Lecture 20 – Course Review

Stage of DIP

This Course

Low level process	Mid level process	High level process
INPUT: Image **OUTPUT:** Image **EXAMPLE:** Enhancement Restoration Compression	**INPUT:** Image **OUTPUT:** Attributes **EXAMPLE:** Segmentation Representation Description	**INPUT:** Attributes **OUTPUT:** Understanding **EXAMPLE:** Image analysis Image understanding

There are no clear-cut boundaries from image processing to computer vision

Overview

- Image Fundamental
- Image Enhancement
- Image Restoration
- Image Segmentation
- Feature Extraction

Image fundamental

- **Image acquisition**
  - Sampling : spatial resolution
  - Quantization: intensity resolution
- **Pixels**
  - Neighbors of Pixel: N4(p), ND(p), N8(p)
  - Relationship between Pixels: adjacency, connectivity, regions, boundaries
  - Distance measures: Euclidean distance, City-block distance, Chessboard distance
- **Image Processing Tools**
  - Operations: array/vector/matrix, linear/nonlinear, set and logical, arithmetic, spatial, image transformation, probabilistic methods
  - Interpolation: a resampling method; intensity interpolation
  - Registration and Reconstruction (3D)
- **Color space**
  - Color fundamentals: primary and secondary colors, color gamut
  - Color models: RGB,CMY and CMYK, HSI
  - Pseudocolor image processing
  - Color transformation

Image Enhancement

- **Spatial domain: direct manipulation of pixels**
  - Intensity Transformation: Linear transformation, Log Transformation, Power-law (gamma) Transformation
  - Histogram:
    - ✓ Global histogram processing: Equalization, Matching, Exact Matching
    - ✓ Local histogram processing
    - ✓ Histogram Statistics for Image Enhancement
  - Spatial filtering : convolution and correlation
    - ✓ Smoothing: Box and Gaussian (Linear), Order-statistic filter (Nonlinear)
    - ✓ Sharpening: Laplacian, gradient, Unsharp Masking
- **Frequency domain : transform and inverse transform image**
  - 2D Image Transform: sampling theorem, DFT, spectrum and phase angle
  - Frequency Domain Filtering: Ideal, Butterworth, Gaussian Filter
    - ✓ Lowpass Filtering
    - ✓ Highpass Filtering : Laplacian, High Frequency Emphasis Filter, Homomorphic Filtering
    - ✓ Selective Filtering : Bandreject and Bandpass Filters, Notch Filter

Image Restoration

- **Model of Image Degradation Process**
- **Noise Reduction**
  - Noise Models: properties, Probability Density Function (PDF), estimation of noise parameter
  - Spatial Filtering
    - ✓ Mean Filters: arithmetic, geometric, harmonic, Contraharmonic
    - ✓ Order-statistic Filters: median, max and min, midpoint, alpha-trimmed mean filter
    - ✓ Adaptive Filters: adaptive local noise reduction filter, adaptive median filter
  - Frequency Domain Filtering
- **Image degradation and restoration**
  - Degradation Function
  - Restoration Filtering
    - ✓ Inverse Filtering
    - ✓ Wiener Filtering
    - ✓ Constrained Least Squares Filtering
    - ✓ Geometric Mean Filtering

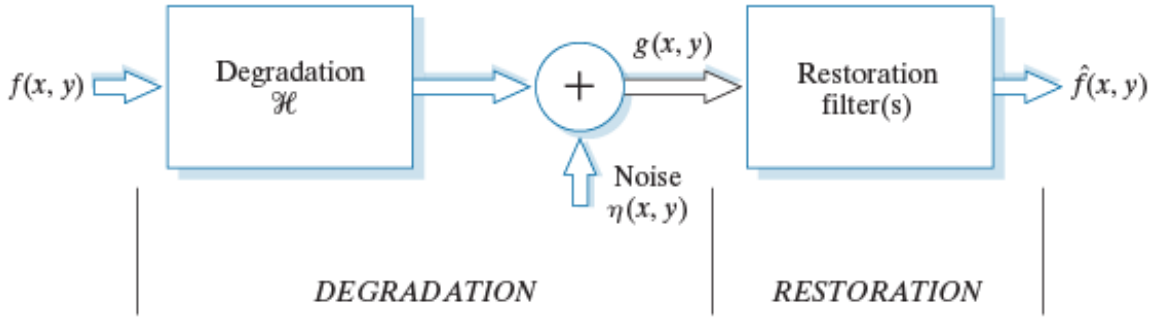


FIGURE 5.1
A model of the image degradation/ restoration process.

