IMAGE COMPRESSION: JPEG COMPRESSION

WHAT IS IMAGE COMPRESSION?

Image compression is the process of reducing the size of data files without losing essential information. It enables efficient storage and transmission of data.

JPEG (Joint Photographic Experts Group) compression *is a widely used data compression standard that employs* ***lossy compression*** *techniques to reduce the file size of digital images while maintaining a visually acceptable level of image quality. It is particularly effective for compressing photographs and images with complex color variations.*

TYPES OF COMPRESSION

When information is compressed, the redundancies are removed. Sometimes removing redundancies is not sufficient to reduce the size of the data object to manageable levels. In such cases, some real information is also removed. The primary criterion is that removal of the real information should not perceptly affect the quality of the result. In the case of video, compression causes some information to be lost and a small loss of image quality is generally acceptable to achieve smaller file sizes. This type of compression is called lossy compression. Audio compression, on the other hand, is not lossy. It is called lossless compression.

LOSSY COMPRESSION

- Lossy data compression is used to compress larger files into smaller files. In this compression technique, some specific amount of data and quality are removed (loss) from the original file.
- It takes less memory space from the original file due to the loss of original data and quality. This technique is generally useful for us when the quality of data is not our first priority.
- Lossy data compression is most widely used in JPEG images, MPEG video, and MP3 audio formats.

LOSSLESS COMPRESSION

- Lossless data compression is used to compress the files without losing an original file's quality and data. Simply, we can say that in lossless data compression, file size is reduced, but the quality of data remains the same.
- The main advantage of lossless data compression is that we can restore the original data in its original form after the decompression.
- Lossless data compression is mainly used in the sensitive documents, confidential information, and PNG, RAW, GIF, BMP file formats.

JPEG COMPRESSION

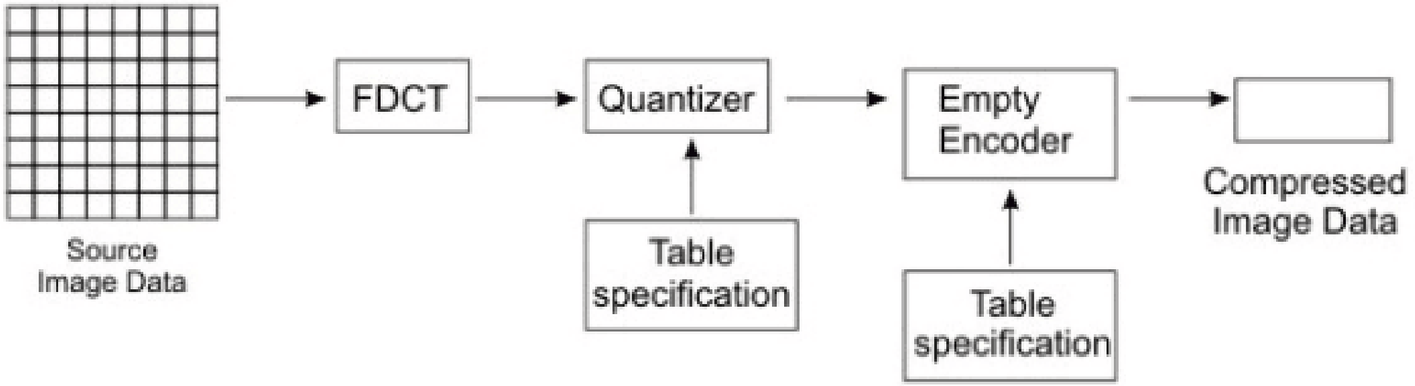


***Fig. 16.1:** JPEG Encoder*

The JPEG compression scheme is lossy, and utilizes forward discrete cosine transform, a uniform quantizer, and entropy encoding. The DCT function removes data redundancy by transforming data from a spatial domain to a frequency domain; the quantizer quantizes DCT co-efficients with weighting functions to generate quantized DCT co-efficients optimized for the human eye; and the entropy encoder minimizes the entropy of quantized DCT co-efficients.

