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DETECTION OF A SEISMIC SIGNAL BY A THREE-COMPONENT SEISMIC STATION AND DETERMINATION OF THE SEISMIC EVENT CENTER

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ABSTRACT

Context. The work is devoted on the development of theoretical foundations aimed at automating process of determining location at the seismic event center.

Objective. The purpose of the work is to develop a method for determining the center of a seismic event based on the use of the features of the angular characteristics of the constituent volume waves of a seismic signal obtained with the help of a three-component seismic station. The proposed method will reduce the time it takes to provide users with preliminary information about the fact of a seismic event and its parameters.

Method. The method of automatic detection focal point is based on features of orthogonality in the angular characteristics volume waves registered sample of three-component seismic recordings from a certain direction. Implementation of the proposed approaches makes it possible to reduce the processing time of the seismic record with appropriate reliability compared to processing in manual mode.An example application of the proposed method (algorithm) for processing a seismic signal in the Vrancea zone on 27.10.2004 with magnitude M=5.7 is considered.

Results. The proposed approach to processing the measured data of a separate seismic three-component seismic station using a polarization analysis device allows detecting the arrival of a seismic signal, identifying the main components of a seismic signal, and estimating the location of the epicenter of a seismic event.Experimental research on the use of the proposed algorithm for determining the location of the epicenter of a seismic event showed that the time of establishing an emergency event within the borders of Ukraine was reduced five times (from 15 to 3 minutes), and the detection error was 37 km.

Conclusions. The formed basis and proposed approach to detecting a seismic signal, identifying its components and determining a seismic event focal point based on results of processing a three-component seismic record are effective. Proposed method (algorithm) should be used to automate process of seismic signal detection by a three-component seismic station and to determine the seismic event center.

KEYWORDS: Earthquake, seismic waves, seismic signal, signal detection, three-component seismic station, seismic monitoring, automatically controlled monitoring system, source of emergency.

ABBREVIATIONS

CPS is a Civil Protection System;

CSE is center of the seismic event;

DMNS is a disaster monitoring system;

ES is emergency situations;

MCSM is a Main Center for Special Monitoring;

OP is a observation points;

SGS is a seismic grouping system;

SON is a seismic observation network;

SSA is a State Space Agency;

STA/LTA Short Time Average to Long Time Average;

TCSS is a three-component seismic stations;

UN is a United Nations.

NOMENCLATURE

T is a sample duration for which signal estimation is performed;

η is a signal-to-noise value;

$\{n_i, e_i, z_i\}$ – a actual coordinates of soil particle displacement;

G is a linearity coefficient;

b is a smallest semi-axis of ellipsoid;

c is a largest semi-axis of ellipsoid;

M is a covariance matrix;

G_i is a current value of the linearity coefficient;

P-waves is a seismic wave that travels through the Earth in a longitudinal manner;

S-waves is another type of seismic wave that travel through the Earth;

L_r Rayleigh is surface waves that have both longitudinal and transverse motion;

L_q Love is surface waves that only have transverse motion;

Ω_i value of angle between the position of the main semi-axis of ellipsoid for the obtained sample and direction of *P*-wave arrival;

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$\{x_p, y_p, z_p\}$ – coordinates of a unit vector position for the main axis in P-wave;

$\{x_i, y_i, z_i\}$ – coordinates of a unit vector position the main semi-axis by the current sample.

INTRODUCTION

The direct result of human activity is man-made ES, which arise as a result of disruptions in normal living conditions and human activity at facilities or territories. According to UN, more than 70 thousand people die annually in Ukraine as a result of emergencies and significant material losses are incurred by the state [1].

Earthquakes are one of the most dangerous natural phenomena that can occur in Ukraine. Depending on causes and location, earthquakes are divided into tectonic, volcanic, landslide, and seaquakes [2]. Earthquake centers are located almost 60 km deep, and sometimes up to 700 km deep. Many earthquakes are accompanied by large human casualties. Number of victims depends on suddenness of natural disaster, strength, area of damage and population density in the area of the earthquake.

