

# Image Compression Alternatives and Media Storage Considerations

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## **Introduction**

The capacity of generation of massive amount of information skyrockets. Image data is perhaps the greatest single threat to the capacity of data networks. As image analysis systems become available on lower and lower cost machines, the capability to produce volume of data becomes available to more and more users. While the market for image processing systems is still small related to the market for word processing and spreadsheets, the newly developed document imaging and desktop publishing market are enormous.

New data storage technologies have been developed to try to keep pace with the potential for data creation. A major technology that may help alleviate some of the problems associated with the massive data creation and data transfer capacity is the general class of algorithms for data compression and decompression. With these techniques, data storage requirements may be compressed by factors of four to 1 to factors of 80 to one. Some of the compressions and decompressions can be handled in real time using specialized computer hardware, while some of the techniques require seconds or even minutes. Some techniques are symmetric in nature (compression and decompression take the same amount of time) while others are significantly asymmetric in nature. Asymmetric techniques generally require considerably more time to compress imagery than to decompress it.

The development of these compression/decompression techniques for images is not necessarily driven by needs and requirements of the scientific image analysis community, but by the much larger desktop publishing and document imaging markets. The good news is that the scientific community can also take advantage of these innovations.

## **Storage**

For earth resources analysis, and particularly for far reaching global change studies, the amount of data that must be processed, even using the current

generation of sensors, is astounding. One Landsat frame (as defined by EOSAT) is 185 km by 185 km or 100 statute miles. For this area, Landsat MSS occupy approximately 32 megabytes of data storage. A data set from TM, covering the same area, is approximately 300 megabytes. To cover the state of Georgia with one date of Landsat TM data would require parts of 14 TM scenes or approximately 4 gigabytes.

<b>CHARACTERISTIC IMAGE SIZE</b>	
Landsat MSS	30 Mby
Landsat TM	300 Mby
SPOT XS	27 Mby
SPOT Pan	36 Mby
Aircraft	75 Mby

A SPOT multispectral scene covers less of the earth's surface than a Landsat scene. A SPOT multispectral scene is approximately 60 km by 60 km and has 3 spectral channels resulting in a data storage of 27 megabytes; however, since it would take over 9.5 SPOT scenes to occupy the area covered by 1 TM scene, the data volume of  $9.5 \times 27$  megabytes = 256 megabytes is similar to the total Landsat TM storage. A SPOT 10 meter resolution panchromatic scene would need 36 megabytes to cover the 60 km by 60 km scene, so a coverage equal to 1 TM scene's area would be 342 megabytes. For vegetation, geologic, and land cover analysis, multiple dates are often necessary to correctly identify different types of crops, locate road networks, etc. If ten dates of data were required with SPOT panchromatic and multispectral data combined with Landsat TM data for the state of Georgia, the data volume would be greater than 10 gigabytes. These data volumes neglect the size of intermediate files for geometric correction, image sharpening, and spectral merges. A reasonable rule of thumb is to allocate at least four to five times the data storage necessary for the raw image data for full analysis space. Thus, for a statewide effort for Georgia, approximately 50 gigabytes of data storage would be necessary.

These sources of data are only a few of the data layers that might be gathered for a statewide analysis. Elevation digital data, soil type information, and existing cultural information such as census data, road networks, and geographic and political boundaries are generally used in a statewide Geographic Information System. The resulting data storage needs overwhelm our capacity to have online

storage available. Archiving and various forms of data compression are necessary to effectively allocate our scarce resources and still meet project requirements.

### **Multispectral/Hyperspectral Instrumentation**

To digitally analyze photographic data, the hard copy negative or positive product must be scanned by a digital image scanning system to produce a digital file. This step is usually the point at which errors are introduced into the image generation process. The distortion must be minimized by gathering photography with a large amount of overlap and only scanning the central part of the image. For example, to scan a color nine by nine inch photograph at scanning resolution of 400 dots per inch will result in a file of approximately 40 megabytes.

There are various types of hyperspectral sensing. The most recent digital imagery system is a new technique being developed for NASA and a number of private companies that involves the use of a gradient detector to provide high spectral resolution in the analysis of reflected light from the earth's surface. This technique uses a detector that has varying bandpass characteristics along wedge to separate the incident radiation into as many as two to four hundred spectral bands with ten nanometer spacing. The output from such an imaging radiometer such as AVIRIS (NASA-AMES/JPL) is essentially a continuous spectral curve, at 16 bit resolution instead of 8, for each resolution element in a scanned image. This type of information may provide discrete information that may allow the efficient and unambiguous discrimination of geological rock types as well as species level discrimination for vegetation. This level of information may be invaluable in allowing better classification potential, but it is still being evaluated in terms of its inherent complexity and huge data production rate.

