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DESIGN OF THE OPTICAL-ELECTRONIC COMPUTER SYSTEMS FOR IMAGE PROCESSING IN STATIONARY AND DYNAMIC MODES

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ABSTRACT

The theory of designing the optical-electronic image processing computer systems has been presented. A model of parallel image processing system has been considered, that is based on the principle of function decomposition. A structure model of computer system has been examined, that is a conveyor of parallel processors. The implementation possibilities of different image processing operations by optical and electronic computer means have been analyzed. Evaluation of time outlay in the system, while processing an image or a series of them has been made. There have been exposed the dependence of image processing time from conveyor length change and the correlation of optical and electronic devices. The designing method of image processing systems in static mode has been described. The results of investigations of the influence of the median square deviation, of the processing time in the modules on the throughput capacity of the system under the different electronic and optical modules quantity are presented. The recommendations of increasing the system's throughput capacity are formulated. On the bases to these recommendations, the system design method of image processing in the dynamic mode is elaborated.

Keywords: computer system, conveyor, electronic, image, optical, processor

1. INTRODUCTION

Over the last years a significant progress was achieved in the development of special and general - purpose electronic multiprocessor computer systems[1-3]. Such systems are characterized by a high productivity (up to hundreds billions operations per second). Although they are complicated and consume a significant power that in some cases limits the employment sphere.

The significant results have been obtained in the construction of the optical and optical-electronic processors with acceptable weight - size characteristics and high through - put[4,5]. High productive processors, which implement different operations of preliminary image processing, image features extraction and invariant pattern recognition have been developed.

However the analysis shows that not all of the image processing operations can be implemented at present by the help of the optical processors. Besides, optical computers are characterized by the limited flexibility. Therefore the construction of high productive efficient computer systems for image processing is connected with the development of multiprocessor systems, which are based on the combination of optical and electronic structures, optimal distribution of the solving problem function among the processing devices of different type.

A number of questions, which are connected with investigation and development of the theory of image processing optical-electronic computer systems design are being presented in this paper.

In section 2 a model of parallel image processing system have been considered. In section 3 the generalized structure of parallel image processing computer system and the implementation possibilities of different image processing operations with the help of optical, electronic computer means are presented. In section 4 there have been made time expenditures in the system and the through-put at the processing of one and series of images. In section 5 there have been presented the method of image processing system design in static mode at different processing devices resources. In section 6 are presented the results of investigations of the influence of the median square deviation, the influence of time of the

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processing in the modules on the throughput capacity of the system under the different electronic and optical modules quantity. According to the results of investigations the recommendations of increasing the system's throughput capacity are formulated. On the bases to these recommendations, the system design method of image processing in the dynamic mode is elaborated. An example of image processing computer system design is presented in section 7.

2. MODEL OF PARALLEL IMAGE PROCESSING

Let the image processing problem is determined in the following way: $W\{P(x,y)\}\rightarrow RO$, where W - is the function of image processing; P(x,y) - initial image; RO - the processing result, which can be an image or numerical data.

The most of the image processing problems can be represented in the form of a linear sequence of separate sub problems. The decomposition principle utilization allows to organize parallel processing of two types: in time and in space. Parallel processing in time consists in organization of the sub problems conveyor, which are implemented consecutively.

The spatial concurrency means that on each step of the conveyor processing, the parallel processing of the whole image or its separate fragments is organized. The last type of concurrency is defined by the fact that we can point out some classes of operations while proceeding the image processing. They are executing at each of the image pixels, over separate regions of the image or over the whole image. In other words, to obtain the result we need local (as in the first two cases) or global (as in the last case) initial information. At the working with the local information, the image can be represented as a set of sub images, which are processed by the corresponding set of processor units. The spatial concurrency can be implemented by the help of processor units set of electronic or optical type.

