Advances in digital image compression techniques

Introduction

- Introduce the basic concept of each compression method
- A good compression scheme is always composed of many compression methods.

Outline

- Basic concept of compression
- Human visual system
- Compression method
- Conclusion

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Basic concept of compression

- Amount of data ≠ Amount of information
- How to compress visual information? Exploit the:
  - Spatial redundancy
  - Temporal redundancy (for video)
  - Psycho-visual redundancy

Basic concept of compression

- Spatial redundancy

Amount of Data

= 1600*1200*8*3

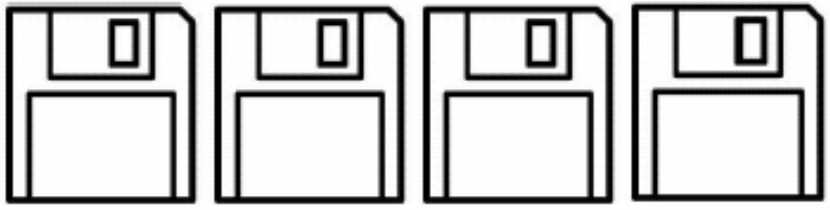
= 46,080,000 (bits)

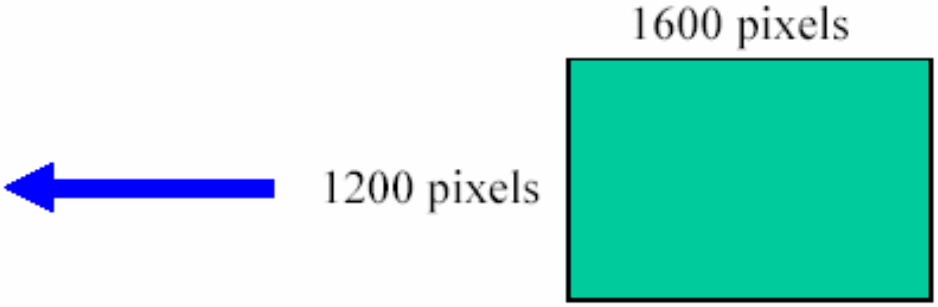
= 5,760,000 (bytes)

= 5.76 (MB)

= 1.44 *4 (MB)

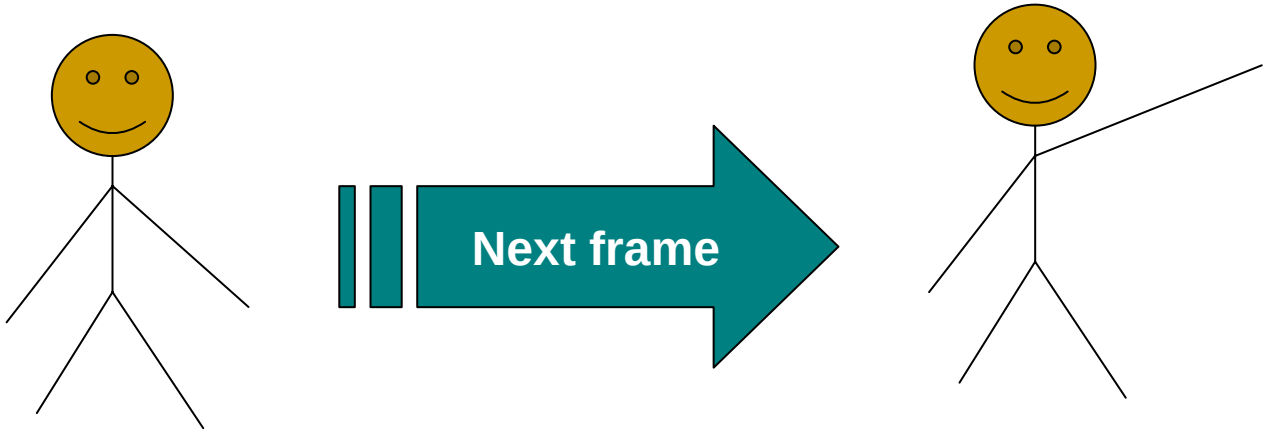
=





Basic concept of compression

- Temporal redundancy



Basic concept of compression

- Psycho-visual redundancy
  - more detail in section “human visual system”

Basic concept of compression

- Relative redundancy =

  $1-(D_c)/(D_o)$

  D_c: volume of the compressed data

  D_o: volume of the original data

Basic concept of compression

- Important property
  - Compression ratio
  - Complexity (speed)
    - Real time compression
  - Reliability (for transmission)
  - Randomly accessing or interactive (for video)
  - Image quality
    - Ex: blocking effect、ringing effect
  - Progressive transmission
  - Hardware Implementation cost

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Human visual system

- Human eye is less sensitive to **chrominance** than to **luminance**.
- Less sensitive to **high and low** spatial frequency than to **mid**-spatial frequency.
- Sensitivity to *quantizing distortion* decreases with increasing **luminance** *levels. (noise masking property).*

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Compression method

- Classification 1
  - Lossy
  - Lossless
- Classification 2
  - Spatial methods
  - Transform methods
  - Hybrid methods
- There are more classifications in other survey paper

Compression method

- Pulse code modulation (PCM)
  - Sample and quantization
    - Choose the **quantization level** and the **sampling frequency**
  - Just a D/A converter
  - First step in a compression scheme.

