Improved UMHexagonS Algorithm And Architecture For Low Power H.264 Video Compression

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A thesis submitted in fulfilment of the requirements for the degree of Master of Science (Microelectronic)

School of Microelectronic Engineering
UNIVERSITI MALAYSIA PERLIS

2013

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ACKNOWLEDGEMENT

Alhamdulillah….that's the best word that I can say to express my gratitude upon the completion of this research.

First of all, the special thank goes to my supervisor, Dr. Asral Bahari Bin Jambek. The supervision and support that he gave truly help the progression and smoothness of this thesis completion.

Without his enthusiasm, this project would not be completed.

Not forget to mention, the contribution of my engineering school - all the staff and technicians of School's of Microelectronic Engineering (UniMAP). Without their co-operation and patient, the completion of this research would be hard.

My great and special appreciation goes on and on to Dr. Werner Knoben for supporting me in terms of monthly allowances and research fees for these past two years.

Last but not least, I would like to thank my family especially my mother and my wife, and also my friends and colleagues for standing beside me throughout the hard times while writing this thesis.

May ALLAH S.W.T bless all of you.

THANK YOU

-ARIEF AFFENDI BIN JURI-

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LIST OF ABBREVIATIONS

CSP	Centro symmetric pattern
CBB	Current Block Buffer
DP	Diagonal pattern
DSW	Dynamic search window
FME	Fractional ME
JVT	Joint Video Team
MET	ME encoding time
ME	Motion Estimation
MV	Motion vectors
MPEG	Moving Picture Experts Group
NTSS	New Three Steps Search
PSNR	Peak Signal –to-Noise Ratio
PE	Processing element
PU	Processing Unit
QBMO	Quadrant-based multi-octagon searc
RBB	Reference Block Buffer
SIR	Speed Improvement Rate
SOP	Small octagon pattern
SAD	Sum of Absolute Differences
Verilog HDL	Verilog Hardware Description Language
VCEG	Video Coding Experts Group

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LIST OF SYMBOLS

dB	Decibel
Hz	Hertz
kb/s	kilobits per second
µW	Microwatt
mJ	Millijoule
ps	Picosecond
s	Second

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Algoritma Dan Binaan UMHexagonS Yang Diperbaiki Untuk Pemampatan Video H.264 Berkuasa Rendah

ABSTRAK

Video telah menjadi sebahagian daripada kehidupan harian kita sama ada untuk hiburan, kerja atau komunikasi. Video boleh digunakan dalam bentuk televisyen, filem, video strim, panggilan video bahkan untuk rakaman peribadi. Proses rakaman dan memindahkan data video memerlukan banyak sumber seperti masa pengiraan, ruang penyimpanan dan lebar jalur (kadar bit). Proses ini telah menjadi lebih kompleks kerana permintaan untuk kualiti yang lebih baik dan pengekodan video yang lebih cepat meningkat. Piawaian pemampatan video terbaru, H.264, mampu untuk memenuhi permintaan ini tetapi dengan kos peningkat dalam kerumitan pengiraan. Ini seterusnya meningkatkan penggunaan tenaga piawaian pemampatan video ini. Anggaran Gerakan (ME) adalah modul yang menggunakan kebanyakan masa pengekodan dan kerumitan pengiraan dalam pemampatan video. Untuk mengatasi peningkatan dalam kerumitan pengiraan ME, perisian rujukan H.264 telah melaksanakan algoritma carian pantas dikenali sebagai Carian Pelbagai Hexagon Tidak Simetri (UMHexagonS) sebagai enjin anggaran gerakan utama. Tesis ini mencadangkan beberapa penambahbaikan untuk UMHexagonS dalam algoritma dan seni bina. Algoritma yang dicadangkan mengurangkan kerumitan pengiraan daripada UMHexagonS dengan mengurangkan bilangan calon carian sehingga 58.54% berbanding algoritma UMHexagonS konvensional. Ia dapat mengurangkan anggaran gerakan pengekodan masa (MET) sehingga ke 28.66% berbanding simulasi menggunakan perisian rujukan H.264. Di samping itu, seni bina UMHexagonS yang dicadang melaksanakan algoritma yang dicadangkan cekap. Seni bina yang dicadangkan mampu untuk mengurangkan kitaran jam sehingga 87.80% dengan jumlah tenaga penjimatan sehingga 78.79% berbanding seni bina UMHexagonS konvensional.