<b>HYPERSPECTRAL SENSING</b>	
<i>PROTOTYPES</i>	
AIS (JPL)	128 Channels
AVIRIS (JPL)	224 Channels
GEOSCAN	20 Channels
<i>PURPOSE</i>	
Vegetation Discrimination	
Mineral Exploration	
Pollution Detection	

### **Compression/Decompression Techniques**

Numerous methods have been developed for the compression of digital image data. The principal evaluation criterion for the analysis of compressed versus uncompressed imagery is whether a person can tell the difference between the images. A more implementable measure is the Root Mean Square (RMS) error between the original image and the image that has been compressed. Compression rates may be generated by determining the size of the compressed image in terms of number of bits per image pixel for the original image.

There are two categories of compression: lossless, and lossy. Lossless compression means that you can achieve a certain compression factor and be able to exactly reproduce the original image. Lossy compression on the other hand allows some loss, but has the potential for much higher compression rates. Symmetry is related to the time an image takes to be compressed and decompressed. Symmetric means that the time it takes to compress and decompress the image is the same.

### **Compression**

In remote sensing imagery it is well known that there may be significant correlation between different bands of multispectral data. In image processing, a procedure called principal components has been designed to identify correlation between image bands and to create a new set of transformed bands that represent a new

color space in which the new image bands are uncorrelated. Another type of transform coding represents images in terms of spatial frequency of certain base functions. Fourier transforms map an image into a spatial frequency image based on cosine and sin functions. Discrete Cosine Transforms (DCT's) map the same image to spatial frequency image based only on the cosine function. Each pixel may be represented by a series of trigonometric functions and coefficients derived from the images. If all terms of the transform's trigonometric functions are used, compression is minimal. As more terms are deleted, compression goes up, but the resulting compressed image develops certain artifacts of the procedure.

<b>COMPRESSION TYPE</b>	
<i>Lossless</i>	
	Run Length Coding
	Huffman Coding
<i>Lossy</i>	
	Joint Photographic Experts Commission (JPEG) - DCT
	Vector Quantization (VQ)
	Fractal Coding
	Graphics Interchange Format (GIF)

<b>LOSSLESS COMPRESSION</b>	
<i>Advantages</i>	
	Completely Preserves Image
	Can be used for Executables
	Decode and Encode Realtime with Hardware
<i>Disadvantages</i>	
	Low Compression Rate (2 to 4 factor)
	Image Degrades Rapidly at Higher Rates
	Software Implementation Requires CPU Resources

## **Types of Compression**

### **Run Length Coding**

The run length coding stores the image in a sequence of pairs where the first element is the gray level and the second element is the length of the occurrence of that gray value. This coding can be reversible because the sequence of image elements can be reconstructed from the sequence of runs [12].

### **Huffman Coding**

The Huffman code can be constructed by ordering the input probabilities according to their magnitudes. These input probabilities are gotten from the histogram of the image in which the probability of occurrence of gray levels within the image is calculated. The Huffman code continues adding the two smallest probabilities generating a new set. In this way, the set of probabilities is decreased by one, and is ordered again. Equal magnitudes can be ordered in any order. The process stops when the set contains only two probabilities. The decoding process is done by starting at the last couple of probabilities and working backwards. The following example taking from "Digital Image Processing" [12] explains the process in a better way.

Input levels	Input probabilities	Step 1	Step 2	Step 3	Step 4
w1	0.4	0.4	0.4	0.4	0.4
w2	0.3	0.3	0.3	0.3	0.6
w3	0.1	0.1	0.1	0.3	
w4	0.1	0.1	0.2		
w5	0.06	0.1			
w6	0.04				

			Step 1	Step 2	Step 3	Step 4
w1	1	0.4 <- 1	0.4 <- 1	0.4 <- 1	0.4 <- 1	0.4
w2	00	0.3 <- 00	0.3 <- 00	0.3 <- 00	0.3 <-0	0.6
w3	011	0.1 <- 011	0.1 <- 011	0.1 <- 01	0.3	
w4	0100	0.1 <- 0100	0.1 <- 010	0.2		
w5	01010	0.06 <- 0101	0.1			
w6	01011	0.04				

