FAST DIRECTIONAL FRACTAL CODING OF SUBBANDS USING DECISION-DIRECTED CLUSTERING FOR BLOCK CLASSIFICATION

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ABSTRACT
We propose a new image compression scheme based on fractal coding of a wavelet transform coefficients using a fast non-iterative algorithm for the codebook generation. The original image is first decomposed into subbands containing information in different spatial directions and different scales, using an orthogonal wavelet filter bank. Subbands are encoded using Local Iterated Function Systems (LIFS) with range and domain blocks presenting horizontal or vertical directionalities. Their sizes are estimated according to the correlation lengths and resolution of each subband. The computational complexity is greatly decreased by using subband decomposition. In addition a fast non-iterative algorithm is implemented for the blocks classification. This algorithm creates progressively the codebook during only one scanning of the training set. We proves the efficiency of the proposed approach both in terms of PSNR/bit rate and computation time.

1. INTRODUCTION
Fractal image compression using self-similarity has recently drawn considerable attention since the Iterated Function System (IFS) was proposed by Barnsley [1]. The first automated fractal coding algorithm based on Local Iterated Function Systems (LIFS) with range and domain blocks presenting horizontal or vertical directionalities. Their sizes are estimated according to the correlation lengths and resolution of each subband. The computational complexity is greatly decreased by using subband decomposition. In addition a fast non-iterative algorithm is implemented for the blocks classification. This algorithm creates progressively the codebook during only one scanning of the training set. We proves the efficiency of the proposed approach both in terms of PSNR/bit rate and computation time.

2. ADAPTIVE PARTITION AND FRACTAL CODING OF SUBBANDS (FCS)
The sizes of range blocks $R_i$ and domain blocks $D_j$ are estimated by computing the correlation length of both rows $C_i(k)$ and columns $C_j(k)$ in each subband in order to take into account the directionality [14].

Figure. 1 shows the size of the range blocks adapted to the directionality and to the resolution of the "Building" image.
Figure. 1: Octave decomposition of an image until resolution $2^{-2}$. LLi, LHi, HLi, HHi are the low frequency, the horizontal high frequency, the vertical high frequency and the angular high frequency subbands at resolution $2^{-i}$. A Uniform Scalar Quantizer (USQ) is applied on LL2.

Given a total bit budget, the subband bit rate and the number of decompositions are determined using an algorithm similar to the one proposed by Ramchandran et al. [15]. This algorithm selects the optimal bit allocation and the best decomposition number in order to minimize the overall mean square error under the constraint of a total number of coding bit lower than a coding bit budget.

Table.1 gives PSNR/bit per pixel results associated to the whole coding scheme (FCS with adaptive partition + Full search) for "Peppers" and "Building" images.

3. FRACTAL COMPRESSION OF SUBBAND USING CLUSTERING

The subband/fractal hybrid approach leads to a 12:1 gain in computation time [11]. In addition, we implement a block clustering technique in each subband.

The idea is to divide the set of domain blocks into clusters, each cluster having a representative block. We assume that a distance between any two domain blocks within a cluster is small. For a given range block, the search for a matching domain block is done in two steps. At the first step, the best cluster is located by minimizing the distance between the range block and the cluster centroid. At the second step, the best domain block within the cluster is located.

We suppose, that we have $C$ clusters, $N$ range blocks $R_i$, $M$ domain blocks $D_j$. For simplicity we assume that the codebook clusters are uniformly distributed, then the encoding involves $NC + \frac{M}{C}$ comparisons (distance calculations). The computation time is minimized by taking $C = \sqrt{M}$, each cluster containing $\sqrt{M}$ blocks.

**a-PROGRESSIVE CONSTRUCTIVE CLUSTERING ALGORITHM (PCC)**

The idea here consists of creating the codewords progressively, during only one scanning of the training set [16]. At the beginning, the codebook is initialized by the first vector $v_1$ found in the training set; then each input vector $v_m$ is mapped into the nearest neighbor codeword $w_i$, which minimizes the distortion error (the squared error is used here), expressed as $E = d(w_i, v_m)$.

