

#### Compression

- Reduce amount of data used to represent an image/video
  - > Bit rate and quality requirements
- Necessary to facilitate transmission and storage
- Required quality is application dependent
   Medical vs. entertainment
- Data is "information"
  - > Bits per second (bps), bits per pixel (bpp)

#### Compression is *Necessary*

- Example of a normal TV picture over a telephone network<sup>1</sup>:
  - ➤ Capacity of network: 56, 000 bps
  - > Signal:
    - Image is 288 x 352
    - RGB color, 8 bits each channel
    - 30 frames per second
    - Data need: 288 x 352 x 8 x 3 x 30 = 72, 990, 720
      - 1289 times greater than capacity!
- Current networks are faster, but videos are larger
- 1. From: "Image and Video Compression" by Shi and Sun

#### Lossy vs. Lossless Compression

- Lossless Compression
  - > No information is lost
  - > Original image/video can be completely restored
- Lossy Compression
  - Some information is lost
  - > Reduction in "quality" of image/video
  - > Generally higher compression rates

#### Reason for hope

- Not all the data is required for a believable image
  - > There is redundancy

#### **Statistical Redundancy**

#### Interpixel Redundancy

- > Groups of pixels are not independent
- Related in space and time
- Spatial Redundancy
  - For most images, consecutive rows (or columns) will be highly correlated
  - Same for rows slightly further a part, but this decreases as the separation gets larger
  - → Can predict pixel intensity from neighbor

## Statistical Redundancy

- Temporal Redundancy (Interframe Redundancy)
  - > Pixels do not change much from frame to frame in a sequence
  - Observation from videophone-like signal:
     Less than 10% of pixels change by more than 1% from frame to frame
  - $\rightarrow$  Can predict pixel intensity from previous frame

#### **Statistical Redundancy**

#### Coding Redundancy

> Some values will occur more frequently in an image than others

e.g. Some colors are rare

- > Use less bits for the common colors and more for the uncommon ones
   Reduces the total number of bits
  - e.g. Huffman codes
- > Better coding schemes can more efficiently represent the data
- > Compare index color and RGB for a three color image

## **Psychovisual Redundancy**

- Image must read correctly to the human visual system (HVS)
  - > Complicated and nonlinear
  - > Tune to what people perceive
  - > Some differences are much more important than others

## Masking

• How sensitive the eye is to stimulus depends on the presence of another stimulus

## **Psychovisual Redundancy**

#### Luminance Masking

- > If background is bright, larger difference in intensity is needed to distinguish an object from the background
- > Suggests that noise will be more visible in a dark area than a light one
- > Nonuniform quantization can be more effective

## **Psychovisual Redundancy**

#### Texture Masking

- Discrimination threshold increases with picture detail
- > i.e. Errors will be more noticeable in uniform/smooth areas of the image

#### **Psychovisual Redundancy**

#### Frequency Masking

- > Human eye acts like a low-pass filter
- Less sensitive to high frequency noise

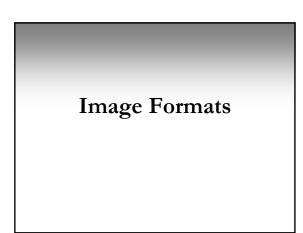
#### Temporal Masking

- > It takes time for the visual system to adjust after a rapid change in the image
  - Lower sensitivity during this time

#### **Psychovisual Redundancy**

#### Color Masking

- > People are most sensitive to green, then red and last blue
  - Can allocate data (bits) based on this
- > Luminance (intensity) and chrominance (hue and saturation) can be a better representation than RGB
  - Can work in luminance space without distorting color (e.g. bring out shadow details with histogram equalization)
- People are more sensitive to luminance than chrominance
  - Use more compression for chrominance than luminance



## **Common Image Formats**

- JPEG (jpg)
- PNG
- GIF
- TIFF
- Bitmap

## JPEG (.jpg)

#### Became an international standard in 1992

#### Different modes

#### > Lossy

- Uses Discrete Cosine Transform (DCT)-based coding
  Beyond the scope of this course
  - Image is divided into 8x8 blocks, DCT run on each block
  - Coefficients of DCT are stored with image

#### > Lossless

- Based on predictive coding (also beyond scope)
- Three neighboring pixels are used to predict current pixel
- Huffman or arithmetic coding is used to store prediction difference

# JPEG Different modes

#### > Hierarchical

- Image is spatially down sampled into a pyramid of
- progressively lower resolution images e.g. an 4x4 can be sampled to a 2x2 can be sampled to 1 pixel
- Can transmit progressively, lower resolution first and then add higher resolution detail
- Can use either a lossy or lossless coding scheme

## JPEG 2000 (.jp2, .jpx)

- Uses wavelet transform instead of DCT
- Provides excellent coding efficiency and good quality
- Wavelet transform also used in MPEG-4

## More on (lossy) JPEG

- Can control amount of compression
   > Tradeoff between quality and image size
- Every time you save an image, it will be recompressed and there will be a loss of quality
  - > Do not repeatedly edit and save lossy jpeg files
- 8-bit gray scale images
- 24-bit color images (8 bit each for RGB)

#### TIFF

- Lossless (in practice)
- Large file sizes
- 1 to 48 bit color

#### GIF

- Old format, developed by Compuserve
- 8-bit indexed color
  - > Table of 256 colors (8 bits)
  - Each pixel stores a table index
  - > All the colors that can be displayed in the image
  - Image can only contain 256 colors
    - 24 bit color gives 16 million colors
    - Huge reduction in color space
  - > Bad for photographs, may work for images with limited colors
  - > Lossless for those 256 colors

#### **PNG**

- Designed as open-source successor to GIF
- 8, 24 or 48-bit color
- Lossless
  - > Image files can be large
  - > No loss of quality
  - > Good format for working with images
- Compression based on patterns in image
- Does well with large, uniformly colored areas

#### **Read More**

 Image and Video Compression for Multimedia Engineering: Fundamentals, Algorithms, and <u>Standards</u>, Yun Q. Shi and Huifang Sun, CRC Press, 2008

## Analog vs. Digital Transmission

## **Transmission of Signals**

- Goal of analog and digital transmission is different
- Analog signals:
  - > Goal is to exactly reconstruct the original signal
  - > Errors lead to degradation
  - Diagram on board

## **Transmission of Signals**

- Digital signals:
  - > Goal is to reconstruct the pattern of 0's and 1's encoded in signals
  - Signal may be noisy, but no loss in quality as long as the 0's and one's can be detected
  - > Checksums to verify transmission
  - > Diagram on board
  - With digital, it is possible to make an *exact* copyNot true with analog