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A Fuzzy and Wavelet-Based Image Compression  
Algorithm

A thesis presented in partial fulfillment  
of the requirements for the degree of  
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## **Abstract**

Nowadays, the Internet and digital image widespread are used in the industry, commerce, military, traffic and all walks of life. However, this kind of general use resulted in required for less transmission time and storage space. Image compression can address the problem of reducing the amount of data to represent a digital image. The image will satisfy the transmission and the preserved request after the compression. With the increasing use some technologies in the image processing, image compression also requires new technology to get the high compression ratio and more better image quality. Therefore, a new standard has been developed by Joint Photographic Experts Group (JPEG). Apart from JPEG, there are other algorithms developed for image compression, Normally, EZW, SHIPT and VQ algorithms. However, they all deal with the calculation of coefficients with too much complexity; as a consequence, compressing still image takes too much time. In the light of these problems, this thesis introduces a new method for dealing with the requirements of the coefficients while retaining the important detail in the image, by employing a Fuzzy Logic technique reduce the number of the coefficients, and then utilizes the Huffman or LZW algorithm to complete the image compression. The algorithm developed in this research, called IWF algorithm, is based on four key techniques: 1) a wavelet transform for decomposition. This technique allows the combination of lossless and lossy compression with extremely high compression rate and image quality. 2) Quantization, this technique generally works by compressing a range of value to a single quantum value. By reducing the number of discrete symbols in a given stream, the stream becomes more compressible. This step in the IWF process is a lossy transformation. 3) Adaptation of Fuzzy logic techniques. This step uses the Fuzzy Logic techniques to handle the wavelet coefficients, enable the wavelet coefficients to have the same value in the high subbands. 4) Adaptation of Lossless data compression techniques.

**Keywords:** Image Compression, Fuzzy Logic, Wavelet transforms, Decomposition, Haar Wavelet transform,

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## List of Abbreviation

- 1-D - 1 Dimension
- 2-D - 2 Dimension
- ANN - Artificial neural Network
- DCT - Discrete Cosine Transformation
- DFT - Discrete Fourier Transformation
- DHT - Discrete Hada Masurium transformation
- DM - Delta Modulation
- DPCM - Differential Pulse Code Modulation
- EZW - Embedded Zerotree Wavelet
- GIF - graphic interchange format
- ISDN - Integrated Services Digital Network
- IWF - Image Compression Based on Wavelet and Fuzzy Logic
- IZ - Isolated Zero
- LIP - List of Insignificant Pixels
- LIS - List of Insignificant Set
- LSP - List of Significant Pixels
- LZW - Lempel Ziv Welch
- MSE - Mean Square Error
- N - Negative
- P - Positive
- PCM - Pulse Code Modulation
- PDF - portable document format
- PSNR - Peak Signal to Noise Ratio
- RMSE - root mean square error
- SPHIT - Set Partitioning in Hierarchical Trees
- TIFF - tagged image file format
- VQ - Vector Quantification
- ZTR - Zero Tree Root

# Chapter 1

## Introduction

### 1.1 Overview of the Current State of Technology

The main goal of image compression is to minimise the data volume of an image with no significant loss of information. The reduction in file size allows more images to be stored in a given amount of disk or memory space, and it also reduces the transmission cost of images sent over the Internet or downloaded from Web pages.

Several different methods exist for the compression of images. All basic image compression groups have advantages and disadvantages. Methods for image compression fall into several major categories:

- Transform-based methods
- Vector quantisation methods
- Pyramid-based techniques
- Hybrid compression methods
- Huffman encoding

Transform-based techniques are renowned to better preserve subjective image quality and are less susceptible to statistical image property changes both inside a single image, and between images. One attractive quality of transform-based techniques is their insensitivity to transmission channel noise. If one transform coefficient is altered during transmission, the resulting image distortion is distributed homogeneously through the image or image section and therefore undesirable disruptive effects are minimised. Predictive compression techniques is transmitted, the error causes image distortion not only in a particular pixel, but within a neighbourhood of pixels because

the predictor involved has a considerable visual effect in a reconstructed image. are plagued with the problem of propagating difference value transmission errors. When an erroneous difference value

Vector quantisation methods have the advantage of only employing a single decoding scheme; comprising of a look-up table only. Vector quantisation methods, however, require complex code, and parameters are very sensitive to image data, often blurring the edges of images.

Pyramid-based techniques have a natural compression ability, and are suitable for dynamic image compression and smart transmission approaches. Pyramid-based methods have shown the potential for further improvement of compression ratios.

Hybrid compression methods generally combine the different dimensionalities of transform compressions with predictive compressions. Hybrid compression methods can also combine predictive approaches with vector quantisation.

Huffman encoding falls into a separate category of image compression, and is distinguished by its provision of optimal compression and error-free decompression.

