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# INTELLECTUAL TELEMETER SYSTEM OF A NOISE MONITORING OF THE TECHNICAL CONDITION OF SOCIAL SIGNIFICANT OBJECTS AND ABNORMAL SEISMIC PROCESSES

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In countries located in seismically active zones the regular control of a technical condition of habitable houses and strategic objects [1,2] is required for good safety of the population. The importance of this problem repeatedly grows for cases when besides the seismic danger there is also a probability of occurrence of a landslip.

The numerous destructions resulting in catastrophic consequences in these countries for the last years show the necessity of creating intellectual distributed systems of monitoring of a technical condition of socially significant objects. These systems are given in fig.1.

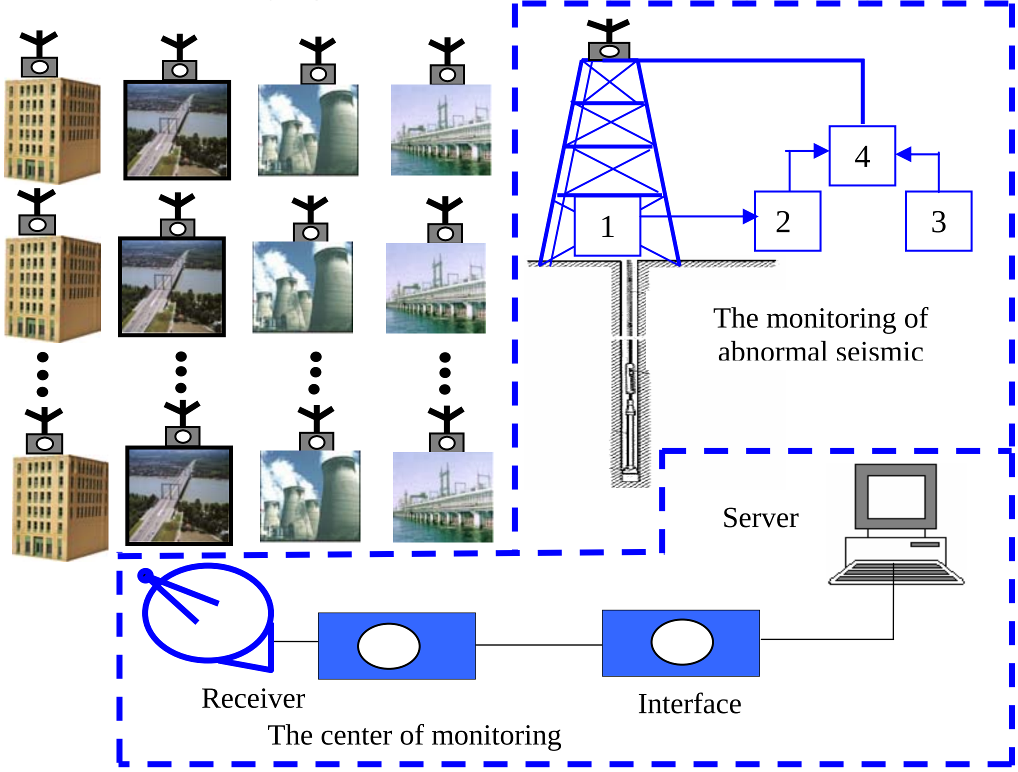

Fig 1. The scheme of the system of noise monitoring.

In creating a system each of the objects $O_1$, $O_2$, …, $O_N$ is supplied with the local block consisted of a controller and appropriate vibro-, seismo-, pieso-, tenso- sensors $D_1$, $D_2$, …, $D_m$, established in the most vulnerable parts of the object. Signals $g_1(i\Delta t)$, $g_2(i\Delta t)$, …, $g_n(i\Delta t)$ from these sensors are analyzed on the controller of local system and received results through modems and means of a radio communication are transferred in the receiver of the centre of monitoring. During the decision of the problem of monitoring at the initial stage training is carried out. First, for this purpose by means of taking turns in analyzing indicated signals according to the mentioned below algorithms, the appropriate estimations are determined. In this case the approximate values of samples $\varepsilon_j^*(i\Delta t)$ of the noise of the total signal $g_j(i\Delta t)$ is determined according to the following expression:

$$\overset{\circ}{\varepsilon}{}_j^{*}(i\Delta t) \approx \operatorname{sgn}\left[\varepsilon_j'(i\Delta t) - \varepsilon_j''(i\Delta t)\right]\sqrt{\left|\varepsilon_j'(i\Delta t) - \varepsilon_j''(i\Delta t)\right|}\,, \tag{1}$$

