Efficient H.264 Encoder with High Profile for High Frame Rate Video Streams

Submitted by:

Fariaa Faheem	2019-EE-001
Marwa Waseem	2019-EE-007
Hamza Akhtar	2019-EE-012
Filza Shahid	2019-EE-151

Supervised by: Dr. Muhammad Tahir

Department of Electrical Engineering

University of Engineering and Technology Lahore

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Declaration

I declare that the work contained in this thesis is my own, except where explicitly stated otherwise. In addition this work has not been submitted to obtain another degree or professional qualification.

Signed: _____

Date: _____

Acknowledgments

The acknowledgements and the people to thank go here, don't forget to include your project advisor...

For/Dedicated to/To my...

Contribution to Sustainable Development Goals

Write a short description of how the work carried out in this thesis has contributed to some of the sustainable development goals listed below.

1. No poverty
2. Zero hunger
3. Good health and well-being
4. Quality education
5. Clean water and sanitation
6. Affordable and clean energy
7. Decent work and economic growth
8. Industry, innovation and infrastructure
9. Sustainable cities and communities
10. Responsible consumption and production
11. Climate action
12. Life below water
13. Life on land
14. Peace, justice and strong institutions

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Abbreviations

LAH **L**ist **A**bbreviations **H**ere

Abstract

The Thesis Abstract is written here (and usually kept to just this page). The page is kept centered vertically so can expand into the blank space above the title too...

Chapter 1

Introduction

Digital video is a series of image frames moving on a screen at a predefined rate. The transfer of a video from one medium to another depends on the length of video and the size of its encoding bits. To reduce the size of overall video, a **Video Compression** technique is applied that leads to reduction in amount of data required to represent that digital video signal, prior to transmission and storage.

The latest video coding standard **H.264/AVC**, also known as **MPEG-4 Part-10**, developed jointly by **ITU-T Video Coding Experts Group** and **ISO/IEC JTC 1 Moving Picture Experts Group** provides considerable higher efficiency (capable of saving upto 50% bit rate at te same level of video quality) than a usual video coding standard. It covers a wide range from QCIF to HDTV.

The overall procedure of H.264 includes various components. The top level block diagram of an H.264 Encoder is shown in Figure

1.1 H264 Profiles

The H.264 family of standards includes various capabilities. These profiles are mainly used to reduce the frame count by implementing motion prediction and temporal compression. The most common ones are:

- Baseline Profile
- Main Profile
- High Profile

1.1.1 Baseline Profile

Baseline profiles are used for low-power and low-cost applications. These profiles can achieve a compression ratio of 1000:1 which means a streamlet of 1 Gbps can be compressed to about 1 Mbps. 4:2:0 chrominance sampling is used, meaning that color information is sampled at a half-vertical and half-horizontal resolution of the black-and-white

information. Moreover, this profile uses Universal Variable Length Coding (UVLC) and Context Adaptive Variable Length Coding (CAVLAC) entropy encoding techniques.

1.1.2 Main Profile

The improvements in Baseline Profile were made by introducing efficient frame prediction algorithms. This new profile was regarded as Main Profile. It is used for standard-definition digital TV broadcasts (MPEG-4 format). But it is not used for High Standard broadcasts.

1.1.3 High Profile

Introduces in 2004, High Profile is the most efficient and powerful profile in H.264 family. This profile is used for high-definition television applications (Blu-ray Disc storage and DVB HDTV broad cast service)

The compression ratio achieved using this profile is 2000:1. It uses an adaptive transform by which 4x4 or 8x8 pixel blocks can be selected. The video quality of image while reducing network bandwidth is preserved up to 50 percent. By applying this compression, a 1 Gbps stream can be compressed to about 512 Kbps.

