Model and the Hardware Implementation of the Method of Selection of Images of Objects for Efficient Coding of Complex Images

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Abstract: In this paper we have proposed a method for selecting images of objects for efficient coding of complex images using cellular automata. The proposed method allows selection of individual objects in the image in the form of groups of cells. The selected groups form separate objects of complex image. Encoding is performed by ordering of selected objects to a given law and the formation of the code sequence, which carries information about the objects and their arrangement relative to the reference point of the complex image.

Key words: Image, object selection, cellular automata, the code, contour.

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1. Introduction

Modern communication quality is characterized by many parameters. One of the important parameters is how much data transmitted per unit time. The amount of information transmitted through the communication channels is constantly increasing, which leads to an increase the load on the transmission channel and limits the transmission of information. This situation is also applied to images that are inherently electronic which occupy large amounts of bit in transmission space.

In the literature, there are limited numbers of methods that reduce the volume of images without distorting the visual structure of the image [1]-[3]. Most available methods analyze bit structure of image and are remove elements that do not affect the overall structure. This reduces image size significantly

In general, available methods in literature are useful for simple images that represent the same characteristic object [4]-[6]. Therefore, much attention must be paid to the development of methods and tools for describing complex images, which are formed by set of objects. In such images, one of the main tasks is to select each object and its consistent structuring.

To perform these operations some researchers use cellular automata (CA) [4]-[8]. CA helps in analyzing all cells that represent each images' point.

The aim of this paper is to develop a methodology to be use in selecting of objects in the visual scene for efficient coding of complex images. This methodology is used for homogeneous cell structure analysis, which is based on CA.

2. General Approach for Complex Image Coding

For coding of complex visual scenes which consist of individual local objects we use the method described in [5]. In [5] carried out analysis and structuring of the descriptions of all objects in the scene, as well as their location in it. According to the developed method carried out binarization in the entire complex image and the allocation of individual images in the circuit. To each selected object in the visual scene is assigned an identifier according to the set parameters and characteristics of the object. Is determined by the location of each object relative to each other, or relatively of the given point of the image. Are determined their values. Moreover additionally threshold processing is carried out by removing an objects, which have the number of cells is less than a predetermined threshold. Are given sequences of the objects location by selected in advance by the quantitative parameters. Is determined the location of each object relative to a given point of the image. Describes each object. Is formed sequence that places the sequence of the objects, the distance of objects to a given point, the relationship between objects. Is encoded the resulting sequence. Coding each object is performed by the method which is represented in the [6].

In this sequence it is important to choose an effective structure for the implementation of all the operations with high productivity. It is therefore proposed the use of technology of homogeneous cell environment functioning, which in hardware required reprogrammable architecture forming for efficient image descriptions. The second action is to transform of a gradation color images to binary. The logical "1" encode the point or cell of environment, which belongs to the object in obtained binary images. In the state of logical "1" remain those cells which have states of intensity greater than a predetermined threshold value. All other points of the image move to the cells of background, that is, take the value of the logical «0».

Selecting objects in the visual scene is based on search of groups of cells that combine the same properties. For a binary image feature is this the distance between adjacent groups of cells. To extract binary objects in the visual scene with the lowest spending hours is best to use a homogeneous computing environment, in particular CA [5], [8]. CA, due to their own flexibility and reinstallation the internal architecture can efficiently perform various operations on arrays of data.

Selected objects in a real scene can be quite a large number of. As a rule, there are small objects that do not carry useful information about the image and generate noise. Noise impairs the accuracy of the analysis and understanding of complex images. For the removal of small objects is used thresholding by the number of cells that includes the object. After the selection of objects and of thresholding to each object of a complex image is assigned an identifier, which indicates the location of it's hierarchically. An example of the formation of such a sequence displayed on Fig. 1. Value B_i quantitatively indicates the geometric center coordinates of the i -th object.

Fig. 1. An example of the formation of a sequence of selected objects of complex image.

