Detection of affectings on fensing surfaces in systems of protection and life-support of buildings

L I Suchkova1, A G Yakunin2
1Professor, Altai State Technical University named after I.I.Polzunov, Barnaul, Russia
2Head of chair, Altai State Technical University named after I.I.Polzunov, Barnaul, Russia
E-mail: lara8370@yandex.ru

Abstract. Typical features of oscillograms of signals from the piezoelectric transducer are installed at supernumerary affectings on barring surface. Possibility of use for identification of affectings of patterns of behaviour of group of the time rows realising the hybrid approach to the analysis of signals is shown.

1. Introduction
By consideration of functional features of a wide spectrum of security systems for buildings and premises it is possible to note, that early identification of attempts of penetration through the guarded perimeter is a perspective direction of perfection of their software and hardware. For small guarded objects access inside usually is carried out through doors [1, 2].

For anticipation of attempt of penetration through the protected perimeter of object probably to supervise following actions of the malefactor:
- approach to object on distance, smaller the admissible;
- destruction of obstacles;
- attempt of not authorised opening door and window locking mechanisms.

The most vulnerable link of protection after window apertures is the door cloth, locking which mechanisms probably to destroy or open a skeleton key. Therefore for increase of efficiency of hardware-software security systems are actual perfection existing and working out of new algorithms for analysis of the measuring information from gauges and the devices supervising influence on a door cloth. Existing vibrating and capacitor devices do not provide identification of blows, drilling process of locking mechanisms, process of unlocking of the lock by a skeleton key [3–5].

The purpose of researches is studying of features of the signals registered by piezoelectric transducers at oscillations of a door leaf in cases of regular and supernumerary opening of locking mechanisms, and development of algorithms for identification of a condition of controllable object.

2. Theoretical and experimental research methods
Theoretical and experimental methods were applied to research of oscillations of a door leaf. Revealing of a range of an oscillation frequency was carried out by mathematical modeling, namely the equation of oscillations of a plate of the set sizes dared [6]. Modeling was carried out with application of package MathCad.

Results of modeling of oscillations of a surface of a door leaf at an impulse excitation have allowed to establish numerical dependence of an oscillation frequency on density of a material of a door, thickness \( h \), a Poisson's ratio and rigidity \( E \) (Figure 1).
It is established, that at various constructive parameters of a door leaf for identification of type of external affecting it is necessary to analyse area of the low frequencies which are not exceeding 15 kHz. Most considerably the door oscillation frequency is influenced by sizes of a linen and the characteristic of the material used at its manufacturing.

For natural experiment the arrangement which circuit design is shown in Figure 2 and containing, besides actually door leaf and piezoelectric transducers, amplifiers formed on their outputs signals, the personal computer with sound card Creative SB-128 was used [7]. All software for conducting of experimental researches has been realised with application of a package for engineering mathematical calculations MathCAD.

Experimental arrangement carries out removal of a signal from the piezoelectric transducer fixed on the fencing surface. Its lateral oscillations change a potential difference between the metal basis of the piezoelectric transducer and a segnetoelectric plate with a dusting from the metal, playing a role of electrodes. The potential difference depends on affecting on controllable object. The signal from the piezoelectric transducer after passage through the broadband preamplifier arrives on an entry of analogue-digitizer sound card which forms the numeric code arriving in the computer for the further complex analysis of behaviour of a signal during the chosen time gap for the purpose of identification of type of affecting [6].

