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PRELIMINARY DETECTION OF SEISMIC SIGNAL ARRIVAL BY POLARIZATION FEATURE

Research is aimed at developing methodological principles for preliminary detection of the seismic signal arrival registered by a three-component seismic station (TCSS), taking into account polarization properties of background and signal components. Methods. Seismic signals were recorded using the GURALP CMG seismic observation network of the Main Special Control Center (MSCC) of the State Space Agency (SSA) of Ukraine. Result. The main difference between a signal component of a three-component seismic record and a background is polarization properties. Considering these characteristics makes it possible to detect seismic signals and determine their components. Traditional methods for analyzing polarization in a three-component seismic record often involve significant computational effort and are typically employed for processing and analyzing seismic data in real time. In this study, we propose a new approach that evaluates the linearity of the implemented methods and determines the angles of seismic wave arrivals. This is particularly crucial for monitoring potential emergency sources, such as hazardous objects and seismically active areas. Our method can also be applied in real-time scenarios. Scientific novelty. Considering the properties of polarization, as opposed to relying solely on amplitude detection criteria, enables the detection of signals with a lower signal-to-noise ratio. This increases the sensitivity of the Transient Coherent Seismic Source (TCSS) to magnitudes. By utilizing polarization analysis in seismic signal detection, we not only enhance detection capabilities but also gain additional information about the parameters of seismic signal components, such as their azimuth and angle of arrival at the surface. This information can be instrumental in identifying the seismic signal components and determining the location of the seismic event source in relation to the observation point (OP). Significance of research. This approach makes it possible to increase the magnitude sensitivity of OP and the observation system as a whole. The relative simplicity of implementation makes it possible to apply it in real time. Determining angular characteristics of seismic wave arrival allows applying the proposed approach in a continuous monitoring loop for potential emergency sources.

Keywords: seismic monitoring, three-component seismic station, seismic signal detection, polarization analysis.

Introduction

Recently, a trend has emerged in both international and national seismic observation networks to adopt relatively simple yet highly effective methods for detecting seismic signals at each station in a dense seismic observation network. This is followed by the comprehensive processing of these signals in specialized data centers [Vashchenko et al., 2012; Gordienko et al., 2017; Mashkov, Kyrylyuk, 2002a].

The territorial limitations of the National Seismic Observing System of Ukraine, which includes the *MSCC SSA* network [Vakaliuk, et al., 2023], highlight the necessity for developing strategies to address a comprehensive range of seismic monitoring tasks. This is especially important due to the temporary loss of the Crimean segment and the current inability to expand the network. Establishing individual seismic observation points where Temporary Seismic Centers (TSCs) are set up is essential for tasks such as detecting seismic signals, determining the components of seismic records, estimating parameters, pinpointing the focal point of seismic events, identifying their nature, and assessing the parameters of seismic sources and their potential implications.

Therefore, improving existing and developing new methodological approaches to processing TCSS measurement data is relevant.

This work is part and parcel of a planned set of research aimed at improving existing and developing new theoretical foundations for detecting by seismic means the hazards of natural and man-made emergencies that pose a threat to life.

Analysis of latest research and publications

The process of seismic signal detection consists of the following stages:

1. Preliminary detection. It includes real-time identification of a seismic recording area where a signal component is believed to be present with a certain probability;
2. Detection. It involves the post-operational mode, or a time mode close to real-time, for detecting seismic signals, identifying their components, and determining their parameters;
3. Processing of seismic signal. In the post-operational mode, it includes refining seismic signal

parameters, determining the focal point of a seismic event, identifying its nature, estimating seismic source parameters, and assessing the possible consequences of a seismic event.

It is preliminary detection that is most important, as it must detect a signal component at a certain level of false positives and be implemented in a real-time loop. Using this approach, seismic data processing can be unloaded from the main processing loop to apply algorithmic principles of full processing, which require more computational resources than preliminary detection.

Detection of seismic signals based on TCSS observations has been the subject of a number of studies [Mashkov, Kyrylyuk, 2002a; Mashkov, Kyrylyuk, 2002b; Gordienko et al., 2017; Li et al., 2020; Rivero-Moreno, & Escalante-Ramirez, 1996; Vakaliuk, et al., 2023; Withers, 1998; Zhao, 2021].

Most implemented approaches of preliminary detection use seismic signals from TCSS observations. They employ a criterion of exceeding the amplitude threshold, which is quite effective when signal-to-noise ratio is at least 2÷3.

Currently, the STA/LTA (Short Time Average to Long Time Average) detector is commonly used for the preliminary detection of seismic signals, including those within the MSCC observation network. This method involves processing a three-component seismic record, as defined in references [Trnkoczy, 2009; Vakaliuk, 2023, May; Withers, 1998]:

$$STA_i = \frac{1}{T}\sum_{j=i}^{i+T}\sqrt{n_j^2+e_j^2+z_j^2}\,, \qquad (1)$$

$$LTA_i = \frac{1}{M}\sum_{j=i-M}^{i}\sqrt{n_j^2+e_j^2+z_j^2}\,, \qquad (2)$$

$$\eta_i = \frac{STA_i}{LTA_i}\,, \qquad (3)$$

where $\{z_i, n_i, e_i\}$ are the current coordinates of soil particle displacement; T is the sample duration for which the signal is assessed; M – is the sample duration for which the background parameters are estimated; η is a signal-to-noise ratio.

