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Research Paper

Using Technologies for Calculating the Noise Characteristics to Assess the Technical Condition of Building Structures

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Abstract. Building structures undergo physical and moral deterioration over time, developing destructive processes that cause visible and hidden defects, such as cracks, deformations, sagging, corrosion and oxidation of metal elements. Hidden defects are particularly dangerous as they can cause sudden structural collapses if left undetected. While existing monitoring systems use sensors for detection of hidden defects, processing incoming noisy signals, which consist of a useful component and noise, they cannot effectively separate the noise from the useful signal component, even though analyzing these components individually yields the most informative data. To address this, this paper introduces algorithms and technologies that separately calculate and analyze the characteristics of the noise and useful signal components to detect hidden defects at their earliest stages. While deviations in the useful component's estimates (such as variance, standard deviation, high-order moments, and distribution functions) indicate benign structural changes caused by external environmental factors, variations in the noise characteristics specifically signal the formation of physical defects. Integrating these algorithms into monitoring systems enables early damage detection, prevents catastrophic emergencies. The study directly supports Sustainable Development Goals (SDG 9: Industry, Innovation and Infrastructure, and SDG 11: Sustainable Cities and Communities).

Keywords: Technical condition, Building structures, Noisy signal, Noise, Noise characteristics.

1. Introduction

During operation, building structures are exposed to various external factors, including mechanical, technogenic, climatic, and seismic loads. Over time, these factors cause deformations, corrosion, and damage, which decrease structural and operational quality. To avoid catastrophic failures and accidents, systematic control is required to assess the technical condition of these buildings [1]. Consequently, monitoring systems are created [2] to prevent defects, detect damage at an early stage, increase safety levels, and minimize accident risks. These monitoring systems typically integrate hardware and software tools designed to collect, process, and analyze structural condition data [3].

To develop the monitoring system hardware, the required number and types of sensors must first be determined [4]. Each sensor is strategically installed in informative locations to evaluate specific aspects of the building structure. For example, accelerometers measure inclination and vibration; strain gauges monitor the deformation of structural elements; inclinometers track sagging and tilt; and piezometers determine water pressure and groundwater levels [4]. The software of the monitoring system includes algorithms and programs to process signals from the installed sensors. Typically, to control structural condition, the system determines the average values, variances, standard deviations, high-order moments, and distribution laws for each incoming signal. It also calculates the probabilities of signals falling within permissible intervals and determines other characteristics to compare against regulatory reference values. This process allows the system to control tilt, sagging, crack opening widths, building foundation yields, reinforcement stress, vibrations, humidity, and temperature [5].

However, sensor signals contain inseparable mixtures of useful data and noise, with early-stage structural deformations like cracks and corrosion characterized by distinct, separate attributes for each component. Consequently, proposed algorithms calculate these individual components to assess the technical condition of building structures.

2. Problem Statement

Traditionally, structural health monitoring systems analyze sensor signals to control the technical condition of building structures by calculating for each signal $G(t)$ the mean value m_G, variance D_G, standard deviation σ_G, moments μ_{Gq} of order q

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are calculated, as well as constructing the normal distribution function $N(g)$ [5]:

$$m_G = \sum_{i=1}^{N} G(i\Delta t), \tag{1}$$

$$D_G = \frac{\sum_{i=1}^{N}\left(G(i\Delta t) - m_G\right)^2}{N}, \tag{2}$$

$$\sigma_G = \sqrt{D_G} = \sqrt{\frac{\sum_{i=1}^{N}\left(G(i\Delta t) - m_G\right)^2}{N}}, \tag{3}$$

$$N(g) = \frac{1}{\sigma_G\sqrt{2\pi}} e^{-\frac{(x-m_G)^2}{2(\sigma_G)^2}}, \tag{4}$$

$$\mu_{Gq} = \int_{-\infty}^{+\infty} (g - m_G)^q N(g)dg. \tag{5}$$

The normal distribution function $N(g)$ is characterized by inflection points:

$$A1_G = \left(m_G - \sigma_G; \frac{1}{\sigma_G\sqrt{2\pi e}}\right), \tag{6}$$

$$A2_G = \left(m_G + \sigma_G; \frac{1}{\sigma_G\sqrt{2\pi e}}\right), \tag{7}$$

which indicate the curvature change of the probability density function and lie one standard deviation σ_G from the mathematical expectation m_G. These points define the probability $P\left(m_G - \sigma_G \le G(t) \le m_G + \sigma_G\right)$ of the noisy signal falling within the most probable interval $m_G - \sigma_G \le G(t) \le m_G + \sigma_G$, which serves as a metric to monitor structural health.

