Fundamentals of Multimedia

Lecture 6
Lossy Data Compression

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Outcomes of Lecture 5

- *VariableLength Coding*
  - Shannon-Fano Algorithm
  - Huffman Coding Algorithm
- *Lossless Compression in JPEG images.*
  - Differential Coding
  - Lossless JPEG

Outline

- *Lossy Compression*
  - Definition
  - Distortion measure
- *Quantization*
  - Uniform scale quantization
  - Nonuniform scale quantization

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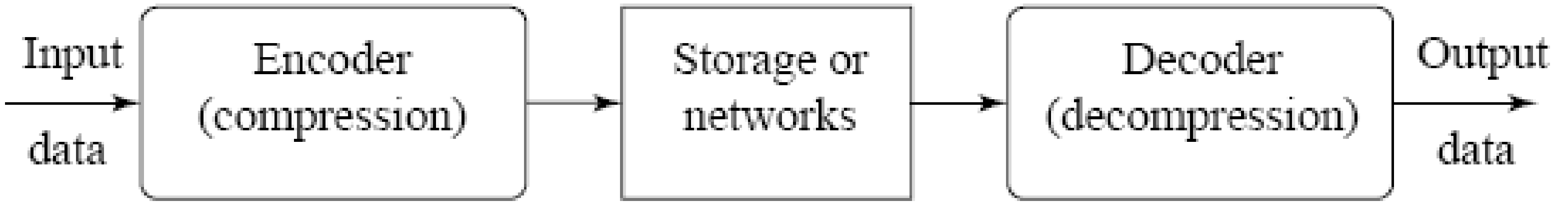
Lossy Compression

- *Lossy compression yields a much higher compression ratio*
  - Multimedia compression implementations generally are combination of lossy and lossless compression
  - The compression and decompression processes induce information loss
  - The recovered file from the compressed data is a close approximation of its o riginal
- *Distortion measures*
  - How close an approximation is to its original



Distortion Measures

- *Mean square error (MSE)*

$$\sigma^2 = \frac{1}{N}\sum_{n=1}^{N}(x_n - y_n)^2$$

- *Signal to noise ratio (SNR)*

$$SNR = 10log_{10}\frac{{\sigma^2}_x}{{\sigma^2}_d}$$

- *Peak signal to noise ratio (PSNR)*

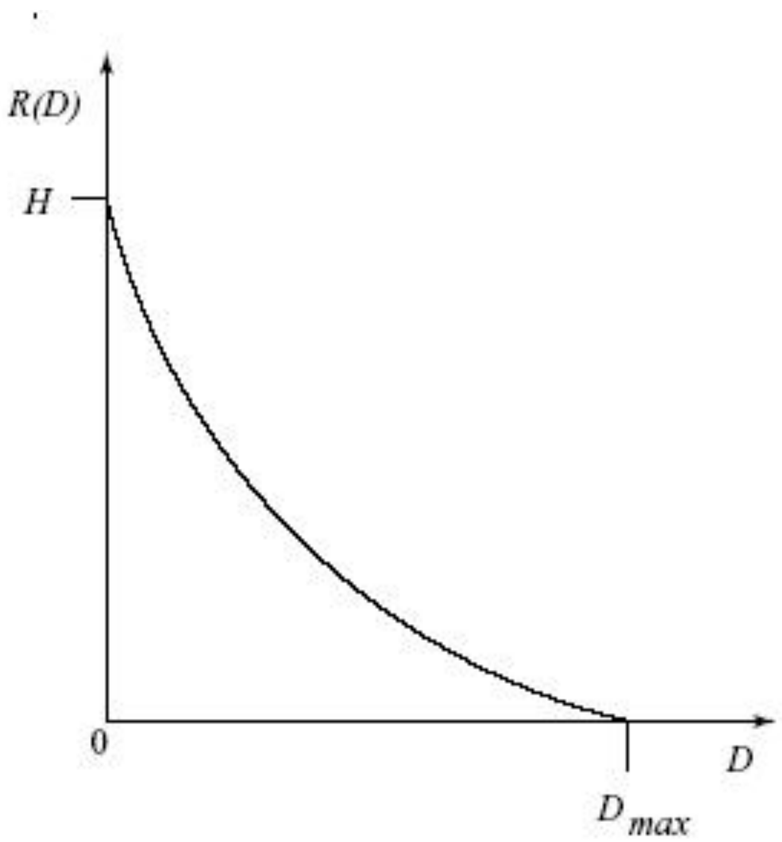
$$PSNR = 10log_{10}\frac{{x^2}_{peak}}{{\sigma^2}_d}$$

Example of Distortion Measures

- *Example data*
  - Orginial data: {12 16 16 12 12 8 8 12 }
  - Compressed data: {8 12}
  - Recovered data:{12 12 12 12 12 12 12 12}
- *Calculation of distortion measures*
  - MSE= 8
  - SNR=12.78
  - PSNR=15
  - Typical values for the PSNR in lossy image and video compression are between **30 and 50**, where higher is better.

