Overview of Computer Science

CSC 101 — Summer 2011

Digital Video

Lecture 17 — July 28, 2011

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Announcements

- Lab #6 Today (Due Monday)
- Writing Assignment #6 Due Today
- Quiz #3 Tomorrow!

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Objectives

- Analog and digital video standards
- Digital video compression methods
Disadvantages of Analog Video

- Limitations of analog video (television & video tape)
  - Sequential access—must be fast-forwarded or rewound
    - Playback
    - Editing
  - Low resolution
    - Standard NTSC video image is only 60 fields × 484 lines
    - Standard NTSC video is 30 images per second
      - A poor match to film’s 24 frames per second
  - Poor color reproduction
  - Susceptible to noise and interference
  - High bandwidth requirement
    - Bandwidth: amount of data transmitted per unit time
    - Not compressible

Advantages of Digital Video

- Scalable
  - Can be played on a variety of output devices
  - Higher resolution possible (depending on output device)
    - HDTV standard allows up to 1920 × 1080 resolution
  - Higher frame rate possible
    - HDTV uses 60 fps
      - Easily matched to film’s 24 fps by using 3:2 pulldown
- Random access
  - Analog video is linear, but digital video has random access
- Compressible
  - Digital video can be compressed to reduce bandwidth requirement; analog video cannot

Advantages of Digital Video

- More flexible playback
  - Fast, slow, freeze-frame, looping, etc. work well
- Interactive possibilities
  - Realistic video games, information kiosks, etc.
- Powerful editing possibilities
- **But:** large computer resource requirements
  - High-quality digital video uses lots of storage space
  - Video compression techniques are critical, but use a lot of computational power
Analog vs. Digital Broadcast

• NTSC (analog) phased out June 12, 2009
  – Over-the-air TV broadcasts are now all digital (ATSC)
  – Analog televisions only work if connected
to cable, satellite, or a converter box
• Much lower bandwidth needs frees up
  radio spectrum for other uses
  – US auctioned off much of the bandwidth
  – Google was one bidder
  – Almost $20 billion in proceeds to the US,
    mostly from AT&T and Verizon
  – Also to be used for public safety and military uses

Digital Video

• Moving pictures are a series of still images (frames)
  – Movies whole photographic frames projected sequentially
    • (24 images per second)
  – Analog video ‘paints’ images on a screen, line-by-line
    • (30 images per second)
  – Analog broadcast video started around the 1940s
• Digital broadcast video has replaced analog
  – Digital requires less bandwidth for the same or better
    quality
  • Bandwidth: amount of data transferred per unit of time

HDTV

• One digital broadcast standard:
  **HDTV – High Definition TV**
    • HDTV is a digital format,
      but not all digital TV is high-definition
    • Wide aspect ratio: 16:9
    • High resolution, up to 1920 × 1080 pixels
    • 60 frames per second
    • Uses lossy compression (MPEG-2)
Digital Bandwidth Requirements

- How much bandwidth would digital video require?
- HDTV-quality, full-screen movie with no compression:
  - 1920 × 1080 resolution
  - 24-bit color
  - 60 frames per second
  - CD-quality audio (16-bit stereo; 44.1 KHz sample rate)
  - 373 MB/sec bandwidth needed
    (or, 1,340 GB for a one-hour video file)
    (that's 300 standard DVDs! at ~4.7 GB each)

These data sizes are too large for most uses
- Compression is necessary to reduce bandwidth requirements
- Tradeoff between video quality and compressed size due to lossy compression
- Changes in available bandwidth (network congestion, transmission interference, etc.) can affect video quality
  - Want to be able to dynamically reduce the required bandwidth when necessary to maintain the 'speed' of the video

Video Compression

- Compressor: encodes the digital video data into a smaller file (or a smaller data stream)
- Decompressor: decodes the compressed data to reproduce the original video
- A codec is a compressor / decompressor pair for a particular compression method
  - There are many different codecs in common use
Codecs

- Some codecs require specific, proprietary players such as:
  - QuickTime
    - .qt or .mov files
    - QuickTime Player is required
  - RealMedia
    - .rm, .ra, or .ram files
    - RealPlayer is required
- Many other codecs are freely available
  - Can play in Windows Media Player, Winamp, DivX, or others