In addition, to determine the probability of the noisy signal $G(t)$ taking the mean value m_G, we calculate the maximum of the normal distribution density function $N(g)$ of the noisy signal $G(t)$, which is located at the point m_G:

$$N(g = m_G) = \frac{1}{\sigma_G\sqrt{2\pi}}, \tag{8}$$

The mean m_{G-ti}, variance D_{G-ti}, standard deviation σ_{G-ti}, moments μ_{Gq-ti} of order q, distribution function $N(g)_{ti}$, inflection points $A1_{G-ti}$, $A2_{G-ti}$, maximum $N(g = m_G)_{ti}$ of the normal distribution density function calculated at each time instant t_i are compared against their reference values m_{G-t0}, D_{G-t0}, σ_{G-t0}, μ_{Gq-t0}, $N(g)_{t0}$, $A1_{G-t0}$, $A2_{G-t0}$, $N(g = m_G)_{t0}$. If the differences exceed certain threshold values:

$$\left|m_{G-ti} - m_{G-t0}\right| \ge m_{G-p}, \tag{9}$$

$$\left|D_{G-ti} - D_{G-t0}\right| \ge D_{G-p}, \tag{10}$$

$$\left|\sigma_{G-ti} - \sigma_{G-t0}\right| \ge \sigma_{G-p}, \tag{11}$$

$$\left|\mu_{Gq-ti} - \mu_{Gq-t0}\right| \ge \mu_{Gq-p}, \tag{12}$$

$$\begin{gathered} N(g)_{ti} \ne N(g)_{t0}, \\ A1_{G-ti} \ne A1_{G-t0}, \\ A2_{G-ti} \ne A2_{G-t0}, \\ N(g = m_G)_{ti} \ne N(g = m_G)_{t0}, \end{gathered} \tag{13}$$

it indicates tangible changes in the structural condition. However, these changes can occur for two reasons: (1) variations in external influences, or (2) the development of defects and faults.

Existing monitoring algorithms and software cannot distinguish between these two causes. Furthermore, traditional algorithms only detect explicit defects once conditions (9) to (13) are met, whereas the primary function of a monitoring system is early defect detection during the latent period.

The studies [6, 7] show that effective, continuous structural monitoring requires calculating the characteristics of the noise $E(t)$, the noisy signal $G(t) = X(t) + E(t)$ itself:

$$m_{\mathrm{E}}=\sum_{i=1}^{N}\mathrm{E}(i\Delta t), \tag{14}$$

$$D_{\mathrm{E}}=\frac{\sum_{i=1}^{N}\left(\mathrm{E}(i\Delta t)-m_{\mathrm{E}}\right)^{2}}{N}, \tag{15}$$

$$\sigma_{\mathrm{E}}=\sqrt{D_{\mathrm{E}}}=\sqrt{\frac{\sum_{i=1}^{N}\left(\mathrm{E}(i\Delta t)-m_{\mathrm{E}}\right)^{2}}{N}}, \tag{16}$$

$$\mathrm{N}(\varepsilon)=\frac{1}{\sigma_{\mathrm{E}}\sqrt{2\pi}}e^{-\frac{(x-m_{\mathrm{E}})^{2}}{2(\sigma_{\mathrm{E}})^{2}}}, \tag{17}$$

$$\begin{gathered}
A1_{\mathrm{E}}=\left(m_{\mathrm{E}}-\sigma_{\mathrm{E}};\frac{1}{\sigma_{\mathrm{E}}\sqrt{2\pi e}}\right),\\
A2_{\mathrm{E}}=\left(m_{\mathrm{E}}+\sigma_{\mathrm{E}};\frac{1}{\sigma_{\mathrm{E}}\sqrt{2\pi e}}\right),\\
\mathrm{N}(\varepsilon=m_{\mathrm{E}})=\frac{1}{\sigma_{\mathrm{E}}\sqrt{2\pi}},\\
\mu_{\mathrm{E}q}=\int_{-\infty}^{+\infty}(\varepsilon-m_{\mathrm{E}})^{q}\,\mathrm{N}(\varepsilon)d\varepsilon,
\end{gathered} \tag{18}$$

