Discrete Cosine Transform based Image Fusion Techniques

VPS Naidu
MSDF Lab, FMCD, National Aerospace Laboratories, Bangalore, INDIA
E.mail: vpsnaidu@gmail.com

Abstract: Six different types of image fusion algorithms based on discrete cosine transform (DCT) were developed and their performance was evaluated. Fusion performance is not good while using the algorithms with block size less than 8x8 and also the block size equivalent to the image size itself. DCTe and DCTmx based image fusion algorithms performed well. These algorithms are very simple and might be suitable for real time applications.

Keywords: DCT, Contrast measure, Image fusion

I. INTRODUCTION

Off late, different image fusion algorithms have been developed to merge the multiple images into a single image that contain all useful information. Pixel averaging of the source images (the images to be fused) is the simplest image fusion technique and it often produces undesirable side effects in the fused image including reduced contrast. To overcome this side effects many researchers have developed multi resolution [1-3], multi scale [4,5] and statistical signal processing [6,7] based image fusion techniques.

In similar line, contrast based image fusion algorithm in DCT domain has been presented [8] to fuse the out of focus images. Local contrast is measured by 8x8 blocks. However, there is no discussion on the fusion performance by choosing different block sizes. The present paper presents six different DCT based image fusion techniques and studies their performance.

II. DISCRETE COSINE TRANSFORM

Discrete cosine transform (DCT) is an important transform extensively used in digital image processing. Large DCT coefficients are concentrated in the low frequency region; hence, it is known to have excellent energy compactness properties [9-11]. The 2D discrete cosine transform $X(k_1, k_2)$ of an image or 2D signal $x(n_1, n_2)$ of size $N_1 \times N_2$ is defined as [12-14]:

$$X(k_1, k_2) = \alpha(k_1) \alpha(k_2) \sum_{n_1=0}^{N_1-1} \sum_{n_2=0}^{N_2-1} x(n_1, n_2) \cos \left( \frac{\pi (2n_1 + 1)k_1}{2N_1} \right) \cos \left( \frac{\pi (2n_2 + 1)k_2}{2N_2} \right), 0 \leq k_1 \leq N_1 - 1, 0 \leq k_2 \leq N_2 - 1$$

(1)

Where $\alpha(k_i) = \begin{cases} \frac{1}{\sqrt{N_i}}, & k_i = 0 \\ \frac{2}{\sqrt{N_i}}, & 1 \leq k_i \leq N_i - 1 \end{cases}$ and $\beta(k_i) = \begin{cases} \frac{1}{\sqrt{N_i}}, & k_i = 0 \\ \frac{2}{\sqrt{N_i}}, & 1 \leq k_i \leq N_i - 1 \end{cases}$ for $k_i$ discrete frequency variables $(n_1, n_2)$ pixel index

Similarly, the 2D inverse discrete cosine transform is defined as:

$$x(n_1, n_2) = (k_1, k_2) \sum_{k_1=0}^{N_1-1} \sum_{k_2=0}^{N_2-1} \alpha(k_1) \alpha(k_2) X(k_1, k_2) \cos \left( \frac{\pi (2n_1 + 1)k_1}{2N_1} \right) \cos \left( \frac{\pi (2n_2 + 1)k_2}{2N_2} \right), 0 \leq n_1 \leq N_1 - 1, 0 \leq n_2 \leq N_2 - 1$$

(2)

III. CONTRAST MEASURE

DCT decomposes the image/block into a series of waveforms, each with a particular frequency. DCT coefficients are segregated into $2N - 1$ different frequency bands for image or block of size $N \times N$. The $m^{th}$ band is composed of the coefficients with $m = k_1 + k_2$. The contrast measure at each coefficient in $m^{th}$ the band is computed as [15-17]:

$$C(k_1, k_2) = \frac{X(k_1, k_2)}{\sum_{j=0}^{N-1} E_j}$$

(3)

