Hindawi
International Journal of Analytical Chemistry
Volume 2022, Article ID 1393024, 7 pages
https://doi.org/10.1155/2022/1393024

Research Article

Mining Geological Environment Monitoring and Real-Time Transmission Based on Internet of Things Technology

Yi Wang[1,2], **Deqiang Zhang**[1,2], **Shengliang Pei**[1,2], **and Peiyong He**[1,2]

[1]*China Institute of Geological Environment Monitoring, Beijing 100081, China*
[2]*Key Laboratory of Mine Ecological Effects and Systematic Restoration, Ministry of Natural Resources, Beijing 100081, China*

Correspondence should be addressed to Deqiang Zhang; 631418020227@mails.cqjtu.edu.cn

Received 23 May 2022; Revised 7 June 2022; Accepted 15 June 2022; Published 7 July 2022

Academic Editor: Nagamalai Vasimalai

A landslide monitoring technology based on BeiDouand, a wireless sensor network, is proposed in order to solve the problem that landslide has brought severe threat to people's life and safety of property. The landslide monitoring system based on the BeiDouand wireless sensor network is analyzed and designed from the point of view of hardware and software. BeiDou message and GPRS double redundancy transmission mode are adopted to improve the reliability of transmission. It also adopts the factor compression method to improve the effectiveness of BeiDoutransmission and adopts queue management and packet scheduling mechanism to improve the real-time and reliability of wireless sensor network transmission. The result is that, as the number of visible satellites increases, the efficiency of the algorithm decreases. However, the overall efficiency of the algorithm has been significantly improved. When there are 28 visible satellites, the number of algorithm times decreases from 20,475 to 1,140, and the efficiency of the algorithm increases by 16.9 times. The GDOP simulated by the fast star selection algorithm proposed in this paper is less than 3.9, reaching an excellent grade.

1. Introduction

The complex geological environment in China endangers people's life and health and causes serious economic losses [1]. According to the 2014–2018 analysis report on the Monitoring and Development Prospects of China's Geological Disaster Prevention Industry, since 2000, geological disasters such as sudden landslides, debris flow collapse, and ground subsidence have caused an average of 1,100 deaths and missing people every year, with direct and indirect economic losses reaching 12 billion to 15 billion yuan [2].

In addition, the construction and operation of many key projects in China are also threatened by landslides, such as the Three Gorges Water conservancy project in most mountainous areas in the southwest and Xiluodu Hydropower Station safety. It can be seen that landslide geological disaster has become a nonnegligible environmental problem, and the study of landslide monitoring and early warning technology is of great significance [3].

Due to the characteristics of natural disasters such as landslide, debris flow, and collapse, it is impossible to completely control them. In order to reduce the loss and harm caused by geological accidents, it is necessary to monitor the site of geological disasters and give out early warning as early as possible. Therefore, the reliability and effectiveness of deformation monitoring and early warning system are very important, and the monitoring and early warning system need further development and improvement.

2. Literature Review

For a long time, the high precision measurement based on the satellite navigation system mainly relies on the GPS of the United States. Based on the different needs of users, GPS high precision positioning technology has rapidly developed. Since the data model and method of carrier phase' relative positioning was proposed in 1983, GPS technology has been widely used in various industries, and the RTK virtual reference station technology derived from this technology provides users with the possibility to obtain real-time dynamic high-precision position information [4, 5]. GNSS high precision application market at home and abroad is almost completely dominated by GPS, and GPS technology has become one of the most important space geodesy technology means [6].

China's satellite navigation applications are basically monopolized by foreign technologies, and important infrastructure, such as transportation, power dispatching, communication network and financial system, excessively rely on GPS, resulting in huge risks and serious consequences [7]. Once international relations change or war breaks out and Sino-US relations are affected, the United States will shut down or interfere with GPS signals covering China or use GPS to collect relevant important data about China, causing chaos and losses that are inestimable, and China's many GPS-dependent systems will also face collapse. Apple's powerful positioning ability has brought immeasurable harm to China's national security and personal user privacy. On June 2, 2014, the news broadcast reported that the GPS endangers national security, and Russia will completely terminate the operation of GPS ground base stations within the territory on September 1. Thus, the development of the BeiDou System plays an extremely important role in China's national security [8].

IoT technology is suitable for landslide monitoring applications:

(1) However, GPS and other monitoring systems find it difficult to achieve a more fine-grained monitoring network due to the cost and labor intensity, thus imperceptibly reducing the accuracy and effectiveness of monitoring data. IoT sensor nodes have the characteristics of low cost, flexible layout, diversified independent remote communication, strong anti-interference, and antidamage, and it is of great significance to increase corresponding monitoring points to form a fine-grained and comprehensive coverage of IoT monitoring network for the reliability and authenticity of system monitoring.

(2) The sensor node battery can be self-powered, and the wireless AD hoc network can be independently networked to realize the integration of sensor nodes. In addition, it also has a variety of independent long-distance communication (such as BeiDou SMS communication mobile communication), thus greatly reducing and reducing the interference of human factors [9].

