Image Restoration and Super-Resolution

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Overview

- Image Restoration
- Different approaches for Image Restoration
- Image Super-Resolution (SR)
- Super-Resolution using motion as a cue
- Learning based Super-Resolution - Use of Wavelet Transform (WT) and Discrete Cosine Transform (DCT)
- Our recent Works on Restoration and Super-Resolution
Image Restoration

- Goal of image restoration is to improve the quality of the image from its degraded version.

- Different from image enhancement.

- Enhancements are heuristic procedures designed to manipulate an image and are image dependent. No strong mathematical reasoning exists.
Restoration techniques are based on modeling the degradation which takes place during image capture.

Degradation may be due to camera defocus blur, motion blur that may occur when there is relative motion between camera and the object, atmospheric turbulence, sensor noise, etc.
Restoration- to apply inverse process on the degradation to obtain the estimate of the original.

Contrast stretching is an enhancement technique while removal of blur by deconvolution is a restoration process.
Restoration applications:

- Medical imaging - X ray images noisy - better diagnosis
- Film industry - old film prints - scratches
- Law enforcement - license plates motion blurred (numbers not clear in the image)
- Remote sensing
The objective of restoration is to obtain an estimate of \( f(x,y) \) given some knowledge of the \( H \) and \( N \). This is an inverse problem.

\[
g(x, y) = f(x, y) * h(x, y) + n(x, y)
\]

\[
OR
\]

\[
G(u,v) = F(u,v)H(u,v) + N(u,v)
\]

Restoration model
 Restoration and blind deconvolution are different

**Restoration** – degradation is known- PSF (H) and noise statistics are known or assumed depending on application

**Blind deconvolution** – estimate both the original signal as well as the degradation function when partial knowledge on degradation is known.
Restoration and Super-Resolution - Comparison

- Restoration – The model do not consider the aliasing. The restored image is of same size as the degraded image.

- Super-resolution – Aliasing is taken care by suitably modeling the aliasing due to under sampling. The size of the super-resolved image is bigger than the degraded one. Difficult problem to solve.
Different Approaches: Restoration

- Inverse Filtering
- Weiner Filtering
- Constrained optimization
- Unconstrained approaches.
Original Image  Blurred and noisy image (degraded image)  Restored image using Weiner filter
Image Super-Resolution (SR)

- **Resolution**: Smallest measurable detail in a visual presentation. Tells about the fineness of detail that can be distinguished in an image.

- **Spatial Resolution**: spacing of pixels in an image measured in pixels per inch (ppi).

- **High Spatial Resolution**: Pixel density is high. (Larger number of pixels in an image.)
HR Applications: Medical Imaging, remote sensing, robot vision, industrial inspection, etc

Super-Resolution (SR): Obtain high resolution from several low resolution observations of the same scene. (minimizes aliasing and blurring).
Example on SR:

Deepu and Chaudhuri

Observations

Super-Resolved
Why SR?

1. Cost  
2. Shot noise

Conventional **Interpolation** Methods:
Nearest Neighbor or zero order hold
or pixel replica, Bilinear, Bicubic

**Disadvantage**:
Single image used.
Do not consider the aliasing or blurring.
Different approaches to Solve Super-resolution Problem

- Motion
- Zoom
- Blur
- Photometry
- Learning based techniques
Use of Motion Cue
Dipti and Chaudhuri

MPEG sequence
A key frame
Super-Resolved
The Idea!

- Scene
- Camera
- Video sequence

If there exist subpixel shifts between LR images, SR reconstruction is possible.
Learning based Super-Resolution
USE OF DISCRETE WAVELET TRANSFORM (DWT)
AND DISCRETE COSINE TRANSFORM (DCT)
Prakash Gajjar, PhD student
Problem Definition

- Given a low resolution image and a set of high resolution training images, learn the high frequencies from the training data set and obtain SR.
Approach

- Learn the wavelet coefficients at finer scales of the unknown high resolution image from high resolution training set.
An image and its Wavelet Transform (DB4)
Learning:
Results

Low resolution image

Bilinear interpolation

Super-resolved image
Learning using DCT

- **Objective**: Given a set consisting of pair of LR and HR images of a camera obtain high resolution image for an LR image captured using the same camera.

- **Motivation**: HR Video with a very low memory.
Sample training pairs of images
A 4x4 DCT block
DCT coefficients related to high frequency details in a block
DCT based Learning from LR-HR pairs:
Results

<table>
<thead>
<tr>
<th>Observation</th>
<th>Bicubic Interpolation</th>
<th>DCT based Super-resolved</th>
</tr>
</thead>
<tbody>
<tr>
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<td>MSE=0.003784</td>
<td>MSE=0.003245</td>
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Conclusions

- A learning based technique for super-resolution using a single low resolution image is described.

- Advantage: 1. No cue used 2. Single LR observation used.

- Learning represents the next challenging frontier for computer vision.
Our recent works in SR and Restoration

- Super-resolution in real time- Graph cuts optimization- Swati Sharma (M.tech student)
- Particle Swarm Optimization for SR (B.tech student)
- SR based on histograms of different filters as priors (B.Tech students).
- Learning based methods for restoration–Kishor (PhD student)
- Super-resolution of multi-spectral images in remote sensing (B.tech student)
THANK YOU