CHAPTER 5

LOSSLESS WAVELET TRANSFORMS AND HISTOGRAM MODIFICATION

5.1 BRIEF DESCRIPTION

For a given medical image, after the data has been embedded as DWT and DCT coefficients, it is possible to cause overflow and underflow. This indicates that after the Discrete Wavelet Transform, the pixel grayscale values [0,255] of the marked medical image may exceed the upper bound (255 for eight bit gray scale image) and the lower bound (0 for eight bit gray scale image) (Guorong Xuan et al. 2003), Lei Yang Pengwei (2007). Histogram modifications are adapted to prevent overflow and underflow and to narrow the histogram from both sides. The information is then embedded into the cover media (image) together with the overhead, and recovery of the original image is done successfully (Yimin Qiu et al. 2013).

5.2 LOSSLESS DATA HIDING BASED ON DISCRETE WAVELET AND DISCRETE COSINE HISTOGRAM SHIFTING

5.2.1 Introduction to Wavelet Histogram Shifting

Histogram shifting takes care of the specificities of the medical image content as the image that can be watermarked is shifted in a different manner, and as a result, the data embedding and extraction remain synchronized in
In order to achieve better PSNR and capacity (Wei Pan Cuppens-Boulahia et al 2012). In this scheme, wavelets have been successfully used in image enhancement analysis and histogram shifting (Ying Yang et al 2008). These wavelets are represented with good resolution, in different frequency sub-bands. The characteristic feature of histogram shifting is that it provides a compact representation of the image (Agma Traina et al 2001). Hence, the wavelet transformed domain is believed to be more optimal than the spatial domain. The wavelet coefficients have been distributed in the high frequency sub-bands. The histograms of high frequency sub-bands, referred to as wavelet histograms, are explained in this paper (Guorong Xuan et al 2007). There are two axes in histograms, one is the horizontal axis and the other is the vertical axis. The horizontal axis represents the wavelet coefficients and vertical axis represents the occurrence of the number of corresponding wavelet coefficients.

![Figure 5.1 (a) Original Histogram](image1)

![Figure 5.1 (b) Histogram after a zero point is created](image2)

We consider a simple example as shown in Figure 5.1 a & b for our discussion. This demonstrates the principle of data embedding using histogram shifting. Figure 5.1 (a), shows the original histogram shifting of a
Discrete Wavelet high frequency sub-band (Rafal Dlugosz et al 2011). In Figure 5.1(b), a zero point, wherein no other coefficient in this sub-band assumes this specific value, (M) is created. This implies that we shift the part of the histogram with values larger than M towards the right hand side by one unit. The original M value now becomes M+1, while the original M+1 becomes M+2 and so on. The part of the histogram (Bagnall et al 2006) with values less than and equal to M remains unchanged. In the data embedding technique, the DWT and DCT coefficients in the high frequency subband are scanned. Primarily, when the DWT coefficient, of value ‘M’ is encountered and the embedded bit is 1, the coefficient value will be added by 1 i.e., it becomes ‘M+1’. If the embedded bit is ‘0’, the coefficient value remains M. The data extraction is in fact, the reverse process of data embedding Chia-Chen Lin (2008). When the DWT coefficients of the high frequency sub-bands i.e., HL, LH, and HH of value ‘M+1’ is met, bit ‘1’ is extracted and the coefficient value reduces to ‘M’. Consecutively, if the value of ‘M’ is met, bit ‘0’ is extracted. Following the extraction of all data, a specific region of histogram, equal to or larger than M+2, needs to be shifted towards the left side by one unit Harsh (Vikram Singh et al 2007). It is known that histogram shifting can also be carried out on the left-hand side. Evidently, the occurrence of the number of coefficients having the value ‘M’ in the histogram is the payload. The wavelet coefficients, encountered in the embedding process, are controlled by using a key in order to make the hidden data secure. The data embedding and the data extraction process elucidated above are summarized (Chia-Chen Lin 2010, Ying Yang 2008). As shown in Figure 5.1 we shift or move the histogram, starting from value M+1 towards the right-hand side one by one without making the value of M+1 empty i.e., by generating a zero point at M+1 histogram. Therefore, in accordance with the embedded bit sequence, we keep the coefficients of M constant, by not changing their embedded values. During data retrieval, we extract a bit ‘0’ from those coefficients with value M. The same bit is repeated for those
coefficients having a value of M+1. The value of coefficients may also be reduced from M+1 to M. After all of the hidden bits have been extracted, the part of the histogram larger than M+1 is shifted towards the left-hand side by one unit (Shiva Kumar et al 2010). In the data embedding process, the DWT and DCT coefficients of the marked image are obtained. Furthermore, the original cover image should be recovered. As the histogram of the DWT high frequency sub-bands follow a Laplacian-like distribution, experiments confirm that our histograms offer a substantial and steady improvement in its accuracy (Waleed Al-Nuaimy et al 2011). It may be inferred that, based on the algorithm, we can embed the data on both sides of the histogram until all the bits that need to be embedded are embedded (Chaumont & Puech 2006).

