Cellular Automata Based Transform Coding for Image Compression

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Abstract. In this correspondence, we propose a new Cellular Automata based transform coding scheme for grey level and color still images. This new scheme is markedly superior to the currently available DCT based schemes both in terms of Compression Ratio and Reconstructed Image Fidelity.

1 Introduction

This paper sets a new direction in the application of Cellular Automata (CA) technology for image compression. A large number of image compression algorithms have have been reported in last few years [1]. A new transform, termed as CA based Transform (CAT) coding has been reported in this paper to achieve the above goals for image compression. Compared to the current state of the art algorithms, this scheme is computationally simple and achieves superior reconstructed image quality at higher compression ratios.

2 CA Preliminaries

Cellular Automata are mathematical idealizations of physical systems in which space and time are discrete, and physical quantities take on a finite set of discrete values. A cellular automata consists of a regular uniform lattice (or "array") with a discrete variable at each site("cell"). The state of a cellular automata is completely specified by the values of the variable at each site. A cellular automaton evolves in discrete time steps, with the value of the variable at one site being affected by the values of the variables in its "neighborhood" on the previous time step. The cellular automaton evolution can be expressed in the form

\[ b_{i,(t+1)} = f(b_{(i-1),t}, b_{i,t}, b_{(i+1),t}) \]  (1)

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In [2] we have studied 3 neighbourhood $GF(2^p)$ CA where each cell may have a value in the extension field from 0 to $(2^p - 1)$. Encouraging results have been obtained from the application of two dimensional $GF(2^p)$ CA theory in the field of image video processing. However for the sake of simplicity, we shall mainly use one dimensional $GF(2)$ CA framework in subsequent discussions.

3 Transform Coding

The underlying principle of transform coding can be stated as follows. A set of data sample values is taken and the basic objective of the transformation is to alter the distribution of the values representing the luminance levels so that most of the values can either be ignored or can be quantized with a very few number of bits. The basic objective of the transform process is to perform the operation

$$d_i = \sum_j c_j B_{ij}$$

where the values $d_i$ are the values of the image data in the spatial domain while $c_j$ are the values of the data in the transform domain and $B_{ij}$ is the underlying basis function of the transform domain. We perform this transformation because the set $c_j$ is more amenable to further processing to realize the specified objective.

4 CA Based Transform Coding (CAT)

The basic principle of CAT is introduced in this section. We are given a physical process described by a set of discrete values say $\gamma_i$. This function is defined in a cellular space (grid) $i$. We want to express $\gamma_i$ in the following manner

$$\gamma_i = \sum_j c_j B_{ij} \quad \forall i$$

where $B_{ij}$ are the basis functions and $c_j$ are the associated transform coefficients defined in the CA space $j$. The basis functions are related to the evolving field of the cellular automata.

One dimensional $GF(2)$ cellular spaces offer the simplest environment for generating CA transform with a small number of bases. It is also possible to generate two dimensional $GF(2^p)$ CA bases from combinations of one dimensional base elements. In a one-dimensional space consisting of $N$ cells, the transform base is

$$B_j \equiv B_{ij} \text{ for } i, j = 0, 1, ..., (N-1)$$

For the data sequence $\gamma_i (i=0,1,2,...,(N-1))$ we have

$$\gamma_i = \sum_{j=0}^{N-1} c_j B_{ij}$$