and the useful component $X(t)$:

$$m_{X}=\sum_{i=1}^{N}X(i\Delta t), \tag{19}$$

$$D_{X}=\frac{\sum_{i=1}^{N}\left(X(i\Delta t)-m_{X}\right)^{2}}{N}, \tag{20}$$

$$\sigma_{X}=\sqrt{D_{X}}=\sqrt{\frac{\sum_{i=1}^{N}\left(X(i\Delta t)-m_{X}\right)^{2}}{N}}, \tag{21}$$

$$\mathrm{N}(x)=\frac{1}{\sigma_{X}\sqrt{2\pi}}e^{-\frac{(x-m_{X})^{2}}{2(\sigma_{X})^{2}}}, \tag{22}$$

$$\begin{gathered}
A1_{X}=\left(m_{X}-\sigma_{X};\frac{1}{\sigma_{X}\sqrt{2\pi e}}\right),\\
A2_{X}=\left(m_{X}+\sigma_{X};\frac{1}{\sigma_{X}\sqrt{2\pi e}}\right),\\
\mathrm{N}(x=m_{X})=\frac{1}{\sigma_{X}\sqrt{2\pi}},\\
\mu_{Xq}=\int_{-\infty}^{+\infty}(x-m_{X})^{q}\,\mathrm{N}(x)dx.
\end{gathered} \tag{23}$$

Thus, $G(t)$, $X(t)$, $\mathrm{E}(t)$ are stationary ergodic signals and have normal distribution law [8, 9] and $m_{\mathrm{E}}=0$.

Below, we present a method for calculating the characteristics of the useful component $X(t)$ and the noise $\mathrm{E}(t)$ from an inseparable signal $G(t)$, demonstrating their application for early-stage structural health monitoring.

3. Algorithms for Calculating the Noise Characteristics

It is shown in [10-12] that the variance and standard deviation of the noise $\mathrm{E}(t)$ can be calculated using the expression for the autocorrelation function $R_{GG}(\mu)$:

$$D_{E}^{*} = R_{GG}(0) - 2R_{GG}(\Delta t) + R_{GG}(2\Delta t), \tag{24}$$

$$\sigma_{E}^{*} = \sqrt{R_{GG}(0) - 2R_{GG}(\Delta t) + R_{GG}(2\Delta t)},$$

$$R_{GG}(\mu) = \frac{1}{N}\sum_{i=1}^{N} \overset{\circ}{G}(i\Delta t)\overset{\circ}{G}((i+\mu)\Delta t), \tag{25}$$

$$\overset{\circ}{G}(i\Delta t) = G(i\Delta t) - m_{G}.$$

The normal distribution density function of the noise $E(t)$ and its inflection points can then be determined using the following formula [13, 14]:

$$N^{*}(\varepsilon) = \frac{1}{\sigma_{E}^{*}\sqrt{2\pi}} e^{-\frac{(x-m_{E})^{2}}{2(\sigma_{E}^{*})^{2}}}. \tag{26}$$

$$A1_{E}^{*} = \left(m_{E} - \sigma_{E}^{*}; \frac{1}{\sigma_{E}^{*}\sqrt{2\pi e}}\right),$$

$$A2_{E}^{*} = \left(m_{E} + \sigma_{E}^{*}; \frac{1}{\sigma_{E}^{*}\sqrt{2\pi e}}\right). \tag{27}$$

These inflection points determine whether the noise in the interval $m_{E} - \sigma_{E}^{*} \le E(t) \le m_{E} + \sigma_{E}^{*}$ takes values unacceptable for the normal functioning of building structures with a high probability $P(m_{E} - \sigma_{E}^{*} \le E(t) \le m_{E} + \sigma_{E}^{*})$ [15]. This assessment reveals the severity of the defect and the intensity of its development.

The maximum of the normal distribution density function $N^{*}(\varepsilon)$ of the noise $E(t)$ of the noisy signal $G(t)$, which is located at the point $m_{E} = 0$, is calculated by the expression:

$$N^{*}(\varepsilon = 0) = \frac{1}{\sigma_{E}^{*}\sqrt{2\pi}} \tag{28}$$

and allows determining the probability of the noise taking the average value $m_{E} = 0$.