Compression method

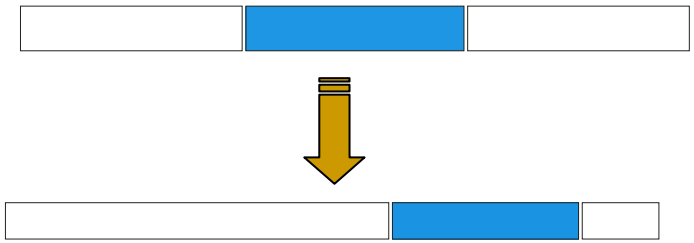
- Subsampling coding
  - Subsample and interpolate
  - Simple but efficient
  - We can put more emphasis on **luminance** than **chrominance**
- Spatial coding → intraframe coding
- Temporal coding → interframe coding

Compression method

- Predictive coding (DPCM)
  - Also called "*differential pulse-coded modulation*"
  - **Prediction error** = true value **-** prediction value
  - Only prediction error are coded
  - **Prediction error's** dynamic range is smaller than **true value's**
  - Sensitivity to **transmission** and **statistic** error
  - Temporal predictive coding is difficult to **random accessing**

Compression method

- Conditional replenishment
  - Video image is segmented to **stationary** and **moving** areas
  - Movement detector locates the interframe differences
  - The significant pixels tend to occur in **clusters** along a scan line
  - Only transmit the cluster's beginning address and differences



Compression method

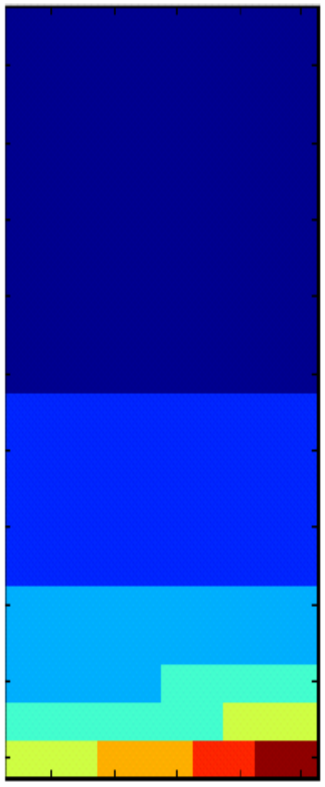
- Motion estimation and compensation
  - Add a predictor (estimator) on conditional replenishment method

Compression method

- Statistical coding
  - Assign fewer bits to the values (characters) that appear more often
  - Example: aaaaaaaabaacad
    generally, each symbol takes two bits.
    if “a” take 1 bit and ”b”、”c”、”d” take 3 bits each, we can decrease volume of the data
  - **Huffman coding** is the most commonly used statistical coding

Compression method

- Run coding
  - Run-length coding
  - Run-end coding



Example of run-length coding

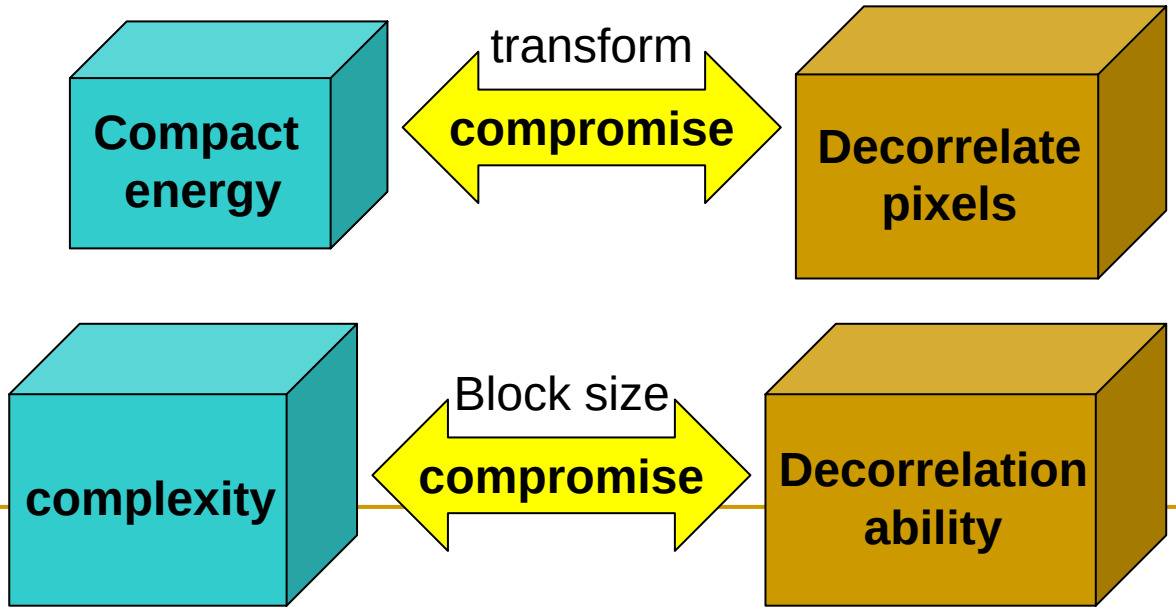
(1, 100) (2, 50) (3, 25) (4, 12)
(5, 6) (6, 3) (7, 2) (8, 2)