In Ukraine, seismically active zones are located in the southwest and south: Zakarpattia, Vrancha, Crimean-Black Sea and South Azov zones. It is known [2] that 290 thousand square kilometers of the territory of our country with a population 15 million people are located in earthquake zones. In order to organize and ensure the protection against consequences of man-made disasters, the CPS was created in Ukraine [3]. Main tasks of civil protection are as follows [4]: prevention and implementation measures to reduce damages and losses in case of industrial and natural disasters; prompt notification on occurrence or threat of disasters, timely and reliable information about the current situation and measures taken to prevent disasters and overcome their consequences; organization of protection against disasters, provision emergency psychological, medical and other assistance to victims.

In order to fulfill tasks assigned to the civil protection system, it is necessary timely receive information about emergencies and their consequences. For this purpose, according to the Civil Protection Code of Ukraine, a DMNS is created. In Ukraine, the disaster monitoring system is based on collecting and analyzing information coming from various means of control and surveillance about conditions of relevant hazardous facilities or territories. At the same time, the task of enhancing SES capabilities by expanding monitoring methods is becoming urgent.

One information segment within the DMNS is the MCSM of SSA, which, through the National Seismic Observation System and the Governmental Information and Analytical System for Disasters, provides information to the CPS on the seismic situation in Ukraine and neighboring countries [5]. The SON of MCSM includes TCSS, a SGS, which was included in the International Seismic Monitoring Network as PS-45 station, and a National Data Center (Fig. 1).

Figure 1 – Network of seismic observation MCSM SSA of Ukraine

The object of study is the process for monitoring seismic situation and determining location of a seismic event center.

The subject of study is method automatic determination of seismic event center.

Currently, processing of seismic observation data is carried out in manual and automatic modes. However, decisions on seismic event parameters and possible consequences are made by operational duty officer on duty of MCSM based on the results analysis of information on seismic signal parameters (time arrival of main types a seismic waves, their amplitude and period) received from each observation point [5]. The temporary loss the Crimean peninsula led to territorial limitations of the GCSC seismic observation network. This necessitated the development algorithms for identifying nature a seismic source based upon results of seismic data processing in automatic mode from individual observation points.

The aim of the work is to develop a methodology for determining location of the seismic event center based on data analysis of a three-component seismic station, which is part of the MCSM SON.

1 PROBLEM STATEMENT

Currently, the MCSM has implemented methods of seismic measurement data processing that allow providing users with preliminary information about the parameters of a seismic event and possible consequences within 15 minutes, and the final information within 40 minutes from the time of event [6]. This period is due to data processing based on algorithms for “manual” processing by seismic station operators. Within the framework established by national and international programs, the MCSM is modernizing seismic observation equipment, transmission and processing of measurement data (transition to digital information processing). This will allow us to move to a qualitatively new level of seismic monitoring.

These circumstances require solving an important scientific task, essentially developing a method for determining a center of a seismic event based on determining angular characteristics of components of TCSS seismic signal volume waves.

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Formulate a mathematical statement of the problem. Assume a given distance between a post and a monitoring object, as well as angular characteristics of first seismic signal arrival at ground surface. Then the problem of determining a seismic event center by a three-component seismic station is to calculate coordinates of a seismic source. Specifically, azimuth at the source relative from the observation point and distance between our observation point and source of seismic event. A polarization analysis apparatus is used to solve the problem.

2 REVIEW OF THE LITERATURE

In [7], a method is considered of data polarization analysis, which determines angular characteristics a seismic wave arrives to the Earth's surface in certain seismic survey areas identified as a result of preliminary detection. Polarization analysis units used to process TCSS measurement data are also considered. This method of automatic seismic event detection is based on neural networks. In general, the method is reliable and capable of correctly identifying phase types, while ensuring the accuracy and precision needed to assess them. The disadvantage of using this method is that it is difficult to apply.

In [8], another approach to using polarization analysis devices is considered, which consists in increasing a signal-to-noise ratio of seismic vibrations from a certain direction (polarization filtering). This approach allows detecting seismic signals from sources with cells located along the propagation path (beam), which is characterized by azimuth α and angle of incidence on Earth's surface γ, but does not determine the exact position within the beam.