The compact code is :

$$\begin{aligned}
 H &= (-0.4)\log(0.4) - (0.3)\log(0.3) - (0.1)\log(0.1) - (0.1)\log(0.1) - (0.06)\log(0.06) - (0.04)\log(0.04) \\
 &= 2.14 \text{ bits.}
 \end{aligned}$$



## Vector Quantization

### Definition

Vector Quantization (VQ) is a type of encoding that defines a vector representation of non-overlapping area blocks within an image. A vector consists of values representing the data values for each pixel within the region. Using these vectors, clusters of vectors are derived using a spectral distance measure. A code book consisting of the clusters vectors is stored, representing the characteristics of the image. This process is numerically intensive and may be iterative.

- **Advantages**
- Potentially High Compression rates (20 to 40)
- Asymmetric Implementation (Faster Decode) (20 to 40)
- Multispectral Implementation
- **Disadvantages**
- Requires Large Amounts of Training Data
- Encoding is Computationally Expensive
- Possible Problems with Extension to Other Areas

## Fractal Compression

Definition Fractal compression is based on Mandelbrot sets which take advantage of a self similar, scaling dependent, statistical feature of nature (Mandelbrot, 1983). Fractal compression and decompression involves a clustering approach to find regions which show the same characteristics as a sample region independent to rotation and scale. The fractal image compresses images as recursive equations and instructions about how to reproduce them. The equations describe the image in terms of the relationships between its components. The reduction in storage need is due to the fact that fractal compression saves equations and instructions instead of a pixel representation of the image. Real-world images have fractal properties; for example an entire fern. The entire fern looks like each of the fronds in it, each frond resembles the smaller fronds in it, and so on. The more the fern is magnified, the more levels of these fronds are visible [1]. These fractal properties of the real-world images can be mathematically represented. Fractal Transformation is the process

developed to express a real-world image in terms of its fractal properties [2] The following is a comparison between different compressions ratio with observed image quality. A 20:1 ratio means that an image originally 900K will be compressed to 45K, which is one twentieth its original size [2]: - 20:1 to 50:1 - High quality, with little or no observable loss of resolution to the human eyes. - 50:1 to 90:1 - Moderate quality. -100:1 and greater - Poor quality, suitable for thumbnails and previews. Fractal compression has the following advantages and strengths [2]: \* Full 24 bit color images are the focus of this technique. \* Fractal compression is ideally suited to real world image compression, due to the inherent fractal nature of many natural images [3]. \* The degree of compression can be traded off against compression time. Therefore, this technique is ideal for creation of archives. \* Fractal compression provides a high degree of compression. Compressed image size does not generally increase strictly linearly as the image size increases; it increases at a lower rate (i.e. better effective compression for larger and larger images). \* Compression is non symmetrical. Decompression takes significantly less time than compression. Decompression can also be significantly faster than JPEG. \* Fractal compression provides scalability/resolution independence - because the image is defined by a set of equations that can be arbitrarily scaled. It is not possible to create more information in the image as it is enlarged. For this reason, at a certain point during this process, image quality starts being sacrificed for size. This point is however always significantly higher than it is for JPEG or bitmapped images. \* Fractal compression can be used as a component in live video compression. The weaknesses and disadvantages of fractal compression are [2]: \* It is not standard. \* The compression scheme is not documented in the public domain. This situation is currently being reviewed by Iterated Systems [4], and in the near future it is foreseen that the decompressor will be in the public domain. It is essential for source code to become widely available to general adoption. \* The software compression times are very long, unless hardware assisted. \* It is not suited for repeated compression/decompression cycles due to its lossy nature.