$$C_R = \frac{(200)(3)}{(3+8)(8)} = 6.82$$

$$R_D = 1 - \frac{1}{6.82} = 0.853$$

Compression method

- Transform coding
  - To compact the **energy** of image in a few coefficients
  - To decorrelate the image pixels
  - Block size matter! (block size is 8x8 in JPEG)



Compression method

- Transform coding
  - Computational demanding
    - But fast algorithm is mature
  - Not sensitive to **statistic** and **transmission** error

Compression method

- Hybrid coding
  - Combine transform and predictive coding techniques
  - Ex: In video coding, DCT in the **spatial** plane while DPCM in the **temporal** direction

Compression method

- Vector quantization

$$X = (x_1, x_2, x_3, \ldots x_k)$$

$$Y = Q(X) = (y_1, y_2, y_3, \ldots y_k)$$

$$C = \{Y_i \mid Y_i \in R^k, i \in \mathrm{I}\} \text{ with } \mathrm{I} = \{1,2,\ldots., N\}$$

  - X is set of values which will be coded
  - Y is output of “vector quantizer” Q
  - C is the codebook
  - Transmit the index of Y in the codebook

Compression method

- Vector quantization
  - Better performance can always be achieved by coding **vectors** instead of **scalars.** (Shannon's rate-distortion theory)
    - Relatively high compression ratio
  - Computational demanding at **encoding** process
    - Major problem of VQ: how to design a good codebook
    - Fast search algorithms are being developed (in 1993)

Compression method

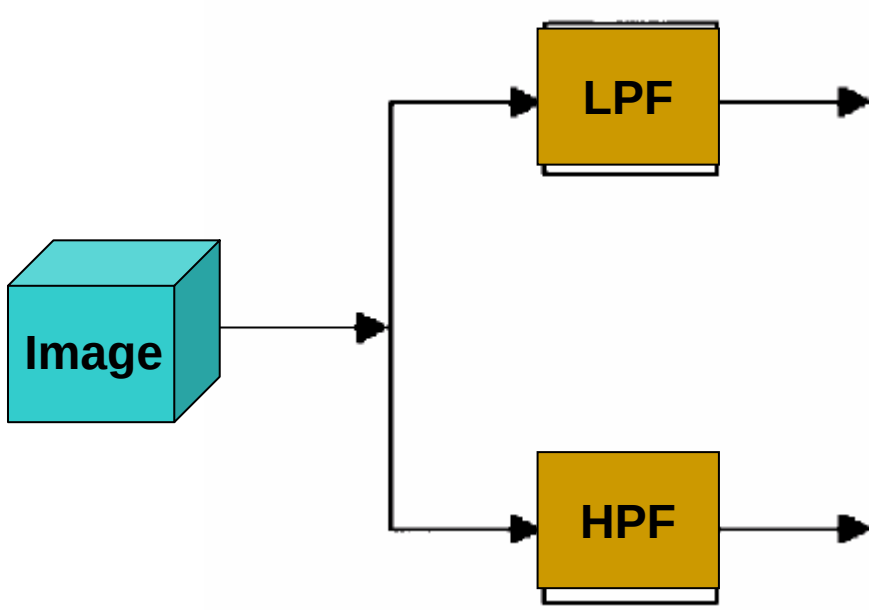
- Fractal image coding
  - Extract **self similarity** in the image
  - Describe an image region with a simple transformation of another region
  - Transmit only the sequence of transformation
  - Relatively high compression ratios (about 70~80)
  - Encoding process is complex
    - Complexity of decoding process is relatively reasonable

Compression method

- Model/knowledge-based coding
  - Transmitter and receiver agree on the basic model for the image
  - Transmit the parameters to manipulate this model
  - Application example: teleconferencing system

Compression method

- Sub-band coding
  - A set of **band-pass filters** divide the image into different sub-band (spectral component)
  - Then code each component
  - Progressive coding
  - Example: wavelet coding



Compression method

- Contour-texture oriented techniques
  - Segment the image into **texture** and **contour,** coded separately
    - Whole picture = texture + contour
  - How to extract Contour?
    - Region growing
    - Edge detection

Compression method

- Other technique
  - Adaptive coding
    - Coding parameters are adjusted according to the data statistics

Practical coding schemes

- Spatial and temporal subsampling
- DPCM based on motion estimation and compensation
- Two-dimensional DCT
- Statistical coding
- Run-length coding

Applications

- Videoconferencing and videophone
  - Speed
  - Compression ratio
  - progressive
- Multimedia electronic mail
  - Compression ratio
- Picture archiving and information distribution
  - Reliability
  - Compression ratio

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- We had review many compression methods