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Improved UMHexagonS Algorithm And Architecture For Low Power H.264 Video Compression

ABSTRACT

Video has been part of our daily life either for entertainment, work, or communication. The video can be used in form of television, movies, streaming video, video call or even for personal recording. The process of recording and transferring the video data requires a lot of resources such as computational time, storage space and bandwidth (bit rate). This process has become more complex since the demand for better quality and faster video encoding is increasing. The latest video compression standard, H.264, is able to meet this demand but at the cost of increasing computational complexity. This in turn increases the energy consumption of this video compression standard. Motion estimation (ME) is the module that consumes the most of encoding time and computational complexity in video compression. To overcome the increase in computational complexity of ME, H.264 reference software has implemented fast search algorithm known as Unsymmetrical Multi Hexagon-grid Search (UMHexagonS) as the main motion estimation engine. This thesis proposes several improvements for the UMHexagonS in term of algorithms and architectures. The proposed algorithms reduce the computational complexity of the UMHexagonS by reducing the number of search candidate up to 58.54% compared to the conventional UMHexagonS algorithm. It is able to reduce the motion estimation encoding time (MET) up to 28.66% when simulated using H.264 reference software. In addition, the proposed UMHexagonS architectures implement the proposed algorithms efficiently. The proposed architecture is able to reduce the clock cycle up to 87.80% with total energy saving up to 78.79% as compared to the conventional UMHexagonS architecture.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter summarize the main content of this thesis. It first describes the main problem that this work tries to solve. Then, the main objective and the scope of the thesis will be discussed. The significant finding and contribution of this thesis will be explained in detail in this chapter. Finally, the structure of this thesis will be briefly explained.

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1.2 Motivation of Study

Video compression refers to the process of reducing the amount of data needed to represent a video while the reconstructed video quality satisfies the requirement of the application or the individual. Digital video compression and decompression algorithms (codecs) are at the heart of many modern video products. The products can be ranging from general usage of video streaming or real time video streaming such as YouTube and Skype application, to portable video recording and/or playback device like the camera or a smartphone.

The world today demands a better video quality while keeping the bitrate low to minimise the use of bandwidth. Several video compression standards have been introduced and improved to achieve this result. The latest video compression standard

(H.264) is able to exceed the quality of previous video standard such as MPEG-4 part 2 while having half of the size of the MPEG-4 standard. However, this compression algorithm requires a higher computational load. It can reach up to seven times of the MPEG-4 operation per second, thus, making it more energy consuming (Chung-Jr, Po-Chih, & Liang-Gee, 2006).

The most computational intensive operation in H.264 encoder is motion estimation (Yun-Teng & Pei-Yin, 2000). In order to prolong the device useable period between battery recharges and the make the video compression to be more energy efficient, it is important to develop the low-energy ME algorithm and architecture.

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1.3 Problem Statement

The problem statement of the study is simplified as below:

i. Video compression requires long encoding time since motion estimation requires complex computation.
ii. Video compression requires high energy consumption to achieve the best result due to complex computation need to be performed by the processor.

1.4 Objectives

This research embarks on the following objectives:

i. To propose a new low complexity ME algorithm with better performance especially in its computational speed.

ii. To propose a new ME architecture that able to reduce the energy consumption of the module.

1.5 Scopes

Limitations and scopes of the study:

i. The improvement of video compression will be done in the ME part of the video compression as this is the part that determine the speed and quality of a video compression.

ii. The algorithm chosen to be review is the H.264 fast search algorithm specifically the Unsymmetrical-cross Multi-Hexagon-grid Search (UMHexagonS) as this is one of the algorithm that is embedded in H.264 as its fast search technique.

iii. Comparison of UMHexagonS algorithm performance is done in term of ME encoding time (MET), video quality denotes by Peak Signal–to-Noise Ratio (PSNR) and compression size denotes by bit rate.

iv. New algorithm with better performance than the conventional UMHexagonS algorithm is proposed and the performance is evaluated.

v. New architectures for the proposed UMHexagonS algorithm is design and the power and energy consumption is evaluated.