Image Segmentation

- **Traditional segmentation method**
  - Based on Discontinuity (Edge-based segmentation):
    - ✓ Point, line, edge detection: Sobel, LoG, Canny
    - ✓ Edge Linking: local or region processing, global (Hough transform)
  - Based on Similarity
    - ✓ Thresholding: Global (Otsu's method) and Variable
    - ✓ Region-based segmentation: Region Growing, Region Splitting and Merging, Region Clustering, Superpixels, Graph Cuts
- **Morphological Image Processing**
  - Morphological operation: erosion and dilation, opening and closing, HMT
  - Morphological algorithms: basic algorithms, morphological reconstruction
  - Morphological Watersheds
- **Active Contours**
  - Snakes: explicit (parametric) representation of segmentation curves
  - Level Sets: implicit representation of curves

Other contents

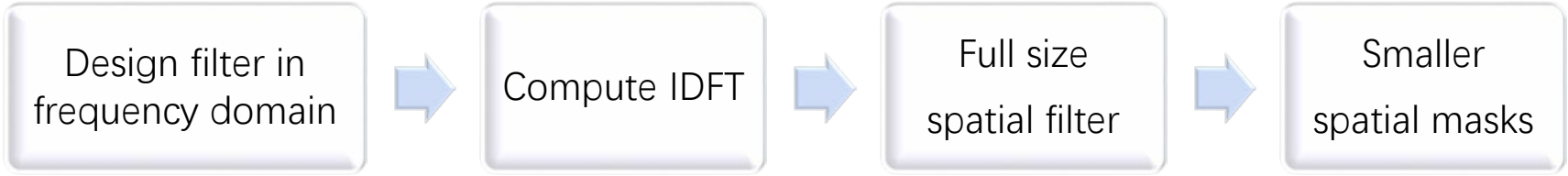
- **Other image transform**
  - Discrete Cosine Transform
  - Walsh Transform
  - Discrete Wavelet Transform
- **Image compression**
  - Basis: coding redundancy, spatial and temporal redundancy, irrelevant information
  - Measuring Image Information
  - Fidelity Criteria
  - Image Compression Model:
- **2D Image Reconstruction**
  - Reconstruction modalities
  - Reconstruction from projection: Radon transform, Filtered back projection
  - Reconstruction from reflection

Spatial *vs* Frequency

- **Spatial Domain**
  - Refer to Image plane
  - Intensity and Location
  - Direct manipulation of pixels (pixel or neighborhood processing)
  - Computation efficient
- **Transform / Frequency Domain**
  - Transform and inverse transform
  - Spectrum and Phase
  - Manipulation of frequency components
  - Mostly zero-phase-shift filtering

Filtering

➢ Filtering in Spatial *vs* Frequency domain



➢ Linear *vs* Nonlinear

- Linear spatial filter corresponds to spectral filter in frequency domain;
- Nonlinear spatial filter cannot be accomplished in frequency domain;

➢ Enhancement *vs* Restoration

- Smoothing, Sharpening, denoising (Spatial and Spectral)
- Restoration from degeneration model (Spectral)

Intensity *vs* Location

- **Intensity (Frequency spectrum)**
  - Enhancement
  - Restoration
  - Edge detection, Thresholding, Region-based processing
- **Location**
  - Morphological operation & Morphological algorithms
  - Active contours
  - Feature extraction

Image Properties

- Histogram: $h(r_k) = n_k \quad \& \quad p(r_k) = \frac{n_k}{MN}$

- Average Intensity （平均灰度）and Intensity Variance（灰度方差）

$$m = \sum_{i=0}^{L-1} r_i p(r_i) = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) \qquad \sigma^2 = \sum_{i=0}^{L-1} (r_i - m)^2 p(r_i) = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} [f(x,y) - m]^2$$

- SNR (Signal-to-noise ratio) and Root Mean Square Error (均方根误差) :

$$\text{SNR} = \frac{\sum_{(x,y)} \hat{f}^2(x,y)}{\sum_{(x,y)} \left[g(x,y) - \hat{f}(x,y) \right]^2} \qquad e_{\text{rms}} = \left\{ \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y-0}^{N-1} \left[\hat{f}(x,y) - f(x,y) \right]^2 \right\}^{1/2}$$

- Fourier Spectrum

$$F(u,v) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) e^{-j2\pi(\frac{ux}{M} + \frac{vy}{N})} \qquad f(x,y) = \frac{1}{MN} \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} F(u,v) e^{j2\pi(\frac{ux}{M} + \frac{vy}{N})}$$