Corresponding with the above-mentioned, the model of the parallel processing of the images can be represented in the following way:

$$RO = C_h\{\underset{i}{U}[\underset{j}{W}{}^{j}_{i}(P_{ij})]\},$$

where C_h - the superposition operation, i - the step number of the conveyor; U - the processing results union operation during one of the conveyor steps; j - the image fragment number; Wji- the operation of the processing of the j-th image fragment on i-th step; Pij- the j-th image fragment on i-th step.

This model can be also represented in the form of the operator:

$$P(x,y)\Rightarrow\{W1\}_{M1}\rightarrow\{W2\}_{M2}\rightarrow\ldots\rightarrow\{Wk\}_{Mk}\Rightarrow RO.$$

The peculiarity of the presented model consists in the maximum level of disparalleling of image processing operations that ensure the high productivity of the computer system, which implements this model. The productivity also depends on element base which is utilized. In connection to this fact let us look through the generalized structure of parallel image processing computer system and the implementation possibilities of different image processing operations applying optical and electronic computer means.

3. GENERALIZED STRUCTURE OF PARALLEL IMAGE PROCESSING COMPUTER SYSTEM

According to the proposed model, the generalized structure of parallel image processing computer system can be represented as shown in Fig.1, where Yi - is a device that implements the operation W_i, B_i - buffer device. The device Y_i may be optical or electronic. In the last case it can contain one or a group of processor elements that function in parallel way.

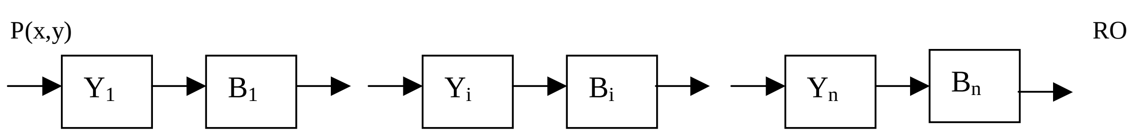

Fig.1. The structure of the image processing computer system

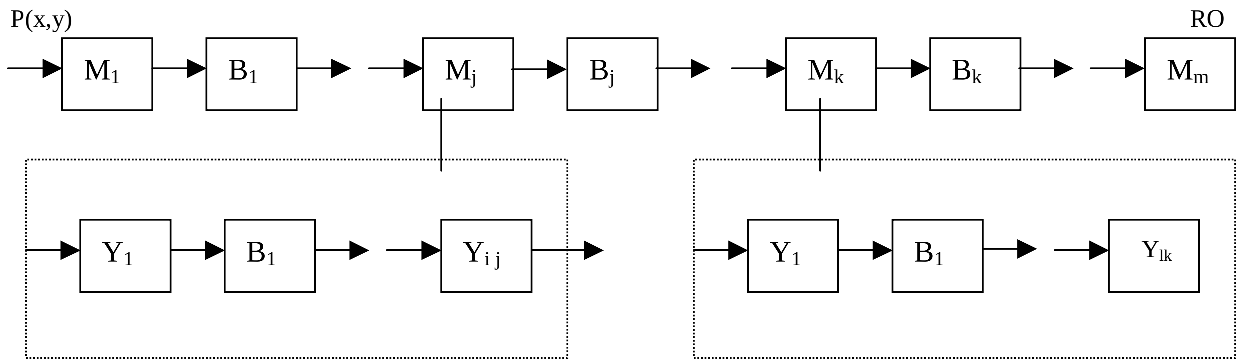

Fig.2. The module structure of the image processing computer system

The utilization of optical or electronic processing devices during different steps of the image processing conveyor system will be defined by some factors.

At first, from the way of initial image forming. The image can be formed by the help of electronic or optical means. The analysis of image forming units (IFU) characteristics showed that electronic and optical IFU provide the identical resolution ability. The difference between them is in implement forming speed. Optical IFU allow to form images 2-8 times faster.

The next factor is the implementation possibility of the operations by the help of the optical means. In the Table 1 the possibilities and the execution time of the image processing operations by the help of the different computer means are presented.

