THEORY AND METHODS OF SIGNAL PROCESSING

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ROBUST ALGORITHMS OF OBJECTS MOVEMENT DETECTION IN THE VIEWING FIELD OF THE LIGHTING CONTROL SYSTEM

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Abstrakt. *Distributions of signals probabilities of the movement detector have been investigated; statistical models of signals have been inobtained in situations when movement is present in a scanned area and when it is abcent. The nonparametrical rank algorithm of movement detection and robust algorithm have been synthesized and their working capacity is investigated.*

Keywords: rank algorithm, robust algorithm,statistical models, movement detector.

In the article [1] the movement detection system is considered, in which passive infrared movement detector is used. This sensor discovers the changes in the infrared radiation, which arise with movement of a human or an object, the temperature of which differs from environment temperature.

As this sensor detects the temperature difference, it can be used for the human motion detection (fig. 1).

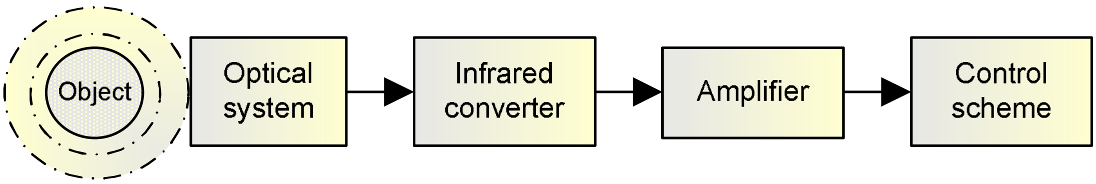

Fig. 1. The sensor block diagram

The discovered object is a body of a human. Dependently on the temperature difference of the background and of the discovered object, as well as the speed of object transference, these sensors are capable of discovering the objects motion on different distances. However, the sensors must be used in the bounds technical limitations.

The signal investigation of the different sensors of the same types showed, that the noises probabilities distribution can be approximated by Gauss law, and the signals distribution law from a motion object depends on the object size and on the signal / noise ratio [1]. With increasing this correlation the probabilities distribution law changes from Gauss law to exponential law with increasing parameter of the scale.

In the article [1] parametrical detection movement algorithm is synthesized, which computes statistics S and compares it with the assumed decision threshold V

$$S(\bar{X}) = \sum_{i=1}^{n} x_i^2 - 2(m_1 + \sigma^2\lambda)\sum_{i=1}^{n} x_i > V(m_1, \lambda, \sigma, n), \quad (1)$$

where $m_1, \sigma,^2 \lambda$ are parameters of the noise and the noise and signal compound distributions; $V(m_1, \lambda, \sigma, n)$ is the detection threshold, dependent on the noise parameters $m_1, \sigma,^2$ intensity of signal λ and the sampling size n; x_i , $i = 1,\ ...,\ n$ – are the sample values of the sensor signal.

The advantage of this algorithm lies in the fact that it accounts the shape of the distribution laws of the sensor signals with or without movement and by it presence. Under this the maximal efficiency is provided.

However, such detector demands the adjustment of the detection threshold for every sensor and for every separate setting. By this the constancy of the false alarm probability is not ensured at the situation, when the temperature mode or the background lighting are changed.

In fig. 2 the signals of two sensors of the same series in one labor are shown. The figure shows signal splashes, caused by the movement at the field control. The difference of the reaction of two sensors under the same conditions is obvious.

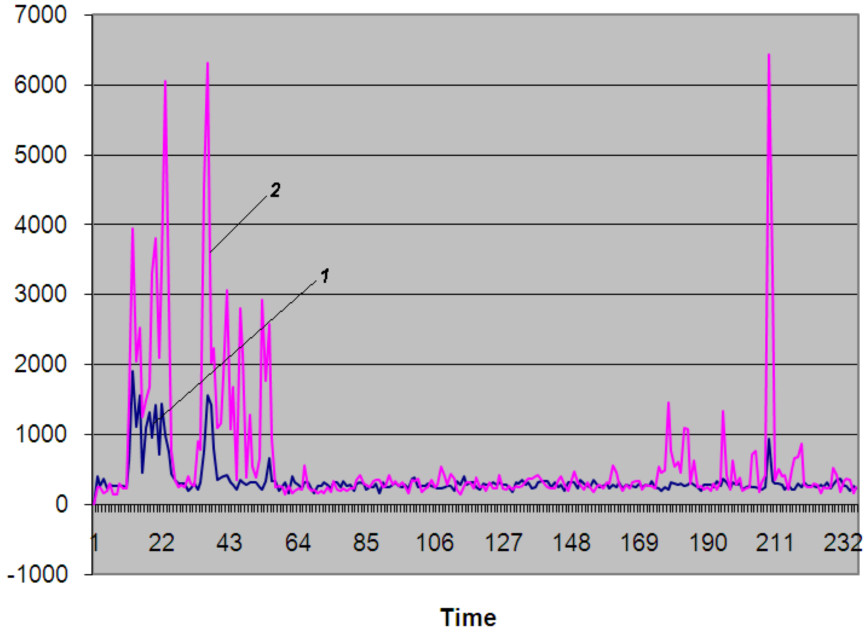

Fig. 2. There are the signals of two movement sensors: BN 5 and BN 110. Vertical axis is the voltage (Microvolt). Horizonnal axis is the time (Second). The implementations of 270 signal values at the output described sensors are shown. The section from 12 sec. to 57 sec. conforms to intensive movement in the sensor zone. The section from 60 sec. to 177 sec. conforms to absence of the movement. The weak movement was at the section from 180 sec. to 211 sec.: *1* – BN 5; *2* – BN 110.

