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Vytautas Gargasas

CLASSIFICATION OF SIGNALS OF RAILWAY RAIL DIAGNOSTICS

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Scientific supervisor:
Prof. Dr. Habil. Vytautas Algimantas Buinevičius (Kaunas University of Technology, Technological Sciences, Electronics and Electrical Engineering – 01T).

Council of Electronics and Electrical Engineering trend:
Prof. Dr. Habil. Danielius Eidukas (Kaunas University of Technology, Technological Sciences, Electronics and Electrical Engineering – 01T) – **chairman**,
Prof. Dr. Habil. Pranciškus Balaišis (Kaunas University of Technology, Technological Sciences, Electronics and Electrical Engineering – 01T),
Assoc. Prof. Dr. Gintautas Daunys, (Šiauliai University, Technological Sciences, Electronics and Electrical Engineering – 01T),
Prof. Dr. Jonas Daunoras (Kaunas University of Technology, Technological Sciences, Electronics and Electrical Engineering – 01T),
Prof. Dr. Habil. Algimantas Juozas Poška (Vilnius Gediminas Technical University, Technological Sciences, Electronics and Electrical Engineering – 01T).

Official opponents:
Prof. Dr. Habil. Vilius Antanas Geleževičius (Kaunas University of Technology, Technological Sciences, Electronics and Electrical Engineering – 01T),
Prof. Dr. Habil. Ignas Skučas (Vytautas Magnus University, Technological Sciences, Informatics Engineering – 07T).

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Address: K. Donelaičio g. 73, LT-44029 Kaunas, Lithuania.
Tel.: (370) 7 300 042, fax: (370) 7 324 144, e-mail: mok.grupe@adm.ktu.lt.

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Vytautas Gargasas

GELEŽINKELIO BĖGIŲ DIAGNOSTIKOS SIGNALŲ KLASIFIKAVIMAS

Disertacija rengta 2000 – 2004 metais Kauno technologijos universitete

Mokslinis vadovas:
prof. habil. dr. Vytautas Algimantas BUINEVIČIUS (Kauno technologijos universitetas, technologijos mokslai, elektros ir elektronikos inžinerija – 01T).

Elektros ir elektronikos inžinerijos mokslo krypties taryba:
prof. habil. dr. Danielius Eidukas (Kauno technologijos universitetas, technologijos mokslai, elektros ir elektronikos inžinerija – 01T) – **pirmininkas**,
prof. habil. dr. Pranciškus Balaišis (Kauno technologijos universitetas, technologijos mokslai, elektros ir elektronikos inžinerija – 01T)**,**
doc. dr. Gintautas Daunys (Šiaulių universitetas, technologijos mokslai, elektros ir elektronikos inžinerija – 01T),
prof. dr. Jonas Daunoras (Kauno technologijos universitetas, technologijos mokslai, elektros ir elektronikos inžinerija – 01T)**,**
prof. habil. dr. Algimantas Juozas Poška (Vilniaus Gedimino technikos universitetas, technologijos mokslai, elektros ir elektronikos inžinerija – 01T)**.**

Oficialieji oponentai:

prof. habil. dr. Vilius Antanas Geleževičius (Kauno technologijos universitetas, technologijos mokslai, elektros ir elektronikos inžinerija – 01T)**,**
prof. habil. dr. Ignas Skučas (Vytauto Didžiojo universitetas, technologijos mokslai, informatikos inžinerija – 07T).

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Adresas: K. Donelaičio g. 73, LT-44029 Kaunas, Lietuva.
Tel.: (8-37) 300042, faksas: (8-37) 324 144, el. paštas: mok.grupe@adm.ktu.lt

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Introduction

The principal of works means and reception of the solution, used for the investigation of rails flaw do not change. Even the newest microprocessor systems of rails' flaw detection which is found in the latest year uses the simplest criteria's, that are the amplitude of the reflected ultrasound signal and delaying time.

While computer and microprocessor technology improves, the means of numerical measurement and possibilities of processing data, that is signals capable to measure the large majority of the more difficult structure and the algorithm or functions, are found out.

The widest classification of the objects is used for identifications' solution based on separating random processes. The acoustic diagnostic of engines and mechanics, sound and ultrasound defectoscopy, and objects' identification in accordance with spread signals' of noise that are in the random background and etc. are named in all those areas where the method of random processes' classification is suitable.

Specific features of the railroad rails' ultrasound inspection

Rails are the main element railroad. During the exploitation experience a huge impact of power. Those various flaws appear inside them. That could damage the safety of the trains' traffic. The reasons of defects appearing in rails are:

- defects of manufactured technologies, welding,
- supervisions of road are defects ,
- insufficiency of contactable steadfastness,
- violations of rails because of going trains' activity.

One of most reliable sources for inspection of rail condition is the ultrasound defectoscopies. Based of them all possible 98 – 99% flaws are found out.


Figure 1. Formation of signal in rail-head whit longitudinal and transverse flaws
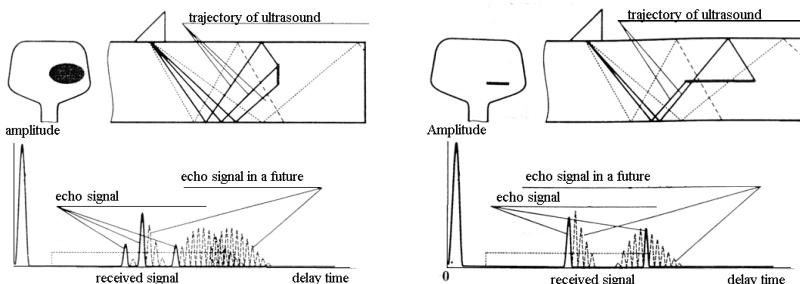
Formation of signals. Process of echo signals' formation reflecting from transverse end longitudinal flaws is very complicated. Keeping in mind, that the

main reflection of ultrasound quavers happens because of transverse flaws' sides. It is possible to get the features of characteristics signals close to real ones.