- **Advantages**

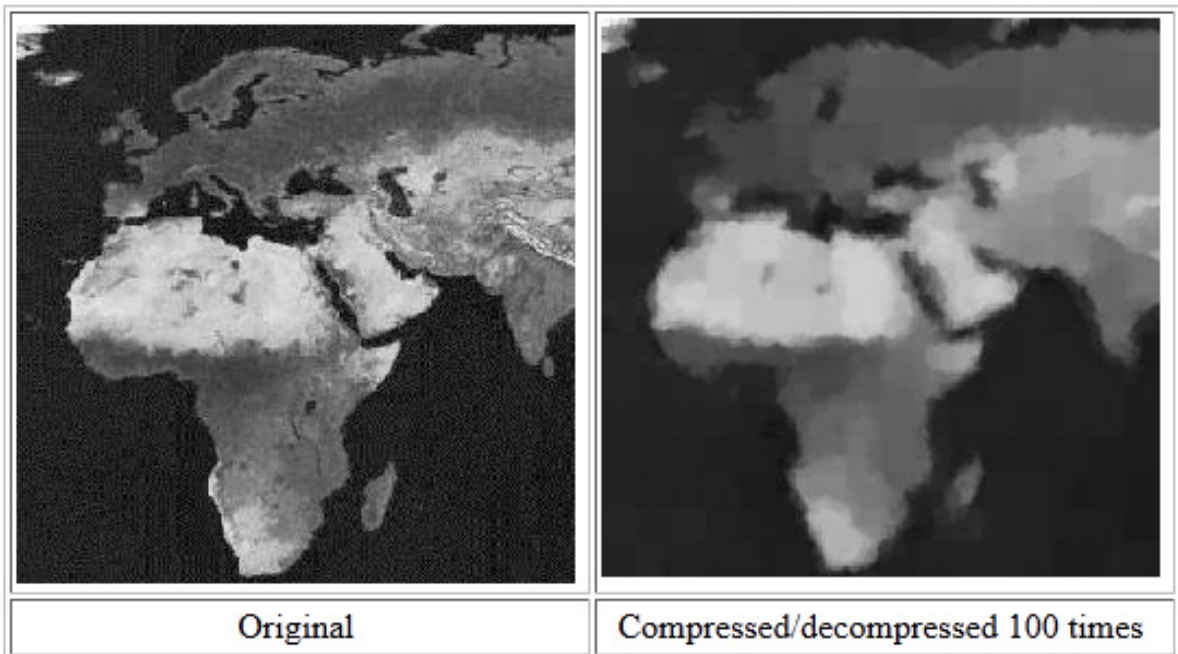
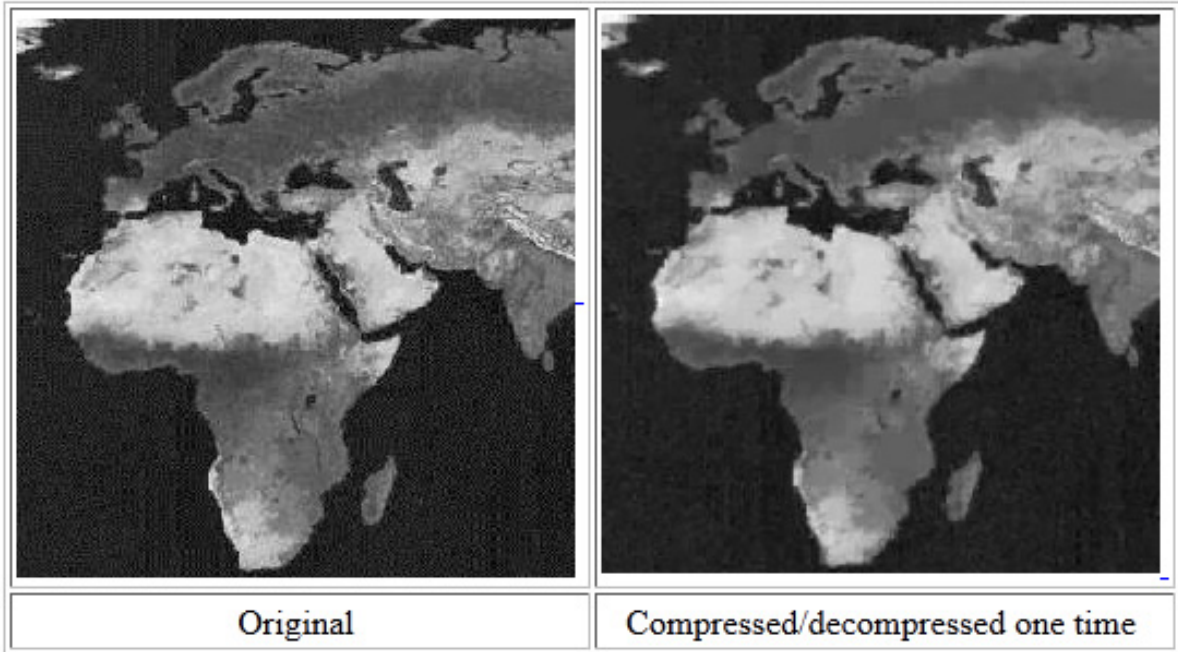
- Highest Potential Compression Rates (25 to > 100)
- Potential for Operating on Compressed Data
- Can Produce Imagery at Multiple Scales
- Real-time Compression with Hardware