In [9], automatic methods for detecting seismic events are considered, which allow for quick data analysis. The simplest automatic methods for processing seismic data that have become popular in international and national data centers around the world are STA/LTA [10]. These methods use a criterion for exceeding amplitude thresholds when detecting seismic signals based on TCSS observations. The disadvantage with these methods is that their application leads to an increase in the number of observations in the seismic monitoring system and, accordingly, the number of individual OP.

Since MCSM seismic station network has limited territorial coverage, especially after temporary loss of Sevastopol and Yevpatoriya stations due to occupation of Crimea by the Russian Federation, there is a need to develop methodological principles for solving seismic monitoring problems by individual stations with TCSS [11]. In addition, this need is caused by problems of ensuring functional stability of seismic observation network as a whole, especially in cases when seismic data from several stations cannot be used – equipment failure, communication interruption, maintenance.

Thus, it is important to develop an automated method for determining a focus of a seismic event that could lead to an emergency situation involving man-made and natural hazards using a single OP.

3 MATERIALS AND METHODS

Solving seismic monitoring tasks at a single observation point consists of the following stages: detection a seismic signal, identification of seismic record components (determination of seismic wave types), location a seismic event center, and estimation seismic source parameters. In case of single-position observations, the last three stages are solved if the problem of determining main components of the seismic record is confidently solved. Therefore, when analyzing the existing methods of seismic data detection and processing, the main attention will be paid to this problem solving capability. Another criterion should be the simplicity of the software and algorithmic implementation of processing methods, which in turn will ensure a possibility of processing the measurement data in real time.

Most of the implemented approaches to detecting seismic signals based on TCSS observations use the criterion of exceeding the threshold in amplitude, which are quite effective at an energy signal-to-noise ratio of at least 3. At present, the STA/LTA detector, whose definition is given in [7], is widely used for preliminary detection of seismic signals based on TCSS observations

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

$$LTA_i = \frac{1}{5T}\sum_{j=i-5T}^{i}\sqrt{n_j^2 + e_j^2 + z_j^2}, \tag{2}$$

$$\eta_i = \frac{STA_i}{LTA_i}. \tag{3}$$

This approach requires a relatively small amount of computation, which is a significant argument for its use in real-time measurement data processing systems [7]. However, use of this approach leads to a limitation of the magnitude sensitivity of the seismic station. In addition, this method doesn't allow to accurately determine the components of a seismic signal, since arrival of a next seismic wave occurs against background of tail part of the previous one.

Figure 2 shows results of processing seismic signals from earthquakes with centers in the Vrancea seismically active zone (Romanian part of the Carpathians) using the STA/LTA detection method.

As can be seen from this example, the application of the amplitude-based detection method doesn't always allow to determine the seismic signal components. For the second signal after first arrival, threshold is exceeded five times, since the arrival of next seismic wave occurs against a background of tail part of the previous one (Figure 2 b).

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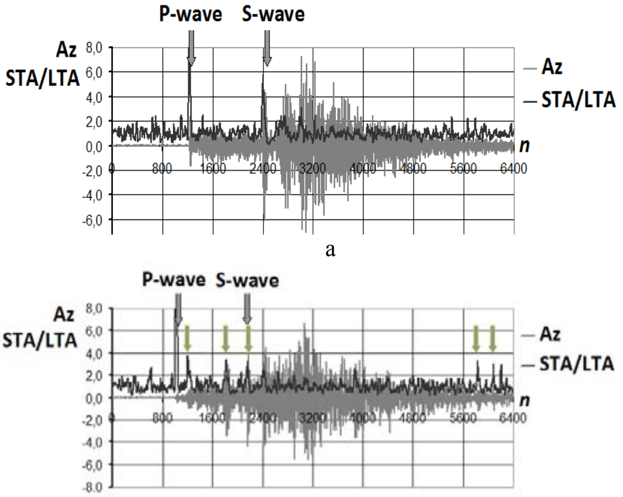

a

b

Figure 2 – Results of processing seismic signals from earthquakes with centers in the Vrancea zone, using the STA/LTA detection method: a – 27.9.2004, M=4.6; b – 27.10.2004, M=5.7

As can be seen from this example, the application of the amplitude-based detection method doesn't always allow to determine the seismic signal components. For the second signal after first arrival, threshold is exceeded five times, since the arrival of next seismic wave occurs against a background of tail part of the previous one (Figure 2 b).

