CHAPTER - 5

DOMAIN POOL CLASSIFICATION TECHNIQUE
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5.1 Domain Pool Classification

Fractal image Compression is a novel technique promises higher compression ratio. But it is lossy compression method for digital images. The method is best suited for natural images, depending on the fact that parts of an image often resemble other parts of the same image. The encoding procedure consists of partitioning the image into range blocks and obtaining a transformation for each block. The domain blocks are chosen to be larger than the range blocks. The Domain pool classification FIC scheme selects domain pool for each range block. So there is a more effective and smaller domain library for each range. This technique decrease the computational time [120]. The elements of the domain pool are divided into shade and edge block to improve the CR and PSNR values for the Lena and Satellite imageries also reducing the encoding and decoding time. Dividing the image into blocks \( R_k \) called range blocks, and obtain a transformation \( f_k \) for each block. The transformations \( f_k \) are not fixed point transformations since they do not satisfy the equation (5.1).

\[
f_k \left( R_k \right) = R_k
\]  

(5.1)

Rather, they are a mapping from a block of pixels domain block \( D_k \) from other part of the image. While every individual mapping \( f_k \) is not a fixed point mapping, that can combine all these mappings to produce a fixed point mapping. The image blocks \( D_k \) are called domain blocks, and they are chosen to be bigger than the range blocks. The domain blocks are acquired by sliding a \( K \times K \) window over the image in steps of \( K/2 \) or \( K/4 \) pixels. The transformations \( f_k \) are combination of a geometric transformation \( g_k \) and a massic transformation \( m_k \). The geometric transformation consists of moving the domain block to the location of the range block and adjusting the size of the domain block to match the size of the range block. The massic transformation adjusts the intensity and orientation of the pixels in the domain block after by the geometric transform [121].

\[
R_k' = f_k(D_k) = m_k(g_k(D_k))
\]  

(5.2)
$R_k'$ instead of $R_k$ in equation (5.2) because it is not possible to find an exact functional between domain and range blocks, since few loss of information. This loss is measured in terms of mean squared error. In order to reduce the computations, restrict the number of domain blocks to search. However, in order to get the best possible approximation, the pool of domain blocks to be as large as possible. The elements of the domain pool are then divided into shade blocks and edge blocks. The shade blocks are those in which the variance of pixel values within the block is small. The edge block contains those blocks that have a sharp change of pixel values within the block.

The encoding process continues as a range block is classified into one of these categories described above. If the range block is a shade block, it is simple to send the average value of the block. If the range block $R_k$ is an edge block, selection of the massic transformation and also the block is first divided into a bright and a dark region.

The geometric transformation $g_k$ is defined in the equation (5.3) and massic transformation $m_k$ as in equation (5.4).

$$T_k = g_k (D_k) \quad (5.3)$$

$$M_k (t_{ij}) = P(\alpha_k t_{ij} + \Delta_k) \quad (5.4)$$

Where $t_{ij}$ is the $ij^{th}$ pixel in $T_k$ and $i, j = 0, 1, 2, \ldots M-1$. $\alpha_k$ is selected from a small set of values. $P(\cdot)$ denotes a rearrangement of the pixels with the block. The value of $\Delta_k$ is selected as the difference of the average values of $R_k$ and $\alpha_k T_k$. It is obtained as the difference of either the average values of the bright regions or the average values of the dark regions.

The dynamic range of the block $r_d (R_k)$ is computed as the difference of the average values of the light and dark regions. For a given domain block, compute the value of $\alpha_k$ as in equation (5.5) and $\alpha_{max}$ is an upper bound on the scaling factor.

$$\alpha_k = \min \left\{ \frac{r_d (R_k)}{r_d (T_j)}, \alpha_{max} \right\} \quad (5.5)$$
The fractal image encoding is a computationally intensive method of compression because of finding the best match between images subblocks by repeatedly searching a large virtual codebook constructed from the image under compression. One of the most innovative and promising approaches to speed up the encoding is to solve the range-domain block matching problem to a nearest neighbor search problem. Furthermore, an optimal adaptive scheme is determined for the approximate search parameter to improve the performance. It is able to enhance both the fidelity and compression ratio while significantly decrease memory requirement and computational time [66].