Forming echo signals that have been reflected from longitudinal flaws it is considered that ultrasound quavers are reflected for the ends of the flaws (the closer, in the case of PE transformer and less far end).

Concluding the analysis of defectoscopy of rails' and methods ultrasound sources of could be necessary to acknowledge that used system is sufficiently well analyzed and enough various analysis methods are created based on ultrasound assistance in order to find all possible rails' flaws.

Despite that defects are possible to find:
1. a big probability of terminate measurements error,
2. the influence of subjectivity evaluating objects' to a person-operator,
3. a big duration of results' processing,
4. high requirements to operator's qualification.

Those defects are possible to remove using classification method of random processes.

Classification of random processes

In order to avoid already mentioned defects of used rail diagnostic's system it is needed to try the classification model of random processes which gives the opportunity to use given qualities using informatics' systems and calculation technology. In this way it is possible to automate diagnostic's process and increase efficiency of this process avoiding made classification defects by operator. There is no unified system of indications in classification theory. Often it depends on possessed probabilities of measurements' results and experience of the investigation. In principal to get the best system of indications it is possible by drawing up different systems of indications and classification roads into rows according to received classification results and priori knowledge. After that datum, which characterize the objects, are collected and formed *n*-dimensional vectors $\vec{X}$ of measured indications. It is necessary to define which classes of the objects of those indications depend on. It is possible to look into classification task like into *m* resolution classes, separating criterions' areas of the limits' creations.

Using Bajas's formula

$$p(v_i / \vec{X}) = \frac{p(\vec{X} / v_i)p(v_i)}{p(\vec{X})}, \qquad (1)$$

where $p(\vec{X}/v_i)$ - probability function of class v_i.

Euclid classification. Solution's function based on distance's metric,

$$d_i(\vec{X}) = (\vec{X} - \overline{X}^{(i)})^T (\vec{X} - \overline{X}^{(i)}) = \sum_{j=1}^{n} (x_j - \overline{X}_j^{(i)})^2 \cdot \qquad (2)$$

Fisher classification. If we suppose that distribution of random process in classes conforms to the distribution of Gauss law has the same covariance matrix and differs only by medium meanings then solution's function will look in this way:

$$d_i(\vec{X}) = (\vec{X} - \overline{X}^{(i)})^T K^{-1}(\vec{X} - \overline{X}^{(i)}), \tag{3}$$

where $\overline{X}^{(i)}$ – average meaning of $\vec{X}$ parameters v_i.

In order to evaluate the distance among classes it is recommended to use also those distances:

Kolmogorov distance

$$d_k(v_i, v_j) = \int \left| p(v_i)p(\vec{x}/v_i) - p(v_j)p(\vec{x}/v_j) \right| dx, \tag{4}$$

Chernov distance

$$d_{CH}(v_i, v_j) = -\ln \int p^S(\vec{x}/v_i)p^{1-S}(\vec{x}/v_j)dx, \tag{5}$$

Matsiusita distance

$$d_{MC}(v_i, v_j) = \{\int \left[\sqrt{p(\vec{x}/v_i)} - \sqrt{p(\vec{x}/v_j)}\right]^2 dx\}^{\frac{1}{2}}. \tag{6}$$

Patrice and Fisher distance

$$d_P(v_i, v_j) = \{\int \left[p(v_i)p(\vec{x}/v_i) - p(v_j)p(\vec{x}/v_j)\right]^2 dx\}^{\frac{1}{2}}, \tag{7}$$

Lisak and Fu distance,

$$d_L(v_i, v_j) = \int \left| p(v_i/\vec{x}) - p(v_j/\vec{x}) \right|^2 dx. \tag{8}$$

Mentioned distances gain the maximum meaning to informative indications. The several separating functions, used to classify random processes exist. In creating new classification systems, the question is in which way to select one of them that could be optimal to the specific and optimal classification task. To give one answer is hard because there is no one more acceptable comparison and their possible evaluation criterions.

Stochastic method of rail diagnostic

While technical resources of processing and installation of data improves, new probabilities of analysis' system are discovered. Even though used methods of diagnostic's signals investigation are enough reliable, its speed will increase when system is automated. Diagnostic system can be analyzed as random process, which has many characteristics.

Creating automate object's condition investigation system, the notice can be mode that signals reflects that could have a various origin. Very often objects themselves generate those signals but sometimes they are increased by special optical, electrical, mechanical, magnetically or ultrasound stimulus.

We can characterize generally offered diagnostics systems' situation is way the experimenter has analyze objects $o \in O$ condition which is not known in advance. The goal of analysis' experiment is to get the information about objects.
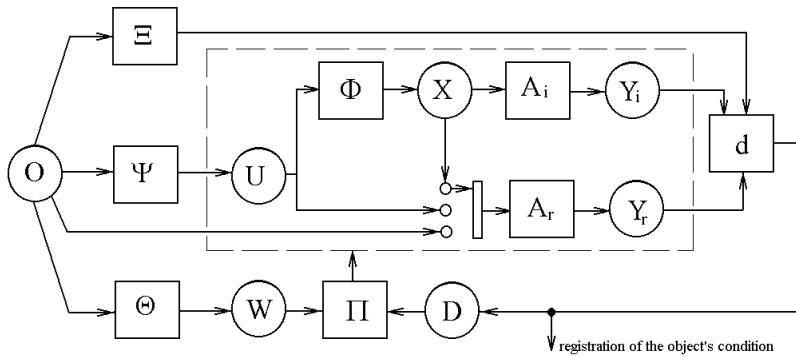

Figure 2. The system registration and the observation of the objects' condition

This information is lying in y_r meanings, which in general don't agree with real meaning y_r of objects' characteristics. The model of this situation is shown by dotted line.

