HADARMARD TRANSFORM AND SUM OF ABSOLUTE DIFFERENCE IMPROVEMENT ON HIGH EFFICIENCY VIDEO CODING USING INTEL ADVANCED VECTOR EXTENSION-512

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This thesis is dedicated to my lovely family members, helpful lecturers and supportive friends.

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ABSTRACT

High Efficiency Video Coding (HEVC) doubles the data compression ratio compared to previous generation compression technology, Moving Picture Expert Group-Advanced Video Codec (MPEG-AVC/H.264) without sacrificing the image quality. However, this superior compression come at a cost of more computation payload resulting in longer time consumed in encoding and decoding. Hence, the objective of this thesis is to perform vectorization on HEVC data heavy computation algorithm, Hadamard Transform or Sum of Absolute Transform Difference (SATD) and Sum of Absolute Difference (SAD) to achieve optimized compression performance. Single Instruction Multiple Data (SIMD) acceleration will be based on the Intel AVX-512 (Advanced Vector Extension) Instruction Set Architecture (ISA). Since HEVC supports more coding tree block (CTB) sizes, SATD and SAD algorithm eventually become more complex compared to AVC. As a result, SATD and SAD algorithms with various block sizes will be subjected to SIMD acceleration. On the other hand, the second objective is to provide performance evaluation or analysis based on different SIMD ISA and without SIMD implementation on HEVC SATD and SAD. In the end, AVX-512 optimized was performed faster when compared to non optimized SATD and SAD but showed sign of slower in time execution when compared to SSE optimized SATD and SAD.

ABSTRAK

HEVC (High Efficiency Video Coding) mengandakan nisbah mampatan data berbanding dengan teknologi mampatan generasi sebelumnya, MPEG-AVC (Advanced Video Codec / H.264) tanpa mengorbankan kualiti imej. Walau bagaimanapun, mampatan unggul ini datang pada kos muatan pengiraan yang lebih banyak mengakibatkan penggunaan lebih lama dalam pengkodan dan pengekodan. Oleh itu, matlamat projek ini adalah untuk melaksanakan vektor dalam algoritma pengiraan berat HEVC, Hadamard Transform (SATD) dan Sum of Absolute Difference (SAD) untuk mencapai optimum performance compression. Percepatan SIMD (Single Instruction Multiple Data) akan berdasarkan ISA Intel AVX-512 (Advanced Vector Extension). Oleh kerana HEVC menyokong lebih banyak saiz cod block tree (CTB), algoritma SATD and SAD akhirnya menjadi lebih kompleks berbanding dengan AVC. Akibatnya, algoritma SATD and SAD dengan pelbagai saiz blok akan dikenakan percepatan SIMD. Sebaliknya objektif kedua ialah menyediakan penilaian atau analisis prestasi berdasarkan SIMD ISA yang berlainan dan tanpa pelaksanaan SIMD pada HEVC SATD dan SAD. Pada akhirnya, diharapkan bahawa percepatan AVX-512 ISA SIMD perlu dilakukan dengan lebih cepat dibandingkan dengan SIMD ISA yang lain seperti SSE (Extension Streaming SIMD) kerana rangkaiannya yang lebih meluas.

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LIST OF ABBREVIATIONS

AVC	-	Advanced Video Coding, H.264
AVX	-	Advanced Vector Extensions
Codec	-	Coder-decoder
CSV	-	Comma Separated Values
CTU	-	Coding Tree Unit
FHD	-	Full High Definition, 1080p
H.264	-	Recommendation ITU-T H.264, AVC
H.265	-	Recommendation ITU-T H.265, HEVC
HEVC	-	High Efficiency Video Coding, H.265
IEC	-	International Electrotechnical Commission
ISA	-	Instruction Set Architecture
ISO	-	International Organization for Standardization
ISOBMFF	-	ISO Base Media File Format
ITU	-	International Telecommunication Union
ITU-T	-	ITU Telecommunication Standardization Sector
JCT-VC	-	Joint Collaborative Team on Video Coding
JPEG	-	Joint Photographic Experts Group
JPEG2000	-	An image format developed by JPEG in 2000
JPEGXR	-	JPEG extended range
KNL	-	Knight Landing processor codename
MP4	-	MPEG-4 Part 14, a multimedia format
MPEG	-	Moving Picture Experts Group
RDO	-	Rate-Distortion Optimization
SAD	-	Sum of Absolute Difference