5.2 Geometric and Massic transformation

The geometric transformation consists of moving the domain block to the location of the range block and adjusting the size of the domain block to match the size of the range block. The massic transformation adjusts the intensity and orientation of the pixels in the domain block. These transformation is defined in equations (5.3) and (5.4), the possible rearrangements or isometries of the pixels with the block are shown as following.

- Rotation by 90 degrees, $P(t_{ij}) = t_{j(M-1-i)}$.
- Rotation by 180 degrees, $P(t_{ij}) = t_{(M-1-i)(M-1-j)}$.
- Rotation by -90 degrees, $P(t_{ij}) = t_{j(M-1-i)}$.
- Reflection about midvertical axis, $P(t_{ij}) = t_{i(M-1-j)}$.
- Reflection about midhorizontal axis, $P(t_{ij}) = t_{j(M-1-i)}$.
- Reflection about diagonal, $P(t_{ij}) = t_{ji}$.
- Reflection about cross diagonal, $P(t_{ij}) = t_{j(M-1-j)(M-1-i)}$.
- Identity mapping, $P(t_{ij}) = t_{ij}$.

For each massic transformation $m_k$, need to find values of $\alpha_k$, $A_k$, and an isometries.
5.3 The Encoding and Decoding Algorithm

- Partition the original image into range block and domain block. Domain block is the twice the size of range block.
- Consider the range block size KxK that is the 4x4, 8x8 and 16x16. Create the domain pool.
- Classify the elements of the domain pool into shade blocks and edge blocks.
- Perform geometric transformation for every range block to find the matching with the domain pool.
- If the range block is a shade block, it sends the average value of the block. If the range block is an edge block, selection of the massic transformation. Apply entropy coding and calculating CR.
- For the decoding process apply iterations and inverse transform to reconstruct the image and calculating PSNR.

5.4 Results and Discussions

The Domain pool classification FIC technique, the algorithm is realized for range block size 4x4, 8x8 and 16x16 to encode and decode the images. The CR, PSNR and computational time are determined for the Lena image, Satellite Rural image and Satellite Urban image and displayed in Table 5.1.
Table 5.1: The CR and PSNR Values Derived Using Domain Pool Classification Technique.

<table>
<thead>
<tr>
<th>Test Images</th>
<th>Range Block Size</th>
<th>Compression Ratio (CR)</th>
<th>PSNR (dB)</th>
<th>Time Taken for Encoding (Sec)</th>
<th>Time Taken for Decoding (Sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lena Image</td>
<td>4x4</td>
<td>3.6</td>
<td>29.5</td>
<td>250.4</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>8x8</td>
<td>5.0</td>
<td>24.6</td>
<td>39.0</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>16x16</td>
<td>5.6</td>
<td>20.3</td>
<td>6.19</td>
<td>0.1</td>
</tr>
<tr>
<td>Satellite Rural Image</td>
<td>4x4</td>
<td>4.0</td>
<td>27.7</td>
<td>309.6</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>8x8</td>
<td>6.2</td>
<td>23.5</td>
<td>49.7</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>16x16</td>
<td>7.1</td>
<td>20.9</td>
<td>6.9</td>
<td>0.1</td>
</tr>
<tr>
<td>Satellite Urban Image</td>
<td>4x4</td>
<td>3.4</td>
<td>28.1</td>
<td>1198.9</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>8x8</td>
<td>4.9</td>
<td>22.2</td>
<td>87.2</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>16x16</td>
<td>5.4</td>
<td>18.7</td>
<td>8.1</td>
<td>0.04</td>
</tr>
</tbody>
</table>

The Table 5.1 shows that for the range block size 4x4 shows for the Lena image CR ~3.6, PSNR ~29.5 dB, for Satellite Rural image CR ~4.0, PSNR ~27.7 dB and Satellite Urban image CR ~3.4, PSNR ~28.1 dB. The range block size 8x8 shows for the Lena image CR ~5.0, PSNR ~24.6 dB, for Satellite Rural image CR ~6.2, PSNR ~23.5 dB and Satellite Urban image CR ~4.9, ~22.2 dB. The range block size 16x16 shows for the Lena image CR ~5.6, PSNR ~20.3 dB, for Satellite Rural image CR ~7.1, PSNR ~20.9 dB and Satellite Urban image CR ~5.4, PSNR ~18.7 dB.

