Any Differences?

Image Compression.

JPEG

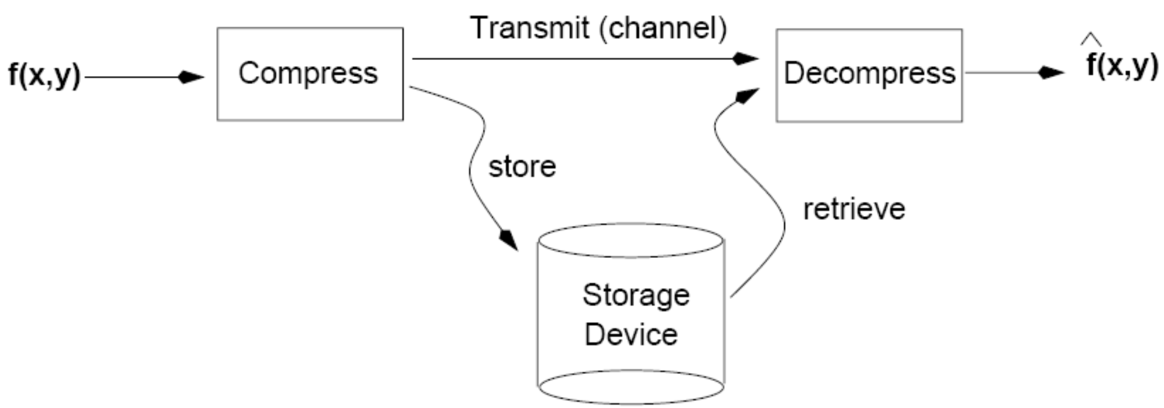
Size-270 KB

Size-22 KB

“Without Compression a CD store only 200 Pictures or 8 Seconds Movie”

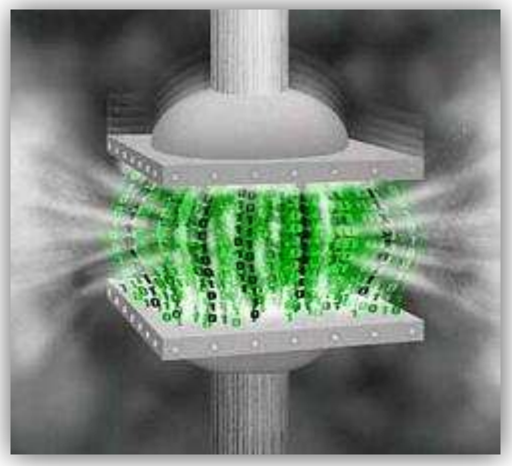
What is Image Compression?

- Image compression is the process of reducing the amount of data required to represent an image



Why Compression?

Storage



Ease of Transmission

Compression Fundamentals

- ✓ Image compression involves reducing the size of image data files, while retaining necessary information
- ✓ Retaining necessary information depends upon the application
- ✓ Image segmentation methods, which are primarily a data reduction process, can be used for compression
- ✓ The ratio of the original, uncompressed image file and the compressed file is referred to as the *compression ratio*

Why Compression?

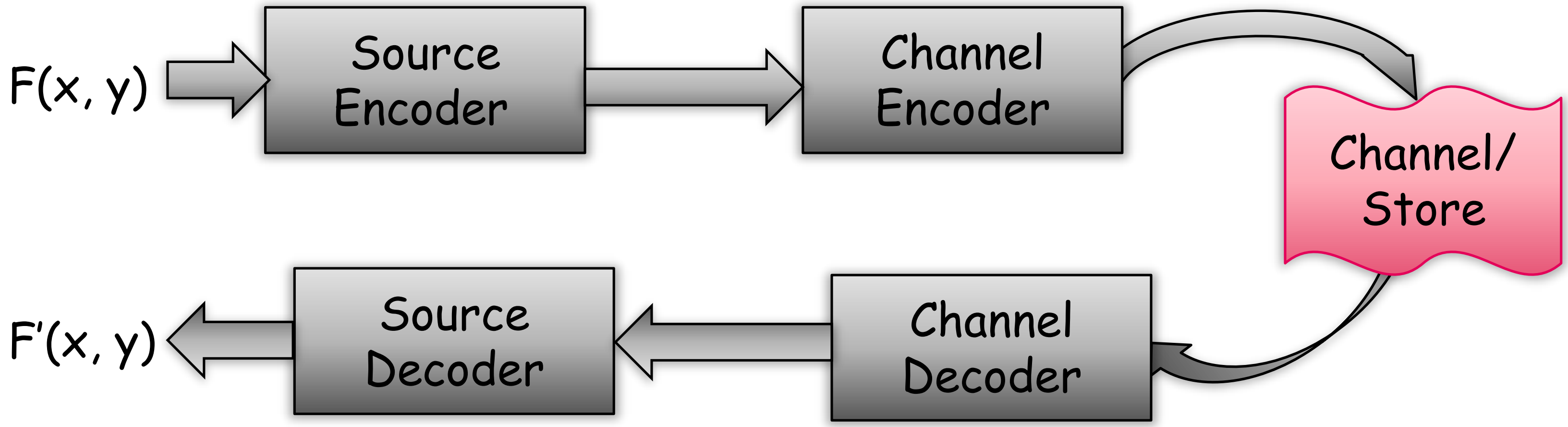
- ✓ Now, consider the transmission of video images, where we need multiple frames per second, If we consider just one second of video data that has been digitized at 640x480 pixels per frame, and requiring 15 frames per second for interlaced video, then:
- ✓ Waiting 35 seconds for one second's worth of video is not exactly real time.

