Image Compression

Image Compression

- The goal of image compression is to reduce the amount of data required to represent a digital image.

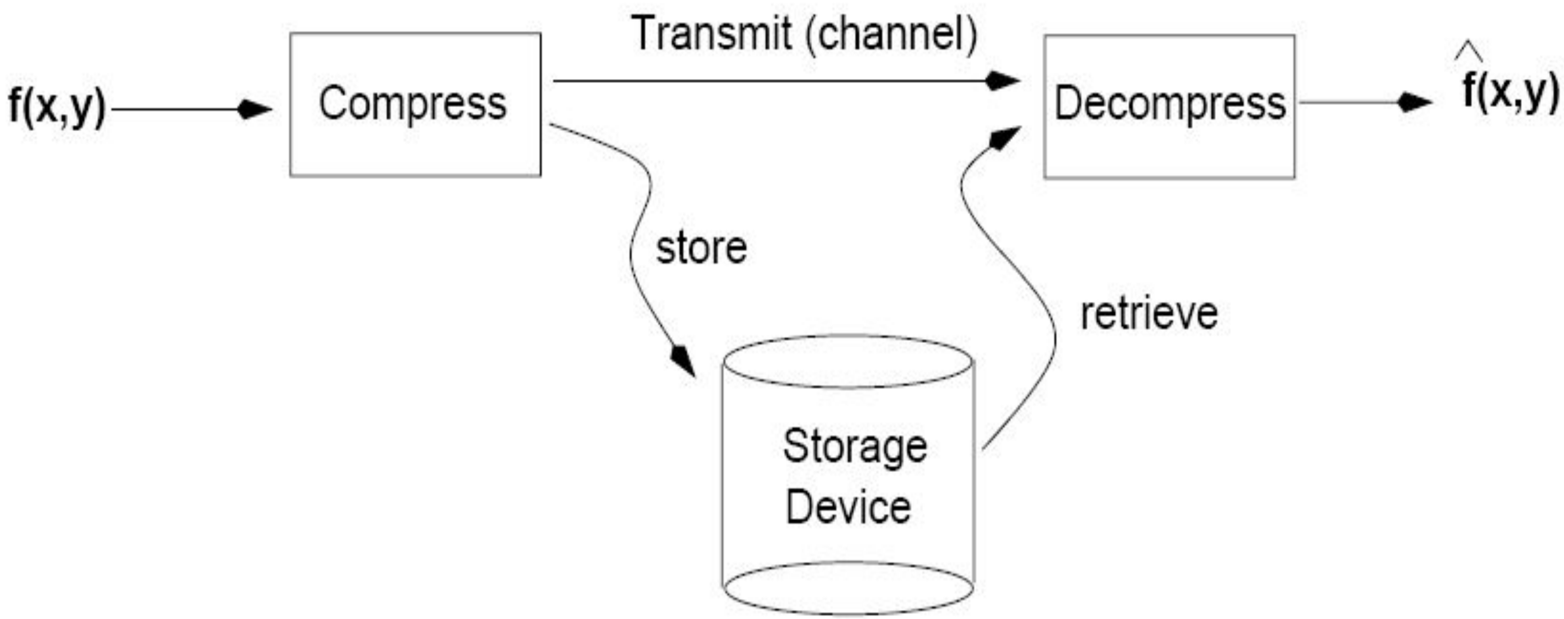


Image Compression (cont'd)

- Lossless
  - Information preserving
  - Low compression ratios

- Lossy
  - Not information preserving
  - High compression ratios

information loss **VS** compression ratio

Data ≠ Information

- Data is the means by which information is conveyed.
- Data compression aims to reduce the amount of data while preserving as much information as possible.