The stabilization of the false alarm probability is the most important condition of the movement control system stability.

Robust and nonparametric decision rules are used for support of the stabilization of the false alarms probability [3].

Providing stabilization of the false alarm probability the algorithms use two samplings – the training sampling $y_1,...y_m$, which a priori does not contain the signal, caused by movement in the field of the view, and the sampling $x_1,...x_n$, concerning which the hypothesis about the presence of movement is tested. These samplings are formed at the separate windows, carried away in time or in space.

As robust, stable for the noise power change algorithm can be suggested, synthesized at the assumption about the exponential distribution law of the sensor signals

$$S = \frac{\sum_{i=1}^{n} x_i}{\sum_{i=1}^{m} y_i} > V, \qquad (2)$$

where V is threshold of decision making.

The probabilities distribution density of the statistics (2) does not depend on the distribution parameter scale in the situation, when a signal movement is absent, that allows us to stabilize false alarm probability condition of invariable shape of the noise distribution probability law.

As the nonlinear amplitude characteristic of sensor changes the noise distribution law by its variance change, the false alarm probability will be changed also. However these changes will be essentially smaller, than for parametrical algorithm (1).

The application of the rank algorithm is another approach to stabilization of the false alarm probability.

The rank algorithm computes statistics

$$S = \sum_{i=1}^{n} \varphi\left(\sum_{j=1}^{m} \text{sign}\,(x_i - y_j) \right), \tag{3}$$

Where $\text{sign}(z) = \begin{cases} 1, & z \geq 0; \\ 1, & z < 0; \end{cases}$ $\varphi(r)$ – is in general case nonlinear function of rank r.

The statistics of the algorithm (3) is free from distribution of the initial sampling values by absence of the movement signal. Its mathematical expectation and root mean square error when $\varphi(r) = r$ are determined as [2]

$$m_1\{S\} = \frac{mn}{2};\ \sigma\{S\} = \sqrt{\frac{mn(m+n+1)}{12}}. \tag{4}$$

In general case with nonlinear $\varphi(r)$ these parameters can be determined by statistical simulation method.

Using approximation of distribution law of the statistics criterions (1) – (3) by Gauss law with parameters $m_1\{S\}$, $\sigma\{S\}$, the decision making threshold about movement presence in the checked space with false alarm probability α is determined as

$$V = m_1\{S\} + \chi_{1-\alpha}\sigma\{S\}, \tag{5}$$

where $\chi_{1-\alpha}$ – is the ***quantile*** of normalized normal probabilities distribution of level $1-\alpha$.

The processing is realized at “sliding window” mode

$$\gamma_k = I[V - \sum_{i=k-30}^{k+30} \varphi(\sum_{j=k-30}^{k+30} I(x_i - y_j))]),\ k = \overline{30,225};$$

$$I[z] = \begin{cases} 1, & z > 0; \\ 0, & z \leq 0. \end{cases}$$

To build the detection algorithms characteristics the mathematical model of the signal/noise situation is developed. This model accounts the nonlinear nature of the sensor amplitude characteristic, which forms the normal random process by small signal/noise ratio, and by large signal/noise ratio it forms the output signal, which probabilities distribution is similar to the exponential with scale parameter

$$\frac{1}{\lambda} = \sigma^2{}_{s+n} = \sigma^2{}_n(1+b),$$

where b is the signal/noise ratio in power.

As nonlinear amplitude characteristic of amplifier $K(x)$ with such attributes the following function can be suggested

$$K(x) = x^{1+\frac{2x}{C+x}},$$

where the factor C determines the steepness of the characteristics.

The obtained detection characteristics of algorithms (1) – (3) are shown in fig. 3.

For analysis of the robustness of the false alarm probability to the changes of noise power at the sensor output stability of algorithms characteristics were built by Monte–Carlo method. This characteristics are shown in fig. 4.

From analysis of the curves (fig. 4) it is seen , that rank algorithm has the best stability of the false alarm probability. Robust algorithm conserves relatively small change of the false alarm probability from 0,005 to 0,08 by relative change of the noise power for 7 dB. Parametrical algorithm practically loses operating qualities under conditions of the change of the noise power.