SATD	-	Sum of Absolute Transform Difference
SATD	-	Hadamard Transform
SAO	-	Sample Adaptive Offset
SDE	-	Software Development Emulator by Intel
SIMD	-	Single Instruction Mutiple Data
SKX	-	Skylake-X processor codename
SSE	-	Streaming SIMD Extensions
TDD	-	Test Driven Development
UHD	-	Ultra High Definition, 2160p
VCEG	-	Video Coding Experts Group
VP9	-	A video compression format developed by Google
WebP	-	An image format, currently developed by Google

CHAPTER 1

INTRODUCTION

1.1 Problem Background

In 1957, Russell A. Kirsch who is a researcher in the United States at the National Bureau of Standards along with other researchers successfully produced a devices that generated digital data to memory of a computer with *drum scanner* and *photomultiplier tube* [13]. However, the storage consumed on a computer for a single image could take up more than half of it back in the day [14]. Cost of owning data storage was extravagant in the past storing large quantity is considered unrealistic. The creation of first digital image eventually led to drastic development of cheaper equipment such as digital cameras and high storage capacity, not to mention the growth of Internet. Over the past, uses of digital computer images was only affordable by governments in the fields of medical technology, remote sensing and astronomy [15].

As technology advancement continues, digital images are becoming norm of people's live today. With Internet widely introduced and accepted worldwide, it allows viewing, editing, capturing and sharing digital images become effortless. On the other hand, electronic devices such as digital cameras and smartphones equipped with digital camera become more affordable and available to mass consumers for storing and capturing images. As of now, Full HD or FHD resolution (1920x1080) had become the basic requirement in most of the electronic devices especially in smartphone's camera. Smartphone companies are pushing towards higher resolution images in the smartphone camera to attract consumers as the pursuit of clearer images are always the main consideration for consumers buying a smartphone.

Without a doubt, higher image resolution means larger storage required. As a result, newer video codec standard known as *High Efficiency Video Coding (HEVC)/H.265* was introduced and developed that not only supports for video compression but for still image as well. Today, *Advanced Video Coding (AVC)/H.264* is the dominant video coding technology used world-wide but HEVC is likely to be the inflection point that will soon cause that growth to cease as the next generation rises towards dominance [16]. HEVC standard provides significant improved compression performance relative to AVC standard without sacrificing the quality but with cost of higher computing and memory requirements as complexity of processing has increased tremendously.

1.2 Problem Statement

HEVC implements enhanced tools to improve compression efficiency at the cost of far more computational payload than the capacity of real-time video applications. Therefore, time consumed in the encoding and decoding would be longer since HEVC supports more coding tree block (CTB) sizes, more transform sizes, additional loop filter, and more intra prediction angles. All of these or improvements over HEVC makes it become more complex than its predecessor.

SIMD instructions had been used to optimize video codec such as H.264/AVC. Thus, HEVC is well suited for SIMD acceleration. However, most of the SIMD implementation of HEVC are based on older version of reference software and SIMD ISA that did not include Intel AVX-512 and still images. Evaluation in previous was mostly based on the optimization on HEVC using SIMD ISA up to AVX2.

1.3 Objective

The objectives or works carried out in this thesis consist of:

1. to implement SIMD technologies using latest Intel AVX-512 ISA on HEVC

Hadamard transform (SATD) and Sum of Absolute Difference (SAD) to achieve optimized computation performance.

2. to provide performance evaluation between AVX-512 ISA and Non SIMD implementation on both Hadamard transform and Sum of Absolute Difference.

1.4 Scope

Implementation will be performed based on the latest reference software HM test model (HM-16.17) which is in C++ programming language. Focus will be on the encoder module algorithms of Hadamard transform and Sum of Absolute Difference only using Intel AVX-512. Datasets in this project will mainly be comprised of still images with varying resolution only from FHD (1080p) to Ultra HD (UHD) (2160p).

Besides, Intel Software Development Emulator (SDE) will be utilized in the absence of processor with AVX-512 capability to validate optimization performed on SAD and SATD and allows development to go on without any hindrance. Compilers include Visual Studio C++ 15.7, G++ 7.3.0 and Intel C++ v18 will be used to compare the final results.

1.5 Thesis Outline

This thesis consists of five chapters. Chapter 1 reveal the background of the problem, the problem statement, objectives, scope and thesis structure. The review of literature and previous works are discussed in Chapter 2. Chapter 3 documents the research methodology that includes the details of the overall project flow and implementation of SIMD as well as Test Driven Development (TDD) approach. The results of the design is presented and analyzed in Chapter 4. Chapter 5 concludes the whole project and recommends future works.

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