Where $E_j = \sum_{p=0}^{N-1} \left| X(p, t) \right|$ and $Y = \begin{cases} j+1 & 0 \leq j < N \\ (2N-1-j+1) & j \geq N \end{cases}$

(4)

$E_j$ is the average amplitude over a $j^{th}$ spectral band. The DCT output for image or block size of 8x8 is shown in Fig-1. It also illustrates the 1st and 5th bands (enclosed with rectangles).
Let the \( X_f(k_1,k_2) \) be the DCT coefficients of image block from image \( I_1 \) and similarly let the \( X_f(k_1,k_2) \) be the DCT coefficients of image block from image \( I_2 \). Assume the image block is of size \( N \times N \) and \( X_f \) be the fused DCT coefficients.

**DCT av:** In this fusion rule, all DCT coefficients from both image blocks are averaged to get fused DCT coefficients. It is very simple and basic image fusion technique in DCT domain.

\[
X_f(k_1,k_2) = 0.5 \ X_1(k_1,k_2) + X_2(k_1,k_2) \quad (5)
\]

Where \( k_1,k_2 = 0,1,2,...,N-1 \)

**DCTma:** The DC components from both image blocks are averaged. The largest magnitude AC coefficients are chosen, since the detailed coefficients correspond to sharper brightness changes in the images such as edges and object boundaries etc. These coefficients are fluctuating around zero.

\[
X_f(0,0) = 0.5 \ X_1(0,0) + X_2(0,0) \quad (6a)
\]

\[
X_f(k_1,k_2) = \begin{cases} 
X_1(k_1,k_2) & |X_1(k_1,k_2)| \geq |X_2(k_1,k_2)| \\
X_2(k_1,k_2) & |X_1(k_1,k_2)| < |X_2(k_1,k_2)|
\end{cases} \quad (6b)
\]

Where \( k_1,k_2 = 1,2,3,...,N-1 \)

**DCTah:** The lowest AC components including DC coefficients are averaged and the remaining AC coefficients are chosen based on largest magnitude.

\[
X_f(k_1,k_2) = 0.5 \ X_1(k_1,k_2) + X_2(k_1,k_2) \quad (7a)
\]

Where \( k_1,k_2 = 0,1,2,...,0.5N-1 \)

\[
X_f(k_1,k_2) = \begin{cases} 
X_1(k_1,k_2) & |X_1(k_1,k_2)| \geq |X_2(k_1,k_2)| \\
X_2(k_1,k_2) & |X_1(k_1,k_2)| < |X_2(k_1,k_2)|
\end{cases} \quad (7b)
\]

Where \( k_1,k_2 = 0.5N,0.5+1,0.5N+2,...,N-1 \)

**DCTch:** The DC coefficients are averaged and the AC coefficients are chosen based on largest contrast measure.

\[
X_f(0,0) = 0.5 \ X_1(0,0) + X_2(0,0) \quad (8a)
\]

\[
X_f(k_1,k_2) = \begin{cases} 
X_1(k_1,k_2) & C_1(k_1,k_2) \geq C_2(k_1,k_2) \\
X_2(k_1,k_2) & C_1(k_1,k_2) < C_2(k_1,k_2)
\end{cases} \quad (8b)
\]

Where \( k_1,k_2 = 1,2,3,...,N-1 \)

**DCTcm:** It is very much similar to DCT ah. The lowest AC components including DC coefficients are averaged and the remaining AC coefficients are chosen based on largest contrast measure.

\[
X_f(k_1,k_2) = 0.5 \ X_1(k_1,k_2) + X_2(k_1,k_2) \quad (9a)
\]

Where \( k_1,k_2 = 0,1,2,...,0.5N-1 \)
Components are averaged 

\[ X_f(k_1,k_2) = \begin{cases} 
X_1(k_1,k_2) & \text{if } E_{j_1} \geq E_{j_2} \\
X_2(k_1,k_2) & \text{if } E_{j_1} < E_{j_2} 
\end{cases} \] (10b)