5.2.2 Data embedding algorithm

For a given medical image, the embedding and extracting algorithms are presented. Assume that there are N bits to be embedded into a frequency subband of DWT and DCT. The data embedding process is carried out in the following manner:

1. Set a peak. Let the number of high frequency wavelet coefficients in[-p, p] be greater than N.

2. In the wavelet histogram, shift the histogram to the right hand side by one unit to leave a zero point at the peak value. Subsequently, embed the data in this point.

3. If the data to be embedded remains let peak = - peak. Move the histogram to the left hand side, by one unit, to leave a zero point at the value (-peak -1). Subsequently, the data are embedded at the point.
4. When the entire data has been embedded, stop the embedding process and record the peak P. Else, go back to step (2) to continue the embedding of the remaining data.

5.2.3 Data Extraction Algorithm

Data extraction is the exact opposite of data embedding. Without any loss, assume that the data embedding process is positive. The data extraction steps are as follows:

1. Set P (peak).

2. Decode the value P and the value P+1. Extract all the data until P+1 becomes a zero point. Move the DWT and DCT coefficients of the histogram towards the left hand side by one unit, to eliminate or cover the zero point.

3. If the amount of extracted data is less then set P←P-1, continue to extract the data until (P-1) becomes a zero point. Then, move the histogram (less than P-1) to cover or eliminate the zero point.

4. If all the hidden bits have been extracted, stop the process. Else, set P←P and retrace to step (2), to continue the data extraction.

5.2.4 Detailed Algorithm

The embedding and extraction algorithms for medical MR images is being clearly presented with respect to DWT and DCT. Here, the bits are embedded into the frequency sub-band of DWT and DCT. The embedding process commences for those high frequency coefficients with a value greater
than N. In the wavelet technique, we shift the histogram to the right hand side and embed that value. Subsequently, we move the histogram to the left hand side and embed the value as (-). The data that have been embedded causes overflow and underflow, thus indicating that the pixel gray scale values of marked medical images may exceed the upper bound gray scale image in order to recover the original data. The data extraction is just the exact opposite of the data embedding process. Without losing any information all the values are decoded and the zero point is eliminated. The extracted data will be less than the peak values. Once all the data are extracted, we say that the recovered data is obtained without any loss.

5.3 EXPERIMENTAL RESULTS AND THEIR COMPARISON

In this section, experiments are carried out to test the performance in terms of capacity and the PSNR. The image to be embedded has a dimension of 256x256. In all our experiments, the quality and recovery of the image have been executed perfectly. Data embedding and extraction are done precisely. The proposed method has been implemented using MATLAB, and tested with the database of different medical images. The extraction and recovery of the original image, with respect to PSNR, in the proposed method are better when compared to the performance measures of the existing work. Moreover, the maximum number of bits embedded for DWT is 15336 and the maximum number of bits embedded for DCT is 10000 the difference between the original and the recovered image is 0. Thus, the bits embedded for DWT are more than that of DCT. The PSNR value is high for those medical images and the visual quality is still acceptable. The medical images of the iris, brain and abdomen, each of 256x256 pixels are reported here and the PSNR versus embedding capacity are shown in Tables 1 and 2 for DCT and DWT, which shows the difference between the two transforms. Furthermore, the embedding algorithm and the extraction algorithm are tested and compared.
Figure 5.2  PSNR and Capacity of marked images with a payload of 0.5bpp
(a) Iris: 58.9 dB & 85x10^4,  (b) Retina: 49.8dB & 80x10^4, (c) Brain: 56.7 dB & 70.5x10^4, (d) Abdomen: 56.6 dB & 75.5x10^4, (e) Stomach: 54.1 dB & 70.5x10^4, (f) Skull: 53.5 dB & 69.5x10^4