A low probability indicates a high likelihood the noise mean deviates from the baseline condition $m_{E} = 0$, suggesting a potential shift from a normal distribution due to structural faults.

Higher-order moments of the noise $E(t)$ are calculated as follows:

$$\mu_{Eq}^{*} = \int_{-\infty}^{+\infty} (\varepsilon - m_{E})^{q} N^{*}(\varepsilon) d\varepsilon,$$

$$\mu_{Eq}^{*} = (q-1) D_{E}^{*} \mu_{E(q-2)}^{*}. \tag{29}$$

3.1. Algorithms for calculating the characteristics of the useful component

To calculate the characteristics of the useful component, let us take into account [8, 9]:

$$m_{X} = m_{G}, \tag{30}$$

since $m_{G} = m_{X} + m_{E}$, $m_{E} = 0$,

$$D_{X}^{*} = D_{G} - 2r_{XE}^{*} - D_{E}^{*},$$

$$\sigma_{X}^{*} = \sqrt{D_{X}^{*}}, \tag{31}$$

where the correlation coefficient between $X(t)$ and $E(t)$:

$$r_{XE}^{*} = \frac{R_{XE}^{r*}(0)}{\sqrt{\frac{2}{\pi} \cdot D_{E}^{*}}},$$

$$R_{XE}^{r*}(0) = R_{GG}^{r}(0) - 2R_{GG}^{r}(1) + R_{GG}^{r}(2), \tag{32}$$

where $R_{GG}^{r}(\mu)$ is the relay correlation function of $G(t)$:

$$R_{GG}^{r}(\mu) = \frac{1}{N}\sum_{i=1}^{N} \operatorname{sgn} \overset{\circ}{G}(i\Delta t)\overset{\circ}{G}((i+\mu)\Delta t),$$

$$\operatorname{sgn} G(i\Delta t) = \begin{cases} +1 \text{ if } \overset{\circ}{G}(i\Delta t) > 0 \\ 0 \text{ if } \overset{\circ}{G}(i\Delta t) = 0, \\ -1 \text{ if } \overset{\circ}{G}(i\Delta t) < 0 \end{cases} \tag{33}$$

$$N^*(x) = \frac{1}{\sigma_X^* \sqrt{2\pi}} e^{-\frac{(x-m_X)^2}{2(\sigma_X^*)^2}},$$

inflection points:

$$A1_X^* = \left(m_X - \sigma_X^*; \frac{1}{\sigma_X^* \sqrt{2\pi e}}\right), \qquad A2_X^* = \left(m_X + \sigma_X^*; \frac{1}{\sigma_X^* \sqrt{2\pi e}}\right), \tag{34}$$

which allow determining the probability $P(m_X - \sigma_X^* \le X(t) \le m_X + \sigma_X^*)$ of the useful signal taking the regulatory values; the value of this probability determines the extent of the external impact changing the values of the parameters of normal operation without causing structural harm.

The maximum of the normal distribution density function $N^*(x)$ of the useful signal $X(t)$ of the noisy signal $G(t)$, which is located at the point m_X, is calculated using the expression:

$$N^*(x = m_X) = \frac{1}{\sigma_X^* \sqrt{2\pi}}$$

and allows determining the probability of the useful signal $X(t)$ taking the average value m_X. A low probability implies that the external influence has changed the course of the normal process.

Formula for calculating high-order moments of the useful signal $X(t)$ is:

$$\mu_{Xq}^* = \int_{-\infty}^{+\infty} (x - m_X)^q N^*(x) dx \tag{35}$$

or,

$$\mu_{Xq}^* = (q-1)\left(\sigma_X^*\right)^2 \mu_{X(q-2)}^*.$$

4. Experimental Validation

Analytical expressions (24) to (29) and (31) to (35) were verified via MATLAB numerical simulations and tested on various technical objects [8–11, 16–20]. The results were validated and published in several papers, including [16].