Where

$$\varepsilon_j'(i\Delta t) = \overset{\circ}{g}{}_j^{2}(i\Delta t) + \overset{\circ}{g}_j(i\Delta t)\overset{\circ}{g}_j((i+2)\Delta t) - 2\overset{\circ}{g}_j(i\Delta t)\overset{\circ}{g}_j((i+1)\Delta t), \tag{2}$$

$$\varepsilon_j''(i\Delta t) = \overset{\circ}{g}_j(i\Delta t)\overset{\circ}{g}_j((i+1)\Delta t) + \overset{\circ}{g}_j(i\Delta t)\overset{\circ}{g}_j((i+3)\Delta t) - 2\overset{\circ}{g}_j(i\Delta t)\overset{\circ}{g}_j((i+2)\Delta t). \tag{3}$$

Then, having samples $\varepsilon_j^*(i\Delta t)$, approximate values of samples of a useful signal $X_j(i\Delta t)$ are determined and the appropriate estimations necessary for monitoring are also determined according to the following expressions:

$$X_j^*(i\Delta t) = g_j(i\Delta t) - \varepsilon_j^*(i\Delta t), \tag{4}$$

$$D_\varepsilon = \begin{cases} \dfrac{1}{N}\displaystyle\sum_{i=1}^{N}\varepsilon'(i\Delta t) & at \quad r_{x\varepsilon} = 0, \\ \dfrac{1}{N}\displaystyle\sum_{i=1}^{N}\left[\varepsilon'(i\Delta t) - \varepsilon''(i\Delta t)\right] & at \quad r_{x\varepsilon} \neq 0, \end{cases} \tag{5}$$

$$R_{x\varepsilon}^{(\mu)} = \begin{cases} \dfrac{1}{N}\displaystyle\sum_{i=1}^{N}\left[g(i\Delta t) - \operatorname{sgn}\varepsilon'(i\Delta t)\sqrt{|\varepsilon'(i\Delta t)|}\right]\operatorname{sgn}\varepsilon'(i\Delta t)\sqrt{|\varepsilon'(i\Delta t)|} \quad at\, r_{x\varepsilon} = 0, \\ \dfrac{1}{N}\displaystyle\sum_{i=1}^{N}\left[g(i\Delta t) - \operatorname{sgn}[\varepsilon'(i\Delta t) - \varepsilon''(i\Delta t)]\sqrt{|\varepsilon'(i\Delta t) - \varepsilon''(i\Delta t)|}\right]\times \\ \times\operatorname{sgn}[\varepsilon'(i\Delta t) - \varepsilon''(i\Delta t)]\sqrt{|\varepsilon'(i\Delta t) - \varepsilon''(i\Delta t)|} \qquad at\, r_{x\varepsilon} \neq 0, \end{cases} \tag{6}$$

$$R^R_{\overset{\circ}{g}_j\overset{\circ}{g}_j}(\mu) = \frac{1}{n}\sum_{i=1}^{n}\overset{\circ}{g}_j(i\Delta t)\overset{\circ}{g}_j((i+\mu)\Delta t) - [n^+(\mu) - n^-(\mu)]\langle\Delta\lambda(\mu=1)\rangle \tag{7}$$

Where

$$\left|R_{g_jg_j}(\mu=1) - R_{\overset{\circ}{g}_j\overset{\circ}{g}_j}(\mu=1)\right| = \lambda(\mu=1)\,, \tag{8}$$

$$r^*_{\Delta g_i\Delta g_{i+1}} \approx \frac{1}{N}\sum_{i=1}^{N}\operatorname{sgn}\Delta g_{\mathrm{j}}(\mathrm{i\Delta t})\operatorname{sgn}\Delta g_i((i+1)\Delta t), \tag{9}$$

$$r^*_{x_jx_\mu} \approx r^*_{g_jg_\mu} \approx \frac{1}{N}\sum_{i=1}^{N}\operatorname{sgn}\Delta g_{\mathrm{j}}(\mathrm{i\Delta t})\operatorname{sgn}\Delta g_\mu(i\Delta t)\,, \tag{10}$$