COLOR TRANSFORM

$$Y = 0.3R + 0.6G + 0.1B$$

$$U = \frac{B - Y}{2} + 0.5$$

$$V = \frac{R - Y}{1.6} + 0.5$$

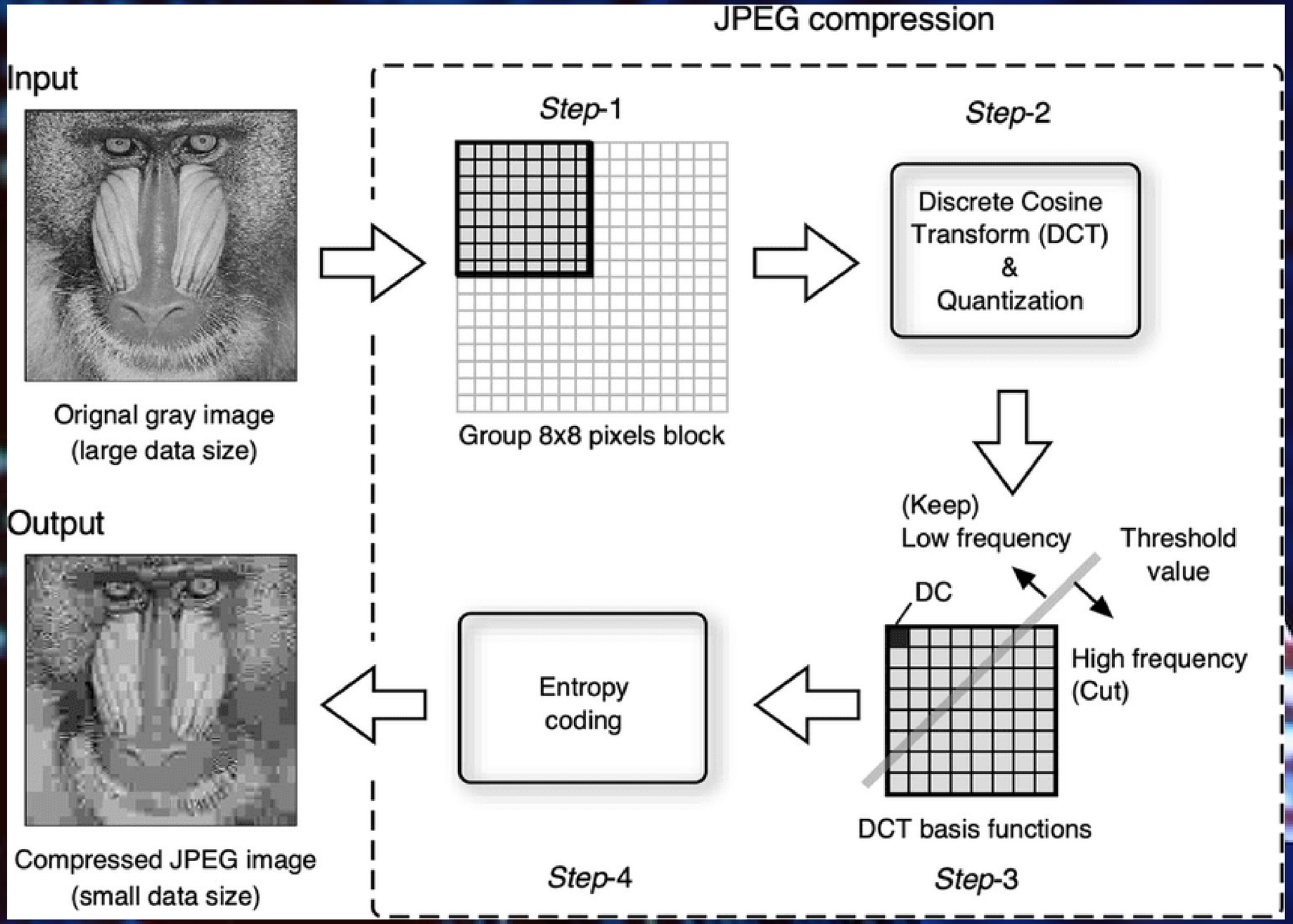
If we have multichannel image, we need to apply the algorithm individually to every channel. We must convert RGB Image to the equivalent YUV format before we can do DCT processing. These formats are more efficient from image compression considerations

DCT

JPEG divides the image into 8x8 pixel blocks. For each block, a mathematical transformation called the Discrete Cosine Transform (DCT) is applied. The DCT converts the pixel values into frequency components, where higher-frequency coefficients typically represent image details and lower-frequency coefficients represent the overall structure.

QUANTIZATION

After the DCT, the resulting coefficients are quantized. Quantization reduces the precision of these coefficients, effectively discarding some of the less significant details. The extent of quantization is controlled by a quantization matrix. It uses DCT co-efficient and provides many-to-one mapping. The quantization process is fundamentally lossy due to its many-to-one mapping. Higher quantization results in more data loss and higher compression.


JPEG compression
Input
Orignal gray image
(large data size)
Output
Compressed JPEG image
(small data size)
Step-1
Group 8x8 pixels block
Step-2
Discrete Cosine
Transform (DCT)
&
Quantization
(Keep)
Low frequency
Threshold
value
DC
High frequency
(Cut)
DCT basis functions
Step-3
Entropy
coding
Step-4

HUFFMAN ENCODING

Step-1: Arrange the symbols in the decreasing order of their probabilities.

