SYDE 575: Introduction to Image Processing

Image Zooming:
Digital Image Super-resolution

Challenges in Digital Zooming

- Zooming methods discussed so far converts an image from a lower resolution to a higher resolution
- No new image information is introduced by the high resolution image
- Result: While the resolution is higher, the image appears to lack fine details and no better than the high resolution image
- Solution: Super-resolution

What is Super-resolution?

- Underlying goal: enhance image resolution as well as image detail
- Has gained popularity in various fields of image processing and computer vision:
  - Digital photography
  - Security surveillance
  - Medical imaging

Why Super-resolution?

- Resolution of imaging systems often limited by factors such as
  - Technical limitations
    - e.g., high resolution x-rays require high radiation dosage
  - Cost
    - e.g., high-end sensors are expensive to manufacture
- Super-resolution offers an inexpensive solution to such resolution limitations

How does it work?

- Idea
  - Suppose we take a series of images under different imaging conditions
    - If images are identical, no new information can be obtained
  - Each image has unique information
  - Using the unique information from all the images, it is possible to interpolate sub-pixel values with greater detail than zooming techniques

Problem Formulation

- A low resolution image can be modeled as a high resolution image that has been decimated by D

$$I_{LR} = DI_{HR}$$

- Given a series of n low resolution images, each captured under a different motion M

$$I_{LR,k} = \left(DM_k \right) I_{HR},\ 1 \le k \le n$$

Problem Formulation

- Problem can be expressed as an inverse problem, where the goal is to estimate the original high-resolution image from which the low-resolution images were created

$$\begin{bmatrix} I_{LR,1} \\ \vdots \\ I_{LR,n} \end{bmatrix} = \begin{bmatrix} DM_1 \\ \vdots \\ DM_n \end{bmatrix} I_{HR} \qquad Find\ \hat{I}_{HR}$$

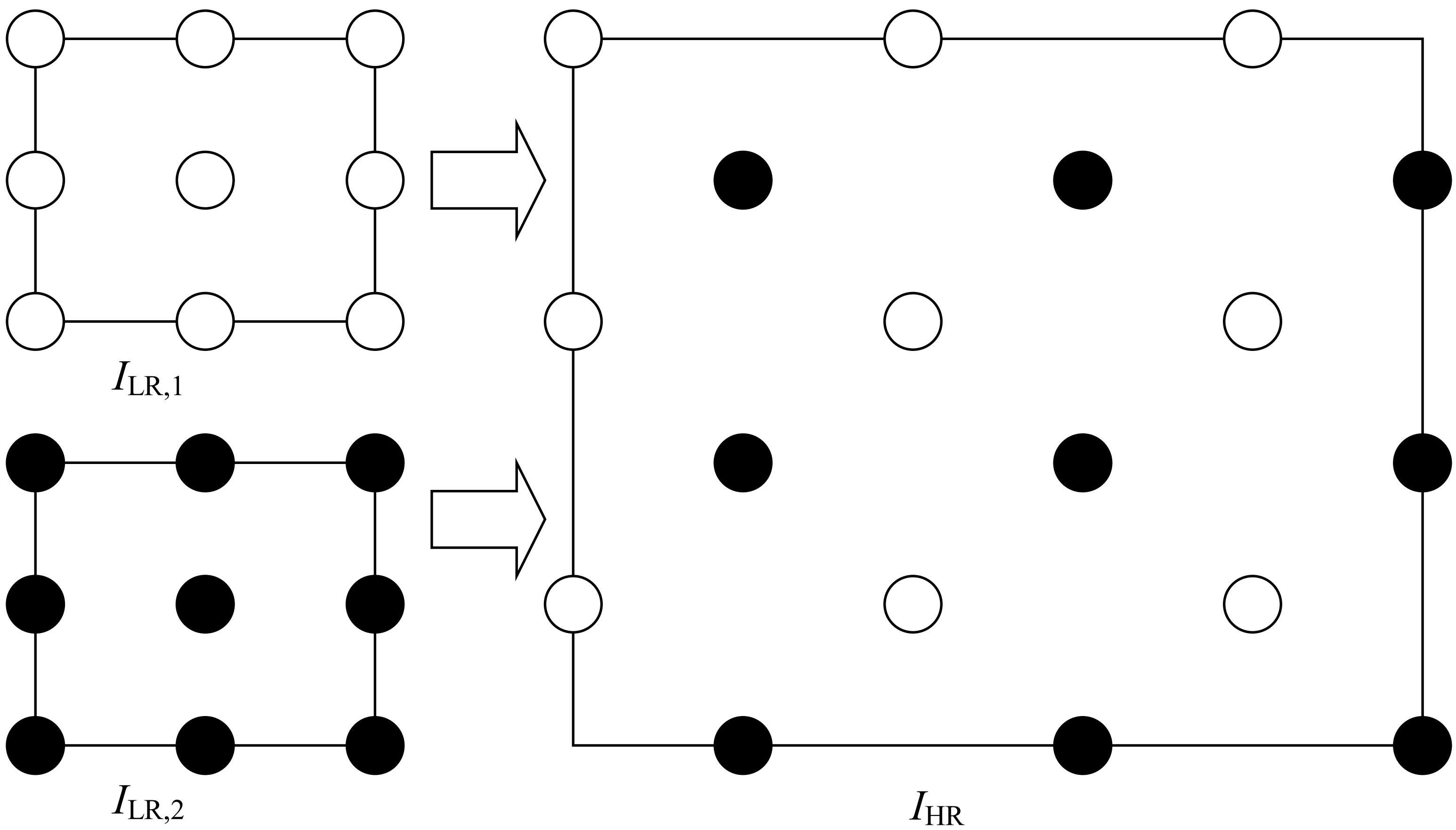
Simple Super-resolution Algorithm

- Select a reference low-resolution image (typically first on the sequence)
- Expand the low-resolution image into a lattice with the desired higher resolution
- Transform the pixels from the other low-resolution image onto the high resolution lattice
  - May result in an irregularly spaced lattice

Simple Super-resolution Algorithm

- For each sub-pixel location, interpolate the associated intensity value based on the neighboring pixels and their relative distances to the sub-pixel location
  - e.g., bilinear interpolation, bicubic interpolation, thin-plate spline interpolation, etc.

Visualization



Iterative Super-resolution Algorithm (Irani et al., 93)

- Expand reference image into a lattice with the desired higher resolution (used as initial guess of high resolution image)
- Use this initial guess to generate a set of simulated low resolution images
- Compare simulated low resolution images to real low resolution images to find error difference
- Use error difference to update and improve initial guess (minimizing squared error)

Results: Security Surveillance

- Super-resolution using 9 low resolution images

Results: Medical Imaging

- Super-resolution using 6 low dosage mammograms