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The Still Image Lossy Compression Standard – JPEG

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INTRODUCTION

Reducing image files will be an important procedure when we transmit files across networks (Wiseman, Schwan, & Widener, 2004) or when we would like to archive libraries. Usually, JPEG can remove the less important data before the compression; hence JPEG will be able to compress images meaningfully, which produces a huge difference in the transmission time and the disk space. The processing time of the compression can be overlapped with the disk access time (Wiseman & Feitelson, 2003).

Another advantage of JPEG is the capability of storing full color information: 24 bits/pixel or 16 million colors, while for example the GIF format, can store only 8 bits/pixel or 256 colors.

One more advantage of JPEG is automatic error recovery. The default compression algorithm of JPEG is based on Huffman codes (Huffman, 1952). Utilizing the tendency of Huffman codes to resynchronize quickly, i.e. recovering after potential decoding errors in most cases, JPEG also recovers quickly after possible errors as is explained here in below.

BACKGROUND

"JPEG" stands for Joint Photographic Experts Group. JPEG is a well known standardized image compression technique for compressing pictures which do not have sharp changes e.g. landscape pictures. JPEG supports either color or grayscale images.

JPEG loses information, so the decompressed picture is not the same as the original one. By adjusting the compression parameters, the degree of loss can be adjusted. The wide use of JPEG is because of three fundamental reasons: reducing the size of image files, storing full color information, automatic error recovery.

The JPEG committee was established in 1986 by the CCITT and ISO Standards organizations with the aim of creating universal standards for image compression. The committee finalized the standard by early 1991 and latter the standard was approved as an International Standards Organization (ISO). Initially, JPEG targeted achieving a 15:1 average compression ratio; however, currently JPEG achieves even better compression ratios. Some real-time, full-motion and video applications also used JPEG. In the mid of the last decade of the 20th century, a new standard called Moving or Motion-JPEG based on the JPEG algorithm was established. This standard aims at compression of video sequences and it stores JPEG format images in a sequential order.

OVERVIEW OF THE JPEG ALGORITHM

JPEG compression algorithm consists of several steps. The steps are summarized in Figure 1. In this section the steps will be comprehensively explained.

The first step transforms the image color into a suitable color space. There are several methods to transform the image into a color space (Hearn & Baker, 1986), (Jain, 1986). The most common methods are the split into YUV components (Hunt, 1995) or the split into RGB components (Laplante & Stoyenko, 1996). These components are interleaved together within the compressed data. The ratio between these components is usually not one to one. When YUV components are used, usually the Y component will have a four times weight. The human eye is less sensitive to the frequency of chrominance information than to the frequency of luminance information which is represented by the Y component in the YUV format. Hence, the Y component gets a higher weight (Awcock, 1996).

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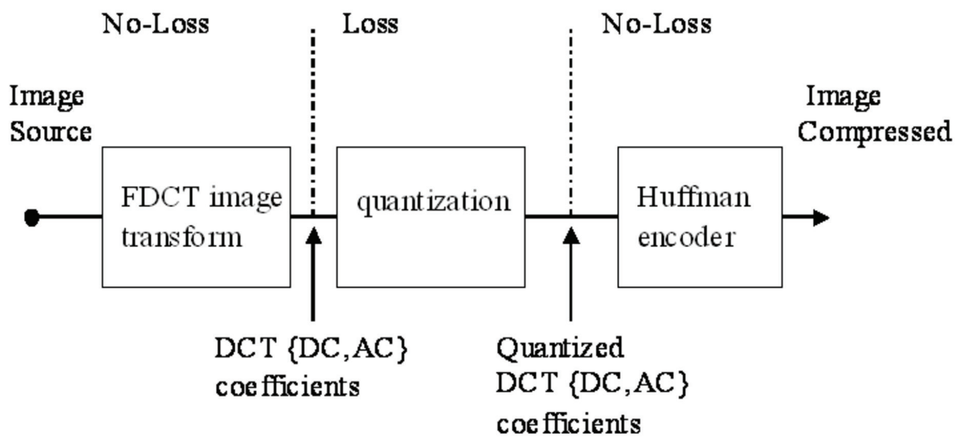
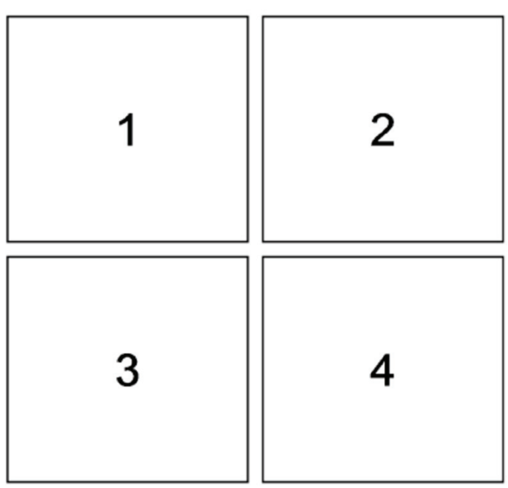
Figure 1. JPEG model for a lossy image compression



JPEG employs Chroma subsampling which is a technique of encoding images by using less resolution for chrominance information than for luminance information, taking advantage of the human eye's lower sensitiveness for color differences than for luminance differences. JPEG supports the obvious 4:1:1 chroma subsampling which denotes the color resolution is quartered, compared to the luminance information i.e. for each sampled element as in Figure 2, there is 4 numbers for luminance and just one number for chrominance; however the default chroma subsampling of JPEG is 4:2:0 which denotes the horizontal sampling is doubled compared to 4:1:1, but as the U and V components are only sampled on each alternate line.

Figure 2. One JPEG sampled element



JPEG allows samples of 8 bits or 12 bits. In the original JPEG all values contained by the same source image must have the same precision. The values are shifted from unsigned integers with range $[0,2^{p}-1]$ to signed integers with range $[-2^{p-1},2^{p-1}-1]$, by reducing 2^{p-1} from the original values, where p can be either 8 or 12. These biased values are then sent to the next step.

The second step groups the pixels into blocks of 8X8 pixels. The order of the blocks is line by line and each line is read from left to right. After the group into blocks, JPEG transforms each block through a Forward Discrete Cosine Transform (FDCT) (Rao & Yip, 1990). The DCT gives a frequency map, with 8X8 or 64 elements. The transformation keeps the low frequency information which a human eye is sensitive to. In each block the DCT coefficients are composed of: A single Direct Current (DC) coefficient number, which represents the average intensity level value in each block and the remaining 63 are named Alternating Current (AC) coefficients. They reflect the frequency information of their row and column. These coefficients indicate the amplitude of a specific frequency component of the input array. The frequency content of the sample set at each frequency is calculated by taking a weighted sum of the entire set.

Table 1 contains the values of weight for one row in a 8x8 matrix:

In other words, these AC values of one row are the results of this formula: