Methods of the Objects Identification and Recognition Research in the Networks with the IoT Concept Support

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Abstract

An emergence of intelligent devices, a large number of sensors, the issue of their identification and interaction becomes relevant in the era of information technologies development. A control object, a structural diagram of an identification system, an algorithm for the correlation method of identification have been considered in the article, and a general idea of managing the process of recognizing an information network object has been given.

Keywords

Identification, recognition, Internet of things, correlation method of identification, networks.

1. Introduction

One of the fundamental concepts in real life is the concept of identifiers, the variety of which is infinite, the scope of which is limitless [1].

The development of electronic communications is constantly increasing the threshold of permissible entropy in identification systems. Digital objects are becoming more complex, they have many previously missing functions and properties.

One and the same digital object can be described in different identification systems, but at the same time, the task is to reduce the description of these properties into a single base and manage these properties from the point of view of such a single base [2–4].

The growing number of telecommunications network facilities leads to problems in recognition and identification, management to ensure the quality of networks. This problem is one of the most important in wireless LANs operating in the unlicensed frequency band [5].

There is a need to study the methods of forming an object recognition system, to solve the problem of object selection and determine its type and functionality. The recognition system is a dynamic system consisting of technical means of obtaining and processing information for solving based on the algorithm of object recognition problems.

There is a need to analyze the possibilities of implementing intelligent recognition systems to optimize the identification process at the access level, without the involvement of central management and identification systems [6].

Cybersecurity Providing in Information and Telecommunication Systems, January 28, 2021, Kyiv, Ukraine
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2. Problem Identification

Consider a control object described by the equations

$$x = Ax + bu + \psi f; \tag{1}$$

$$y = dx + x, \tag{2}$$

where the matrix A and the n-dimensional vectors b, ψ, d' are unknown; $f(t)$ and $x(t)$ are the external disturbance and noise, which are immeasurable random functions with zero mathematical expectation.

Depending on the identification method, additional restrictions will be imposed on external disturbances and interferences (their white noise, limited dispersion, etc.).

Since the object (1), (2) is excited by a random external action, the estimate of the vector of its unknown parameters will be a random variable. This value should have the properties of unbiasedness, consistency, efficiency, and sufficiency.

The purpose of object identification (1), (2) is to determine estimates of its parameters that have the listed properties.

The essence of the correlation method. Consider an object described by the equations

$$x = Ax + \psi f; y = dx + x. \tag{3}$$

The solution of these equations for zero initial conditions has the form

$$x = Ax + \psi f; \tag{4}$$

where $h(t-\tau)$ is an impulse transient function, which is determined by the correlation method. Equation (4) can be written at $t_0 = -\infty$ as a convolution integral

$$y(t) = \int_0^\infty h(\theta) f(t-\theta) d\theta + x(t). \tag{5}$$

We multiply (5) by $f(t-\tau)$, then we obtain

$$z(t) = y(t) f(t-\tau) = \int_0^\infty h(\theta) f(t-\theta) f(t-\tau) d\theta + x(t) f(t-\tau).$$

Assuming further $M\{f(t)\} = M\{x(t)\} = 0$ and applying the mathematical expectation operation, we write

$$M\{y(t) f(t-\tau)\} = \int_0^\infty h(\theta) M\{f(t-\theta) f(t-\tau)\} d\theta + M\{x(t) f(t-\tau)\}. \tag{6}$$

If external influence $f(t)$ and hindrance $x(t)$ are independent, then $M\{x(t) f(t-\tau)\} = 0$. In addition, denoting the correlation function $M\{f(t-\theta) f(t-\tau)\} = r_{ff}(\tau-\theta)$, and the cross-correlation function $M\{y(t) f(t-\tau)\} = r_{fy}(\tau)$, we write (6) in the form of the Wiener-Hopf equation

$$r_{fy}(\tau) = \int_0^\infty h(\theta) r_{ff}(\tau-\theta) d\theta. \tag{7}$$

Let the input signal $f(t)$ is the white noise. It means that

$$r_{ff}(\tau) = r_{ff}^{(1)} \delta(t-\tau), \tag{8}$$

where r1ff is a known number characterizing the intensity of the "white noise."

