A novel method for multi-modal fusion based image embedding and compression technique using CT/PET images.

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Abstract

Image embedding has a wide range of applications in the medical field. This method is helpful in securing the information of the patients from the intruders with high storage capacity. The medical images of different modalities like CT and PET along with Patient Medical Image (PMI) can be sent to the physicians across the world for the diagnosis. Due to the bandwidth and storage constraint, medical images must be compressed before transmission and storage. This paper presents an evaluation on fusion based image embedding and reconstruction process for CT and PET images. The comparison of image fusion technique is processed using Wavelet Transform (WT) and Complex Contourlet Transform (CCT) and the analysis of compression method is estimated by using Run Length Encoding (RLE) and Huffman Encoding (HE) respectively. The proposed method is helpful in securing the patient information and it provides high hiding capacity for storage in the hospital digital database with improved values of MSE and PSNR.

Keywords: Complex contourlet transform, Image registration, Image fusion, Image embedding, Image compression, Image reconstruction, Wavelet transform, Run length encoding, Huffman encoding.

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Proposed Methodology

This section illustrates the proposed method for fusion based image embedding and reconstruction techniques. Multi-modal images like CT and PET are registered properly and then the resulting registered images are fused using different transform methods. At the encoder block, two-dimensional Complex Contourlet Transform (CCT) is first applied to the fused image. The transform coefficients are then entropy coded before forming the output code stream. In the decoder block, the code stream is first entropy decoded and inverse the Complex Contourlet Transform (ICCT). Thus, the resulting reconstructed image is obtained in the decoded block. The block diagram of image encoding and decoding for the proposed method is shown in Figures 1 and 2.

Figure 1. Block diagram of image encoding.

Figure 2. Block diagram of image decoding.

Image registration

Medical images are taken from different imaging devices likeComputed Tomography (CT) along with Positron Emission Tomography (PET) at a different time or different perspectives. Variation in patient orientation, dissimilarity in resolution and variation of the modalities can make it difficult for a clinician mentally to fuse all the image information accurately. For this justification, there has been considerable interest in using image registration technique to transfer all the acquired image details into a common coordinate frame.

Registration of medical images is the most important aspect of image fusion technique. It provides an efficient geometrical transformation between two data sets, by matching the PET image data set to CT image data set. Hence, the output fused image will provide the complete information from source images, without any artifacts or inconsistencies.

Image fusion

Image fusion is an important feature for medical diagnostics and treatment. It is created by combining details from multiple modalities which can provide the most standard details of both physiological and anatomical with a large spatial resolution which is used for clinical diagnosis and therapy purpose. It reduces uncertainty and redundancy in the output while maximizing relevant details from two or more images of a scene into one composite image that is more informative and most suitable for visual perception or processing task like medical imaging, remote sensing, and biometrics, etc.

Low pass sub band:

CT image=$(ALow1+BLow1)/2 \rightarrow (1)

PET image=$(ALow2+BLow2)/2 \rightarrow (2)

High pass sub band:

Decision map=$(abs (AHigh) \geq abs (BHigh))

The decomposed CT source image and PET registered image is divided into a low-frequency component and a high-frequency component. The efficient average fusion rule is applied to the low-frequency component and the highest energy fusion rule is applied to the high-frequency component which is given in Equations 1 and 2, then to renovate the original fused output Inverse Complex Contourlet Transform (ICCT) is applied.

Embedding and retrieving algorithm

- Choose the cover image, and decompose the image using CCT block.
- Load the fused image to be hidden, and decompose the image using CCT block.
- Calculate the pixel values of the defined sub-band coefficient for the cover image and the loaded fused image from the decomposed CCT block to obtain the embedded image.
- Apply the zigzag scan to form low-frequency coefficient in the top and high-frequency coefficient at the bottom for the better-compressed image, and estimate the parameters of Compression Ratio (CR) and Space Saving (SS).
- Apply the ICCT block to reconstruct the original embedded image.

