WAVELET IMAGE COMPRESSION IMPLEMENTED USING RASPBERRY PI

by

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LIST OF ABBREVIATIONS

DCT	Discreta Cosine Transform
DWT	Discreta Wavelet Transform
SBC	Single Board Computer
CV	Computer Vision
MSE	Means Square Error
PSNR	Peak Singnal To Noise Ratio
CR	Compression Ratio
BPP	Bit Per Pixel

LIST OF SYMBOLS

F (X, Y)	Original image
ˆ f (x,y)	Reconstructed image
ϕ(x,y)	Scaling function
Ψ (x,y)	Basic function of wavelet
$w\phi$ (j ,m,n)	Discrete wavelet transform of function *f* (*x*, *y*)
e(x, y)	Error between images

Mampatan Imej Wavelet Dilaksanakan Menggunakan Raspberry Pi

ABSTRAK

Imej mengandungi saiz data digital yang besar dan perlu dikurangkan saiz data digital dengan menggunakan kaedah pemampatan imej untuk mengurangkan saiz simpanan dan mengurangkan masa penghantaran data. Projek ini memfokuskan pada pemampatan imej menggunakan Raspberry Pi board. Tujuan projek ini adalah untuk mengekalkan sejumlah besar maklumat dalam imej dan mengekalkan kualitinya berbanding dengan kaedah berasaskan PC. Transformasi Haar adalah dari keluarga pemampatan imej wavelet di mana imej asal diubah kepada domain lain untuk menghasilkan saiz data yang lebih kecil. Transformasi Wavelet mempunyai kerumitan komputasi yang rendah dan algoritma pemprosesan yang cepat. Dalam projek ini, transformasi wavelet berdasarkan Haar dilaksanakan menggunakan komputer papan tunggal Raspberry Pi yang dibangunkan dengan pemproses berasaskan ARM. Raspberry Pi mempunyai kelebihan pelaksanaan pemprosesan imej kerana perisian yang digunakan mempunyai banyak fungsi untuk pemprosesan gambar seperti OPENCV dan Numpy. Projek ini terdiri daripada beberapa peringkat rekabentuk seperti pra-pemprosesan imej, pembangunan algoritma Haar, pengiraan kadar ralat dan pengukuran berasaskan PSNR dan MSE. Algoritma ini dibangunkan menggunakan bahasa pengaturcaraan Python dengan pemprosesan tambahan seperti OpenCV dan fungsi matematik NumPy. Algoritma pemampatan diuji pada beberapa imej biometrik seperti imej muka dan jari.

Wavelet Image Compression Implemented Using Raspberry Pi

ABSTRACT

An image contains large size of digital data and it is necessary to reduce digital data volume by using image compression method in order to reduce storage size and reduce data transmission time. This project mainly concentrates on image compression using a low cost Raspberry Pi board. The purpose of this project is to preserve a large number of information in the images and retaining its quality compare with PC based method. Haar transform is a family of wavelet image compression where the raw image is transformed to the other domain to produce smaller size of data. Wavelet transform has low computational complexity and fast processing algorithm. In this project, wavelet transform based on Haar is implemented using Raspberry Pi single board computer running on an ARM based processor. The raspberry Pi board has an advantage of image processing implementation due to the existing of software development tool offered a rich feature for image processing such as OPENCV and Numpy libraries. The project consists of several design stages such as image pre-processing, the development of Haar algorithm, error rate computation and measurement by PSNR and MSE. The algorithm is developed using Python programming language with the additional image processing library such as OpenCV and NumPy mathematical library. The compression algorithm is tested on several biometric images such as face and fingerprint images.

CHAPTER 1 : INTRODUCTION

1.1 Background of Study

Image processing is considered as a type of signal processing where an image, such as a photograph or a video frame is used as an input, and a corresponding even set of parameters that is related to the image, in the form of a video frame or a photograph, is given as an output. There are numerous reasons that make image processing a necessity, such as an unwanted camera shake, or a random unstable camera, or compressing of a large image so that it can be used as an input for certain applications.

In different areas of research such as telecommunication, automotive, biometric, medicine, and so on, image, signal, and data compression are regarded as essential tools for signal processing. The primary objective of compression is to bring down the amount of data required to represent the signal or image while maintaining the quality of the original signal or image. Haar transform refers to a group of wavelet image compression which transform raw image into another domain while creating a smaller sized data. Wavelet transform, unlike DCT transform, is characterised by speedy processing algorithm and low computational complexity.(Sahitya, Lokesha, and Sudha 2017) In this study, the Haar wavelet transform will be implemented with the help of Raspberry Pi SBC development board that runs on an ARM-based processor in order to attain the desired compression.

