Motion Detection Using 3D Image Histograms Sequences Analysis

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Abstract *- This paper presents an unconventional approach for motion detection using 3D image histogram sequence analysis. The idea of this approach is to remove the process of motion estimation into the field of 3D image histogram sequences by analysis of their statistical characteristics. A functional and statistical model of a system for motion detection has been created. This model includes procedures for image processing like: mode filtering for homogenizing the area of objects and its background, defining 3D image histogram sequences as well as procedures for defining statistical characteristics of the 3D image histograms sequences, choice and analysis of criterions for motion estimation. The experimental results prove that the relationship between statistical characteristics of the 3D image histograms sequences and process of motion estimation is a guarantee for creating a reliable and high precision motion detection system as well as for image compression using 3D entropy functions analysis. Such a system can be used for security control of banks, airports, military objects, embassies, shops etc.*

Keywords - Motion estimation, detection, modeling.

I. Introduction

Motion is the fundamental of life. No life if no motion. How can be the motion discovered?

Motion detection is a very difficult problem for solving. For human beings and animals it is not a problem and they discover very easy whether there is or not motion in an observed scene because of theirs natural possibilities to see in 3D and to analysis the environment using the potential of their brain. So, where the problem is? The problem is that we cannot create a system, which is similar to psycho physiological parameters of human beings vision.

What we can do is to shorten the distance between the possibilities of human beings and a technical system, which will be able to discover motion in a scene like human beings, approximately.

The purpose of this paper is to create functional and statistical models for motion detection using 3D image histogram sequences by analysis of their statistical characteristics.

The technical system is built using one or more conventional video cameras and one of them can be infrared, computer with a large memory and a high speed of data processing and specialized software. What we mean is to create functional and statistical model for motion detection, which is closer to mechanism of motion detection of human beings using an unconventional approach. Unconventional approach means that we really create a model for motion detection, which is similar to the mechanism of motion detection inherent human beings because we divide the process of motion detection on two parts. The functional model includes: appropriate preliminary procedures for image processing as well as a statistical model inside, which simulates the process of motion detection and estimation as human beings do it.

Some remarks for researches in the area of motion detection. For 2D motion there are three approaches: the Fourier method, matching and use of differentials. To solve the case of 3D motion can be extended the method of differentials. The matching approach can be extended for 3D case directly, but unfortunately the dimensionality becomes very large and the computational requirement impossible [1, 2, 3]. So, we need to develop a new model for processing on a higher level. This is what we propose. This paper is based on another paper [4] and it presents a new point of view for solving the problem of motion detection.

II. Functional and Statistical Model for Motion Detection

A. Functional model

The idea for creating a functional model of a system for motion detection is based on the assumption that all changes in an observed scene can be defined using image sequence analysis. Moreover, these changes can be estimated using 3D image histogram sequences analysis by defining their statistical characteristics. The relationship between image sequences and their statistical characteristics has to be established.

The means, which we will use for motion detection and estimation are: 2D black and white image sequences, 3D image histogram sequences and its statistical parameters and rules for decision whether there is or not motion in an observed scene.

The functional model for motion detection using 3D image histogram sequences is shown in Fig.1.