- **Disadvantages**

- Software Compression is Time Consuming
- Less Compression for Complex Images

- Non Standard

Example: This example takes an image and compressed/decompressed it once. (see the first row). Then, the image is compressed/decompressed 100 times (see second row).



## Compression JPEG

### JPEG

Definition JPEG stands for Joint Photographic Experts Group. It is a standard compression aimed to color or gray scale images with some degree of complexity (for example, photographs of the `real' world). JPEG is a lossy compression scheme. The greater the compression, the greater the degree of information loss. This can be determined by the user who optimizes the trade-off between resultant image size and image quality. The algorithm exploits some of the ways in which the human eye perceives and analyzes images, so these compressed images still appear to be of high quality when looked at by human eyes . Times for compression/decompression are symmetric.

The algorithm is based on the forward discrete cosine transform (DCT), as applied to a block breakdown of the original image into 8 by 8 blocks, quantized down to a finite set of possible values, and then further transformed (run length encoding) and finally entropy encoded using Huffman or arithmetic coding [5].

With a high quality JPEG compression factor, this technique produces an image 4 to 5 times smaller than GIF images.

JPEG compression shows the following advantages and strengths [2]:

- \* It provides support for full 24 bit color images.
- \* The user can determine the trade-off between image size and image quality.
- \* It is ideal for images of real world scenes, or computer generated images which are complex.
- \* It is platform independent for displaying 24 bit images. This compression technique is currently the most widely used with the algorithm and source code implementations on public domain [6].
- \* It provides fast compression time compared to fractal compression [7].

The weaknesses and disadvantages of JPEG are [2]:

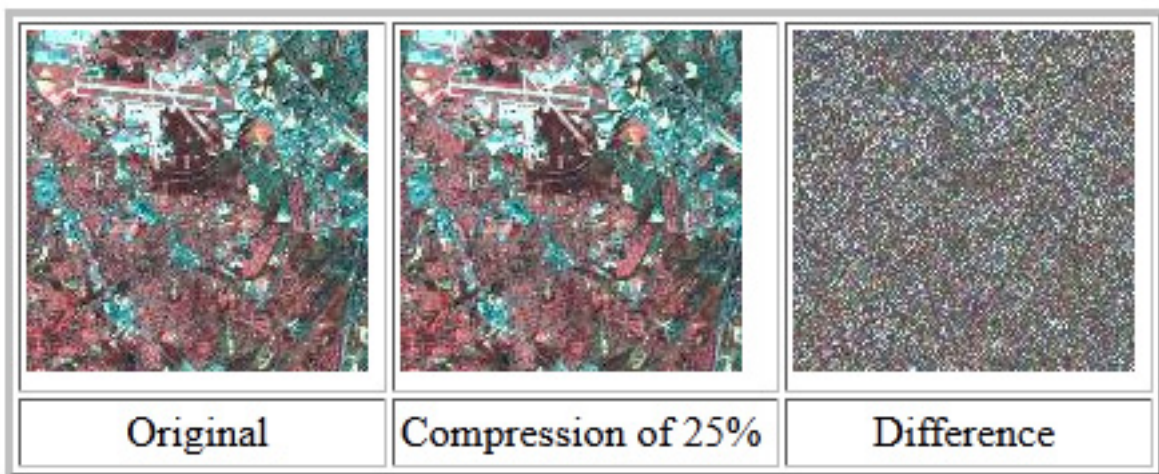
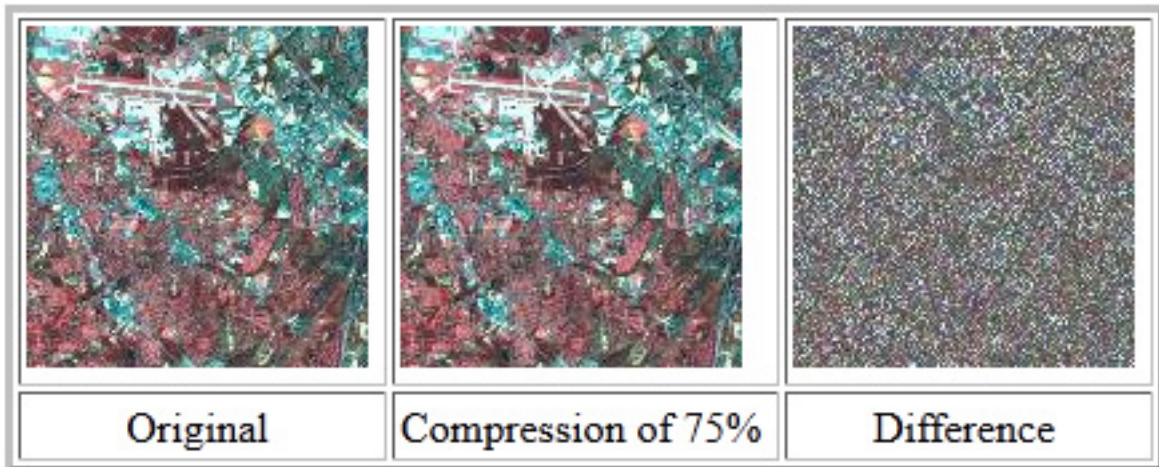
- \* Blockiness results at high image compression ratios.
- \* JPEG compression produces poor image quality when compressing text or images containing sharp edges or lines. Gibb's effect is the name given to this phenomenon where disturbances/ripples may be seen at the margins of objects with sharp borders.
- \* It is not suitable for 1 bit black and white images.
- \* The degree of compression is greater for full color images than it is for gray scale images.
- \* It is not suitable as a strategy for images that are still in the process of editing because every compression/decompression cycle continues to lose information.
- \* It is not recommended for moving images/video.
- \* It is not resolution independent. Therefore, the image is displayed optimally depending on the resolution of the viewing device . [8]