EXAMPLE 10.1.6: To transmit one second of interlaced video that has been digitized at 640x480 pixels:

$$\frac{(640 \times 480 \times 15\ frames/\mathbf{sec})(24 bits/pixel)}{3 \times 1024 \times 1024 bits/\mathbf{sec})} \approx 35\ \mathbf{sec}onds$$

- ✓ Even attempting to transmit uncompressed video over the highest speed Internet connection is impractical

Image Compression General Models

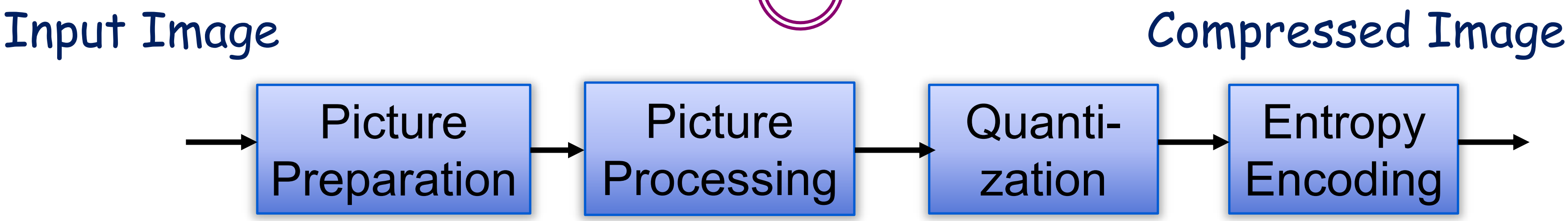


- Some image Compression Standard
  - JPEG-Based on DCT
  - JPEG 2000-Based on DWT
  - GIF-Graphics Interchange Format etc.

Data ≠ Information

- Data and information are not synonymous terms.
- Data is the means by which information is conveyed.
- Data compression aims to reduce the amount of data required to represent a given quantity of information while preserving as much information as possible.
- Image compression is an irreversible process.
- Some Transform used in Image Compression
  - DCT-Discrete Cosine Transform
  - DWT-Discrete wavelet Transform etc.

Compression Steps



- **Preparation**: analog to digital conversion.
- **Processing**: transform data into a domain easier to compress.
- **Quantization**: reduce precision at which the output is stored.
- **Entropy Encoding**: remove redundant information in the resulting data stream.

Image Compression-Lossy or Lossless

- But its resolution or features should be unchanged for human perception.
- Relative Data Redundancy Rd of the first data set is Rd=1-1/CR
  - ✓ Where CR-Compression Ratio=n1/n2.
  - ✓ n1 and n2 denote the nos. of information carrying units in two data sets that represent the same information.
- In Digital Image Compression, the basics data redundancies are-
  - ✓ Coding Redundancy
  - ✓ Inter pixel Redundancy
  - ✓ Psycho-visual Redundancy

Data Redundancies

Compression algorithms are developed by taking advantage of the redundancy that is inherent in image data

Coding Redundancy

✓ Occurs when the data used to represent the image is not utilized in an optimal manner

Interpixel Redundancy

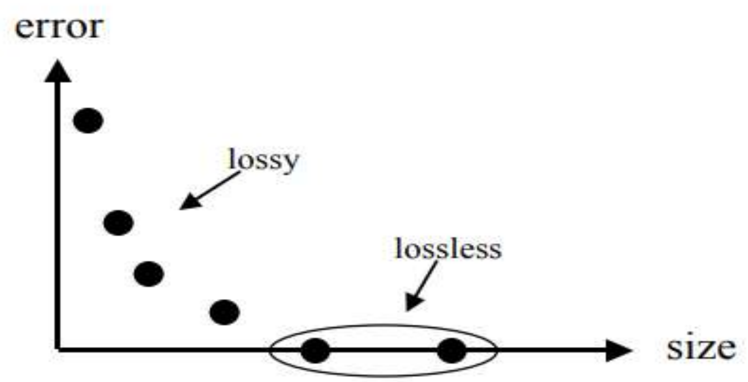
✓ Occurs because adjacent pixels tend to be highly correlated, in most images the brightness levels do not change rapidly, but change gradually.

