# RESEARCH of OPTIMUM DEPTH of OVERLAPPING in CELLULAR AUTOMATA

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**ABSTRACT**

The speed of calculations homogeneous cellular automata is determined depending on depth of overlapping with use of a method of overlapped windows. Optimum depth of overlapping also is investigated depending on parameters cellular automata.

## 1: Introduction

One of the important information tasks at the present stage of development of a science and engineering is the image processing. Cosmo- and aeroshooting, systems of navigation and detection, recognition and identification, medicine, geodesy - these and other areas of human activity require image processing.

In most cases images are represented as two-dimensional matrix by M x N. For processing such images are widely used cellular logic and cellular automata (CA).

The widespread matrixes of operational elements (OE) CA - four-coherent and eight-coherent.

OE in a matrix are connected among themselves by local communications. OE carries out some set of operations of cellular logic, when the result of operation is defined as logic function of meaning of the element and its neighbours.

One of problems of the image processing on CA is connected that the image in most cases has the sizes exceeding the sizes of a matrix OE. In this case image process by a successive - parallel way, breaking them on separate window [1]. The image by the size M x N is processed on a matrix OE by the size m x n (size of a window), and m < M and n < N.

As boundary OE in a window have not the informations from a part of neighbours, taking place outside a window, after performance of one operation the boundary cells in a window will contain false meanings. After two operations already two layers of boundary elements will contain the false information etc. For elimination of the given phenomenon use overlapping windows with depth p (Fig. 1).

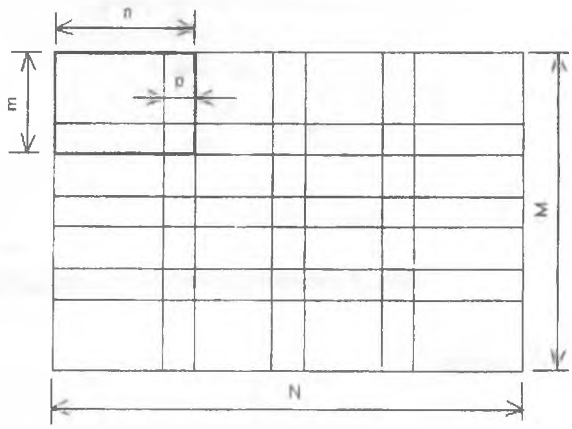


***Figure 1.Processing by a method of overlapping windows.***

Depending on a kind of processing the various variants of use of overlapped windows are possible [2,3]. Actually the CA can use the various kinds of processing and the size of a source image can be changed in a wide range. Therefore the problem of choice of depth of overlapping depending on parameters of a system is of interest.

In work the efficiency of use of the given method is considered depending on the sizes of the image, matrix OE, depth of overlapping and reloading speed of a matrix OE. Optimum depth of overlapping also is considered depending on parameters of system.

## 2: Dependence of time of processing on depth of overlapping

Let's define time required for image processing, if m x n - size of a window, M x N - size of the image, p - depth of overlapping, k - number of operations, which are necessary to execute, $t_{op}$ - the time of performance of one operation (is supposed, that any operation is carried out for identical time), $t_{rl}$ - time spent on reloading CA with transition from one window to another.

Let $V_h$ - number of windows on a horizontal. Then

$$(V_h - 1)\cdot(n-p)+n=N$$
$$V_h = \mathrm{int}^+[(N-p)/(n-p)] \qquad (1)$$

Here $\mathrm{Int}^+[x]$ means nearest greater whole. Similarly, the number of windows on a vertical $V_v$ is defined by

$$V_v = \mathrm{int}^+[(M-p)/(m-p)] \qquad (2)$$

The complete number of windows V is determined by

$$V = V_h \cdot V_v \qquad (3)$$

The number of operations G, which can be executed without occurrence of the erroneous data, found by

$$G = \mathrm{int}[\frac{p}{2}] \qquad (4)$$

Here int[x] means the whole part of number. The number of passes H under the image specified by

$$H = \mathrm{int}^+[\frac{k}{G}] \qquad (5)$$

The time of processing of the image T is given by

$$T = t_{op}\cdot k \cdot V + t_{rl}\cdot V \quad H \qquad (6)$$

By substituting (1-5) in (6), we shall receive

$$T = \mathrm{int}^+[\frac{N-p}{n-p}]\cdot \mathrm{int}^+[\frac{M-p}{m-p}] \cdot (t_{op}\cdot k + t_{rl}\cdot \mathrm{int}^+[\frac{k}{\mathrm{int}[\frac{p}{2}]}]) \qquad (7)$$