By the spent researches it is established, that the oscillogram of a signal and its amplitude responses are essentially discriminated depending on a way of affecting on fencing surface: opening
by a key, knock, blows, drilling locking mechanisms and skeleton key application. Experiment data are resulted in Table 1 [6, 8].

| Type of affecting | The maximum width of a spectrum signal, Hz | The most expressed frequency components of a signal (in decreasing order of intensity), Hz |
|------------------|------------------------------------------|--------------------------------------------------------------------------------------------------|
| Blow             | 0…2500                                   | 300…900 1300…1900 1300…2000 600…700 1300…1900 500…700 1500…1800 |
| The instrumental affecting | 600…6000 | 500…5300 600…700 1500…1900 500…700 1500…1800 1300 |
| Free moving of a key | 500…3000 | 1300 |
| Movement of lever mechanizm | 500…6000 | 500…5600 1300…2000 2300…2700 500…700 3000…3500 5500…6000 |
| Opening by a key | 0…11500 | |

The analysis of data of Table 1 confirms results of the mathematical modeling testifying to sufficiency of processing of a signal only in the field of low frequencies of a signal for identification of attempt of supernumerary baring of a door [6].

3. Results

At regular opening of the lock fixed on a door leaf, the signal oscillogram is characterised by specific parameters to which it is possible to refer to duration of observation of signals with certain amplitude, sequence of an interleaving of intervals of the frequencies, caused by consecutive change of a position of components of the locking mechanism. In Figure 3 the oscillogram of a signal from the piezoelectric transducer at opening the lever locking mechanism by a key in a regular regime is shown. The time gap 1 matches to a key insert in a locking mechanism larva, time gaps 2 and 6 match to free moving of a key. On a time gap 3 locking mechanisms fixing a collar beam are freed, and on a period 4 the signal matching to moving of a collar beam at change of a position of a key is observed, on a gap 5 installation of lock mechanisms in the fixed position is carried out. All periods, except first, match to one turn of a key in the locking mechanism, and repeat at more quantity of turns.

![Figure 3. The signal oscillogram at opening the lever locking mechanism in a regular regime.](image-url)
For locks with the cylinder mechanism on the oscillogram absence of sections of a free moving is observed at a locking mechanism rendering the conducting in a regular regime as collar beam moving do not occur. At conducting of a series of experiments for locking mechanisms of various designs of different producers delimitation of the time gaps matching to the above-stated stages of a rendering the conducting of lock mechanisms is executed.

In Figure 4 the order of occurrence of the characteristic frequency emissions appearing in a spectrum of a signal at opening of the locking mechanism in a regular regime is shown.

![Figure 4](image)

**Figure 4.** The signal oscillogram at locking lever mechanism opening in a regular regime.

When locking mechanism drilling the signal from the piezoelectric transducer is influenced by a rotational speed installed in the drilling apparatus. The amplitude of a signal registered by experimental arrangement belongs to an interval from 150 to 250 mV. By the spent researches it is established, that such affectings on barring surface as knock and blows, lead to fixing same on behaviour of a signal of oscillograms, difference consists only in crest values. At knock of value of amplitude make 20…100 mV, and at value blow lay over the range 250…300 mV. Duration of a gap 1 makes in both cases from 20 ms to 200 ms, finishes a gap a section of attenuation of a signal [2]. At supernumerary opening the locking mechanism on the oscillogram it is possible to observe sections, characteristic for a gap 4 (Figure 5).

![Figure 5](image)

**Figure 5.** The signal oscillogram at supernumerary opening of the locking mechanism.
By the spent researches it is installed, that for classification of type of affecting on fencing surface the complex analysis of value of amplitude of a signal from the primary measuring converter and time intervals on which characteristic emissions of amplitude of a signal are observed is required [9,10]. So, at a regular rendering the conducting of the locking mechanism on the oscillogram some series of peak emissions with the value exceeding 100 mV are fixed, and duration of each series does not exceed 3 seconds. At trying of supernumerary opening by a skeleton key duration of excess by a signal of level 100 mV makes 3 seconds and more.

