3D OPENJPEG2000 WITH INTEGER KLT

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3D OPENJPEG2000 WITH INTEGER KLT

by

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ABSTRACT

A hyperspectral image processing system especially remote sensing technology is very important as it able to provide extremely useful information for the various type of Earth monitoring system – terrains, weather, oceanology, pollution control and etc. Hyperspectral image which includes the spatial (inter-pixel) and spectral (multi-component images) redundancy. The amount of acquired data of the hyperspectral image greatly increased since the spectral and spatial resolution of sensors which monitoring Earth terrains increase as well. Increased size of imagery data will require an image compression as there are lot issues need to overcome, such as downlink speed for bandwidth image and on-board satellite database storage are limited. The distance and downlink speed for image transmission from Earth Observation (EO) Satellites to the ground station need to be measured. The developed image processing system need to optimize the compression performance of image data in order to maximize the transmission of image data as well as high speed downloading capacity. The compression and decompression algorithm include in Integer Karhunen-Loève Theorem (Integer KLT) which efficient in spectral decorrelation and OpenJPEG2000 is a suitable for spatial decorrelation. The lossless compression ratio (CR) and execution time (ET) of hyperspectral image in *.rawl file from OpenJPEG2000 will be compared to get better result which will lead the improvement of EO Technology for reduction of data size which allows more images to be stored in the on-board satellite database storage and also shorter the time required to transfer the images from EO satellites to the ground station within a single pass.

ABSTRAK

Sistem pemprosesan imej hiperspektral terutamanya dalam teknologi penginderaan jauh adalah sangat penting dalam menyediakan maklumat yang sangat berguna untuk pelbagai jenis system pemantauan Bumi – kawasan, cuaca, bidang perlautan, pengawasan pencemaran dan sebagainya. Imej hiperspektral yang mempunyai redundansi spatial (antara piksel) dan spektral (imej pelbagai komponen). Peningkatan resolusi sensor spektral dan spatial yang memantau kawasan Bumi menyebabkan jumlah data imej hiperspektral yang diperolehi meningkat juga. Peningkatan saiz data imej akan memerlukan pemampatan imej disebabkan banyak isu yang perlu diselesaikan, seperti terhadnya tempat penyimpanan pangkalan data satelit udara dan kelajuan turun pautan jalur lebar imej. Jarak dan kelajuan turun pautan sistem penghantaran imej dari Satelit Permerhatian Bumi (EO) ke stesen Bumi perlu di ukur. Sistem pemprosesan imej yang sudah direka perlu mengoptimumkan prestasi pemampatan data imej untuk memaksimakan sistem penghantaran imej dan juga keupayaan memuat turun berkelajuan tinggi. Algoritma untuk pemampatan dan penyahmampatan termasuk Integer Karhunen-Loève Theorem (KLT) yang mana berkesan dalam dekorelasi spektral dan OpenJPEG2000 yang sesuai untuk dekorelasi spatial. Nisbah pemampatan tidak hilang (CR) dan masa pelaksanaan untuk imej hiperspektral dalam bentuk fail *.rawl daripada OpenJPEG2000 akan dibandingkan untuk mendapatkan keputusan lebih baik yang mana akan menyumbangkan kepada penambahbaikan Teknologi EO dalam pengurangan saiz data untuk mengizinkan lebih banyak imej disimpan dalam tempat penyimpanan pangkalan data satelit udara dan jugak menyingkatkan masa untuk menghantar imej dari Satelit EO ke stesen Bumi dalam sekali lalu.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Nowadays, camera, remote sensing and other quality image technologies advance parallel with the mission and vision of Industry 4.0 which take seriously about quality of the data, products and etc. Current image technology increase by time as the quality of the image data be greater as well as the size of image data. The larger the size of the image data, the bigger the storage needed to save the image. This absolutely will increase the cost of certain products in order to increase the capacity of the storage such as memory cards inside the smartphone, camera and etc.

Image compression is a suitable technique to reduce size of the image. Two types of image compression which lossless and lossy compression. In order to maintain the quality of image, lossless image compression technique should be used to minimize the size in byte of image data without degrading the quality to unacceptable level. The size reduction of image data can allow more image to be store and reduce transmission time of the image. This is a perfect process for on-board satellites remote sensing of EO system as it will improve the performance image data transmission since smaller image data size and faster transmission rate for high speed downlink from satellite to the ground station.

The latest version of Joint Photographic Expert Group (JPEG) created in 1994 is standard by International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) under ISO/IEC 10918-1 which is about digital compression and coding of continuous-tone still images. JPEG file created by choosing a range of compression image qualities from a suite of compression algorithm. According to the JPEG, the compression of image data mostly lossy as at that time this technique still growing.

Advancement of JPEG algorithm is JPEG2000 which more complex but have better compression performance with high quality image such as 3D hyperspectral image. JPEG2000 is an image coding system based on wavelet technology. Compression of JPEG2000 can be consider as lossless compression due to the efficient of coding structure. The output image data is lossless as it maintain the original detail and the higher range supported by the format with no limitation of bit depth of an image.

The source code that involved in this project is an open-source which is OpenJPEG written in C language. Since the codec is open-source, everyone can use the codec. Besides that, the codec itself officially recognized by ISO and IEC – OpenJPEG is a set of lossless and lossy compression methods for coding continuous-tone, bi-level, greyscale or color digital still images. It also recognized by International Telecommunication Union – Telecommunication Standardization Sector (ITU-T) as a JPEG2000 Reference Software. OpenJPEG fully respects the JPEG2000 specification which can do lossless compression and decompression of 16-bit images.

Kakadu Software is a complete implementation of JPEG2000 standard but this software need to be purchased to get the source code to integrate the robust JPEG2000 data. This software includes the general multi-constituent transforms and arbitrary wavelet transform kernels.