1.2 H264 syntax

H264 consists of 2 layers. The **Network Abstraction Layer (NAL)** consists of series of NAL Units. These units that signal certain common control parameters to the decoder are Sequence Parameter Sets (SPS) and Picture Parameter Sets (PPS). In **Video Coding Layer (VCL)** units, coded video data is communicated, also known as **slices**. There is an **access unit**, a code frame or field which is made up of one or more slices. Next is the **slice layer**, at which each slice consists of a Slice Header and Slice Data. Slice Data is regarded as series of code **macro blocks (MB)** and skip macro block indicators which signal that certain macro block positions contain no data. Each Macro block has following syntax elements:

- **MB type:** I/intra coded, P/inter coded from one reference frame
- **Prediction information:** prediction mode for I macro block, choice reference frame and motion vectors for P macro block
- **Coded Block Pattern CBP:** indicates which luma and chroma blocks contain non zero residual co-efficient
- **Quantization Parameter QP:** for macro blocks with CBP not 0
- **Residual Data:** for blocks containing non-zero residual coefficients

1.3 H264 Process

An H264 encoder has a **forward path** and a **reconstruction path**. The forward path uses **intra** and **inter predictions** to encode a video frame to create a bit stream.

The reconstruction path is used to decode the encoded frame and to reconstruct the decoded frame. Reconstruction path in encoder ensures that both encoder and decoder make use of similar reference frames for inter and intra prediction. This is to avoid encoder-decoder mismatches.

1.3.1 Forward Path

The input frame is partitioned into **Macro-Blocks (MB)**. These MB are then encoded in intra or inter mode. This depends on mode decision. The current MB is predicted from reconstructed frame. This predicted MB is generated by intra prediction based on **spatial redundancy**, and by inter prediction based on **temporal redundancy**. The mode is chosen based on better quality and bit rate performance of these 2 modes. The Predicted MB is subtracted from current MB to create a **Residual MB**. Residual data is **transformed** (4x4 integer transform), then **quantized**. The obtained coefficient are re-ordered in a **zig-zag order** which are regarded as **entropy encoded**. These coefficients along with header information form the **compressed bit stream**. This stream is forwarded to NAL for storage or transmission.

1.3.2 Reconstruction Path

This path takes quantized transform coefficients and performs inverse quantization and inverse transform. In this way, reconstructed residual data is generated, but they are not identical to original residual data as quantization is a lossy process. In order to create the reconstructed frame, the reconstructed residual data are added to predicted pixels.

In this thesis, we developed an FPGA based H.264 intra and inter frame coder hardware targeting **High Profile** (see which one to mention, See from wikipedia)

1.4 H264 Major Components

1.4.1 Prediction

In order to guarantee a high compression ratio in H.264 encoders, prediction is a technique utilized. In prediction, a 16x16 pixel block known as a macroblock from a previous video frame or the present frame is utilized to forecast macroblocks in the current frame.

There are basically 2 modes for prediction:

1.4.2 Intra-Prediction

Intra prediction is performed without referring to any data outside the current slice i.e prediction from previously coded data in the same slice. It reduces spatial redundancies by exploiting spatial correlation between adjacent blocks in a given picture. There are 3 choices of block size for luma component i.e. 16x16, 8x8 or 4x4. Whereas for chroma component, a single prediction block is generated. Once, the prediction has been made, it is subtracted from current block to make a residual.

1.4.3 Inter-Prediction

Inter prediction is the process of predicting a block of luma and chroma samples from a picture that has been previously coded and transmitted i.e reference picture. It uses temporal sampling technique. For this, a prediction region is selected, then a prediction block is generated. After that the prediction block is subtracted from original block of samples to form a residual.

1.4.3.1 Motion Vector Prediction

Chapter 2

Motivations and Problem Statement

2.1 Motivations

(add the relevant info related to our project reason open source camera chip - nust , 10x (isp), us (encoder))

With the rapid increase in the development of products and benefits offering full-motion digital video, digital video coding is currently gaining importance and has a considerable monetary impact on computer, imaging and telecommunications technology. Throughout the early phases of technology, there have been many international video coding standards as engines behind the commercial success of digital video compression. In comparison to current existing standards, H264 has many new features that makes it more emphatic. The important features that distinguish H264 from other standards are good video quality at high and low bit rates and network friendliness.

It is proposed that H264 can deliver two times better performance than the previous MPEG-2 coding standard, both in terms of compression efficiency and picture eminence. Moreover, previous H.63 and MPEG-4 implement block-based motion estimation to reduce temporal redundancy between frames. But in H.264, block matching efficiency is improved by some innovative features such as variable block size motion estimation (VBS_ME) and motion vector prediction. The computational complexity of this model is increased by the factor of four due to these features.

