CHAPTER 5

STEREO IMAGE COMPRESSION WITH DWT IMAGE TRANSFORMATION

5.1 Introduction

Although the DCT-based image compression Algorithms such as JPEG have provided satisfactory quality, it still leaves much to be desired. Thus, the new DWT-based image compression Algorithms such as JPEG 2000 became increasingly popular. DWT (Discrete Wavelet Transform) is an application of Sub band coding; thus, before introducing DWT, briefly the theory of Sub band coding could be described.

In sub band coding, the spectrum of the input is decomposed into a set of Band limited components, which is called sub bands. Ideally, the sub bands can be assembled back to reconstruct the original spectrum without any error.

At first, the input signal will be filtered into low pass and high pass components through analysis filters. After filtering, the data amount of the low pass and high pass components will become twice that of the original signal; therefore, the low pass and high pass components must be down sampled to reduce the data quantity[68]. At the receiver, the received data must be up sampled to approximate the original signal.
Finally, the upsampled signal passes the synthesis filters and is added to form the reconstructed approximation signal. After sub band coding, the amount of data does not reduce in reality. However, the human perception system has different sensitivity to different frequency band. For example, the human eyes are less sensitive to high frequency-band color components, while the human ears is less sensitive to the low-frequency band less than 0.01 Hz and high-frequency band larger than 20 KHz. We can take advantage of such characteristics to reduce the amount of data. Once the less sensitive components are reduced, one can achieve the objective of data compression.

A low pass filter and a high pass filter are chosen, such that they exactly halve the frequency range between themselves. This filter pair is called the Analysis Filter pair. First, the low pass filter is applied for each row of data, thereby getting the low frequency components of the row. But since the lowpass filter is a half band filter, the output data contains frequencies only in the first half of the original frequency range[70]. So, by Shannon’s Sampling Theorem, they can be sub sampled by two, so that the output data now contains only half the original number of samples. Now, the high pass filter is applied for the same row of data, and similarly the high pass components are separated, and placed by the side of the low pass components. This procedure is done for all rows.
Next, the filtering is done for each column of the intermediate data. The resulting two-dimensional array of coefficients contains four bands of data, each labeled as LL (low-low), HL (high-low), LH (low-high) and HH (high-high). The LL band can be decomposed once again in the same manner, thereby producing even more sub bands. This can be done upto any level, thereby resulting in a pyramidal decomposition as shown below.

![First level DWT Decomposition](image1)

**Fig 5.1 First level DWT Decomposition**

![Second level DWT Decomposition](image2)

**Fig 5.2 Second level DWT Decomposition**
Fig 5.3 Third level DWT Decomposition

As mentioned above, the LL band at the highest level can be classified as most important, and the other 'detail' bands can be classified as of lesser importance, with the degree of importance decreasing from the top of the pyramid to the bands at the bottom.

Fig 5.4 Combined 2nd level 2D DWT

The separable 2-D wavelet transformation can be implemented by applying a two level decomposition of the 1-D DWT in the horizontal and
vertical dimensions respectively[70]. The resulting sub-band decomposition of this transformation is described in Figure 5.4, where G(n) and H(n) represent the low-pass and high pass wavelet filters, respectively. In the 2-D DWT filter bank structure, in each stage, the row computations precede the column computations. In stage 1, 1-D DWT is computed along the rows of the input array to generate H1 (high-pass) and L1 (low-pass) outputs.

If the image is of size N x N, then the H1 and L1 output arrays are each of size N/2 x N/2. The HH1 and HL1 outputs are obtained by computing the 1-D DWT on the H1 columns. Similarly the LL1 and LH1 outputs are obtained by operating upon the L1 columns[80]. Each of the LL1, LH1, HL1, HH1 arrays are of size N/2 x N/2. The LL1 outputs are again decomposed to obtain the outputs for stage 2 namely, LL2, LH2, HL2, and HH2 which are each of size N/4 x N/4. Out of these the LL2 outputs are sent to stage 3 for further decomposition.

In the inverse wavelet transform processing, Just as a forward transform is used to separate the image data into various classes of importance, a reverse transform is used to reassemble the various classes of data into a reconstructed image. A pair of high pass and low pass filters is used here also. This filter pair is called the Synthesis Filter pair. The filtering procedure is just the opposite - we start from the
topmost level, apply the filters column wise first and then row wise, and proceed to the next level, till we reach the first level.

5.2 Stereo Image Compression with DWT

Generally wavelet based analysis can be used to divide the information about the image into approximation and detailed sub signals. The sub signals approximation show the characteristics of pixel value and other three detailed sub signals show vertical, horizontal and signal details as well as charges in the Image. If the value of detailed sub signals are very small, they are set to zero without any significant changes in the Image. If the number of zeros is larger in the image information then the compression ratio of the image is also greater.