The Rate Distortion Theory

- *Lossy compression always involves a tradeoff between Rate and Distortion*
  - **Rate:** Average number of bits required to represent each symbol
  - If D is a tolerable amount of distortion, R(D) specifies the lowest rate at which the source data can be encoded while keeping the distortion bounded above by D.



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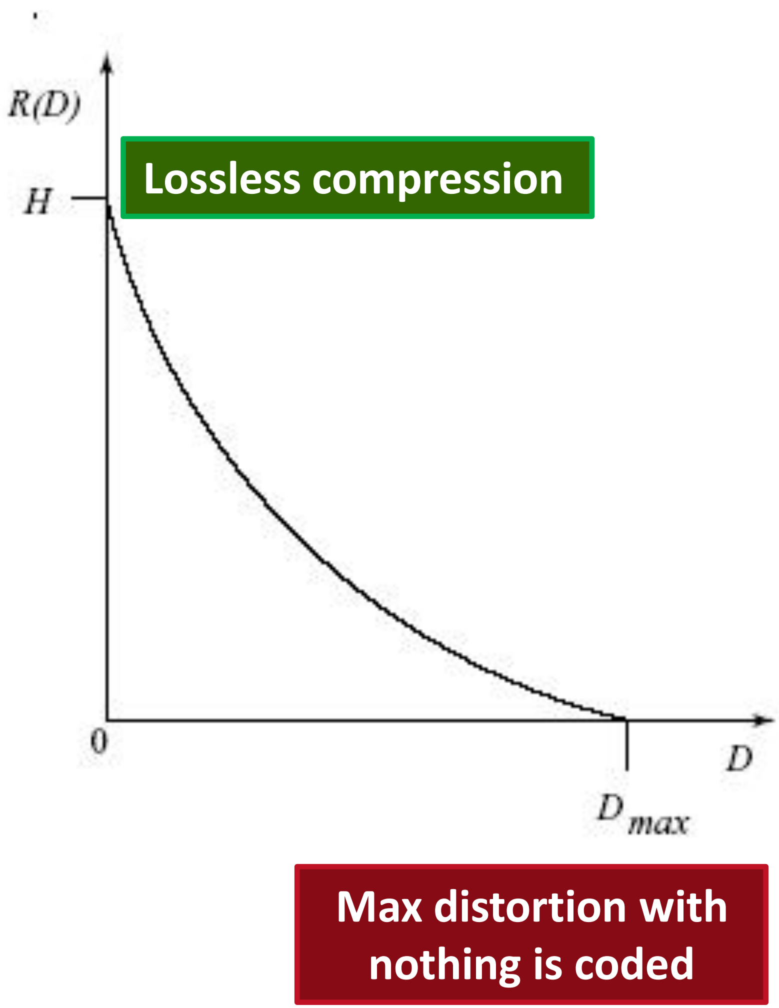

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  - Definition
  - Distortion measure
- ***Quantization***
  - Uniform scale quantization
  - Nonuniform scale quantization

Quantization

- *Quantization is the heart of any lossy compression scheme*
- *Reduce the number of distinct output values to a much smaller set*
  - Original: { 0,1,2, … 64 … 128 … 192 … 255 }
  - Smaller set: {0, 64, 128, 192 }
- *Two different forms of quantization*
  - Partition the domain of input values into equally (unequally) spaced intervals
  - Uniform scalar quantization (**equally**)
  - Nonuniform scalar quantization (**unequally**)

Example of Quantization

- *Original data*
  - Total 64 data D: $\{ d_1, d_2, \dots \dots d_{64} \}$
  - Total 16 values X: { 0, 1, … … 16 }
  - Probabilities of each value f(x):

$$S = \{ \; 0 \quad 1 \quad 2 \quad 3 \quad 4 \quad 5 \quad 6 \quad 7 \quad 8 \quad 9 \quad 10 \quad 11 \quad 12 \quad 13 \quad 14 \quad 15 \; \}$$

$$P = \{ \frac{16}{64} \; \frac{16}{64} \; \frac{4}{64} \; \frac{4}{64} \; \frac{4}{64} \; \frac{4}{64} \; \frac{0}{64} \; \frac{0}{64} \; \frac{0}{64} \; \frac{0}{64} \; \frac{0}{64} \; \frac{2}{64} \; \frac{4}{64} \; \frac{0}{64} \; \frac{2}{64} \; \frac{8}{64} \}$$

- *Compressed data Y:* $\{y_1, y_2, y_3, y_4\}$
  - The number of distinct output values will be decreased from 16 to 4
  - How to choose the boundaries of the intervals and how to choose the values in each intervals

Uniform Scalar Quantization

- *Partition the domain of input values into equally spaced intervals*

$$S = \{\ 0\ \ 1\ \ 2\ \ 3\ \ 4\ \ 5\ \ 6\ \ 7\ \ 8\ \ 9\ \ 10\ \ 11\ \ 12\ \ 13\ \ 14\ \ 15\ \}$$

$$P = \{\ \frac{16}{64}\ \frac{16}{64}\ \frac{4}{64}\ \frac{4}{64}\ \frac{4}{64}\ \frac{4}{64}\ \frac{0}{64}\ \frac{0}{64}\ \frac{0}{64}\ \frac{0}{64}\ \frac{0}{64}\ \frac{2}{64}\ \frac{4}{64}\ \frac{0}{64}\ \frac{2}{64}\ \frac{8}{64}\ \}$$