Psychovisual Redundancy

✓ Some information is more important to the human visual system than other types of information

Trade Off: **Quality** vs. **Compression**

- **Lossless Compression** (Information Preserving) - *Original can be recovered exactly. Higher quality, bigger.*
- **Lossy Compression**- *Only an approximation of the original can be recovered. Lower quality, smaller*.



Data Redundancies

Compression algorithms are developed by taking advantage of the redundancy that is inherent in image data

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Psychovisual Redundancy

✓ Some information is more important to the human visual system than other types of information

Coding Redundancy

- Length of the code words (e.g., 8-bit codes for grey value images) is larger than needed.
- Coding redundancy is associated with the representation of information.
- The information is represented in the form of codes.
- If the gray levels of an image are coded in a way that uses more code symbols than absolutely necessary to represent each gray level then the resulting image is said to contain coding redundancy.

Coding Redundancy

- Let n_k be the number of times that intensity $k \in [0, L-1]$ occurs in an $M \times N$ image, and r_k a random variable representing intensities. Probability of r_k:

$$p_r(r_k) = \frac{n_k}{MN}, \quad k = 0, 1, \ldots, L-1$$

- If r_k is represented by $l(r_k)$ bits, the average number of bits per pixel is:

$$L_{\text{avg}} = \sum_{k=0}^{L-1} l(r_k)\, p_r(r_k)$$

- Total number of bits: $MN\, L_{\text{avg}}$.
  For a fixed-length code of m bits: $L_{\text{avg}} = m$.

Coding Redundancy

Measuring the Information
I=Log[1/P(E)]
=-log P(E)

r_k	$p_r(r_k)$	Code 1	$l_1(r_k)$	Code 2	$l_2(r_k)$
$r_{87} = 87$	0.25	01010111	8	01	2
$r_{128} = 128$	0.47	10000000	8	1	1
$r_{186} = 186$	0.25	11000100	8	000	3
$r_{255} = 255$	0.03	11111111	8	001	3
r_k for $k \neq 87, 128, 186, 255$	0	—	8	—	0

- Code 1: fixed-length 8-bit code: $L_{\text{avg}} = 8$ bits
- Code 2: variable-length code: $L_{\text{avg}} = 1.81$ bits
  $C = \frac{8}{1.81} = 4.42$, $R = 1 - \frac{1}{4.42} = 0.774$ (77.4% of original data is redundant)

Measuring Information

- These methods, from information theory, are not limited to images, but apply to any digital information. Here uses "symbols" instead of "pixel values" and "sources" instead of "images"

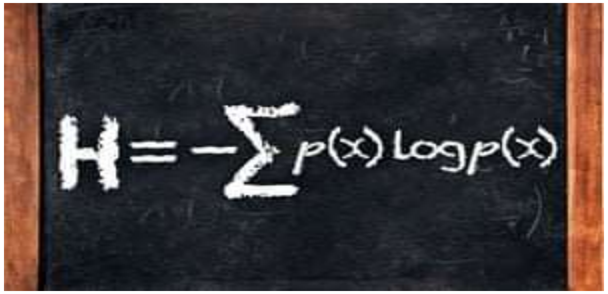
Given a zero-memory source of statistically independent random events (source symbols) $\{a_j\}$ occurring with probability $P(a_j)$, $j = 1, 2, \ldots J$.

- Source entropy: $H = -\sum_{j=1}^{J} P(a_j) \log P(a_j)$
- Estimated source entropy for L-level image:

$$\tilde{H} = -\sum_{k=0}^{L-1} p_r(r_k) \log_2 p_r(r_k)$$

- $\tilde{H}$ is the minimum number of bits per pixel needed to code the image.

Shanon’s First Theorem



- Shanon looked at group of n consecutive source symbols with a single code word (rather than one code word per source symbol) and showed that-

$$\lim_{n \to \infty} \left| \frac{L_{avg}}{n} \right| = H$$

- Where Lavg is the average number of code symbols required to represents all n symbols groups.