The resulting sequence does not fully describe and does not allow understand complex images. It also does not allow reproducing the original image. For this purpose, the additional information signs entered. For complex images such feature is the quantitative characteristics that describe the location of objects in the

visual scene. The topology of each object is described relatively of a given point of the image.

Point count is selected from such considerations, that it must carry information about the order the beginning of a sequence of image description. The choice of this point and bind objects of the visual scene to it allows to determine the orientation of complex images. To coincide point count and assignment of the first sequence object is to choose the best option in terms of counting on the plane of the first object.

3. Methods of Selecting Objects on a Complex Image

The most common method is a method using cluster analysis [9]-[12]. The image can be viewed as an environment with the set of objects of different sizes and colors. When it is difficult to determine which object is useful and what a hindrance (relate apply to noise). The task is to select any of the objects that belong to the image. Data clustering – this task partitioning a given sample of objects into subsets called clusters. Each cluster should consist of similar objects, and objects of different clusters differed significantly. The task of clustering refers to a broad class of learning without a teacher.

Most of the existing methods for selecting objects consist of two categories of methods.

- Per-pixel methods [13], [14].
- Methods based on the minimization of the energy functional for throughout the image.

The first category of methods is based on the processing of all pixels in the image independently. Initially built color model, and then the background model. Background model can be, for example, a normal distribution or a mixture of statically or dynamically specified the number of normal distributions [13], [14]. These methods are used as analysis of neighboring pixels and to have high performance, but are sensitive to noise. The second category of methods is processed independently not individual pixels and groups of pixels that are combined into separate blocks [12]. These methods have high performance, but have no high accuracy. If the block has a boundary, then in these areas the boundary of the object is defined inaccurately. These methods include Background Cut [13]. It takes into account the pixel color, contrast it with neighboring pixels, as well as take into account any changes in background.

3.1. Selecting Objects in a Binary Image Based on CA

CA are implemented by lattice which have nodes where are located processor elements (PE), which are associated with neighboring PE. These neighboring PE and communication with them to form neighborhood [4], [5], [8], [14]. CA is characterized by general condition, which depends on the state of each cell. State of the cells is formed a function whose argument is the state of cell neighborhood. To facilitate the process selection of objects in the image the real image is binarized by using thresholding in intensity or color of each cell CA. An example of this binarization is shown in Fig. 2.

Fig. 2. An example of binarization of image.

If the image is binary, then cells, which are combined into one object, characterized by the feature distance. That is, cells which have a logic "1" state and combined into a single object must not exceed specified

distance between them. This suggests that there must be at least two cells of a set of cell objects that satisfy the distance. Moreover, each cell is connected with another cell which belongs to the object so that they can transmit a signal to each other through other cell object.

Cells which belong to a separate binary object can be determined by performing the following steps.

1. Selected contour of binary object.
2. Calculate the area that is covered by a separate object in the field of CA.
3. Fills cells within the contour area of each object.

Edge detection of image objects is performed by different methods based on CA [4], [8], and [14]. Contours allow delimit the boundaries the object in the form of the curve, which outlines the area of the visual scene. To set the an identifier to each object using a serial search of all contours by running the excitation signal from one cell CA. Signal is given from one cell of CA, which can be freely selected depending on the priority. The excitation signal is transmitted to neighboring cells and is distributed all over the field CA. When it reaches the cell, which belongs to the contour, the output signal of that cell is formed, which is supplied to the reset inputs of the excitation propagation process in cells that belong to the background.

After passing the excitation signal by all the selected contours are formed set of numbers, which are connected into the set of features belonging to one object contour

$$K_j = \{k_i^j\},$$

where k_i^j - i-th cell which belongs to the j-th object.

The index i indicates the number of cells that excited after the start of circumvention cell contour of the object, it indicates the number of excited cells and between the first i-th cell contours.