Importance of information.

When solving problems of detecting seismic signal components based on the results of processing measurement data of a three-component seismic recording, it is necessary to apply additional criteria (features).

4 EXPERIMENTS

One of features of the seismic signal and its components in TCSS recording is polarization properties [7, 9]. Recordings of seismic waves from explosions, earthquakes, and other sources are characterized by linear polarization of oscillations, while noise is the result a superposition of waves arriving on the station from different sources and having a low level of linearity of polarization. These differences between signals and noise can be detected by polarization analysis of oscillations. They are especially useful in detecting signals with a frequency close to noise frequency, where frequency filtering is ineffective. Advantage of using PAA is that its results, in addition to the time of seismic signal arrival, make it possible to determine main components of seismic record and their angular characteristics (azimuth and angle of exit to day surface), which in turn is related to location of seismic event center relative to OP [8].

Figure 3 shows the nature of soil particle displacement for main types a seismic waves typical for seismic events with foci in local and regional zones.

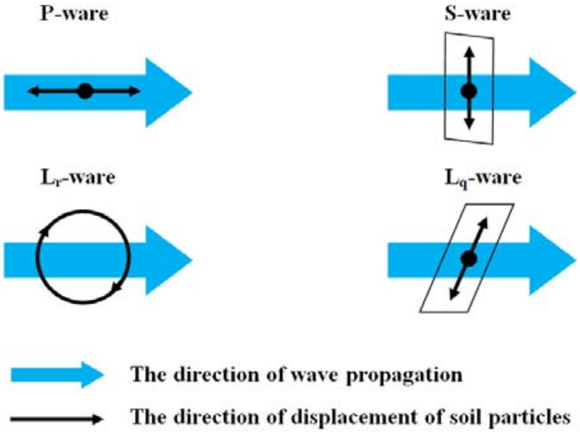

Figure 3 – The nature of soil displacement for different types of seismic waves

According to the nature of soil movement during seismic wave propagation, they are divided into volumetric – longitudinal *P*, transverse *S*; and surface – L_r and L_q waves. For *P*-waves, compression and liquefaction occurs in direction of wave propagation. For *S*-waves, soil displacement occurs perpendicular to direction of wave propagation. Along with bulk waves, surface waves propagate. These waves are of two types: L_r and L_q. In a Rayleigh wave, soil particles move in a vertical plane oriented along wave propagation, and their trajectories form ellipses. In the Lova wave, particles move in a horizontal plane across wave propagation direction [12].

Figure 4 presents a three-component record of seismic signal from earthquake with a center in Vrancea seismic zone (1.05.2011, M=4.8) registered by TCSS installed at OP Vorsovka (Zhytomyr region) and shows horizontal components of soil particle displacement for background and seismic signal components. A similar pattern of ground vibrations is typical for the Chornobyl NPP location.

Taking into account specific features of soil particle displacement for each main type of seismic waves in an event with centers in regional areas, angle characteristics of such waves will be related to the position of the seismic source relative to the OP as follows [8]:

– *P*-wave – since oscillation of particles in soil occurs along seismic wave propagation direction, the calculated angular characteristics coincide with position of seismic event center relative to the OP ($\alpha_P=\alpha_{sec}$, $\gamma_P=\gamma_{sec}$);

– *S*-wave – due to soil oscillation occurs perpendicular to direction of wave propagation at this phase, angular characteristics are calculated (α_S, γ_S) will be different from direction to seismic event center relative to OP at 90°;

– *Lr*-wave – a superficial wave with elliptical polarization focused perpendicular to propagation direction, so its calculated azimuth will be different from input azimuth one on 90°,that is $\alpha_{Lr} \perp \alpha_P$;

– *Lq* – wave is a surface wave with an elliptical polarization in direction of propagation, so the calculated azimuth will coincide with actual azimuth to seismic source ($\alpha_{Lq}=\alpha_P$) [3].