There are two types of wavelet transforms used. They are continuous wavelet transform and discrete wavelet transform. The wavelet analysis is performed by the filter bank there are two types of filters. One is high pass filter, in which high frequency information are kept and low frequency information are lost; another one is low pass filter in which low frequency information is only kept and high frequency information is lost. So that the signals of the images are effectively decomposed into two distinct parts that is, a detailed part represent high frequency and an approximation part represent low frequency[76]. The level of detail are classified into three that is level 1 detail is horizontal
detail level 2 detail is vertical detail and level 3 detail is dragal detail of the signal of the image.

The Algorithm for stereo image compression using DWT transformation is divided into two parts. First part contains encoding process next part is decoding process.

5.3 DWT Based Stereo Image Compression Algorithm

Encoding process

Step 1:  The left and right Image of the stereo image pair are divided into 8x8 blocks.

Step 2:  By applying the block matching process between the stereo pair images, the error image is computed, which means that, the differed block in the right image is compared with left image. This process is called smart estimation. (Because of the high correlation between the stereo image pairs, it is inefficient to compress the left and right images separately)

Step 3:  The left image has to be been passed through the high pass filter as well as low pass filter by applying on row by row

Step 4:  The output of the above process is low l and high h which are combined into t1 (l1, h1)

Step 5:  Now t1 is down sampled by 2

Step 6:  t1 has been given as input to high pass filter and low pass filter by applying column by column
Step 7: output of step 6 is represented as l₂ and h₂ then l₂ and h₂ are combined into t₃ that is, t₃[l₂, h₂]

Step 8: The signals in t₃ down sampled by 2, the result is our compressed image.

Step 9: Instead of compressing the right image by applying the above steps we only use error image to find the compression of right image. The similar block signals are appeared from left image, the varied blocks are separately included into the encoding process of DWT.

The above Algorithm shows one level of discrete wavelet transform. One can increase the level of DWT by applying the above procedure more than one time. When we increase the level of DWT, the process yields better compression ratio. But the quality of the reconstructed image is very poor. The first level DWT in better and quite reasonable for both high compression ratio and yields good quality with less value of Mean Square Error.

Decoding Process

The decoding process in stereo image compression is not exactly a reverse process of encoding process, the steps of decoding process is given below,

- For the left image, separate high pass filter image and low pass filter image from the compressed image. The upper half rectangle
of image matrix is called low pass filter image and the lower half rectangle is called high pass filter image.

- Both the portions of the image is up sampled by 2
- Perform summation of resultant image into one image.
- Then divide the image vertically into two parts, Here the first half image low pass filter image and second half image is high pass filter image.
- Again both the partitions of the image are upsampled by 2.
- Perform summation of both the images that is our remonstrated image.
- To decode the left image, consider the error image, that is the difference between the right and left image and then go through the decoding process. Here the invariant image junk is appended with other junk (blocks) of right image to retrieve the reconstructed right image.

Through the compression process using DWT transformation of stereo images, very high compression ratio can be got and very minimum amount of information is lost. When we go beyond next level of DWT we get more compression ratio, but the quality of reconstructed image is poor, that is the reconstructed image is not identical to original image. The following table illustrates the results of the stereo image compression Algorithm applied to the various stereo image pairs. The PSNR and the
Bit rate value of the images are represented by table as well the graphical form.

**Table 5.1 Performance of DWT II Stereo Image Compression**

<table>
<thead>
<tr>
<th>Image Name</th>
<th>Bit Rate</th>
<th>PSNR</th>
<th>Size of Original Image</th>
<th>Size of Compressed Image</th>
<th>Compression Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corridor</td>
<td>1.521664</td>
<td>18.0</td>
<td>27Kb</td>
<td>7.43kb</td>
<td>3.633</td>
</tr>
<tr>
<td>Hotel Lane</td>
<td>1.404928</td>
<td>22</td>
<td>26 kb</td>
<td>6.86 kb</td>
<td>3.790</td>
</tr>
<tr>
<td>Forest</td>
<td>1.605632</td>
<td>31.0</td>
<td>33 kb</td>
<td>7.55 kb</td>
<td>4.370</td>
</tr>
<tr>
<td>Pillar</td>
<td>1.777664</td>
<td>24.5</td>
<td>38 kb</td>
<td>8.68 kb</td>
<td>4.377</td>
</tr>
</tbody>
</table>

![Graph](image.png)

Fig 5.5 Performance of DWT II Stereo image compression (graph)

The table 5.1 and the Fig 5.5 illustrate the characteristics of the stereo pair image compression Algorithm using DWT image transformation. It shows the PSNR and Bitrate value of the images and the size of original image as well as compressed image with their compression ratio.