Non-parametric Sampling (2)

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- Disadvantages :
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  - Not suitable for non-homogeneous textures
- Many improvements
  - Multiresolution synthesis (Wei 2000, ...)
  - Coherent match method (Ashikhmin 2001)
  - Image Analogies (Hertzmann 2001)
  - Patch-Based Sampling (Efros 2001, Liang 2001, Nealen 2003, Cohen 2003...)
  - ...

Our method

Return to the Question

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- Low frequency part:
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  $\Rightarrow$ Non-parametric Sampling
- To combine both methods :

  $\Rightarrow$ Frequency decomposition

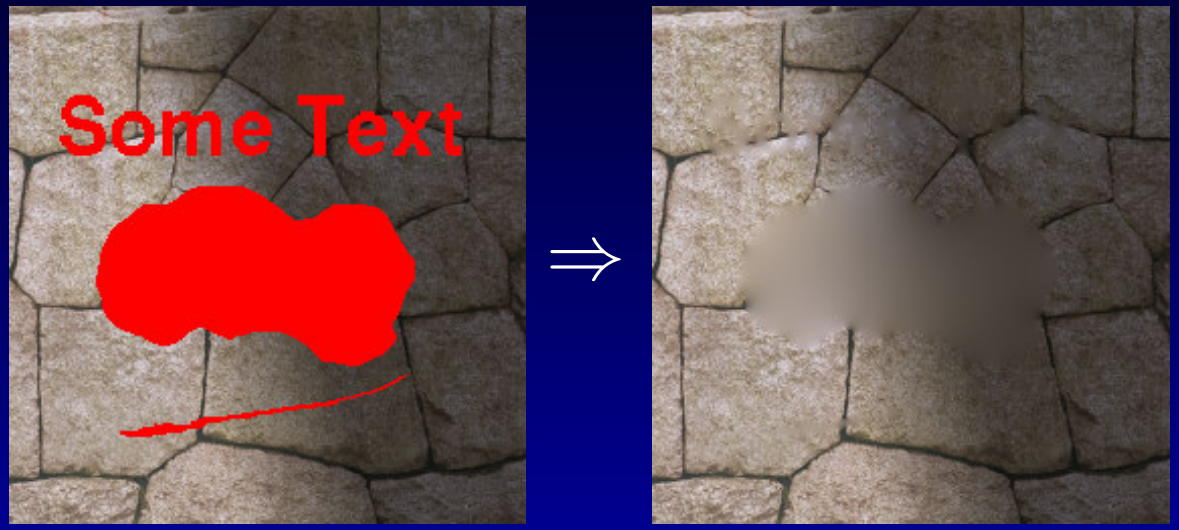
The Algorithm

Input Image

- Red part will be reconstructed

The Algorithm

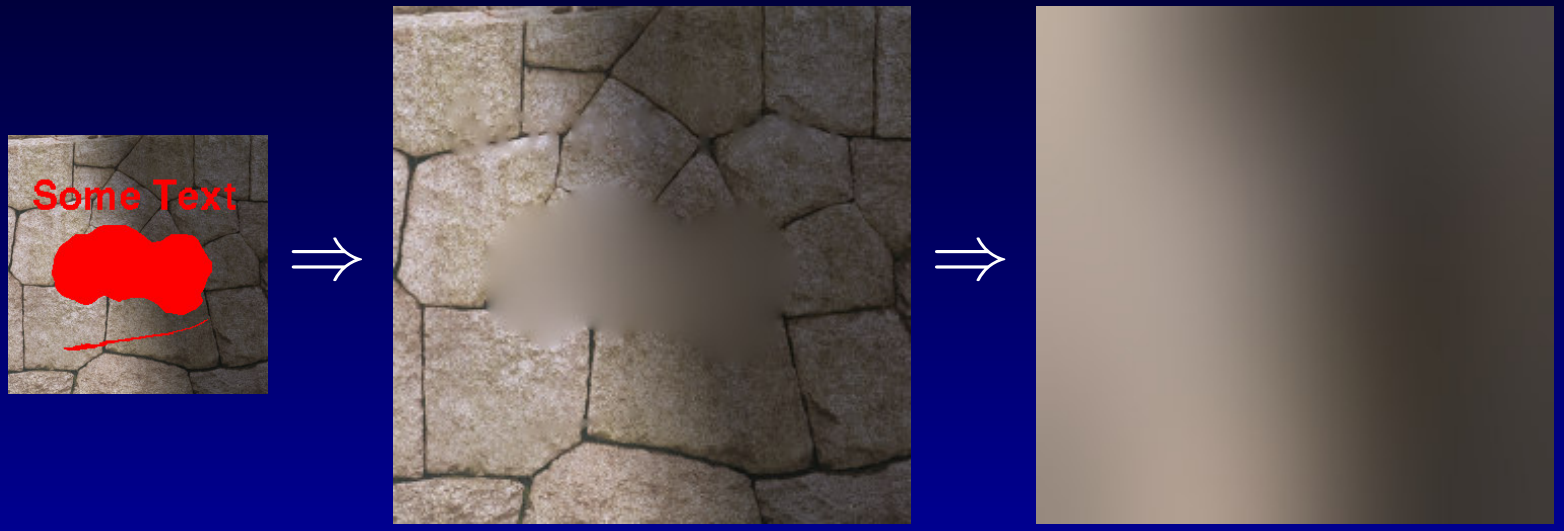
Fill in hole region with diffusion



- Scratch and Text region is well reconstructed
- Large area : Problematic

The Algorithm

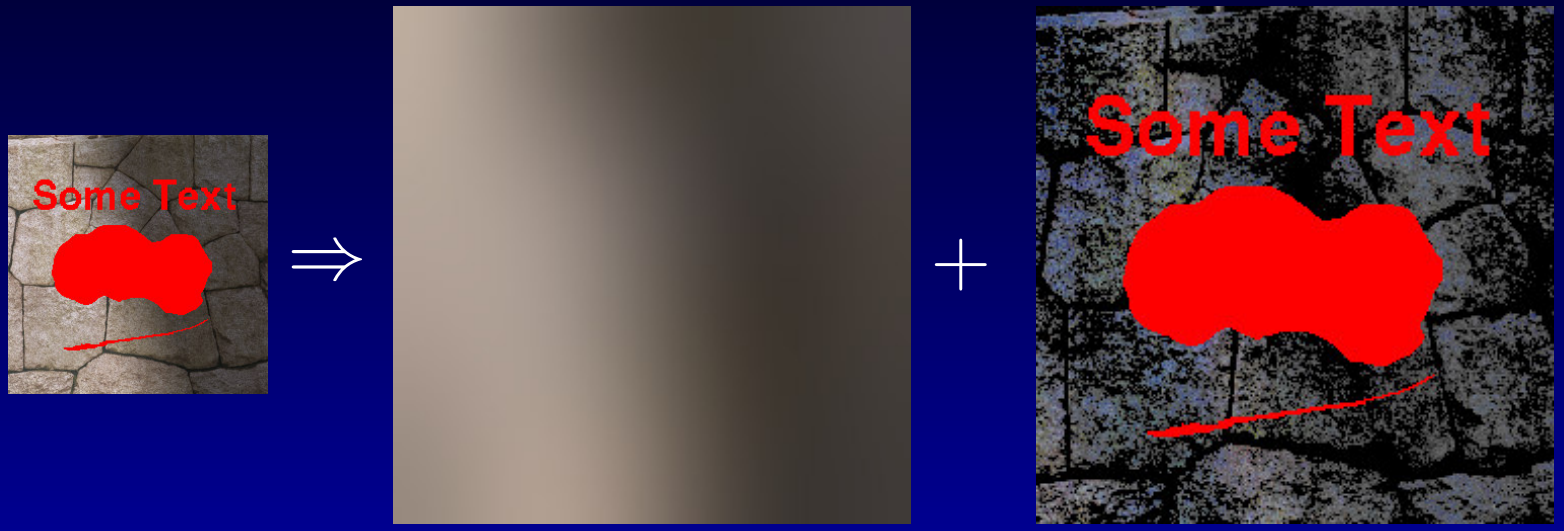
Frequency Decomposition



- Using FFT (DCT)

The Algorithm

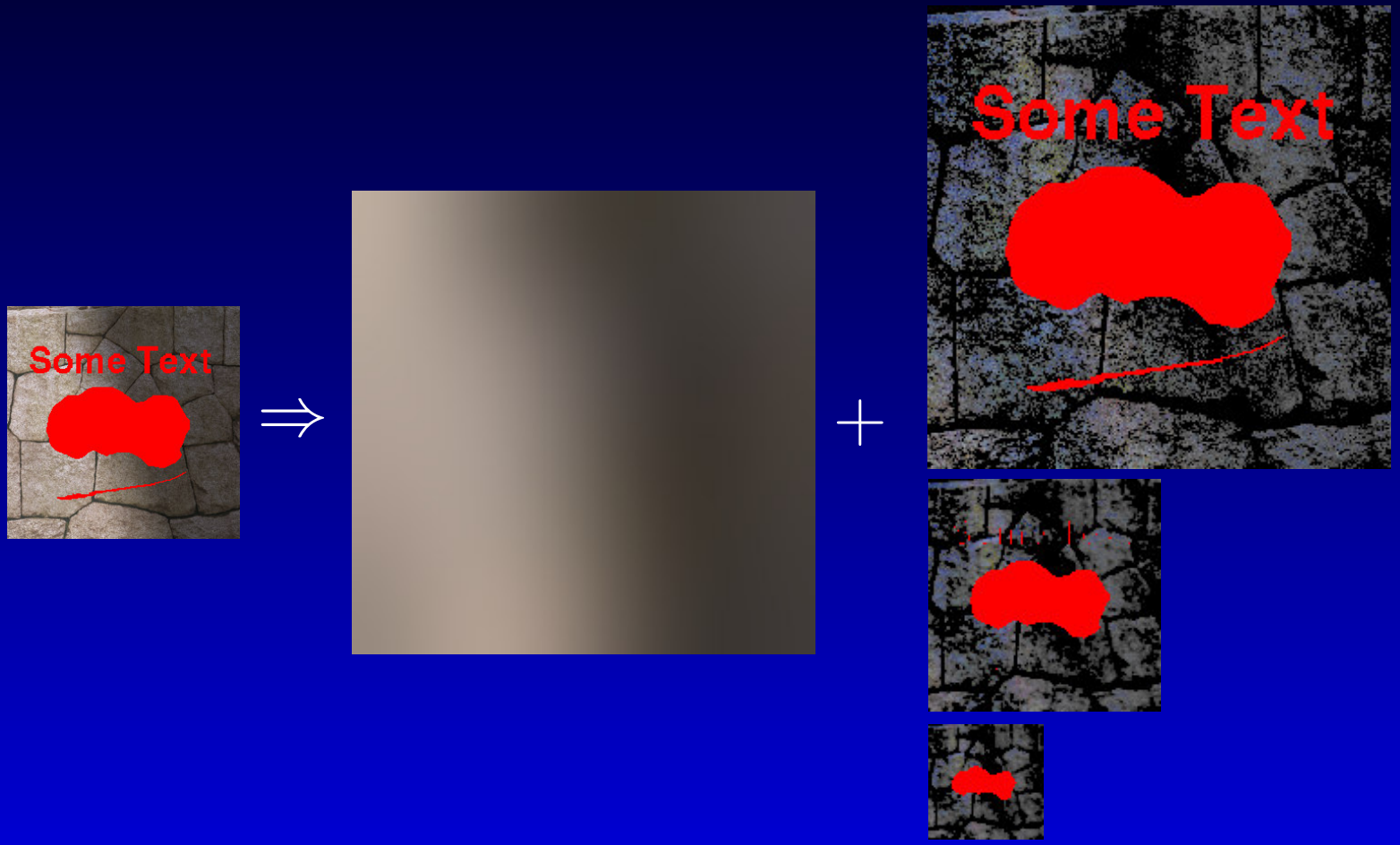
Extract High Frequency Part



- (High frequency image is gamma corrected)