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1.6 Contribution

This thesis has contributed toward the following findings:

- Proposing new algorithms that can reduce the UMHexagonS encoding time by up to 28.66 % without scarifying the encoding quality.
- Proposing new energy efficient architecture to implement the proposed algorithms with up to 78.79% energy saving

1.7 Report Structures

This thesis is organised as follow. Chapter 1 introduces the problem, objectives and scopes of the thesis. This chapter also highlights the main contribution of this work. Chapter 2 discusses the background theory used in this. Chapter 3 explains the methodology used throughout the work. The results obtained in this work are discussed and evaluated in Chapter 4. Chapter 5 concludes this thesis.

1.8 Summary

This chapter discussed the introduction to low energy video compression. The introduction to the problem and the problem were stated to give ideas, how this improvement can affect the current video technology. The main objectives of this study were determined, and the scopes and limitations were stated. The contributions of this project are also mentioned. In the next chapter, the fundamentals of video compression and methods are explained further.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter explains the main theoretical background used in discussing this thesis. It will first describe the fundamental theory of video compression with emphasised in motion estimation which is the main focus of this work. It will then discuss existing fast search motion estimation technique developed prior the H.264 standard. The Unsymmetrical Multi-Hexagon Search (UMHexagonS) algorithm is then explained, followed by related studies on this algorithm. Several UMHexagonS architectures proposed in the past will also be explained. Then the method for software profiling and power comparison will be explained in this section.

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2.2 Background Theory

2.2.1 Digital Video

Two types of video recording system used nowadays are analogue and digital. Video compression focused on digital video since it allows data to be stored and transmitted in wire and wireless channel efficiently. Digital video comprises of a series of orthogonal bitmap digital images displayed in rapid succession at a constant rate as shown in Figure 2.1. This orthogonal bitmap are called frames. The rapid succession rate is measured in frames per second (FPS). Each frame is comprised of pixels. The number of pixels in the frame depends on the size of the image. A video with 640x480 resolution contains 307,200 pixels. A macroblock is a group of pixels in matrix that consists of 16 x 16 pixels (256 pixels in total). Each pixel keeps the property of their colour. This colour is represented by a fixed number of bits called colour depth. In compressing a video, the property of each pixel's colour is converted into YUV format where it is represented as luminance and chrominance.

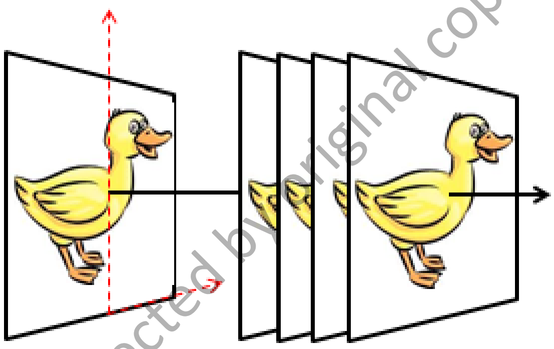

Figure 2.1: Series of orthogonal bitmap digital images

2.2.2 Video Compression

The demand for higher quality video and better video compression is increasing. Video compression is achieved by eliminating spatial redundancies and temporal redundancies from video signals (Wootton, 2003). Spatial information of a video sequences is repeated in a single frame. For example, a video with a plain white wall as a background will have a homogenous white colour across the frame. Temporal redundancies of a video sequence are repeated across several frames sequences. An example of temporal redundancies is a video of a newscaster talking with a static background.

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There are two kinds of video compression: lossy and lossless. A lossy compression will remove some information from the original video. In most cases, this will result in lower quality of video. A lossless compression will not remove any information from the video source. However, since a lossless compression is usually not aimed for smaller size, but instead, preserving the video quality, this method usually ends up being the same size as they were before compression (Wells, 2008) .

Typically, a video compression operates on groups of neighbouring pixel known as macroblock. A macroblock is compared with another macroblock from another frame and the different between these macroblocks is calculated. Higher motion video will cause the different between macroblocks increases because of large number of pixels are changing. Thus, this could leads to decrease in video quality or increase in compressed bitrates.