This project is constituted of a number of design stages, which include of Haar algorithm, image pre-processing, MSE measurement and error rate calculation. The

Python programming language is used to develop the algorithm, along with the NumPy mathematical library and an additional image processing library such as OpenCV.

The latest advancements in digital technology have resulted in a transformation in communication media, where visual information has evolved to play a significant role. A few of the applications where visual information is emerging include conferencing, medical imaging, High definition TV, virtual reality, telephony, server, CD and CD-ROM archiving, and wireless transmission. Since a raw signal or digital image generally contains a large amount of information, it requires large storage space and communication channels to save and transmit the information. Regardless of the developments in storage capacity and communication channels, the cost of implementation often becomes a limitation on capacity. In general, as the bandwidth requirement increases, the cost of transmission or storage increases accordingly. In order to meet the requirement of storage capacity or transmission channel, it is imperative to use compression techniques that reduce the data rate while retaining the subjective quality of the decoded signal or image.

The image compression techniques function by taking advantage of the statistical redundancies in the data and traits of the human visual system in order to attain compression. While still image compression techniques exploit only spatial redundancies, the compression techniques exploit both spatial and temporal redundancies to attain high compression ratios. During compression, an inter frame coding named motion compensated predictive coding is used to remove the temporal redundancies. The residual frame is then coded with the help of an inter frame coding methodology.

The two widely used techniques in inter frame image coding are transform coding and sub band coding. Both the coding techniques have the potential to remove statistical redundancies and exploit certain traits of the human visual system using frequency weighted distortion measures. There are several compression algorithms that can be implemented to achieve compression of images. Some of the algorithms that have been established as compression standards include JPEG, MPEG, H.261, and H.263(Zulkalnain Yusof et al. 2000).

1.2 Problem Statement

In the multimedia sector, the image compression system is very useful and necessary since it is important to send and receive the multimedia data from one device to another efficiently (Kaimal, Manimurugan, and Devadass 2013)without compromising on the quality of the data. It is observed that using large size of data will lead to traffic in the network, resulting in a need to increase the bandwidth. In order to avoid these shortcomings, a number of experiments by other researchers have been performed and it has been shown that Raspberry Pi is able to perform this task (Kaimal, Manimurugan, and Devadass 2013). The use of Raspberry Pi image compression has been proven to provide a fast and steady data stream flow between Raspberry Pi devices and CMOS camera.

The development of Internet and multimedia technologies that grow exponentially, resulting in the amount of information managed by computer is increased.

This causes a serious problems in storage and transmission image data in real time. Therefore, a compression method should be considered to compress image data so that the storage capacity required will be smaller. The analysis of wavelet compression is to know the influence of wavelet to the compression ratio and to the PSNR (Peak Signal to Noise Ratio). Then the compression ratio and PSNR is tested in real time to provide excellent visual quality (Al-Ani 2017).

The popular approach to compress image is lossy compression method. This method discard some information in order to obtain higher compression ratio without compromise the quality of the image. Another compression method such as DCT has high computational complexity and time consuming process.

The use of MATLAB software and the development in C/C++ has driven the Image Processing and Computer Vision (CV) algorithms. Even though MATLAB provides an effective high level platform for prototyping and testing algorithms, it is still not as good as the performance of a well-designed and optimised C/C++ implementation. In recent times, numerous potential solutions have been developed for efficient image processing and computer vision algorithms in Python. Two Python libraries are primarily used for developing image processing and computer vision algorithms: NumPy/SciPy and OpenCV with a Python wrapper. In this project, the use of basic computer vision routines from OpenCV and SciPy has been discussed.

1.3 Aims and Objectives

The objective of this project are as follows:

1) To develop image compression method using Haar algorithm implemented on Raspberry Pi development board.
2) To evaluate the performance of compression based on PSNR and MSE for Haar compression techniques.

1.4 Project Scope

The primary objective of this project is to develop an image compression algorithm using Raspberry Pi development board. In this project, the implementation of Haar image compression algorithm is performed and the measurement of performance in terms of error rate computation and MSE measurement. Haar code development using Phyton programming language is used to model the algorithm. The use of wavelet transform is able to convert the image into time scale domain from the spatial domain. Furthermore, the compression system would eliminate redundancy that is seen more in low frequency content.