*0 1 * 2 3 / 4 5 * 6 7 / 8 9 * 10 11 / 12 13 * 14 15*

- *Y = {1.5 5.5 9.5 13.5 }*

- *Example in image compression*
  - Divide the RGB cube into equal slides in each dimension
  - R: 3-bit; G: 3-bit; B: 2-bit;

Nonuniform Scalar Quantization

- *Partition the domain of input values into unequally spaced intervals*
  - Concentrate the bits to where is most need
- *Lloyd-Max quantization*
  - Try to minimize MSE

Lloyd-Max Quantization

- *If the source distribution is not uniform, we must explicitly consider its probability distribution (probability density function) $f_X(x)$. Now we need the correct decision boundaries b_i and reconstruction values y_i*

Begin

Choose initial level set Y0

i = 0;

Repeat

Compute Bi using

$$b_j = \frac{y_{j+1} + y_j}{2}$$

i = i + 1

Computer Yi using

$$y_j = \frac{\int_{b_{j-1}}^{b_j} x f(x) dx}{\int_{b_{j-1}}^{b_j} f(x) dx}$$

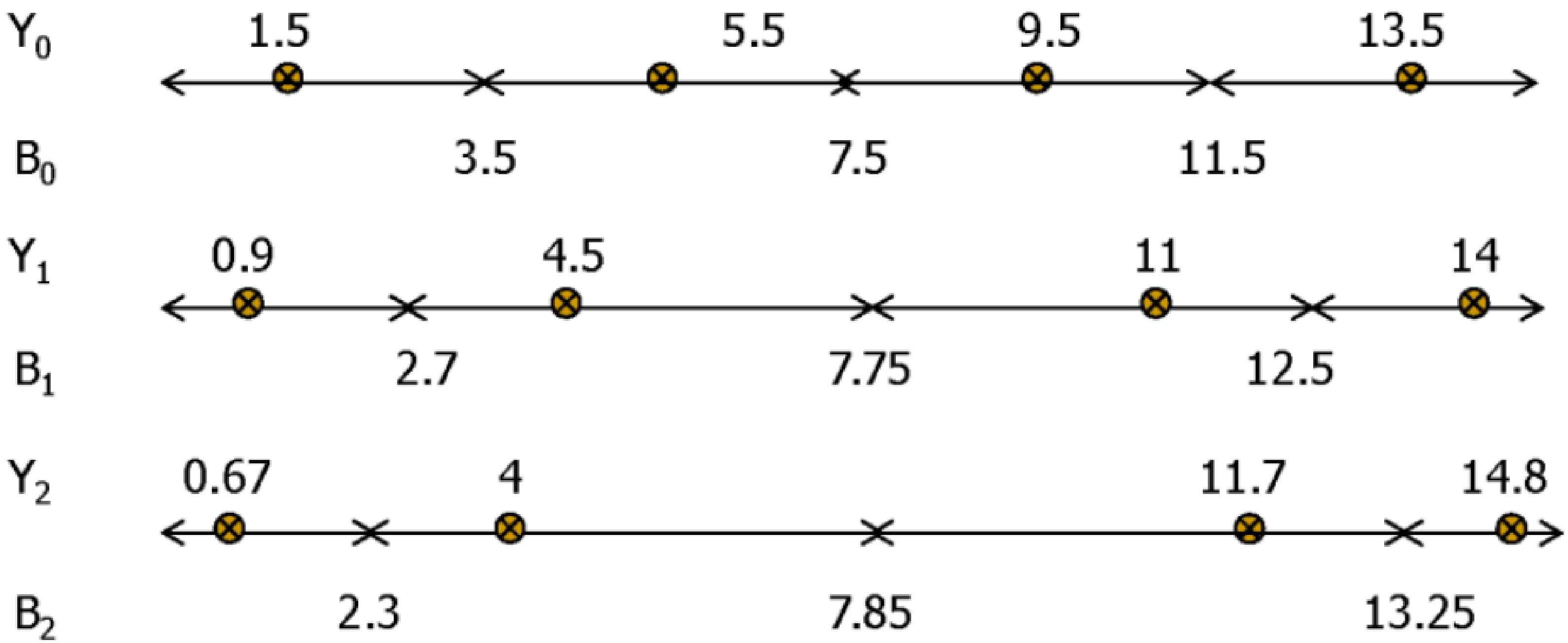
Until | Yi – Yi-1 | < threshold

End

Lloyd-Max Quantization

0 1 * 2 3 / 4 5 * 6 7 / 8 9 * 10 11 / 12 13 * 14 15

Y={1.5, 5.5, 9.5, 13.5}



0 1 2 / 3 4 5 6 7 / 8 9 10 11 12 13 / 14 15

Summary

- *Lossy Compression*
  - Definition
  - Distortion measure
- *Quantization*
  - Uniform scale quantization
  - Nonuniform scale quantization