Video Compression

- Two main types of video compression
  - Spatial compression techniques are used on individual frames
    - Image compression
    - Dynamic resolution reduction
  - Temporal compression techniques work by comparing differences in consecutive video frames
    - Dynamic frame rate adjustment
    - Interframe coherency

Spatial Image Compression

- Each frame of a video is just a single image
  - Each image (each frame) can be compressed using standard image compression techniques, like JPEG
- This reduces video size somewhat, but more compression is still possible
  - Dynamic resolution reduction is a spatial image compression technique that takes advantage of the character of the image being compressed
Dynamic Resolution Reduction

- Need high resolution for fine detail, but not all parts of an image need full detail.
- Different parts of an image can have different resolution levels.
  - Fewer, larger pixels, or large rectangular patches, can be used where fine detail is not needed.
- The compression system can dynamically choose different resolution levels for different parts of each frame.

Dynamic Frame Rate Adjustment

- Full-quality digital video is at least 60 frames per second.
  - Not every frame needs to be shown, especially when images don’t change much between frames.
- Frame rate can be dynamically adjusted to adapt to:
  - The amount of change (motion) in the video.
  - Bandwidth limitations due to slower hardware, a slower connection, transmission interference or network congestion.

Interframe Coherency

- While parts of a scene may change rapidly from frame to frame, other parts don’t change much.
  - Instead of including all details on each successive frame, the compression system can avoid updating parts of the image that don’t change between frames.
MPEG Video

- Most digital video signals use the **MPEG-2** format
  - (MPEG = Motion Experts Group)
  - Each video frame is compressed with a JPEG-like compression scheme
  - Interframe coherency greatly reduces the required bandwidth
  - Dynamic frame-rate adjustment and dynamic resolution reduction are also used
  - MP3 audio files use just the audio part of the MPEG format (“MP3” = “MPEG-1 Audio Layer 3”)

Video Compression Example

- This 30-second video clip shows effects of too much use of dynamic resolution reduction and interframe coherency compression techniques
Editing Digital Video

• Analog video editing is performed linearly
  – Playback and recording (dubbing)
  – Actual cutting and pasting of pieces of film
    • (But, this isn’t even possible for videotape)

• Digital editing is nonlinear
  – Random access avoids need for dubbing
  – Editing software just maintains a list of clips and the instructions for assembling them

Live Video Modification

• Technology now exists to modify live video
  – Yellow first-down line and other kinds of virtual advertising
    http://www.pvi.tv

Live Video Modification

• Live news broadcast from Times Square
  – CBS News replaced NBC’s famous video screen with a CBS logo
    www.commercialalert.org/cbs-news.htm
Examples of Digital Video Editing

Computer Graphics

- **2D Graphics**
  - Creating and displaying two-dimensional images
- **3D Graphics**
  - Creating, manipulating and displaying images of three-dimensional objects and scenes
  - “Computer graphics” usually refers to 3D graphics

Creating 3D Graphics

- First step: creating and placing the 3D objects in the scene
  - A creative, artistic process
- Second step: producing the image from the scene
  - Computationally intensive
3D Graphics

- **Modeling:**
  - Mathematically represent objects and shapes as a series of points
    - Connecting the points creates a mesh of polygons – a “wireframe” version
  - Construct 3D objects to represent the creative ideas

- **Modeling:**
  - Replace the mesh with smooth, solid surfaces
  - Identify hidden and visible parts of each object
    - The hidden parts of objects should not be visible

- Adding details
  - “Sully” has over 2,300,000 individual hairs modeled on his surface
- Adding surface characteristics: texture mapping
- Lighting and shading
3D Graphics

- **Rendering**: Creating the final frame in full detail
  - A single movie frame may take many hours to render, even on a massive compute cluster
  - ~0.04 sec of movie time
  - A feature film may have more than 250,000 frames
  - 174 minutes @ 24 fps
- A rendering farm at Pixar

3D Graphic Animation

- How do we change the model to simulate motion?
  - Dynamics
    - Describe the motion of objects using simple physics
  - Kinematics
    - Simulating motion by describing all the individual moving parts of an object, such as the bones, joints, muscles and tendons of a human figure
    - Each movable component of an object is called an **avar** (animation variable)

3D Graphic Animation

- "Woody" (from *Toy Story*) has about 100 avars in his face for
  - Expressing emotions
  - Mouthing spoken words
- Each avar manually changed by animator