For the numerical simulations, useful signals $X(t)$ were generated as a sum of harmonic oscillations with random coefficients $a_{\nu k}$, $b_{\nu k}$ and phases $\phi_{\nu k}$, $\phi_{1\nu k}$, $\phi_{2\nu k}$ [9, 11, 17]:

$$X_k(t) = \sum_{\nu=1}^{n}\left(a_{\nu k} \cos\left(\frac{2\pi\nu}{T}t + \phi_{1\nu k}\right) + b_{\nu k} \sin\left(\frac{2\pi\nu}{T}t + \phi_{2\nu k}\right)\right).$$

A normally distributed noise $E(t)$ with varying distribution parameters $m_E \approx 0$, σ_E was generated using a random number generator. This generated noise $E(t)$ was treated as the true noise. The noisy signals $G(i\Delta t) = X(i\Delta t) + E(i\Delta t)$ were then generated.

Next, noise and useful signal characteristics were calculated using traditional formulas (14) to (18), (19) to (23) and the methods proposed in (24) to (29), (30) to (35). A comparative analysis was then performed by calculating the relative errors [9, 11, 17]:

- For noise characteristics:

$$\Delta D_E = \left|D_E - D_E^*\right| / \left|D_E\right| \cdot 100\%, \quad \Delta\sigma_E = \left|\sigma_E - \sigma_E^*\right| / \left|\sigma_E\right| \cdot 100\%,$$

$$\Delta N(\varepsilon(i\Delta t)) = \left|N(\varepsilon(i\Delta t)) - N^*(\varepsilon(i\Delta t))\right| / \left|N(\varepsilon(i\Delta t))\right| \cdot 100\%,$$

$$\Delta N(\varepsilon = m_E) = \left|N(\varepsilon = m_E) - N^*(\varepsilon = m_E)\right| / \left|N(\varepsilon = m_E)\right| \cdot 100\%,$$

$$\Delta A1_E = \left|(m_E - \sigma_E) - (m_E^* - \sigma_E^*)\right| / \left|(m_E - \sigma_E)\right| \cdot 100\%,$$

$$\Delta A2_E = \left|(m_E + \sigma_E) - (m_E^* + \sigma_E^*)\right| / \left|(m_E + \sigma_E)\right| \cdot 100\%,$$

$$\Delta O_E = \left|\left(\frac{1}{\sigma_E \sqrt{2\pi e}}\right) - \left(\frac{1}{\sigma_E^* \sqrt{2\pi e}}\right)\right| \Big/ \left(\frac{1}{\sigma_E \sqrt{2\pi e}}\right) \cdot 100\%.$$

$$\Delta\mu_{Eq} = \left|\mu_{Eq} - \mu_{Eq}^*\right| / \left|\mu_{Eq}\right| \cdot 100\%,$$

- For useful signal characteristics:

$$\Delta D_X = \left|D_X - D_X^*\right| / \left|D_X\right| \cdot 100\%, \quad \Delta\sigma_X = \left|\sigma_X - \sigma_X^*\right| / \left|\sigma_X\right| \cdot 100\%,$$

$$\Delta N(x(i\Delta t)) = \left|N(x(i\Delta t)) - N^*(x(i\Delta t))\right| / \left|N(x(i\Delta t))\right| \cdot 100\%,$$

$$\Delta N(x = m_X) = \left|N(x = m_X) - N^*(x = m_X)\right| / \left|N(x = m_X)\right| \cdot 100\%,$$

$$\Delta A1_X = \left|(m_X - \sigma_X) - (m_X^* - \sigma_X^*)\right| / \left|(m_X - \sigma_X)\right| \cdot 100\%,$$

$$\Delta A2_X = \left|(m_X + \sigma_X) - (m_X^* + \sigma_X^*)\right| / \left|(m_X + \sigma_X)\right| \cdot 100\%,$$

$$\Delta O_X = \left|\left(\frac{1}{\sigma_X\sqrt{2\pi e}}\right) - \left(\frac{1}{\sigma_X^*\sqrt{2\pi e}}\right)\right| \Big/ \left(\frac{1}{\sigma_X\sqrt{2\pi e}}\right) \cdot 100\%.$$

$$\Delta\mu_{Xq} = \left|\mu_{Xq} - \mu_{Xq}^*\right| / \left|\mu_{Xq}\right| \cdot 100\%,$$