However, exploring classification goal and using those classification rules the rate setting goal remains not solved. When amplification coefficients of investigation signal changes, classifications distance d changes as well. For that reason, classificatory could carry out wrong resolution, reckoning signal in a different class. In case of railroad rail analysis the signal reflecting objects' condition is not stationary and amplification coefficient changes because of often changing parameters of acoustic contact between analyzing surface of rail-head and accepting sensor. While transformer moves along the surface if railhead, the acoustic contact, can change because of several reasons. The main ones are pollution of railhead top-surface, roughness, and derangement of rending contractual liquid.

Also, using the Bajas's formula, which gives the least probability of mistake, exist as standard according to that other classification algorithms test the probability characteristics of classified signals' parameters are to be evaluated. In this case the measurements are the complicated procedure and it takes a lot of times. When possible distribution laws are counted, the power of the investigated signal may be changed. This change can give additional errors to classification result, obviously decreases reliability of classification and damage whole diagnostics. For that reason, one of the work goals is to find the ways, which would abolish sensitivity of classification results into change of the amplification's

coefficient or searching power. We abolish mentioned defects using the so-called covariance metric.

Suppose, we have several realizations of accidental processes $x_1(t)$, $x_2(t)$, ..., $x_n(t)$, which are in defined area C, when $t \in [t, t+T]$, here T the observation interval (the realization length) and F transformation (operator) exists:

$$\begin{cases} g_1(z) = Fx_1(t), \text{kai } z \in [0, b], \\ g_2(z) = Fx_2(t), \text{kai } z \in [0, b], \\ \text{…………………………………} \\ g_n(z) = Fx_n(t), \text{kai } z \in [0, b]. \end{cases} \tag{9}$$

Signal characteristics $g_n(z)$ are in defined areas C . Proposition is valid. If $x_1(t)=x_2(t)$, then $g_1(z)=g_2(z)$,

then, bringing a new variable quantity $v[0,b]$, a metric space is determinate as covariance metric which can be used for classification. The characteristics of covariance metric are those:

$$\begin{cases} d(g_1, g_2, v) = d(g_2, g_1, v), \\ 0 < d(g_1, g_2, v) < 1, \\ d(g_1, g_2, v) = 0, \text{ jei } g_1(z) = kg_2(z), \\ d(g_1, g_3, v) < d(g_1, g_2, v) + d(g_2, g_3, v). \end{cases} \tag{10}$$

Two kinds of covariance metrics $d_1(g_1, g_2, v)$ and $d_2(g_1, g_2, v)$ are defined. Covariance functions of signal, which characteristics $g_1(z)$ and $g_2(z) \in C$ and $v \in [0, b]$:

$$\begin{cases} R_{12}(v) = \dfrac{1}{b} \int\limits_0^b g_1(z) g_2(z-v) dz, \\[2mm] R_{21}(v) = \dfrac{1}{b} \int\limits_0^b g_2(z) g_1(z-v) dz, \\[2mm] R_{11}(v) = \dfrac{1}{b} \int\limits_0^b g_1(z) g_1(z-v) dz, \\[2mm] R_{22}(v) = \dfrac{1}{b} \int\limits_0^b g_2(z) g_2(z-v) d, \\[2mm] R_{12}(v) \le R_{11}(0) \cdot R_{22}(0). \end{cases} \tag{11}$$

Covariance functions are very simple to rate and to get rate set covariance functions:

$$\rho_{12}(v) = \frac{R_{12}(v)}{\sqrt{R_{11}(0) \cdot R_{22}(0)}}, \tag{12}$$

$$\rho_{11}(v) = \frac{R_{11}(v)}{R_{11}(0)}. \tag{13}$$

Rate set covariance functions have the conditions $-1 < \rho_{12} < 1$ and $-1 < \rho_{11} < 1$. Identity functions can be used to compare (separate) characteristics $g_1(z)$ ir $g_2(z)$.

$$a_{12}(v) = 0.5[\rho_{12}(v) - \rho_{21}(v)], \tag{14}$$
$$b_{12}(v) = \rho_{11}(v) - \rho_{22}(v). \tag{15}$$

$a_{12}(v)$ used when $\rho_{12}(v)$ and $\rho_{21}(v)$ uneven functions, but $b_{12}(v)$ when even. Then covariance metric is defined like distances:

$$\begin{cases} d_1(g_1, g_2, v) = |a_{12}(v)|, \\ d_2(g_1, g_2, v) = |b_{12}(v)|. \end{cases} \tag{16}$$

Modeling of mathematics classification algorithms

Even though we have suggested methodic, we can use a lot of ways to adapt it dependently on which mathematical processing of signal algorithm we will carry out before counting identity function of covariance metric. Besides, we identity function can not be classification distance which simply is described with one vector but not function. Thus for classification to use covariance metric it's important to evaluate characteristics of identity function and to select the proper classification algorithm. Because autocorrelation function is symmetrical, for the sake of the elaboration it's shown only one it's side or only the most informative part is shown. Even though theoretically the symmetrical axis of covariance function would have to begin from zero, Mat Lab software shows it in the middle of the massive. Here instead of zero another number corresponding to half of the massive is put a side.

a) Covariance metric, using autocorrelation function of signal itself.

