Digital Images & Sound

Representing Digital Images

Digital images are composed of PIXELS (or picture elements)

- a natural image is typically represented by a continuous or analog signal (such as a photograph, video frame, etc.)

Representing Digital Images

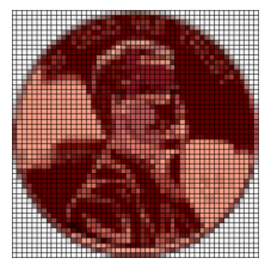
Digital images are composed of PIXELS (or picture elements)

- digitizing samples the natural image into discrete components

Representing Digital Images

Digital images are composed of PIXELS (or picture elements)

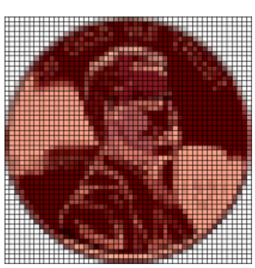
- each discrete sample is averaged to represent a uniform value for that area in the image



Representing Digital Images

Digital images are composed of PIXELS (or picture elements)

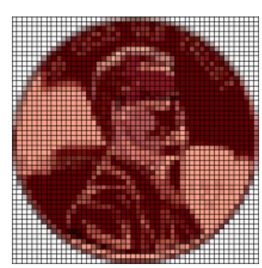
- PICTURE RESOLUTION is the number of pixels or samples used to represent the image



Representing Digital Images

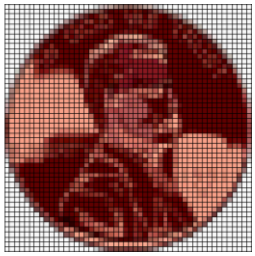
Digital images are composed of PIXELS (or picture elements)

- ASPECT RATIO expresses this resolution as the product of the no. of horizontal pixels by the no. of vertical pixels



Representing Digital Images

Digital images are composed of PIXELS (or picture elements)



- this image is square, 50 X 50
- typical ratios are 320 X 200 or 1.6:1, 640 X 480, 800 X 600, and 1024 X 768--all of which are 1.33:1

Representing Digital Images

Picture resolution determines both the amount of detail as well as its storage requirements

- here is a (edited) digitized image with a resolution of 272 X 416

Representing Digital Images

Picture resolution determines both the amount of detail as well as its storage requirements

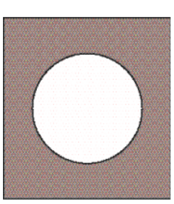
- notice the changes when the resolution is reduced (136 X 208)

Representing Digital Images

Picture resolution determines both the amount of detail as well as its storage requirements

- notice more changes when the resolution is reduced (68 X 104)

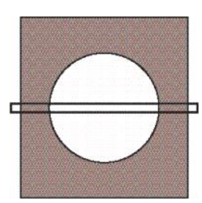
Representing Digital Images



QUANTIZING a sampled image refers to representing each discrete sample by a set of numbers chosen from a given scale

- imagine a simple image with a bright object in the foreground surrounded by a dark background

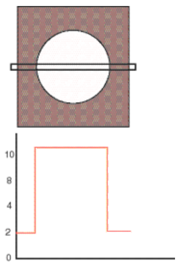
Representing Digital Images



QUANTIZING a sampled image refers to representing each discrete sample by a set of numbers chosen from a given scale

- suppose that we sampled the signal horizontally across the middle of the image

Representing Digital Images



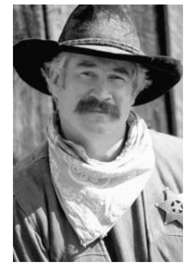
QUANTIZING a sampled image refers to representing each discrete sample by a set of numbers chosen from a given scale

- if we assigned a numeric scale for the signal it might look like this

Representing Digital Images

DYNAMIC RANGE (also called COLOR DEPTH) refers to the number of values for the measuring scale used in quantizing

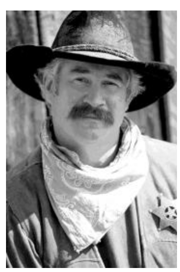
- Here is an intensity or graylevel image with 256 levels (i.e., 0 to 255 scale)



Representing Digital Images

DYNAMIC RANGE or COLOR DEPTH

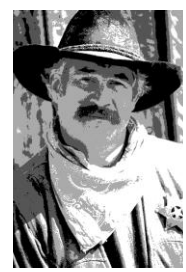
- Here is an intensity or graylevel image with 16 levels (i.e., 0 to 15 scale)



Representing Digital Images

DYNAMIC RANGE or COLOR DEPTH

- Here is an intensity or graylevel image with 4 levels (i.e., 0 to 3 scale)



