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# Encoding Binary Images using Cellular Automata for Data Compression

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## ABSTRACT

In this paper, I propose a method for efficient coding of images using cellular automata. This method allows us to describe each selected group of neighboring cells of bend points in the contour. This method enables us to compress the image code. These groups will be separated to objects in an image by using cellular automata which uses bend-points determination.

## Keywords

Image, cellular automata, code, contour.

## 1. INTRODUCTION

Taking into account the rapid development of science and technology, especially the rate of growth of information volumes, there is a need for rapid processing and finding the necessary useful information. This includes the development of devices that contribute to the search for optimal solutions and choice of specific data. The development of worldwide micron technology leads to a transition to a brand new, high-quality level of the organization of the technological process.
In order that operative processes transmit the image of an object with high speed and with the least expenses, we need to use effective methods for encoding images. Coding should represent images in a compressed form, but without the loss of information that describes it. Moreover, compression encoding enables us to reduce the load on the transmission channel as well as reduce the transmission of images.

This encoding represents an image in the form of its individual elements that give a full description of the image. This can lead to loss some of the individual elements at the receiving end.

Digital communication systems and coding techniques have been used widely in many applications. They can be considered as a branch of science or the scope of industrial activity, where they are used or will be used in the coming years. These methods and tools are used in the field of automatic control of product quality, compression of data arrays in communication channels, identification of objects, video processing, pattern recognition and identification of objects, compression and processing of graphic information [1-4]. In this paper, we propose a method with hardware for optimal encoding of images by extracting the information elements using cellular automata methodology.

## 2. FORMULATION OF THE PROBLEM

The purpose of the following paper is to develop a method of image coding that meets the following requirements:

- high speed;

- High resolution;

- Low cost;

- Ability to read, encode, and to allocate part of the image;

- A small amount of data compared with the original;

- Ability with high speed and accuracy to encode images which are invariant to rotation and scale;

- Ability to restore images without losses and with high speed;

- Introduction of additional functions to improve the service.

## 3. MAIN CHARACTERISTICS OF CELLURLAR AUTOMATA

For processing images increasingly used SIMD structure which is one of the branches of cellular automata (CA) [5-15]. For the first time, the concept of CA introduced in the late 40-ies of the 20th century by John von Neumann and Conrad Tsuse independently of each other. In his work, J. von Neumann says that the computing environment is a homogeneous field, which consists of an array of processor elements (PE). Each PE contains vertically and horizontally homogeneous connections with neighboring PEs [1, 2, 6]. Neighborhoods that connect each PE environment with two horizontal and two vertical neighbors and has connections with diagonally neighboring PE are called neighborhoods Moore [2].

Considerable attention is paid to PEs due to the fact that the automata of this group is a universal model of parallel computing similar to a turning machine for sequential computations.

Simple nontrivial CA must be single-dimensional, with two possible states per cell. Cells of neighborhood must determine neighboring cells on either side of CA. Cell and its state are determined by the possible states of the neighborhood and certain rules. Decision rule is for each state neighborhood. Cells will have the state "1" or "0" in the next generation. There are 28256 possible rules as shown by Stephen Wolfram's code that gives each rule a number from 0 to 255. Rule 30 and Rule 110 of CA are particularly interesting.

Formally, the cellular automaton can be defined as a set of {G, Z, N, f},

Where G is a metric field on which a cellular automaton operates;

Z is a set of states for each cell;

N are neighborhood cells that affect the status of the selected cell;

f is a cellular automaton rule.

Communication between processors influences the width of the functional range and speed of operations. All modern developments aimed at the use of the necessary communication network that provides the greatest efficiency and performs the specified operation [8, 13].

Standard cellular automata are described by classical definitions. CA standard cell changes its state based on the states of neighboring cells, and thus, the field changes its state.

CA themselves have an internal structure that depends on the task in the processing array. But for speed, they are divided into two large classes: structure to perform operations per clock cycle; structure to perform operations at time that depends on the array that is processed and on the character the operations.

Using CA allows us to efficiently describe images with high compression ratio. In this area, a lot of research is carried out to obtain high results.

## 4. IMAGE ENCODING METHOD BASED ON THE CA

When images are encoded, much attention is given to methods of image compression. This reduces the time of its transmission of communication channels, and the load on the communication channel. In the proposed multi-channel system of encoding images, each channel encodes individual attributes and forms its own channel feature vector. The output of such a system forms the common code of the entire image, which is fed by information specific cells.

The input image is represented by a set of CA cells in the following way:

$$I_{in} = \{a_{i,j}\}.$$

All the cells that belong to the image may consist of different states. They represent the brightness, color, background affiliations, affiliations interference and affiliations of object visual scene. Thus, each cell can be represented by the following code (fig. 1).