Over the years, many video coding standards have been designed to increase the quality of video compression. H.264/MPEG-4 AVC is the latest video coding standard developed by a Joint Video Team (JVT) that consists of experts from Moving Picture Experts Group (MPEG) of ISO/IEC and Video Coding Experts Group (VCEG) of the ITU-T. On average, the H.264 is able to achieve PSNR of 2 dB more than MPEG-4 and 3dB more than H.263. With the same video quality, H.264 can save about 50% bit-rate compared to MPEG-4 (Yuwen, Shiqiang, & Yuzhuo, 2003). However, the overall computational complexity increases significantly where the encoding and the decoding time increase three and two times compared to H263, respectively. With the increase of the computational complexity, the energy consumption is also increased. Its motion estimation (ME) consumes 70% (one reference frame) to 90% (five reference frames) of the total encoding time of H.264 (Zhibo & Yun He, 2002). This means, motion estimation is the most energy consuming part of the video compression. Figure 2.2

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shows a complete structure of video compression system. First, the video will be converted into YUV form, and the motion vector will be calculated in the ME part. The DCT and Quantize will reduce the number of colours used in a video and smoothing the artifacts. The next section will explain the ME in more detail.

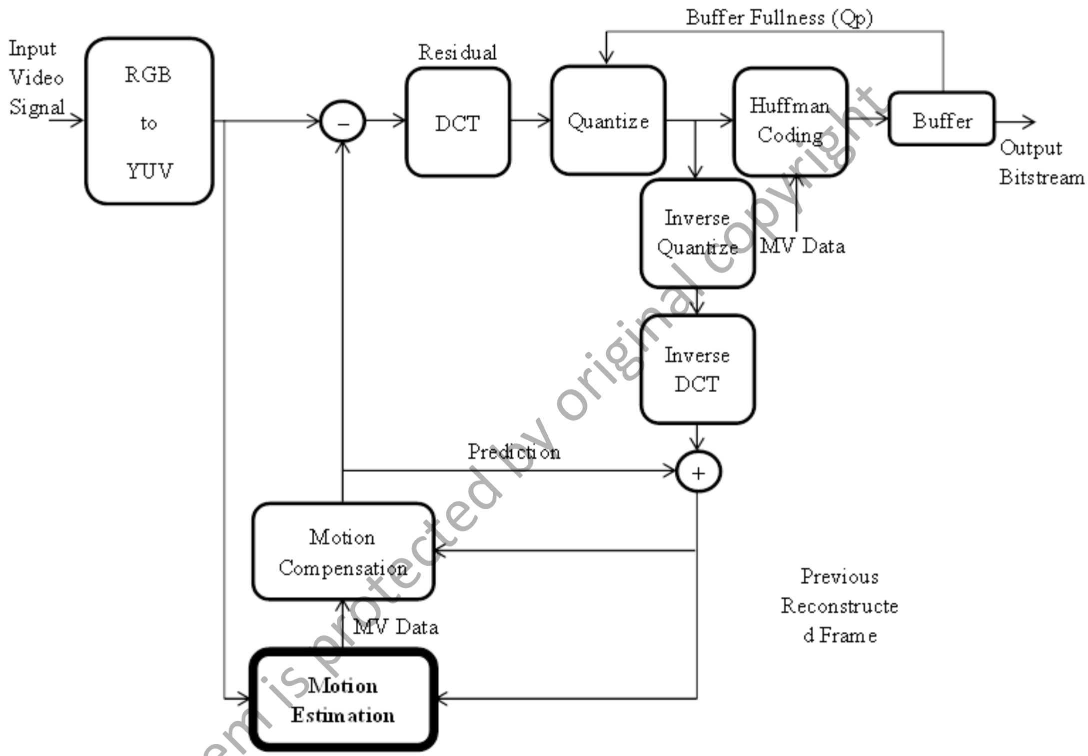

Figure 2.2: Video compression structure

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2.2.3 Motion Estimation

ME is the process of determining motion vectors (MV) that describes the motion from one image to another in a video sequence. It needs to project the 3D motion onto a 2D image and bring out information about motion of objects from the video sequence (Thomas, Gary, Julien, Heiko, & Mathias, 2007). It requires a multistep process, such as locating the motion starting point, motion search algorithm, adaptive control to early terminate the algorithm and avoidance of magnitude computational burden. In motion