Representing Digital Images

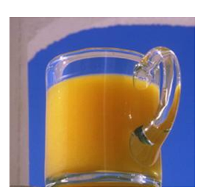
DYNAMIC RANGE or COLOR DEPTH

- Here is an intensity or graylevel image with 2 levels (i.e., 0 to 1 scale or a binary image)

Storing Digital Images

RGB Colors: Binary Representation

Color intensity is represented as a quantity (0 through 255)



RGB color model represents natural color as a combination of three channels: RED, GREEN, and BLUE

- RGB color model employs additive primaries
- RGB color is employed by most color video displays

Storing Digital Images

RGB color model represents natural color as a combination of three channels: RED, GREEN, and BLUE

- Here is an RGB image
- We will separate it into three separate color channels for comparison

Storing Digital Images

RGB color model represents natural color as a combination of three channels: RED, GREEN, and BLUE

- Here is the RED channel
- Note that bright values denote high amounts of red; dark means low amounts

Storing Digital Images

RGB color model represents natural color as a combination of three channels: RED, GREEN, and BLUE

- Here is the GREEN channel
- It closely resembles the normal graylevel image (black and white photo)

Storing Digital Images

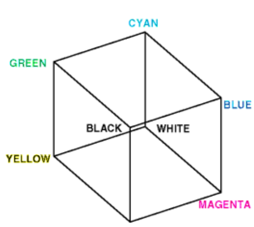
RGB color model represents natural color as a combination of three channels: RED, GREEN, and BLUE

- Here is the BLUE channel

Storing Digital Images

The CMYK color model employs four channels to create color: CYAN, MAGENTA, YELLOW, and BLACK

- CMYK is based on subtractive primaries (paint pigments)
- is used for printing
- employs BLACK (K) for highlights and details



CMY Color Cube

Storing Digital Images

The CMYK color model employs four channels to create color: CYAN, MAGENTA, YELLOW, and BLACK

- Here is a CMYK image
- again, we will separate it into four channels

Storing Digital Images

The CMYK color model employs four channels to create color: CYAN, MAGENTA, YELLOW, and BLACK

- Here is the CYAN channel
- Note that white space here means no ink or pigment; dark means a concentration of ink

Storing Digital Images

The CMYK color model employs four channels to create color: CYAN, MAGENTA, YELLOW, and BLACK

- Here is the MAGENTA channel

Storing Digital Images

The CMYK color model employs four channels to create color: CYAN, MAGENTA, YELLOW, and BLACK

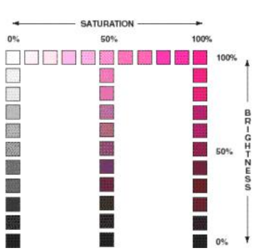
- Here is the YELLOW channel

Storing Digital Images

The CMYK color model employs four channels to create color: CYAN, MAGENTA, YELLOW, and BLACK

- Here is the BLACK channel

Storing Digital Images



HSB color is defined by three separate values: HUE, SATURATION, and BRIGHTNESS

- A single hue value is depicted with a series of changing brightness and saturation values

Storing Digital Images

- INDEXED COLOR images are derived from full color images
- INDEXED COLOR images are smaller or more compact in storage
- are composed of pixels selected from a limited palette of colors or shades

Storing Digital Images

- Digital images are converted to files for storage and transfer
- The file type is a special format for ordering and storing the bytes that make up the image
- File types or formats are often not compatible
- You must often match the file type with the application

Storing Digital Images

- **TIFF** (Tagged Image File Format)
  - used by most document preparation programs
  - has optional lossless compression
  - Windows and Macintosh formats differ
- **GIF** (Graphic Interchange Format)
  - indexed color image (up to 256 colors)
  - compressed
  - used in Web applications

Storing Digital Images

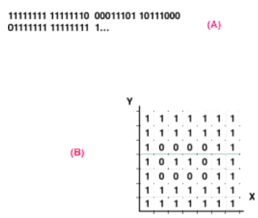
- **PNG** (Portable Network Graphics)
  - 2nd generation format for Web
  - Can use several different color depths
- **PCD** (Kodak Photo CD)
  - Compressed format for CD storage
  - Lossy compression

Storing Digital Images

- **JPEG** (Joint Photographic Experts Group)
  - lossy compression with variable controls
  - also used in Web applications
- **WMF** (Windows Metafile Format)
  - “metafile” formats permit a variety of image types
- **PICT**
  - the metafile format for Macintosh apps

Bit Mapped Graphic images

- (for display) graphic images are composed of pixels
- this type of graphic is called bit-mapped or raster graphics
- the image is stored as a sequence of bits (a) representing the pixel properties (b)