Where \( k_1,k_2 = 0.5N,0.5 + 1.05N + 2,\ldots,N - 1 \)

\[ X_f(0,0) = 0.5 \cdot X_1(0,0) + X_2(0,0) \] (10a)

\[ X_f(k_1,k_2) = \begin{cases} 
X_1(k_1,k_2) & \text{if } C_1(k_1,k_2) \geq C_2(k_1,k_2) \\
X_2(k_1,k_2) & \text{if } C_1(k_1,k_2) < C_2(k_1,k_2) 
\end{cases} \] (9b)

\[ X_f(k_1,k_2) = \begin{cases} 
X_1(k_1,k_2) & \text{if } j \geq 0 \\
X_2(k_1,k_2) & \text{if } j < 0 
\end{cases} \]

\[ \text{DCTc: It is similar to DCTcm. DC components are averaged together. AC coefficients correspond to the frequency band having largest energy is chosen.} \]

\[ X_f(0,0) = 0.5 \cdot X_1(0,0) + X_2(0,0) \]

\[ X_f(k_1,k_2) = \begin{cases} 
X_1(k_1,k_2) & \text{if } j \geq 0 \\
X_2(k_1,k_2) & \text{if } j < 0 
\end{cases} \]

\[ \text{Where } k_1,k_2 = 1,2,3,\ldots,N - 1 \text{ and } j = k_1 + k_2 \]

\[ \text{V. Fusion Evaluation Metrics} \]

The following fusion evaluation metrics are used to evaluate the performance of the developed six image fusion algorithms. When the ground truth image is available:

1. Peak Signal to Noise Ratio (PSNR) [3,6,18] PSNR value will be high when the fused and the ground truth images are comparable. Higher value implies better fusion. The peak signal to noise ratio is computed as:

\[ \text{PSNR} = 20 \log_{10} \left( \frac{L^2}{\sum_{i=1}^{M} \sum_{j=1}^{N} (X(i,j) - \tilde{X}(i,j))^2} \right) \] (11)

Where \( L \) in the number of gray levels in the image

2. Structural Similarity (SSIM) Index [19,20] It is a method for measuring the similarity between the fused and reference images. Its value may vary from -1 to 1. The value 1 implies that both images are identical. The fused image with high SSIM would be considered. The SSIM is computed as:

\[ \text{SSIM}(l_f,I_f) = \frac{2\mu_l \mu_{I_f} + C_1}{\mu_l^2 + \mu_{I_f}^2 + C_1} \cdot \frac{2\sigma_{l,I_f} + C_2}{\sigma_{l}^2 + \sigma_{I_f}^2 + C_2} \] (12)

Where \( \mu_l \): mean of \( l_f \)

\( \mu_{I_f} \): mean of \( I_f \)

\( \sigma_l^2 \): Variance of \( l_f \)

\( \sigma_{I_f}^2 \): Variance of \( I_f \)

\( \sigma_{l,I_f} \): Covariance of \( l_f \) and \( I_f \)

\( c_1 = (0.01L)^2 \) and \( c_3 = (0.03L)^2 \) are the constants to stabilize the division with weak denominator

When the ground truth image is not available, the following metrics can be used to evaluate the proposed six fusion algorithms.

1. Spatial Frequency [6,21] The frequency in spatial domain indicates the overall activity level in the fused image and it is computed as Row frequency:

\[ RF = \sqrt{\frac{1}{MN} \sum_{i=0}^{M-1} \sum_{j=1}^{N-1} \left( I_f(i,j) - \tilde{I_f}(i,j) \right)^2} \] (13a)

Column frequency:

\[ CF = \sqrt{\frac{1}{MN} \sum_{j=0}^{N-1} \sum_{i=1}^{M-1} \left( I_f(i,j) - \tilde{I_f}(i,j) \right)^2} \] (13b)

Spatial frequency: \( SF = \sqrt{RF^2 + CF^2} \) (14)

The fused image with high SF would be considered.