Data vs Information (cont'd)

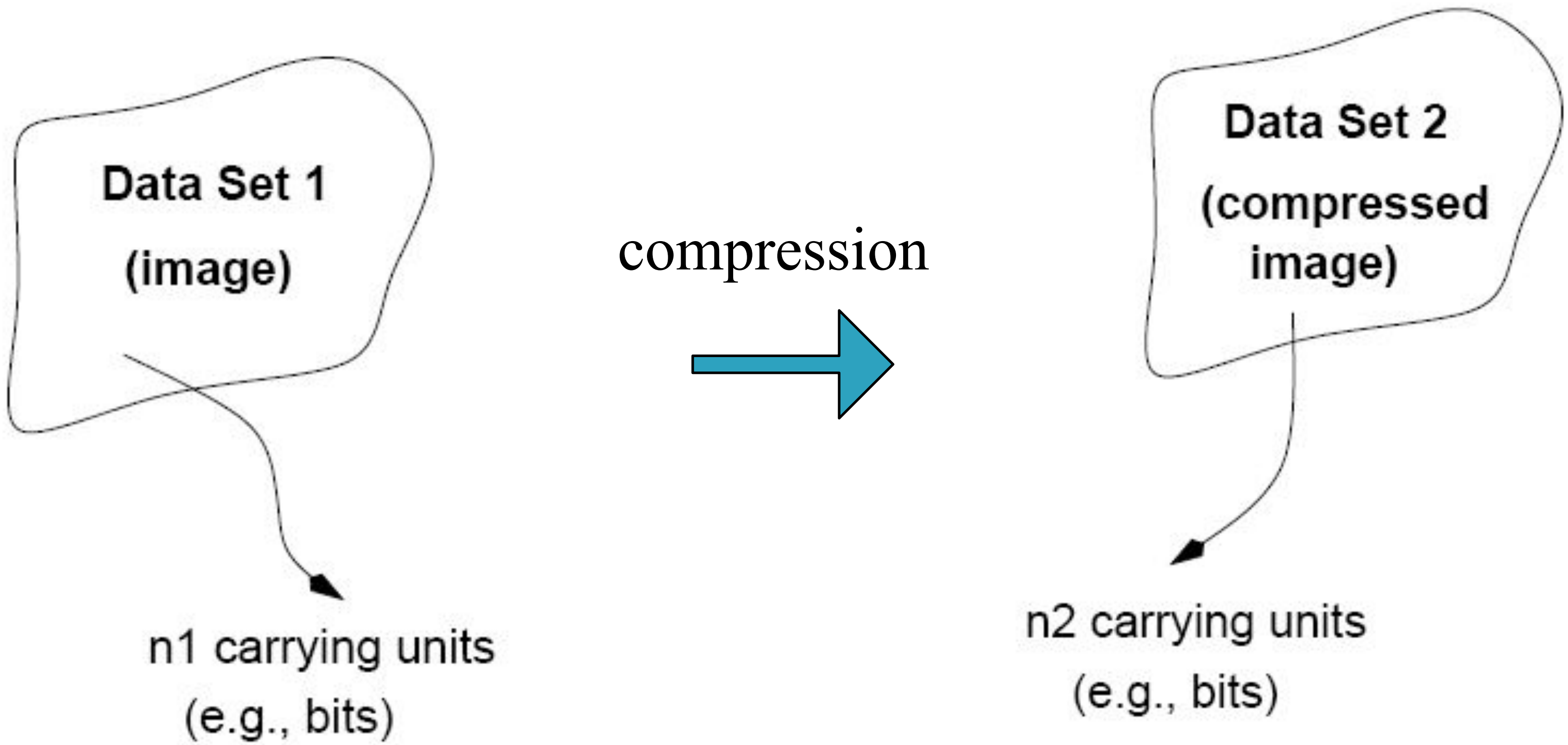
- The same information can be represented by different amount of data – for example:

<u>Ex1:</u> *Your wife, Helen, will meet you at Logan Airport in Boston at 5 minutes past 6:00 pm tomorrow night*

<u>Ex2:</u> *Your wife will meet you at Logan Airport at 5 minutes past 6:00 pm tomorrow night*

<u>Ex3:</u> *Helen will meet you at Logan at 6:00 pm tomorrow night*

Compression Ratio



Compression ratio: $C_R = \dfrac{n_1}{n_2}$

Relevant Data Redundancy

$$R_D = 1 - \frac{1}{C_R}$$

Example:

If $C_R = \frac{10}{1}$, then $R_D = 1 - \frac{1}{10} = 0.9$

(90% of the data in dataset 1 is redundant)

if $n_2 = n_1$, then C_R=1, R_D=0

if $n_2 \ll n_1$, then $C_R \to \infty$, $R_D \to 1$

Types of Data Redundancy

(1) Coding Redundancy
(2) Interpixel Redundancy
(3) Psychovisual Redundancy

- Data compression attempts to reduce one or more of these redundancy types.