Algorithm of Integer Karhunen-Loève Transform (KLT) is a lossless spectral decorrelator and suitable for hyperspectral imagery data. Integer KLT is spectral decorrelators to reduce the spectral redundancy in multi-component compression of hyperspectral image.

1.2 Problem Statements

High quality and resolution image will use more storage as the image processing technologies nowadays is more advance. When the image compression take place, maybe there are some imagery data will loss if the compression is a lossy one. The method of compression by OpenJPEG and Kakadu Software will ensure the compression is lossless in order to retain the original data. In case of remote sensing of hyperspectral image from the EO Satellite, the size of the original image data cannot be transferred to the EO ground station within the single pass after reconsidering the downlink speed. By applying the lossless compression method, the quality of output image data will be same as input data and it also can decrease the size of image data as well as will faster the transmission to ground station. The compression ratio and execution time are very important component that need to take priority in order to completely the system flow of the compression and CR need to meet the certain ratio as well as ET need to optimum to pass the output image.

1.3 Research Project Objectives

1. To measure the compression performance (compression ratio and execution time) of OpenJPEG2000 with Integer KLT for lossless hyperspectral image compression and decompression.
2. To compare the OpenJPEG2000 and Kakadu Software performance as spatial compressor in Integer KLT.

1.4 Research Project Scope

In this project, compression and decompression of 3-D image utilized by using Microsoft Visual Studio C/C++ 2008 and 2010 which run the open-source codec of OpenJPEG2000 and Integer KLT algorithm. Comparison of image processing performance for both OpenJPEG2000 will be integrate by using Integer KLT to get the compression ratio (CR) and execution time (ET) in order to optimize the lossless compression result.

1.5 Report Outline

This progress report has five chapters. The first chapter is the Introduction that cover the research background, problem statement, objectives, project scope and outline of this project.

Chapter 2 covers the Literature Review of the project. Within this chapter, compression and decompression of JPEG2000 will be overviewed. The 3-D hyperspectral image data should be compress in lossless way by using open-source codec of OpenJPEG2000 before integrate with Integer KLT in order to get CR and ET.

Chapter 3 discusses the Methodology. Microsoft Visual Studio C/C++ 2008 and 2010 are used to utilize the code. Clustering technique is used to optimize compression performance.

Chapter 4 represents the result of hyperspectral image compression and decompression. AVIRIS sample images are used for testing. Tables and graphical Figures shown the compression ratio and execution time. The CR and ET performance are compared with previous research which applied other software (Kakadu Software). Within this chapter, factors that affect the compression process are well discussed.

Chapter 5 covers the conclusion of this project and future improvement can be made.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Remote sensing (RS) technology started in the late of 1800's on-board a balloon for aerial photography. In the early 1970s, the first imaging satellite (ERTS-1) captured the image of Earth. Since then, Earth surveillance technology being advanced which Earth Observation (EO) satellites were developed. Besides, a hyperspectral image remote sensing is able to provide extremely useful information for the different type of applications other than Earth surface monitoring, such as weather, oceanology, pollution control and etc. The image that takes into account is the hyperspectral image which includes the spatial (inter-pixel) and spectral (multi-component images) redundancy. The amount of acquired data of the hyperspectral image greatly increased since the spectral and spatial resolution of sensors which monitoring Earth terrains increase as well. Thus, imagery data volumes that increase immensely required image compression as there are lot issues need to overcome which the downlink bandwidth and limitation of on-board satellite storage.

Transferring the image from EO satellites to the ground station required to measure the distance and downlink speed. For example, the distance between EO satellites and the ground station about 500km to 800km and the range of the ground station from the EO satellites is about 7 minutes. Furthermore, the downlink bandwidth speed of 1Megabit per second (Mbps) and the maximum amount of data that could be transferred is around 420 Megabits (Mb) per pass which is not enough to send a hyperspectral image to the ground station within a single pass. In this bottleneck situation, image compression especially lossless compression is being focused and compression ratio (CR) and execution time (ET) are the important elements that need to be considered. Images could be downloaded easily through 1 Mbps downlink in a single pass if compress image to certain CR for example 3:1. In 2016, EO satellite done the demonstration of transmitter that on-board on Hodoyoshi 4 satellite resulted 505 Mbps downlink rate which enormously push EO technology to the next better level (Saito *et al.*, 2016) . Nowadays, remote sensing technology improve drastically as a few years ago, European Space Agency (ESA) satellites only provide the downlink speed around 420Mbps.

The hyperspectral image compression leads to the improvement of EO technology for reduction of imagery data size which allows more images to be stored in the on-board storage and also faster the time required to transfer the images from EO satellites to the ground station within a single pass. In addition, lossless compression is the perfect way of spectral and spatial decorrelation to retain the quality of original imagery data after the compression. The National Aeronautics Space Administration (NASA) and European Space Agency (ESA) focused on monitoring and capturing image in a space thus they should use JPEG2000 Compression which can help them advanced their technology and space industries.

2.2 Architecture for JPEG2000

JPEG2000 standard by ISO/IEC is an image coding system utilize image compression techniques based on wavelet technology. JPEG2000 is a very efficient compression algorithm that support spatial random access or region of internet access. Lossless data compression JPEG2000 is being used in many high-end applications for hyperspectral imaging in magnetic resonance imaging in medical applications, remote sensing in EO Technology, meteorology, oceanology and etc. Focused one is for military/surveillance satellite which monitor Earth terrains required image compression in order to minimize the usage of on-board storage and reduce the size of the image and the time to transfer image data to the ground station within a single pass.

The architecture for JPEG2000 includes of tiling, multi-component transformation, wavelet transforms, quantization and entropy coding which follow the standard. The compression of JPEG2000 includes two basic compression method which lossy compression and lossless compression. The lossless compression is based on predictive method which is independent of Discrete Cosine Transform (DCT) processing (Wallace, 1992). Figure 2-1 below shows the architecture for encoding process of JPEG2000.