(3) From a reliability point of view, the effect is better because redundancy with heterogeneous devices is more reliable than redundancy with homogeneous devices. For example, when the same jamming method is used to destroy the monitoring system, the jamming effect is different for two heterogeneous systems. When traditional monitoring is compromised, the IoT monitoring system can still obtain accurate data, improving the reliability of the overall system and the credibility of the content of the monitoring information [10].

(4) Internet of Things technology can be made into a monitoring sensor processor power supply and remote communication-body closed device so that the opportunity to tamper with and destroy the monitoring system is greatly reduced, with the development of sensor technology, its accuracy gets higher.

Macciotta and Hendry proposed to apply a wireless sensor network to landslide monitoring and designed a wireless sensor network. Simulation and physical experiments show that the proposed wireless sensor network architecture can meet the requirements of long-term observation and data transmission [11]. Song et al. designed a landslide monitoring system based on a wireless sensor network, and through the theoretical and error analysis of the data collected in the example, it is concluded that the wireless sensor system can save energy, have wide applicability and strong practicability, and can better solve the uncertainty problem in landslide monitoring [12]. Mazzanti et al. have carried out corresponding research and design on wireless sensor networks in landslide monitoring [13].

Relevant research study shows that there are still many shortcomings in the current geological disaster monitoring and early warning system. Remote transmission is delayed and data is lost. However, at present, many scholars are committed to the study of geological disaster deformation monitoring and early warning systems and other relevant convenient technology [14]. On the basis of the current research, this paper proposes a landslide monitoring system based on BDS and VSN.

3. Research Method

3.1. Landslide Monitoring. Landslide is a geological phenomenon in which rock mass migrates downward along the inclined plane. Landslide in the broad sense is a general term for the unstable downward movement of slope rock and soil mass, that is, the rock and soil mass on the slope moves forward and downward as a whole along the transfixable structural plane in the slope. Landslides are varied in various forms, including landslide cause and landslide harm, and are classified according to landslide characteristics, dynamic cause, and activity characteristics [15, 16].

Lastly, leave it to the experts to make corresponding early warning processing. From the landslide monitoring and early warning process, it is not difficult to see that the monitoring content, monitoring curve, and early warning mechanism are the important components of landslide monitoring and early warning, as shown in Figure 1.

According to the classification, development process, and characteristics of landslides, landslide monitoring can be divided into deformation monitoring, influencing factors monitoring, and precursor anomaly monitoring, as shown in Figure 2.

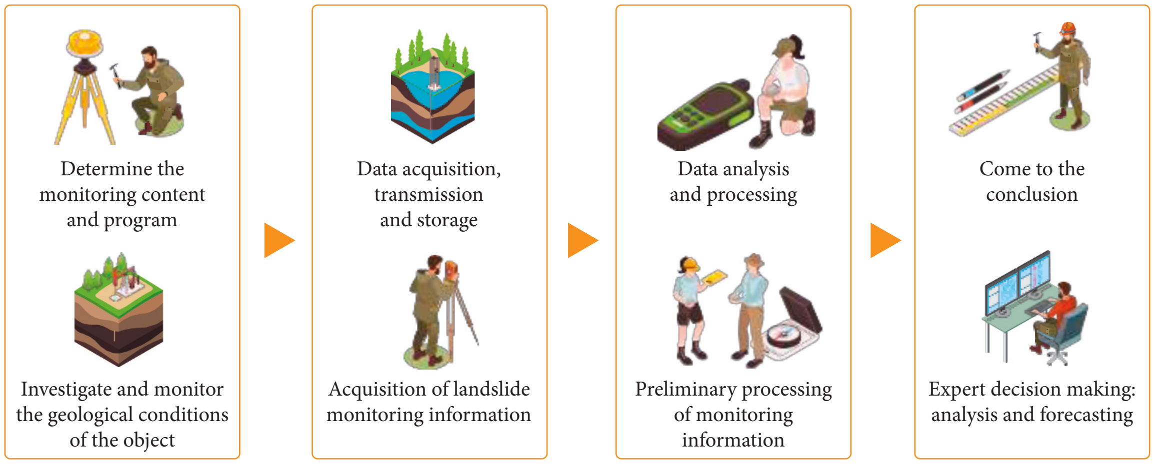

Figure 1: Flow chart of landslide monitoring.