$$K_{ii}(v) = \frac{1}{b} \int_0^b g_i(z) g_i(z - v) dz. \tag{17}$$

Received identity functions (figure 3) have many similarities which real signals and their classification can slightly differ from real signals classification. Because

of the normative actions identity functions doesn't change when the power of searching signal changes and noise appear (everything is checked while modeling).
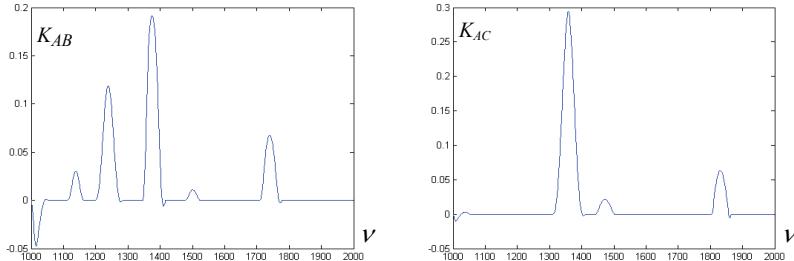

a) Identity function of class B   b) Identity function of class C
Figure 3. Identity functions using autocorrelation function

b) Covariance metric, using fast Fure transformation function of signals (spectral density). Already choosed classification algorithm to various diagnostic systems it was noticed that signal spectral density often is more cautious then signal itself ant it's easier to select the set of informative characteristics. Even more, the chosen principle of covariance metrics is to classify characteristics not depending on time

$$S_f(f) = \int_0^T g(t)e^{-j2\pi ft}\,dt \tag{18}$$
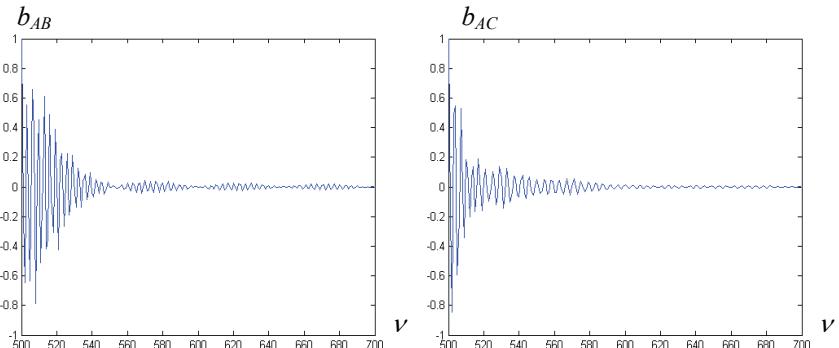
a) Identity function of class B   b) Identity function of class C
Figure 4. Identity functions using the module of signal spectral density

Received identity functions (figure 4) among themselves have similarities but separating those parameters is very distinct. If created goals of diagnostic system design signal one of three classes, then those identity functions will be enough.

Investigating the part of informative signals without sent impulse and used mentioned way of covariance metric, we get those identity functions.

Because difference exist between classes B and C which are reflected by identity functions, we can tell that after the signal changes are done, the way remained proper to classification and covariance metric is sensitive to the change of investigated signal form. However, while it is adjusted to the specific classification goals, informative indications of classifications are to be selected.

If it would be enough to make investigated frequency range shorter, processing of signal will be quicker and would require less computer's resources.

a) class A   b) class B   c) class C
Figure 5 The spectral densities of various classes's signals
(x axle 500 correspond to 5 MHz).
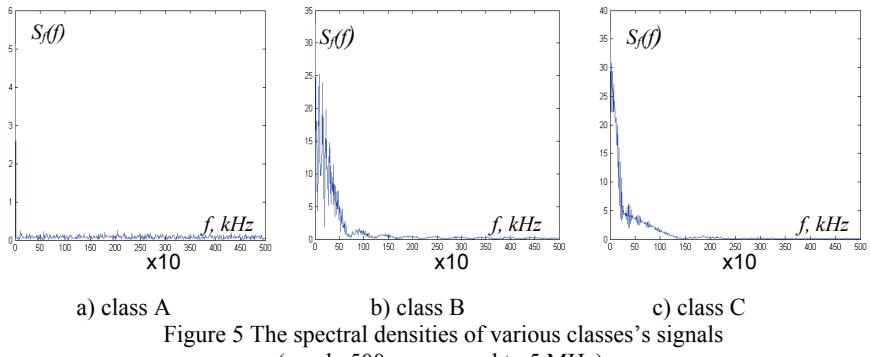
It would be important also to select several frequency ranges of densities in which we would investigate separately spectral density part. Because the highest density f_i is in real signal 2,5 MHz, then it is not worthy to investigate the higher density part, but from figure 5 it's obvious that spectral density part, which is above 2,5 MHz limits, is closed to zero.
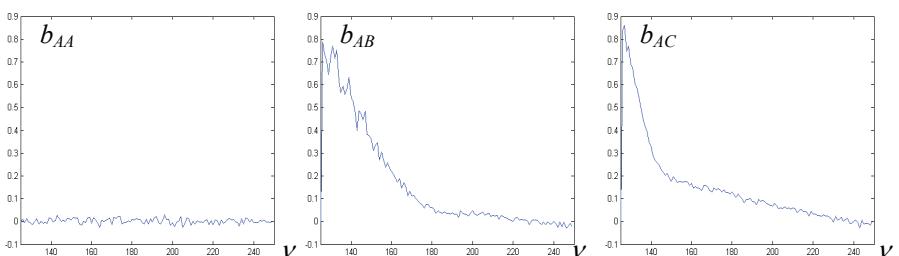
a) class A   b) class B   c) class C
Figure 6. Identity functions received using the low frequency range (0-1,25) MHz

Because of that signal would be analyzed whose frequency range is (0-1,25) MHz. If we want to understand which part of frequencies (high frequencies or low frequencies), we divide investigated frequencies range into two exact parts:

1. (0-1,25) MHz - low frequencies,
2. (1,25-2,5) MHz - high frequencies.