Symbol	Probability
a_4	0.6
a_1	0.2
a_2	0.1
a_3	0.05
a_5	0.05

STEP 2,3,4: Listen

Symbol	Probability	Assigned Code
a_4	0.6	0
a_1	0.2	10
a_2	0.1	110
a_3	0.05	1110
a_5	0.05	1111

This is the final processing step of the JPEG encoder. The JPEG standard specifies two entropy coding methods – Huffman and arithmetic coding. The baseline sequential JPEG uses Huffman only, but codecs with both methods are specified for the other modes of operation. Huffman coding requires that one or more sets of coding tables are specified by the application. **The same table used for compression is used needed to decompress it**

Modes of Operation

BASELINE ENCODING

Each block is encoded in a single left-to-right and top-to-bottom scan. It encodes and decodes complete 8x8 blocks with full precision one at a time and supports interleaving of color component.

The previous slides explain baseline encoding

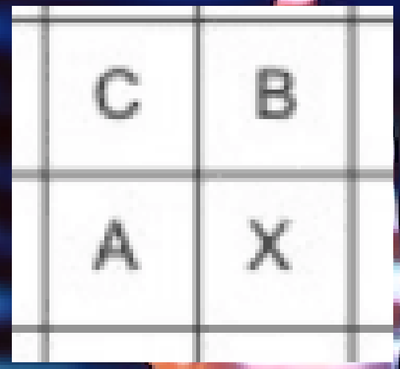
Progressive Encoding

Each block in progressive encoding is encoded in multiple scans, rather than a single one.
Takes much less time to encode and decode, as compared to the single scan of baseline encoding.
You must have experienced this while downloading web pages containing images.
It is very convenient for browsing applications, where crude reconstruction quality at the early scans may be sufficient for quick browsing of a page.

Modes of Operation

Lossless Encoding

- The lossless mode of encoding in JPEG follows a simple predictive coding mechanism, rather than having FDCT + Entropy coder for encoding and Entropy decoder + IDCT for decoding.
- The 8x8 block structure is not used and each pixel is predicted based on three adjacent pixels.
- Lossless JPEG encoding finds applications in transmission and storage of medical images.



Selection Value	Prediction
0	None
1	A
2	B
3	C
4	A+B-C
5	A+(B-C)/2
6	B+(A-C)/2
7	(A+B)/2

Modes of Operation

Hierarchical Encoding

The hierarchical encoding is also known as the pyramidal encoding in which the image to be encoded is organized in a pyramidal structure of multiple resolutions, with the original, that is, the finest resolution image on the lowermost layer and reduced resolution images on the successive upper layers. Each layer decreases its resolution with respect to its adjacent lower layer by a factor of two in either the horizontal or the vertical direction or both. Hierarchical encoding may be regarded as a special case of progressive encoding with increasing spatial resolution between the progressive stages.

Hierarchical encoding is used for applications in which a high-resolution image should be accessed by a low resolution display device.

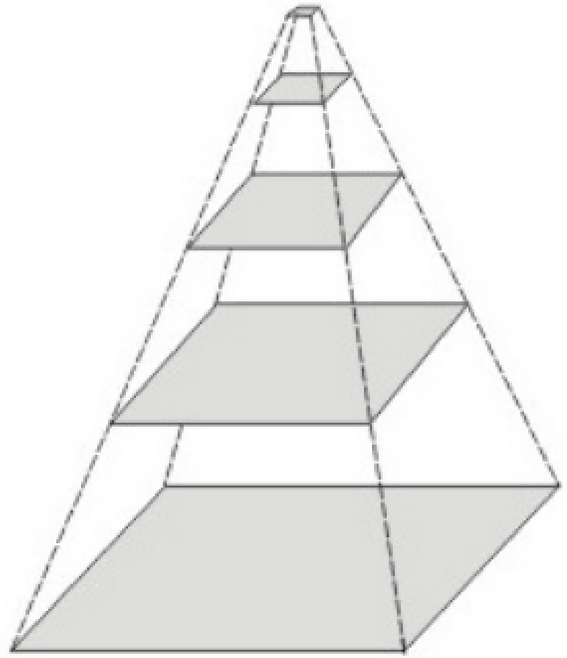


Fig. 16.5 Hierarchical encoding (Pyramid structure)

CONCLUSION

In conclusion, JPEG Compression is a powerful technique for efficient data compression. It allows for high compression ratios while maintaining acceptable image quality.
(And to fill those pesky application forms who have a size limit)

Thank You!