This approach requires a relatively small amount of computation, which is a significant argument for its use in real-time measurement data processing systems [Alkaz, 1977].

A common disadvantage of existing approaches used in the preliminary detection stage, such as the Short-Term Average/Long-Term Average (STA/LTA) method, is the low information content of the results. These results only indicate a segment where a seismic signal is considered to be present with a certain probability. Furthermore, this approach does not always enable the detection of seismic signal components, which is particularly important for single-position seismic observations.

The next step involves estimating the parameters of the signal components. This includes specifying the arrival time, determining the amplitude, period, azimuth, and angle of the day's surface. This process takes place during the second stage of real-time detection.

However, based on the results of three-component seismic observations, it is possible to apply other criteria (signs) of signal components besides amplitude.

One of the characteristic features of a seismic signal and its components in TCSS recording is polarisation properties [Alkaz, 1977; Liashchyk, & Karyagin, 2018; Vakaliuk, 2023, May; Bataille, & Chiu, 1991]. Recordings of seismic waves from detonations, earthquakes, and other sources are characterised by linear polarisation of oscillations. At the same time, noise is a result of a superposition of waves coming from different sources and has a low level of linear polarisation. Polarisation analysis of vibrations can help detect this difference between signals and noise. The advantage of using a polarization analysis device (PAD) lies in its ability to not only determine the timing of seismic signal arrival but also to identify the main components of the signal and their angular characteristics, such as azimuth (α) and the angle of incidence relative to the daytime surface (β). This information is crucial as it relates to the location of a seismic event's focal point in relation to an observation point (OP) [Vakaliuk, 2023].

Linearity degree of a three-component seismic record $\{z_i, n_i, e_i\}$ is determined by results of calculation a covariance matrix ***K*** [11]:

$$K = \begin{vmatrix} \mathrm{cov}(n,n) & \mathrm{cov}(n,e) & \mathrm{cov}(n,z) \\ \mathrm{cov}(e,n) & \mathrm{cov}(e,e) & \mathrm{cov}(e,z) \\ \mathrm{cov}(z,n) & \mathrm{cov}(z,e) & \mathrm{cov}(z,z) \end{vmatrix}. \qquad (4)$$

The square shape (ellipsoid), defined by this matrix, is reduced to the main axes. The major axis of the ellipsoid characterizes orientation in space of full seismic wave displacement vector by angles, including azimuth α and angle for access to the daytime surface γ. Linearity coefficient G ($0<G<1$) an accepted implementation of a three-part record is defined as [Li et al., 2020; Bataille, & Chiu, 1991]:

$$G = 1 - \frac{b}{a}\,, \qquad (5)$$

where b and a are values of the smallest and largest semi-axis of the ellipsoid.

To determine the degree of linearity in a three-component seismic record, methods such as sequential polarization filtering [Gordienko, 2011] and the ellipsoidal approximation of the trajectory for soil particles are also utilized [Mashkov, Kyrylyuk, 2002a].

Current approaches for implementing PAD are used only in a post-operational mode, as their application requires significant computational costs.

Another approach for processing TCSS measurement data is polarisation filtering (PF). PF of three-component seismic data consists in recalculating the original three-component seismic record into full displacement vectors in a selected direction, which are multiplied by a weighting function [Gordienko, et al., 2010]:

$$p_i(\alpha,\gamma) = g_i \cdot G_1 \cdot G_2 , \qquad (6)$$

where g_i is full displacement vector in selected direction; G_1 is linearity coefficient ($0 < G_1 < 1$) accepted implementation of a three-component record, which is determined by expression [Gordienko, 2011]; G_2 – is the value of the angle between the position in space with the largest ellipsoid axis and a certain direction, which is set by the signal output angle on the daily surface γ and azimuth α.

The limitation of the Particle Filter (PF) application is the requirement for prior knowledge about the expected direction of seismic signal arrival. Additionally, in order to apply PF, it is necessary to assess the degree of linearity within the seismic recording area [Gordienko et al., 2010; Gordienko, 2011].

Therefore, an important task is to develop methodological foundations for the preliminary detection of seismic signals by considering their polarization properties, which can be implemented in real-time.

The object of research is a process of monitoring seismic situations and identifying sources of emergency events based on seismic observations.

The subject of research is methods of processing three-component seismic data.

Objective

The research aims to develop methodological principles for the implementation of seismic signal pre-detection considering the polarisation properties of a signal and background components.

Methods

Trajectory of soil particles during seismic wave transmission has a shape of a strongly elongated ellipsoid, and for background it is close to a sphere [Gordienko, et al., 2017]. Figs. 1 and 2 illustrate a three-component seismic recording of the first arrival (***P***-wave) signal from an earthquake with its epicenter in the Vrancha Mountains (Romanian part of the Carpathians, magnitude 4.2, dated May 22, 2004). This data was captured by the TCSS "Vorsovka" station located in Malyn, Zhytomyr region. The figures also show the trajectory of soil particle movement represented in three orthogonal projections, highlighting the corresponding areas of the seismic recording in Fig. 1. These examples demonstrate differences in nature of ground motion for background and signal. These differences are based on application of the PAD.