## **1.2 Research Objectives**

The focus of this study is on developing a new image compression method based on Wavelet transforms and Fuzzy Logic techniques. Many researches have been conducted using Wavelet transforms, however, only very few researches have been done using the fuzzy approach, and the full potential of Fuzzy Logic in the field of image compression has not yet been fully explored.

The general objectives of this study are:

1. To understand the basic concepts of wavelet transform operation.
2. To learn about image compression techniques developed using the Wavelet

transform and Fuzzy Logic.

3. To combine Wavelet transforms and Fuzzy techniques to reduce the computational cost of image compression.

The specific objectives of this study are:

1. To develop a Hybrid Wavelet approach to image compression that would be faster and more efficient than other Fuzzy Logic approaches.
2. To develop a fast and simple Fuzzy coding technique for generating the Wavelet coefficients.

### **1.3 Scope and Limitations of Research**

The scope of this study will include only static images. Both grey-scale and colour images will be used. The scope of the study will not, however, be extended to testing the algorithm on video sequences.

### **1.4 Assumptions**

It is assumed that the performance of the algorithm developed in this research can be compared against other algorithms by compressing and decompressing the same set of images used by other algorithms and inspecting speed, compression ratios, and root mean square errors.

## 1.5 Significance of Research

Image compression addresses the problem of reducing the amount of data required to represent a digital image. From the information theory viewpoint, image compression is the removal of redundant information, namely keeping the non-definite information, and removing the determined information. From a mathematical viewpoint, image compression means to transform a 2-D pixel array into a statistically uncorrelated data set, where such transformation is applied to storage or transmission of the image. At some rate, the compressed image is decompressed to reconstruct the original image or an approximation of it.

Wavelet compression [Antonini, M., Barlaud, M., Mathieu, P., & Daubechies, I. (1992)] is one of the most effective methods of image compression. The algorithm is based on multi-resolutional analysis. Like conventional JPEG compression, the JPEG compression algorithm is based on the DCT transform, and separated the whole image to small sub-images. This method however, returns grainy compressed images, or those reflecting the “block effect”. On the other hand, Wavelet compression algorithm presents an image as sets of real coefficients. After the wavelet decomposition step, the most important image information is located at the low frequency subband. In addition, the other Wavelet coefficients of a typical image are nearly zero, and the image is thus well-approximated with a small number of high-valued Wavelet coefficients. The advantage of Wavelet compression is that, in contrast to JPEG, the Wavelet algorithm does not divide the image into small blocks, but takes and analyzes the whole image. The distinguishing characteristic of Wavelet compression is that it allows arriving at the best compression ratio.

Fuzzy Logic techniques are mainly employed in digital imaging for Contrast Adjustment, Image Enhancement, Image Segmentation, and Image Edge Detection [Tizhoosh, H. R. (1997)].

By and large, Wavelet image compression is gaining acceptance in the internet community for its robustness in the presence of noise during the transmission of images. Unlike predictive methods, Wavelet-based techniques do not generate square image compression artifacts. On the other hand, one advantage of predictive methods over Wavelet-based techniques is that they achieve larger compression ratios in a much less expensive way. In light of this problem, this research amends the weaknesses of pure Wavelet image compression techniques by injecting Fuzzy techniques to speed up the calculation of Wavelet coefficients. As a result, image compression is achieved by utilizing Fuzzy logic in the quantization of Wavelet coefficients, allowing for the preservation of important image details while discarding less significant ones.

## **1.6 Research Methodology**

In devising a new Fuzzy and Wavelet-based image compression algorithm, the following steps have been taken:

1. Study of the basic concepts of image compression.
2. Study of the different colour spaces and implementation of colour space transformation equations.
3. Study of the Run Length Coding.
4. Study and implementation of the Huffman algorithm.
5. Study and implementation the LZW algorithm.
6. Study of Wavelet transforms.
7. Study and implementation of the EZW algorithm.
8. Study of the SPHIT algorithm.
9. Comparison of EZW and SPHIT.
10. Study of JPEG and JPEG 2000.
11. Comparison of JPEG and JPEG 2000.
12. Study of Fuzzy Logic and Fuzzy image processing.

13. Study and analysis of other image compression algorithms based on Wavelet transforms.
14. Study and analysis of other existing image compression algorithms based on Fuzzy logic.

## **1.7 Organisation of the Thesis**

This work is divided into five chapters and is described briefly as follows:

Chapter 2 provides a theoretical framework for the issues relating to different kinds of image compression and Fuzzy Logic techniques (Basic image concepts, image coding, transform coding, Fuzzy Logic and Fuzzy image processing).

Chapter 3 presents a review of related literature, and discusses relevant algorithms in detail with analysis.

Chapter 4 presents a brief overview of the algorithm developed. The chapter starts by introducing the principles of the algorithm, and then follows with the intricacies of the algorithm applied to both grey-scale and colour images, including analysis and experimental results.

Lastly, in Chapter 5, conclusions and future works are presented.