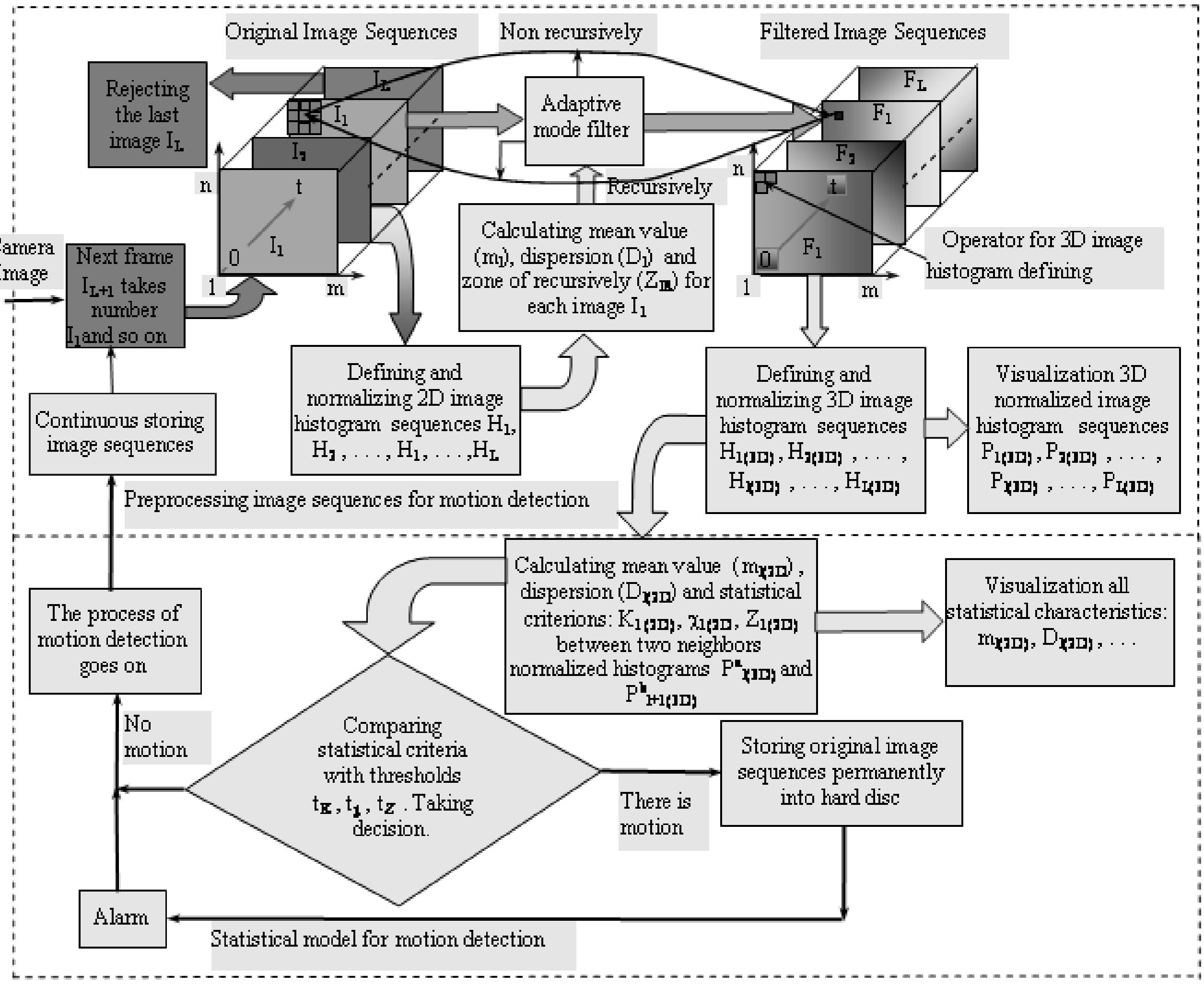

Fig.1. Functional model for motion detection using 3D image histograms sequences analysis.

The proposed functional model includes several procedures for preprocessing image sequences. All procedures are directed for creating appropriate conditions for solving this rather difficult problem namely discovering of motion using a visual technical system. We have to take account that if we want to say that our method for motion detection is reliable and precision we need to introduce some limitations. First of all we have to explain the meaning of the phrase “there is a moving object in an observed scene”. We should consider that “there is a moving object in an observed scene” when:

- there are a lot of changes in a large image sequences,
- the changes include a large number of image elements,
- there are not periodical changes in the images.

The process of motion detection includes the following procedures for image sequences preprocessing:

- creating a computer memory space for saving large image sequences,
- choice of an appropriate filter,
- defining and normalizing 2D image histogram sequences,
- calculating mean value, dispersion and zone of recursively,
- scanning each image with operator 3×3, 5×5 or else and controlling the type of the mode filter.

B. About mode filter and zone of recursively

Image filtering plays an important role in the process of the next image processing and analysis. The choice of the right image filtering is the key and guarantee for the next successful image processing and analysis. Why do we choose mode filtering?

We chose mode filter because it gives some advantages. Mode filter is a probable filter. The mode filtering goes deep the process of homogeneity of each image in result of that image histograms become more presentable for calculating and comparing of their statistical characteristics. The process of motion detection becomes easier because the distance between vectors of the statistical parameters of two neighborhoods histograms is increased. Introducing a zone of recursively in the process of filtering the homogeneity of the image becomes more and more. The mode filter can be switched as recursive or non-recursive, depending on the zone of recursively, which has been calculated from the global image histogram. The global image histogram expects to be clear and near to bimodal one.