This error is then compared with a pre-defined threshold $Th$, and two cases are considered (see Figure.2):
1. $E \leq Th$: in this case, $v_m$ belongs to the cluster $w_i$ and its centroid is adjusted to take $v_m$ into consideration.
2. $E > Th$: this means that $v_m$ does not belong to the cluster $w_i$; the new codeword $v_m$ is added to the codebook if its size is not yet out of range. If this codebook size is reached, $v_m$ is associated to the nearest cluster.
b-DECISION DIRECTED CLUSTERING ALGORITHM (DDC)

The PCC algorithm presented in the previous section has been modified to introduce a guard zone, as proposed in the Decision-Directed Clustering (DDC) algorithm [16]. Similarly, as seen in the PCC algorithm, the codebook is initialized by the first vector \( v_1 \) found in the training set, then each input vector \( v_m \) is mapped into the nearest neighbor codeword \( w_i \), which minimizes the distortion error \( E \).

For a certain predetermined threshold \( A \); \( E \leq A \), \( v_m \) belongs to the cluster \( w_i \) and its centroid is adjusted to take \( v_m \) into consideration. All other centroids are unchanged.

Now if, for a certain \( B > A \); \( E \geq B \), that means \( v_m \) does not belong to the cluster \( w_i \), we decide that a new cluster is generated which consists of \( v_m \) only and the number of clusters is increased by one.

The new codeword \( v_m \) is added to the codebook if its size is not yet out of range; If this codebook size is reached, \( v_m \) is associated to the nearest cluster.

\( E = A \) and \( E = B \) defines hyperellipsoids. The region between the two hyperellipsoids is called the guard zone. If \( v_m \) falls into the guard zone, \( A < E < B \), it is temporarily stored and tagged for later processing. This approach avoiding the creation of unnecessary clusters, is called "guard zone" and is illustrated on Figure 3.

In our case, after creating all the codewords, during only one scanning of the training set, we come back to the guard zone, calculate the associated codeword of each guard zone vector and the codebook is adjusted to take this zone into consideration.

4. RESULTS

The DDC algorithm has been implemented. Table 1 shows, for a global bit rate of 0.8 bpp, the improvement in computational time on "Peppers" and "Building" in addition to the algorithms discussed in section 3. Our approach leads to a gain of 50:1 factor comparing to the fractal coding of the full resolution image. The encoding process is about 20 seconds on a Silicon Graphics Indigo2. Considering these results, this fractal image compression technique appears as a potential candidate for time constraint applications such as satellite and medical imaging [17].
A new image compression scheme based on Fractal Coding of Subbands (FCS) is proposed. Subbands are encoded using Local Iterated Function Systems (LIFS) with range and domain blocks presenting horizontal or vertical directionalities. The computational complexity of the fractal compression algorithm is reduced by about 12 :1 factor when generating LIFS for subbands of lower resolutions instead of for a full resolution image. In addition, a fast non-iterative algorithm for codebook generation is implemented to accelerate the LIFS generation in each subband. FCS using this clustering technique leads to a 50:1 gain in computational time comparing to fractal coding of a full resolution image. In terms of PSNR/bit rate, the proposed hybrid coding scheme improves the quality of the reconstructed images compared to the quality obtained with other fractal coding techniques.

Table 1 also shows that the quality of the reconstructed images are better than those obtained by using the clustering on the full resolution image. The proposed approach results in a significant improvement comparing to Fisher [3] variance classification algorithm in terms of PSNR. Remark that the PSNR slightly decreases with clustering because of the choice of the best cluster for a range block. Indeed by minimizing the distance between the range block and a representative block of one cluster, we are not sure to find the optimal domain block in this cluster. However the PSNR remains higher or almost equivalent to the other algorithms considered in Table 1.

6. CONCLUSION

A new image compression scheme based on Fractal Coding of Subbands (FCS) is proposed. Subbands are encoded using Local Iterated Function Systems (LIFS) with range and domain blocks presenting horizontal or vertical directionalities. The computational complexity of the fractal compression algorithm is reduced by about 12 :1 factor when generating LIFS for subbands of lower resolutions instead of for a full resolution image. In addition, a fast non-iterative algorithm for codebook generation is implemented to accelerate the LIFS generation in each subband. FCS using this clustering technique leads to a 50:1 gain in computational time comparing to fractal coding of a full resolution image. In terms of PSNR/bit rate, the proposed hybrid coding scheme improves the quality of the reconstructed images comparing to the quality obtained with other fractal coding techniques.

7. REFERENCES