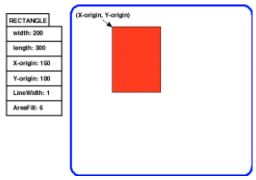


Vector Graphic Images

- object-oriented or vector graphics treat the image as a collection of graphic objects such as lines, curves, and figures
- vector graphics are resolution independent and scalable
- vector graphics are more easily edited and often more compact in storage
- vector graphic images must often be converted to bitmapped images for display

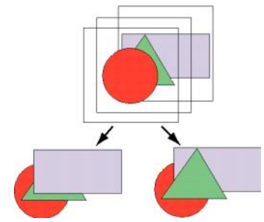
Vector Graphics

- the image is composed of graphic objects (lines, curves, figures, etc.)
- each object is defined by its graphic properties
- these properties may be changed and scaled easily



Vector Graphics

- each object occupies a separate layer
- layers may be moved, scaled, and arranged in different orders
- objects may be deleted and inserted easily



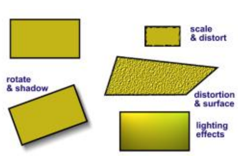
Graphic Applications

Bit-mapped graphics	Vector graphics
painting programs (Photoshop)	drawing programs illustration programs 3-D modeling and rendering programs

Painting Programs

- two-dimensional, bitmapped images/ files
- interface based on artwork metaphor
- image (canvas) painted with brushes, pencils, chalk, etc.
- colors, patterns, and textures selected from palettes
- image is divided into foreground and background layers

Painting Programs



- offer a variety of patterns, textures, and colors
- have assorted tools for transforming selected portions of the image
- have tools for creating pixel masks

Drawing Programs

- are simple vector graphic programs
- best-suited for basic illustrations
- employ an artwork metaphor for the user interface like painting programs
- an image is a set of graphic objects that are created individually and composed together

Compression

- Changing the representation to use fewer bits to store or transmit information
  - Example: fax is a long sequence of 0's and 1's encoding where page is white or black. Run length encoding is used to specify length of first sequence of 0's, following sequence of 1's, etc.
    - Lossless compression—original representation can be perfectly reproduced

11-43

JPEG

- Used for still images
- Our eyes are not very sensitive to small changes in hue (gradation of color), but are sensitive to small changes in brightness
  - Store a less accurate description of hue (fewer pixels)
  - Gets a 20:1 compression ratio without eyes being able to perceive the difference

11-44

(a) (b)

Figure 11.7. Detail from an image compressed using JPEG. (a) 14:1 compression (b) 140:1. Check images at www.aw.com/snyder

11-45

MPEG Compression Scheme

- Same idea as JPEG, applied to motion pictures
- JPEG-like compression is applied to each frame
- Then "interframe coherency" is used
  - MPEG only has to record and transmit the differences between one frame and the next
  - Results in huge amounts of compression

11-46

Digitizing Images and Video

- It would take 51 minutes to display an 8 x 10 color image scanned at 300 pixels per inch (21.6 MB) with a 56kb/s modem
- How can we see screen-size pictures in second while surfing the web?
- Typical computer screen has under 100 pixels per inch
  - Storing picture digitized at 100 ppi saves a factor of 9 in memory (reducing resolution)
    - This would still take 5 1/2 minutes to send at 56kb/s
  - Solution: JPEG Compression scheme

11-47

Optical Character Recognition (OCR)

- Reading license plate to deduct toll from car's account
- What are the difficulties?
  - Computer must capture image of license plate but camera will see other highway images
  - *Frame grabber* recognizes when to snap image and send to computer for processing
  - Computer must figure out where in the image the plate is
    - Scans groups of pixels looking for edges where color changes
    - Looks for *features*
    - *Classifier* matches features to letters of alphabet

11-48

OCR Technology

- Enables computer to "read" printed characters
  - Business applications: Sorting mail and banking

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Digitizing Sound

- An object creates sound by vibrating in a medium such as air
  - Vibrations push the air
  - Pressure waves emanate from the object and vibrate our eardrums
  - The *force*, or intensity of the push determines the volume
  - The *frequency* (number of waves per second) is the pitch

11-50

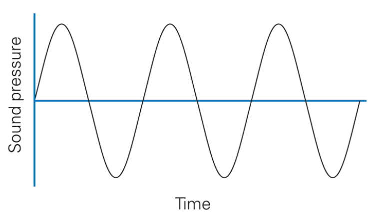

Figure 11.3. *Sound wave. The horizontal axis is time; the vertical axis is sound pressure.*

11-51

Analog to Digital

- To convert continuous information into discrete information, convert it to bits
- From zero line on graph, record with binary number the amount by which the wave is above or below it (positive or negative sound pressure)
- At what points do we measure? We can't record every position of the wave

11-52

Sampling

- Take measurements at regular intervals
- Number of samples in a second is the *sampling rate*
  - The faster the rate, the more accurate the recording

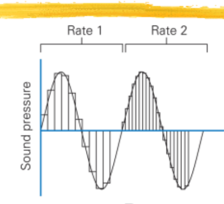

Figure 11.4. *Two sampling rates; the rate on the right is twice as fast as that on the left.*

11-53

How Fast a Sampling Rate?