**Table 1. Shape of code sequence of the state of cell in CA.**

| Coordinates | Color | Brightness | Back-ground | Hindrance | Object |
|---|---|---|---|---|---|

Each cell is represented by the following set of elements

$$b_{i,j} = \{x, y, c, b, bc, n, o\} \tag{1}$$

Where x, y are coordinates of the cell, which can also be represented by the number of cycles Nx,y of predetermined scan sequence.

c is a color code; b is a code of brightness; bc is a code of background; n is a code of hindrance; o is a code of object.
In each cell, this form of coding is redundant. The last three elements of the set (1) introduce redundancy and indicate a logical connection state of the cell in the visual scene.

To reduce the code sequence in (Table. 1), individual groups of cells that have equal values c and interconnected neighborhood are selected in (fig. 1). This merging is based on parameter *b*, given the specified threshold $b > b_{thr}$ .

After processing the parameter b, the image is binarized. In this situation, the state of each cell will correspond to a set {0, 1}. In the image obtained, there will be groups of combined cells and noise cells (fig. 2). In this example, the noise is previously deleted.

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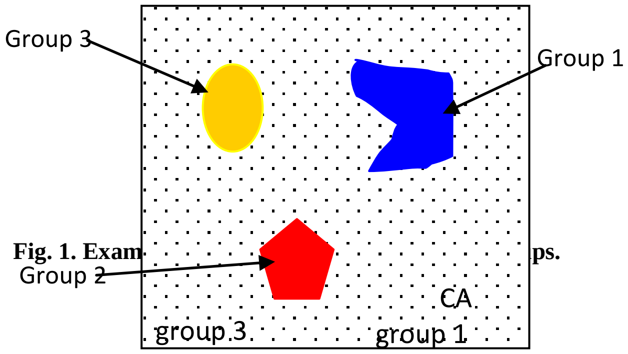

**Fig. 1. Exam ps.**

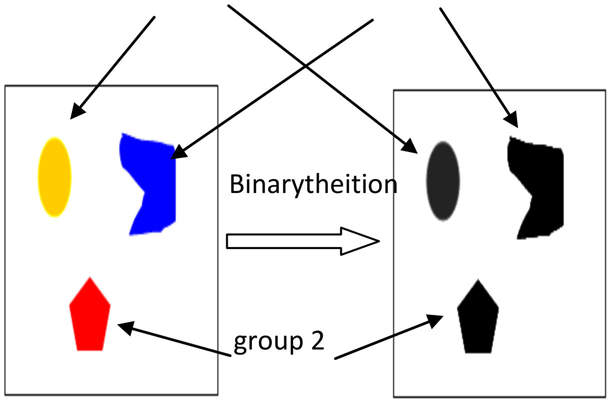

**Fig. 2. Example of images after binarization.**

Proceeding from such an approach, a binary image may be represented by the following expression

$$I_B = \{d^k_{i,j}, O_k, M_k, B\} \tag{2}$$

where $d^k_{i,j}$ is a cell that was bound to the k-th group of combined cells;

$O_k$ is a set of elements code describing the combined group K;

$M_k$ are cells that are combined into a k-th group and have a unit a state;

$B$ is a set of cells that belong to the background and are in the zero state.

Component $O_k$ is a code sequence which carries out the contour description of the particular code group

$$O_k = \{b_i, N_{i+1}, Z_{i+1}\}, \qquad (3)$$

where $b_i$ - coordinate i-th cells bend contour;

$N_{i+1}$ - direction of signal flow circumvention along a contour to the point of bend of contour i+1;

$Z_{i+1}$ - the number of cells through which the signal passed on the contour between i-th and (i+1)-th cells bend contour.
At the same time, the image contains aliasing for sides that have a slope at an angle, not multiple 450. Therefore it is necessary to introduce an additional parameter that would describe the existing equal code sequences.

$$O_k = \{b_i, N_{i+1}, Z_{i+1}, P_{i+1}\}, \qquad (4)$$

where $P_{i+1}$ indicates the number of repeated code combinations.
This value removes aliasing and reduces code combination, which describes the object.