For identification of concrete type of affecting on fencing surface was possibly application of various methods of the intellectual data analysis, for example, a method of basic vectors, method of main components, neural networks added with methods spectral or cepstral analysis, including with application wavelet transformations [11–17]. In the given work for these purposes it is offered to use the hybrid approach merging fuzzy-temporal and linguistic methods of the analysis [18–21]. The analysis of the time rows which readout are values of amplitudes of a signal from the piezoelectric primary measuring converter, was carried out on the basis of a matrix predicting pattern of behaviour which is presented by a set [21]:

\[ P = \langle \text{Before}, F\text{Before}, D\text{Before}, \text{After}, F\text{After}, D\text{After}, D\text{Pattern}, R \rangle. \]

Let's observe appointment of each component of a matrix pattern of behaviour. The pattern basis is made by a matrix – template \( \text{Before} \), consisting of numbers and-or terms of linguistic variables, a lines of a matrix are compared with time processes observed during some interval. Matrix-template columns match to time countdowns, last column is formed for current moment of a time. Matrix \( \text{Before} \) is necessary for comparison with really observed on the controllable object values of time rows which can be preliminary processed by means of functions from assemblage \( F\text{Before} \), forming auxiliary matrix \( B' \). Matrix \( \text{After} \) is called as predicting, it contains numbers and-or the terms of the linguistic variables matching to processes on controllable object during the moments of a time, following a present situation. As elements of matrix \( \text{After} \) can be formed by the additional analysis of values of observable time rows depending on various conditions the matrix pattern includes functions \( F\text{After} \) used for additional transformations of sample predicted values.

\( D\text{Before} \) and \( D\text{After} \) represent descriptors of matrixes \( \text{Before} \) and \( \text{After} \), presenting ways of transformation of elements of these matrixes by means of a set of functions of a pattern. \( D\text{Pattern} \) represents a vector containing the general properties of a matrix pattern. Each pattern has label \( R \), comparing to a pattern some condition of controllable object [6, 20].

So, with reference to guarding systems discriminate, first, a regular condition when on barring construction there are no affectings, or these affectings represent noise, handicapes, procedural affectings for the purpose of regular penetration on guarded object, by, for example, a rendering the conducting of the locking mechanism and door leaf opening; and, secondly, the supernumerary condition called by disturbing mechanical affecting.

It is established, that for identification of the audible signal simple and fixed in a time the method of identification of supernumerary situations on the basis of behaviour patterns causes smaller quantity of errors in comparison, for example, with a differential method. If the signal structure is difficult, and contains the elementary fragments which sequence for the same type of behaviour of system can vary, is expedient apply to identification of an aspect of affecting the gibrid linguistic approach combining flexibility with simplicity and a high speed of identification [21].

It provides processing of values of linguistic variables. For system of identification of affectings on fensing surfaces the linguistic variables characterising duration, amplitude, a rate of speed of change of fast-head and back leading edges with reference to frequency channels have been chosen. For linguistic variables forms matching to features and other parametres of fragments of a signal terms were set. So, for the description of amplitude bending around a signal from the piezoelectric transducer the variable with five terms – “to 20”, “from 20 to 100”, “from 100 to 150”, “from 150 to 250”, “more 250” was used, fitting functions had the trapezoid form. The general number of the variables analysed
by algorithms of identification with realisation of operations over fuzzy data, made 20, for four variables the information from five channels (3 frequency and 2 peak) undertook.

As a result of experiments it is established, that probabilities of delivery by security system of false alarms, the dropping of the purpose and an identification error at use of gibrid linguistic patterns of the analysis temporal regularity have made accordingly 0.7 %, 0.7 %, 1.0 %, that essentially exceeds analogous parameters of other approaches to implementation of algorithmic maintenance of devices of protection. Such devices were possibly to use as a part of adaptive subsystems of protection as they have a small number of a false wears.

4. Conclusions
The advantage of using patterns to analyze the behavior of a time series is the independence of algorithms for testing the applicability of the left part of the pattern from the pattern itself. It is possible to add new patterns without adjusting the software of the computing device that performs identification of regular and abnormal situations.