All these prerequisites are a guaranty for increasing the reliability of the process of motion detection.

Mode filter works like other filters. For example median, Laplacian, Sobel ect. Every image has to be scanned from left to right and from top to bottom with an operator 3 × 3, 5 × 5 etc. and always has to be taken a decision for the image element which is central for the operator. In our case the mode filter functions following the next procedure:

- defining an normalizing the local image histogram of the operator in every position of its moving,
- defining the mode of the local image histogram and checking whether its value is inside in the zone of recursively;
- if it is not store the gray level value belonging to the mode directly in the same position of the central element of the operator but only into the filtered image corresponding to the original image which is processing at one and same time – non recursively mode filter,
- if it is yes store the gray level value belonging to the mode in the position of the central element in both original and filtered images – recursively mode filter.

The process of switching the type of the mode filter is shown in Fig.1, symbolically.

The procedure for defining the zone of recursively is following:

1. Let an image sequence be given as a set of images,

$$I = \{I_1, I_2, I_3, ..., I_l, ..., I_L\}, l = 1, 2, ..., L \qquad (1)$$

where each image I_l is presented as a matrix with (m x n) elements and k gray-level values for element.

2. Let each image sequences be presented as a set of its own gray-level 2D image histogram sequences,

$$H_{2D} = \{H_{1(2D)}, H_{2(2D)}, ..., H_{l(2D)}, ..., H_{L(2D)}\} \qquad (2)$$

and also let each image histogram be presented as a **k** - measured vector of its own samples,

$$P_{l(2D)} = \{p_{l0}, p_{l2}, ..., p_{lr}, ..., p_{lk}\} \qquad (3)$$

where $p_{lr} = N_{lr}/(m \times n)$ is the r^{-th} sample presented with its probability in the normalized histogram, and N_{lr} is the number of elements with r gray-level in non normalized histogram, r = 0, 1, . . . , k are gray-level values.

3. Defining the statistical characteristics of each 2D image histogram and the zone of recursively:

- statistical function of the probable distribution is as follows,

$$f_1(x) = \begin{cases} 0 \quad for \quad x < 0 \\ \sum_{r=0}^{k} p_{lr}, \ for, x \in [0, k] \\ 1 \quad for \quad x > k \end{cases} \qquad (4)$$

- statistical mean value,

$$m_l = \sum_{r=0}^{k} r p_{lr} \qquad (5)$$

- statistical variance,

$$D_l = \sum_{r=0}^{k} (r - m_l)^2 . p_{lr} \qquad (6)$$

- zone of recursively,

$$z_l = m_l \pm \frac{D_l}{2} \qquad (7)$$

C. 3D image histogram sequences defining

3D image histogram sequences can be defined using a procedure for scanning each filtered image from their sequences F_1, F_2 , . . . , F_l , . . . , F_L with an operator, which is shown in Fig1 (F_1). The procedure includes the following steps:

1. Creating a memory space into the computer for storing every time +1 for current combinations of the gray-level values in the horizontal (direction x) and vertical (direction y) pairs of the operator using them like an address, where has be stored the current value of the h_{lrr}^{-th} sample = h_{lrr} + 1 of the image histogram $H_{l(3D)}$ represented in 3D coordinate system ($H_{l(3D)}$, x, y), where h_{lrr} = = h_{lrr} + 1 , r = 0, 1, . . , k . The role of directions x and y is to be created one and same way for treating of gray-level pairs on the operator corresponding to both directions.

2. On the base of step 1 each current 3D image histogram $H_{l(3D)}$ can be presented as a matrix,

$$H_{l(3D)} = \begin{pmatrix} h_{l(0,0)}, h_{l(0,1)}, ..., h_{l(0,r)}, ... h_{l(0,k)} \\ h_{l(1,0)}, h_{l(1,1)}, ..., h_{l(1,r)}, ... h_{l(1,k)} \\ ... \\ h_{l(r,0)}, h_{l(r,1)}, ..., h_{l(r,r)}, ... h_{l(r,k)} \\ ... \\ h_{l(k,0)}, h_{l(k,1)} ..., h_{l(k,1)}, ... h_{l(k,k)} \end{pmatrix} . \qquad (8)$$

