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INTEGRATION OF CYBER-PHYSICAL SYSTEMS INTO THE LANDSLIDE MONITORING PROCESS

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Abstract
Landslides occupy an important place among natural disasters and cause serious damage to human life, infrastructure, and economy. Given the limitations of traditional monitoring methods, Cyber-Physical Systems (CPS) can provide revolutionary advances in landslide prediction and prevention. The main objective of the study is to investigate in depth the benefits provided by the integration of CPS into landslide monitoring processes. In this context, the use of modern technologies such as wireless sensor networks and big data analysis is reported. The processes of information collection, transfer and analysis are explained in detail; Emphasis has been placed on the use of different sensors and real-time processing of the data obtained from these sensors. The results of the research will contribute significantly to the better understanding and management of landslide risk, and will lead to the development of strategies to reduce the effects of natural disasters. These results reveal the effectiveness of using CPS in landslide monitoring and early warning systems.

Key words. Cyber-physical systems, sensor, machine learning, wireless sensor networks, early warning, geological information

Introduction

Landslides occupy an important place among natural disasters and cause serious problems to human life, infrastructure and economy. In this context, the development of landslide monitoring and early warning systems is of great importance[2]. Although traditional landslide monitoring methods are based on the collection and analysis of geological and meteorological data, the integration of Cyber-Physical Systems (CPS) in recent years has brought revolutionary advances in this process.

CPS are systems that integrate information and communication technologies to monitor and control physical processes. These systems optimize real-time data collection, analysis, and decision-making processes by creating a two-way interaction between the physical world and the cyber world. In this context, the use of CPS in landslide monitoring processes helps to obtain more accurate and faster results[6].

This paper examines the integration of CPS in the landslide monitoring process and makes comparisons with previously published studies in this area. First, the literature on landslide monitoring and early warning systems was reviewed, and the advantages and disadvantages of existing methods were discussed. Then the integration of CPS into landslide monitoring processes and the benefits of this integration were discussed.

Purpose

Landslide monitoring and development of early warning systems should not be limited to traditional methods. The capabilities provided by cyber-physical systems (CFS) can provide a significant improvement in landslide monitoring processes. This advancement means faster real-time data collection, analysis and decision-making, resulting in more accurate results.

The main objective of this study is to investigate in depth the benefits of integrating CPS into landslide monitoring processes. In this context, it will be discussed in detail how technological tools such as wireless sensor networks, big data analysis, machine learning algorithms and automatic warning systems can be used[10].

In addition, measures that can be taken to mitigate the effects of landslides and how CPS can support these measures will also be discussed. Consequently, it is expected that this study will contribute to a better understanding and management of landslide risk, leading to the development of strategies to mitigate the effects of natural disasters.

In this context, the following main objectives have been defined:

- Research and evaluation of existing methods used in landslide monitoring processes
- Explanation of the main features and working principles of CPS
- Identifying the benefits of integrating CPS into landslide monitoring processes
- Analyzing existing studies in the literature to reveal how CPS can be used in landslide monitoring and early warning systems.

Methods

In this study, a number of methods were used to integrate Cyber-physical systems into landslide monitoring processes. These methods include the stages of data collection, transmission, analysis and evaluation of results.

Information gathering

In the landslide monitoring process, it is important to integrate data collected using different sensors and devices. These data include topographical, geological, meteorological and hydrological data. CPS plays an active role in the process of collecting, transmitting and analyzing these data[9].

• Topographic Information: A detailed three-dimensional model of the region is created using technologies such as topographic maps and LIDAR (Light Detection and Ranging) [4]. This model provides information on soil slope, elevation differences, and potential landslide surfaces.

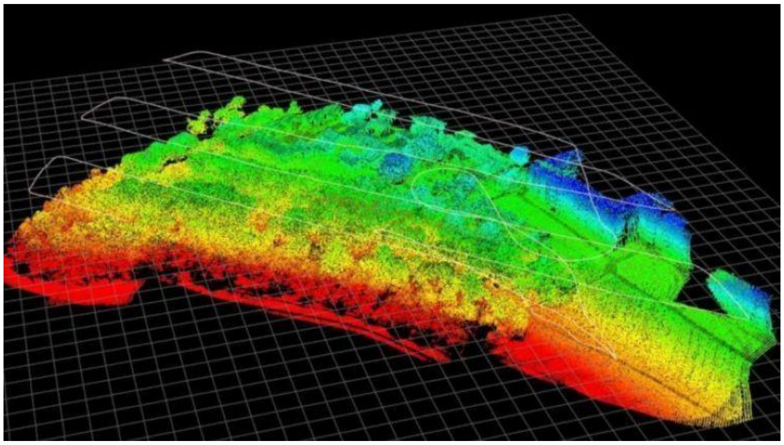

Figure 1. Obtaining a 3D map of the earth's surface using a LIDAR sensor

• Geological Information: Used to determine the geological structure of the area, soil types and layers with landslide potential. This information is usually obtained through field surveys and geotechnical drilling.