Substituting (8) into (7), we obtain

$$r_{fy}(\tau) = r_{ff}^{(1)} h(\tau). \tag{9}$$

Thus, if the external influence is a random process of the white noise type, uncorrelated with the measurement noise, then the cross-correlation function of the input and output signals is directly proportional to the impulse transient function. The block diagram of the identification system is shown in **Ошибка! Источник ссылки не найден.**.

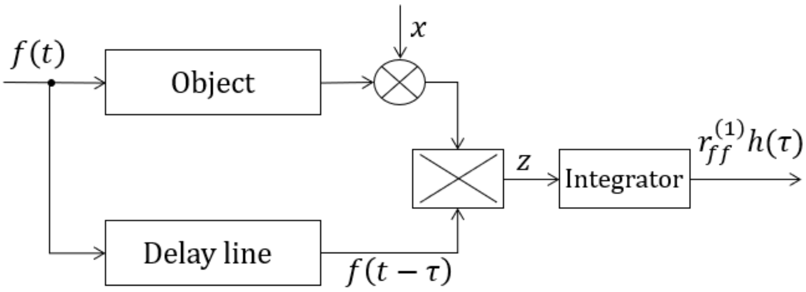

Figure 1: Block diagram of the identification system

Integrator serves to calculate the cross-correlation function, which, in the case of a stationary random process with the ergodic property, is defined as

$$r_{fy}(\tau) = \lim_{t_1 \to \infty} \frac{1}{t_1} \int_0^{t_1} f(t-\tau) y(t) dt. \tag{10}$$

Returning to the general case, we note that equation (7) is an integral equation for the unknown function $h(\theta)$. The numerical solution of this equation forms the basis of the correlation identification method.

3. Algorithm of the Correlation Identification Method

Passing to the solution of equation (7), we replace the upper limit in the integral by a finite number t_1. This means that the impulse transient function will be determined on the interval $[0, t_1]$, and for $t > t_1 h(t) = 0$. This assumption is quite acceptable for asymptotically stable objects. In addition, we will determine the value of the function $f(t)$ for discrete instants of time that differ from one another by the value T, therefore, we divide the interval $[0, t_1)$ into $N = t_1/T$ intervals.

Thus, we will assume that

$$\left.\begin{matrix} r_{ff}(t)=r_{ff}(iT) \\ h(t)=h(iT) \end{matrix}\right\} iT \le t \le (i+1)T \ \ (i = \overline{0,N}). \tag{11}$$

Then equation (7) takes the form

$$r_{fy}(iT) = T \sum_{l=0}^{N} r_{ff}[(i-l)T h(lT) \ \ (i = \overline{0,N}). \tag{12}$$

For $i = 0$, equation (12) is written as

$$r_{fy}(0) = \left[r_{ff}(0)h(0) + r_{ff}(-T)h(T) + \cdots + r_{ff}(-NT)h(NT)\right]T;$$

For $i = 1$

$$r_{fy}(T) = \left[r_{ff}(T)h(0) + r_{ff}(0)h(T) + \cdots + r_{ff}(-(N-1)T)h(NT)\right]T;$$

For $i = 2$

$$r_{fy}(2T) = \left[r_{ff}(2T)h(0) + r_{ff}(T)h(T) + \cdots + r_{ff}(-(N-2)T)h(NT)\right]T$$

etc.

Let us introduce vectors

$$r'_{fy} = \left\|r_{fy}(0) r_{fy}(T) \dots r_{fy}(NT)\right\|; \ h' = \|h(0), h(T) \dots h(NT)\|$$

and matrix

$$R = \begin{Vmatrix} r_{ff}(0) & r_{ff}(-T), \dots, r_{ff}(-NT) \\ r_{ff}(T) & r_{ff}(0), \dots, r_{ff}[-(N-1)T] \\ \vdots & \vdots \\ r_{ff}(NT) & r_{ff}[(N-1)T], \dots, r_{ff}(0) \end{Vmatrix}.$$