3. As a result of steps 1and 2 3D image histogramsequences can be presented as a set of matrix,

$$H_{(3D)} = \{H_{1(3D)}, H_{2(3D)}, ..., H_{l(3D)}, ..., H_{L(3D)}\} \quad (9)$$

as well as a set matrix on the normalized 3D image histogram sequences,

$$P_{(3D)} = \{P_{1(3D)}, P_{2(3D)}, ..., P_{l(3D)}, ..., P_{L(3D)}\}, \quad (10)$$

where $P_{l(3D)}$ is presented as kk - measured vector of its own samples,

$$P_{l(3D)} = \{p_{l(0,0)}, p_{l(0,1)}, ..., p_{l(0,k)}, p_{l(1,k)}, ... \\ ..., p_{l(r,r)}, ..., p_{l(r,k)}, p_{l(k,0)}, ..., p_{l(k,k)}\} \quad (11)$$

as well as $p_{l(rr)} = h_{l(rr)}/(m \times n)$ is the rr^{-th} sample presented with its probability in the normalized histogram, and $h_{l(rr)}$ is the number of elements with rr gray-level in non normalized histogram, r = 0, 1, . . . , k, r = 0, 1, . . . , k are gray-level values.

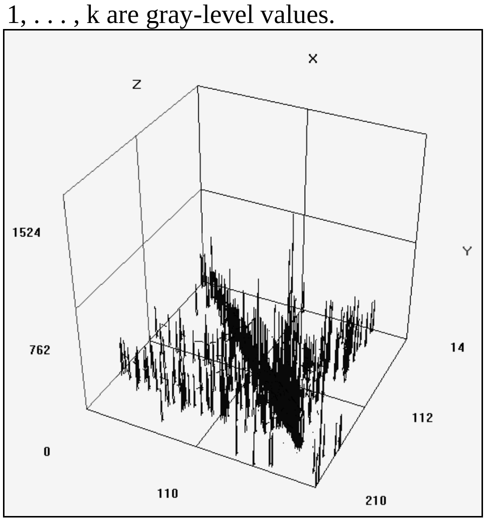

Fig.2. 3D normalized image histogram $P_{l(3D)}$.

3. Visualization 3D normalized image histograms sequences $P_{1(3D)}$, $P_{2(3D)}$, . . . , $P_{l(3D)}$, . . . , $P_{L(3D)}$.

D. Statistical model

The statistical model is the most important parts in our model for motion detection and estimation. It is so, because the right choice of statistical criterions predefines the reliability of the process of motion detection and estimation. Statistical characteristics, which we define using 3D image histogram sequences analysis can be considered as "brain" of the system for motion detection.

First of all we will define 2D statistical function of the probable distribution, 2D statistical mean value and 2D statistical variance by the following expressions:

1. Defining 2D statistical function of the probable distribution,

$$f_l(x,y) = \begin{cases} 0 & for \quad x,y < 0, \\ \sum_{r=0}^{k}\sum_{r=0}^{k} p_l r_x r_y & for \quad x,y \in [0,k], \\ 1 & for \quad x,y > k. \end{cases} \quad (12)$$

2. Defining 2D statistical mean value,

$$m_{l(2D)} \sum_{r=0}^{k}\sum_{r=0}^{k} (\sqrt{r_x^2 + r_y^2} . p_{l\, r_x r_y}) \quad (13)$$

3. Defining 2D statistical variance,

$$D_{l(2D)} = \sum_{r=0}^{k}\sum_{r=0}^{k} [\sqrt{r_x^2 + r_y^2} - m_{l(2D)}]^2 . p_{l(r_x, r_y)} \quad (14)$$

4. Defining the above statistical characteristics for all 3D normalized image histograms sequences.

- Kolmogorov' criterion,

$$K = \max_{x,y} f_a(x,y) - f_b(x,y) \quad (15)$$

where f_a(x, y) and f_b(x, y) are the functions of probable distribution $P^a_{l(3D)}$ and $P^b_{l+1(3D)}$ of two neighbour filtered images F^a_l and F^b_{l+1} , respectively; l = 1, 2, . . . , L .