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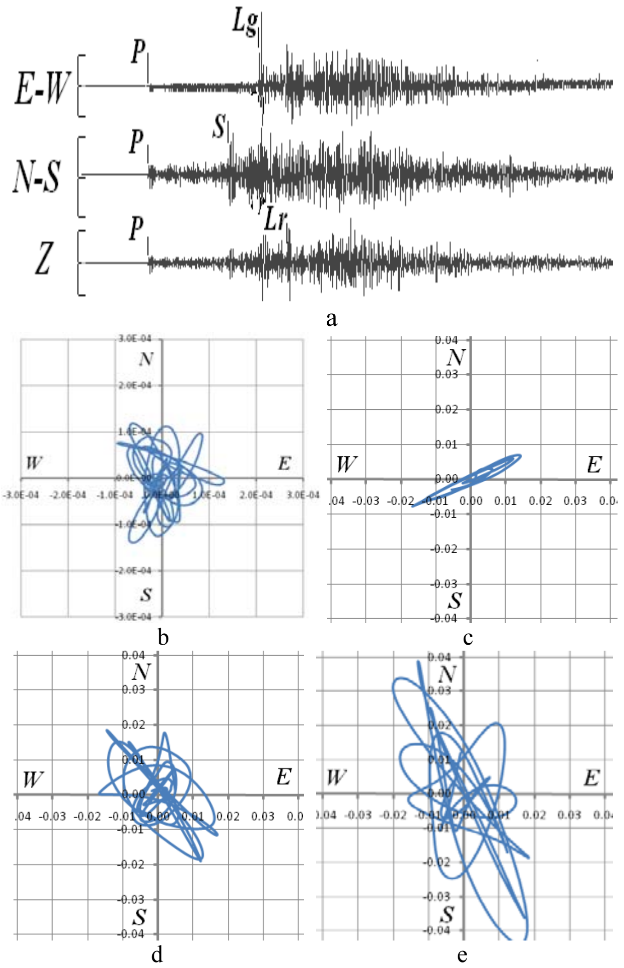

a

b c

d e

Figure 4 – Seismic signal from an earthquake with a focus in Vrancea area (a), horizontal displacements of soil particles for background area (b) and seismic signal components *P*-wave (c), *S*-wave (d) and L_g-wave (e)

At the same time, for seismic events with foci in local and regional zones, it is advisable to limit detection and identification to only bulk waves, since for a group of surface waves, due to relatively small distances, differences in arrival times of surface waves between each other and *S*-wave are insignificant, which leads to a complex wave pattern.

Taking into account the peculiarities of displacement particles in soil during passage by bulk waves, detection S-wave seismic signal can be realized as a search for seismic signal recording area for which conditions of orthogonal angular characteristics are met $(\alpha_P,\gamma_P)\perp(\alpha_S,\gamma_S)$.

Polarization analysis of a three-component seismic record. Trajectories of soil particles during seismic wave propagation have a shape of elongated ellipses, and in case of noise, they are close to circular. Polarization analysis of a seismic wave recording allows us to numerically estimate how closely oscillations describe a shape that corresponds to an ellipsoid. For this purpose, a three-component recording is used to $\{x_i, y_i, z_i\}$ covariance matrix M is calculated [13].

$$M=\begin{Vmatrix}\operatorname{cov}(x,x) & \operatorname{cov}(x,y) & \operatorname{cov}(x,z)\\ \operatorname{cov}(y,x) & \operatorname{cov}(y,y) & \operatorname{cov}(y,z)\\ \operatorname{cov}(z,x) & \operatorname{cov}(z,y) & \operatorname{cov}(z,z)\end{Vmatrix}. \qquad (4)$$

A quadratic shape (ellipsoid) defined by this matrix is reduced to major axes. Major axis of ellipsoid characterizes orientation in space of full seismic wave displacement vector by angles – azimuth α and angle of incidence γ. At the same time, azimuth of the *P*-wave arrival coincides with azimuth of seismic event center relative to the observation point. Linearity coefficient $G\,(0<G<1)$ adopted for the implementation a three-component recording is defined as [11]:

$$G=1-\frac{b}{c}. \qquad (5)$$

For determining a degree of linearity in a three-component seismic record, sequential polarization filtering, approximation the trajectory path of the soil particles by an ellipsoid, etc. [11, 13, 14]. Despite different methodological principles, main goal of known approaches to polarization analysis is determining how close oscillations within a registered sample of a three-component seismic record are to a certain direction.

