Special Module on Media Processing and Communication

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SIV 864
Digital Video

Video is a sequence of images in time
  • can be edited
  • can be stored on any digital medium
  • can be compressed
The Need for Video Compression

- Huge data

**Example: High-Definition Television (HDTV)**

- 1920x1080
- 30 frames per second (full motion)
- 8 bits for each three primary colors

→ Total 1.5 Gb/sec!
- Channel bandwidth 19.2 Mb/sec
- Reduced to 18 Mb/sec w/audio + control ...

→ Compression rate must be 83:1!
Video Compression

Image Compression: Transform Coding → JPEG

Pipeline

Compression

Decompression

Input image $(N \times N)$ → Construct $n \times n$ subimages → Forward transform → Quantizer → Symbol encoder → Compressed image

Compressed image → Symbol decoder → Inverse transform → Merge $n \times n$ subimages → Decompressed image

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Slide
Video Compression

MJPEG (Motion JPEG)

• Each frame can be compressed as single image.
• Compression is achieved only due to the **spatial redundancy** in the frame.
• Takes care of intra-frame redundancy

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*Slide*
Video Compression

Anything else that can be done?

• What about temporal redundancy or inter frame redundancy?

  MPEG (Motion Picture Experts Group)

• What about irrelevancy – perceptually unimportant?
Video Compression

Spatial Redundancy

Take advantage of similarity among most neighboring pixels
Video Compression

Temporal Redundancy
Video: Sequence of images in time (that are related!)
Take advantage of similarity between successive frames

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Video Compression

Intuitive Methods

• **Subsampling**
  Drop frames

• **Differencing**
  Differential coding of pixels

• **Block Differencing**
  Differential coding of blocks (big pixels)

• **Motion Compensation**
  Figure out the motion vector and compensate for it
Video Compression

Subsampling
Drop frames (repeat frames)

Image (Frame)

Time
Video Compression

Subsampling

Drop frames (repeat frames)

Image (Frame)

Time
Video Compression

Differencing

Frame N

Frame N+1
Video Compression

Differencing

Difference frame
Video Compression

Block Differencing

- Frame is divided into non-overlapping blocks

- Block level comparison rather than pixel level to decide which blocks for the difference is to be coded
- May work when the motion is relatively small of foreground objects
- If the motion is large and not limited to portion of image then it may not be effective
Video Compression

Motion Compensation

- Simple frame difference will fail if there is a significant motion
- Should account for the motion
  - Motion-compensated (MC) prediction
- How can we estimate motion?
Video Compression

Motion Compensation

Difference frame without motion prediction

Difference frame with motion prediction

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Video Compression

Motion Estimation

• Possible approach
• Segment video into moving objects
• Describe (model) object motion
  ➢ May be somewhat difficult
• Another (practical) approach
• Block matching motion estimation
• No object segmentation and identification required
• Good performance
Video Compression

Motion Estimation

Motion Vector \((m_{v1}, m_{v2})\)
Video Compression

Motion Estimation

- Translation motion model
- All pixels within the block have the same motion
- Motion is estimated using only luminance
- The motion vector is encoded in place of the target block itself.
- Fewer bits are required to code a motion vector
Video Compression

Motion Compensation

Frame N

Search Area

Macro Block 16X16 Pixels

Frame N+1

Motion Vector
Video Compression

Motion Estimation

**Issues:**

- Block size?
- Search range?
- Motion vector accuracy?
- Complex motion?

Search area in previous frame is usually limited to a region close to the target block.

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Video Compression

Motion Estimation

Forward, Backward, Bidirectional
Video Compression

Motion Estimation

Example

Frame N-1  Frame N  Frame N+1
Video Compression

Motion Estimation

As a general scheme a block in current frame can be estimated from a block in

- Previous frame
- Future frame
- Average of a block from the previous frame and a block from the future frame
- Neither (no prediction)
Video Compression

Encoding

Input Video Signal

RGB to YUV

DCT

Quantize

Huffman Coding

Buffer

Output Bitstream

Residual

Buffer fullness

Inverse Quantize

Inverse DCT

Frame Store

Previous Reconstructed Frame

MC-Prediction

Motion Compensation

MV data

Motion Estimation

MV data
Video Compression

Decoding

- Buffer
- Huffman Decoder
- Inverse Quantize
- Inverse DCT
- Residual
- Reconstructed Frame
- YUV to RGB
- Output Video Signal
- MC-Prediction
- Frame Store
- Previous Reconstructed Frame
- Motion Compensation
- MV data
- Input Bitstream
Video Compression

MPEG Standard

- **Block**: A basic unit for DCT operation (8x8)
- **Macroblock**: A basic unit for motion compensation operation (16x16)
- **Slice**: String of macroblocks
- **Picture/Frame**: I/B/P
- **Group-of-pictures (GOP)**: Collection of pictures (10 or so)
- **Video**: Global context unit
Video Compression

MPEG Standard

Video Sequence

Group of Pictures

Picture

Slice

Macroblock

Block

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Video Compression

Three types of coded frames

- **I-frame**: Intra coded frame, coded independently
- **P-frame**: Predictive coded frame, coded based on previously coded frame
- **B-frame**: Bi-directionally predicted frame, coded based on previous and future coded frames
Video Compression

Three types of coded frames

Display order: \( I_0, B_1, B_2, P_3, B_4, B_5, P_6, B_7, B_8, I_9 \)

Transmission Order: \( I_0, P_3, B_1, B_2, P_6, B_4, B_5, I_9, B_7, B_8 \)