Any Differences?

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Motivation towards Compression

- Digital images require huge amounts of space for storage and large bandwidths for transmission.
  - A 640 x 480 color image requires close to 1MB of space.
- Calculate the space required for a SD (Standard Definition 720 * 480) movie of 2 hours running at 30 fps…!! (Answer = 224 GB)
- Imagine how movies came in two CD's / DVD's of very less size than required 224 GB size…?

Motivation Continued…

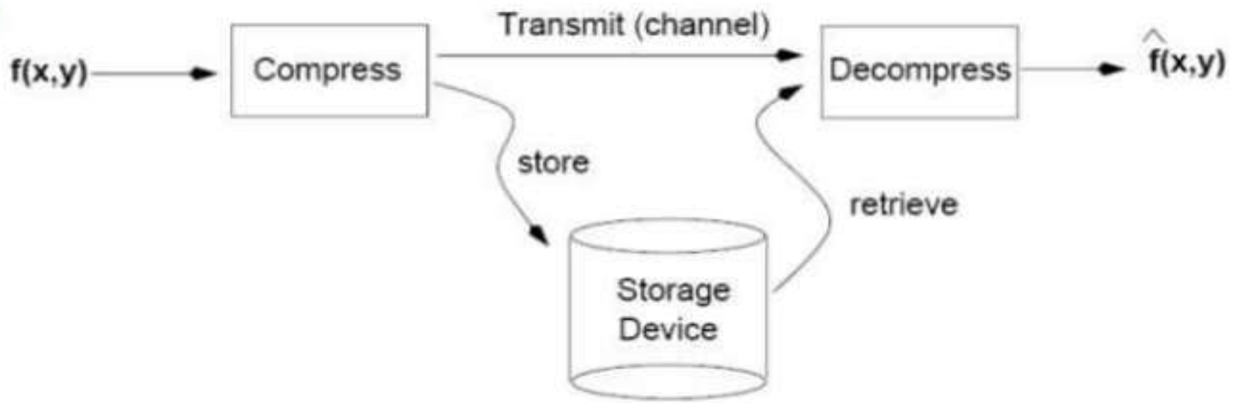
- Have you checked the size of any image when its clicked by your camera and compared it to the ones you share on social media…?
- Imagine the network congestion if all images shared over Whatsapp or any social media did not have any provision for compression.
- What would have been the cost of data transmission then?

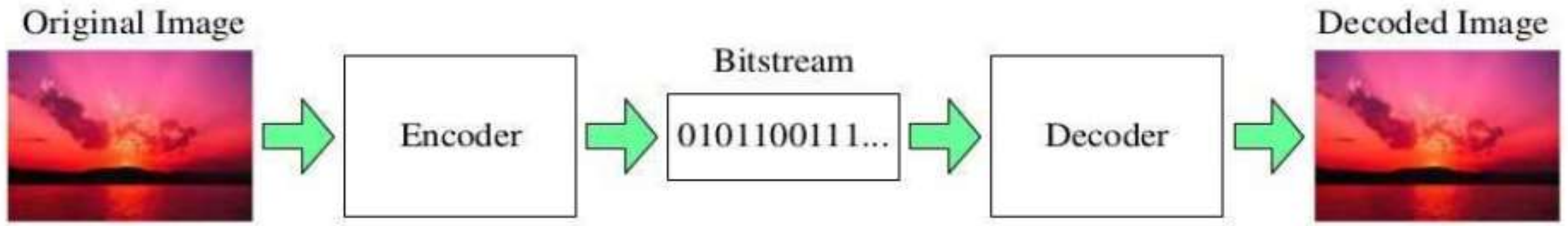
Data Compression

- It aims at reducing the amount of data required to represent a given quantity of information.
- Data is the means by which information is conveyed.
- Information are said to contain **redundant** data.

What is Image Compression?

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





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.

- The same amount of information can be represented by various amount of data.

- For example:-
- *Your wife, Helen, will meet you at Logan Airport in Boston at 5 minutes past 6:00 pm tomorrow night*

- *Your wife will meet you at Logan Airport at 5 minutes past 6:00 pm tomorrow night*

- *Helen will meet you at Logan at 6:00 pm tomorrow night*
- ***All 3 statements represent the same information with different levels of data redundancy, the first line containing maximum redundant data.***