Note that the matrix R is symmetric, since the correlation function is even, therefore

$$r_{ff}(iT) = r_{ff}(-iT) \ (i = \overline{0, N}).$$

Taking into account the adopted designations, equation (12) takes the form

$$r_{fy} = TRh. \tag{13}$$

Whence the required vector is

$$h = R^{-1} r_{fy} T. \tag{14}$$

Let us now determine the vector r_{fy} and the matrix R from the experimental data. In this connection, we write on the basis of (10) an approximate expression

$$r_{fy}(iT) = \frac{1}{N}\sum_{s=0}^{N-1} y(sT) f[(s+i)T] \ \ (i = \overline{0, N}), \tag{15}$$

Similarly,

$$r_{ff}(iT) = \frac{1}{N}\sum_{s=0}^{N-1} f(sT) f[(s+i)T] \ \ (i = \overline{0, N}). \tag{16}$$

Thus, the algorithm for identifying the impulse transient function is reduced to calculating the correlation and cross-correlation functions by formulas (16), (15), and then solving equation (14).

4. General Idea of Recognition Process Control Algorithm

The considered concepts and definitions make it possible to construct an algorithm for the recognition process in the form of a rule of the sequential search for solutions, which ensures the development of an optimal plan for conducting experiments. The meaning of such an algorithm is that, based on the prehistory of experimentation, as well as on the basis of information obtained as a result of previous experiments, it determines the optimal plan for further experiments, all subsequent stages of experiments, i.e., determines at each step what next technical means should be used and what features of the object with the help of these means should be identified.

The general record of the algorithm providing sequential planning of experiments can be represented as

$$R = \{z_i^0;\ a_1, z_i^1(x_{a_1});\ a_2(x_{a_1}), z_i^2(x_{a_1}, x_{a_2}); \dots;\ a_k(x_{a_1}, \dots, x_{a_{k-1}}), z_i^k(x_{a_1}, \dots, x_{a_k}), \dots\}, \quad (7.10)$$

In the algorithm z_i^0 means that the final decision that an object belongs to the Ω_i class is made without experiments. In this case, all operations indicated in the algorithm $a_1, \dots, a_k;\ z_i^1, \dots, z_i^k$ are absent. If the algorithm z_i^0 is absent, then the first stage experiments are assigned a_1. If, on the basis of the characteristics of the object, determined from the information of the experiments of the first stage, a final decision is made about its belonging to any class $z_i^1(x_{a_1})$, then all operations indicated in the algorithm $a_2, \dots, a_k;\ z_i^0, z_i^2, \dots, z_i^k$ absent.

The presence of a member in the algorithm $a_k(x_{a_1}, \dots, x_{a_{k-1}})$ means that, based on the study of the features of the recognized object, obtained as a result outcome experiments $x_{a_1}, \dots, x_{a_{k-1}}$.

If the algorithm contains a term $z_i^k(x_{a_1}, \dots, x_{a_k})$, then this means that after receiving the outcomes $x_{a_1}, \dots, x_{a_k}$ experiments $a_1, \dots, a_k$, conducted according to the rule R, the final decision is made about the belonging of the recognized object to the Ω_i class and no further experiments are carried out. The procedure for planning experiments in accordance with the algorithm (17) is schematically shown in **Ошибка! Источник ссылки не найден.**.