Coding Redundancy

r_k	$p_r(r_k)$	Code 1	$l_1(r_k)$	Code 2	$l_2(r_k)$
$r_{87} = 87$	0.25	01010111	8	01	2
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$r_{255} = 255$	0.03	11111111	8	001	3
r_k for $k \neq 87, 128, 186, 255$	0	—	8	—	0

- Code 2: variable-length code: $L_{\text{avg}} = 1.81$ bits
- Entropy

$$\tilde{H} = -(0.25 \log_2 0.25 + 0.47 \log_2 0.47 + 0.25 \log_2 0.25 + 0.03 \log_2 0.03) = 1.6614 \text{ bits}$$

- Is there a code attaining the lower bound of 1.6614 bits/pixel ?

Two common algorithms: Huffman coding and LZW coding

Fidelity Criteria

Input image $f(x,y)$, approximation $\widehat{f}(x,y)$, both of size $M \times N$.

- Root-mean square error:

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

- Mean-square signal-to-noise ratio:

$$\text{SNR}_{\text{rms}} = \frac{\sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \widehat{f}(x,y)^2}{\sum_{x=0}^{M-1} \sum_{y=0}^{N-1} \left(\widehat{f}(x,y) - f(x,y) \right)^2}$$

RMS Error

a b c

The rms of the three images are 5.17, 15.67, and 14.17.

Image Compression

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.

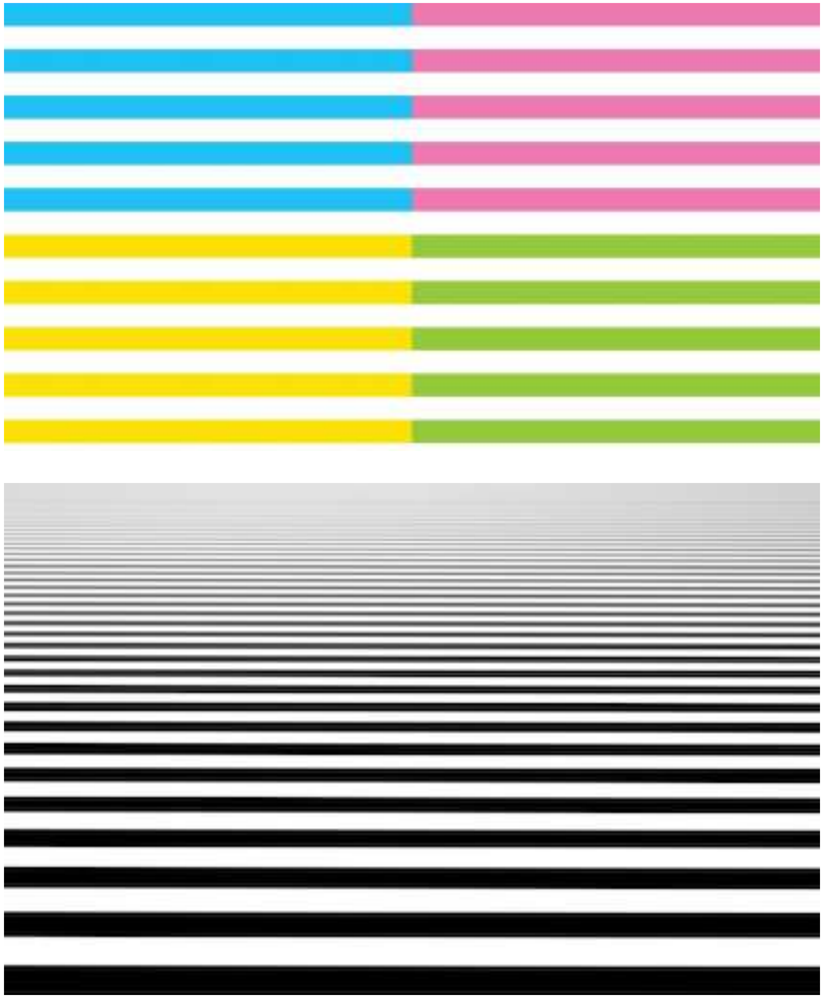
Inter-Pixel Redundancy

- **Inter-Pixel Spatial Redundancy:**
  - Inter-pixel redundancy is due to the correlation between the neighboring pixels in an image.
  - The value of any given pixel can be predicated from the value of its neighbors (Highly Correlated).
  - The information carried by individual pixel is relatively small.
  - To reduce inter-pixel redundancy the difference between adjacent pixels can be used to represent an image.