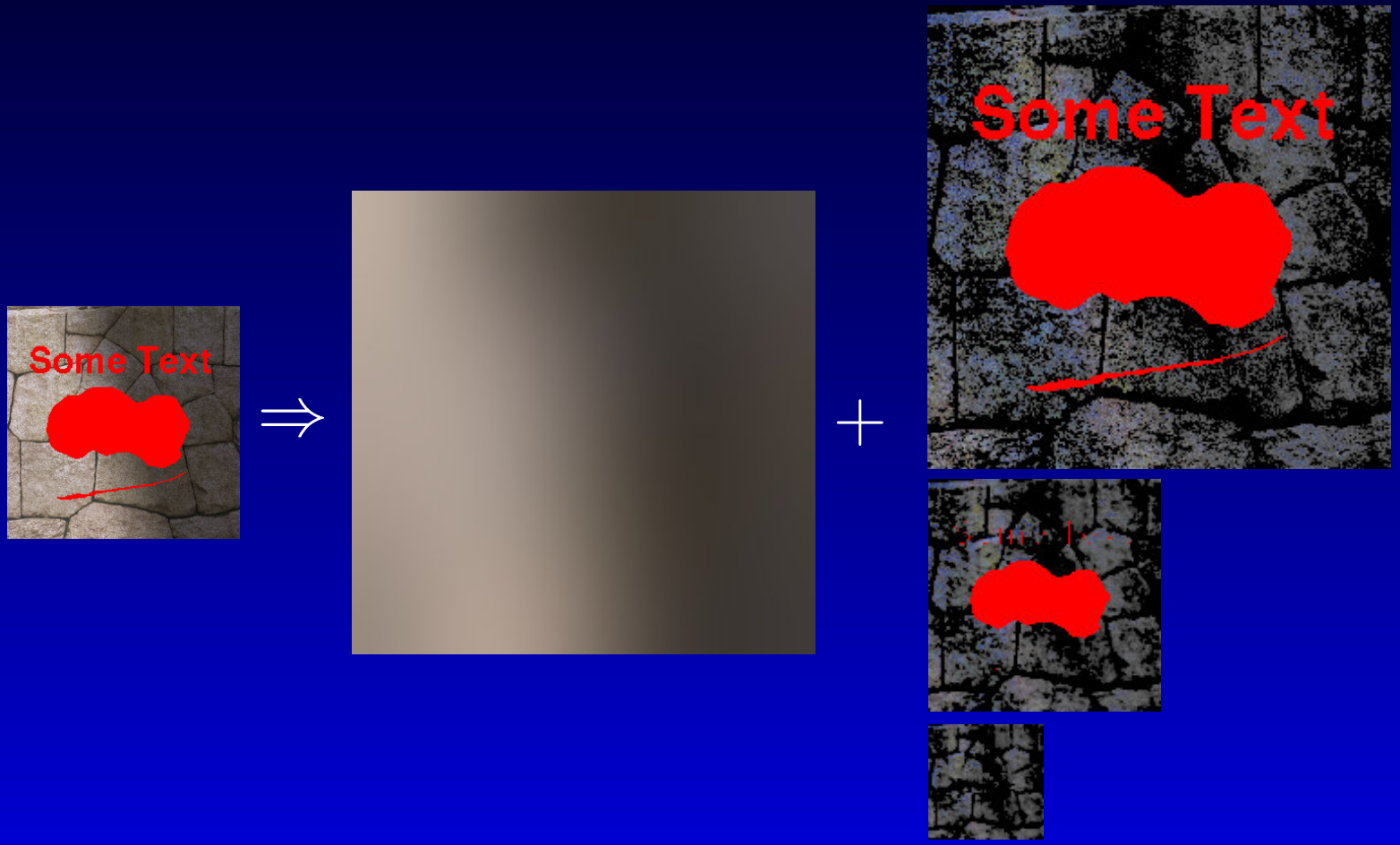
The Algorithm

Multiresolution Analysis



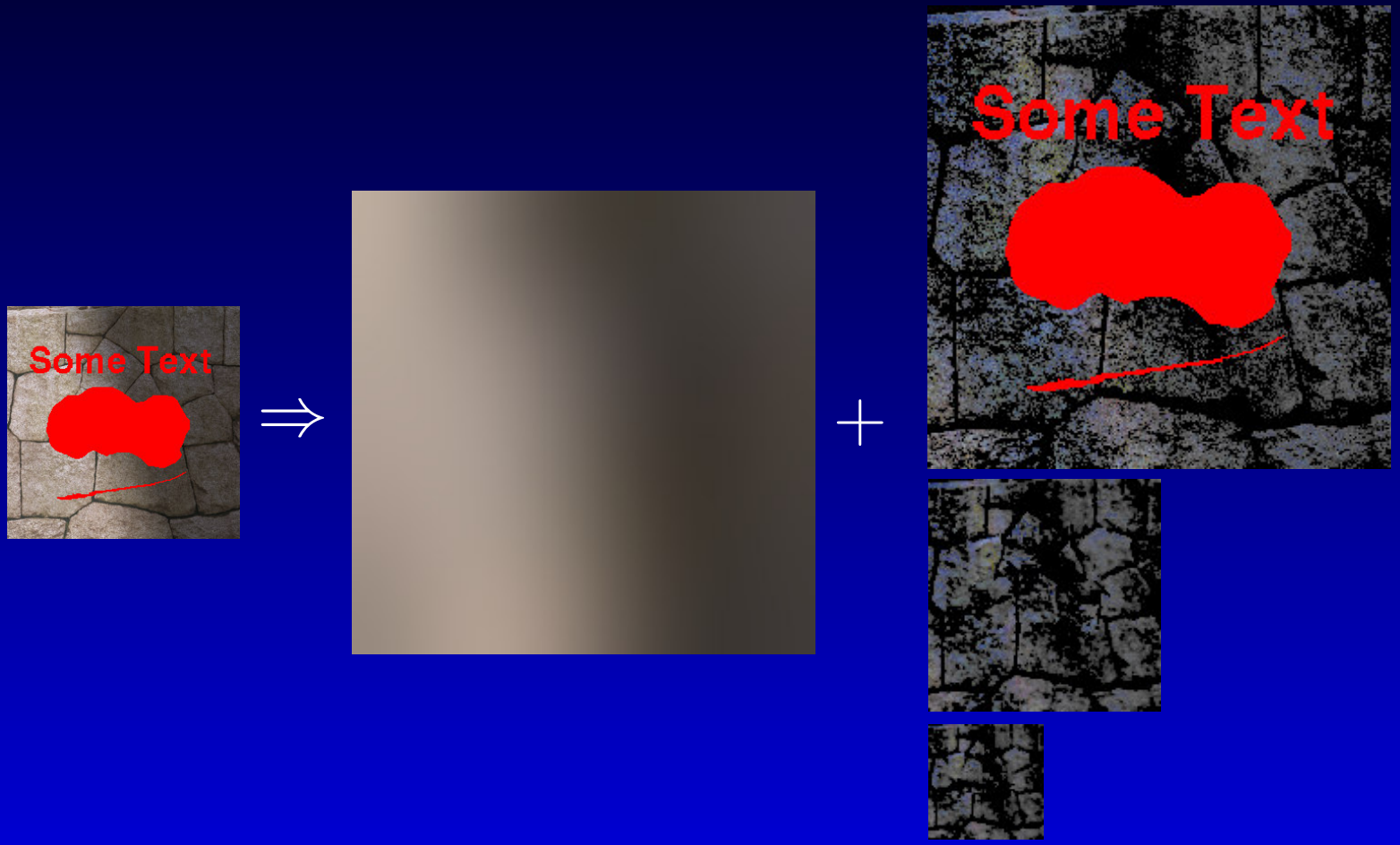
The Algorithm