2. Fusion quality index [22] The range of this metric is 0 to 1. One indicates the fused image contains all the information from the source images.

\[ QI = \sum_{w \in w} \lambda(w) QI(I_1,I_f \mid w) + (1 - \lambda(w)) QI(I_2,I_f \mid w) \] (15)

Where \( \lambda(w) = \frac{\sigma_{I_f}^2}{\sigma_{I_f}^2 + \sigma_{I_1}^2} \) computed over a window

\[ C(w) = \max \left( \sigma_{I_f}^2, \sigma_{I_1}^2 \right) \] Over a window

\( c(w) \) is a normalized version of \( C(w) \)

\( QI(I_1,I_f \mid w) \) is the quality index over a window for a given source image and fused image

\[ \text{VI. Results and Discussions} \]

The ground truth image \( I_f \) (SARAS) is shown in Fig-3. The complementary source images \( I_1 \) & \( I_2 \) (images to be fused) are generated by blurring the source image as shown in Fig-4. The fused and the error images using the developed image fusion techniques are shown in Fig-5 to Fig-10. The error image is the
difference of ground truth and the fused images. It is observed from the error image (Fig-5) that DCTav image fusion algorithm has not performed well. There is information less at edges. DCTmx performed better than DCTav. DCTah is not performed well. There is information loss at the edges and some ringing tones are observed at the sharp edges as shown in Fig-7. Image fusion by contrast measure (DCTcm) performed well compare to the previous techniques. DCTch is not producing good results. It is almost similar to DCTah and same observations are made. The algorithm DCTe provides superior fusion results among all fusion techniques. It is computationally simplest fusion algorithm compare to DCTcm and DCTch. The fusion quality evaluation metrics are shown in Table-1 and 2. It is observed that DCTe performed very well followed by DCTcm and DCTmx.

Fig-3 Ground truth image - SARAS

Fig-4 Source images for image fusion - SARAS

Fig-5 The fused and error image using DCTav fusion algorithm - SARAS
### Table-1a Peak signal to noise ratio – SARAS

<table>
<thead>
<tr>
<th>Block size (rows x columns)</th>
<th>2x2</th>
<th>4x4</th>
<th>8x8</th>
<th>16x16</th>
<th>32x32</th>
<th>64x64</th>
<th>128x128</th>
<th>256x256</th>
<th>512x512</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCTav</td>
<td>38.4255</td>
<td>38.4255</td>
<td>38.4255</td>
<td>38.4255</td>
<td>38.4255</td>
<td>38.4255</td>
<td>38.4255</td>
<td>38.4255</td>
<td>38.4255</td>
</tr>
<tr>
<td>DCTmx</td>
<td>38.8067</td>
<td>39.6028</td>
<td>40.7588</td>
<td>42.0532</td>
<td>43.5130</td>
<td>44.6817</td>
<td>45.8894</td>
<td>53.7908</td>
<td>39.3178</td>
</tr>
<tr>
<td>DCTah</td>
<td>38.8067</td>
<td>38.7442</td>
<td>38.6715</td>
<td>38.6400</td>
<td>38.6225</td>
<td>38.6140</td>
<td>38.6089</td>
<td>38.6051</td>
<td>38.4843</td>
</tr>
<tr>
<td>DCTe</td>
<td>38.8073</td>
<td>39.6142</td>
<td>40.7857</td>
<td>42.1961</td>
<td>43.7510</td>
<td>45.2481</td>
<td>47.1747</td>
<td>61.4135</td>
<td>37.6962</td>
</tr>
<tr>
<td>DCTch</td>
<td>38.8098</td>
<td>38.7442</td>
<td>38.6715</td>
<td>38.6400</td>
<td>38.6225</td>
<td>38.6140</td>
<td>38.6089</td>
<td>38.6051</td>
<td>38.4842</td>
</tr>
<tr>
<td>DCTcm</td>
<td>38.8098</td>
<td>39.6152</td>
<td>40.7970</td>
<td>42.0552</td>
<td>43.5079</td>
<td>44.6773</td>
<td>45.8894</td>
<td>53.7829</td>
<td>39.3171</td>
</tr>
</tbody>
</table>

