The concept of an automatic system for preliminary entry of hazardous facility into emergency mode with an approaching earthquake

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Abstract. The article discusses the concept of introducing an automatic system for preliminary input of hazardous facilities into emergency mode in the event of an approaching earthquake, developed at the South Ukrainian National Pedagogical University named after K. D. Ushinsky. Theoretical prerequisites for the study of heterogeneities, using a passive method based on the location of secondary waves reflected from the inhomogeneities under the basements and foundations of buildings of already operated building structures, were taken as the basis of the proposed system. Due to the finite speed of propagation of seismic waves and having a sensor in the focus of an earthquake, it is possible for distant objects to learn about an impending disaster in a few tens of seconds. The effective use of the time window from the focus of the earthquake to hazardous facilities requires the development of: measuring equipment, data transmission systems, automatic event recognition, elements for automating the process of putting hazardous objects into emergency mode - all this is the goal and objectives of this article.

1. Introduction
Among natural disasters, earthquakes are the most destructive. Unlike hurricanes and floods, which can be predicted by meteorological services, earthquakes occur suddenly for no apparent reason, leaving no opportunity to prepare for a disaster. The influence force of nature finds trains in motion, people in elevators, cranes with lifted loads, hazardous production in the midst of a shift, etc. It is obvious that this force of nature can provoke a number of technogenic accidents, which lead to an increase in human casualties and economic losses. Until now, all attempts at early prediction of earthquakes have been unsuccessful [1-3]. However, due to the finite speed of propagation of seismic waves, it is still possible for distant objects to learn about an impending disaster in a few tens of seconds [4]. Effective use of this time window, which requires the development of: measuring equipment, data transmission systems, automatic event recognition, elements of automation of the process of putting hazardous facilities into emergency mode - all this is the goal and objectives of this project.
2. Theoretical information and main idea concept
The velocities of seismic waves in the earth's crust are known - they are about 6 km/s for longitudinal waves and 3.5 km/s for shear waves, which have the main destructive effect. Consider an element of the Google map of the Vrancea area (Figure 1), which is known for the periodic epicentre of earthquakes and adjacent earthquake-prone regions (investigation in Greece region [5]). This area is located 110 km from Bucharest, 250 km from Chisinau and 350 km from Odessa. With the help of a special manual for the speed of transverse waves, it is not difficult to calculate that they will reach Bucharest in $\approx 30$ s, Chisinau in $\approx 70$ s, and Odessa in $\approx 100$ s.

![Figure 1. Google map of Vrancea area and adjacent earthquake-prone regions](image.png)

Obviously, having a sensor in the center of the earthquake, which is connected with the indicated cities by a radio channel, it's possible to know about the approaching element in advance for those very few tens of seconds. Naturally, notifying the population at such time intervals is out of the question. Mass evacuations from apartment buildings, schools and public institutions will only exacerbate the situation. However, this time may be sufficient to lower elevators to the first floor, stop the movement of goods in ports and construction sites, start emergency braking of trains, stop conveyors and shut off pipelines of hazardous chemical industries, cut off gas supply, cut off ammonia pipelines at refrigeration plants, transfer hospitals for autonomous power supply, etc.

For this task, special seismic receivers were developed, which are distinguished by high performance characteristics and are easily integrated into modern telemetry systems.

When designing low-frequency seismic receivers, an optical method was chosen for converting mechanical vibrations into electrical ones, which does not depend on the frequency of ground vibrations. The signal-to-noise ratio of optical converters is much higher than that of capacitive and inductive ones. In works [6, 7], successful results are given on the use of interferometric laser seismic receivers. Such seismic receivers are distinguished by high sensitivity and a relatively simple converter circuit, but their weak point is the laser, which has a relatively short service life (about 10,000 hours) and requires a rather complex temperature stabilization circuit. The high-power consumption of such seismic receivers causes problems with autonomous power supply. Converters using an optocoupler (LED / photodiode) are less sensitive to pendulum oscillations, but their service life is 10 times longer, they are more economical and do not require additional temperature and current stabilization circuits.
In works [8, 9], a method is given for calculating an integrator and a differentiator for adjusting the amplitude-frequency response of seismic receivers assembled on analogue microcircuits. However, the modern architecture of microcontrollers allows to completely abandon analogue control circuits, solving the problem of adjusting the amplitude-frequency response by changing the coefficients directly in the control equation, which in discrete representation has the form:

\[ U(t) = P x(t) + I \sum \left( \frac{x(t_i) + x(t_{i-1})}{2} \right) \Delta t + D \left[ x(t + \Delta t) - x(t - \Delta t) \right] / 2 \Delta t \]  

where P, I, D – weight coefficients, x(t) – deviation from the equilibrium position on the seismogram, Δt – time between measurements.