Table 5.1 Experimental Results of Peak signal to noise ratio and capacity for DWT

<table>
<thead>
<tr>
<th>Medical images</th>
<th>Peak signal to noise ratio(db)</th>
<th>Embedding Capacity in bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Img(a)</td>
<td>57.9</td>
<td>85522</td>
</tr>
<tr>
<td>Img(b)</td>
<td>54.8</td>
<td>60389</td>
</tr>
<tr>
<td>Img(c)</td>
<td>55.8</td>
<td>70555</td>
</tr>
<tr>
<td>Img(d)</td>
<td>56.7</td>
<td>80656</td>
</tr>
<tr>
<td>Img(e)</td>
<td>54.1</td>
<td>75633</td>
</tr>
<tr>
<td>Img(f)</td>
<td>53.5</td>
<td>70533</td>
</tr>
</tbody>
</table>
Tables 5.1 and 5.2 show the PSNR and embedding capacity for different medical images such as - iris, brain, retina and abdomen - using DWT and DCT transform techniques. It indicates that the increase of the PSNR does not always lead to the increase in payload. When the payload is smaller, we can choose a larger peak. During data embedding, a fewer number of coefficients are altered and the resultant PSNR and capacity are found to be high for DWT and moderate for the DCT technique. Hence, tremendous improvement is observed using this approach. It has to be noted that performance comparisons between these methods have been carried out experimentally with respect to PSNR and capacity. PSNR vs the embedding capacity for DWT is found to be superior to that of DCT and the experimental results are reported in this paper. The performances, in terms of PSNR vs. embedding capacity, are shown graphically in Figure 5.3, 5.4, 5.5, 5.6, 5.7, 5.8 respectively.
Figure 5.3  Capacity v.s. medical images with data hiding using histogram shifting method in the Differential wavelet transform domain

Figure 5.4  Capacity vs different medical images with data hiding using histogram modification in the DCT domain
Figure 5.5  PSNR vs different medical images with data hiding using histogram modification in the Differential wavelet transform domain

Figure 5.6  PSNR vs medical images with data hiding using histogram modification in the Discrete Cosine Transform domain
Figure 5.7  Comparison of PSNR vs. medical images with data hiding using histogram modification in the DWT and DCT domains

Figure 5.8  Performance comparison of capacity vs medical images with data hiding using histogram shifting method in the DWT and DCT domains
The graphs clearly depict PSNR vs their corresponding embedding capacities for different values of medical images with respect to quality, the images used, and the algorithms implemented. The capacity PSNR performance of DWT and DCT based on our algorithm highlights the improvements made by using our method. The graphs show that the highest PSNR value for DWT is 57.9 and the capacity is 85522 and for DCT, the PSNR value is 47.9 and the capacity is 80522. Therefore, PSNR and capacity differ for different medical images as shown above. Hence, it may be inferred, that the capacity at PSNR is higher for DWT, when compared with the embedding capacity at PSNR for DCT.

5.3.1 Discussion

In order to evaluate the extracted data of medical images in both DWT and DCT domains, the images have been recovered successfully without any loss. Image enhancement analysis and the characteristic features of shifting provide a compact representation of the image. The wavelet coefficients are distributed in frequency sub-bands in order to determine a futuristic approach. The images are represented in the transform domain so that it is applicable for all applications which facilitate data embedding. The coefficients of these medical images are of pixel values [0,255] after decomposition and form the coefficient statistics. This wavelet basis gives better PSNR and embedding capacity. Thus, this approach clearly proves the superior quality of the recovered data with respect to peak signal to noise ratio and capacity. The performance evaluation of the proposed medical image is reported in metrics of charts. The results depict the images in the data set with respect to PSNR and capacity.