$$r^*_{x_j\varepsilon_j} \approx r^*_{g_j\varepsilon_j} \approx \frac{1}{N}\sum_{i=1}^{N}\operatorname{sgn}\varepsilon_j^*(i\Delta t)\operatorname{sgn} g_j(i\Delta t) \tag{11}$$

$$r_{x_j\varepsilon_j} \approx r^*_{g_j\varepsilon_j} = \frac{1}{N}\sum_{i=1}^{N}\operatorname{sgn}\Delta g_j(i\Delta t)\operatorname{sgn} g_j(i\Delta t) \tag{12}$$

$$a^R_{ng_j} = \frac{2}{N}\left\{\sum_{i=1}^{N}\left[\overset{\circ}{g}_j(i\Delta t)\cos n\omega(i\Delta t) - \lambda^R_{a_n}\right]\right\}, \tag{13}$$

$$b^R_{ng_j} = \frac{2}{N}\left\{\sum_{i=1}^{N}\left[\overset{\circ}{g}_j(i\Delta t)\sin n\omega(i\Delta t) - \lambda^R_{b_n}\right]\right\}. \tag{14}$$

The detailed statement of technology of determining $\lambda^R_{a_n}$, $\lambda^R_{b_n}$ is given in [1,2]. In solving the problem of monitoring it is expedient to determine the estimations of these coefficients for the most informative spectrum $\omega^*$ as follows:

$$a^*_{g_j} = \frac{1}{N}\sum_{i=1}^{N} g_j(i\Delta t)\cos\omega^*(i\Delta t) \tag{15}$$

$$b^*_{g_j} = \frac{1}{N}\sum_{i=1}^{N} g_j(i\Delta t)\sin\omega^*(i\Delta t) \tag{16}$$

Determining the frequency of this harmonic $\omega^*$ is carried out, according to the algorithms described in [1,2]. Now we shall consider an opportunity of the application of a position-binary technology for monitoring a technical condition of controllable objects. In work [2] it is shown that signals $q_k(i\Delta t)$ are formed in iterated manner as codes of ones (1) or zeros (0) during the analog-digital conversion of continuous signals in each step $\Delta t$ of discretization from the values of appropriate binary digits $q_k$ of binary codes of samples of the signal $g(i\Delta t)$.

The sequence of these signals $q_k(i\Delta t)$ represents position – binary signals (PBS) the sum of which will be equal to an initial signal, i.e.,

$$g(i\Delta t) \approx q_{n1}(i\Delta t) + q_{n2}(i\Delta t) + \ldots + q_k(i\Delta t) + \ldots + q_{n-1}(i\Delta t) + q_n(i\Delta t) = g^*(i\Delta t). \tag{17}$$

The average values of the frequency of the unit and zero periods of these signals as well as the coefficients of the relations and their numbers for the time $T$, i.e.,

$$K_{q_0} = \frac{N_{q_0}}{N},\ K_{q_1} = \frac{N_{q_1}}{N},\ \ldots,\ K_{q_n} = \frac{N_{q_{n-1}}}{N} \tag{18}$$

$$K_{q_0q_1} = \frac{N_{q_0}}{N_{q_1}},\ K_{q_1q_2} = \frac{N_{q_1}}{N_{q_2}},\ \ldots,\ K_{q_{n-1}q_n} = \frac{N_{q_{n-1}}}{N_{q_n}} \tag{19}$$

are not casual magnitudes. At the origin of the defect these coefficients vary, and the short – term pulses $q_{\varepsilon k}(i\Delta t)$ are formed from the influence of the noise $\varepsilon(i\Delta t)$ on the PBS: The duration of the mentioned pulses is repeatedly less than the duration of positional signals $q_k(i\Delta t)$. It is shown in references [1,2] that according to the following expression:

$$q^*_{\varepsilon k}(i\Delta t) = \begin{cases} 1,\ at\ \overline{q_k((i-1)\Delta t)} \wedge q_k(i\Delta t) \wedge \overline{q_k((i+1)\Delta t)} \vee q_k((i-1)\Delta t) \wedge \overline{q_k(i\Delta t)} \wedge q_k((i+1)\Delta t) \\ 0,\ at\ q_k((i-1)\Delta t) \wedge q_k(i\Delta t) \wedge \overline{q_k((i+1)\Delta t)} \vee \overline{q_k((i-1)\Delta t)} \wedge \overline{q_k(i\Delta t)} \wedge q_k((i+1)\Delta t) \\ q_k((i-1)\Delta t) \wedge \overline{q_k(i\Delta t)} \wedge \overline{q_k((i+1)\Delta t)} \vee \overline{q_k((i-1)\Delta t)} \wedge q_k(i\Delta t) \wedge q_k((i+1)\Delta t) \end{cases} \tag{20}$$