Reconstruct by Non-Parametric Sampling (Level 2)



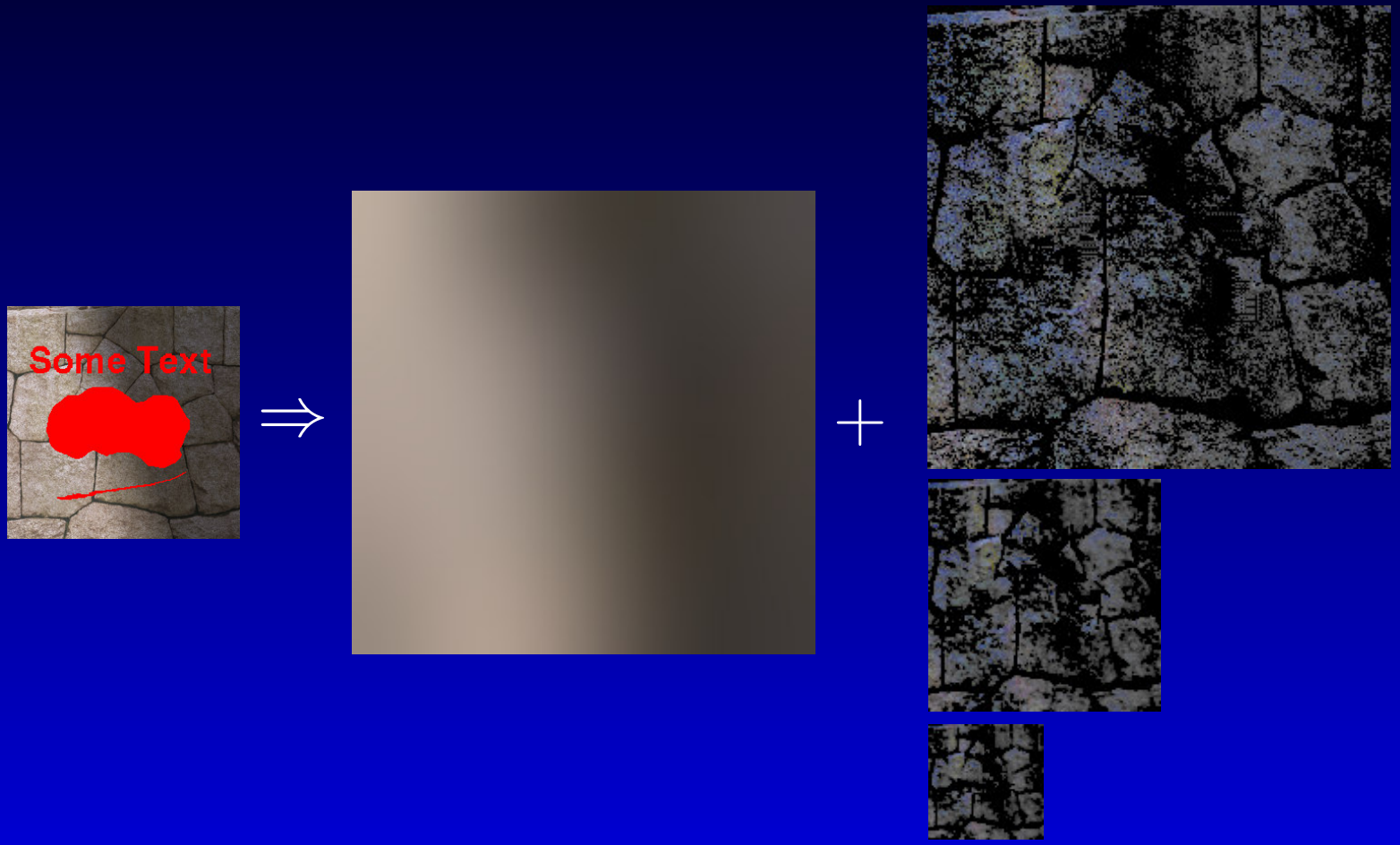
The Algorithm

Reconstruct by Non-Parametric Sampling (Level 1)