However, this description simply edge detection and makes it impossible to quickly define an accessory of the cell to the object. For rapid separation of the cells that they belong to the object to be considered two states:

- Information state (logic "0" or "1");
- switching state.

Information state indicates the state of the cells, which determines whether the cell background (logic state "0") or object (a logic "1"). Switching condition determines the belonging of cell defined group selected (object visual scene). For this we introduce the following model

$$b_i^j(t+1) = \begin{cases} 1, & \text{if } b_{i-1}^j = b_{i+1}^j = 1, \quad f_i^j(t) = 1. \\ 0, & \text{if other case} \end{cases}.$$

The first line of the model indicates that the i-th, (i-1)-th and (i+1)-th unit cells are in state of "1". At the same time, through these cells are passed the switching excitation signal $f_i^j(t)$, which united these cells to the inputs.

The union of these cells by the inputs allows these cells to respond simultaneously to the same parish signals to the inputs of any merged cells. This situation is described by the following signal model

$$b_i^j(t+1) = \begin{cases} 1, & \text{if } \forall X_s^j(t) = 1, \\ 0, & \text{if other case} \end{cases},$$

where $\forall X_s^j(t)$ - value of the input signal at a signal input of each cell belonging to the j-th selected object.

The model describes that with the signal applied to the input X_S^j of cell there is a signal of logic "1". Cell belongs to the j-th object and all the cells of the object set into the state of logical "1". In fact, all selected and combined cells perform the same operation at the same time as a single entity. The complexity represents the switching system for each cell of CA.

The main task is tough union of cells of images of an individual object into one. This determines the that with a signal is received by one cell of set react all cells of the set. To do this, must enter in every cell of additional functional entity that performs an operational link and combine cells in the set.

This module should implement a constant connection of all cells of the object. The structure of this fragment is shown in Fig. 3.

Fig. 3. Cell Structure of CA to select objects in the visual scene.

The cell comprises an operational unit (OU) and the commutation unit (CU). OU performs logical function whose arguments are the individual input signals and output signals from information output of OU of neighboring cells. Logic functions are also performed taking into account the presence of the excitation signal at the cells input.

If the excitation signal (a logic "1" signal) is present on the input excitation then is switched CU which connects the inputs of the cells to the inputs of previous excited cells.

Present in every cell of CA additional CU twice as complicates scheme. To simplify the scheme using additional external units that control the installation of CA. CA is the main module of the system to implement the selection of binary objects.

Consider the sequence of steps performed by the CA for selected objects.

1. Image recording.
2. The propagation of the excitation signal in the field of CA.
3. When the excitation signal reaches the nearest cell which is at logic "1" state, the spread of the excitation signal by background cells (cells which have a logic state "0") stops. Begins from cell spread signal with the logical state "1" to the neighboring cells that have a state of "1".
4. The implemented by circuit fixing the cells with a logic "1" through which passed the excitation signal.
5. When the propagation of a signal in cells with logic "1" is completed and the cells are blocked. For propagation of the excitation signal, these cells have a zero state, and they have logic "1" to read.
6. Since the beginning of the new propagation is the selection of the next closest object to the rules described above.

Location of cells that belong to the object, the additional storage unit is fixed or saved in the additional layer of cells. In operation, the CA made sequentially excitation of cells grouped into a single object. The relationship between the cells of the object is carried out by their selection and translated into a separate

storage layer in a given time interval.

In such a CA, each cell operates on to a given law and has the same relationship between neighboring cells, which organize neighborhood. Such cell of CA by the following functional circuitry is represented (Fig. 4).

Fig. 4. Functional diagram of CA cells for selection of binary objects in the image.

Such cell works on the following algorithm.