- Pirson's criterion,

$$\chi^2 = (m \times n) . \sum_{r=0}^{k}\sum_{r=0}^{k} \frac{(Pb(r_x r_y) - Pa(r_x r_y))^2}{Pa(r_x r_y)} \quad (16)$$

where $p_{b(rr)}$ and $p_{a(rr)}$ are the values of the probabilities of rr^{-th} gray-levels of two neighbour filtered images F^b_{l+1} and F^a_l , respectively.

- Complex criterion (test of meaning),

$$Z = \frac{m_a - m_b}{\sqrt{(D_a + D_b)/(m \times n)}} \quad (17)$$

where $m_{l(2D)}$ and $m_{l(2D)}$ are the statistical mean values of two neighbour filtered images F^a_l and F^b_{l+1} , and $D^a_{l(2D)}$ and $D^b_{l(2D)}$, respectively.

Choosing the above criterion we guarantee the following advantages of our model for motion detection using 3D image histograms sequences analysis:

- these criterions are sufficient to discover the changes in image sequences,
- easy calculation and estimation of all criterions in real time,
- statistical criterions do the process of motion detection more invariant and reliable in comparison with traditional methods.

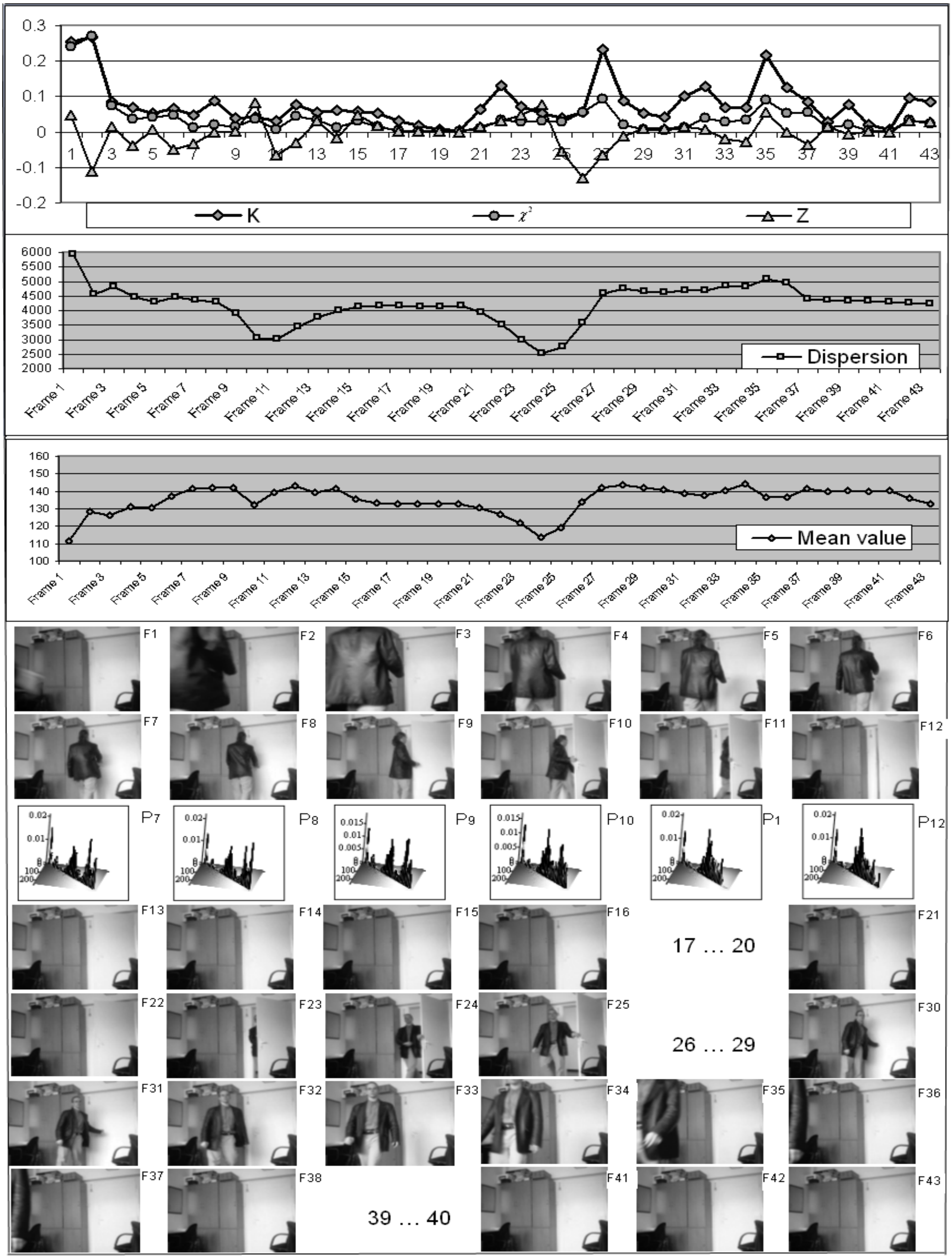

Fig.3. Experimental results showing calculations for 43 frames film recorded by digital camera (15 f/s 640x480).

D. Finalizing the process of motion detection

It is obvious that for motion detection we need to compare every one of the chosen criteria with certain thresholds.

So we have to introduce three different thresholds for each of the criterions.

Let these thresholds be t_K, t_{χ^2}, t_Z. Also we have to use some conditions for comparing the meaning of all criterions have been calculated with their own thresholds. We choose very simple logical rules to compare calculated values of all criterions have been chosen.

One of the problems to realize a reliable system for motion detection is how many criterions are sufficient to say that the system takes a right decision that there is or not a moving object in an observed scene. We propose if one of the criterions executes the logical rules R_K, R_{χ^2}, R_Z defined below then the decision is that there is moving object in the scene has been observed. The rules are defined as follows:

$$R_K = \begin{cases} 0, & if \quad K > t_K \\ 1, & if \quad K \le t_{K,} \end{cases} \tag{18}$$

$$R_{\chi^2} = \begin{cases} 0, & if \quad \chi^2 > t_{\chi^2} \\ 1, & if \quad \chi^2 \le t_{\chi^2,} \end{cases} \tag{19}$$

$$R_Z = \begin{cases} 0, & if \quad Z > t_Z \\ 1, & if \quad Z \le t_{Z,} \end{cases} \tag{20}$$

Final decision whether there is moving object or not is the following one:

$$R^* = R_K \wedge R_{\chi^2} \wedge R_Z = \begin{cases} 0, & \text{there is a moving object} \\ 1, & \text{there is no moving object} \end{cases} \tag{21}$$