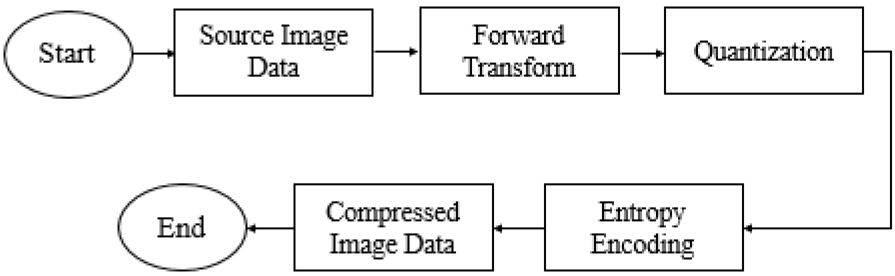

Figure 2- 1: Architecture for Encoding Process of JPEG2000 (Wallace, 1992).

The source image data is firstly applied the discrete transform before undergoing the quantization and then will be compressed to get the final compressed image data as an output image data – entropy coding (Wu, 1997).

In decompression technique perspective, the process is opposite or reverse to the compression method which shows in Figure 2-2. The JPEG2000 codec will be entropy decoded first, inversely quantized, and inverse discrete transformed. Then the image data will be reconstructed back to the original source image data. The flow of decompression image data shows in Figure 2-2 below.

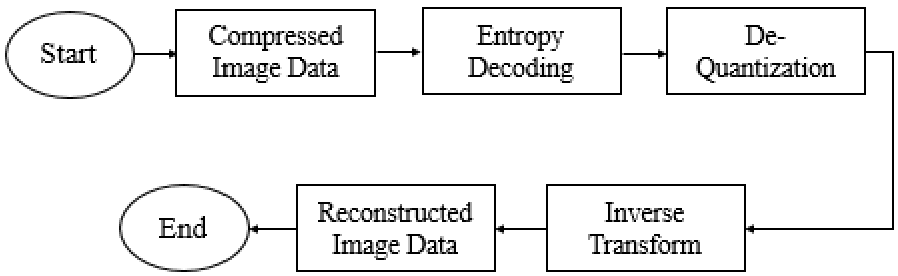

Figure 2- 2: Architecture for Decoding Process of JPEG2000 (Wallace, 1992).

2.2.1 Source Image Data

The source image data can be in variety of size and the digital information of the image that take into consideration commonly is 8-bits, 16-bits and 32-bits. Before applying Discrete Wavelet Transform (DWT), the standard works on tiling the source image into rectangular non-overlapping blocks – tiles, in the pre-processing.

2.2.2 Pre-processing

Image tiling is the process where the partitions of the original source image are compressed independently. The tiles exactly have same dimension but maybe there are different dimensions for the boundary tiles. This processing is very important since all other operations are performed independently on the each image tiles and tiling process to reduce memory requirements which is perfect to other operations as it can increase the efficiency of the operation.

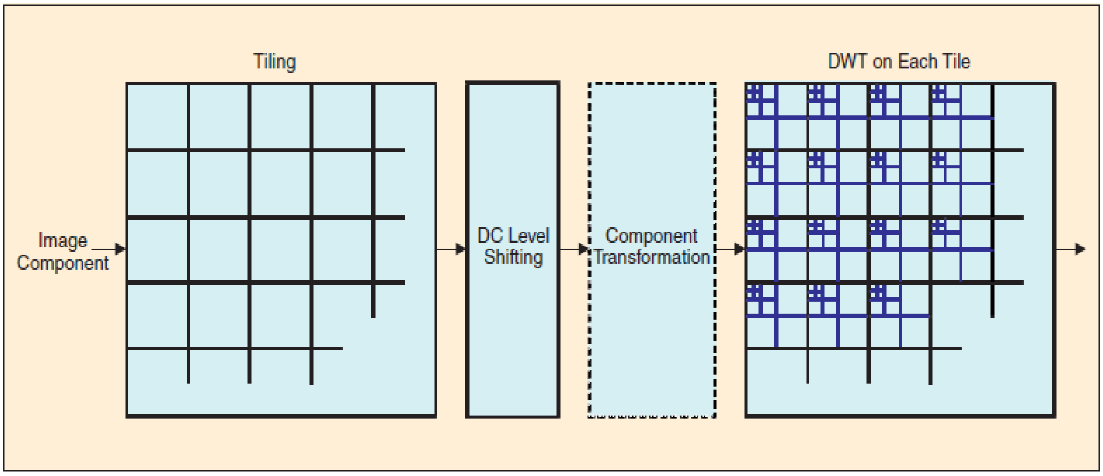

Figure 2- 3: Image Tiling Method (Skodras *et al.*, 2001).

Figure 2-3 shown the step of image tiling for pre-processing to reduce the memory required in the source image data. Before DWT step, there are two more steps, Discrete Cosine (DC) Level Shifting and Multi-Component Transformation.

DC Level Shifting is a process where the component's precision, P^i , is subtracted the same quantity,2^{P^i-1}.The optional purpose of this process is to confirm the input image samples,$I_i(x,y)$ have a dynamic range is approximately centred about zero by differentiate or shift the precision to produce the DC level shifted sample, $I_i'(x,y)$ as follows in Equation below ,

$$I_i(x,y) - 2^{P^i-1} \to I_i'(x,y)$$

DC Level Shifting (Acharya and Tsai, 2005).