Coding - Definitions

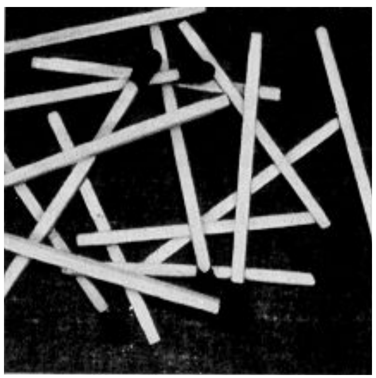
- Code: a list of symbols (letters, numbers, bits etc.)
- Code word: a sequence of symbols used to represent some information (e.g., gray levels).
- Code word length: number of symbols in a code word.

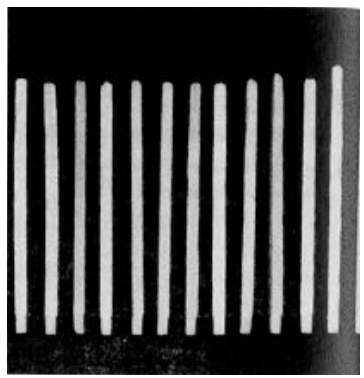
Example: (binary code, symbols: 0,1, length: 3)

0: 000	4: 100
1: 001	5: 101
2: 010	6: 110
3: 011	7: 111

Interpixel redundancy

- Interpixel redundancy implies that pixel values are correlated (i.e., a pixel value can be predicted by its neighbors).





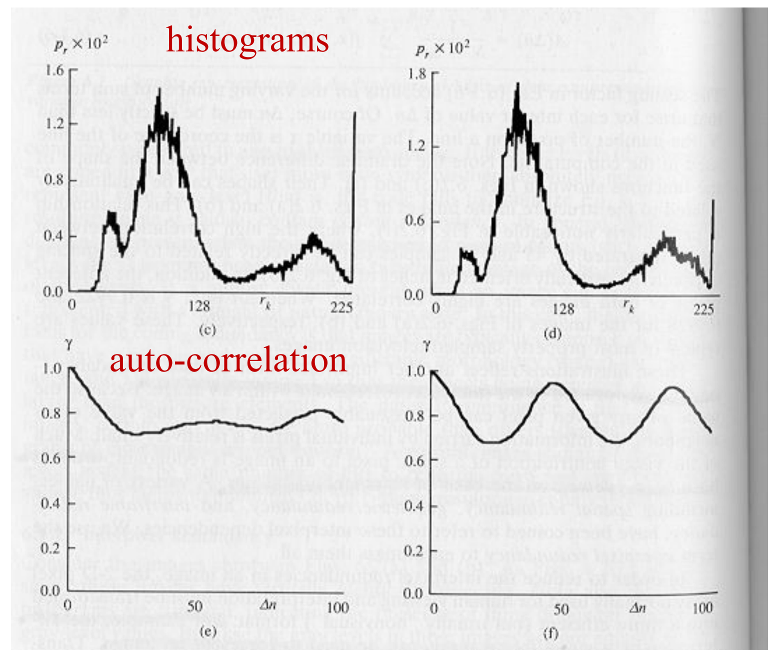


Figure 6.2 Two images and their gray-level histograms and normalized autocorrelation

$$f(x) \circ g(x) = \int_{-\infty}^{\infty} f(x) g(x+a) da$$

auto-correlation: f(x)=g(x)

Psychovisual redundancy

- The human eye is more sensitive to the lower frequencies than to the higher frequencies in the visual spectrum.

- Idea: discard data that is perceptually insignificant!