Compression Fundamentals

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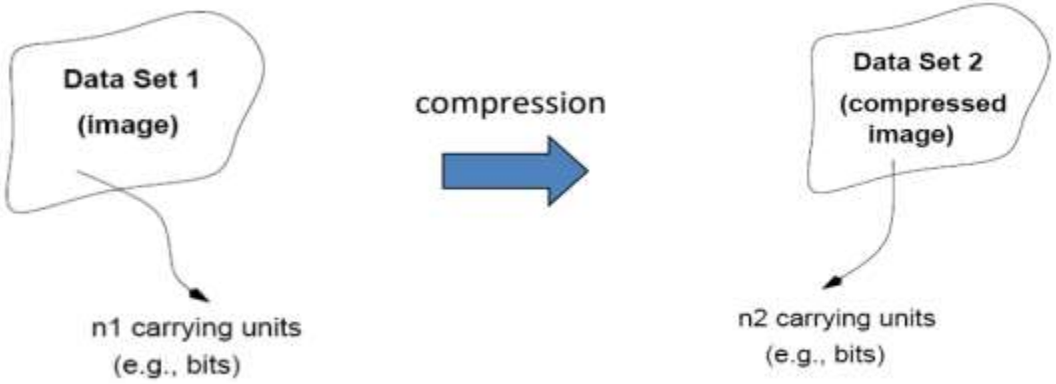
- ✓ Image compression involves reducing the size of image data files, while retaining necessary information
- ✓ Retaining necessary information depends upon the application
- ✓ Image segmentation methods, which are primarily a data reduction process, can be used for compression
- ✓ The ratio of the original,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

Compression Ratio



Compression Ratio: $C_R = \frac{n_1}{n_2}$

Data Redundancy

- Relative 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 $C_R \to \infty$, $R_D \to 1$

if $n_2 \gg n_1$, then $C_R \to 0$, $R_D \to -\infty$

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

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.

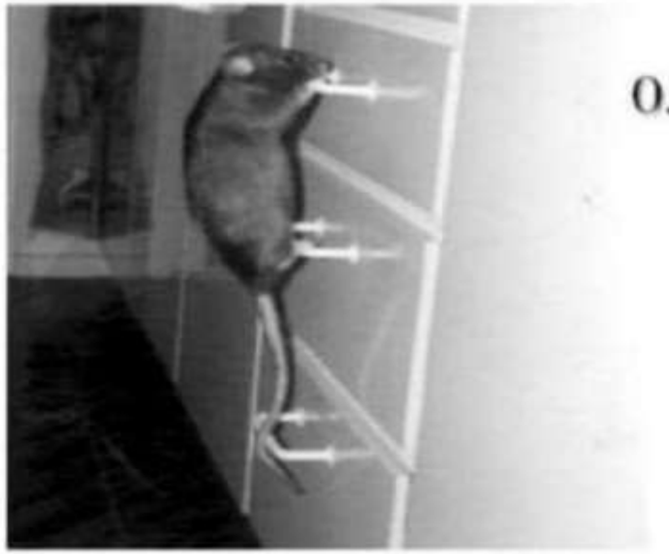
Inter-Pixel Redundancy

- **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.

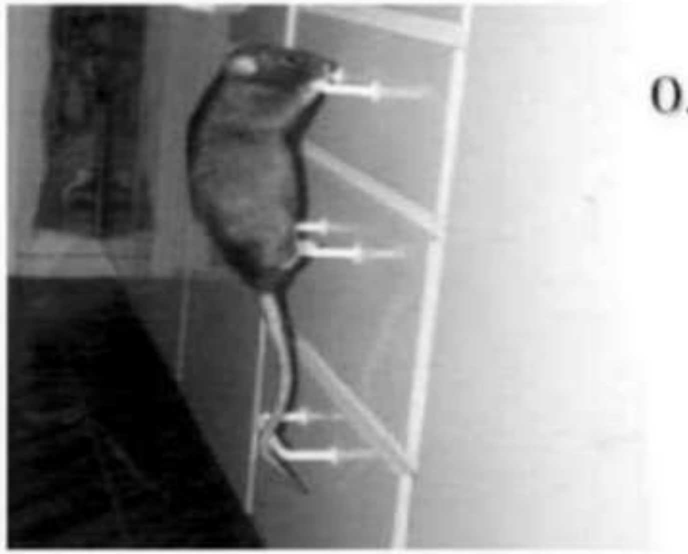
- **Inter-Pixel Temporal Redundancy**
  - Inter-Pixel temporal redundancy is the statistical correlation between pixels from successive frames in video sequence.
  - Temporal redundancy is also called inter-frame redundancy.
  - Removing a large amount of redundancy leads to efficient video compression.

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

Fidelity Criteria

$$f(x,y) \longrightarrow \boxed{\text{Compress}} \longrightarrow g(x,y) \longrightarrow \boxed{\text{Decompress}} \longrightarrow \hat{f}(x,y)$$

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

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

- 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.