Image compression

Image compression technique is about reducing the amount of data required to represent an image. In this work, zigzag scan [9,10] with RLE and Huffman techniques are used to decrease the space and improve the efficiency to transfer the image over the network for better access by using Wavelet Transform (WT) and Complex Contourlet Transform (CCT).

Wavelet transform (WT) [11-13] is one of the methods to represent the medical image. It allows multi-resolution analysis of an image. The main aim of this transform is to gather relevant information from an image. It has a better modification in representing non-stationary image signal and its ability to adapt human visual characteristics. Due to the 1D base, wavelets in higher dimensions can only gather less directional data, because it provides only three basic directional components, namely horizontal, vertical and
diagonal. It uses a Directional Filter Bank (DFB) which involves non-separable filtering and sampling. Hence, the major drawback in wavelet transform is less set of direction, shape, and high computational complexity.

Complex Contourlet Transform (CCT) is very successful in detecting image activities along curves while examining images at multiple scales, location, and orientations. The complex contourlet transform exhibit the following important characteristics such as multi-resolution, localization, translation invariant, directionality, and anisotropy [1,14].

A comparative study is performed for WT and CCT analysis in terms of result such as Peak Signal to Noise Ratio (PSNR), Compression Ratio (CR), and Space Saving (SS). After image compression technique Inverse Complex Contourlet Transform (ICCT) is applied to renovate the original image without any loss in information.

**Results and Discussion**

In this section, experimental evaluation is carried out for the different type of images such as CT/PET images using WT and CCT. CT and PET images are chosen for image registration, fusion, embed, compression and reconstruction techniques. There are totally 5 slices of CT/PET multi-modal images, but the resultant 5th slice (CT and PET) images are taken for discussion and it is shown in Figure 3.

![Figure 3. Resultant 5th Slice of CT/PET images to find the misalignment. (a) Reference CT image; (b) Target PET image; (c) Initial misalignment of reference and target images.](image)

Measure the misalignment or difference between two images (Reference CT and Target PET) then perform the transformation or shifting of the target image based on the reference image. The process of the 5th slice (CT and PET) image registration is shown in Figure 4.

![Figure 4. Shows shifting of target image based on the reference image. (a). First shift; (b) Second shift; (c) Third shift; (d) Fourth shift.](image)

After the alignment of target (PET) image based on the reference image (CT), image fusion for reference and registered image (Fourth Shift) are performed. Image fusion is shown in Figure 5.

![Figure 5. Result of fusion. (a). Fused image-CCT; (b). Fused image-WT.](image)

Image fusion is performed using Wavelet Transform (WT) and Complex Contourlet Transform (CCT) then entropy and mutual information are calculated. The resultant multi tumor part is located as well as evaluated and validated by the radiologist. The evaluated tabulation is shown in Table 1.

**Table 1. Entropy and mutual information values for input and output fused images using different transform.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Wavelet Transform (WT)</th>
<th>Complex Contourlet Transform (CCT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entropy</td>
<td>3.4162</td>
<td>3.6921</td>
</tr>
<tr>
<td>Mutual information</td>
<td>3.704</td>
<td>4.4029</td>
</tr>
</tbody>
</table>

Entropy is used to assess an amount of details contain in an image, comparing entropy value for the output fused image and mutual information [15] is the relative entropy between input and output fused image which justifies that the CCT output image which is obtained by fusion contains more information when compared with the WT. Hence, the total 5 slices of CT/PET image entropy value and mutual information values are tabulated to select the particular slice for compression technique which is shown in Table 2.