Psychovisual redundancy (cont'd)

Example: quantization

256 gray levels

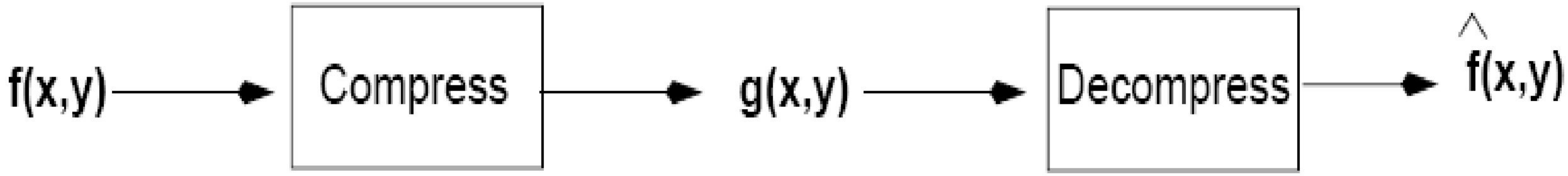
16 gray levels

16 gray levels + random noise

$C=8/4 = 2:1$

add a small pseudo-random number to each pixel prior to quantization

Image Compression Model



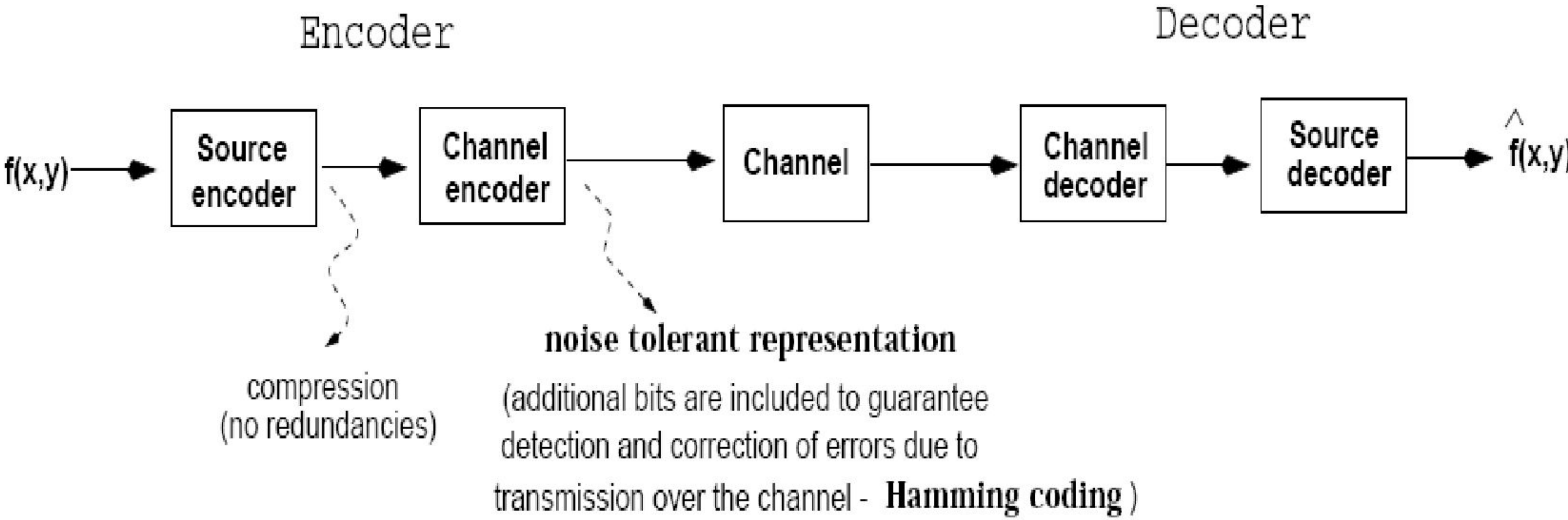
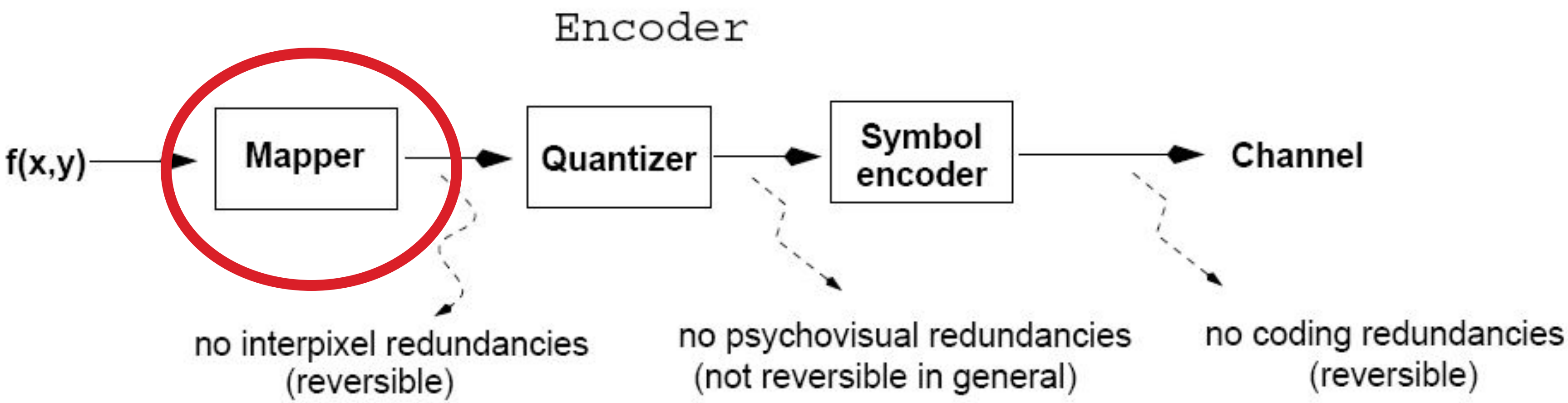
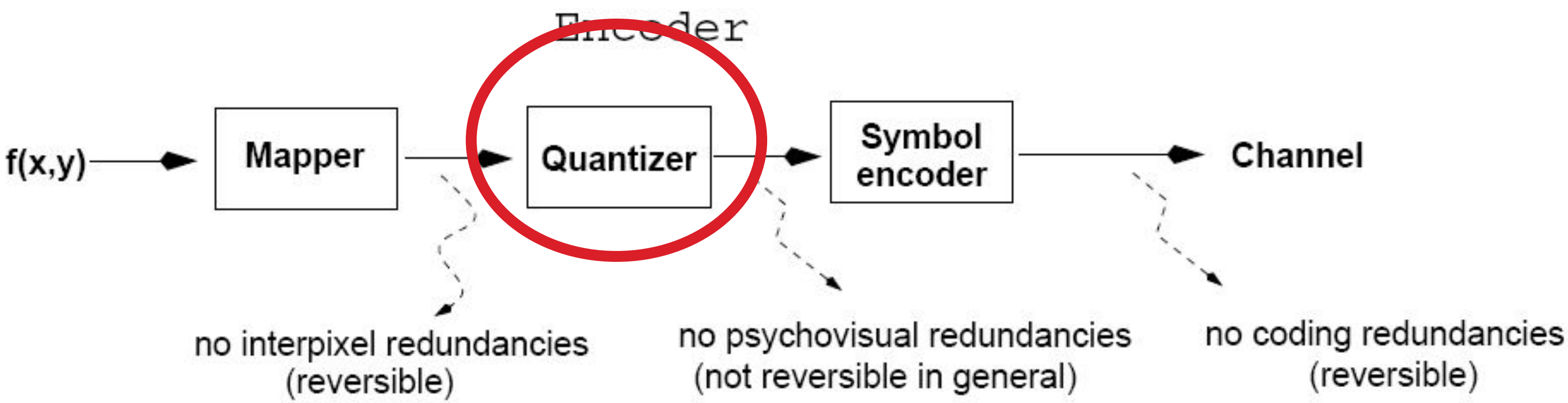