5 RESULTS

Feature of angular characteristics orthogonality of volume waves can be used as a basis for the algorithm of seismic event focal point detection. Based on above, algorithm for determining seismic event focal point by using angular characteristics of seismic signal volume wave components based on results of TCSS measurement data processing will include the following stages:

Stage 1 – detection of seismic signal arrival (*P*-wave);

Stage 2 – estimation of angular characteristics of the seismic signal arrival (*P*-wave) – α_P and γ_P;

Stage 3 – finding the seismic signal recording areas with angular characteristics that correspond to the S-wave – fulfillment of the condition $(\alpha_P,\gamma_P)\perp(\alpha_S,\gamma_S)$;

Stage 4 – determination coordinates of the seismic source center.

Let us consider application this approach (algorithm) for processing seismic signal from earthquake with center in Vrancea zone on 27.10.2004, M=5.7 (Figure 5).

At first stage, seismic signal arrival is detected by amplitude criterion using STA/LTA detector (Figure 5 a). Detector parameters: T = 40 samples, which at a sampling rate of 40 Hz corresponds to 1s of seismic recording. A decision on presence signal is made if the STA/LTA threshold is exceeded STA/LTA≥3 (Figure 5 b).

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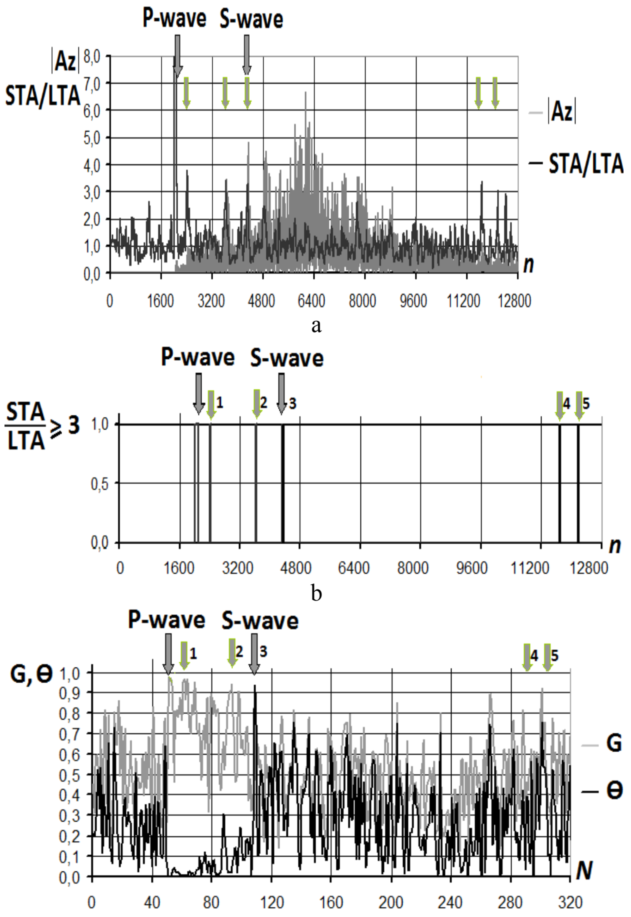

a

b

c

Figure 5 – Results of processing a seismic signal from an earthquake with a center in the Vrancea zone (27.10.2004, M=5.7) by a proposed method: a – envelope of a seismic record; b – STA/LTA detector response; c – values of linearity coefficient G and solving function θ

At stage two, polarization analysis apparatus (4) is used for first seismic signal arrival, which results in value of linearity degree G_P, angular position of major axis ellipsoid, which in turn determines azimuth of seismic wave arrival α_P by angle of exit to day surface γ_P. Azimuth of *P*-wave arrival coincides with azimuth to seismic event center relative to observation point.