### Table-1b Structural similarity index – SARAS

<table>
<thead>
<tr>
<th>Block size (rows x columns)</th>
<th>2x2</th>
<th>4x4</th>
<th>8x8</th>
<th>16x16</th>
<th>32x32</th>
<th>64x64</th>
<th>128x128</th>
<th>256x256</th>
<th>512x512</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCTav</td>
<td>0.9821</td>
<td>0.9821</td>
<td>0.9821</td>
<td>0.9821</td>
<td>0.9821</td>
<td>0.9821</td>
<td>0.9821</td>
<td>0.9821</td>
<td>0.9821</td>
</tr>
<tr>
<td>DCTmx</td>
<td>0.9741</td>
<td>0.9760</td>
<td>0.9753</td>
<td>0.9815</td>
<td>0.9911</td>
<td>0.9941</td>
<td>0.9967</td>
<td>0.9998</td>
<td>0.7624</td>
</tr>
<tr>
<td>DCTah</td>
<td>0.9741</td>
<td>0.9738</td>
<td>0.9719</td>
<td>0.9706</td>
<td>0.9695</td>
<td>0.9687</td>
<td>0.9680</td>
<td>0.9674</td>
<td>0.9238</td>
</tr>
<tr>
<td>DCTe</td>
<td>0.9740</td>
<td>0.9760</td>
<td>0.9755</td>
<td>0.9826</td>
<td>0.9924</td>
<td>0.9965</td>
<td>0.9987</td>
<td>1.0000</td>
<td>0.9121</td>
</tr>
<tr>
<td>DCTch</td>
<td>0.9740</td>
<td>0.9737</td>
<td>0.9719</td>
<td>0.9706</td>
<td>0.9695</td>
<td>0.9687</td>
<td>0.9680</td>
<td>0.9674</td>
<td>0.9237</td>
</tr>
<tr>
<td>DCTcm</td>
<td>0.9740</td>
<td>0.9760</td>
<td>0.9751</td>
<td>0.9814</td>
<td>0.9910</td>
<td>0.9940</td>
<td>0.9967</td>
<td>0.9998</td>
<td>0.7616</td>
</tr>
</tbody>
</table>

### Table-2a spatial frequency – SARAS

<table>
<thead>
<tr>
<th>Block size (rows x columns)</th>
<th>2x2</th>
<th>4x4</th>
<th>8x8</th>
<th>16x16</th>
<th>32x32</th>
<th>64x64</th>
<th>128x128</th>
<th>256x256</th>
<th>512x512</th>
</tr>
</thead>
</table>
Table-2b Fusion quality index – SARAS

<table>
<thead>
<tr>
<th>Block size (rows x columns)</th>
<th>2x2</th>
<th>4x4</th>
<th>8x8</th>
<th>16x16</th>
<th>32x32</th>
<th>64x64</th>
<th>128x128</th>
<th>256x256</th>
<th>512x512</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCTav</td>
<td>0.7466</td>
<td>0.8560</td>
<td>0.7470</td>
<td>0.8560</td>
<td>0.7576</td>
<td>0.8560</td>
<td>0.7700</td>
<td>0.8565</td>
<td>0.8059</td>
</tr>
<tr>
<td>DCTmx</td>
<td>0.7888</td>
<td><strong>0.8950</strong></td>
<td>0.8081</td>
<td>0.8890</td>
<td>0.8041</td>
<td>0.8423</td>
<td>0.7495</td>
<td>0.8012</td>
<td>0.6425</td>
</tr>
<tr>
<td>DCTah</td>
<td>0.7888</td>
<td>0.8843</td>
<td>0.7893</td>
<td>0.8709</td>
<td>0.7917</td>
<td>0.8354</td>
<td>0.7729</td>
<td>0.7591</td>
<td>0.5576</td>
</tr>
<tr>
<td>DCTe</td>
<td>0.7883</td>
<td>0.8940</td>
<td>0.8067</td>
<td>0.8861</td>
<td>0.7955</td>
<td>0.8455</td>
<td>0.7862</td>
<td>0.8496</td>
<td>0.5270</td>
</tr>
<tr>
<td>DCTch</td>
<td>0.7886</td>
<td>0.8843</td>
<td>0.7892</td>
<td>0.8709</td>
<td>0.7917</td>
<td>0.8353</td>
<td>0.7728</td>
<td>0.7590</td>
<td>0.5574</td>
</tr>
<tr>
<td>DCTcm</td>
<td>0.7886</td>
<td>0.8949</td>
<td>0.8081</td>
<td>0.8892</td>
<td>0.8042</td>
<td>0.8423</td>
<td>0.7492</td>
<td>0.8011</td>
<td>0.6438</td>
</tr>
</tbody>
</table>