Where,

$I_i(x,y)$ is the image sample
P^i is the precision of image samples
$I_i'(x,y)$ is the DC level shifted sample

Multi-component Transformation is functioning to improve compression performance and reduce the redundancy. In certain images, especially hyperspectral image, multi-component transformation is very effective in reducing the correlations among the components of imagery data. In the other hand, there are two standards – Irreversible Component/Colour Transformation (ICT) and Reversible Component/Colour Transformation (RCT). ICT usually used for lossy coding only and RCT suitable for both lossy and lossless coding which RCT is a perfect standard for lossless compression of JPEG2000. The component interpret is three colour planes (Red, Green, Blue). For lossless compression, the bit-depth of each image component should be identical dimension. RCT suitable for lossless compression because RCT can be inversed to reconstruct back the compressed image to the original source image but according to the standard, it also can be involved in lossy compression too.

2.2.3 Discrete Wavelet Transform

Discrete Wavelet Transform (DWT) is the most popular technique of transformation for image compression which approved by the standard (Gupta and Choubey, 2015). This technique widely used in signal processing as well as image compression especially JPEG and JPEG2000 image compression (Acharya and Tsai, 2005). DWT is the step after tiling so each tiles is decomposing into different decomposition levels. This decomposition levels contains a number of sub-bands at different levels of resolution. The sub-bands consist of coefficients that define the horizontal and vertical spatial signal characteristics of the original data of tile. DWT in JPEG2000 standard also essential for decomposing three dimensions of image, 1-D, 2-D and 3-D according to certain Part of JPEG2000. In Part 1 of JPEG2000 standard, which the file type is *.jp2, only power of 2 decompositions are allowed in the form of dyadic decomposition which have the best compression performance (Skodras *et al.*, 2001).

Mostly degree of scalability can be destroyed by DWT by implementing a natural framework (Zhang and Wu, 2006).

DWT method offered highly efficient and flexible for sub-band decomposition of image signal. The key of operation is 2-D DWT is already established a few years ago. 2-D DWT is a result from the extension of 1-D DWT by applying filter-bank. From the statements from (Skodras *et al.*, 2001), dyadic decomposition is the best compression performance and it is perfect for 2-D decomposition. Dyadic is called as binary relation which is a function for wavelet transform. The least or lowest frequency of sub-band decomposed into four smaller sub-band (Rabbani, 2002). This process will be repeated until there is no more tangible gains that can affect compression efficiency. Figure 2-4 below shows the level of dyadic decomposition of the "Lena" image.

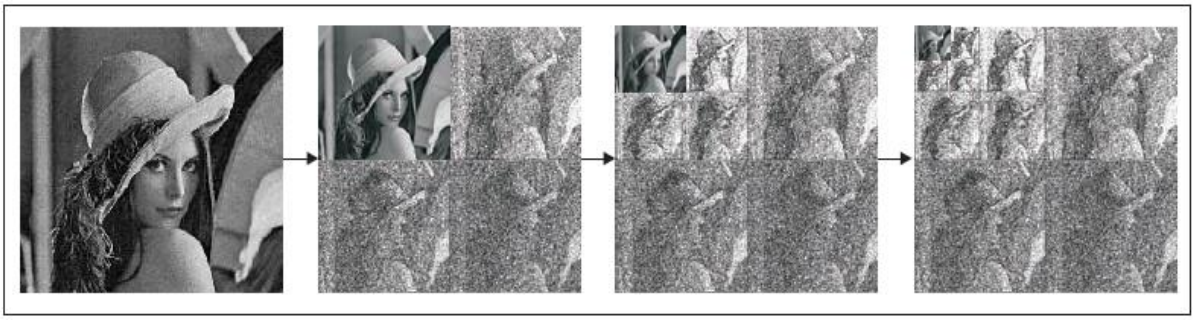

Figure 2- 4: Filter-bank of three level Dyadic Decomposition

In theory of sub-band decomposition, horizontal high pass filter (H) has been applied to the rows, follow by the vertical low pass filter (L) to columns. Figure 2-5 shows the decomposition of sub-band images – low-low (LL), low-high (LH), high-low (HL), and high-high (HH) (Sheng *et al.*, 1998).

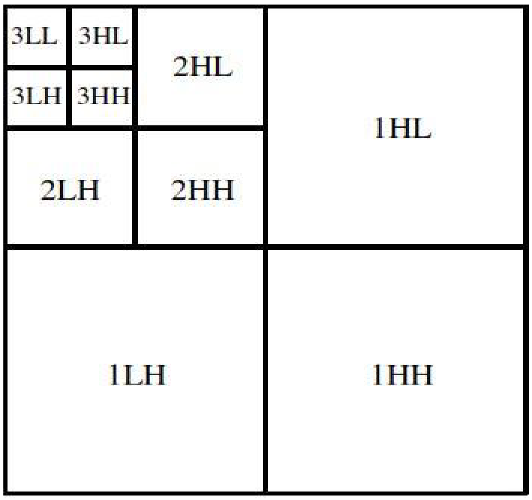

Figure 2- 5: 2-D DWT decomposition (Rabbani, 2002)

A high degree of spectral and spatial correlation images which known as hyperspectral images, the DWT process have been extended to 3-D. 3-D DWT analysis strategized to extract spectral-spatial information (Ye *et al.*, 2014). It encodes each group of wavelet coefficients independently. Addition of spectral information, 3-D DWT implements in the spatial-row, spatial-column and spectral-slice directions which resulting in eight subbands for one block from LLL, LLH, LHL, HLL, HLH, HHL and HHH – L for low pass and H for high pass filter (Ye *et al.*, 2014).

2.2.4 Quantization

Coefficients from DWT are quantized to reduce precision. Furthermore, quantization is lossy operation unless the coefficient is integer as it produced by the reversible integer 5/3 wavelet (Skodras *et al.*, 2001). After wavelet transform, the output is a set of integer numbers which have to be encoded bit-by-bit. The quantization step is changing the parameter to the final quality. If the step keeps changing and become greater, the quality losses also will increase. For lossless compression, there almost no quantization occurs because during DWT, image is encoded and the algorithm already concluded.

