Scope of ENEE631

- First graduate course on image/video processing
- **Prerequisites:** ENEE620 and 624, or by permission
  - Not assume you have much exposure on image processing at undergraduate level
  - Random processes and DSP are required background
- **Emphasis on fundamental concepts**
  - Provide theoretical foundations on multi-dimensional signal processing built upon pre-requisites
  - Coupled with assignments and projects for hands-on experience and reinforcement of the concepts
  - Follow-up courses
    - image analysis, computer vision, pattern recognition
    - multimedia communications and security

Textbooks

- **Primary**

- **References**

- **Other references**
  - Will be announced in lectures
A picture is worth 1000 words.

A video is worth 1000 sentences?

- Rich info. from visual data
- Examples of images around us
  - natural photographic images; artistic and engineering drawings
  - scientific images (satellite, medical, etc.)
- "Motion pictures" => video
  - movie, TV program; family video; surveillance and highway/ferry camera

Why Do We Process Images?

- Enhancement and restoration
  - remove artifacts and scratches from an old photo/movie
  - improve contrast and correct blurred images
- Transmission and storage
  - images from oversea via Internet, or from a remote planet
- Information analysis and automated recognition
  - providing "human vision" to machines
- Security and rights protection
  - encryption and watermarking

Why Digital?

- "Exactness"
  - Perfect reproduction without degradation
  - Perfect duplication of processing result
- Convenient & powerful computer-aided processing
  - Can perform rather sophisticated processing through hardware or software
  - Even kindergartners can do it!
- Easy storage and transmission
  - 1 CD can store hundreds of family photos!
  - Paperless transmission of high quality photos through network within seconds

List of Image and Video Processing Examples

- Compression
- Manipulation and Restoration
  - Restoration of blurred and damaged images
  - Noise removal and reduction
  - Morphing
- Applications
  - Visual mosaicing and virtual views
  - Face detection
  - Visible and invisible watermarking
  - Error concealment and resilience in video transmission
**Compression**

- Color image of 600x800 pixels
  - Without compression
    - 600*800 * 24 bits/pixel
    - = 11.52K bits = 1.44M bytes
  - After JPEG compression (popularly used on web)
    - only 89K bytes
    - compression ratio ~ 16:1

- Movie
  - 720x480 per frame, 30 frames/sec, 24 bits/pixel
  - Raw video ~ 243M bits/sec
  - DVD ~ about 5M bits/sec
  - Compression ratio ~ 48:1

**Denoising**

From X.Li [http://www.ee.princeton.edu/~lixin/denoising.htm](http://www.ee.princeton.edu/~lixin/denoising.htm)

**Deblurring**

Blurred & noisy image
Restored image


**Morphing**

Princeton CS426 face morphing examples
**Visual Mosaicing**
- Stitch photos together without thread or scotch tape

**Face Detection**
- Face detection in '98 @ CMU CS, http://www.cs.cmu.edu/afs/cs/Web/People/har/faces.html

**Visible Digital Watermarks**
- From IBM Watson web page "Vatican Digital Library"

**Invisible Watermark**
- 1st & 30th Mpeg4.5Mbps frame of original, marked, and their luminance difference human visual model for imperceptibility: protect smooth areas and sharp edges
**Data Hiding for Annotating Binary Line Drawings**

- original
- marked w/ "01/01/2000"
- pixel-wise difference

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**Error Concealment**

- (a) original lenna image
- (b) corrupted lenna image
- (c) concealed lenna image

25% blocks in a checkerboard pattern are corrupted
Corrupted blocks are concealed via edge-directed interpolation

Examples were generated using the source codes provided by W. Zeng.

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**What is An Image?**

- **Grayscale image**
  - A grayscale image is a function $I(x,y)$ of the two spatial coordinates of the image plane.
  - $I(x,y)$ is the intensity of the image at the point $(x,y)$ on the image plane.
  - $I(x,y)$ takes non-negative values
  - Assume the image is bounded by a rectangle $[a,b] \times [c,d]$.

- **Color image**
  - Can be represented by three functions, $R(x,y)$ for red, $G(x,y)$ for green, and $B(x,y)$ for blue.

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**Sampling and Quantization**

- **Computer handles “digital” data.**
- **Sampling**
  - Sample the value of the image at the nodes of a regular grid on the image plane.
  - A pixel (picture element) at $(i,j)$ is the image intensity value at grid point indexed by the integer coordinate $(i,j)$.
- **Quantization**
  - Is a process of transforming a real valued sampled image to one taking only a finite number of distinct values.
  - Each sampled value in a 256-level grayscale image is represented by 8 bits.
Examples of Sampling

- 256x256
- 64x64
- 16x16

Examples of Quantization

- 8 bits / pixel
- 4 bits / pixel
- 2 bits / pixel