Let compare identity functions received while searching separated frequency's signals. From the figure 6 it can be seen low frequency's signal covariance metric gives identity functions that among themselves differ their form and classified characters are easily found.

a) class A   b) class B   c) class C
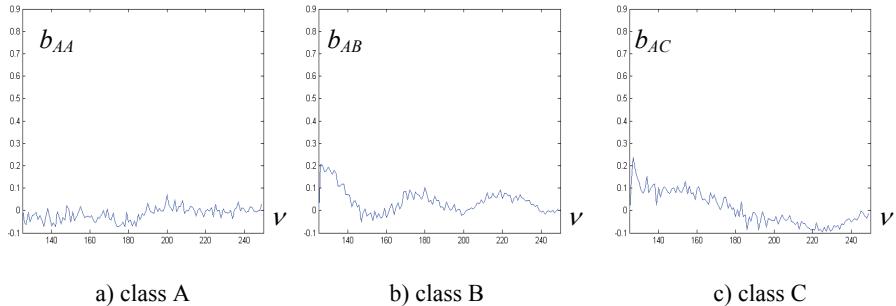
Figure 7. Identity functions of the different signal classes received using the high densities' signal's frequency range (1,25-2,5) MHz

From figure 7 it is seen that using high frequencies identity are very uneven. Even though identity functions have differences and they have big unevenness, it would be complicated to evaluate their indications. However, the most important is that class A - "Rail is not damaged" and signal identity function of damaged classes are not different mostly from one another. During mathematical modeling it became obvious those identity functions sensitively reacts into notice, which is inside of signal. Signal of white noise and small amplitude practically speaking alters from form of identity function. For that reason, we can clearly state that the high frequency range (1,25-2,5) MHz of signal doesn't reflect the rail's condition and it's not recommended to use in diagnostic system.

Still it remains not searched that all frequency range (0-1,25) MHz is necessary to be found out indications of rail defects. We will calculate identity functions when we analyze the segment of frequency range (0,62-1,25) kHz.

Here (figure 8) differences of identity functions appear as separately characteristics of the different object's condition. However continuity of identity function changes in signal even though identity signal's fragments form remains. We can conform that studied diagnostic's system would work but its reliability would be low.
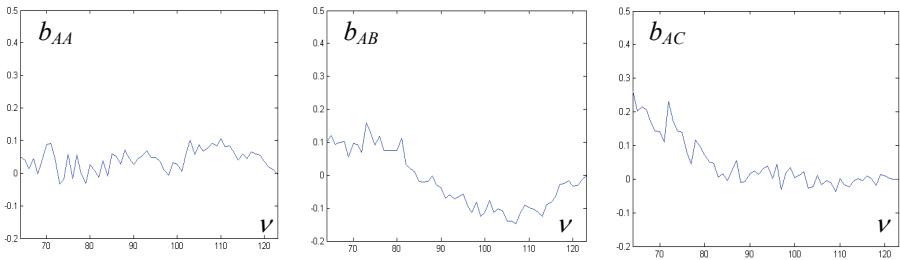
a) class A   b) class B   c) class C

Figure 8. Identity functions of different signal classes received using signals' frequency range (0,62-1,25) MHz

Finally, we have to be sure that low frequency (0-620) kHz would give enough information to signals' classifications.

From figure 9 given identity functions clearly seen that form of functions differ among themselves and it's not hard to evaluate characteristics, which separate those functions and are good enough for classification. Besides, a very clear different between B and C – identity functions of damaged classes (figure 9 c and b). It means that we can reliably classify and attribute defects to one from damage classes. It is enough for identity function received while comparing unknown object's condition that separates signal which class A "Rail is whole" covariance function.
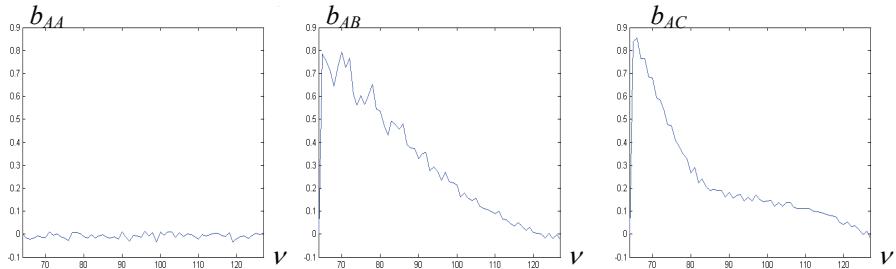
a) class A   b) class B   c) class C

Figure 9. Identity functions of different signal classes received using the low densities' signal's frequency range (0-0,62) MHz

Mathematical processing of signal investigation can be shown simply in the functional scheme.
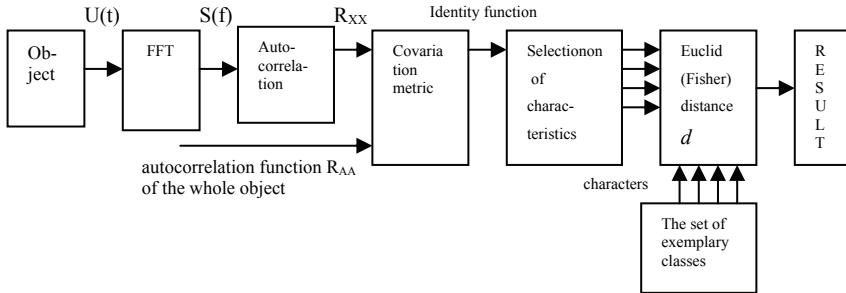
Figure 10. Functional scheme of signal processing

Structure and analysis of system

Creating modern railroad rail diagnostic's system, we have to evaluate some used useful and reliable action principals of separated active junctions. In principal, it is not worthy to change rail condition reflected signal reflection. Transmission of ultrasound signal, fixation of reflection and form of the send impulse and ultrasound frequency. In several years using ultrasound rails' defectoscopy, their parameters were analyzed and chosen as the most reliable for rail diagnostics. For this reason, functions of their junctions and the actions would remain in the suggested diagnostics system, even if most of them would be realized with other technical supplies.