2.2.5 Entropy Coding

Entropy coding is the final stage where every sub-band are divided into rectangular block independently and entropy coding can be achieved by using many coding algorithms (Kabir and Mondal, 2017). Huffman Coding and Arithmetic Coding suitable for lossless data compression. Huffman Coding is an addition coding that able to compress data without any help of data transformation (Sharma, 2010). In the other hand, Arithmetic Coding is a coding technique that less number of bits is used if more frequent symbol occurred (Witten *et al.*, 1987).

Entropy coding by using Embedded Block Coding with Optimal Truncation (EBCOT) is more efficient and reduce the compression time (Saidani *et al.*, 2016). EBCOT function is reduce memory requirement in hardware as well as software (Marcellin *et al.*, 2000). EBCOT has ability in parallelization, improve cropping, efficient rate control and maximum flexibility in arrangement progression order.

After quantization, the code-block is coded one by one starts with the array of integers that contain the most significant bit (MSB) continues until the final array that consist of the least significant bit (LSB). The binary arrays is known as bit-planes, is encoded in three passes, first pass is a significant propagation pass, continue with magnitude refinement pass and finalized by clean up pass. The entropy coding helps the JPEG2000 reducing the redundancy of the image.

2.3 Lossless Hyperspectral Images Compression

This project is focused on hyperspectral image compression for remote sensing. A hyperspectral image compression is a process of removing the redundancies in an image. There are two types of compression – lossy and lossless – determined due to the compression method used.

2.3.1 Image Redundancy

Basically, 2-D image just have statistical redundancy which involved in code-words and symbols, spatial redundancy which exists in an image information that the one pixel contained from neighbouring pixels, human vision redundancy is based on the visual limited capability that not sensitive to high frequency contents. But, hyperspectral image consists one more redundancy which is spectral redundancy refers to multi-component images where the degree of correlation between the bands is too high (Mat Noor *et al.*, 2010; Mat Noor and Vladimirova, 2013).

Each redundancy have its own elimination or reduction technique. For statistical redundancy, entropy coding by using arithmetic code is suitable to decorrelate the redundancy. Intraband compression method is a perfect way to reduce spatial redundancy. Human vision redundancy, high frequency components need to be remove in order to reduce this redundancy so quantization is popular method but during compression, some information will lost and this method is called as lossy compression.

The redundancies in hyperspectral image are spectral and spatial redundancy. Spectral redundancy is due to the correlation between the bands and spatial is due to correlation between pixels in the spectral band (Mat Noor and Vladimirova, 2013). For the lossless compression of hyperspectral image, the lossless spatial decorrelation in 2-D image compression operates after lossless spectral decorrelation. To achieve complete lossless compression, both decorrelation process must be lossless. Figure 2-6 shows the the combination of technique to achieve lossless or lossy compression.

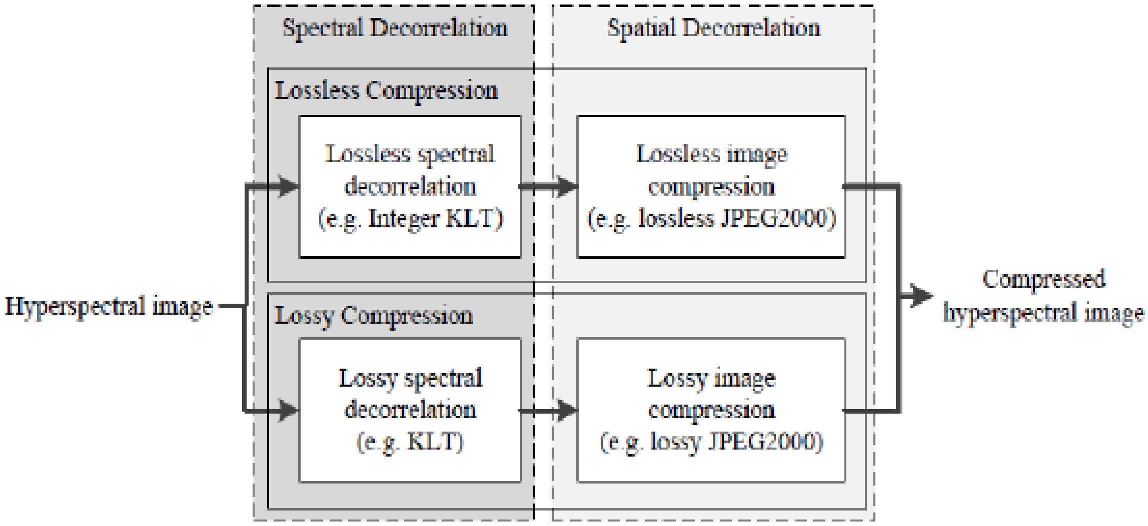

Figure 2- 6: Hyperspectral Image Compression

2.3.2 Source Hyperspectral Image – AVIRIS

AVIRIS stands for Airborne Visible/ Infrared Imaging Spectrometer (AVIRIS) have three datasets – Cuprite, Jasper Ridge and Moffett, for experimental function. The original datasets for one pixel of AVIRIS is 16-bits and have been cropped spatially to a size of 512 rows x 512 columns, and 224 spectral bands are composed together (Du and Fowler, 2007; Wu *et al.*, 2015).

From Figure 2-6, hyperspectral image – AVIRIS, will first performed a spectral decorrelation before spatial decorrelation. Lossless spectral decorrelation must be done by operating Integer KLT to reduce spectral redundancy (Töreyın *et al.*, 2015). This decorrelation process affect the binary size of AVIRIS data as integration of 16-bit datasets become 32-bit. To achieve lossless compression, lossless spectral decorrelation needs to be coupled with lossless spatial decorrelation.