1. The initial setting of the cells to logical "1" state or a logical "0" state.
2. Waiting for the excitation signal.
3. With the coming the excitation signal is determined by the state's own cells.
  - 3.1 If the cell has the state of logical "0", then transferred to the excitation signal to neighboring cells (according to the chosen neighborhood) that have not moved into a state of excitation. Transition to item 8.
  - 3.2 If the cell is in the logic "1" state, then it goes into the excitation state and transition to item 4.
4. Forming signal of stopping for transmission signal of the excitation signal to the cells, which is a logic "0" state.
5. Forming transmission for the excitation signal of cells that are in the logic "1" state.
6. Resetting of the main memory element.
7. The transition to a logic "1" state of additional memory element.
8. End.

The cell can operate in two modes.

1. Mode of operation of its cells during the initial installation of a logic "0" state.
2. Mode of operation of its cells during the initial installation of a logic "1" state.

In the first mode, main and additional triggers D_5 , D_6 have to logic "0" state. The excitation signal through a second disjunctive D_2 to the second input of the second conjunctive D_7 , to a first input of which is fed a logic "1" output from the inverse additional trigger D_6 . The output of the second conjunctive D_7 is formed excitation signal that is supplied to the second input of the fourth disjunctive D_8 , from the output which the signal is applied to the output of excitation signal. From this output is formed drive signal is came to

respective inputs of a second disjunctive of four neighboring cells vicinity. In the first mode, the cell the excitation signal transmits and propagation. At the same time triggers D_5 and D_6 do not change their own state.

In the second mode, the main trigger D_5 is at logic "1" state, and an additional trigger D_6 - a logic "0" state. Excitation signal through a second disjunctive D_2 goes to the second input of the first conjuncture D_3 , the third input of which is supplied as a logical signal "1" is from straight output of the main trigger D_5 . On the first input of the first conjunction D_3 go logic "1" from the first disjunction D_1 , which is formed due to the fact that one (or more) to the inverting input of the first disjunctive D_1 is necessarily a logic "0".

Since on all inputs of the first conjuncture D_3 is a logic "1", which is fed to the input of the installation in one state of additional trigger D_6 . Additional trigger D_6 goes in one state, and the main trigger goes into logic "0" as its input setting to zero state signal is a logical "1" from output of the first conjuncture D_3 through the third disjunctive D_4 .

Thus, the drive signal is applied to a first input of a fourth disjunctive D_8 from direct output of the additional trigger D_6 , and from fourth output disjunctive the excitation signal is fed to the excite output of cell. Reading the cells with a single state is made with direct output additional trigger D_6 and transferred to an additional CA which is temporarily stored for a period of processing.

An example of functioning of CA is shown in Fig. 5.

Fig. 5. An example of functioning of the device for the selection of binary image objects.

At the initial moment being recorded image in CA. In the first step of initial cell selection is made, which begins the spread of excitation signals in CA. In subsequent cycles the signal propagates through the background cells, and the fifth cycle begins selection nearest object. In an additional field formed cells which are read as cells that belong to the object.

The operation of such CA described by the following model.