• Meteorological Data: Meteorological data such as rainfall, temperature, humidity and wind speed play an important role in the occurrence of landslides. These data are constantly monitored by meteorological stations and satellite observations.

• Hydrologic Data: Hydrologic data such as groundwater levels, surface runoff, and soil moisture are important in landslide risk assessment. This data is collected by devices such as water level gauges and humidity sensors[9].

Data Transfer and Integration

Accurate and fast transmission of collected information is an important factor determining the effectiveness of the landslide monitoring process. CPSs allow data from various sensors to be collected and processed in a central database[3,10].

• Wireless Sensor Networks: Various sensors placed in driving areas transmit data to a central station using wireless communication technologies. These networks offer low power consumption and wide coverage, ensuring uninterrupted and reliable data collection.

Information collection, transmission and integration into the central system is of great importance in the processes of traffic monitoring. Wireless sensor networks enable the efficient collection and transmission of data from various sensors, enabling the development of real-time landslide monitoring systems.

Sensor types

Sensors used in motion monitoring processes detect environmental conditions and collect data. The types and names of these sensors may vary depending on the monitored parameters.

Speed and Direction Sensors: Measures wind speed and direction and monitors its effect on drift formation. Wind speed is usually calculated based on pressure changes measured by the sensor[7]. Using Bernoulli's equation, the relationship between wind speed υ and pressure change ΔP can be expressed as follows:

$$\upsilon = \sqrt{\frac{2\Delta P}{\rho}} \quad (1)$$

ρ – air density.Rain Sensors: Measures the amount and intensity of rain, determines soil moisture and saturation. Data from rain sensors generally reflect the amount of precipitation measured over a period of time. Data from rain sensors generally reflect the amount of rain measured over a period of time. At this time, the amount of precipitation R is usually expressed in millimeters and can be calculated by multiplying the intensity of precipitation by I during a certain period of time.

$$R = \int_0^T I(t)dt \quad (2)$$

Here T is the specific time period and $I(t)$ refers to the rainfall intensity at time t. Pressure Sensors: Provides early warning of landslides by detecting soil pressure and ground changes. Soil pressure sensors generally measure soil pressure acting on the surface of the sensor. This pressure is associated with a force acting perpendicular to the surface of the sensor, and this force is usually detected by a gauge inside the sensor.

Ground Motion Sensors: Ground motion sensors measure ground motion usually through accelerometers[8]. If the momentum $a(t)$ is not constant, the velocity $v(t)$, the second derivative of the momentum, is used to calculate the ground motion, and its third derivative, the position $x(t)$, can be taken. In this case, the position-time relationship is expressed as:

$$x(t) = \int_0^t \int_0^{t'} a(t'')\, dt'' dt' \quad (3)$$

where t is the specific time period and a(t) is the acceleration.Data transfer protocols and algorithms

Wireless sensor networks allow data transmission using various data transmission protocols and algorithms. These protocols are selected based on factors such as information security, low power consumption, and efficiency. Example protocols and algorithms include:

- Zigbee: Provides low power consumption and wide coverage and provides reliable communication under environmental conditions [1].
- LoRaWAN: Provides long-range communication and offers high efficiency at low data rates [1].
- MQTT (Message Queuing Telemetry Transport): It is a lightweight message communication protocol that facilitates data exchange between IoT devices.

Data collection and centralized processing

Data collected by wireless sensor networks are processed and analyzed in a central system. This process is supported by big data analysis and machine learning algorithms[3]. The following steps are performed during the data collection and central processing stage:

1. Collecting information from sensors: Wireless sensor networks collect information from sensors that monitor various environmental conditions.
2. Data transmission: Collected information is transmitted to a data storage center using wireless communication protocols.
3. Data storage and security: In the data storage center, data is stored securely and accessible when needed.
4. Data processing and analysis: Using machine learning algorithms and data analysis techniques, data is processed and landslide risk is predicted.
5. Decision making and alerting: Based on processed data, automatic alerts are generated and forwarded to relevant organizations or users.