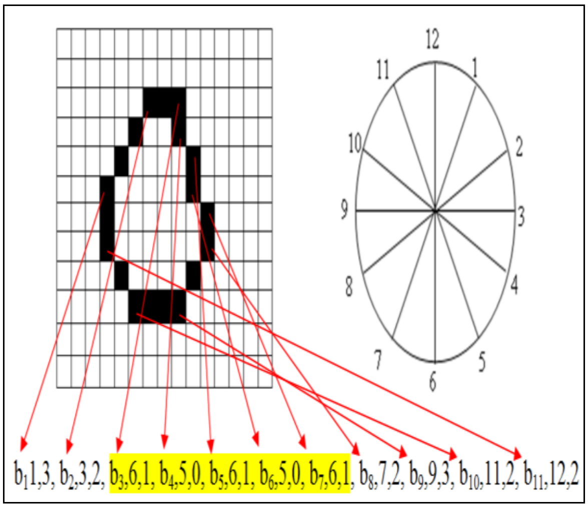

**Fig. 3. Example of the formation of code sequence**

The code consists of the value bi, which encodes the i-th vertex, the sector number which is determined by the example shown in the figure on the left and the number of cells through which the search signal passed the cell bend of contour. Based on this example, the code is redundant because the group comprises repeating sets. These recurring sets (allocated in Fig. 4) are combined into one and get the next optimal code

b11,3, b2,3,3, b3,6,1,3, b4,5,0,2, b5,7,2, b6,9,3, b7,11,2, b8,12,2.

Here we use an approach which was represented by algorithm RLE as shown in[16,17]. This algorithm uses an encoding group of the same values. This algorithm is used in most of the algorithms of image compression.

The number of sectors, which indicate the direction of signal movement on the contour, can be increased; this greatly increases the accuracy of coding.

In the previous example codes present the image as one group of cells. Binary image can be represented by expression (2). This expression describes a binary image in a compressed form. In fact, the image code of parameter $M_k$ can be removed; when recovering, flood fill operation can be applied.

Before intelligent compression is performed, background values of cells and the cells that represent the image noise are taken into consideration. Removing noise in CA is carried out by methods [3, 18]. Using specific threshold values, background cells and noise will go into a state of conditional zero. Such state represents the state whose value is below a predetermined threshold.

This organization of coder enables us to compress the volume of input image intelligently. This encoder developed a device that encodes geometric shapes images by bypassing them and finding the contour bend points, which represent the information of the cell. The resulting image code has a compressed form and implements lossless compression.

Encoding method and function of cellular environment are as follows.

1. By transmitting an excitation signal, the cell medium searches for the nearest bend point contour.

2. Excitation signal moves to the cells that belong to the contour; and signal generation moves from one cell to another.

3. The number of transition signals is calculated and bend cells signals are generated with parameters corresponding to the number of transition signals.

4. Each bend point forms a new signal sequence.

5. In the presence of noise, these sequences will change at the appropriate time, and generate small signals with small and large amplitudes.

6. Signal is identified before the interference of noise signals.

The proposed method is easily implemented by using CA. CA. It implements a signal transmission from one cell to another leading to a unit state. This was described in detail in [1,2]. The compression ratio of the binary image is determined by compression ratio

$$k = \frac{V_{cod}}{V_{in}}, \qquad (5)$$

Where $V_{cod}$ is the size of the encoded (compressed) image; $V_{in}$ is the size of the original image.

The size of the original image represents the number of cells of CA n×m, i.e. its dimension. The size of the compressed image is determined by the number of background B cells and the number of cells, which is described by the expression (4). The aliased contours have the maximum code.

Expression (4) takes the form of the proposed compression algorithm

$$k = \frac{V_{cod}}{V_{in}} = \frac{B + \sum_{i=1}^{k} O_i}{B + \sum_{i=1}^{k} O_i^{'}}, \qquad (6)$$

Where $O_i$ is a set of numbers that describes the number of cells contour $i^{th}$ group of cells; $O_i^{'}$ is a set of numbers, which determines the number of cells contour $i^{th}$ group and defines cells that are inside the contour.

As can be seen, the value of the numerator is smaller than the denominator. The value of each individual image determines the number of cells that form the group of cells. The more cells forming the group, the greater the value of the denominator and the smaller k. (k<1).

## 5. HARDWARE IMPLEMENTATION OF IMAGE CODEING METHOD

The structural scheme of the device which implements this method is shown in Fig. 4. The circuit comprises CA, unifying element (UE), generator of signals code sequence (GSCS), transducer signals into the code sequence (TSCS) and optimal code shaper (OCS).

The input image is an input to the encoder where it is first projected on CA, which functions according to the algorithm. The output signals from CA are supplied to UE. UE output signals go into GSCS where they get distributed in time.