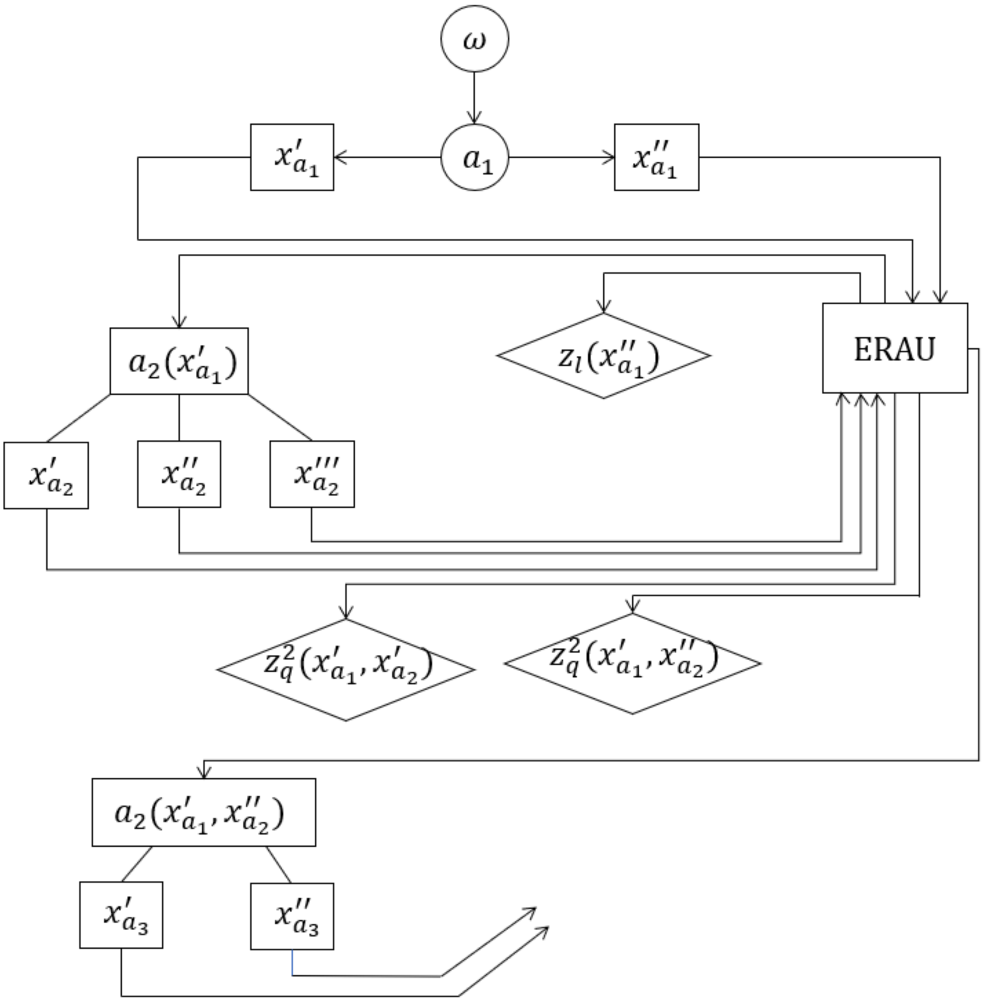

Figure 2: Procedure for planning experiments

It follows from the consideration of the scheme that the algorithm works as follows. Let the object ω enter the recognition system. It was found that making a final decision without conducting experiments z_i^0 inappropriate and to determine its sign it was decided to conduct the experiment a_1. Let us assume that the possible outcomes of the experiment are $a_1 - x'_{a_1}$ and x''_{a_1}. These outcomes are analyzed in the experimental results analysis unit, ERAU. Moreover, if the outcome of the experiment is $a_1 - x''_{a_1}$, then, for example, the final decision $z_l^1\left(x''_{a_1}\right)$ is made, and if the outcome of the experiment is x'_{a_1}, then the decision is made to conduct a new experiment $a_2(x'_{a_1})$,. Let, its possible outcomes x'_{a_2}, x''_{a_2} and x'''_{a_2}. Then their analysis can lead, for example, to such decisions: if the outcomes of the experiment $a_2(x'_{a_1})$ will be x'_{a_2} or x'''_{a_2}, then the final decisions should be made $z_g^2(x'_{a_1}, x'_{a_2})$ or $z_g^2\left(x'_{a_1}, x''_{a_2}\right), l, q, g = 1, \dots, m,$ and if the outcome is x''_{a_2}, then it is necessary to conduct an experiment $a_3(x'_{a_1}, x''_{a_2})$. Outcomes of this experiment x'_{a_3} and x''_{a_3} are analyzed again, and a plan for the further development of experiments is developed.

The algorithm works like a feedback system. Indeed, every time. the experimental results are used to adjust the plan for subsequent experiments.

5. References

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