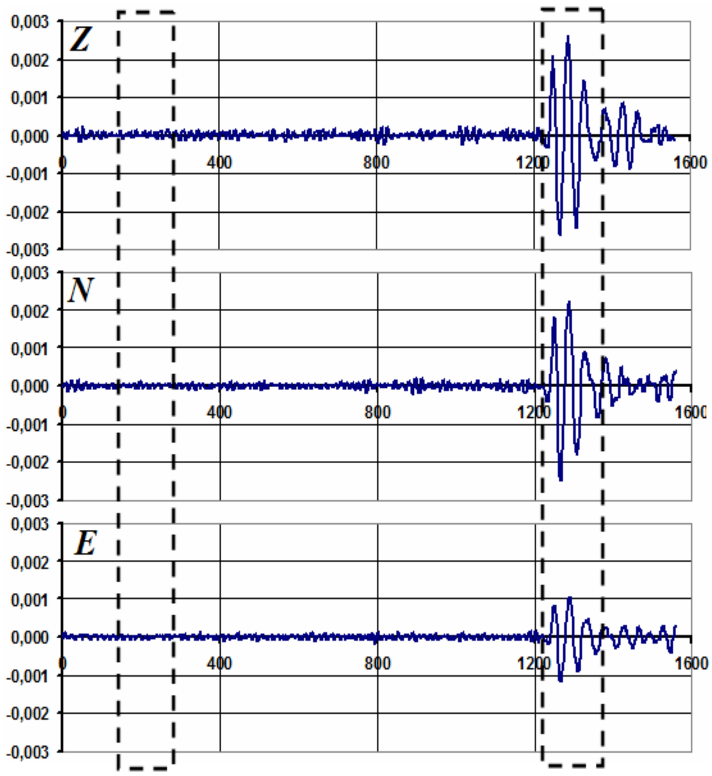


Fig. 1. Waveshapes of three-component seismic record with the first arrival of the signal from the earthquake with the focal point in Vrancea zone.

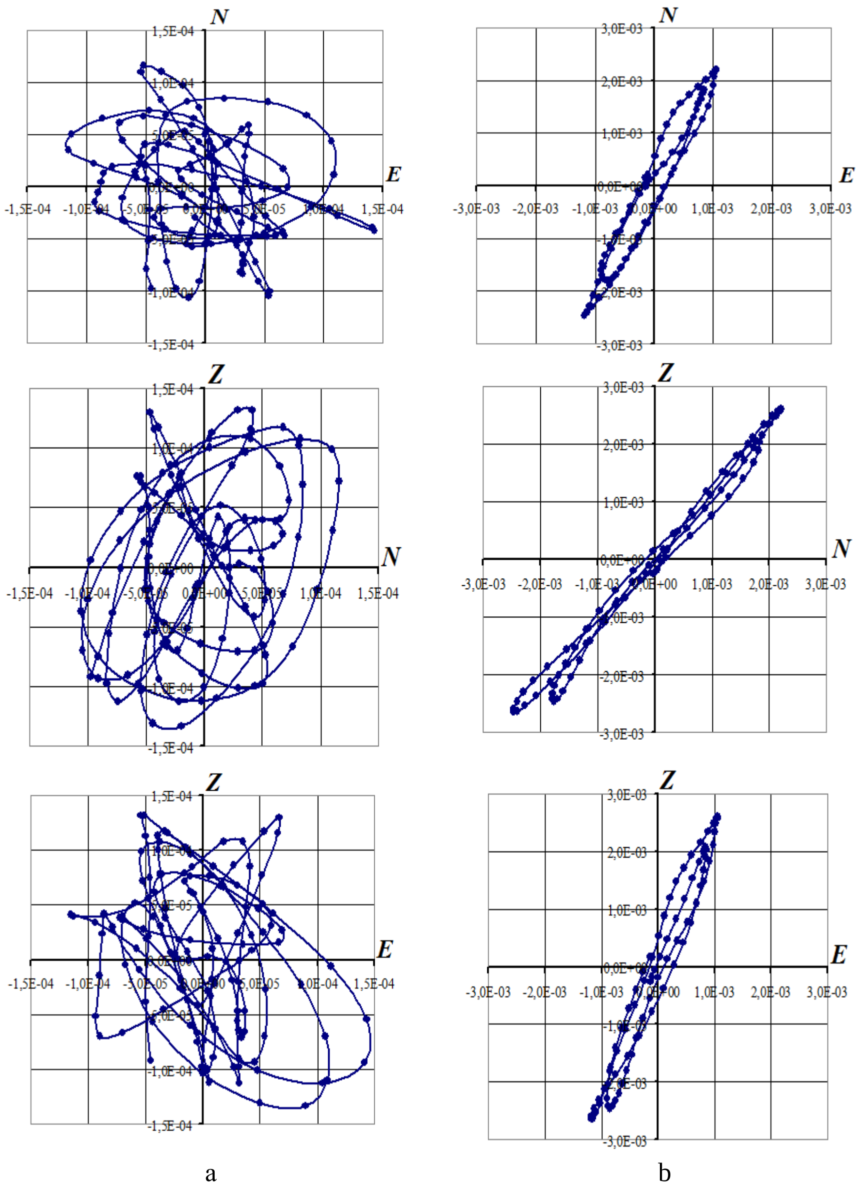


Fig. 2. Projections trajectory of soil particles
for background (a) and signal component (b).