At a third stage, we search for a recording section for which a condition is fulfilled – angular position for the main semi-axis ellipsoid for a sample obtained is orthogonal to position of the *P*-wave $(\alpha_P, \gamma_P) \perp (\alpha_i, \gamma_i)$. Determination from the seismic signal component corresponding to *S*-wave is performed by searching for a maximum value of solving function (Figure 5 c):

$$\theta_i = G_i \cdot \sqrt{1 - \Omega_i^2}\ ; \qquad (6)$$

$$\Omega_i = \left| x_P \cdot x_i + y_P \cdot y_i + z_P \cdot z_i \right| . \qquad (7)$$

Coordinates a unit vector position main axis are related to azimuth *α* and angle exit *γ* seismic wave and is defined as [9]:

$$\begin{aligned} x &= \cos(\gamma) \cdot \cos(\alpha); \\ y &= \cos(\gamma) \cdot \sin(\alpha); \\ z &= \sin(\gamma). \end{aligned} \qquad (8)$$

In the fourth stage, coordinates for a seismic event focal point are determined by applying a direct geodetic problem, which is to determine the coordinates a seismic source (λ, φ) based on information about coordinates of an observation point (λ_{ps}, φ_{ps}), azimuth to source relative an observation point and distance between an observation point and a seismic event source.

Based on results from processing by proposed method, following results were obtained:

– as a result of using STA/LTA detector (Figure 5 b), first seismic signal arrival falls at 52 seconds from beginning of recording. After first signal arrival, detector is triggered at 61, 52, 108, 292 and 304 seconds.

– as a result of applying APA for first arrival, following values were obtained: G_P=0.99, α_P=205°, γ_P=44°;

– maximum decisive function θ falls at 108 seconds relative that of seismic;

– distance between CSE and OP is determined by seismic wave hodograph.

Figure 6 shows results for calculating CSE location using the proposed method and results of processing measurement data from the Ukrainian State Space Agency seismic observation network. Error in determining for the location a CSE when using our pro-posed method and based on results of processing the SON MCSM data is Δ=37 km.

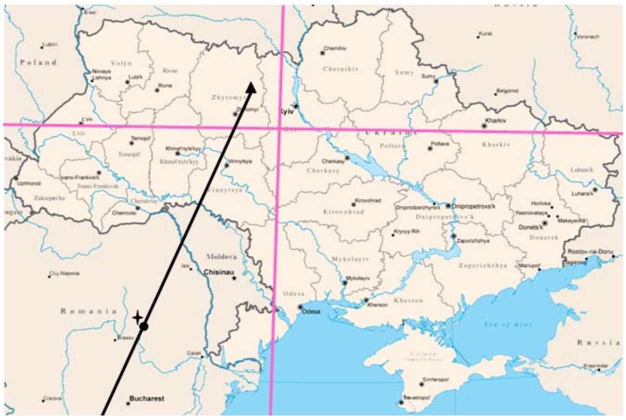

Figure 6 – Results of calculating location of OP using proposed method and based on results from pro-cessing of measurement data of SON MCSM

As a result, a proposed approach to processing the measurement data of a separate three-component seismic station using a polarization analysis apparatus allows detecting seismic signal arrival, identifying the main components of a seismic signal, and estimating location of a seismic event center.

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6 DISCUSSION

Although there is a general global trend in building and developing seismic observation networks, results obtained in this work prove possible to solve almost entire list of seismic monitoring tasks in the regional area by a separate TCSS – detection of a seismic signal, determination of the main components of a seismic record, and location of the seismic event center.

However, this is important in context with the territorial limitations of Ukraine's seismic observation network of the SON MCSM, especially after temporary loss of "Sevastopol" and "Yevpatoriya" observation points due to occupation of the Crimean Peninsula.

Methodological principles for detecting main types of seismic waves are based on polarization properties as well as volume waves and orthogonality oscillations in soil particles. Determination a seismic event center is based on kinetic and dynamic properties of main types a seismic waves and their connection between position a seismic event center relative to OP.

Determined relationships and results obtained on their basis can be considered as basis for approaches on continuous remote monitoring of potential sources of emergency events by seismic means

CONCLUSIONS

Prospects of seismic monitoring, within framework of fulfillment tasks for information support by seismic event center on seismic situation, are development and improvement of methodological and algorithmic means for complex processing seismic measurement data in order to promptly provide conclusions about possibility and fact a dangerous event. In this work, we analyze components of seismic signals from events with foci in the regional zone.

The scientific novelty of the study obtained is to establish a connection between angular characteristics between main seismic signal components for events with foci in the regional zone and position of a seismic event focal point relative to the observation point. Basic principles are formed and an approach is proposed for detecting and identifying seismic signal components in automatic mode, depending on the features and angular characteristics of seismic signal components, and determining seismic event focal point.