$$\frac{b_i(t+1)}{A_i(t+1)} = \begin{cases} \frac{b_i(t)}{A_i(t)}, & \text{if } \forall X_{i\_neigh}^{excit}(t) = 0 \\ \frac{b_i^{excit}(t)}{A_i(t)}, & \text{if } \forall X_{i\_neigh}^{excit}(t) = 1, b_i(t) = 0, \forall b_{i\_neigh}(t) = b_{i\_neigh}^{excit}(t) \\ \frac{0}{A_i(t)}, & \text{if } \forall X_{i\_neigh}^{excit}(t) = 1, b_i(t) = b_i^{excit}(t) = 0, \forall (b_{i\_neigh}(t) = b_{i\_neigh}^{excit}(t) = 1) \\ \frac{0}{A_i(t)}, & \text{if } \forall X_{i\_neigh}^{excit}(t) = 1, X_{i\_neigh}(t) = 1, b_i(t) = 0, \forall (b_{i\_neigh}(t) = b_{i\_neigh}^{excit}(t) = 1) \\ \frac{b_i^{excit}(t) = 1}{A_i(t) = 1}, & \text{if } \forall X_{i\_neigh}^{excit}(t) = 1, b_i(t) = 0, \forall (b_{i\_neigh}(t) = b_{i\_neigh}^{excit}(t) = 1) \\ \frac{b_i^{excit}(t) = 1}{A_i(t) = 1}, & \text{if } b_{i\_neigh}(t) = b_{i\_neigh}^{excit}(t) = 1 \\ \frac{b_i^{excit}(t) = 0}{0}, & \text{if } \forall X_{i\_neigh}^{excit}(t) = 1, \forall b_{i\_neigh}^{excit}(t) = 1, \exists \forall b_{j\_neigh}(t) = 1 \neq b_{j\_neigh}^{excit}(t), \exists b_{j\_neigh}(t) = b_{i\_neigh}^{excit}(t) = 1 \\ \frac{0}{1}, & \text{if } \exists \forall b_{j\_neigh}(t) = 1 \neq b_{j\_neigh}^{excit}(t), \exists b_{j\_neigh}(t) = b_{i\_neigh}^{excit}(t) = 1 \end{cases}$$

where $\frac{b_i(t)}{A_i(t)}$ - state of the cell (numerator $b_i(t)$) at time t and state of additional cells in time t

(denominator $A_i(t)$);

$X_{i\_neigh}^{excit}(t)$ - the excitation signal on the input i -th cell from the neighborhood cells;

$b_i^{excit}(t)$ - i -th cell is in an excited state at time t (while the cell may have a logic "1" or "0");

$b_{i\_neigh}^{excit}(t)$ - state of the cell, which is a neighbor in relation to the i -th cell.

4. The Hardware of the Device for Selecting Objects in an Image Using a Branched Switching System Based on CA

Fig. 6. Fragment of functional circuit of CA for selection of binary objects.

The simplest method of selecting objects of binary image is a method, which a circuit realization is simply because the state takes into account the cells that form the neighborhood. CA, which are intended to select of binary objects and they composed of functional elements and switching elements (Fig. 6). This cell surroundings has a structure that organizes the von Neumann neighborhood. That is commutation units (CU) located between the information cells horizontally and vertically.

Each device has terminals (IO), which are connected with neighboring cells and perform direct electrical connection of both cells. Commutation control exercised by the relevant terminals (CI), which are connected to the CU from the respective cells, which combined data of CU.

Neighboring cells are connected to the information outputs (IO) and outputs of signal excitation (EO). By IO carried out an analysis of information states of neighboring cells, and by EO are transmitted excitation signal.

In the initial state being installed specified cell in the excited state. From this cell environment extends excitation signal by EO from cell to cell. Accordingly, if neighboring cells have a logic "1" state and is excited and by the corresponding signals from the CU performs switching of neighboring cells. Connected cells simultaneously execute commands that are received by IO from any cell cellular environment. The detailed implementation of the circuit cellular environment is shown in Fig. 7.

Fig. 7. Functional scheme of two neighboring cells of the cell of environment.

Cells may also contain elements of the commutation circuit (MK_S), which are included in the total cellular switching system environment. Switching elements are located within the cell to control the state T_S . There may also be additional switching elements which realize the connection between basic switching elements which enable to control the state outside the T_S . Each switching element is controlled by the signals that are received from T_S and T_E .

To simplify switching system the selected cells are united by one control element, which is located in the additional layer. After selecting all objects in the information layer, each of them (each grouped in group of cells) controlled by a unifying element of unifying layer.

5. Conclusion

In this paper we have proposed a method for selecting objects in complex images and offer a hardware implementation, which allows it to implement on the CA. This is parallelize many operations and faster the selection process and reduces the time spent on the selection of objects. Transformation of the set of cells in one object allows simplifying the description of complex images, which are composed from the set local objects. The proposed system shows excellent performance.

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