The primary goal of existing approaches to polarization analysis, regardless of the specific implementation of the solving function, is to assess the degree or linearity of oscillations and determine the angular position in relation to the major axis of an ellipsoid. For the first arrival of a seismic signal (*P*-wave), this angular position indicates the direction of the seismic source relative to the observation point (OP). Having a priori information about the expected direction a seismic wave arrives, a degree or linearity of oscillations can be estimated as [Gordienko et al., 2010]:

$$Y = \frac{\sum_{i=1}^{T} |m_i|}{\sum_{i=1}^{T} |M_i|}, \qquad (7)$$

where $M_i\{z_i, n_i, e_i\}$, i = 1…T is the value (vector) of soil particle displacement;

$$|M_i| = \sqrt{z_i^2 + e_i^2 + n_i^2} \qquad (8)$$

z_i is the value of soil displacement on a vertical channel; e_i is Ground displacement values on the East-West channel; n_i is Ground displacement values on a North-South channel; T is a sample length; m_i is the value of sample projection to a certain (controlled or expected) direction, which is defined as

$$m_i = |M_i| \cdot \cos(M_i \wedge r);$$
$$m_i = z_i \cdot z + e_i \cdot e + n_i \cdot n. \qquad (9)$$

$r\{z,n,e\}$ is a unit vector defining controlled (expected) direction, whose coordinates are defined as

$$z = \sin(\gamma);$$
$$n = \cos(\gamma)\cdot\cos(\alpha); \qquad (10)$$
$$e = \cos(\gamma)\cdot\sin(\alpha).$$

γ is the expected angle of seismic wave exit to the daytime surface; ***α*** is theexpected azimuth of seismic wave arrival.

This approach is less costly than well-known ones based on considering the polarisation properties of signal and background, which allows it to be used in real-time. However, using this approach to solve problems of seismic signal detection also requires a priori information about seismic wave arrival direction, includinginformation about a controlled potentially hazardous object or seismically active zone.

As a preliminary indication of the expected direction of seismic wave arrival, it is suggested to use the angular position of maximum displacement from the obtained seismic data samples in a three-component record $M_{\max}\{z_{\max}, n_{\max}, e_{\max}\}$:

$$M_{\max} = \max|M_i|,\ i=1..T \qquad (11)$$

Fig. 3 presents the averaged angles between the main axes of the $r\{z,n,e\}$ (direction of seismic wave arrival), determined by the PAD application. These angles are compared against the position of the maximum sampling value $q\{z_q, n_q, e_q\}$ for varying signal-to-noise ratios.This example focuses on the first arrivals of *P*-waves from seismic events originating in a regional zone.Dotted lines show confidence intervals for mean angles at level ±*σ*.

Fig. 3 indicates that when the signal-to-noise ratio exceeds 2, the deviation at the maximum displacement position obtained from the main semi-axis of an ellipsoid does not exceed 3 degrees.

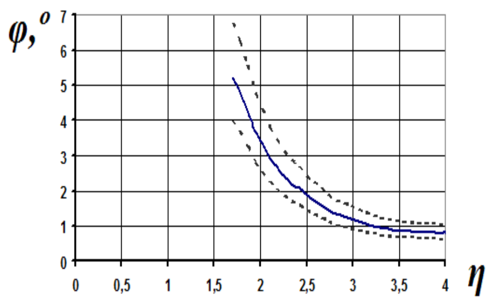


Fig. 3. Dependence of the angle between the position of a maximum sample value and largest semi-axis ellipsoid on signal-to-noise ratio.

Seismic signal detection is based on the assessment of oscillation degree or linearity (7), using value projection of a sample in the direction corresponding to the maximum value of a ground displacement obtained by the sample:

$$m_i = |M_i|\cos(M_i \wedge q); \qquad (12)$$
$$m_i = z_i \cdot z_q + e_i \cdot e_q + n_i \cdot n_q,$$

where, $q\{z_q, n_q, e_q\}$ is a unit vector that defines position in space of maximum displacement value

$$z_q = \frac{z_{\max}}{|M_{\max}|};\ e_q = \frac{e_{\max}}{|M_{\max}|};\ n_q = \frac{n_{\max}}{|M_{\max}|}. \qquad (13)$$

Table 1 presents the results of processing selected fragments of waveforms (Fig. 1, *a*) of a three-component seismic record using both existing (4)–(6) and proposed (11)−(13) methods.