Image Compression Model (cont'd)



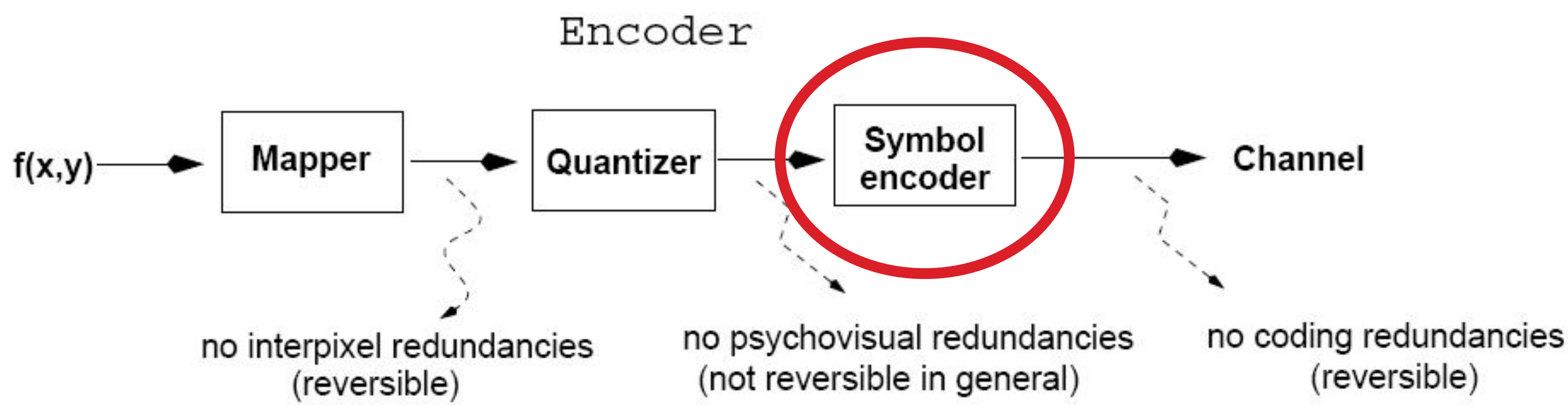
- **Mapper:** transforms data to account for interpixel redundancies.

Image Compression Model (cont'd)



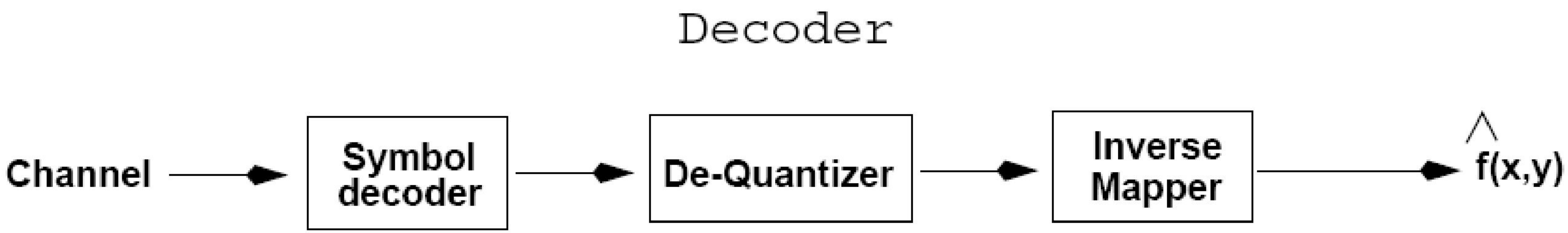
- **Quantizer:** quantizes the data to account for psychovisual redundancies.

Image Compression Model (cont'd)



- **Symbol encoder:** encodes the data to account for coding redundancies.

Image Compression Models (cont'd)



- The decoder applies the inverse steps.

- Note that quantization is irreversible in general.

Fidelity Criteria

- How close is $f(x,y)$ $\hat{f}(x,y)$

- Criteria
  - Subjective: based on human observers
  - Objective: mathematically defined criteria

Subjective Fidelity Criteria

Value	Rating	Description
1	Excellent	An image of extremely high quality, as good as you could desire.
2	Fine	An image of high quality, providing enjoyable viewing. Interference is not objectionable.
3	Passable	An image of acceptable quality. Interference is not objectionable.
4	Marginal	An image of poor quality; you wish you could improve it. Interference is somewhat objectionable.
5	Inferior	A very poor image, but you could watch it. Objectionable interference is definitely present.
6	Unusable	An image so bad that you could not watch it.

Objective Fidelity Criteria

- Root mean square error (RMS)

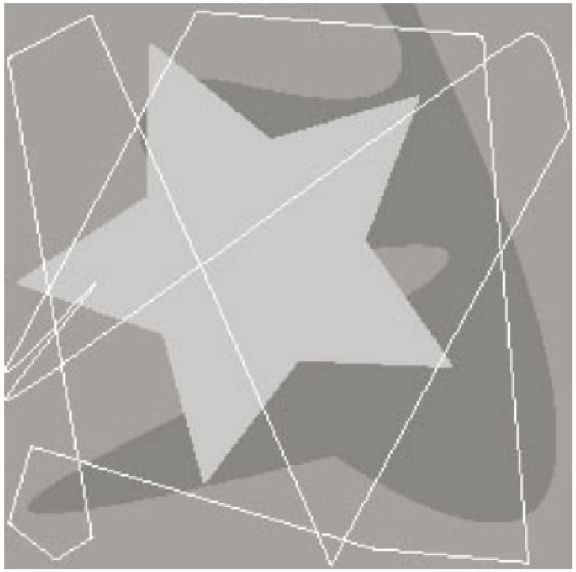
$$e_{rms} = \sqrt{\frac{1}{MN}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\left(\hat{f}(x,y) - f(x,y)\right)^2}$$