The analysis of the data, presented in the Table 1 shows that the time of optical implementation of some image processing operations is much less than one of their implementation by electronic means.

While using an optical processor it is expedient to give the full optical image to the input then on exit we shall have also a formed full optical image. In the case of implementation of an operation in an electronic processing device we can give the information about full image or about its fragment to the input, i.e. in the first case the information is put in/out in parallel way, optically, but in the second case it is done either in parallel way or consecutively in the form of electronic signals.

The structures of communication between two different steps are defined in the dependence on the processors types. Let us denote the buffer storage as $B_{m,n}$, where m,n are taking the values 1 or 2. Let us consider that number 1 corresponds to an electronic device, and number 2 - to an optical one. For example, the device $B_{1,2}$ is a buffer storage for connection of electronic and optical processors.

The time outlay during the signal buffering of different types is represented in Table 2.

The analysis of the possibilities of image processing operations implementation allowed to catch out the following:

1.The significant part of the wide used operations can be implemented optically.
2.The order of time outlay for optical implementation is 2-4 times smaller than for electronic one.
3. At present there exist some operations, which can’t be implemented optically.

Table 1

The possibilities and the time of the implementation of the image processing operations

Image processing operations	**Computing means**		
	Optical	**Optical-electronic**	**Electronic**
1. Image forming	10ms	30ms	20(40)ms
2. Noises removal	10µs		172ms
3. Edge detection	10µs		172ms
4. Object extraction	5ms		2.41sec
5. Image transformation from Cartesian system of coordinates into polar or logarithmic - polar one	10µs	+	20(40)ms
6. Image rotation and scaling with arbitrary parameters	-	0.13sec	12sec
7. Calculation of two-dimensional Fourier transformation	10µs	+	0.5sec - 4min
8. Calculation of two-dimensional correlation and convolution functions	10µs	+	1sec - 8min
9. Calculation of geometrical moment features	10µs	+	+
10.Calculation of central moment features	-	0.6ms	0.2sec
11.Calculation of invariant moment features	-	2.8ms	0.25sec
12. Chords transformation of the image	10µs	+	+
13. Image features processing and comparing with a standards	-	+	2.7sec
14.Correlation fields analysis, calculation of coordinates maxima	-	10ms	20(40)ms
15.Computing process control	-	+	+

Table 2

Time outlay during the signal buffering of different types, ms

Kind of the buffer	Image resolution, pixels	
	512x512	256x256
$B_{1,1}$	40	20
$B_{1,2}$	50	30
$B_{2,1}$	40	20
$B_{2,2}$	10	10

In accordance to the above it is expedient to construct parallel optical-electronic image processing computer systems.

4. THE THROUGH-PUT OF THE IMAGE PROCESSING COMPUTER SYSTEM

Let us evaluate the time outlay in the system while processing one and series of images. In the structure represented in Fig.1 we can join the consecutively situated optical devices into optical processing modules and electronic devices - into electronic processing modules (Fig.2). Let the system consists of n_o optical and n_e electronic modules ($n_o+n_e=m$), and each module contains accordingly l^o_j optical and l^e_q electronic processing devices. The whole number of optical l^o, electronic l^e devices and also the conveyor length l_k will be:

$$l^o=\sum_{j=1}^{n_o} l^o, \quad l^e=\sum_{q=1}^{n_e} l^e q, \quad l_k=l^o+l^e.$$

Let us consider the following time characteristics: t^o_{pj} - processing time in j-th optical module; t^e_{pq}- processing time in q-th electronic module; t^o_{kj} - switching time between devices in optical module; t^b_{oo} - buffering time of two neighbor optical processing devices; t^e_{kq}- switching time between devices in electronic module; t^b_{ee}- buffering time of two neighbor electronic processing devices; t^n_{kq}- switching time between the processors in electronic module devices; t^k_{oe} - time of buffering of optical modules with electronic ones; t^k_{eo} - time of buffering of electronic modules with optical ones. These parameters are estimated in the following way:

$$t^o_{pj}=\sum_{z=1}^{l^o_j} t^o_{pjz}, \quad t^e_{pq}=\sum_{f=1}^{l^e_q} t^e_{pqf}, \quad t^o_{kj}=(l^o_j-1)t^b_{oo}, \; t^e_{kq}=(l^e_q-1)t^b_{ee}$$

$$t^n_{kq}=\sum_{f=1}^{l^e_q} t^n_{kqf},$$

$$t^k_{oe}=\sum_{i=1}^{n} t^b_{oei}, \tag{1}$$

$$t^k_{oe}=\sum_{i=1}^{n-1} t^b_{eoi}. \tag{2}$$

The value of n in expressions (1), (2) is defined in the following way:

$$n=\begin{cases} m/2 & \text{if } n_o=n_e \\ n_e & \text{if } n_o>n_e \\ n_o & \text{if } n_o<n_e. \end{cases}$$

The time outlay in optical and electronic modules can be described as following:

$$t^o_j=t^o_{pj}+t^o_{kj}=\sum_{z=1}^{l^o_j} t^o_{pjz}+(l^o_j-1)t^b_{oo},$$

$$t^e_q=t^e_{pq}+t^e_{kq}+t^n_{kq} - \sum_{f=1}^{l^e_q} t^e_{pqf}+(l^e_q-1)t^b_{ee}+\sum_{f=1}^{l^e_q} t^n_{kqf}.$$

The time outlay in optical-electronic computer system while processing one image can be defined as:

$$T=\sum_{j=1}^{n_o} t^o_j+\sum_{q=1}^{n_e} t^e_q+t^k_{oe}+t^k_{eo} =$$

$$=\sum_{j=1}^{n_o}\sum_{z=1}^{l^o_j} t^o_{pjz}+\sum_{q=1}^{n_e}\sum_{f=1}^{l^e_q} t^e_{pqf}+\sum_{j=1}^{n_o}(l^o_j-1)t^b_{oo}+\sum_{q=1}^{n_e}\{\sum_{f=1}^{l^e_q} t^n_{kqf}+(l^e_q-1)t^b_{ee}\}+\sum_{i=1}^{n}\{t^b_{oei}+t^b_{eoi}\}. \tag{3}$$

The analysis shows that the time outlay for image processing consists of two components - direct processing time and switching time. Switching time is defined by the time of data transfer (or intermediate image time) between conveyor steps (devices buffering time) and the time of processors switching in electronic processing devices.

Let t_{pi} is the time of image processing on i-th step of the conveyor, t_{ki} is the switching time. The whole processing time on the i-th step of the conveyor will be:

$$t_i = t_{pi} + t'_{ki}, \text{ where } t'_{ki} = \max\{t_{ki-1}, t_{ki}\}.$$

The through-put of a conveyor while processing a series of images is defined as[1]:

$$PS = 1/\max_i\{t_i\} = 1/t'_i. \tag{4}$$

On the basis of expressions (3), (4) there has been obtained the time outlay of one image processing and the through-put of the system in the dependence on the conveyor length l_k, different relation between optical and electronic devices $k_{oe}=l^o/l_k$ and on the processing time in electronic processors according to the processing time in optical ones: $a_t=t^e_{pqf}/t^o_{pjz}$.

The analysis showed that the time outlay depends proportionally inverse on the parameter value k_{oe} while having different values of l_k. On decreasing the parameter a_t the maximum time outlay T is observed at $k_{oe}=0.5$ and $l_k<8$. The reason is that on decreasing the parameter a_t the time outlay begins to influence substantially on intermodular switching. This outlay is maximum at $k_{oe}=0.5$. Evaluation of the through-put of the system during the processing a series of images shows that on varying the value t'_i from 50 to 240ms the value PS is variable from 20 to 4 images per second.