Therefore, if result of the usual rail's diagnostic's system is displaying of reflected signal, then this signal in the suggested system would be only intermediate result, which gives form, indications and information reflecting other criterion, and useful for a signals' classification algorithm.
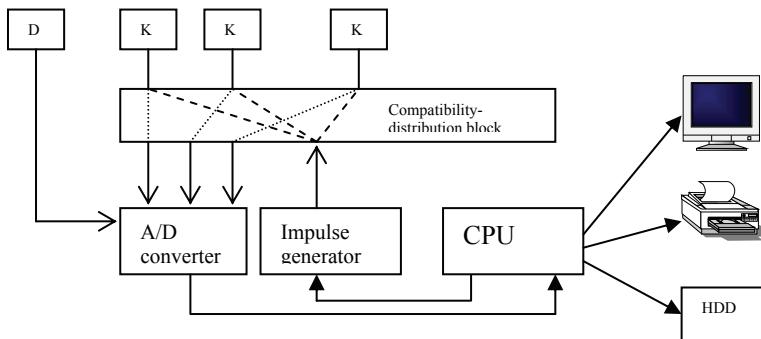

Figure 11. The scheme of structure of modernized rail diagnostic structure

Experiments and their analysis

If hardware of shown elements in structural system is above and, knowing the requirements of their parameters, indications to realize it is not hard to select, then the mathematical part is studied only theoretically. Finally all required parameter are possible to take only into considerations of real diagnostic's signal' indications.

Thus, it is necessary to experimentally check properties of covariance metrics and reliability for classification, while classifying real signals accepted with real railroad rails defectoscopy. Besides, if it is possible to make sure or to choose discovered of identity functions criterions, they are good enough for classification of real identity functions.
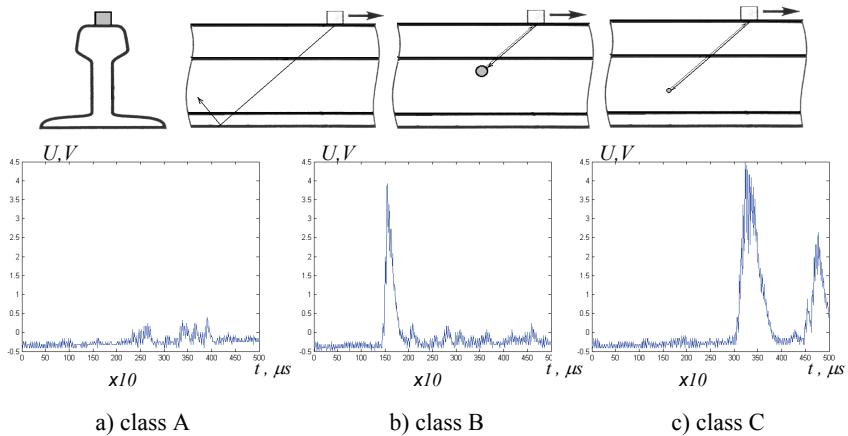

a) class A   b) class B   c) class C
Figure 12. Signals of classes A, B, C, received using 50° sensor

During the time of experiment two of each class exemplary signals are found out. Goal is to compare received identity's functions using covariance metrics way and to find the characteristics, reflecting signal's dependency to one of three classes. Figure 12 shows each of every class exemplary signals.

Received identity functions very well reflect the distance between class A "whole" and the flaw classes B and C even thought it is hard to see characteristics separating the flaw classes B an C. Before starting selection and evaluation of those characteristics, it is important to analyze how informatively of those functions will change when signal frequency range becomes narrow.
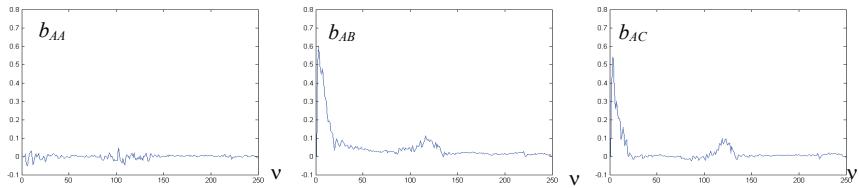
a) class A   b) class B   c) class C
Figure 13. Identity functions of different signal classes, received using
50° sensor

Characteristics better reflect in received identity functions according to which we can classify them. Also, unchecked proposition confirmed itself that in railroads' rail diagnostics it's enough to analyze the lower frequencies range (0-620) kHz.
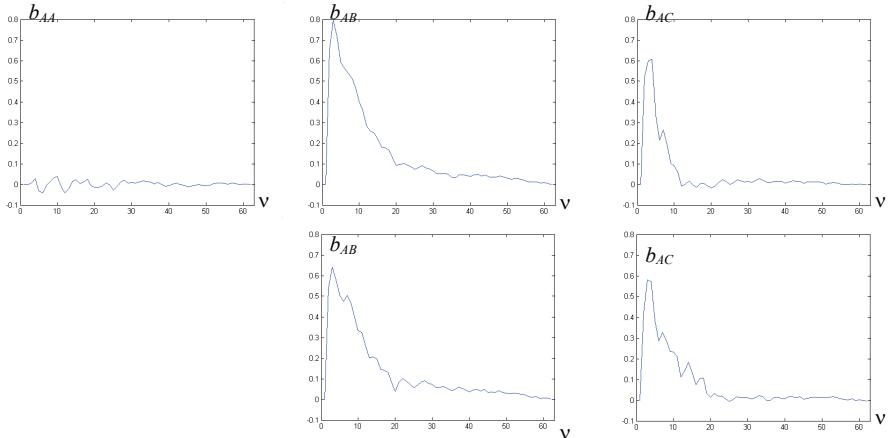
a) class A   b) class B   c) class C
Figure 14. Identity functions of low frequency signals, received using 50° sensor

When we have received signals' identity function during experiment method, we will find the criterions of identify functions, according to which we could classify them. In dissertation selection's methods are enumerated. We would adapt them to evaluation of received identity function's characteristics.