The principle of operation of a digital seismic receiver (Figure 2) is that the signal of the converter is digitized by means of an analogue-to-digital converter (ADC) and the control signal is calculated using the formula (1). The control signal from the pulse width modulation (PWM) generator is applied directly to the electromagnetic feedback coil.

![Block diagram of a digital seismic receiver](image)

**Figure 2.** Block diagram of a digital seismic receiver

Through the digital input / output interface, the seismic receiver is tuned by entering the weighting coefficient and a digital signal is output for recording and visualizing the data.

Obviously, this approach greatly simplifies calibration and allows the seismic receiver to be tuned remotely via digital communication lines and even via the Internet. Figure 3 shows a photo of the system, which includes a digital optical seismic receiver, an optical microbarograph and a minicomputer for registration, automatic data processing and external communication via the Internet or other digital lines.
Figure 3. Digital seismic receiver and microbarograph connected to the Internet by means of a microcomputer

Provided that an optical conversion method is used, where a powerful magnet and an inductor are not required, such a device is no larger than a matchbox with batteries and wireless digital communications. This miniaturization of devices allows you to solve a number of problems, for example:

- reduction in the cost of measuring equipment due to lower consumption of materials;
- reducing the cost of installing seismic receivers due to the smaller diameter of filling wells;
- delivery of equipment to hard-to-reach places by unmanned aerial vehicles;
- creation of reconnaissance and signal systems with the recognition of seismic images by the spectrum of seismic vibrations, etc.

3. Experimental technique.

Seismic receiver will be located around Vrancea in two zones (Fig. 4):

I Focsani, Buzau, Ploiesti;
II Bacau, Bârlad, Galati, Bucharest.

As an example, Figure 7 shows a diagram of the installation of digital seismic receivers developed at Ushinsky University with data transmission over the Internet.

By Internet channel, with a frequency of 1 s, the seismic receivers will transmit to the server the maximum amplitude values for the last 30 seconds. The time of 30 seconds is the maximum value for which a seismic wave propagates from zone I to zone II.
On the server, automatically in on-line mode, according to the amplitudes of seismic waves in zones I and II, the amplitudes of seismic waves will be extrapolated using an exponential approximating function, and a hazard level code will be generated, which will be received by the actuators via the radio channel. In turn, each actuator can only be activated at a certain level of danger. At the same time, in Chisinau, it will take about 40 seconds to take security measures, and about 70 seconds for Odessa.

Figure 5 shows the general structure of an automatic system for preliminary input of hazardous facilities into emergency mode in the event of an approaching earthquake.

Figure 4. Installation diagram of digital seismic receivers with mixed data transmission to the server

Figure 5. The structure of an automatic system for preliminary input of hazardous facilities into emergency mode in the event of an approaching earthquake, where 1 - seismic receivers, 2 - Internet lines, 3 - server and decision-making center, 4 - dedicated radio channel, 5 - actuators.
4. The discussion of the results.
During 2020 - 2021, a prototype of the proposed system was installed at the Ukrainian Antarctic Station "Akademik Vernadsky", which successfully operates to this day in harsh polar conditions. The system includes 4 spaced seismic receivers and 4 microbarographs combined into a seismic and acoustic antenna (Figure 6), which, against the background of strong natural noise, record seismic and atmospheric phenomena with high reliability.

![Figure 6. Scheme of installation of optical seismic receivers and acoustic sensors on Galindez Island in the vicinity of the Antarctic station "Akademik Vernadsky"](image)

Specially developed on-line software detects, locates and recognizes signals, as well as classifies them using a neural network and generates a report, which is sent via the Internet to the Antarctic Center in Kiev.

5. Conclusions
Today, there are all the prerequisites for the creation of an automatic system for preliminary input of hazardous facilities into emergency mode in the event of an approaching earthquake. For this, the main blocks of the system have already been created:
- sensors;
- means of communication;
- software;
- executive devices of the "smart home" type;
which need to be combined into a single system.

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