It has been shown above that the time expenditures depends on the type of the processing device, i.e. it is much smaller in optical device. Moreover, the processing time t in the optical device does not depend on the input image, while the value of t in electronic device can be defined by a number of parameters, e.g. by the quantity of informative pixels, the image complexity. From this point of view for electronic units it is of reason to taking into account the median square deviation (MSO) value of the processing time.

Taking into account this suggestion were elaborated the new methods of design of the image processing computer systems for the next cases:

1.The value of MSO = 0 for all modules in system. This case correspond to optical system or optical electronic system, in which the processing time in the electronic modules do not depend from the input image.

2.The value of MSO $\neq 0$ for all electronic modules or part of them.

The first case correspond to the systems design in stationary mode and the next case - to the systems design in dynamic mode of image processing.

5. COMPUTER SYSTEMS DESIGN IN THE STATIONARY MODE OF IMAGE PROCESSING

Let us suppose that a large enough sequence of images will be processed, therefore the time of the first step of image loading can be neglected.

The suggested method consists of the following:

1. The image processing function W is represented as a set of operations $\{W_i\}$ in such a way that its further dividing is impossible or inexpedient. For example, such a function W_i can be indivisible, if its dividing does not lead to following decreasing of the processing time.

2. It is defined a set of operations $\{W_i\}_o$, which can be implemented with the help of optical means providing the maximum level of spatial concurrency, speed and compactness. Other functions are implemented with the help of electronic processors.

3. A corresponding switching network is forming. It consists of a buffer devices of optical, electronic types.

4. The implementation time t_{pi} of different operations W_i and the switching time t_{ki} are defined. Basing on the sets of the parameters $\{t_{pi}\}$, $\{t_{ki}\}$ a processing operation W'_i that requires the maximum time outlay is determined out:

$$t'_i = \max_i\{t_i\} = \max_i(t_{pi}+t'_{ki}).$$

5. In the case when the operation W'_i is implemented by electronic means the possibility of t'_i decreasing up to the level of other values from the set $\{t_i\}$ is examined. For this reason the possibility of introduction of spatial concurrency using a set of processor elements is being analyzed. The image is dividing into separate fragments and for processing of each of them one or several processor elements are being used.

If, however, the function W'_i is being implemented by optical means and there does not exist a possibility to decrease the parameter t'_i then it is expedient to make the justification of the parameters t_i of electronic modules till the level of t'_i by means of decreasing the number of the used processor elements or by their changing by some less rapid and therefore more inexpensive ones.

As a result we shall obtain a balanced set of the parameters $\{t_i\}$, which provides the maximum through-put of the computer system.

The described method of computer systems design assumes the absence of restrictions on the resources of processor elements in electronic modules. In the case when such limitations take place the design method will be a.f.

Let r_o from n functions, which are to be implemented, can be implemented optically and r_e=n-r_o functions are to be implemented by electronic means. Besides, let the resources of electronic processors are M_r and on each step of electronic processing there M_{ri} processors are used.

Having the restrictions on processor elements (PE) resources, the following variants are possible: $r_e>M_r$; $r_e=M_r$; $r_e<M_r$. In the first case, i.e. when $r_e>M_r$ several processing operations are uniting and their implementation on one processing device are possible. If a group of operations, which are to be realized, are situated consecutively, then such way of processing is not problematical. If, however such operations are not situated consecutively then the necessity of cycle organization in the conveyor is appears. This leads to increasing of switching time outlay.

In the second and the third cases one or several processing devices can be used for each operation.

6. COMPUTER SYSTEMS DESIGN IN THE DYNAMIC MODE OF IMAGE PROCESSING

The dynamic mode of image processing is different because the time of functioning of conveyor's electronic processors is not stationary for different images and can be presented as random variable. That's why the method of system design in the dynamic mode will differ from the method of system projecting in the stationary mode. Such differences are characterized by the influence of indicated random variable on the throughput capability of the system.