- For the correlation coefficient:

$$\Delta r_{XE} = \left|r_{XE} - r_{XE}^*\right| / r_{XE} \cdot 100\%$$

Computational experiments yielded sufficiently small relative errors (1% – 6%), which is attributed to the following approximate equalities [9, 11, 17]:

$$D_E \approx D_E^*, \quad \sigma_E \approx \sigma_E^*, \quad N(\varepsilon(i\Delta t)) \approx N^*(\varepsilon(i\Delta t)), \quad N(\varepsilon = m_E) \approx N^*(\varepsilon = m_E),$$

$$(m_E - \sigma_E) \approx (m_E^* - \sigma_E^*), \quad (m_E + \sigma_E) \approx (m_E^* + \sigma_E^*), \quad \left(\frac{1}{\sigma_E\sqrt{2\pi e}}\right) \approx \left(\frac{1}{\sigma_E^*\sqrt{2\pi e}}\right), \quad \mu_{Eq} \approx \mu_{Eq}^*;$$

$$D_X \approx D_X^*, \quad \sigma_X \approx \sigma_X^*, \quad N(x(i\Delta t)) \approx N^*(x(i\Delta t)), \quad N(x = m_X) \approx N^*(x = m_X),$$

$$(m_X - \sigma_X) \approx (m_X^* - \sigma_X^*), \quad (m_X + \sigma_X) \approx (m_X^* + \sigma_X^*), \quad \left(\frac{1}{\sigma_X\sqrt{2\pi e}}\right) \approx \left(\frac{1}{\sigma_X^*\sqrt{2\pi e}}\right), \quad \mu_{Xq} \approx \mu_{Xq}^*;$$

$$r_{XE} \approx r_{XE}^*.$$

Thus, the proposed algorithmic solutions were validated via computational experiments and via practical deployment of these mathematical formulations into the operation of real-world technical systems, proving their validity and efficiency [8, 16, 18–20].

5. Technologies for Assessing the Technical Condition of Building Structures based on the Characteristics of the Noise and the Useful Component

As noted above, structural condition changes result from either external influences or internal defects and malfunctions. When external influences change, the characteristics of the useful component shift, while the noise $E(t)$ remains uncorrelated with the useful signal. Consequently, correlation coefficient (32) becomes zero:

$$r_{XE}^* = 0. \tag{36}$$

Therefore, to identify the nature of the structural condition change, the correlation coefficient r_{XE}^* should be first calculated using formula (32). If condition (36) is met, the characteristics of the useful signal $X(t)$ are calculated using formulas (30) to (35). The variance D_{X-ti}^*, standard deviation σ_{X-ti}^*, moments μ_{Xq-ti}^* of order q, distribution function $N^*(x)_{ti}$, inflection points $A1_{X-ti}^*$, $A2_{X-ti}^*$, maximum $N^*(x = m_X)_{ti}$ of the $N^*(x)$ normal distribution density function calculated at each time instant t_i are compared against the reference values D_{X-t0}^*, σ_{X-t0}^*, μ_{Xq-t0}^*, $N^*(x)_{t0}$, $A1_{X-t0}^*$, $A2_{X-t0}^*$, $N^*(x = m_X)_{t0}$, obtained during training. If the differences exceed some threshold values:

$$\left|D_{X-ti}^* - D_{X-t0}^*\right| \geq D_{X-p}^*, \tag{37}$$

$$\left|\sigma_{X-ti}^* - \sigma_{X-t0}^*\right| \geq \sigma_{X-p}^*, \tag{38}$$

$$\left|\mu_{Xq-ti}^* - \mu_{Xq-t0}^*\right| \geq \mu_{Xq-p}^*, \tag{39}$$

$$\begin{aligned} N^*(x)_{ti} &\neq N^*(x)_{t0}, \\ A1_{X-ti}^* &\neq A1_{X-t0}^*, \\ A2_{X-ti}^* &\neq A2_{X-t0}^*, \\ N^*(x = m_X)_{ti} &\neq N^*(x = m_X)_{t0}, \end{aligned} \tag{40}$$

it means that the characteristics of the useful signal have changed as a result of external influence. If these new characteristics of the useful signal $X(t)$, i.e., variance D_{X-ti}^*, standard deviation σ_{X-ti}^*, moments μ_{Xq-ti}^* of the order q, distribution function $N^*(x)_{ti}$, inflection points $A1_{X-ti}^*$, $A2_{X-ti}^*$, maximum $N^*(x = m_X)_{ti}$ of the function $N^*(x)$ of the normal distribution density calculated at each time instant t_i fall within regulatory limits, they are stored in the knowledge base as updated reference values.