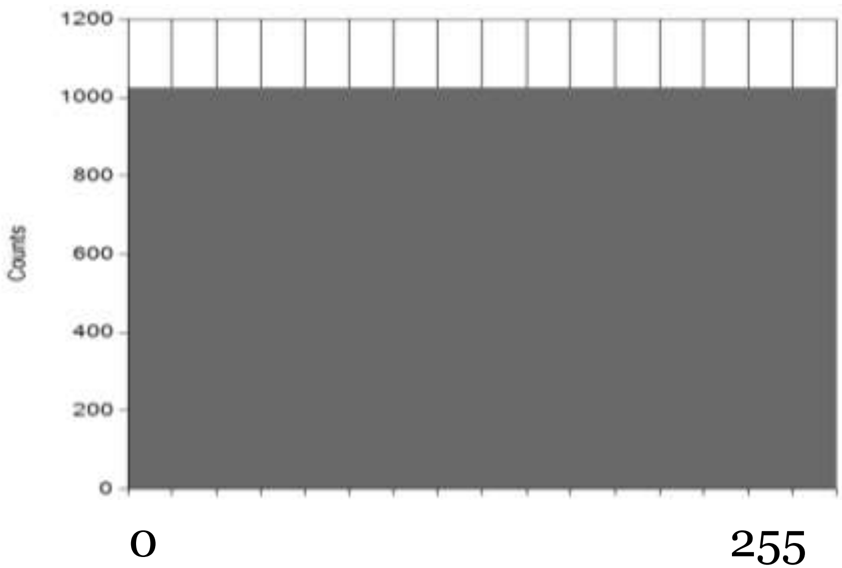
- **Inter-Pixel Temporal Redundancy**
  - Inter-Pixel temporal redundancy is the statistical correlation between pixels from successive frames in video sequence.
  - Temporal redundancy is also called inter-frame redundancy.
  - Removing a large amount of redundancy leads to efficient video compression.

Algorithm: Run Length Coding

Spatial Redundancy



- Its Histogram (Ignore White Background)
- Just variable length coding is not sufficient?

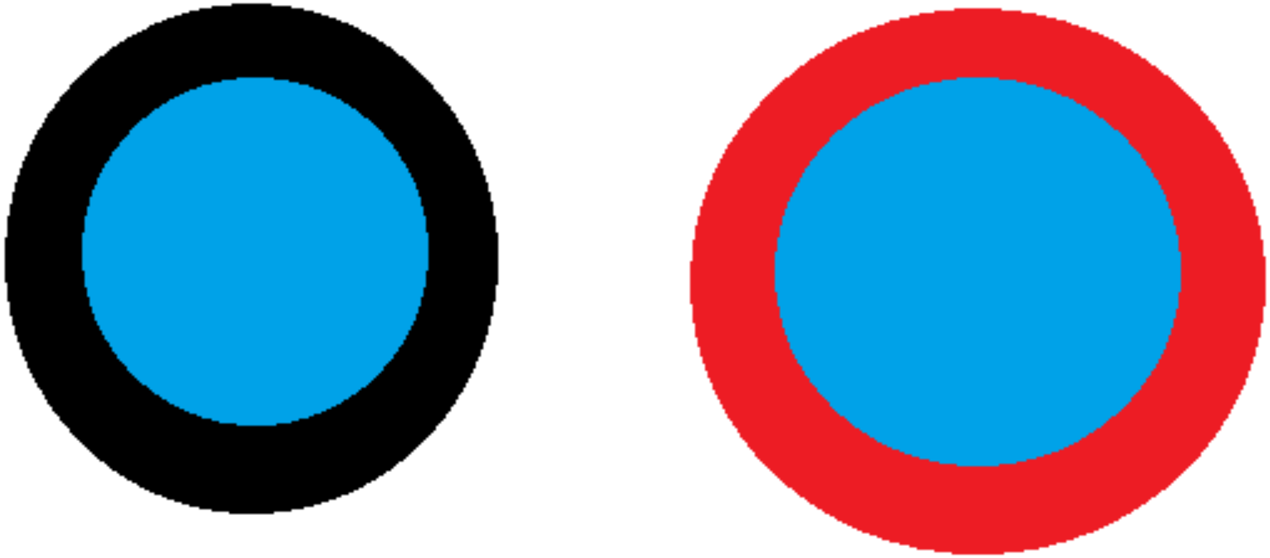


Run Length Algorithm

- Lets Discuss *(During Lecture!)*
  - Consider one Binary Image
  - Its vector representation
  - Size without compression
  - Size after run length algorithm