## **JPEG**

- **Advantages**
- International Standards Organization Supported
- With Special Chips can be done in Realtime
- User Selectable Compression rate
- **Disadvantages**
- Lower Compression rates (4 to 10)
- Fast Degradation in Image Quality
- Symmetric Technique
- Individual Channel Encoding

## **Example**

This example shows an image of Savannah in which compression of 75% and 25% were done. The first column on each row contains the original image. The second column is the compressed-decompressed image. The third column is the difference between the original and the compressed-decompressed images.



## GIF

The Graphics Interchange Format is a lossless 8 bit/256 color protocol for "on-line transmission and interchange of raster graphic data in a way that is independent of the hardware used in their creation or display" [6].

GIF is based on LZW compression (Lempel-Ziv-Welch algorithm) [9,10,11]. There is however significant color loss in quantization of 24 bit images to 8 bits. The LZW technique was originally developed for compression of textual materials. This technique compresses files by substituting commonly occurring character sequences with a reference to the first occurrence of that sequence [2].

GIF compression offers the following advantages and strengths [2]:

- \* It is lossless for 8 bit images (since no image degradation occurs, repeated compression/decompression cycles are possible. It is also suitable for images where information loss can not be tolerated).

\* It is ideally suited to stylized images such as line drawings, or those which contain only a limited number of colours (for these images it can produce good compression ratios).

\* It is widely used and supported with no runtime license required.

The weaknesses and disadvantages of GIF compression are [2]:

\* It is not suitable for 24 bit images. When compressing such images, much of the color information is lost during the quantization process which reduces this to 8 bits. Good algorithms can however optimize this process so that the resultant image still has good quality from a human point of view.

\* The compression ratios are low.

\* It is not intended for moving images/video.

\* It is not resolution independent.

## **Conclusions**

- Compression is necessary for remote sensing applications.
- Computing power and greater data store will help to image processing.
- Lossless compression of 10 to > 30 will generally give good results for human interpretation.
- Evaluation of compression algorithms is an application specific task.
- For some techniques, compression is a trade off between degree of compression, image quality and time required for compression/decompression.
- For moving images, MPEG (Motion Pictures Expert Group) is more appropriate.
- For simple images (highly geometric or stylized) GIF is more appropriate.
- For scanned text images TIFF (Tagged Image File Format), or JBIF (Joint Bi-level Image Experts Group, for black and white images) are more appropriate [2].

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