Chapter 3

Prediction

(some brief intro)

Following modes are possible for each prediction block. write about modes and further details

Chapter 4

Thesis Structure

The flow of information provided in a thesis depends on its structure. The parameters defining the structure of a thesis are discussed in [2] and are quoted below:

> "The structure of a thesis is governed by logic and is invariant with respect to subject. The substance varies with subject, and its quality is determined by the technical knowledge and mastery of essentials exhibited by the student. Style has two components: language and layout. The former deals with the usage of English as a medium of sound technical communication; the latter with the physical presentation of the thesis on paper. All three components structure, substance and style influence one another."

There is no definite structure for a thesis. The author is the best judge. One possible structure of a thesis can be:

- *Chapter 1*: Introduction
- *Chapter 2*: Motivations, Related Literature and Problem Statement
- *Chapter 3*: Proposed Approach
- *Chapter 4*: Implementation and/or Experimentation
- *Chapter 5*: Conclusions and Future Directions

The purpose of the introduction is to provide an outline of your project in a contextual framework systematically. The introduction should be kept short and to the point.

Depending on the substance, you can break Chapter 2 suggested above into separate chapters. For instance, *motivation and related literature* can be one chapter and *problem statement* can be a separate chapter . This is flexible and is decided while writing the thesis.

The rationale behind the structure selected above is to meet the objective of telling a story as clearly and convincingly as possible. We have adapted the following table from [1] to show the flow in the logic:

Introduction/Aim	What did you do and why?
Materials and Methods	How did you do it?
Observations/Results	What did you find?
Discussion	What do your results mean to you and why?
Conclusions	What new knowledge is extracted from experiment?

There are a number of guiding documents e.g. [5], [4], as well as some documents available online, which can be helpful in writing the thesis. Two such documents outlining some general guidelines are [3], [2].

Finally here is a list of words that you should try avoid while writing the thesis: “very much”, “interesting”, “good”, “fun”, “exciting”, “very”, “too much”.

Appendix A

Introduction to Latex

The material provided in this appendix is taken from
http://www.sunilpatel.co.uk/thesistemplate.php

A.1 Learning LaTeX

LaTeX is not a WYSIWYG (What You See is What You Get) program, unlike word processors such as Microsoft Word or Corel WordPerfect. Instead, a document written for LaTeX is actually a simple, plain text file that contains *no formatting*. You tell LaTeX how you want the formatting in the finished document by writing in simple commands amongst the text, for example, if I want to use *italic text for emphasis*, I write the '`\emph{}`' command and put the text I want in italics in between the curly braces. This means that LaTeX is a "mark-up" language, very much like HTML.

A.1.1 A (not so short) Introduction to LaTeX

If you are new to LaTeX, there is a very good eBook – freely available online as a PDF file – called, "The Not So Short Introduction to LaTeX". The book's title is typically shortened to just "lshort". You can download the latest version (as it is occasionally updated) from here:
http://www.ctan.org/tex-archive/info/lshort/english/lshort.pdf

It is also available in several other languages. Find yours from the list on this page:
http://www.ctan.org/tex-archive/info/lshort/

It is recommended to take a little time out to learn how to use LaTeX by creating several, small 'test' documents. Making the effort now means you're not stuck learning the system when what you *really* need to be doing is writing your thesis.

A.1.2 A Short Math Guide for LaTeX

If you are writing a technical or mathematical thesis, then you may want to read the document by the AMS (American Mathematical Society) called, "A Short Math Guide for LaTeX". It can be found online here:

http://www.ams.org/tex/amslatex.html
under the "Additional Documentation" section towards the bottom of the page.

A.1.3 Common LaTeX Math Symbols

There are a multitude of mathematical symbols available for LaTeX and it would take a great effort to learn the commands for them all. The most common ones you are likely to use are shown on this page:
http://www.sunilpatel.co.uk/latexsymbols.html

You can use this page as a reference or crib sheet, the symbols are rendered as large, high quality images so you can quickly find the LaTeX command for the symbol you need.