Comparing figure 14 shown identity function, we see that it's not complicated to find classification criterions. The corresponded average of deduction intervals can be as the criterions. In order to clear up which intervals can be proper we can analyze the average of dependency's function and the damage of classes' identity function.

Table 1. Criterions of identity functions (by figure 13)

	a1	b1	b2	c1	c2
x1	0,0005	0,422	0,367	0,127	0,24
x2	0,0003	0,087	0,076	0,008	0,013

From received functions it can be seen damage classes of signals' characteristics which describe identity functions differ mostly in the interval (5-15). Another interval (20-30) also is good to describe differences of identity functions. This way the signal of every class we will describe in two criterion $x1$ and $x2$.

It's seen, that values of criterions in metric area are informative and they are enough for railroad rail diagnostic's system implemented to classification, when interior flaws in rail-head using 50° ultrasound signal PE sensor.

Conclusion

1. Recently used rail diagnostic methods have defects: operators' subjectivity evaluating parameters of flaw, high requirements for operators' qualification and a big duration of processing of flaw detection result.

2. It's ascertained, that rail flaw reflection signal analyzed as random process has obviously more informative characteristics as the same signal analyzed using the classical method. It is possible to avoid parameter investigation of found rail defect using automated diagnostic system. So, operators' subjectivity is eliminated. The processing duration of flaw parameter's evaluation reduces between 30 and 60 seconds.

3. The model of the observation of the object's condition and registration is created and used for development new automated railroad rail flaw detection and parameter's evaluation method.

4. Diagnostic system of random process classifications reveals all flaws, which are not bigger than 0.00122 m, when the rail inspection speed is not bigger than 42 km/h.

5. The covariance metric based on signal classification method is chosen, which consist of researched signal's FFT module and normalized autocorrelation function and is not sensitive to change of search signal power. Classification goal consist of identity function processing using covariance metric and identity function classification using geometric classificatory.

6. It's analytically ascertained that the low frequency range (0-620) kHz is the most informative in the investigation of the rail diagnostic's signal. It allows to reduce signal processing time 4 times or 4 times increase number of processed signals.

7. During the experiment search the real rail flaw reflection signal, during the research of characters' locations in a metrical surface, it prove covariance metric is reliability to classify real rail flaw reflection signals.

8. Algorithm of geometrical classificatory control is made, which in the training time after collected the number of exemplary indicators instead of the Euclid distance change it to the Fishers distance in order to keep higher classification reliability.

9. Suggested reliability of methods to rail flaw reflection signal investigation. It's recommended to use this method and to introduce the created object's observation model while automate the flaw detection's and evaluation's.

List of publications

ARTICLES
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1.   V.A. Buinevičius, V. Gargasas. Geležinkelio objektų diagnostika // ISSN 1392-1215 Elektronika ir elektrotechnika. - Kaunas: Technologija, 2002 m. – Nr.5(40). – p.73-75.

2.   V.A. Buinevičius, V.Gargasas Geležinkelio objektų būklės įvertinimas atsitiktinių procesų klasifikavimo metodu // ISSN 1392-1215 Elektronika ir elektrotechnika. - Kaunas: Technologija, 2003 m. –Nr.4(46). – p.83-86.

3.   V.A. Buinevičius, V. Gargasas Geležinkelio bėgių diagnostika naudojant geometrinius klasifikatorius // ISSN 1392-1215 Elektronika ir elektrotechnika. - Kaunas: Technologija, 2004 m. –Nr.4(53). – p.86-89.

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1.   A. Požėra, V. Gargasas. Geometrinių klasifikatorių taikymas iešmų pavarų diagnostikai. // Tarptautinės konferencijos "Transporto priemonės-2000" pranešimų medžiaga ISBN 9986-13-843-4. Kaunas, Technologija, 2000. 211-216 p.

2.   V. Gargasas, V. A. Buinevičius. Geležinkelio bėgių diagnostika naudojant signalų klasifikavimą // 9-oji tarpuniversitetinė magistrantų ir doktorantų konferencija "Informacinė visuomenė ir universitetinės studijos", 2004 m. Kaunas, VDU. p 109-112.

Short description about the author
Vytautas Gargasas was born on 1975, in Kaunas. On 1993 has graduated from Kaunas town the 7-th secondary school. On 1997 has obtained Bachelor of Sciences qualification degree in electrical engineering, at a faculty of Electrotechnics and Automation, Kaunas University of Technology. On 1999 has obtained a qualification degree of Master of Sciences. Since 2000 he sturdiest at Kaunas University of Technology, as a doctoral student in electronics and electrical engineering sciences.

Reziumė

Darbo aktualumas

Vilniaus ir Kauno strateginės plėtros projekte numatoma pagerinti susisiekimą tarp šių miestų geležinkeliu ir padidinti keleivinių traukinių greitį iki 160 km/h. Todėl reikia atnaujinti arba specialiai keleiviniams traukiniams nutiesti aukštesnių kokybės rodiklių kelius, kurių bėgių būklės kontrolei būtų keliami didesni reikalavimai. Būtina užtikrinti tokią kelių priežiūrą, kuri garantuotų traukinių eismo saugumą bei patikimumą. Manoma, kad šiuo metu Lietuvos geležinkeliuose esamų bėgių diagnostikos priemonių gali nepakakti – reikia kurti tobulesnes diagnostikos priemones.