5.1. Technologies for assessing the technical condition of building structures by the characteristics of the noise

Alternatively, structural condition changes can stem from internal defects and malfunctions, causing the correlation coefficient r_{XE}^* between the useful signal $X(t)$ and the noise $E(t)$ to become non-zero:

$$r_{XE}^{*} \neq 0 \tag{41}$$

i.e., condition (36) is not met.

Then, noise characteristics (24) to (29) are calculated. The variance D_{E-ti}^{*}, standard deviation σ_{E-ti}^{*}, moments μ_{Eq-ti}^{*} of order q, distribution function $N^{*}(\varepsilon)_{ti}$, inflection points $A1_{E-ti}^{*}$, $A2_{E-ti}^{*}$, maximum $N^{*}(\varepsilon)$ of normal distribution density function $N^{*}(\varepsilon=m_{E})_{t0}$, calculated at each time instant t_i, are compared against the reference values D_{E-t0}^{*}, σ_{E-t0}^{*}, μ_{Eq-t0}^{*}, $N^{*}(\varepsilon)_{t0}$, $A1_{E-t0}^{*}$, $A2_{E-t0}^{*}$, $N^{*}(\varepsilon=m_{E})_{t0}$, obtained during training. If the differences exceed defined thresholds:

$$\left|D_{E-ti}^{*} - D_{E-t0}^{*}\right| \geq D_{E-p}^{*}, \tag{42}$$

$$\left|\sigma_{E-ti}^{*} - \sigma_{E-t0}^{*}\right| \geq \sigma_{E-p}^{*}, \tag{43}$$

$$\left|\mu_{Eq-ti}^{*} - \mu_{Eq-t0}^{*}\right| \geq \mu_{Eq-p}^{*}, \tag{44}$$

$$N^{*}(\varepsilon)_{ti} \neq N^{*}(\varepsilon)_{t0}, \tag{45}$$

this indicates that the technical condition of the building structure has changed as a result of external factors and there are no defects or malfunctions.

In this case, the information is transmitted to the control station to analyze the specific section of the building structure where the signal originated.

Thus, based on relations (30) to (35) and (41) to (45), the technical condition of the building structures is classified as follows: good – no damage or deformations, only minor, reparable defects exist; satisfactory – structural elements are generally operational but require major repairs; unsatisfactory – operation is permitted only after significant major repairs are performed; dilapidated – load-bearing structural elements are in a state of emergency.

6. Conclusion

The primary purpose of structural health monitoring is to detect defects, damages, and faults by collecting, analyzing, and processing noisy sensor signals. The proposed algorithms and technologies successfully provide maintenance personnel with critical data on the initiation and dynamics of malfunctions during the latent period of deformations, stresses, and defects. Ultimately, implementing these methods enables operators to prevent catastrophic emergencies and structural failures.

Author Contributions

N.F. Musaeva and T.A. Aliev developed algorithms for calculating the noise and useful signal characteristics. T.A. Aliev suggested the theory for analyzing interference of noisy signals as a carrier of information about the technical condition of technical objects, formulated the problem. T.A. Aliev, N.F. Musaeva and M.T. Suleymanova developed technologies for assessing the technical condition of building structures based on the characteristics of the noise and the useful component. The manuscript was written through the contribution of all authors. All authors discussed the results, reviewed, and approved the final version of the manuscript.

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References

[1] Sazonova, S., Nikolenko, S., Akamsina, N., Sysoev, D., Stenyukhin, L., Monitoring of the technical condition of structures and building materials of an elevator silo housing, *XIV International Conference on Transport Infrastructure: Territory Development and Sustainability (TITDS-XIV-2023)*, 471, 2024.

[2] Umanets, I., Basarab, V., Monitoring of the technical condition of buildings and structures under operational conditions, *Ways to Improve Construction Efficiency*, 51, 2023, 194-205.

[3] Skachkova, M.E., Lepihina, O.Y., Ignatova, V.V., Information support of monitoring of technical condition of buildings in construction risk area, International Conference Information Technologies in Business and Industry, *Journal of Physics: Conf. Series*, 1015, 2018, 042056.