- Sampling rate should be related to the wave's frequency
  - Too slow a rate could allow waves to fit between the samples; we'd miss segments of sound
  - Guideline is *Nyquist Rule*: Sampling rate must be at least twice as fast as the fastest frequency
    - Human perception can hear sound up to 20,000 Hz, so 40,000 Hz sampling rate is enough.
      - **hertz** (symbol: **Hz**) is a unit of frequency. It is defined as the number of complete cycles per second.
    - Standard for digital audio is 44,100 Hz (44.1 KHz)
    - Nyquist Rule: in other words – sampling rate should be twice as fast as what a human can hear

11-54

ADC, DAC

- Digitizing Process:
  - Sound is picked up by a microphone (called a *transducer*)
  - The signal is fed into an *analog-to-digital converter (ADC),* which samples it at regular intervals and outputs binary numbers to memory
  - To play the sound, the process is reversed
    - Numbers are read from memory into *digital-to-analog converter (DAC),* which creates an electrical wave by filling in between the digital values
    - Electrical signal is output to speaker, which converts it to a sound wave

11-55

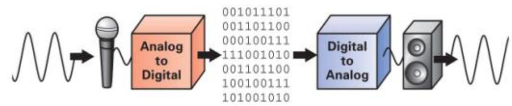

Figure 11.5. Schematic for analog-to-digital and digital-to-analog conversion.

11-56

How Many Bits per Sample?

- How accurate must the samples be?
  - Bits must represent both positive and negative values
  - The more bits, the more accurate the measurement
  - The digital representation of audio CDs uses 16 bits (records 65,536 levels, half above and half below the zero line)

11-57

How Many Bits per Sample?

- How many bits to record a minute of digital audio?
  - 60 seconds X 44,100 samples of 16 bits each X 2 for stereo =
  - 84,672,000 bits <u>or</u>
  - 10,584,000 bytes   > 10 MB

11-58

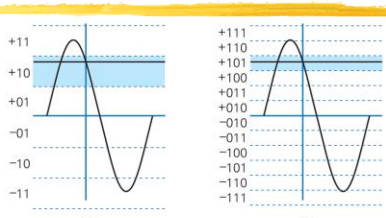

Figure 11.6. (a) Three-bit precision for samples requires that the indicated reading is approximated as +10. (b) Adding another bit makes the sample twice as accurate.

11-59

Advantages of Digital Sound

- We can compute the representation
- MP3 Compression
  - One computation is to compress the digital audio (reduce number of bits needed)
  - Remove waves that are outside range of human hearing
    - Orchestra produces sounds human can't hear
  - MP3 usually gets a compression rate of 10:1
    - Number of bits reduced to 1/10 of original
    - A minute of MP3 music takes less that a megabyte of storage
    - MP3 is popular for Internet transmission because it has lower bandwidth requirements
    - **Bandwidth** – measure of how much information is transmitted per unit of time

11-60

Advantages of Digital Sound continued

- Reproducing the Sound Recording
  - Bit file can be copied without losing any information
  - Original and copy are **exactly the same**
    - This is NOT true of analog

Virtual Reality: Fooling the Senses

- Creating an entire digital world
- Applies to all senses and tries to eliminate the cues that keep us grounded in reality
- *Haptic devices*
  - Input/output technology for sense of touch and feel
  - Haptic glove enables computer to detect where our fingers are. When we bring our fingers close enough together, gloves stop their movement so we feel like we're holding something
  - Demo1
  - Demo 2

The Challenge of Latency

- The challenge is for the system to operate fast and precisely enough to appear natural
- *Latency* is the time it takes for information to be delivered
- Too long latency period ruins the illusion
  - Absolute limit to how fast information can be transmitted—speed of light

The Challenge of Bandwidth

- How much information is transmitted per unit time
- Higher bandwidth usually means lower latency

Bits Are It

- *Bias-Free Universal Medium Principle*:
  - Bits can represent all discrete information, but have no inherent meaning
- Bits: The Universal Medium
  - Everything that can be represented in a sensible way, can be manipulated
- Bits: Bias-Free
  - The meaning of bits comes entirely from the interpretation placed on them through programs
- Bits are Not Necessarily Binary Numbers
  - Bits can be interpreted as binary numbers, or not, depending on use