The Algorithm

Reconstruct by Non-Parametric Sampling (Level 0)

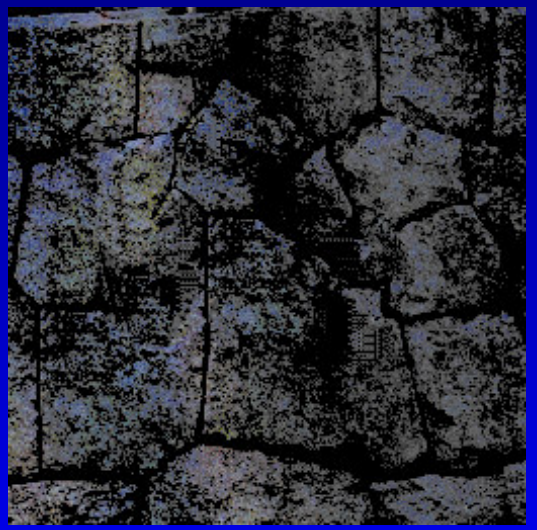


The Algorithm

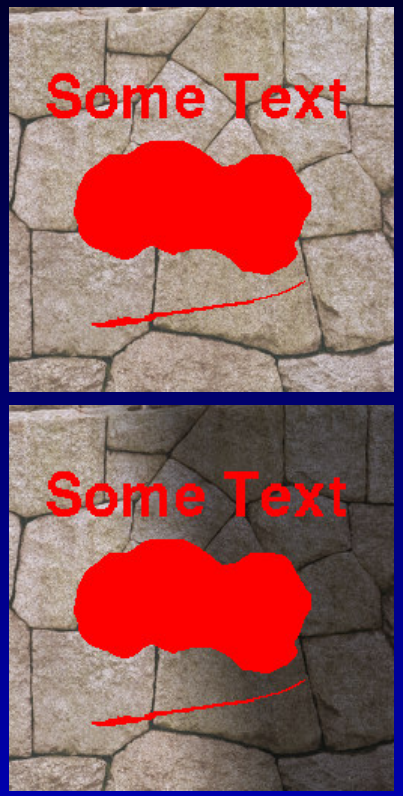
High Frequency part is reconstructed

The Algorithm

Combine them together

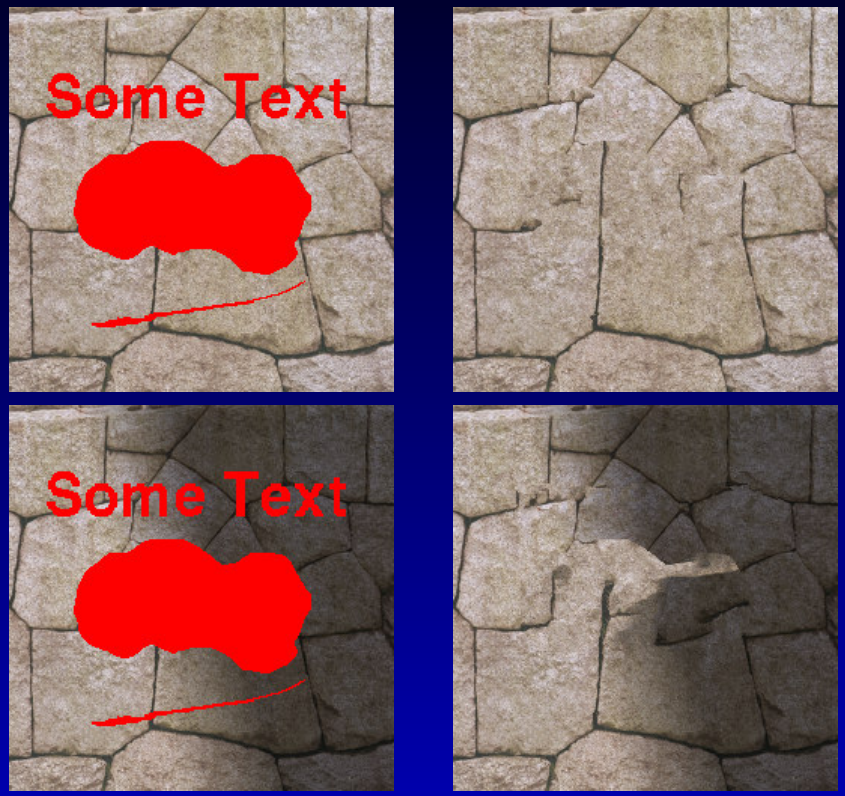


Comparison



input
texture

Comparison



input texture

non-parametric sampling (texture synthesis)

Comparison

input texture

non-parametric sampling (texture synthesis)

image inpainting

Comparison

input texture

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our method

Decomposition parameter (1)

- Question
  - What frequency is the low/high frequency?
  - How can we choose the frequency decomposition parameter?
- Frequency decomposition parameter : κ
  Upper bound for the low frequencies

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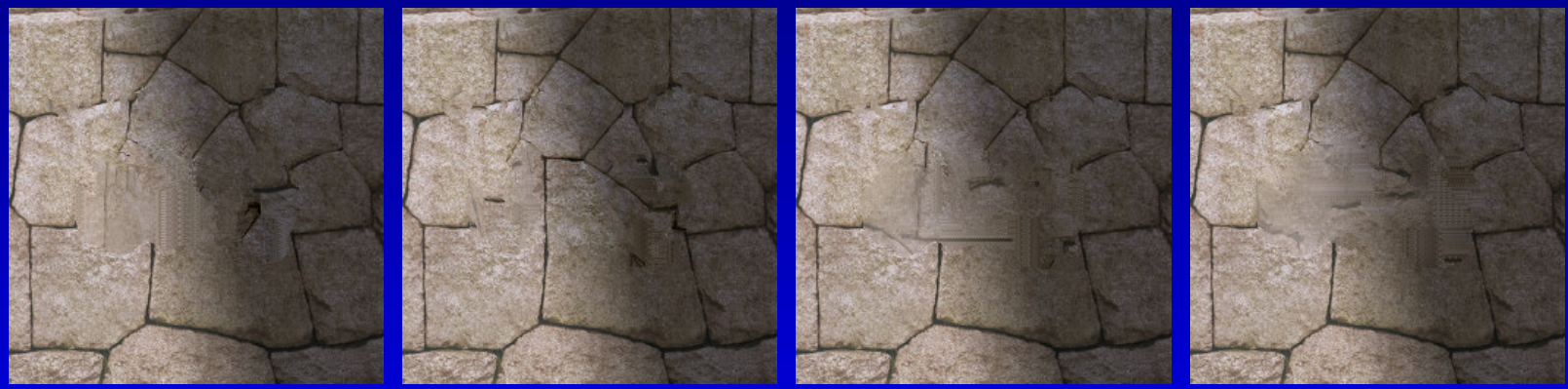