The project consists of several design stages such as image pre-processing, the development of haar algorithm, error rate computation and performance measurement based on PSNR and MSE. The algorithm is developed using Python programming

language with the additional image processing library such as OpenCV and NumPy mathematical library

1.5 Summary

Image compression is considered as a type of signal processing where an image, such as a photograph or a video frame is used as an input, and a corresponding algorithm is performed on the image to produce the output. The project comprises several design phases to process the information. The main objective is to implement Haar algorithm on Raspberry Pi to reduce the image size. Utilising low cost of Raspberry Pi board to perform image compression images is faster and less complex compared to other platform or devices. Algorithm modelling using Python programming language would take into consideration in this project.

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CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

In digital image processing, image compression algorithm is important, especially when there is low capacity of limited resources data transmission procedure. The aim of compression is to decrease the rate of bit size for any image data matrix. This chapter discusses image compression techniques focusing on Haar compression method, which is widely used for many applications. Several issues need to be addressed when implementing image processing in single board computer such as Raspberry Pi due to the limited memory available in the microcontroller.

As it is important to reduce images' bit transmission from one node to the other or to efficiently manage the available memory space that was assigned for processing of an image, in most cases, image compression normally leads to permanent removal of part from the original image. Therefore, this approach will reduce image quality and the process fail to convey proper channel during the compression. In this literature review the algorithm of Haar algorithm used in image processing is discussed in detail. Several works related to implementation of microcontroller in image processing also will be reviewed.

2.2 Image Compression Scheme

There are many concerns associated with the implementation of image compression scheme, while several approaches have been proposed regarding the image compression procedure. In this project, the image compressing is based on the structure approach that can employ a support algorithm to apply in the raspberry pi based image compression system. This provides a basic understanding of the concept to get low complexity and low memory scheme to match with the requirement of the hardware implementation.

The image compression process has few keys, including transformation stage algorithm, and different algorithms have been developed to make it easy and simpler. Examples include DCT, Haar, Viola and Jones algorithm for image detection and construction (Lassaad et al. 2012).

2.3 Wavelet Transform

During image processing, transferring and transformation of image is done from one domain to another; however, the wavelet application basically aids in transforming it from spatial domain to the time domain scale. The fundamental wavelet compression method is designed to decrease redundant information in signal in the form of an image which is 1D or 2D signal.

The redundancy reduction method employs various ways to perform, which is achieved by conducting the process on an original image or on the transferred image instead of the original image. Therefore, an input data is needed even for the basic model for image compression and reduce redundancy. Along with encoding, next is the entropy reduction, while the compressed image would be the final output (Acharya and Tsai 2005).

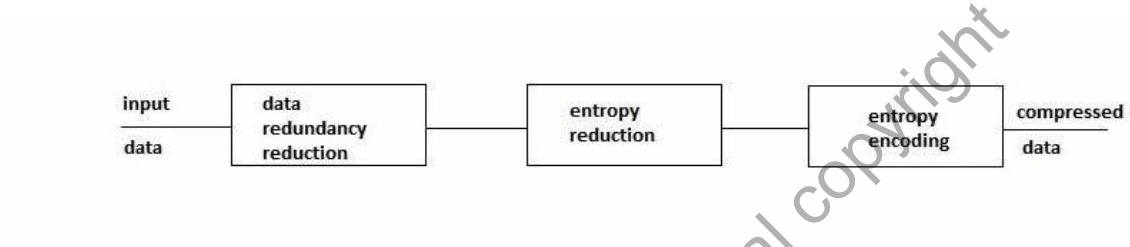

Figure 2.1: Image compression model

The process of redundancy reduction involves removing highly correlated image data of the low content in the image. To achieve this, there are various methods, the most common method being use is discrete wavelet transform (DWT), which has emerged as the most crucial techniques and has contributed greatly to this project because of its high decorrelation and energy compaction efficiency; however, when non-significant information is removed from the data, this method becomes irreversible (M. Singh and Singh 2012). The most popular entropy coding technique is Arithmetic coding and Huffman coding.