Fig-6 The fused and error image using DCTmx fusion algorithm - SARAS

Fig-7 The fused and error image using DCTah fusion algorithm – SARAS
The computational time taken by each fusion algorithm with chosen block size are shown in Table-3 and Fig-11. It is observed that the algorithm with block size less than 8x8 takes more time and performance is also not good. DCTmx takes very less time and produces almost similar results compared to DCTe and DCTcm.
Table-3 Computational time in sec.

<table>
<thead>
<tr>
<th>Block size (rows x columns)</th>
<th>2x2</th>
<th>4x4</th>
<th>8x8</th>
<th>16x16</th>
<th>32x32</th>
<th>64x64</th>
<th>128x128</th>
<th>256x256</th>
<th>512x512</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCTav</td>
<td>22.6578</td>
<td>5.9152</td>
<td>1.5946</td>
<td>0.4896</td>
<td>0.1859</td>
<td>0.1617</td>
<td><strong>0.1085</strong></td>
<td>0.2009</td>
<td>0.2738</td>
</tr>
<tr>
<td>DCTmx</td>
<td>23.1537</td>
<td>6.0213</td>
<td>1.6209</td>
<td>0.4881</td>
<td>0.1886</td>
<td>0.1691</td>
<td>0.1164</td>
<td>0.2028</td>
<td>0.2831</td>
</tr>
<tr>
<td>DCTah</td>
<td>23.7942</td>
<td>6.1585</td>
<td>1.6665</td>
<td>0.5042</td>
<td>0.1988</td>
<td>0.1665</td>
<td>0.1226</td>
<td>0.2065</td>
<td>0.2847</td>
</tr>
<tr>
<td>DCTe</td>
<td>34.4017</td>
<td>11.9302</td>
<td>4.8228</td>
<td>2.3368</td>
<td>1.4845</td>
<td>1.4178</td>
<td>1.8222</td>
<td>4.2950</td>
<td>9.7422</td>
</tr>
</tbody>
</table>

Fig-11 Computational time for different types of DCT based image fusion algorithms

The algorithms are applied on the second set of images (lab) obtained from [23] as shown in Fig-12. Both the images are out of focus. The first image is focused on right half where the time piece visible clearly. The second image is focused on left half where the book self and other things visible clearly. The fused images using the developed fusion techniques are shown in Fig-13 and 14. The fused image is focused everywhere. The fusion quality evaluation metrics are shown in Table-4. Similar observation as earlier can be made here also.
Discrete Cosine Transform based Image Fusion Techniques

Fig-12 Images to be fused - lab

Fig-13 Fused images using DCTav and DCTmx

Fig-14 Fused images using DCTe and DCTcm
Table-4a Spatial frequency – lab

<table>
<thead>
<tr>
<th>Block size (rows x columns)</th>
<th>2x2</th>
<th>4x4</th>
<th>8x8</th>
<th>16x16</th>
<th>32x32</th>
<th>64x64</th>
<th>128x128</th>
<th>256x256</th>
<th>512x512</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCTav</td>
<td>7.3952</td>
<td>7.3952</td>
<td>7.3952</td>
<td>7.3952</td>
<td>7.3952</td>
<td>7.3952</td>
<td>7.3952</td>
<td>7.3952</td>
<td>7.3952</td>
</tr>
</tbody>
</table>

