Image Restoration:
Digital Inpainting
What is Inpainting?

- Term “inpainting” originated from art restorers, who manually fills in parts of a painting that has cracked off over time
- In digital image processing, inpainting refers to the process of automatically restoring missing information in images and videos
Why inpainting?

- Remove physical deterioration
  - Cracks
  - Scratches
  - Dust

Source: Oliveira et al. 2001
Why inpainting?

- Recover lost blocks in transmission of images and videos

Source: Liu et al. 2007
Why inpainting?

- Remove unwanted image content
  - Power-lines
  - Birds
  - People
  - Text

Since 1699, when French explorers landed at the great bend of the Mississippi River and celebrated the first Mardi Gras in North America, New Orleans has brewed a fascinating melange of cultures. It was French, then Spanish, then French again, then sold to the United States. Through all these years, and even into the 1900s, others arrived from everywhere: Acadians (Cajuns), Africans, indige-

Source: Oliveira et al. 2001
Problem Formulation

- Fill in target region $\Omega$ using information from source region $\Theta$
Inpainting Algorithms

- Digital inpainting algorithms generally categorized into two main groups:
  - Diffusion-based methods
  - Exemplar-based methods
Diffusion-based Methods

- Inspired by the physical diffusion process, where molecules spread from areas of high concentration to areas of low concentration to fill a volume.
- For digital inpainting, information from source region is “diffused” into the target region to fill in missing information.
Diffusion-based Methods

- Diffusion in digital images is analogous to repeatedly smoothing (convolution)
- Intuitively, diffusion-based methods repeatedly smooth image content from the source region to the target region until the target region is filled
Simple Diffusion-based Algorithm

- Let $\Omega$ be the target region, $\Theta$ be the source region
  - Define boundary $\partial \Theta_1$ in target region $\Theta$
  - Convolve $\partial \Theta_1$ with isotropic smoothing kernel (e.g., Gaussian) for a number of iterations
  - Define new boundary $\partial \Theta_2$ in new smaller target region
  - Repeat process until the entire target region is filled in
Results

Source: Oliveira et al. 2001
Disadvantages

• Appearance of blurring
  – Very noticeable for large regions and structures
• Difficult to fill in large regions properly
  – Why?
    • Restricted to using local information
    • Many situations where local information does not characterize the missing information
Illustration of Exemplar-based Inpainting
Simple Exemplar-based Algorithm

- Let $\Omega$ be the target region, $\Theta$ be the source region
  - Define boundary $\partial \Theta_1$ in target region $\Theta$
  - Find patches with the best match for patches around $\partial \Theta_1$ as exemplars
- Similarity between patches can be determined using measures such as mean square error (MSE)
Simple Exemplar-based Algorithm (Cont'd)

- Fill patches around \( \partial \Theta_1 \) with the exemplars
- Define new boundary \( \partial \Theta_2 \) in new smaller target region
- Repeat process until the entire target region is filled in
Results

Source: Criminisi et al. 2004