Table 1

Results on processing three-component seismic recordings with background and signal components for different methods to determine angular characteristics and degree of linearity

Parameters	PAD		Maximum value		ME		MLS	
	Image	Signal	Image	Signal	Image	Signal	Signal	Image
Linearity coefficient	0.51	0.99	0.62	0.97	0.65	0.86	0.49	0.99
Azimuth of arrival ***α***, °	142.1	205.6	127.4	204.8	133.1	201.3	141.7	205.9
Exit angle *γ*, °	52.3	46.3	60.8	44.4	28.7	42.4	52.6	46.1

A decision regarding the presence of a seismic signal is made when the current value of the estimated degree of linearity exceeds a predetermined threshold $Y_i \geq h_Y$. This threshold h_Y is determined by Neumann – Pearson criterion [Pichugin, 2006], which minimises the probability β of missing a signal while ensuring that the probability of a false detection α does not exceed a given value α_Y.

The detection threshold is determined by a probability of a false positive is 0.05

$$\alpha_Y = \int_{h_Y}^{\infty} P(Y)dY = 0{,}05 \tag{14}$$

Fig. 4 shows distributions of estimates for degree linearity of seismic background determined by the proposed method (11)−(13) and seismic / noise ratio (1)–(3).

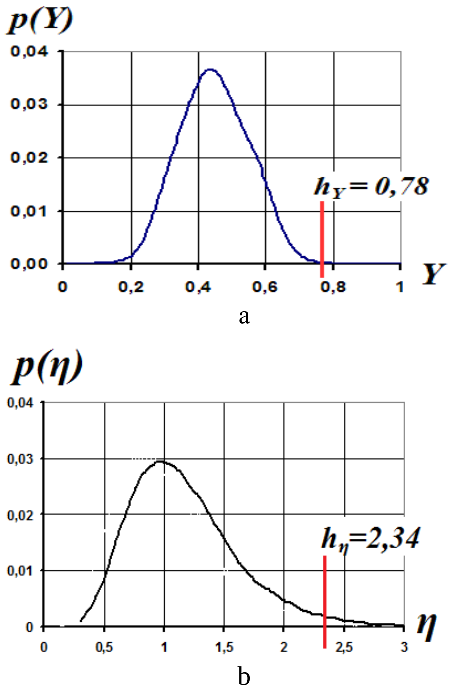


Fig. 4. Distribution values for linearity estimation according to the proposed method (a) and STA / LTA values (b) for the background component.

Under the condition (14), a threshold value is h_Y = 0.78 (Fig. 4, *a*). Under the same condition, when detecting a signal using the STA/LTA ratio, the threshold value is h_Y = 2.34 (Fig. 4, *b*). It is important to note that signal-to-noise ratio thresholds will vary depending on the location of different seismic receivers. Additionally, the detection threshold based on amplitude criteria can be affected by various factors, including seasonal changes, weather conditions, and human activity. Therefore, it is necessary to periodically update this value.

The next issue is to clarify and define the angular characteristics of a seismic signal as it arrives at the observation point (OP), specifically the azimuth and the angle of arrival at the bottom surface.

Azimuth and angle for seismic wave arrival at ground surface are defined as:

$$\gamma = arctg \frac{z_{\max}^2}{\sqrt{e_{\max}^2 + n_{\max}^2}}; \tag{15}$$

$$\gamma = arctg \frac{z_{\max}^2}{\sqrt{e_{\max}^2 + n_{\max}^2}}, \tag{15a}$$

$$\alpha = arctg \frac{e_{\max}}{n_{\max}}. \tag{16}$$

In [Pichugin, 2006], azimuth to exit angle is defined as mathematical expectation (ME) angles calculated for each value obtained from the sample.

$$m_\gamma = \frac{1}{T} \sum_{i=1}^{T} arctg \frac{z_i^2}{\sqrt{e_i^2 + n_i^2}}, \tag{17}$$

$$m_\alpha = \frac{1}{T} \sum_{i=1}^{T} arctg \frac{e_i}{n_i}. \tag{18}$$

Table 1 shows that values of angles obtained by applying classical approaches (15)−(18) differ from those obtained by applying PAD.

To determine angles of seismic wave arrival, it is proposed to use a method of least squares (MLS) [Kosulina et al., 2020]. The azimuth of seismic wave arrival is determined using MLS by:

$$\theta = \frac{T \cdot \sum_{i=1}^{M} e_i \cdot n_i - \sum_{i=1}^{M} e_i \cdot \sum_{i=1}^{M} n_i}{T \cdot \sum_{i=1}^{M} n_i^2 - \left(\sum_{i=1}^{M} n_i \right)^2}. \tag{19}$$

The angle of seismic wave exit onto the daily surface is defined as:

$$\vartheta = \frac{T \cdot \sum_{i=1}^{M} z_i \cdot g_i - \sum_{i=1}^{M} z_i \cdot \sum_{i=1}^{M} g_i}{T \cdot \sum_{i=1}^{M} g_i^2 - \left(\sum_{i=1}^{M} g_i \right)^2}. \tag{20}$$

where

$$g_i = \frac{n_i}{\cos\theta}. \tag{21}$$

The azimuth of seismic wave arrival and angle of exit on the day surface is defined as:

$$\gamma = arctg\vartheta. \tag{22}$$

$$\alpha = \begin{cases} arctg\theta & \vartheta > 0 \\ arctg\theta + \pi & \vartheta < 0 \end{cases}. \tag{23}$$

Fig. 5 shows projections of soil particle movement using signal component (Fig. 1) and regression function values determined using MLS (red line).