The meanings of the thresholds are defined using tables of confidential probabilities. For example the confidential probability is chosen 0.95.

However we would like to do the process of motion detection more and more reliable and we plan to investigate our statistical model for motion detection in different conditions.

We bear in mind the following parameters of the observed scene: the contrast in the images, the light of scene, the number of image elements of the moving object etc. We will introduce a zone δ_C where thresholds can vary with $\pm\,\delta_{thresh.}/2$.

It will be our next research for which we need a financial support. It means that we will plan to create a learning procedure which we will adapt our system more and more and we will be able to give a guarantee that even “a bird can not pass without to be registered”.

We would like to acknowledge ourselves that creating a procedure for learning of any system for motion detection is more difficult problem than motion detection itself.

Otherwise said to increase the speed of the process of motion detection we plan to develop hardware solution for most procedures. Most of them can be solved in real time using modern DSP’s. Something more we will plan to extend the process of analysis using 3D entropy functions analysis will be developed to select and to follow moving objects in an observed scene. By this way we will create a diagram of the velocity of the moving object and we will compress image sequences for transmitting them by means of transmitting channels.

III. Conclusion

In conclusion we would like to summarize our research efforts for creating an unconventional approach for motion detection using 3D image histogram sequences analysis.

The experimental results shown in Fig.3 prove our conception that there is a strong relationship between statistical characteristics of 3D image histograms sequences and the process of motion detection for creating a reliable and high precision motion detection software system. The advantages of our system are: fast process of motion detection, elementary logical and arithmetic operations and high precision of motion detection.

References

[1] J. Aggarwal, “Special issue on Motion and Time Varying Imagery”, Computer Vision Graph. Image Process., Vol. 21, Jan./Feb.,1983.

[2] T. Huang, Image Sequence Analysis, Springer, Berlin, 1981.

[3] T. Huang, Sequence Processing and Dynamic Scene Analysis, NATO ASI Series, Springer, Berlin, 1983.

[4] P. Iliev and L. Tsekov, “Motion detection using image histogram sequence analysis”, Signal Processing, Vol. 30, Elsevier Science Publishers B.V., 1993, pp. 373-384.