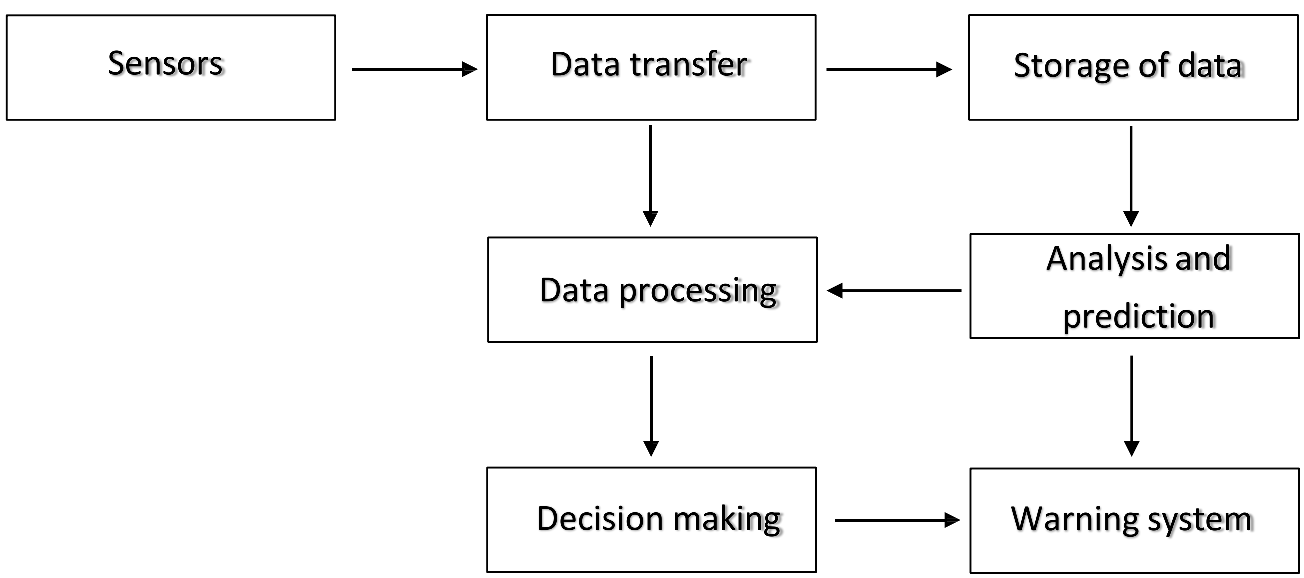

Figure 2. Data collection and centralized processing scheme

Data Analysis and Modeling

Analysis and modeling of collected data is essential for landslide risk assessment. At this stage, advanced techniques such as machine learning algorithms and big data analytics can be used.

- Machine Learning and Artificial Intelligence: Machine learning algorithms analyze and study data to predict landslide occurrence[5-6]. These algorithms estimate the risk of future landslides using patterns derived from historical data. For example, techniques such as regression analyses, decision trees and neural networks are widely used.
- Simulation and Modeling: Physical models and simulation software are used to predict how landslides might occur and their potential impacts. These models simulate landslide dynamics using soil structure, water content, and topographic data.

Mathematical models are used to understand and predict the dynamics of landslides. These models are generally based on the principles of slope stability analysis and fluid dynamics. For example, limit equilibrium analysis evaluates the potential shear strength of a sliding surface and the resulting shear force along that surface.

Early Warning Systems

One of the most critical components of the landslide monitoring process, early warning systems ensure timely detection of potential landslide hazards and notification of relevant authorities. CPS analyzes sensor data, provides instant information about the threat situation and sends warning signals when necessary [2].

- Real-Time Monitoring: Continuous monitoring and analysis of sensor data enables early detection of slips. These systems automatically send warning signals when certain thresholds are exceeded.
- Warning Mechanisms: Early warning systems can deliver warning messages using various communication tools such as SMS, email or siren. These messages minimize possible loss of life and property by timely informing the local population and authorities in the region.

System Integration

The integration of CPS into landslide monitoring processes involves the collection and processing of data from various sensors in a central system. Issues such as data transfer protocols, data security, and system compatibility must be addressed during this integration process.

- Data transfer protocols: Standard data transfer protocols are used to integrate data from different sensors. These protocols ensure secure and accurate data transfer.
- Data Security: The security of collected data is critical to the success of CPS. Therefore, security measures such as data encryption, authentication and access control should be implemented.
- System Compatibility: Standardization is essential in the integration process so that different sensors and devices can work harmoniously with each other. This ensures that the systems work effectively and that the exchange of information is uninterrupted.

Conclusion

In this study, the importance and benefits of integrating Cyber-Physical Systems (CPS) into landslide monitoring processes are thoroughly explored. Although traditional methods are inadequate in detecting and monitoring landslides, the advanced technologies offered by CPS can revolutionize this process. The use of these technologies will contribute to the development of strategies to reduce the effects of natural disasters by providing a better understanding and management of landslides. In the future, the integration of more advanced sensors and more powerful data analysis techniques will further improve landslide monitoring processes and make significant progress in this field.

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SÜNİ İNTELLEKT BAZARININ İNKİŞAFI TENDENSİYALARININ TƏHLİLİ

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Xülasə

Süni intellektin həyatımızdakı rolu və əhəmiyyəti gündən-günə artmaqdadır. Artıq təhsil, marketinq, dizayn və sairə sahələrdəki süni intellektlər qısa zaman müddətində bir-birindən cəlbedici işlər ortaya qoyur, əməliyyatlar aparır və insanın reallaşdırması günlər çəkən əməliyyatları minimal xəta ilə və ya xətasız saniyələr içərisində yerinə yetirir. Məqaləmin mövzusunun aktuallığı məhz süni intellektə olan maraq və süni intellektin iqtisadiyyata olan müvafiq töhfəsi ilə əlaqəlidir. Məqalədə süni intellekt bazarının müxtəlif göstəricilərinin statistik analizi aparılmışdır. Həmçinin, süni intellektə yatırılan