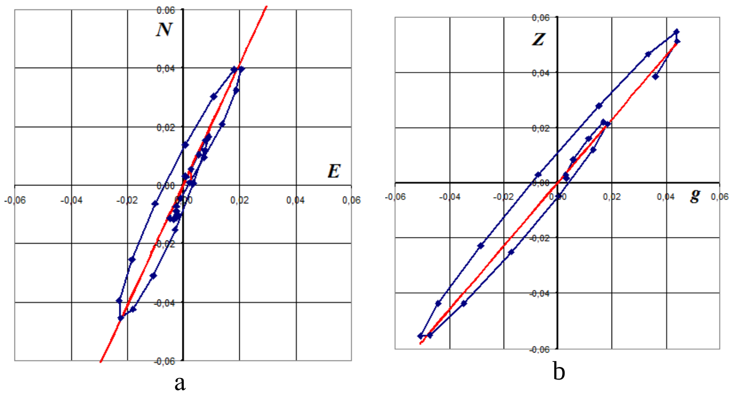


Fig. 5. Projections of particle trajectories on NOE (a) and ZOg (b) planes.

The linearity coefficient is determined by expressions (7)−(10). At the same time, obtained values of seismic wave arrival angles (17)−(21) are used to determine the parameters of a single vector $r\{z,n,e\}$.

Results

Fig. 6 presents the results of using both existing methods (STA / LTA) and the proposed approaches for detecting the arrival of seismic signals (*P*-waves). This analysis is based on the processing of three-component seismic recordings from an earthquake that occurred in the Chernivtsi region (16.01.2020, *M* = 2.4), registered by TKSS of PS "Poltava" (Poltava region). The results of processing using both existing and proposed methods to assess the degree of linearity and angular characteristics of a seismic signal are presented in Table 2. As shown in Fig. 6, applying the amplitude criterion results in the loss of a seismic signal. Conversely, lowering the detection threshold can lead to false detections (area 1 of Fig. 6, *b*).

Application of the proposed approach allows detecting seismic signal arrival (area 2 of Fig. 6, *c*).