$\kappa = 2$ $\kappa = 4$ $\kappa = 8$ $\kappa = 16$

Decomposition parameter (2)

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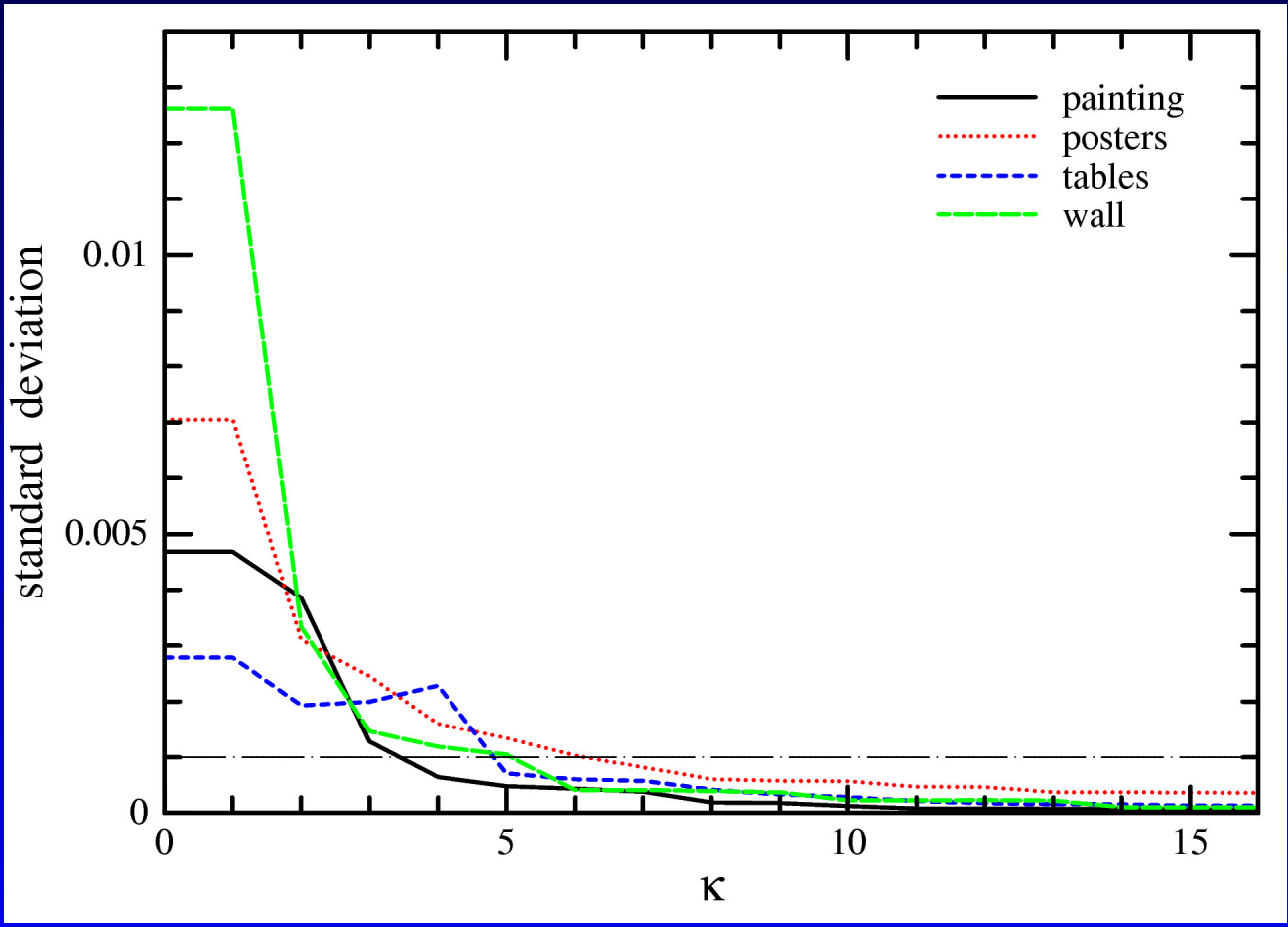
  1. If the low frequency part is sufficiently removed, the rest part is more like a texture
  2. Spatial homogeneity can be measured by autocorrelation
- Method
  - Calculate the autocorrelation matrices of each κ
  - Compute the SD (standard deviation) of the matrices
  - Experimentally, we choose κ at SD ≤ 0.001