In this section are presented the results of investigations of the influence of the median square deviation (MSD), the influence of time of the processing in the modules on the throughput capacity of the system under the different electronic and optical modules quantity. According to the results of investigations the recommendations of increasing the system's throughput capacity are formulated. On the bases to these recommendations, the system design method of image processing in the dynamic mode is elaborated.

6.1. The investigation of computer systems characteristics

The examined in the section 4 structural model of computer system contains the set of processing devices (modules). Each module can be presented as a separate service unit device, because the results of image processing (or processed image) can be transmitted to the next module only after the ending of calculations in the previous.

As it was presented, the time of functioning of full or partial processing in electronic devices can be examined as random variable. That's why the suggested model of the processing system can be presented as the system of mass service (SMS), where the service devices (SD) are connected consequently.

Let's T_i – is the service time of i-th service device. As the distribution of random variable T_i can be characterized by the Gauss law, it makes difficult the receiving of analytical solutions. On the other hand, because of limited capacities of buffer devices, the blocations are possible, that makes unreal the independent analysis of the each of the modules.

The mentioned conditions show that SMS is worth analyzing by the method of imitating modulation. In the process of the system's simulation it was supposed that the distribution of information processing time in the electronic modules corresponds to the normal law.

The following parameters were changing in the process of simulation:
n_e, n_o – the number of electronic, optical processing modules;
SO_e – median square deviation of processing time in the electronic modules;
m_e, m_o – median processing times in the electronic, optical modules respectively;
the coefficient of variation w, $w = SO_e/m_e$.

The measured characteristics were: throughput capability of the system $PS=1/\max\{m'_i\}$, where m'_i – is the delay time in the device; the relative throughput capability $g=(PS/PS_H-1)$, where $PS_H=1/\max\{m_i\}$ - the nominal throughput capacity.

On the first stage the influence of the relation of module number of electronic n_e and optical n_o processing in conveyor of fixed length l_k on it's throughput capability it was investigated. The values $l_k=10$, n_e was changing from 2 to 10, $n_o = l_k- n_e$; $m_e = m_o-120$; SO_e was changing from 0 to 50.
The analysis shows that if SO_e increases to 10, the value g is changing slightly. At $SO_e >10$ the value g is lowering.

On the next stage there was investigated the influence of median processing time m_e in modules on the value g under the different parameters w, n_e. The value of parameter w was changing from 0,1 to 0,3, n_e - from 2 to 8.

The results of simulation show, that with the increasing of parameter m_e, w, n_e the throughput capability of the system is decreasing. At $w\geq0,2$ the value g is lowering sharply.

Also the influence of median processing time m_e in the electronic modules on the value g under the different values of the parameters w, n_e were investigated. The value m_e was changing simultaneously for all electronic modules in the limits from 100 to 160. The processing time in optical modules was $m_o = 120$. The results of simulation show, that at not high value of w ($w\leq0,1$) the parameter g slightly depends from m_e and n_e. At $w>0,1$ and low value of n_e ($n_e = 2$) the throughput capability is minimal if $m_e=m_o$. For $m_e\neq m_o$ the throughput capability is increasing. At more high values n_e ($n_e=6$) with the increasing m_e the throughput capability is lowering.

There was investigated the influence of the value of median processing time m_o in the optical modules on the throughput capability of the conveyor for different values SO_e at $m_e=120$. The analysis shows that with the increasing m_o the g is lowering.

The results of the computer simulation show the following.
1. With the increasing of number of electronic modules in the system and of median square deviation of processing time, the throughput capability of the system is lowering.
2. At the decreasing of the median processing time in the modules and relation SO to this parameter, the throughput capability of the system is increasing.
3. The decreasing of the median processing time in the electronic modules and of the relation SO to this parameter allows also to increase throughput capability of the system.
4. The decreasing of the median processing time in the optical modules and of the processing time in the electronic modules leads to the increasing of throughput capability of the system.