2.3.3 Integer KLT – Spectral Decorrelation Method

Karhunen-Loève Transform (KLT) is an orthogonal linear transform to reduce the redundancy between the spectral bands. KLT algorithm also known as Principal Component Analysis (PCA) is a lossy transform which have some floating-point output undergo different matrix factorizations – Integer KLT – to eliminate the floating-point output and accomplish a lossless spectral decorrelation (Egho and Vladimirova, 2014).

The computation process for KLT and Integer KLT algorithm share a few similar elements such as BandMean, MeanSub, Covariance Matrix and Eigenvectors. Some modification that applied to get Integer KLT is – BandMean vector rounded to the nearest integer, PLUS Matrix factorization is applied to Eigenvectors and Matrix Lifting is replaced the matrix multiplication between Eigenvectors x MeanSub. Figure 2-7 shows the flow of KLT and Integer KLT computation process (Egho and Vladimirova, 2014; Noor and Vladimirova, 2011; Noor and Vladimirova, 2012).

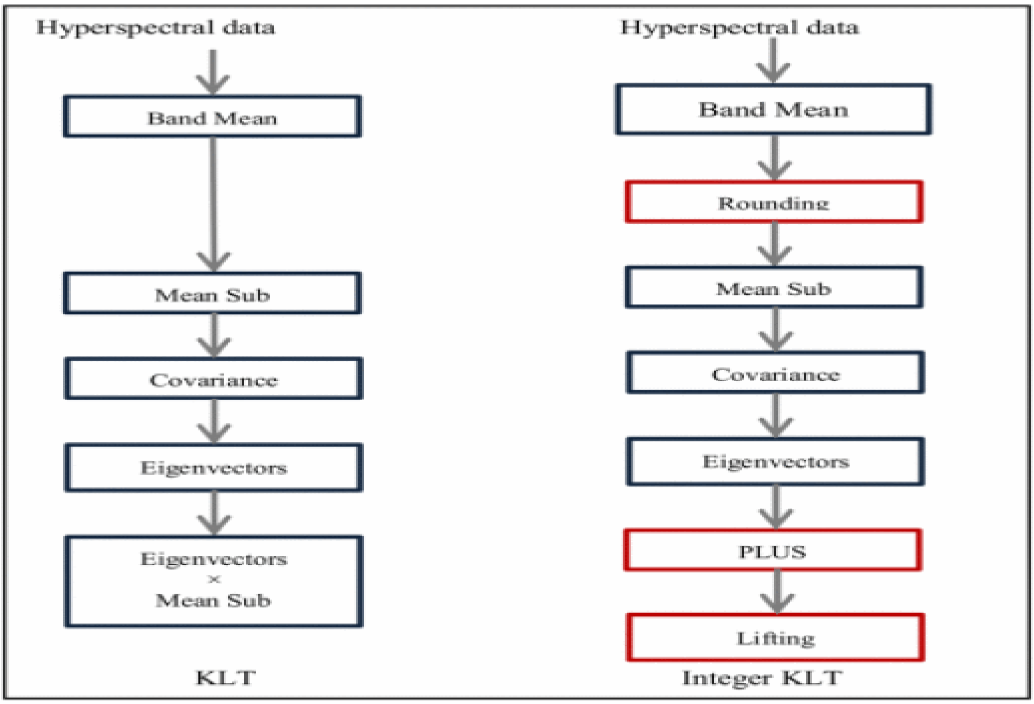

Figure 2- 7: The Computation Process of KLT and Integer KLT (Egho and Vladimirova, 2014)

According to the research article (Töreyın *et al.*, 2015), KLT appeared as the best decorrelation performance. However, KLT disadvantaged in computation power, resource, time and complexity. In order to achieve higher compression ratios, KLT should be chosen instead of other spectral decorrelation methods such as Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT), and Vector Quantization (VQ), due to the it efficiency and performance quality. The computation power is optimized by the modification of Integer KLT through the parallelization process.

Research by (Egho and Vladimirova, 2014) shows the result of lossy and losses compression performance between KLT and DWT. Figure 2-8 below shows the Comparison of the KLT and DWT for Lossy Compression Performance by using AVIRIS source image. Table 2-1 belows show the result for comparison of lossless compression performance by using same AVIRIS image. Comparison of Lossless Compression Performance – Multi-Component Compression (MCP), Linear Prediction (LP), Band Differential (BD), and Integer Wavelet Transform (IWT).