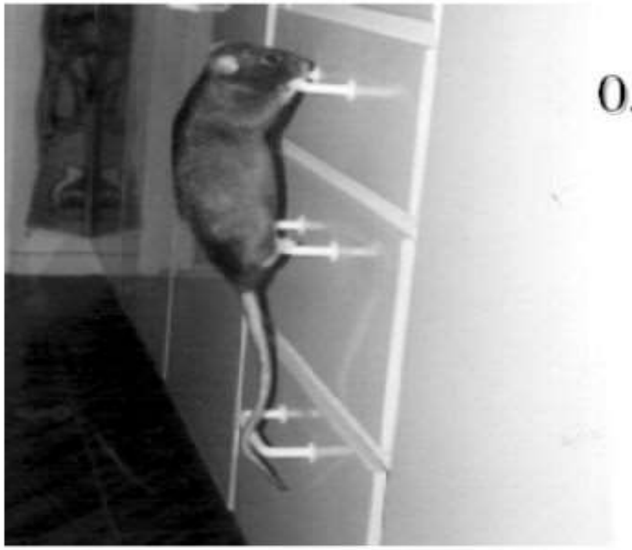
1	1	1	1	1	1
1	1	1	1	0	0
1	1	1	1	1	1
0	0	1	1	1	1
1	1	1	1	1	1
0	0	0	0	0	0

Which have higher intensity (Centre Circle)?

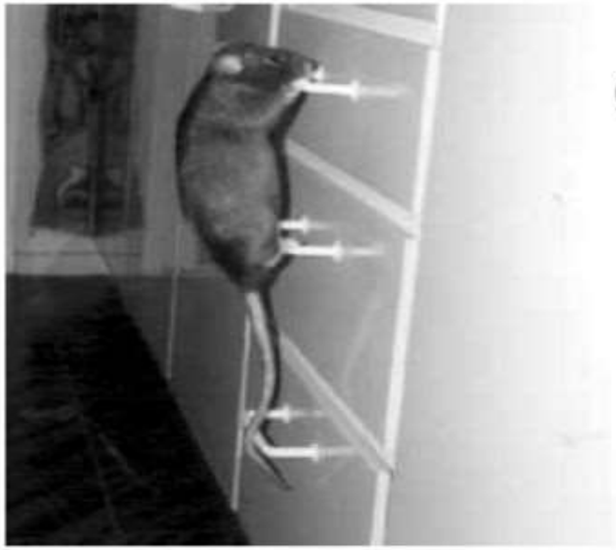


Psychovisual Redundancy

If the image will only be used for visual observation (i.e. illustrations on the web etc), a lot of the information is usually psycho-visually redundant. It can be removed without changing the visual quality of the image. This kind of compression is usually irreversible.