Let's determine expenses of a time $T_n$ if not to make overlapping windows:

$$V_h = \mathrm{int}^+[\frac{N}{n}]$$
$$V_v = \mathrm{int}^+[\frac{M}{m}] \qquad (8)$$
$$H = k$$

By substituting (3) and (8) in (6), we shall receive

$$T_n = \mathrm{int}^+[\frac{N}{n}]\cdot \mathrm{int}^+[\frac{M}{m}]\cdot k\cdot(t_{op}+t_{rl}) \qquad (9)$$

Let's express parameters M, N, m, p through n, and $t_{rl}$ through $t_{op}$, by entering corresponding coefficients and assume $n \le m$ and $t_{rl} \ge t_{op}$:

$$m = S_1\cdot n, \qquad S_1 \ge 1$$
$$N = S_2 \quad n, \qquad S_2 \ge 1$$
$$M = S_3 \quad n, \qquad S_3 \ge 1 \qquad (10)$$
$$p = S_4\cdot n, \qquad 0 < S_4 < 1$$
$$t_{rl} = S_5\cdot t_{op}, \qquad S_5 \ge 1$$

The restrictions on $S_2$ and $S_3$ define the size of the image more or equal to a size of matrix OE. The restriction on $S_4$ defines, that the depth of overlapping lays in limits from 0 up to the short party of a matrix OE. The restriction on $S_5$ specifies, that the reloading time of a matrix OE is not less time of performance of any other operation. Besides that the variables m, n, M, N, p are integers.
Then the expressions (7) and (9) will be copied as

$$T = \mathrm{int}^{+}[\frac{S_2 - S_4}{1 - S_4}] \cdot \mathrm{int}^{+}[\frac{S_3 - S_4}{S_1 - S_4}] \cdot t_{op} \cdot (k + S_5 \cdot \mathrm{int}^{+}[\frac{k}{\mathrm{int}[\frac{n \cdot S_4}{2}]}])$$

$$T_n = \mathrm{int}^{+}[S_2] \cdot \mathrm{int}^{+}[\frac{S_3}{S_1}] \cdot k \cdot t_{op} \cdot (1 + S_5) \quad (11)$$

What to estimate as far as the processing with overlapped windows is effective, we shall calculate the attitude R = T/Tn:

$$R = \frac{\mathrm{int}^{+}[\frac{S_2 - S_4}{1 - S_4}] \cdot \mathrm{int}^{+}[\frac{S_3 - S_4}{S_1 - S_4}] \cdot (k + S_5 \cdot \mathrm{int}^{+}[\frac{k}{\mathrm{int}[\frac{n \cdot S_4}{2}]}])}{\mathrm{int}^{+}[S_2] \cdot \mathrm{int}^{+}[\frac{S_3}{S_1}] \cdot k \cdot (1 + S_5)} \quad (12)$$

So, we have deduced dependence of efficiency of use of a method of the overlapped windows for homogeneous CA from parameters of system.

For determination of optimum depth of overlapping it is necessary to resolve the equation $R'(S_4)=0$. However even if to drop all non-continuous functions int$^{+}$ the problem is reduced to a solution of a equation of fourth grade. On this reason optimum depth of overlapping was simulation.

## 3: Results of modeling

The estimation of efficiency of depth of overlapping depending on parameters of system was simulated on the computer. For it the meanings $S_1$, $S_2$, $S_3$, $S_5$, k, n were fixed. The meaning of depth of overlapping p was changed from 1 up to n with a step in 1 pixel. For each of p the meaning $S_4$ and R under the formulas (10) and (12) accordingly was calculated. Parameters $S_1$, $S_2$, $S_3$, $S_5$, k, n further were varied and again meanings $S_4$ and R for each of p was calculated. The results of modeling are submitted on fig.2.