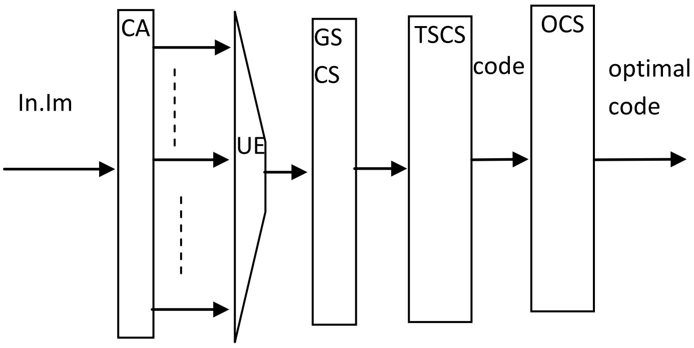

**Fig. 4. Structure of the image encoder by information cells.**

GSCS transforms the received signals into a sequence of signals according to a predetermined algorithm. The sequence obtained is converted into the code by TSCS, which encodes the image. However, aliased used OCS should be taken into account to obtain the optimal code.

The functioning process of the CA is served by the following algorithm of a single cell.

1. Defined cells that belong to a contour.

2. Determined by the excited state of a cell that belongs to a contour.

3. Transmission of excitation signal that neighbors the unexcited cell of a contour in case the cell is excited.

4. Waiting for an excitation signal from a neighboring cell that belongs to a contour.

5. Upon the reception of the excitation signal, the unexcited neighboring cell that belongs to a contour is analyzed and determined by its location.

Bloc- chart algorithm of cell functioning CA in the channel is shown in Fig. 5.

The functional scheme of CA cells which implements the algorithm for the von Neumann neighborhood is shown in fig. 6.

The circuit contains a trigger T and a transmission trigger of the excitation signal Tв and logical elements, which control triggers. In the trigger, the input of record keeps a record about the state of the cell CA. The analysis of neighborhood is carried out by AND which gives signals about the state of neighborhood cells.

If all the cells are in the neighborhood of the unit state, the resetting T is carried out. If at least one cell has a zero state, then this cell is the cell of contour. In this case, the cell expects excitation signals, which come from neighboring cells to the inputs of the OR element. The logic element 2-AND sets Tв in one state. That is, outputs drive signal is transmitted to neighboring cells.

CA simulated cells in (Fig. 6) are organized in the environment of Active-HDL. The obtained cell scheme in fig. 8, shows the resulting timing diagram in fig. 8.

Obtained model and timing diagrams prove the reliability of functioning CA. The obtained model allows us to implement such a coding device on the FPGA.

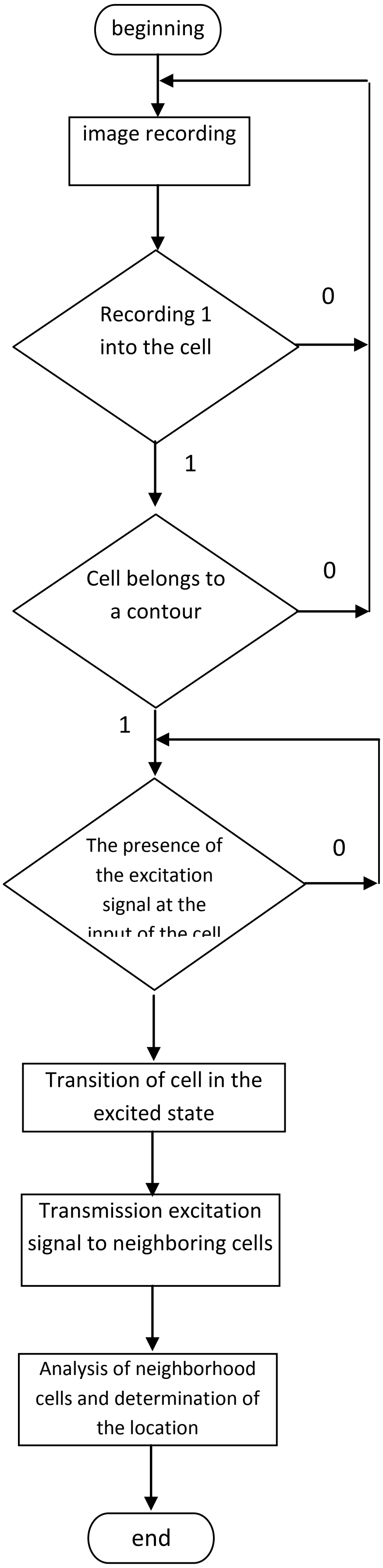

**Fig. 5. Bloc- chart of algorithm of cell function CA.**

## 6. CONCLUSION

This paper proposes a method of image coding with compressed information about the geometric shape of a selected image. The method allows us to represent the image by a set of cells that encode the bend points of the contour. It makes it possible to describe the image by background points, and points of selected objects. In fact, reduction of the code sequence is performed by the number of cells which encode the internal area of each image object. Using CA to implement the method will increase the speed of code formation that is determined by the complexity of the contour. At the same time, CA scans image and forms information signals. The proposed method of image coding allows us to consider the orientation of the identified groups of cells. This is achieved by shifting the code sequence. The proposed algorithm of image compression can belong to high image compression quality algorithms.