0.5kB

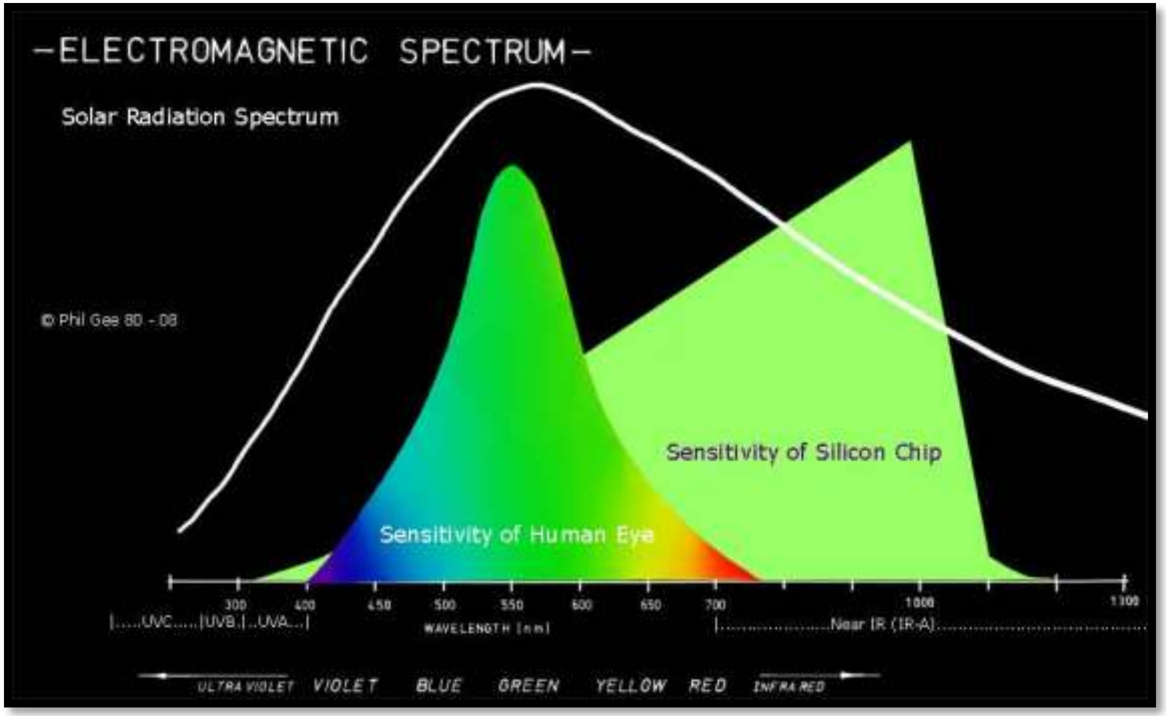


0.05kB

21

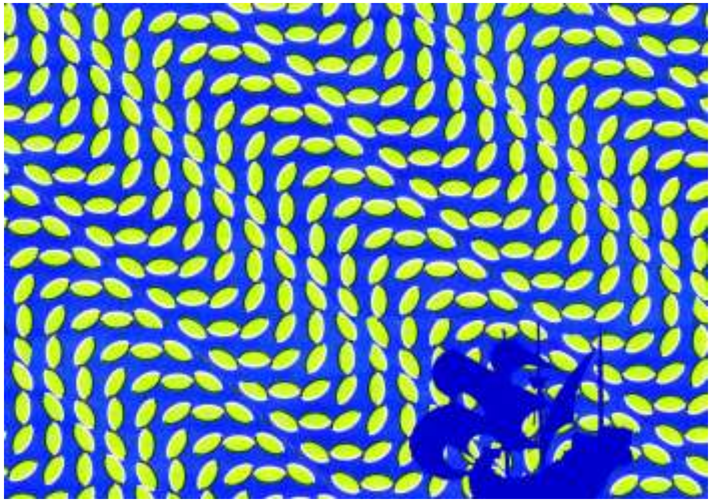
Psychovisual Redundancy

- The Psychovisual redundancies exist because human perception does not involve quantitative analysis of every pixel or luminance value in the image.
- It's elimination is real visual information is possible only because the information itself is not essential for normal visual processing.



Psychovisual Redundancy

- We're more sensitive to differences between dark intensities than bright ones. Encode log(intensity) instead of intensity.
- We're more sensitive to differences of intensity in green than red or blue.
- Use variable quantization: devote most bits to green, fewest to blue.



Some Basic Compression Methods

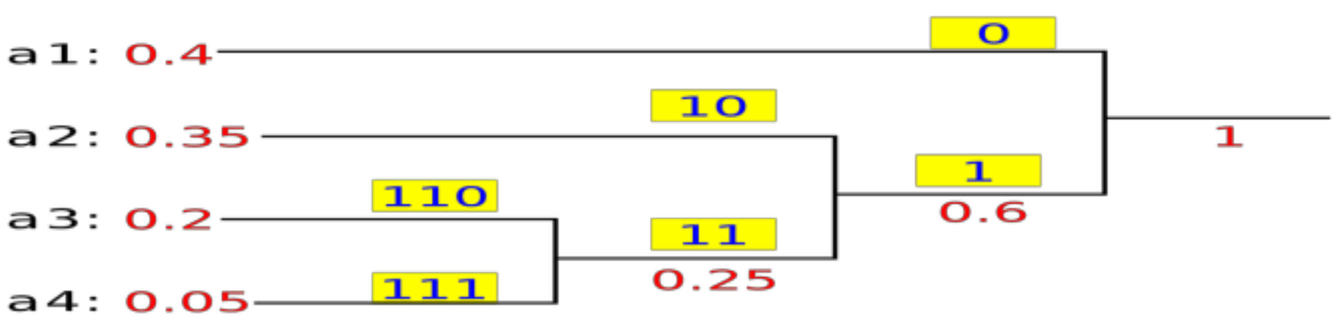
- Huffman coding *(Will Discuss in this Lecture- Coding Redundancy)*
- Golomb Coding
- Arithmetic Coding
- LZW Coding
- Run Length Coding *(Already Discussed)*
- Symbol Based Coding
- Bit Plane Coding *(**You are familiar**)*

....many more for detail:

Image Processing Gonzalez Book (Chapter 8-Image Compression)

Huffman Coding

Original source		Source reduction			
Symbol	Probability	1	2	3	4
a_2	0.4	0.4	0.4	0.4	0.6
a_6	0.3	0.3	0.3	0.3	0.4
a_1	0.1	0.1	0.2	0.3	
a_4	0.1	0.1	0.1		
a_3	0.06	0.1			
a_5	0.04				



Huffman Coding

FIGURE 8.12 Huffman code assignment procedure.