Types of Image Compression

- Based on the loss incurred in the compression scheme, it is classified into the following:-
- Lossless
  - Information preserving
  - Low compression ratios
- Lossy
  - Not information preserving
  - High compression ratios
- Trade-off: image quality **vs** compression ratio

Some Basic Compression Methods

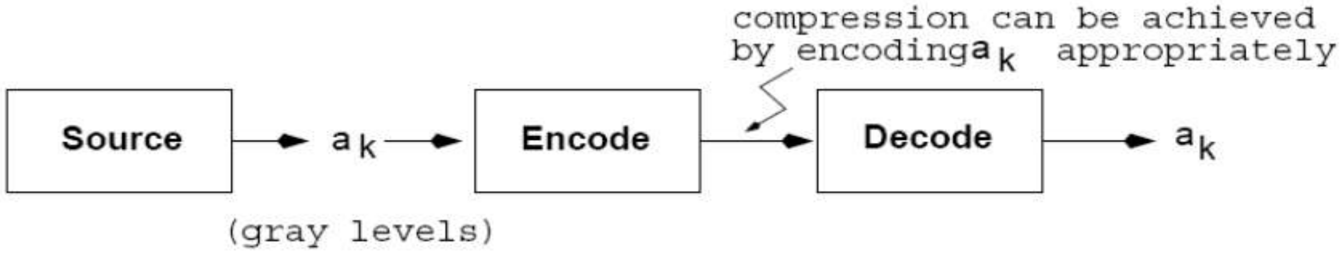
- Huffman coding
- Golomb Coding
- Arithmetic Coding
- LZW Coding
- Run Length Coding *(Already Discussed)*
- Symbol Based Coding
- Bit Plane Coding *(**You are familiar**)*

....many more for detail:

Image Processing Gonzalez Book (Chapter 8-Image Compression)

Lossless Compression

Huffman Coding (coding redundancy)



- A variable-length coding technique.
- Optimal code (i.e., minimizes the number of code symbols per source symbol).
- Assumption: symbols are encoded one at a time!

Arithmetic (or Range) Coding
(coding redundancy)

- No assumption on encoding source symbols one at a time.
  - Sequences of source symbols are encoded together.
  - There is no one-to-one correspondence between source symbols and code words.

- Slower than Huffman coding but typically achieves better compression.

Arithmetic Coding (cont'd)

- A sequence of source symbols is assigned a single arithmetic code word which corresponds to a sub-interval in [0,1].

- As the number of symbols in the message increases, the interval used to represent it becomes smaller.

- Smaller intervals require more information units (i.e., bits) to be represented.

LZW Coding (Interpixel Redundancy)

- Requires no prior knowledge of pixel probability distribution values.
- Assigns fixed length code words to variable length sequences.
- It is a type of **Dictionary based Coding.**
- Included in GIF and TIFF and PDF file formats

LZW Coding

- A codebook (or dictionary) needs to be constructed.
- Initially, the first 256 entries of the dictionary are assigned to the gray levels 0,1,2,..,255 (i.e., assuming 8 bits/pixel)

Consider a 4x4, 8 bit image

39	39	126	126
39	39	126	126
39	39	126	126
39	39	126	126

Initial Dictionary

Dictionary Location	Entry
0	0
1	1
.	.
255	255
256	-
511	-

Lempel-Ziv-Welch (LZW) coding

- Focusses on spatial redundancy.

x

127	127	127	127
25	25	25	25
25	25	127	127
127	127	127	127

Lempel-Ziv-Welch (LZW) coding

- Focusses on spatial redundancy.

Y

127	127	127	127
25	25	25	25
25	25	127	127
127	127	127	127

- Assigns fixed-length code words to variable length sequences.

xxxxxxxxx - 127-127
yyyyyyyyy - 127-127-127
zzzzzzzzz - 25-25

LZW Coding (cont'd)

39	39	126	126
39	39	126	126
39	39	126	126
39	39	126	126

As the encoder examines image pixels, gray level sequences (i.e., **blocks**) that are not in the dictionary are assigned to a new entry.

Dictionary Location	Entry
0	0
1	1
.	.
255	255
256	39-39
511	-

- Is 39 in the dictionary……..Yes
- What about 39-39………….No
- Then add 39-39 in entry 256

Example

39 39 126 126
39 39 126 126
39 39 126 126
39 39 126 126

Concatenated Sequence: CS = CR + P

CR = empty

If CS is found:

(1) No Output

(2) CR=CS

else:

(1) Output D(CR)

(2) Add CS to D

(3) CR=P

Currently Recognized Sequence	Pixel Being Processed	Encoded Output	Dictionary Location (Code Word)	Dictionary Entry
	39			
39	39	39	256	39-39
39	126	39	257	39-126
126	126	126	258	126-126
126	39	126	259	126-39
39	39			
39-39	126	256	260	39-39-126
126	126			
126-126	39	258	261	126-126-39
39	39			
39-39	126			
39-39-126	126	260	262	39-39-126-126
126	39			
126-39	39	259	263	126-39-39
39	126			
39-126	126	257	264	39-126-126
126		126		