Table-4b Fusion quality index – lab

<table>
<thead>
<tr>
<th>Block size (rows x columns)</th>
<th>2x2</th>
<th>4x4</th>
<th>8x8</th>
<th>16x16</th>
<th>32x32</th>
<th>64x64</th>
<th>128x128</th>
<th>256x256</th>
<th>512x512</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCTav</td>
<td>0.8045</td>
<td>0.8053</td>
<td>0.8046</td>
<td>0.8053</td>
<td>0.8059</td>
<td>0.8053</td>
<td>0.8045</td>
<td>0.8048</td>
<td>0.8043</td>
</tr>
<tr>
<td>DCTmx</td>
<td>0.7962</td>
<td>0.7842</td>
<td>0.7711</td>
<td>0.7564</td>
<td>0.7428</td>
<td>0.7305</td>
<td>0.7221</td>
<td>0.7027</td>
<td>0.6673</td>
</tr>
<tr>
<td>DCTah</td>
<td>0.7962</td>
<td>0.7842</td>
<td>0.7711</td>
<td>0.7564</td>
<td>0.7428</td>
<td>0.7305</td>
<td>0.7221</td>
<td>0.7027</td>
<td>0.6673</td>
</tr>
<tr>
<td>DCTe</td>
<td>0.7954</td>
<td>0.7817</td>
<td>0.7674</td>
<td>0.7484</td>
<td>0.7335</td>
<td>0.7237</td>
<td>0.7285</td>
<td>0.7190</td>
<td>0.6549</td>
</tr>
<tr>
<td>DCTch</td>
<td>0.7962</td>
<td>0.7997</td>
<td>0.7997</td>
<td>0.7942</td>
<td>0.7879</td>
<td>0.7825</td>
<td>0.7774</td>
<td>0.7701</td>
<td>0.7549</td>
</tr>
<tr>
<td>DCTcm</td>
<td>0.7962</td>
<td>0.7842</td>
<td>0.7708</td>
<td>0.7559</td>
<td>0.7427</td>
<td>0.7302</td>
<td>0.7218</td>
<td>0.7022</td>
<td>0.6671</td>
</tr>
</tbody>
</table>

From the results, it is observed that DCTe and DCTmx based image fusion algorithms would provide good fused image and these could be suitable for real time applications. Fusion performance is not good while using the algorithms with block size is less than 8x8 and also the block size equivalent to the image size itself. Fusion quality is very much depends on chosen block size and selection of block size is very difficult in practice. One way to obtain best fused image is, compute the performance of the fusion for different block sizes and then select the fused image corresponding to best performance metrics. Since very high computational facility is available, it could be possible to implement this idea for real time applications.

VII. CONCLUSION

Six different types of image fusion algorithms based on discrete cosine transform (DCT) were developed and fused image quality was evaluated using performance evaluation metrics. Fusion performance is not good while using the algorithms with block size less than 8x8 and also the block size equivalent to the image size itself. DCTe and DCTmx based image fusion algorithms performed well and these algorithms are very suitable for real time applications.

REFERENCES


http://www.ece.lehigh.edu/SPCRL/IF/disk.htm

VPS Naidu obtained M.E in Medical electronics from Anna University Chennai and PhD from University of Mysore, Mysore in board of studies, Electronics. He is working at Multi sensor data fusion lab, National Aerospace Laboratories, Bangalore as scientist since December 2001. His areas of interest are: Multi Sensor Data Fusion and Enhanced Flight Vision System. He received four awards for his research contribution. He has more than fifty papers and forty-five technical reports. He is actively involved in student project programme organized by Karnataka state council for science and technology (KSCST) from 2007.