**Table 2. Entropy and mutual information values for all slices.**

<table>
<thead>
<tr>
<th>Slices</th>
<th>Entropy value</th>
<th>Mutual information</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WT</td>
<td>CCT</td>
</tr>
<tr>
<td>1</td>
<td>3.2267</td>
<td>3.50661</td>
</tr>
<tr>
<td>2</td>
<td>3.2505</td>
<td>3.51584</td>
</tr>
<tr>
<td>3</td>
<td>3.3529</td>
<td>3.5856</td>
</tr>
<tr>
<td>4</td>
<td>3.3614</td>
<td>3.66233</td>
</tr>
<tr>
<td>5</td>
<td>3.4162</td>
<td>3.6921</td>
</tr>
</tbody>
</table>

Slice selection is performed based on the highest entropy value and highest mutual information value. From the Table 2, the 5th slice of CT/PET images have higher entropy and mutual
information value, hence it is concluded that 5th slice contains more information compared to other slices. After slice selection, image embedding, compression and reconstruction techniques are performed using WT and CCT. The experimental results for embedding image are shown in Figure 6. RLE and Huffman compression methods are tabulated in Tables 3 and 4.

**Table 3. Image compression using wavelet transforms.**

<table>
<thead>
<tr>
<th>Entropy encoding</th>
<th>Wavelet Transform (WT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression technique</td>
<td>Dimension</td>
</tr>
<tr>
<td>------------------</td>
<td>------------</td>
</tr>
<tr>
<td>RLE</td>
<td>256 × 256</td>
</tr>
<tr>
<td>HUFFMAN</td>
<td>256 × 256</td>
</tr>
</tbody>
</table>

**Table 4. Image compression using Complex Contourlet Transform (CCT).**

<table>
<thead>
<tr>
<th>Entropy encoding</th>
<th>Complex Contourlet Transform (CCT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression technique</td>
<td>Dimension</td>
</tr>
<tr>
<td>------------------</td>
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<tr>
<td>RLE</td>
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<td>HUFFMAN</td>
<td>256 × 256</td>
</tr>
</tbody>
</table>

The result of compression methods on the basis of a parameter such as Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Compression Ratio (CR), Space Saving (SS) are compared. From Tables 3 and 4, it is concluded that Complex Contourlet Transform (CCT)-Huffman based analysis shown is having improved CR and SS compared to RLE compression method.

After this compression technique, Inverse Complex Contourlet Transform (ICCT) is applied to renovate the image and the results are shown in Figures 7 and 8. The resultant evaluation parameters are shown in Table 5.

**Table 5. Parameter evaluation for reconstruction image.**

<table>
<thead>
<tr>
<th>Transforms</th>
<th>MSE</th>
<th>PSNR</th>
<th>MSE</th>
<th>PSNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/P and Fused</td>
<td>I/P and Fused</td>
<td>I/P and Reconstructed</td>
<td>I/P and Reconstructed</td>
<td></td>
</tr>
<tr>
<td>WT</td>
<td>4.2396e+03</td>
<td>11.8914</td>
<td>1.7613e+04</td>
<td>5.7065</td>
</tr>
<tr>
<td>CCT</td>
<td>112.3007</td>
<td>27.661</td>
<td>2.631e-27</td>
<td>30.3943</td>
</tr>
</tbody>
</table>

**Figure 6. Results for image embedding. (a) Cover image; (b) Logo to hide (Fused image); (c). Watermarked image.**

**Figure 7. Evaluation parameter (a). Watermarked image; (b) Reconstructed image for CCT.**

**Figure 8. Evaluation parameter. (a). Watermarked image. (b). Reconstructed image for WT.**

**Conclusion**

In this paper, results of a novel fusion based image embedding and reconstruction are performed for CT/PET images. From the results, it is concluded that Complex Contourlet Transform (CCT) based embedding is better than another transform and Complex Contourlet Transform (CCT) with Huffman coding based image compression is better than WT based
compression. WT cannot perform well when the edges are a smooth curve. CCT is very successful in detecting image activities along the curve while analysing image at multiple scale, location, and orientation. And also, it is concluded that the 5th slice of CT/PET image shows improved entropy and mutual information out of five slices and the multi tumor detected in the image are evaluated and validated by the radiologist.

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References


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