[4] Sha, X., Zhang, X., High rise building steel structure monitoring and energy efficiency optimization based on BIM and strain sensor vibration signal processing, *EAI Endorsed Transactions on Energy Web*, 11, 2024, 1-10.

[5] Qureshi, A.H., Alaloul, W.S., Wing, W.K., Saad, S., Musarat, M.A., Ammad, S., Kineber, A.F., Automated progress monitoring technological model for construction projects, *Ain Shams Engineering Journal*, 14, 2023, 102165.

[6] Musaeva, N.F., A robust method of estimation under 'polluting' rough errors, *Automatic Control and Computer Sciences*, 6, 2003, 50–64.

[7] Musaeva, N.F., Technology for determining the magnitude of robustness as an estimate of statistical characteristic of noisy signal, *Automatic Control and Computer Sciences*, 39, 2005, 64–74.

[8] Aliev, T.A., Musaeva, N.F., Technologies for monitoring the technical condition of transport infrastructure objects based on the coefficient of correlation between critical values of noise and useful signals, *Transport Problems: An International Scientific Journal*, 17, 2022, 213-224.
[9] Aliev, T.A., Musaeva, N.F., Suleymanova, M.T., Gazizade, B.I., Technology for calculating the parameters of the density function of the normal distribution of the useful component in a noisy process, *Journal of Automation and Information Sciences*, 48, 2016, 39-55.
[10] Aliev, T.A., Musaeva, N.F., Technologies for early monitoring of technical objects using the estimates of noise distribution density, *Journal of Automation and Information Sciences*, 51, 2019, 12-23.
[11] Aliev, T.A., Musaeva, N.F., Gazizade, B.I., Calculation algorithms of the high order moments of interference of noisy signals, *Journal of Automation and Information Sciences*, 50, 2018, 1-13.
[12] Abdullayev, S.X., Abdullayev, Z.S., Abdullayeva, O.S., Beknazarova, S.S., Models of entropy encoding of television images in video information systems, *Proceedings of SPIE—The International Society for Optical Engineering*, 14014, 2025, 1401409.
[13] Kussainov, A., Zhomartkyzy, G., Thinakaran, R., Architecture of an intelligent predictive analytics system for gas environment monitoring based on sensor-series IoT devices, *International Journal of Advanced Computer Science and Applications*, 17, 2026, 485–490.
[14] Kakharov, Z., Ashimov, R., Dynamics of production processes with the energy method of calculations, *Lecture Notes in Civil Engineering*, 791, 2026, 470–479.
[15] Alam, M.N., Rahim, M.A., Hossain, M.N., Tunç, C., Dynamics of damped and undamped wave natures of the fractional Kraenkel-Manna-Merle system in ferromagnetic materials, *Journal of Applied and Computational Mechanics*, 10, 2024, 317–329.
[16] Aliev, T.A., *Noise Control of the Beginning and Development Dynamics of Accidents*, Springer, Cham, Switzerland, 2019.
[17] Aliev, T.A., Musaeva, N.F., Suleymanova, M.T., Gazizade, B.I., Analytical Representation of the Density Function of Normal Distribution of Noise, *Journal of Automation and Information Sciences*, 47, 2015, 24–40.
[18] Aliev, T.A., Musaeva, N.F., Quluyev, Q.A., Rzayeva, N.E., Technologies for Analyzing and Calculating the Relationship between the Useful Component and the Noise of Noisy Signal in Monitoring Systems, *Mekhatronika, Avtomatizatsiya, Upravlenie*, 23, 2022, 628–636.
[19] Aliev, T.A., Musaeva, N.F., Suleymanova, M.T., Gazizade, B.I., Sensitive Algorithms for Identifying the Degree of Fault Growth in Sucker Rod Pumping Units, *Mekhatronika, Avtomatizatsiya, Upravlenie*, 18, 2017, 94–102.
[20] Aliev, T.A., Musaeva, N.F., Gazizade, B.I., Technologies for Monitoring the Dynamics of Damage Development in Drilling Rigs Using High-Order Moments of the Noise, *Mekhatronika, Avtomatizatsiya, Upravlenie*, 21, 2020, 213–223.

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