it is possible to form and extract positional noises $q_{\varepsilon k}(i\Delta t)$. It is obvious that their sum will represent the appropriate value of samples of the noise, i.e.,

$$\varepsilon(i\Delta t) \approx \varepsilon_0(i\Delta t) + \varepsilon_1(i\Delta t) + \ldots + \varepsilon_k(i\Delta t) + \ldots + \varepsilon_{n-1}(i\Delta t) + \varepsilon_n(i\Delta t). \tag{21}$$

In works [1,2] it is shown that for sufficient time $T$ of observation at a normal condition of functioning the object, the ratio of the number of these PBS $q_{\varepsilon k}(i\Delta t)$ to the total number $N_{qk}$ of positional signals $q_k(i\Delta t)$, i.e., the coefficient estimations,

$$K'_{q_0} = \frac{N_{\varepsilon_0}}{N_{q_0k}},\ K'_{q_1} = \frac{N_{\varepsilon_1}}{N_{q_1k}},\ \ldots,\ K'_{q_{m-1}} = \frac{N_{\varepsilon(m-1)}}{N_{q(m-1)k}} \tag{22}$$

are close to zero. They only vary at the moment of the origin of the defect.

Thus at the normal mode of the operation of the object the coefficients $K_{q_0}, K_{q_1}, \ldots, K_{q_m};\ K_{q_0q_1}, K_{q_1q_2}, \ldots, K_{q_{n-1}q_n};\ K'_{q_0}, K'_{q_1}, \ldots, K'_{q_m}$ remain stable magnitudes. At the beginning of the defect there are appropriate alterations of combinations of these coefficients.

During functioning the system given in Fig 1 the appropriate estimations are determined according to expressions (1)-(22).

They are stored as standard values, and for them ranges of possible minimal, average and maximal deviations are established. For example, for the estimation of the noise $D_\varepsilon$ the following appropriate ranges $\Delta D_{\varepsilon \min}$, $\Delta D_{\varepsilon cp}$, $\Delta D_{\varepsilon \max}$ are established. For the other estimations obtained according to expressions (1)-(22) the similar ranges are established.

After the stage of training the system passes in a mode of monitoring and the values of the current estimations of the variance, correlation coefficients, Fourier coefficients which allow determining the beginning of the origin of the defect are determined in turn. For this purpose they are compared to the appropriate standard values fixed during the training.

If in this case their difference does not exceed the established ranges, it is considered that the technical condition of the appropriate object $O_1$, $O_2$, …, $O_N$ has not changed. Otherwise, according to the obtained differences the signal is formed showing the beginning of changing a technical condition of the appropriate object. It this case according to the value of the difference of the deviation one can determine the degree of the gravity of the arising situation.

Again in the system provision is made for the control of the safety engineering in objects $O_1$, $O_2$, …, $O_N$. For example, at lift failure, at leakage of gas, at short circuit in electric power supply and so on in objects of monitoring the appropriate signaling with the indication of the character of a failure and an object number will be formed.

Thus, as a result of the analysis of the signals collected from the appropriate sensors with application of the above described technologies the system of monitoring allows one by the comparative analysis of the estimations of the measuring information in time to determine the dynamics of changes of the technical condition of each object.

The comparative analysis of the found estimations of each object and standard objects by means of the value of the difference of the estimations also allows determining the difference of their technical condition and founding the most vulnerable and suspicious buildings. Detecting the simultaneous change of a technical condition of the several close located objects is accepted as a sign of landslide processes.

If these changes are marked on a set of various objects of a far location, it is accepted as a sign of abnormal seismic processes. The necessary level of sensitivity, reliability of monitoring micro-changes of a technical condition of objects is reached by parallel using the traditional, robust, position-binary and digital noise technologies of analysis of signals collected at the output of sensors established on the most vulnerable parts of objects. The received result of monitoring is given to experts for final appropriate decision making.