6.2. The design peculiarities of the systems in the dynamical mode

In the section 5 the method of design of the optical-electronic image processing systems for stationary mode was investigated, i.e. for case when time expenses in the module's system are unchangeable while processing different images. In a number of cases the input images can differ from each other by the complexity, quantity of informational elements and other parameters, that will lead to the change of time expenses in the electronic modules. That's why the method of systems design presented in section 5, must be modified according to the results of investigations with the scope of reaching the maximal throughput capability of systems.
The analysis show that the following techniques of increasing the throughput capability are possible.

1. The maximal substitution of the electronic processing modules by optical modules, in particular of the modules with the high mead square deviation (MSD) of processing time.
2. The simultaneous reduction of the processing time in electronic and optical modules on the bases of utilization of the new algorithms and elements.
3. The reduction of the processing in the electronic devices which characterized by the high ratio of the MSD to the processing time.
4. The reduction of processing time in the optical modules.

Let's examine the design consistence of the optical electronic systems at the lack and availability of limits on the apparatus-programming resources.

The systems design without limits on calculation resources

The method of optical-electronic systems design for dynamic mode of image processing is based on materials, presented in section 5. The difference lies in the position 5. On this stage the one or several approaches, mentioned above can be used. The choice and using of one of them depends on a number of factors and leads to increasing apparatus - programming expenses.

So, the using of the first approach can be limited by the possibility of realization of the processing operation by optical means. The most effective is the second approach, because it allows to reduce the time expenses on the image processing, to increase the throughput capability. But the time expense reduction in optical and electronic modules simultaneously doesn't exist always. In this case the third or fourth approach are used.

The systems design under the limits of calculation resources

While design such systems the following approaches are possible. As in previous section, the first way can be used, i.e. the change of electronic modules on the optical, took place. Besides, it is possible the increasing of the processing time in electronic modules with low value of w under the corresponding reduction of the processing time in the modules with high value of w. Such approach is connected with redistribution of calculation resources.
If electronic modules are characterizing by not high MSD of the processing time, the increasing of time expenses in the optical modules is possible.

7. AN EXAMPLE OF IMAGE PROCESSING COMPUTER SYSTEM DESIGN

Let us investigate the efficiency of the proposed theory on the example of the design of a computer system that implements the algorithm of objects recognition based on the invariant moment features.

The algorithm consists of the following.
1.The analyzing image is being formed.
2.The noises in the image are being removed using the median filtering method.
3.The identification object is being extracted by means of threshold limitation.
4.The moment features set is calculating.
5.The object is being identified by the comparison of the calculated features with standard ones.

In this way the image processing function W can be represented as a totality of five operations W_i, i=1…5. Each of them implements a separate step of the algorithm: $P(x,y) \rightarrow W_1 \rightarrow W_2 \rightarrow W_3 \rightarrow \quad \rightarrow W_4 \rightarrow W_5 \rightarrow RO$. The operations W_2, W_4 can be implemented by optical means, W_5- only by electronic means and W_1- by optical or electronic means.

The computer system structure can be represented as it is shown in Fig.3. In this system the operation W_1 is implemented with the help of image forming unit (IFU), the operations W_2, W_3, W_4 - with the help of optical processors P_1-P_3, and operation W_5 - by an electronic processor P_4. The type of the buffer storage B_1 will depend on the type of IFU. The buffer storages B_2, B_3 are optical, but B_4 is optical-electronic.

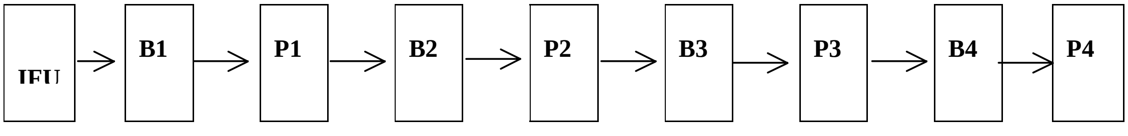

Fig.3. The Structure of an optical-electronic computer system

The implementation of this algorithm in an electronic computer system, consisting of 33 processors, linked by the hypercube topology has been investigated. The operations W_2, W_3 in such system are implemented with the help of a network of 28 processors.