In the integrated control system for the life support of a building, in the event of an abnormal situation, it is possible to generate control actions for other subsystems. In the integrated control system for the life support of a building, in the event of an abnormal situation, it is possible to generate control actions for other subsystems. For example, we can send a signal to the lighting control subsystem to turn on the illumination of the entrance door.

Acknowledgement
Authors express profound gratitude to a management of Altay State Technical University named by I.I. Polzunov (AltSTU) for financial support of the publication of article, firm «Promautomatica» for the technical help in preparation of article and graduate AltSTU Chumakov I.A. for the help at experiment carrying out.

References
[1] Fundamentals of Information System Security. Access Control Systems [Electronic resource] URL: https://en.wikibooks.org/wiki/Fundamentals_of_Information_Systems_Security/Access_Control_Systems
[2] Doors Hinges and Security [Electronic resource] URL: https://www.statefarm.com/simple-insights/residence/3-safer-door-hinges-to-make-your-home-more-secure
[3] Scripnik D 2016 The general questions of technical protection of the information (Moscow: INTUIT)
[4] Avtsinov V 2000 Working out and research of devices of the control of the security alarm system on the basis of the capacitor converter with a branching of currents in a measuring chain [Electronic resource] URL: http://www.dissercat.com/content/razrabotka-i-issledovanie-priborov-kontrolya-okhrannoi-signalizatsii-na-osnove-emkostnogo-pr#ixzz4uzvR3rAm (in Russian)
[5] Yakunin A, Avtsinov V, Chernov K 2000 Measurement, control, automation-2000: Proceedings of the International Scientific Conference 172–173 (in Russian)
[6] Suchkova L, Chumakov I, Yakunin A 2013 Identification of affectings in devices of protection of anticipatory type (Deutschland, Saarbrücken, Palmarium Academic Publishing)
[7] Gibson S 2001 The Illustrated Dictionary of Electronics (USA,McGraw-Hill Publications)
[8] Yakunin A, Chumakov I 2003 61th AltSTU scientific conference: Proceedings of the Conference. Part II. 26–27 (in Russian)
[9] Chen J, Benesty J, Huang Y 2006 EURASIP J. Appl. Signal Processing 2006 26503 doi: 10.1155/ASP/2006/26503
[10] Knapp C, Carter G C 1976 IEEE Transactions on Acoustic, Speech, and Signal Processing 24 320–327 doi: 10.1109/TASSP.1976.1162830
[11] Nwankwo P N, Nsionu I I, Ezeilo C J 2013 Journal of Automation and Control Engineering 1 65–69
[12] Ogri U J, Bassey D E 2013 *International Journal of Engineering and Computer Science* 2 2235–2257
[13] Chung E, Saltzman A Smart locks could make your home less secure [Electronic resource] URL: http://www.cbc.ca/news/technology/smart-locks-could-make-your-home-less-secure-1.3057872
[14] Bamisaye A J, Samuel A 2016 *J Electr Electron Syst* 5 167 doi:10.4172/2332-0796.1000167
[15] Sarp B, Karalar T, Kusetogullari H 2015 *International Journal of Scientific Research in Information Systems and Engineering* (IUSRISE) 1
[16] Song K-T, Chen J-L 2003 *IEEE International Symposium. Computational Intelligence in Robotics and Automation* Istanbul TURKEY 3 1445–1450 doi: 10.1109/CIRA.2003.1222210
[17] Freund Y, Schapire R E 1997 *Journal of Computer and System Sciences* 55 119–139
[18] Kovalev S M 2007 *Proceedings of the IV International Scientific Conference* Moscow 354 (in Russian)
[19] Batyrshin I, Kacprzyk J, Sheremetov L et al 2007 *Series: Studies in Computational Intelligence* 36
[20] Suchkova L, Abdenov A 2013 *Scientific Herald of Novosibirsk State Technical University* 3 78–83 (in Russian)
[21] Suchkova L 2014 *Polzunov Herald* 45–51 (in Russian)