Now we shall consider a concept of functioning a system of obtaining the seismic information from deep layers of the ground and identifying abnormal seismic processes (SP). Block 1 consists of a seismoacoustic well with depth from 3 to 6 k ms and more on the mouth of which the sound sensor and vibroacostic sensor are established. In block 2 the analysis of the received sound and vibrating signals is carried out. Block 3 represents standard seismoequipment allowing fixing and estimating the force of seismic oscillations exceeding the established threshold levels. Block 4 performs functions of the monitoring and identification of abnormal seismicprocesses and the short-term forecasting of earthquakes.

In the SP system for receiving the information from deep (3-6 kms) seismic processes in block 1 preserved oil wells are used as a communication channel. The ones are unutilized after the exhaustion of oil beds. For forming informative signs about the beginning of abnormal seismic processes in deep layers of the ground by means of obtained sound and vibration signals statistical estimations are used which are calculated according to algorithms (1) – (22).

In block 4 of the SP system for the intellectualization of the identification of abnormal seismic processes at the initial stage the training mode is realized. For this purpose according to expressions (1) – (22) the appropriate estimations of sound and vibrating signals collected on appropriate sensors established at the mouth of seismic acoustic well 1 are determined.

With the help of obtained informative signs during the long time when abnormal seismic processes are usually absent appropriate standard sets are formed and stored in block 4. In this case in ground-based seismic equipment 3 seismic processes are also marked as normal as they also do not exceed the given threshold level. According to them appropriate standard sets are formed too. Later on during the work of the system according to the results of the analysis obtained current estimations are compared to standard sets. If their difference does not exceed the established ranges, it is considered that they do not differ from standard and their number is fixed. This process proceeds up to the moment when the current estimations of signals collected from appropriate sensors differ from the values of the estimations of standard sets by the values greater than the established ranges. In this case the time is fixed. If the subsequent estimations also differ from the estimations of standard sets by the value greater than the given range, in block 4 it is marked as the beginning of abnormal seismic processes, and the appropriate information is transferred to a server $S$ of the central system. Thus at the reaction of sound- and vibrating sensors established at the mouth of the steel trunk of the well running on the depth of 3-6 kms and more in the system the information about the beginning of abnormal seismic processes is formed. At the same time the reaction of the standard ground-based equipment 3 at the occurrence of abnormal seismic processes is considerably late as mechanical distribution of seismic oscillations from the depth of 3-6 kms up to surface of the ground demands rather greater time. Therefore, after the certain time interval in equipment 3 the force of a seismic oscillation in Richter scale is determined and transferred in block 4. In block 4 the difference between the time of registration of the beginning of abnormal seismic processes in block 2 and 3 is determined. Their difference may be considered to be the time of the short-term forecasting.

In block 4 the identification of seismic oscillations obtained from standard ground based equipment 3 according to the results of estimations received in block 2 is provided.

During the long operation from the occurrence of numerous seismic oscillations by means of self-training and adaptation according to the indications in block 2 and 3 the intellectualization of identification is performed. In the elementary case proceeding from the estimations of seismic oscillations received in block 2 and 3 in block 4 by means of self-training tabular or linear relations are established according to which it is possible to perform the approached forecasting of earthquakes. With time during the training the system can determine the value of the force and the time of the possible earthquake by means of using the value of the difference between standard and current estimations as well as by means of using the difference of the time of the reaction in blocks 1 and 3 to an increasing extent of reliability.

Thus, in the suggested system for receiving the seismic information from deep layers of the ground the trunks of preserved wells of exhausted petroleum deposits are used as "phonendoscope". Due to the intellectualization of the SP system at the operation the necessary degree of adequacy of the results of forecasting about the force and the time of dangerous seismic oscillations in due course is achieved. This makes it possible to signal about abnormal seismic processes beforehand. In this case in comparison with the standard seismic equipment the time of an advancing is caused by two factors. First, at the origin of abnormal seismic processes their influence is transferred by a steel pipe of a well from the depth of 5-6 kms with the speed of sound and, in block 1 it is caught by means of a sound sensor and after a while by a vibration sensor. At the same time mechanical vibrations of seismic processes reach the surface of the ground with rather smaller speed and consequently they are registered by seismic receivers of standard ground based equipment rather later. Second, the application of the noise technology and position-binary technology allows fixing abnormal seismic processes at the beginning of their origin which usually precedes obviously expressed strong seismic oscillations considerably. As a result there is an opportunity after receiving the information about a forthcoming earthquake in due time to warn the population to leave its apartments.

## Literature

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