A.1.4 Figures

There will hopefully be many figures in your thesis (that should be placed in the 'Figures' folder). The way to insert figures into your thesis is to use a code template like this:

```
\begin{figure}[htbp]
  \centering
    \includegraphics[width = 1.5in]{./Figures/uet_logo.pdf}
    \rule{35em}{0.5pt}
  \caption{The UET Laore logo.}
  \label{fig:uet_logo}
\end{figure}
```

Also look in the source file. Putting this code into the source file produces the picture of the UET logo that you can see in the figure below.

FIGURE A.1: The UET Lahore logo.

Sometimes figures don't always appear where you write them in the source. The placement depends on how much space there is on the page for the figure. Sometimes there is not enough room to fit a figure directly where it should go (in relation to the text) and so LaTeX puts it at the top of the next page. Positioning figures is the job of LaTeX and so you should only worry about making them look good!

Figures usually should have labels just in case you need to refer to them (such as in figure A.1). The '`\caption`' command contains two parts, the first part, inside the square brackets is the title that will appear in the 'List of Figures', and so should be short. The second part in the curly brackets should contain the longer and more descriptive caption text.

The '`\rule`' command is optional and simply puts an aesthetic horizontal line below the image. If you do this for one image, do it for all of them.

The LaTeX Thesis Template is able to use figures that are either in the PDF or JPEG file format. It is recommended that you read this short guide on how to get the best out of figures in LaTeX, available here:
http://www.sunilpatel.co.uk/texhelp5.html

Though it is geared more towards users of Mac and OS X systems, much of the advice applies to creating and using figures in general. It also explains why the PDF file format is preferred in figures over JPEG.

A.1.5 Typesetting mathematics

If your thesis is going to contain heavy mathematical content, be sure that LaTeX will make it look beautiful, even though it won't be able to solve the equations for you.

The "Not So Short Introduction to LaTeX" (available here) should tell you everything you need to know for most cases of typesetting mathematics. If you need more information, a much more thorough mathematical guide is available from the AMS called, "A Short Math Guide to LaTeX" and can be downloaded from:
ftp://ftp.ams.org/pub/tex/doc/amsmath/short-math-guide.pdf

There are many different LaTeX symbols to remember, luckily you can find the most common symbols here. You can use the web page as a quick reference or crib sheet and because the symbols are grouped and rendered as high quality images (each with a downloadable PDF), finding the symbol you need is quick and easy.

You can write an equation, which is automatically given an equation number by LaTeX like this:

```
\begin{equation}
E = mc^{2}
  \label{eqn:Einstein}
\end{equation}
```

This will produce Einstein's famous energy-matter equivalence equation:

$$E = mc^2 \tag{A.1}$$

All equations you write (which are not in the middle of paragraph text) are automatically given equation numbers by LaTeX. If you don't want a particular equation numbered, just put the command, '`\nonumber`' immediately after the equation.

A.2 Sectioning and Subsectioning

You should break your thesis up into nice, bite-sized sections and subsections. LaTeX automatically builds a table of Contents by looking at all the '`\chapter{}`', '`\section{}`' and '`\subsection{}`' commands you write in the source.

The table of Contents should only list the sections to three (3) levels. A '`\chapter{}`' is level one (1). A '`\section{}`' is level two (2) and so a '`\subsection{}`' is level three (3). In your thesis it is likely that you will even use a '`\subsubsection{}`', which is level four (4). Adding all these will create an unnecessarily cluttered table of Contents and so you should use the '`\subsubsection*{}`' command instead (note the asterisk). The asterisk (*) tells LaTeX to omit listing the subsubsection in the Contents, keeping it clean and tidy.

References

[1] R. Barrass. *Scientists must write: a guide to better writing for scientists, engineers and students*. RoutledgeFalmer, 2002.

[2] R. Chandrasekhar. How to Write a Thesis: *A Working Guide*. http://ciips.ee.uwa.edu.au/pub/HowToWriteAThesis.pdf, Last accessed on May 19, 2010.

[3] S. Easterbrook. How Thesis Get Written. http://www.cs.toronto.edu/~sme/presentations/thesiswriting.pdf, Last accessed on May 19, 2010.

[4] D. Evans and P. Gruba. *How to write a better thesis*. Melbourne University Publishing, 2003.

[5] R. Murray. *How to write a thesis*. Open Univ Press, 2006.