In a figure the family of dependences R ($S_4$) is submitted with n = 128, $S_1$ = 1, $S_2$ = 8 and $S_3$ = 10. This parameters approximately corresponds to real system (the size matrix of OE 128x128 elements and the size of image 1024x1280 pixels). The diagrams are given for $S_5$ = 1 and k = 10, for $S_5$ = 10 and k = 10, for $S_5$ = 10 and k = 100, for $S_5$ = 100 and k = 10, for $S_5$ = 100 and k = 100. Such values of $S_5$ and k were taken only with goal to demonstrate that in some cases the use of overlapped windows is increasing speed of image processing.

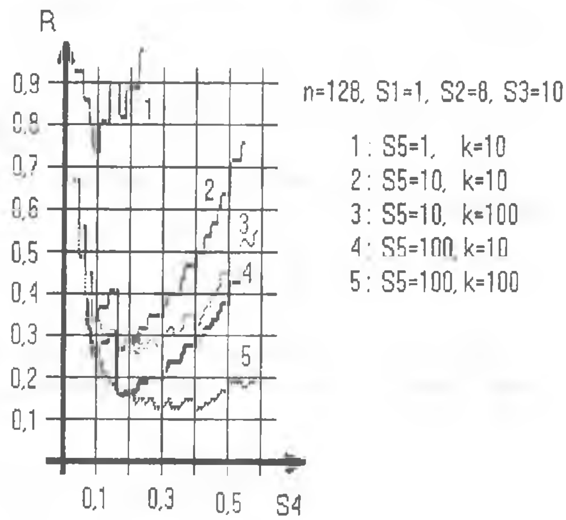


***Figure 2. Family of dependences R (S4) with n = 128, S1 = 1, S2 = 8 and S3 = 10.***

From the diagrams it is visible, that with increase of reloading time CA $S_5$ the efficiency of use of overlapping raises. So, with $S_5$ = 1 R is not lowered below 0.7, and with $S_5$ = 10 can be reduced less than 0.3. Besides that with increase $S_5$ optimum depth of overlapping (the meaning of depth of overlapping p with which is observed a minimum R) is increasing too.

The change of number of carried out operations k influences the diagram differently. With increase k the optimum depth of overlapping practically does not change, however right side of the diagram becomes essential horizontally. Thereof the size R becomes close to minimal for a wide range of depth of overlapping p.

The numerical meanings of optimum depth of overlapping $S_4$, size R achieved with the given depth, and range of depth of overlapping, for which $R \le 1.1R_{min}$ are shown in table 1. $R_{min}$ designates the minimal meaning R for given $S_1$, $S_2$, $S_3$, $S_5$, k, n with change p from 1 up to n-1.

Optimum depth of overlapping in a number of cases is submitted by range of meanings. It not that other as influence of non-continuos function $int^+$. For the same reason there are a few intervals of close to minimal meanings $S_4$ represented in the last column.

***Table.1.***

***Meanings of optimum depth of overlapping $S_4$, and R achieved with the given depth, and range of depth of overlapping, for which $R \le 1.1R_{min}$.***

| with n=128, $S_1$=1, $S_2$=8, $S_3$=10 | Optimum depth of overlapping $S_4^{opt}$ | R with $S_4=S_4^{opt}$ | Range $S_4$ with $R \le 1.1R_{min}$ |
|---|---|---|---|
| $S_5$=1, k=10 | 0.086-0.094 | 0.7425 | 0.070-0.125 |
| $S_5$=10, k=10 | 0.164-0.180 | 0.2727 | 0.164-0.219 |
| $S_5$=10, k=100 | 0.211-0.219 | 0.2659 | 0.164-0.219 0.242-0.250 0.273-0.297 |
| $S_5$=100, k=10 | 0.164-0.180 | 0.1634 | 0.164-0.219 |
| $S_5$=100, k=100 | 0.398 | 0.1287 | 0.273-0.297 0.320-0.352 0.398-0.414 |

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