Geležinkelio ūkyje atsargiai žiūrima į naujoves, o tobulinant bėgių defektoskopijos priemones tobulėja ir įrangos techninė bazė, tačiau bėgio defektų nustatymo metodai nekeičiami: defekto koordinatės ir parametrai nustatomi pagal atspindėto ultragarso signalo impulso vėlinimo trukmę bei amplitudę.

Intensyvi mokslo ir technologijų plėtra suteikia galimybę kelis dešimtmečius naudotas ultragarsines geležinkelio bėgių defektoskopijos priemones bei bėgio diagnostikos metodus grįsti diagnostikos signalo statistinių savybių tyrimo rezultatais. Ultragarsinės kontrolės metu gautas bėgio būklę atspindintis signalas gali būti apibūdinamas daugybe parametrų, kuriuos galima nagrinėti dabartinėmis techninėmis priemonėmis. Šiems procesams tiksliai aprašti tektų spręsti sudėtingas lygčių sistemas, tam reikia daug laiko bei skaičiavimo technikos resursų. Naudojant matematinės statistikos teoriją galima pakankamai tiksliai nustatyti tokių procesų savybes, įvertinti jų parametrus ir priimti sprendimus. Naudojant aukštojo dažnio modulius, keičiančius analoginį signalą į skaitmeninį kodą, galima realiu laiku pakankamai tiksliai užfiksuoti įvairias geležinkelio bėgio ar kitų metalinių konstrukcijų būklę atspindinčio ultragarso signalo charakteristikas.

Darbo tikslas

Ištirti geležinkelio bėgių būklę atspindinčių signalų koreliacijos funkcijų klasifikavimo metodus ir kriterijus.

Uždaviniai

Sudaryti geležinkelio bėgių diagnostikos signalų atsitiktinio proceso charakteristikų gavimo ir tyrimo būdą; ištirti kovariacinės metrikos taikymą geležinkelio bėgio diagnostinių signalų charakteristikoms klasifikuoti, sukurti vidinių bėgio įtrūkimų parametrų įvertinimo būdą; nustatyti diagnostikos metodui informatyviausią tiriamo signalo spektrinio tankio dažnio intervalą; eksperimentiškai patikrinti sukurtą bėgio diagnostikos signalo matematinio apdorojimo būdą.

Darbo naujumas

Sukurtas geležinkelio bėgių diagnostikos signalų klasifikavimo sistemos struktūrinis modelis. Signalo spektrinio tankio normuotosios autokoreliacijos funkcijos charakteristikos (kovariacinė metrika) panaudotos geležinkelio bėgio diagnostikos tiriamo signalo informatyviems požymiams parinkti bei įvertinti,

ištirtas įvairių kovariacinės metrikos taikymo būdų tinkamumas signalui tirti ir parinktas tinkamiausias. Nustatyta tiriamo signalo dažnio juosta, teikianti daugiausia informacijos apie geležinkelio bėgio būklę atspindinčius atsitiktinio proceso charakteristikos požymius.

Sukurtos informatyvių identiškumo funkcijos požymių parinkimo ir įvertinimo rekomendacijos. Naudojantis sukurtu būdu atliktas realių geležinkelio bėgių diagnostikos signalų charakteristikų klasifikavimas. Jis gali būti taikomas ir kitų objektų (dujotiekio vamzdžių, statybinių konstrukcijų) vidiniams defektams tirti.

Aprobacijos:

3 straipsniai Lietuvos mokslo ir studijų departamento patvirtinto sąrašo periodiniuose mokslo leidiniuose;

2 straipsniai mokslinių konferencijų (Lietuvoje) pranešimų medžiagoje.

Disertaciją sudaro: įvadas, keturi skyriai, išvados, literatūros sąrašas ir autoriaus mokslinių publikacijų sąrašas.

Įvade apibūdinta tiriamoji problema, nurodytas jos aktualumas, suformuluoti darbo tikslai.

Pirmas skyrius (Ultragarsinės geležinkelio bėgių diagnostikos signalo gavimo būdai ir atsitiktinių procesų klasifikavimas) sudarytas iš dviejų poskyrių. Pirmame apžvelgti literatūros šaltiniai, kuriuose aprašyti šiuo metu naudojamų bėgių defektoskopijos priemonių veikimo principai, nustatyti jų trūkumai.

Antrame skyriuje išanalizuoti atsitiktinių procesų klasifikavimo teorijos elementai, jų pritaikymo diagnostikos sistemose galimybės.

Trečias skyrius (Geležinkelio bėgių diagnostikos signalų stochastinis tyrimo metodas) yra pagrindinis šio darbo skyrius. Jame keliama kovariacinės metrikos panaudojimo bėgių diagnostikai idėja. Analitiškai tiriami įvairūs kovariacinės metrikos taikymo būdai bei tiriamo signalo dažnių juostos ir nustatoma, kurie jų geriausiai tinka geležinkelio bėgių diagnostikai.

Ketvirtame skyriuje aprašytas eksperimentas, kuriame tiriamas realių objektų atspindėti diagnostiniai signalai ir tikrinami analitinėje darbo dalyje sudaryti signalų klasifikavimo algoritmai. Eksperimentiniai tyrimai visiškai patvirtino matematinę analizę ir įrodė tinkamumą diagnostikai.

Trumpai apie autorių

Vytautas Gargasas gimė 1975 m. Kaune. 1993 m. baigė Kauno miesto 7-tąją vidurinę mokyklą. 1997 m. Kauno technologijos universitete, Elektrotechnikos ir automatikos fakultete įgijo elektros inžinerijos mokslo bakalauro kvalifikacinį laipsnį, 1999 m. ten pat įgijo elektros inžinerijos mokslo magistro kvalifikacinį laipsnį. Nuo 2000 m. studijuoja Kauno technologijos universitete elektros ir elektronikos inžinerijos mokslo krypties doktorantūroje.