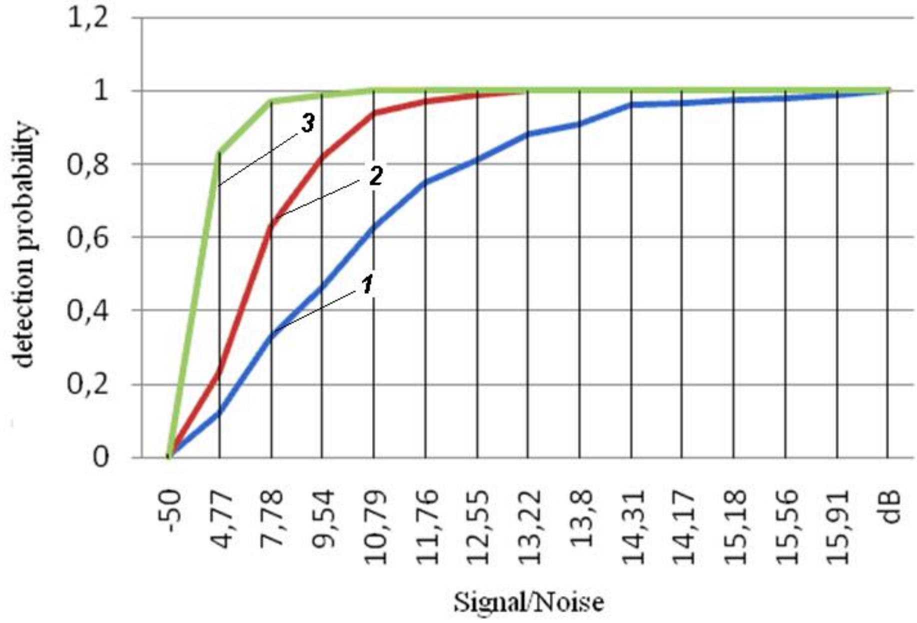

Fig. 3. The detection characteristics of three algorithms of sensors movement signals processing: *1* – rank algorithm $N = 30$, $M = 30$, $F = 0{,}005$; *2* – invariant algorithm $N = 30$, $M = 30$, $F = 0{,}005$; *3* – parametrical algorithm $N = 30$, $F = 0{,}005$

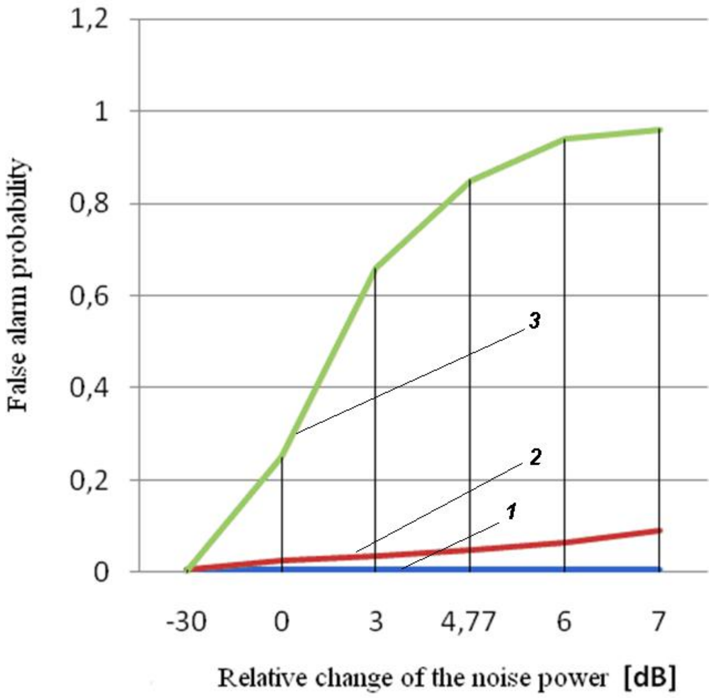

Fig. 4. The characteristics of dependence of the false alarm probability on relative change of the noise power: *1* – rank algorithm $N = 30$, $M = 30$, $F = 0{,}005$; *2* – robuts algorithm $N = 30$, $M = 30$; *3* – parametrical algorithm $N = 30$

Conclusions. The rank nonparametric algorithm (3) provides the stability of the false alarm probability and loses in efficiency to the parametrical algorithm (1) 7,8 dB by detection probability 0,9.

Robust algorithm (2) conserves relatively small change of the false alarm probability by change of the noise power, conserving high efficiency of the signal detection from moving object and losing to the parametrical detector 4,8 dB.

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Робастні алгоритми виявлення руху об'єктів у полі зору системи управління освітленням

Досліджено розподіли ймовірностей сигналів датчика руху, побудовано статистичну модель сигналів в ситуаціях, коли рух присутній в області сканування, і коли його немає. Синтезовано непараметричний ранговий алгоритм виявлення руху і робастний алгоритм, досліджено їх ефективність.

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Робастные алгоритмы обнаружения движения объектов в поле зрения системы управления освещением

Исследованы распределения вероятностей сигналов датчика движения, построена статистическую модель сигналов в ситуациях, когда движение присутствует в области сканирования, и когда его нет. Синтезированы непараметрический ранговый алгоритм обнаружения движения и робастный алгоритм, исследована их эффективность.