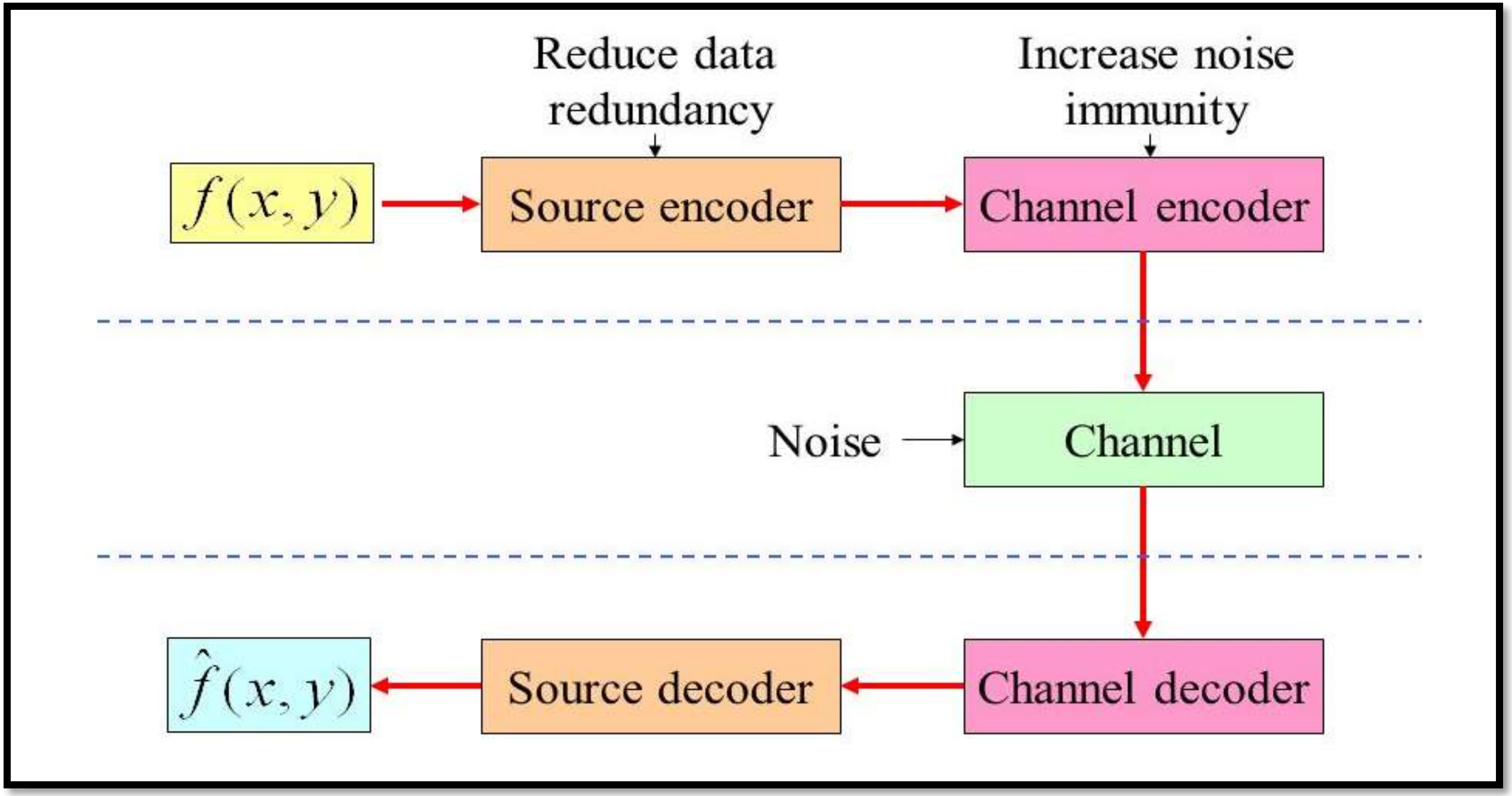
Original source			Source reduction							
Sym.	Prob.	Code	1		2		3		4	
a_2	0.4	1	0.4	1	0.4	1	0.4	1	0.6	0
a_6	0.3	00	0.3	00	0.3	00	0.3	00	0.4	1
a_1	0.1	011	0.1	011	0.2	010	0.3	01		
a_4	0.1	0100	0.1	0100	0.1	011				
a_3	0.06	01010	0.1	0101						
a_5	0.04	01011								

Average length = 1*0.4 +2*0.3+3*0.3+4*0.1+0.06*5 +0.04*5 -2.2

$$L_{avg} = (0.4)(1) + (0.3)(2) + (0.1)(3) + (0.1)(4) + (0.06)(5) + (0.04)(5)$$
$$= 2.2 \text{ bits/pixel}$$

Efficiency=H/L_{avg} x 100 %

Channel Encoder & Decoder



Remember

- To study some standard image compression methods

Like JPG, JPEG2000 etc.

Suggested Further Reading

Gonzalez & Woods, Digital Image Processing Book

Chapter 8: Image Compression