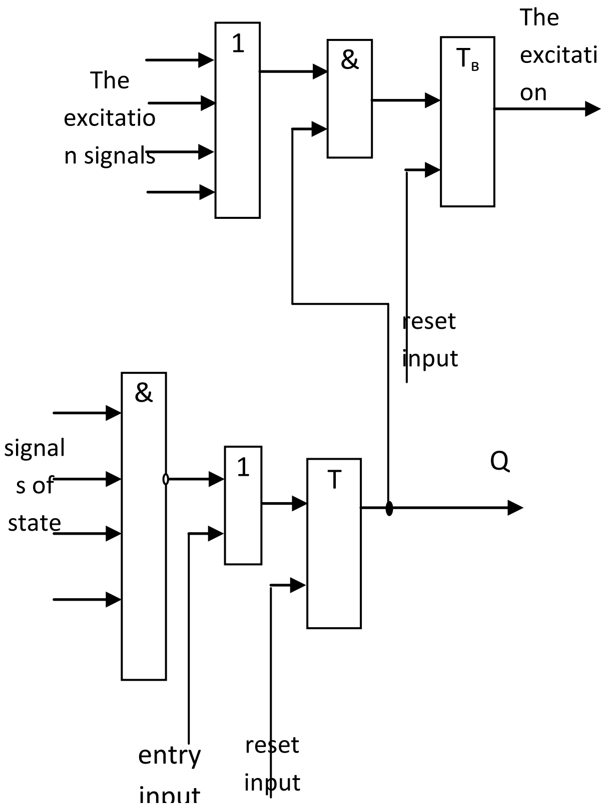

**Fig. 6. Functional scheme of CA cell.**

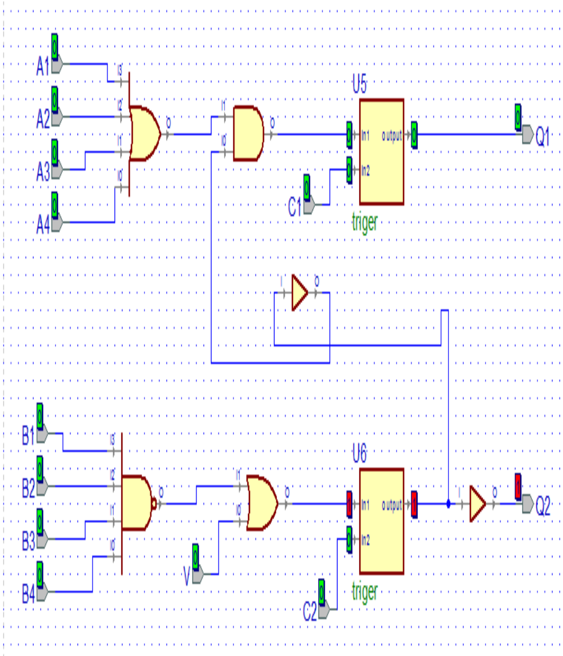

Fig. 7. CA cells scheme, modeled in CAD Active-HDL

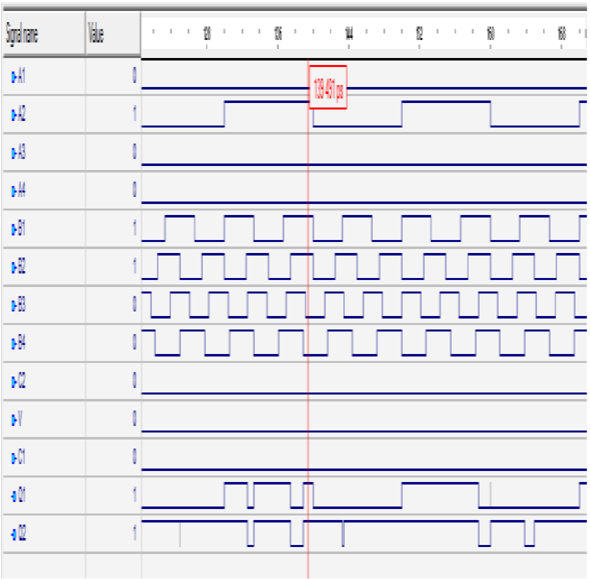

Fig. 8. Timing diagrams of the cells of the scheme shown in Fig. 7.

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