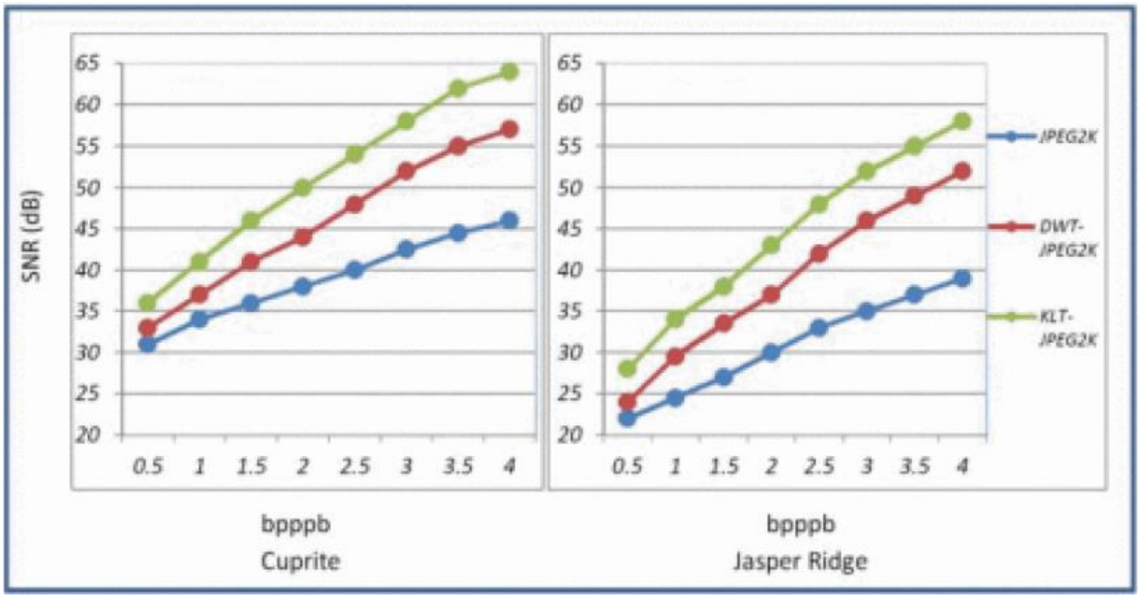

Figure 2- 8: Performance Comparison of KLT and DWT Lossy Compression (Egho and Vladimirova, 2014)

Table 2- 1: Comparison of Lossless Compression Performance

Cuprite			Jasper		
MCP	BD & LP	IWT	MCP	BD & LP	IWT
8.94%	7.7%	8.86%	15.04%	11.84%	14.46%

The result from the research before explained that Integer KLT is the best method for lossless spectral decorrelation. The spectral decorrelation of Integer KLT go through clustering technique to optimize the computational burden by minimizing the number of spectral bands for encoding process (Noor and Vladimirova, 2012). Instead of DWT method which applied to break the correlation of hyperspectral image.

2.3.4 OpenJPEG2000 – Spatial Decorrelation Method

OpenJPEG is an updated and latest open-source code standard by ISO/IEC and ITU-T as JPEG2000 Reference Software. According to the JPEG2000 architecture that have been researched and explained, JPEG2000 suitable for both lossy and lossless spatial decorrelation.

Compression performance of JPEG2000 effected by several factors such as complexity and functionality. In journal (Santa-Cruz *et al.*, 2002), Figure 2-9, the comparison for lossless compression performance of JPEG2000 with other algorithm have been done on seven different images that have same depth of 8 bits per pixel from the official test set of JPEG2000. The natural images - “bike” (2048 x 2560) and “cafe” (2048 x 2048), “cmpndl” (512 x 768) and “chart” (1688 x 2347) are compound documents, aerial photography “aerial2” (2048 x 2048), computer-generated image “target” (512 x 512) and lastly ultra-scan image, “us” (512 x 448).

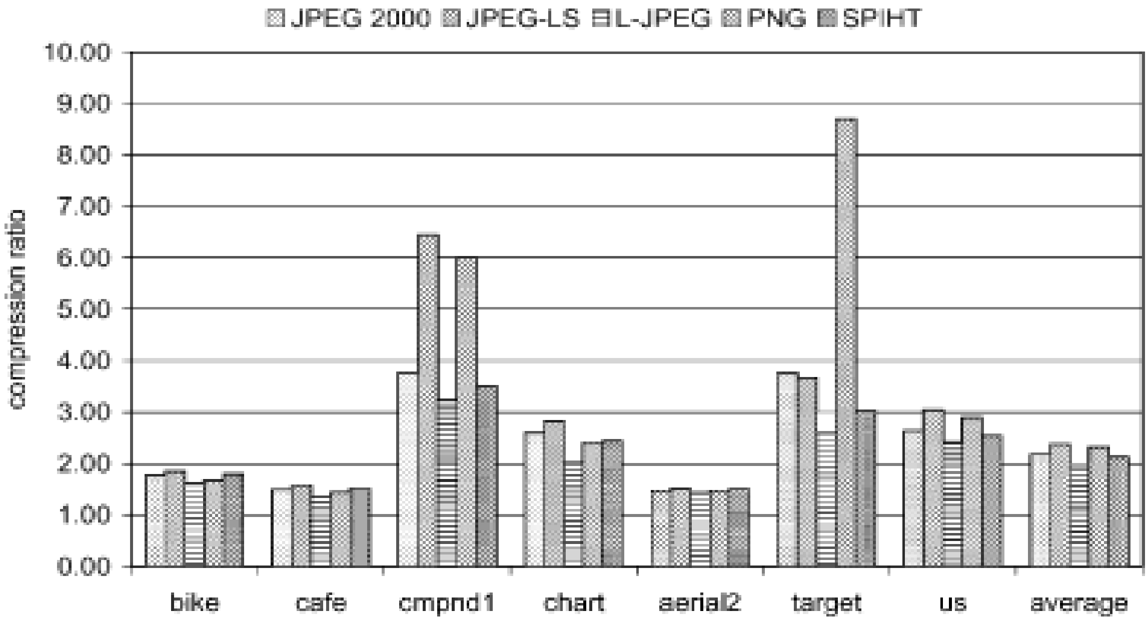

Figure 2- 9: Compression Ratio (CR) for Lossless Compression (Santa-Cruz *et al.*, 2002)

The graphs compare the performance between JPEG2000, JPEG-LS, JPEG, PNG, and SPIHT. From the result shown in Figure 2-9, it can be determined that JPEG2000 is pretty stable and it provides competitive compression ratio in term of its ability to deal with various types of images. The different types of images implement different component of the image, so JPEG2000 performed well to maintain it performance.

Table 2-2 shows other codec compare to OpenJPEG for two video clips, Stefan and Mobile, and two images, Lena and Baboon. The result is OpenJPEG lead MS-SVC 0.07 on average (Tsai and Lin, 2011).