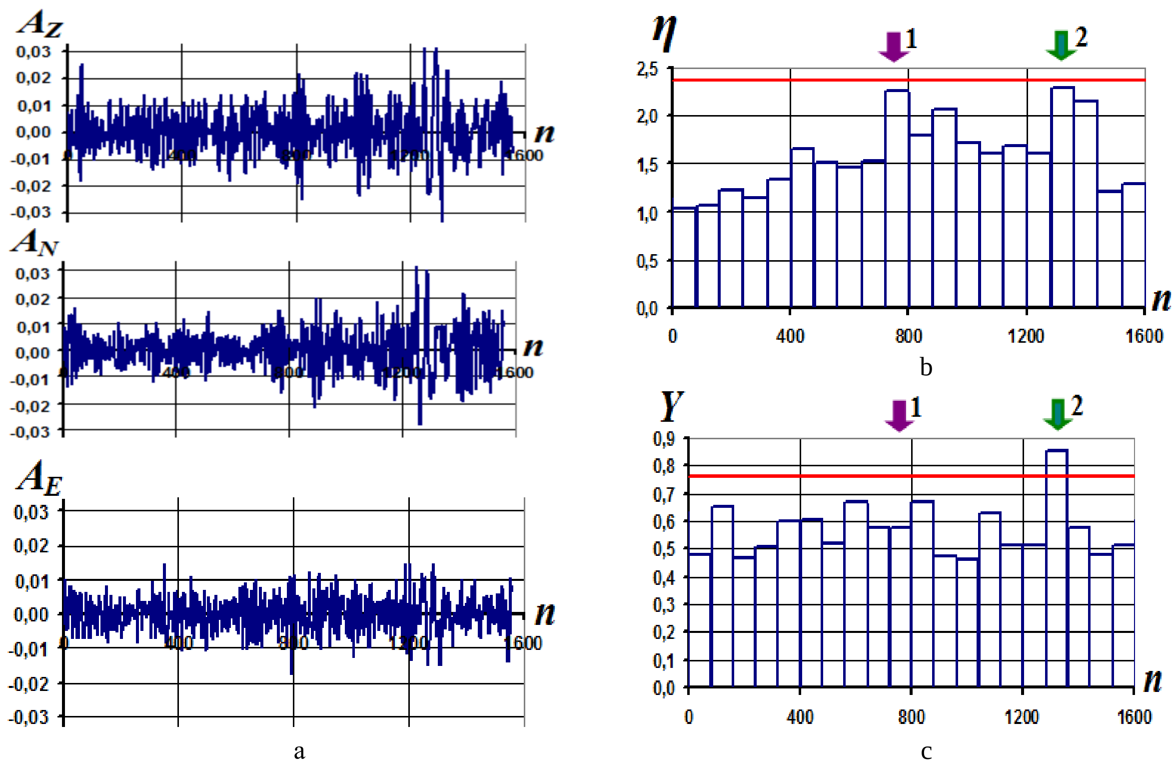


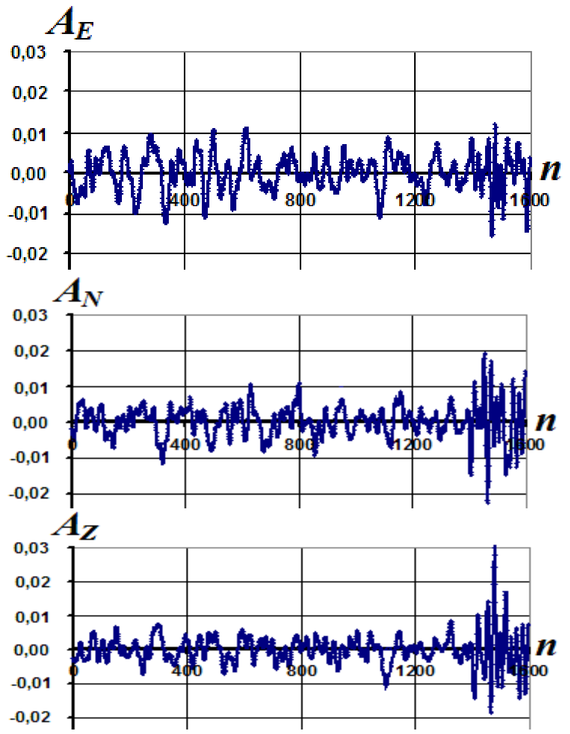
Fig. 6. Waveforms of three-component seismic recording of the first signal arrival from earthquake with focal point in Chernivtsi region:
a – waveforms of seismic recording; b – signal-to-noise ratio (STA / LTA);
c – linearity estimation value based on maximum sample value.

Table 2

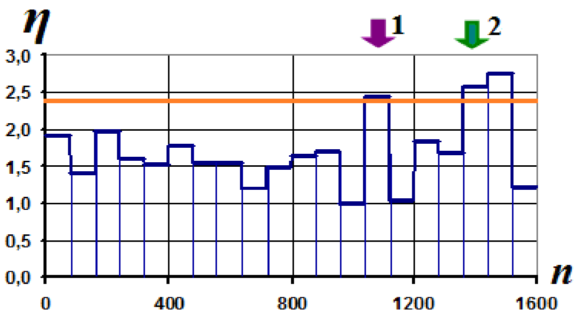
Results for processing a three-component seismic recording with a signal component for different methods in determining angular characteristics and a degree in linearity (background – section 1, signal – section 2, Fig. 6)

Parameters	PAD		Maximum value		ME		MLS	
	Back-ground	Signal	Back-ground	Signal	Background	Signal	Background	Signal
Linearity coefficient	0.67	0.88	0.59	0.86	0.47	0.82	0.63	0.89
Azimuth of arrival *α*, °	47.4	261.1	44.3	257.8	62.2	238.6	46.7	261.3
Exit angle, °	22.6	37.3	20.1	39.5	18.2	26.7	22.4	36.9

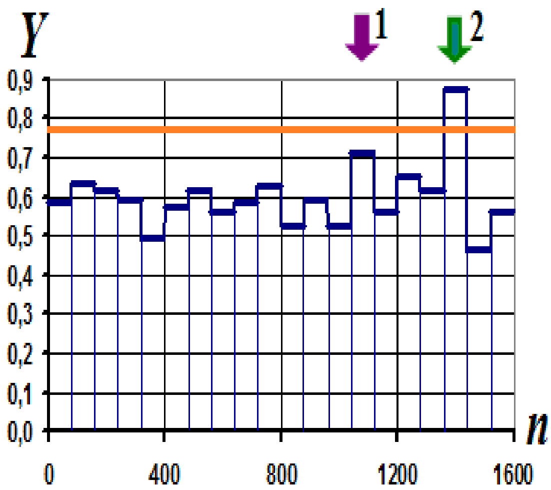
Fig. 7 presents the results of applying the considered approaches to detect the arrival of a seismic signal (*P*-wave) from an earthquake with a center in the Vrancha Mountains (*M* = 2.8, 09.09.2021) registered by the TCSS of the Vorsovka PS.



a



b



c

Fig. 7. Presents the waveforms of the first arrival of seismic signals from an earthquake with the epicenter in the Vrancea Mountains, along with the results of the processing:
a – seismic record waveforms;
b – signal-to-noise ratio (STA/LTA);
c – linearity degree estimation based on the maximum sample value.

As shown in Fig. 7, applying the amplitude criterion leads to false detection of the seismic signal arrival (area 1 of Fig. 7, *b*). Increasing the detection threshold may result in missing the useful signal (area 2 of Fig. 7, *b*).

The application of the proposed approach allows extracting a specific segment of the seismic record (area 1 of Fig. 7, *c*), while also detecting the arrival of the signal component (area 2 of Fig. 7, *c*). The results of determining the linearity degree and angular characteristics of the seismic signal arrival are presented in Table 3.