Correlation between κ and SD

- Four example images (images will be shown up)
- SD is small when κ is large



Results : Painting

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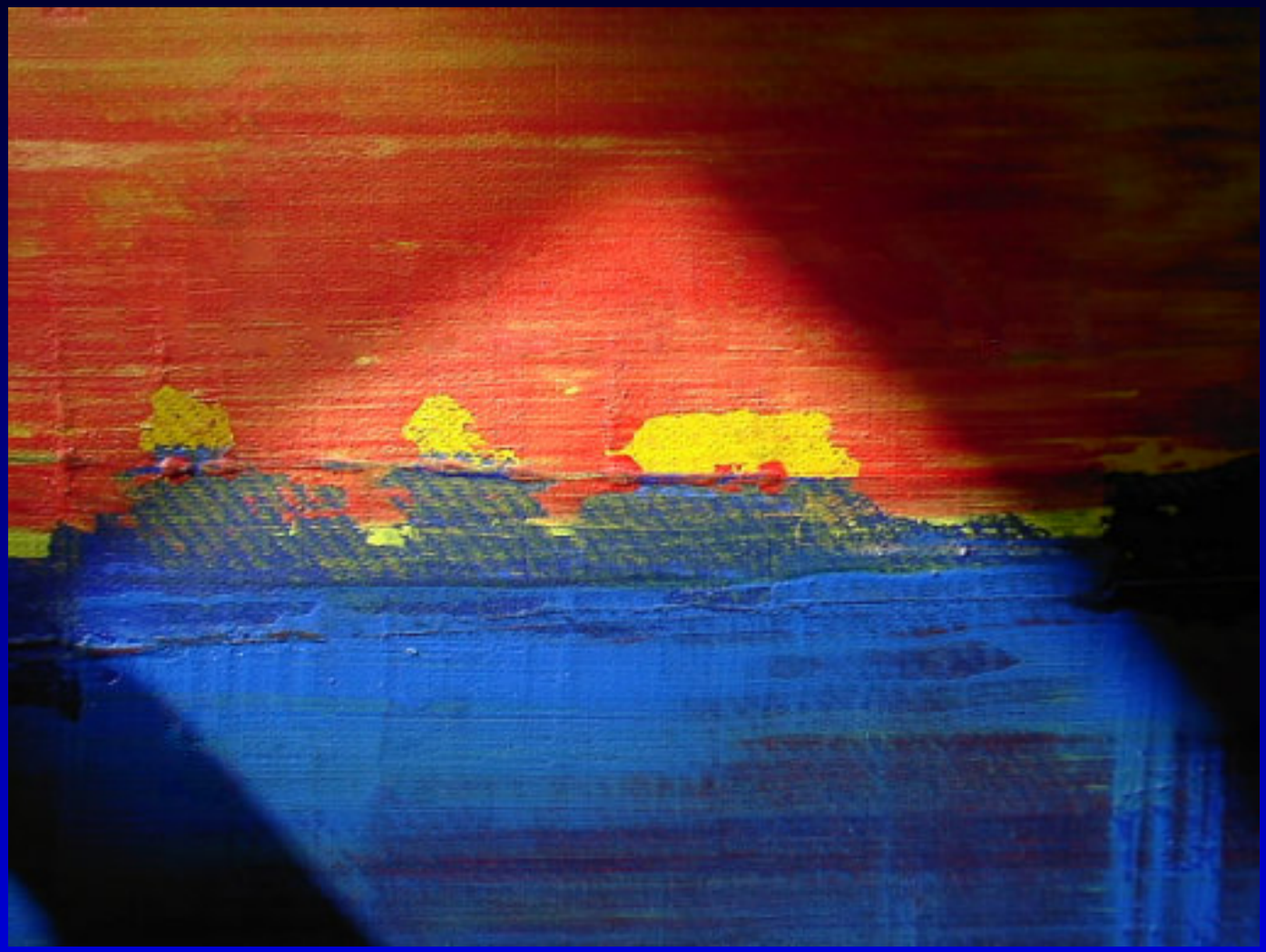