The time outlay for operations implementation in the system are presented in Table 3. The analysis of data shows that the maximum time outlay in optical-electronic system is connected with the implementation of the operation W_5: $t' = t_8 + t_9 = 90$ms. The through-put of the system in this case is $P' = 1/t' = 11$ frames/sec. The maximum time outlay in a hyper cubic system is defined by the implementation of the operation W_3 and is equal to $t'' = t_2 + t_5 = 3.15$sec. That defines the through-put of the system $P'' = 1/t'' = 0.3$ frames/sec.

In such a manner the comparison of optical-electronic and hyper cubic computer systems shows that the through-put of the first of them is in 36 times higher. The total time outlay is 20 times lower.

Table 3

Time outlay in optical-electronic and hypercubic computer systems

Type of operation	Optical-electronic CS		Hypercubic CS	
	Number of processors	Processing time, ms	Number of processors	Processing time, sec
1. W^o_1		10.0		
W^e_1		40.0		1.1
2. Buffering		50.0		1.8
3. W_2	1	0.01		
4. Buffering		10.0		
5. W_3	1	0.01	28	2.07
6. Buffering		10.0		0.15
7. W_4	1	0.01	4	2.09
8. Buffering		40.0		0.2
9. W_5	1	50.0	1	0.05
The total number of processors	4		33	
Total time outlay		170.03 200.03		4.1

CONCLUSION

1. It is shown that one of the perspective ways in creating the highly productive computer means of image processing is elaboration of problem-oriented computer systems, based on combination of optical and electronic processing means. Such approach is caused that the part of operations of image processing can be realized optically with the speed, that in 3-4 levels is higher than corresponding electronic realization. At the same time there exist operations, that can be realized only with the help of electronic computer means.

2. The mathematical model of parallel image processing is suggested, that differs by the possibility of maximal parallel distribution of operations and will provide the high productiveness that realizes it's computer systems.

3. The analytical evaluation of time expenses in parallel optical-electronic image processing computer systems and the results of computer simulation, allowed to determine that while elaborating the systems of mentioned class, the length of the conveyor l_k is important, and also the relation of optical and electronic processor by the their quantity (k_{oe}) and the processing time (a_t). If $a_t > 10^4$, the increasing of throughput capability of the system is possible to achieve by choice of higher value k_{oe}. If $a_t < 10^4$, the choice of value k_{oe} it is of reason to be compared with the value of the parameter 1_k.

4. The investigation of influence of time processing characteristics in processor modules as the throughput value on the throughput capability PS system showed, that PS is increasing if the median processing time m_t in modules and the relations of median square deviation of the processing time to m_t is lowering and reduction of time processing in optical modules relatively to the time processing in electronic modules.

5. The results of the investigation of computer systems characteristics showed the following. If median square deviation of processing time SO_e in the electronic modules increases up to 10, the value of the relative throughput capability g is

changing slightly. At SO_e >10 the value g is lowering. With the increasing of the median processing time m_e in modules, the value w= SO_e/m_e and number of electronic n_e processing modules n_e in conveyor, the throughput capability of the system is decreasing. At $w \geq 0,2$ the value g is lowering sharply. At not high value of w ($w \leq 0,1$) the parameter g slightly depends from m_e and n_e. At w>0,1 and low value of n_e ($n_e = 2$) the throughput capability is minimal if $m_e=m_o$. For $m_e \neq m_o$ the throughput capability is increasing. At more high values n_e ($n_e=6$) with the increasing m_e the throughput capability is lowering.

6. The results of investigations of the influence of the median square deviation, the influence of time of the processing in the modules on the throughput capacity of the system under the different electronic and optical modules quantity permitted the elaboration of the recommendations of increasing the system's throughput capacity.

7. On the basis of the results of investigation, the methods of design the highly productive problem-oriented optical-electronic computer systems for image processing in the static and dynamic modes are elaborated.

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