The higher CR can be achieved by choosing fixed range block size 16x16, otherwise CR decreases for the range block size 8x8 and 4x4. Higher PSNR can be achieved by choosing range block size 4x4 and PSNR decreases for the range block size 8x8 and 16x16.
The Domain pool classification FIC scheme achieves good compression parameters for the range block size 4x4 indicates that the Lena image shows the CR ~3.6, higher PSNR ~29.5 dB, the Satellite Rural image has higher CR ~4.0, PSNR ~27.7 dB and Satellite Urban image shows CR ~3.4, PSNR ~28.1 dB. The Domain pool classification FIC scheme indicates improved CR and PSNR performance for range block 4x4 shows CR >3.4 and PSNR >28 dB for all the three types of imageries.

The Table 5.1 indicates that the computational time for the range block size 4x4 for all three types image shows maximum encoding time >250 Sec and decoding time <0.9 Sec. The range block size 8x8 for all three types image shows encoding time <87 Sec and decoding time <0.2 Sec, range block size 16x6 for all three types image shows less encoding time < 8 Sec and decoding time <0.1Sec. It is found that the encoding – decoding time decreases as the range block size increases and it is noted that for the 4x4 range block size the encoding-decoding time is higher compared to other range block sizes 8x8 and 16x16.

The original and the reconstructed Lena, Satellite Rural and Satellite Urban image obtained from the FIC using Domain pool classification for the range block size 4x4 are shown in Fig 5.1, 5.2 and 5.3.

![original image](image1.png)  ![Reconstructed image](image2.png)

**Fig. 5.1:** Lena Image of Range Block Size 4x4, CR ~3.6 and PSNR ~29.5 dB.
Fig. 5.2: Satellite Rural Image of Range Block Size 4x4, CR ~4.0 and PSNR ~27.7 dB.

Fig. 5.3: Satellite Urban Image of Range Block Size 4x4, CR ~3.4 and PSNR ~28.1 dB.

The Figure indicates that for the FIC scheme using Domain pool classification the quality of the reconstructed Lena, Satellite Rural and Urban images are found to be very good as the PSNR values for the range block size 4x4 for Lena image the CR ~3.6, PSNR ~ 29.5 dB, the Satellite Rural image the CR ~4.0, PSNR ~27.7 dB and the Satellite Urban image the CR ~3.4, PSNR ~28.1dB. It is also found that for the range block size 4x4 the computational time is minimum.
A detailed comparison of the compression parameters achieved using Fixed size range block segmentation (Chapter 3) and Quadtree decomposition (Chapter 4) shows lower values of CR and PSNR for the Lena, Satellite Rural and Satellite Urban imageries. Whereas the FIC technique using Domain pool classification technique is found to be good approach towards achieving higher CR >3.4 with PSNR > 28dB for the Lena, Satellite Rural and Satellite Urban imageries. The encoding – decoding time is found to be better in Domain pool classification FIC technique compared to Fixed size range block segmentation and Quadtree decomposition FIC technique.

From the analysis carried out leads to the conclusions that the FIC using Domain pool classification technique shows improved performance for the range block size 4x4 achieving higher CR and PSNR values for Satellite imageries. Comparison with Fixed size range block segmentation and Quadtree decomposition scheme, the Domain pool classification FIC scheme for the range block size 4x4 shows higher values of CR >3.4 and PSNR >28 dB for the Lena, Satellite Rural and Satellite Urban imageries.