Results : Posters

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Results : Wall

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Results : Tables

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Results : Excursion 1

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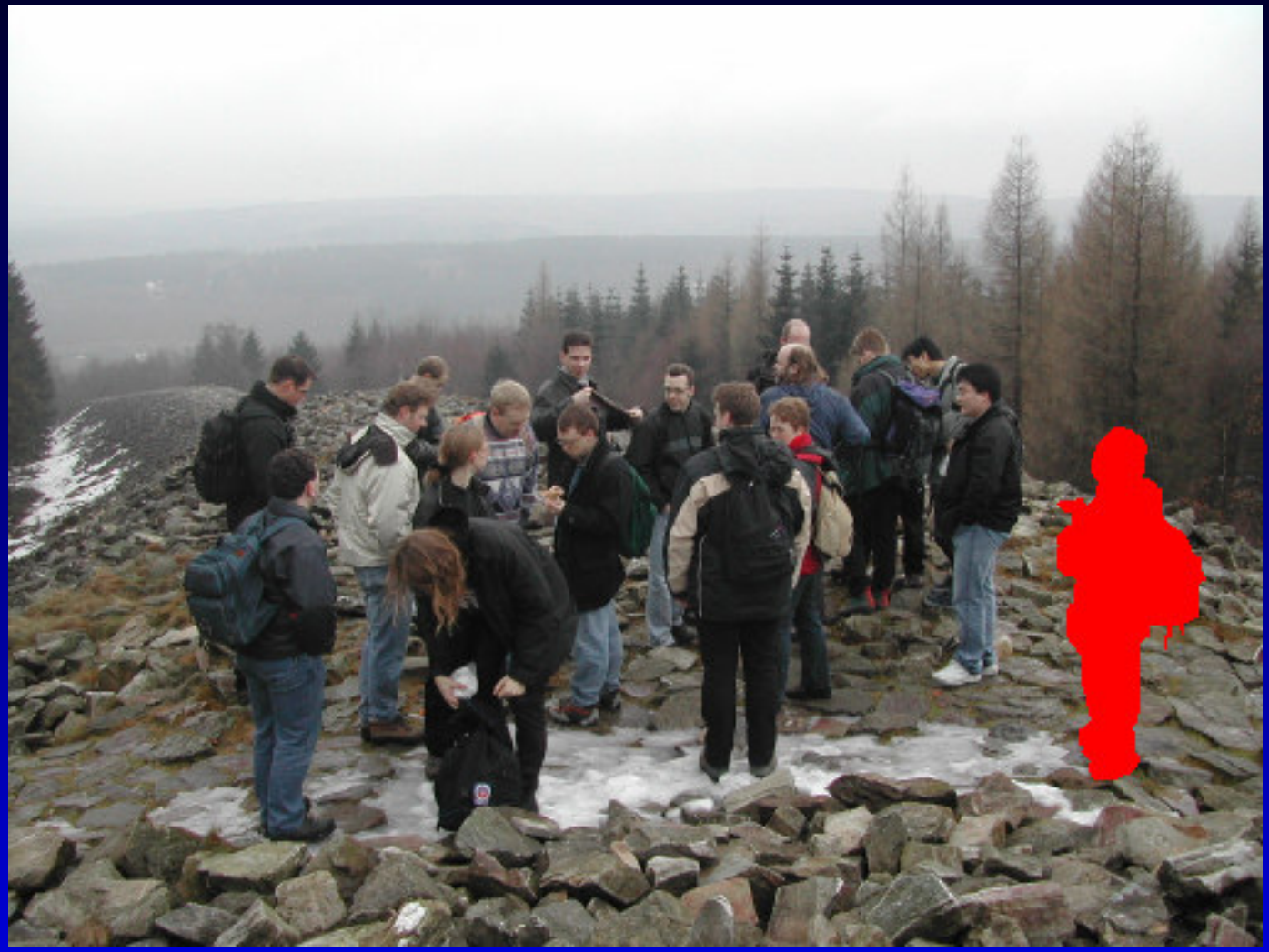
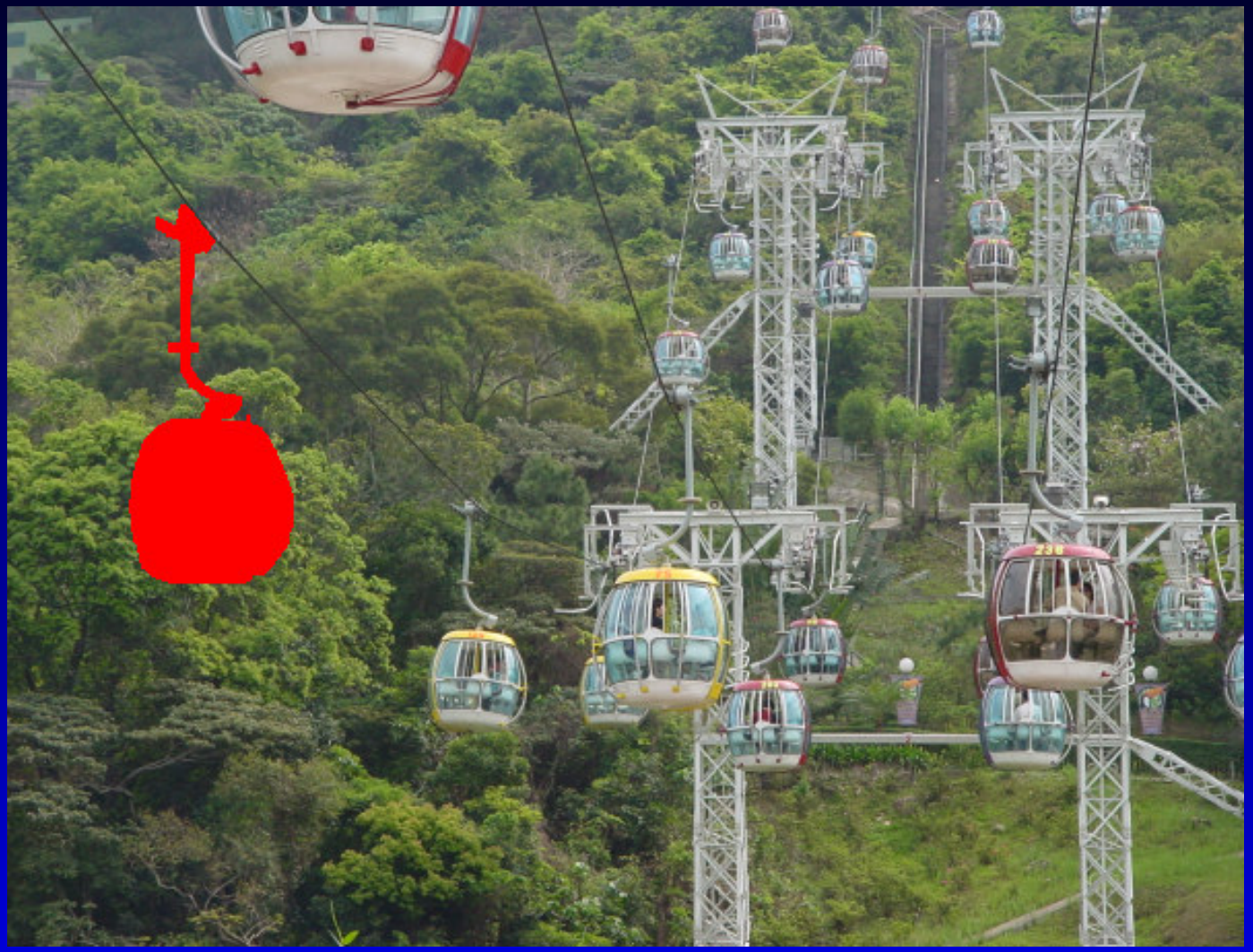


Results : Excursion 1

Results : Cablecar



Results : Cablecar

Results : Excursion 2

image

Results : Excursion 2

input

Results : Excursion 2

image inpainting

Results : Excursion 2

multiresolution texture synthesis

Results : Excursion 2

our method

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  $\longrightarrow$ Frequency decomposition for combining image inpainting and texture synthesis
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    - Image sequences

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    $\longrightarrow$ using image inpainting to suggest the transfer region
  - Expand to 3D
    - Image sequences
    - Fill in 3D holes

Acknowledgements

- Source of some images (textures) are from :
  - Li-Yi Wei's web page
    `http://graphics.stanford.edu/~liyiwei/`
  - David Heeger's web page
    `http://www.cns.nyu.edu/~david/`
  - VisTex database
    `http://www-white.media.mit.edu/vismod/imagery/VisionTexture/vistex.html`
  - Cablecar photo by Goshima, Kazuhiro

Thank you and Questions?