Table 2- 2: Experiment result of OpenJPEG with MS-SVC

Source	**OpenJPEG**		**MS-SVC**	
	CR	**Time (sec)**	**CR**	**Time (sec)**
Stefan	1.81	0.125	1.67	0.040
Mobile	1.44	0.144	1.32	0.052
Lena	1.80	0.332	1.80	0.102
Baboon	1.30	0.403	1.305	0.125

2.4 Conclusion

In conclusion, a lossless hyperspectral image compression can be performed by implementing Integer KLT method for lossless spectral decorrelation and an open-source code, OpenJPEG2000, as an algorithm to reduce the spatial redundancy and carried out lossless spatial decorrelation. Integer KLT method appeared as the best spectral decorrelation technique compared to the other methods. Also, JPEG2000 maintained it performance when compressing various types of images. Its compression performance is stable even though its algorithm is complex. Marking the better performance for image compression is referred to the compression ratio and execution time of the system. The higher the compression ratio, the shorter the execution time, the better the image compression system and the less the image data loss.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Based on literature review that has been complete, there are few major steps are arranged to design the lossless compression in JPEG2000 platform. The system design for implementation and testing are covered in this chapter. Certain methods are implemented to organize a lossless 3-D hyperspectral image compression systematically in order to achieve the objective of this project.

According to the researches that have been done through some journals, books, conference and articles, a lot of information for 3D OpenJPEG2000 with Integer KLT project are studied. The knowledge obtained is analysed the advantage and capabilities for the system. In order to complete the system flows, OpenJPEG, CMake, Integer KLT and Microsoft Visual Studio C/C++ 2008 and 2010 are utilized and implemented JPEG2000 codec for lossless compression before integrate in Integer KLT to measure and compare the compression ratio and execution time of compressed image data.

3.2 Research Flow

Open-source code is used as it is available to be applied in a variety of platform and software. Other than that, open-source code can be used and modified in any suitable program to meet the user's requirements. OpenJPEG.org provides the open-source JPEG2000 codec written in C language. In May 2015, ISO/IEC and ITU-T acknowledged OpenJPEG as an official JPEG2000 Reference Software. OpenJPEG is launched under the 2-clauses BSD license, which copyright holder gives a green light to study, modify or use the code for various applications as well as to share the modified codec through server or website. For this project, OpenJPEG2000 codec is compiled in Microsoft Windows operation system (OS). Figure 3-1 shown the codec is compiled and run in Windows OS through Microsoft Visual Studio C/C++ 2008. Even though Microsoft Visual Studio 2008 is not the latest one, it has the capabilities to run the whole project without problems if we settings it correctly.

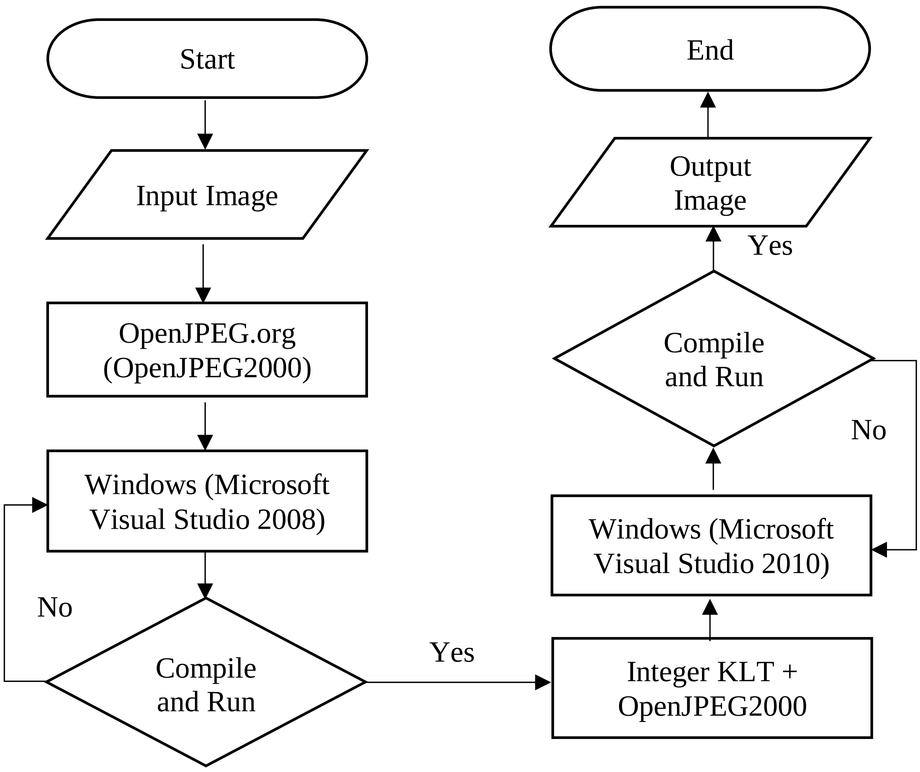

Figure 3- 1: Project Research Flow

3.3 Software Setup

Windows is an only OS used in this project and two source of JPEG2000 codec. Microsoft Visual Studio 2008 is a primary software to compile OpenJPEG codec and Kakadu Software is a different which it is a close-source code for compression JPEG2000 standard. Last software used is CMake which used to generate the codec from OpenJPEG. Finalization of this project by comparing the CR and ET by Integer KLT. The compressed images, *.j2k files can be viewed by using external software, ENVI 5.3 Software which help user to view the compressed images band by band. The properties and quality of image can be clearly viewed.

Figure 3-2 shows the project flow for JPEG2000 lossless image compression by implementing code from OpenJPEG through Microsoft Visual Studio 2008 and integration Integer KLT algorithm followed with OpenJPEG2000 algorithm through Microsoft Visual Studio 2010. OpenJPEG is a versatile codec which executables for JPEG2000 image compression and decompression. Also, it is chosen because it have a trust from ISO/IEC and ITU-T which is allowing users to utilize the codec from OpenJPEG without any doubt. Besides that, the library has been created and it performance still maintained by the Image and Signal Processing Group (ISPGroup) from Université de Louvain (UCL) so OpenJPEG always been supported and retained as this can ensure the good quality and performance of this open-source code.