The practical orientation of the study is intended for use as basis of developed methodological principles for automatic processing of measurement information at output from a TCSS. Implementation of proposed approaches allows to reduce processing time of seismic data compared to manual processing by operator.

1. In order to automate seismic detection process of hazard factors related to man-made and natural disasters, it is advisable to use separate three-component stations that are part of the seismic observation network of the Main Center for Special Control of Ukraine.

2. At present, energy method is used to detect seismic signals based on the results of observations by three-component stations, which requires a small amount related to computation, which is an essential argument for its use in real-time measurement data processing systems. However, using this approach leads to a limitation in magnitude sensitivity a seismic station.

3. When solving the problems of detecting seismic signal components based on the results processing measurement data from a three-component seismic recording, it is proposed using a polarization apparatus, which will allow taking into account the peculiarities and angular characteristics a seismic signal's volume wave components.

4. Experimental studies using the proposed method for determining the location center of a seismic event showed that the time for establishing an emergency event within Ukraine was reduced from 15 to 3 minutes, while the determination error was 37 km. This indicates that our method is effective in determining location of the event center by a three-component seismic station.

Prospects for further research is to develop algorithms for identifying nature a seismic source based on results from seismic data processing in automatic mode in order develop an information system for detecting hazards of man-made and natural disasters by seismic means.

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ВИЯВЛЕННЯ СЕЙСМІЧНОГО СИГНАЛУ ТРИКОМПОНЕНТНОЮ СЕЙСМІЧНОЮ СТАНЦІЄЮ ТА ВИЗНАЧЕННЯ ОСЕРЕДКУ СЕЙСМІЧНОЇ ПОДІЇ

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АНОТАЦІЯ

Актуальність. Робота присвячена розвитку теоретичних засад, спрямованих на автоматизацію процесу визначення місцезнаходження осередку сейсмічної події.

Мета роботи – розробка методу визначення осередку сейсмічної події на основі використання особливостей кутових характеристик складових об’ємних хвиль сейсмічного сигналу, отриманого за допомогою трикомпонентної сейсмічної станції. Запропонований метод призведе до зменшення часу надання попередньої інформації користувачам про факт сейсмічної події та її параметри.

Метод. В основу методу автоматичного визначення осередку сейсмічної події покладено особливості ортогональності кутових характеристик об’ємних хвиль зареєстрованої вибірки трикомпонентного сейсмічного запису з певного напрямку. Реалізація запропонованих підходів дозволяє з відповідною достовірністю зменшити час обробки сейсмічного запису у порівнянні з обробкою у ручному режимі. В роботі розглянутий приклад застосування запропонованого методу (алгоритму) для обробки сейсмічного сигналу у зоні Вранча 27.10.2004 р. з магнітудою M=5,7.

Результати. Запропонований підхід щодо обробки вимірюваних даних окремої сейсмічної трикомпонентної сейсмічної станції з використанням апарату поляризаційного аналізу, дозволяє здійснювати виявлення вступу сейсмічного сигналу, проводити ідентифікацію основних складових сейсмічного сигналу та проводити оцінку місцеположення осередку сейсмічної події. Експериментальні дослідження по використанню запропонованого алгоритму визначення місцезнаходження осередку сейсмічної події показав, що час встановлення надзвичайної події в межах України скорочено в п’ять разів (з 15 до 3 хвилин), а помилка визначення становить 37 км.

Висновки. Сформовані основи та запропонований підхід щодо виявлення сейсмічного сигналу, ідентифікацію його складових та визначення осередку сейсмічної події за результатами обробки трикомпонентного сейсмічного запису є ефективними. Запропонований метод (алгоритм) доцільно застосовувати при автоматизації процесу виявлення сейсмічного сигналу трикомпонентною сейсмічною станцією та визначення осередку сейсмічної події.

КЛЮЧОВІ СЛОВА: землетрус, сейсмічні хвилі, сейсмічний сигнал, виявлення сигналу, трикомпонентна сейсмічна станція, сейсмічний моніторинг, автоматизована система моніторингу, джерело надзвичайних подій.

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