Table 3

Results for processing a three-component seismic recording with a signal component for different methods in determining angular characteristics and a degree in linearity (background – section 1, signal – section 2, Fig. 7)

Parameters	PAD		Maximum value		ME		MLS	
	Backg round	Signal	backg round	Signal	Back ground	Back-ground	Signal	Back-ground
Linearity coefficient	0.56	0.86	0.71	0.84	0.63	0.78	0.56	0.82
Azimuth of arrival α, º	122.1	205.2	133.4	206.3	133.1	197.3	141.7	204.8
Exit angle, º	61.6	46.8	33.5	47.2	19.2	36.3	48.2	46.6

Therefore, the proposed method enables the detection of seismic signals by assessing the linearity of oscillations in relation to the maximum displacement of soil particles within the sample, determining the angular characteristics of seismic signal arrival, and estimating the degree of linearity.

Research innovation and practical significance

Application of the proposed approach in comparison with the amplitude detection criterion has the following advantages:

– increase in magnitude sensitivity of OP;

– possibility to obtain additional information about seismic signal parameters, namely azimuth and angle of seismic wave exit to day surface, which in turn is related to location of seismic event centre relative to OP;

– the approach can also be used to detect seismic signal components.

In addition, application of the proposed approach The method requires less computational effort compared to existing methods of polarization analysis, enabling its implementation in a real-time loop. By determining additional information in the preliminary detection loop of a seismic signal –specifically, the angular characteristics of seismic waves (azimuth and angle of exit) – we can incorporate this data into the monitoring of potential sources of emergency events.

Conclusions

This publication presents a method for the preliminary detection of seismic signals recorded by TCSS based on polarization. The approach proposes using the linearity coefficient, calculated as the ratio of the projection of the sample's ground displacement vector in the direction of the maximum value to the total displacement value of the sample.

This method enables the selection of a segment of the seismic recording containing the signal component and allows for the preliminary determination of angular characteristics, such as azimuth and angle of exit, that are recorded.

An MLS is used to determine angular characteristics of a seismic signal.

The proposed approach enhances detection performance compared to the currently used STA / LTA detector, thereby increasing the magnitude sensitivity of MSCC observation points. Additionally, the low number of computational operations required allows this method to be applied in real time.

The simplicity of the proposed approach not only facilitates the detection of seismic signals with a lower signal-to-noise ratio during the preliminary detection stage but also enables the determination of angular characteristics of the seismic signal component. This capability is particularly important for monitoring potential sources of emergency events.

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ПОПЕРЕДНЄ ВИЯВЛЕННЯ ВСТУПУ СЕЙСМІЧНОГО СИГНАЛУ ЗА ПОЛЯРИЗАЦІЙНОЮ ОЗНАКОЮ

Мета досліджень – розроблення методологічних засад попереднього виявлення вступу сейсмічного сигналу, зареєстрованого трикомпонентною сейсмічною станцією (ТКСС), з урахуванням поляризаційних властивостей фонової та сигнальної складових. Методика. Реєстрацію сейсмічних сигналів здійснено за допомогою ТКСС GURALP CMG мережі сейсмічних спостережень Головного центру спеціального контролю (ГЦСК) Державного космічного агентства (ДКА) України. Результати. Основною відмінністю сигнальної складової трикомпонентного сейсмічного запису від фону є поляризаційні властивості, урахування яких дає змогу виявляти сейсмічні сигнали та визначати їх складові. Відомі підходи щодо поляризаційного аналізу трикомпонентного сейсмічного запису потребують значних обчислювальних затрат та, як правило, застосовуються для опрацювання та аналізу сейсмічного запису за контуром реального часу. У роботі запропоновано підхід, який дає змогу оцінювати ступінь лінійності прийнятої реалізації та визначати кути надходження сейсмічної хвилі, що особливо важливо для вирішення завдань моніторингу потенційних джерел надзвичайних подій (потенційно небезпечних об'єктів та сейсмоактивних районів) і який можна використовувати у контурі реального часу. Наукова новизна. Врахування поляризаційних властивостей, на відміну від амплітудних критеріїв виявлення, дає змогу виявляти сигнали із меншим відношенням сигнал / шум, тим самим підвищуючи магнітудну чутливість ТКСС. Застосування поляризаційного аналізу для виявлення сейсмічного сигналу дає змогу, окрім виявлення, отримувати додаткові відомості про параметри складових сейсмічного сигналу (азимут та кут виходу на денну поверхню), які можна використовувати для ідентифікації складових сейсмічного сигналу та визначення місцеположення джерела сейсмічної події відносно пункту спостереження (ПС). Практична значущість. Запропоновано підхід, який дає змогу підвищити магнітудну чутливість ПС та мережі спостережень загалом. Завдяки відносній простоті реалізації запропонований підхід можна застосовувати у режимі реального часу. Визначення кутових характеристик надходження сейсмічної хвилі дає змогу застосовувати запропонований підхід у контурі безперервного моніторингу потенційних джерел надзвичайних подій.

Ключові слова: сейсмічний моніторинг, трикомпонентна сейсмічна станція, виявлення сейсмічного сигналу, поляризаційний аналіз.

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