In daily life, when one hears the term ‘wavelet’, they perceive as a ‘small water wave’. For instance, their mind does not go towards things like image compression. However, in mathematics, wavelets denote short scalable and translatable wavelike functions. They are named wavelets based on their characteristic that allow integrating to 0, ‘waving’ up and down the x − axis. In fact, any signal can be picked by wavelet

transforms to express it, which is based on those translated and scaled wavelets. This procedure's result is a depiction of the given signal at various scales (Acharya and Tsai 2005). Wavelet transforms are certainly crucial computational tools.

For mathematicians, transform is a well-known concept, which is broadly employed as a standard mathematical tool to solve various problems in multiple areas. The basic idea behind a transform is varying the mathematical quantity (it could be a vector, a number, a function, etc.) to a different desired form that may be unrecognisable, but would provide useful features. This transformed quantity is, therefore, employed for resolving the problem on hand, or for execution of some useful calculation. The result can then be converted back to its original form(Bi 2002).

Initially, wavelets were term used only in mathematics. However, now, their use and popularity have reached areas like image processing, seismology, signal processing, quantum mechanics, data compression and non-stationary signals in particular. Two such examples can be quoted from amongst their various applications in real life.

The application of compression in biometric can be seen from this example. The captured texture data on fingerprint images kept growing in large number and size, the FBI designed a fingerprint compression specification known as Wavelet Scalar Quantisation, which follows the wavelet compression (Abourayan 2016).

It is important to characterise the key lines of the spectra to accurately measure the redshifts occurring in galaxies. Also, this identification issue had to be tackled in a reliable manner with automation due to the involvement of humungous sky surveys that

result in enormous data volumes. Consequently, the Darth Fader algorithm, a wavelet-based method, was developed to determine redshifts of galaxy spectra (Liu 1995).

In image compression and processing, wavelet transforms are widely used. In fact, they allow computers to enable image storage in many scales of resolution. They can break down a particular image into a number of approximations and more details

2.3.1 Wavelet Transform in Data Compression

Data compression can be represented by many different forms. This study will focus on wavelet transforms. Coefficients of discrete image transforms can be employed to characterise image data. Those coefficients that contribute small information to the information contents can be ignored. Typically, the splitting of image is done based on blocks (sub images) of 8×8 or 16×16 windows. Then, transformation of each block is performed separately in sequence. However, this does not consider any correlation present between blocks, and produces 'blocking artefacts', which are not good for smooth image. However, instead of perform compression in sub window, wavelets transform can be applied to whole images. Blocking artefact can be avoided using this method. This is a key advantage of wavelet compression when compared to other transform compression methods such as DCT (Bi 2002).

2.3.2 Wavelets Analysis

Through a series of cascaded filters, discrete wavelet transform can be best described. The feeding of input image X into high pass filter (H) and low pass filter (L) is carried out separately for each path. Then, outputs of both filters are subsampled. Figure 2.2 presents the resulting high pass sub band y_H and low pass sub band y_L. With the help of synthesis filters (L) and (H).

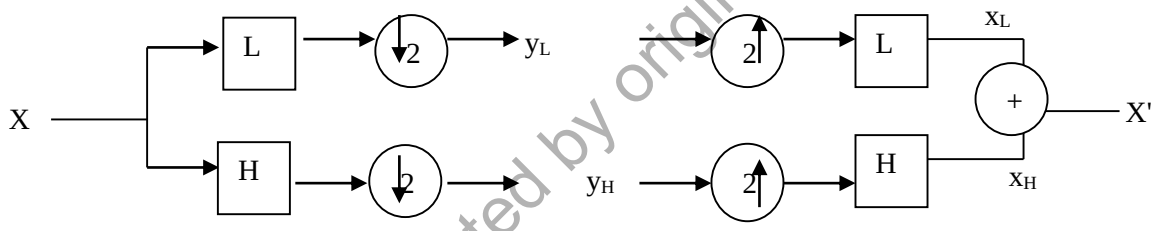

Figure 2.2: Wavelet decomposition and reconstruction process

The mathematical representations of y_L and y_H can be defined as:

$$y_{l\,(n)} = \sum_{i=0}^{tl} L\,(i)\; x(2n-i) \qquad (2.1)$$

$$y_{H\,(n)} = \sum_{i=0}^{tH} H\,(i)\; x(2n-i) \qquad (2.2)$$

Where the lengths of L and H are t_L and t_H, respectively. For two-dimensional (2D) images, a one-dimensional DWT in row direction is performed to approach the 2D