- Mean-square signal-to-noise ratio (SNR)

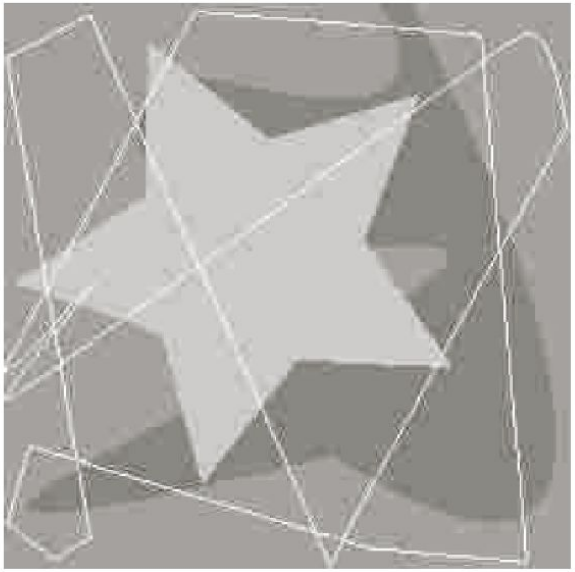
$$SNR_{ms} = \frac{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\left(\hat{f}(x,y)\right)^2}{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\left(\hat{f}(x,y) - f(x,y)\right)^2}$$

Subjective vs Objective Fidelity Criteria

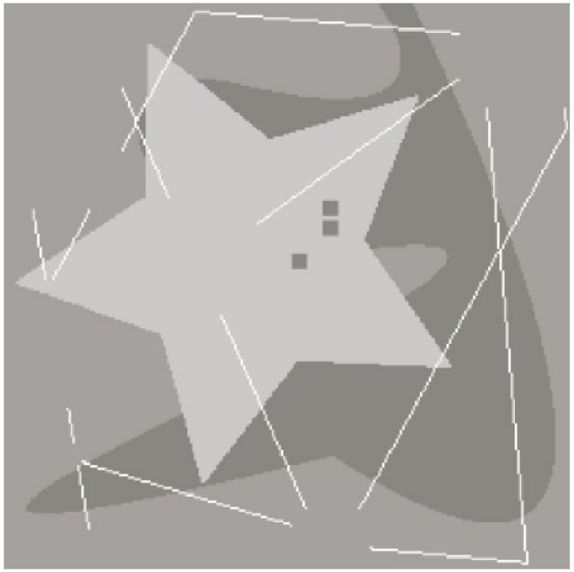
RMSE = 5.17



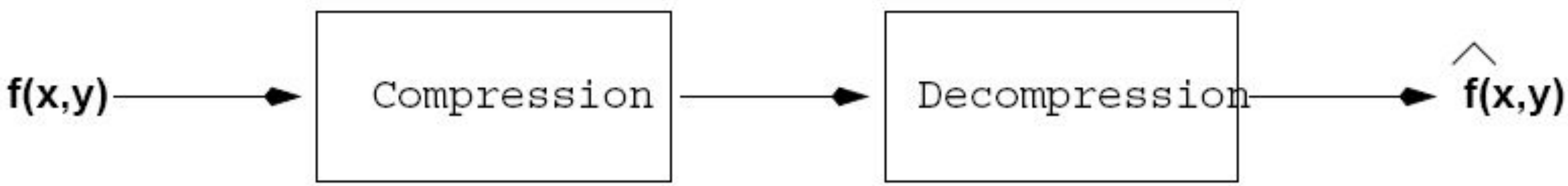
RMSE = 15.67



RMSE = 14.17



Lossless Compression



$$e(x,y) = \hat{f}(x,y) - f(x,y) = 0$$