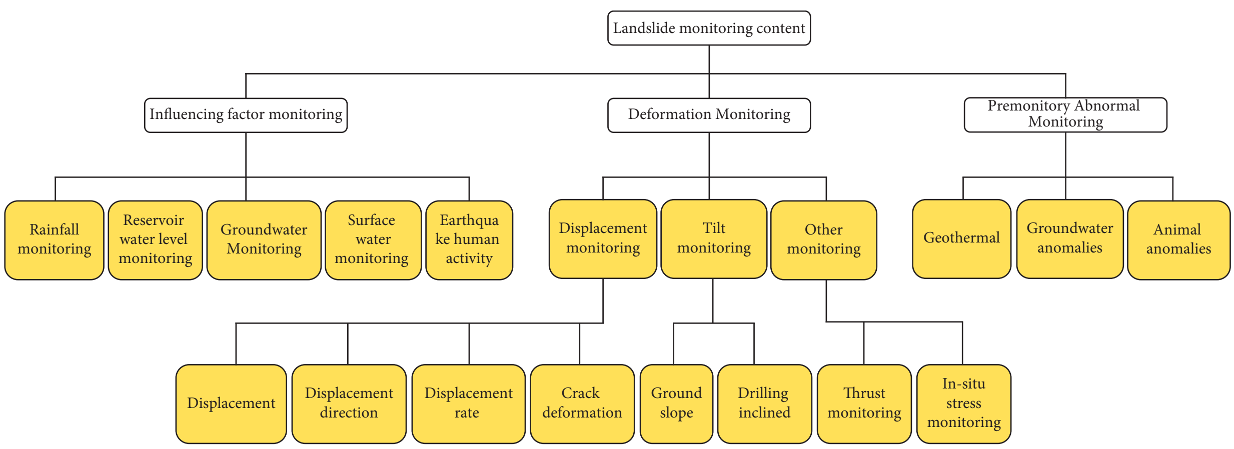

Figure 2: Classification of the landslide monitoring content.

Deformation monitoring includes displacement monitoring, tilt monitoring, and other monitoring, such as thrust monitoring and in situ stress monitoring. The monitoring of precursory anomalies includes monitoring geoacoustic, gas, geothermal, and groundwater anomalies and movement anomalies [17].

Monitoring and early warning of landslides are to collect deformation rainfall information of landslide body and process data to synthesize various curves for further analysis and prediction. Thus, accurate, timely, and secured warning can be obtained. The monitoring curves of landslide include deformation rate-time curve, cumulative displacement time curve, monitoring curve of borehole tiltmeter, relationship between landslide deformation and rainfall, the relationship between landslide deformation and reservoir water level, and groundwater time curve. A part of the curve is analyzed as follows.

3.1.1. Deformation Rate-Time Curve. The deformation rate represents the displacement change in a certain time period, which can be expressed as monthly deformation (mm/m), daily deformation (mm/d), and hourly deformation (mm/h). The deformation rate-time curve represents the deformation rate curve of the landslide monitoring point with the development of time, which generally presents a zig-zag shape. The macrodeformation evolution law of the landslide can be mastered by analyzing and calculating the average deformation rate of each deformation stage.

3.1.2. Cumulative Displacement Time Curve. The cumulative displacement-time curve eliminates the vibration on the displacement rate-time curve and is usually smooth. The change of slope tangent of the curve can be judged by the speed of landslide displacement change. If the slope of the tangent line of the curve becomes larger , it indicates that the landslide becomes more and more intense and deformation has been accelerated.

3.1.3. Relationship Curve between Landslide Deformation and Rainfall. This curve is a combination of displacement time-curve and rainfall time curve, and the correlation between landslide deformation and rainfall can be found through comparative analysis [18].

3.2. Landslide Monitoring Based on Satellite Positioning. The basic principle of GPS positioning is that according to the instantaneous position of the moving satellite in the universe as a known parameter, the three-dimensional space distance intersection method is adopted to finally determine the position of the point to be measured in space. The three-dimensional space distance intersection method is as follows:

(1) The user measures his distance to the three satellites
(2) The precise location of the satellite is known and broadcast to the user by cable
(3) Draw a sphere with a satellite as the center and a distance as the radius
(4) At the intersection of three spheres, all unreasonable points are excluded according to geographical common sense to get the user's position [19]

Assuming that the installation time of the surface receiver is t moment, then the time of transmitting the monitored GPS signal to the satellite receiving is Δt. In addition, the satellite ephemeris and other existing data detected by the satellite receiver can be added to obtain the following four multivariate equations, namely,

$$\left[(x1-x)^2+(y1-y)^2+(z1-z)^2\right]^{(1/2)}+c\left(v_{t1}-v_{to}\right)=D_1, \tag{1}$$

$$\left[(x2-x)^2+(y2-y)^2+(z2-z)^2\right]^{(1/2)}+c\left(v_{t2}-v_{to}\right)=D_2, \tag{2}$$

$$\left[(x3-x)^2+(y3-y)^2+(z3-z)^2\right]^{(1/2)}+c\left(v_{t3}-v_{to}\right)=D_3, \tag{3}$$

$$\left[(x4-x)^2+(y4-y)^2+(z4-z)^2\right]^{(1/2)}+c\left(v_{t4}-v_{to}\right)=D_4. \tag{4}$$

The multivariate equation is composed of four equations x, y, z, and v_{t0}. The three-dimensional coordinates of the points to be calculated are unknown parameters $D_i = c\Delta t_i\,(i = 1, 2, 3, 4)$. In addition, D_i represents the distance of four navigation satellite signals to the receiving device, Δt_i represents the time used by four navigation satellite signals to the receiving device, and c represents the speed of light, respectively. The propagation speed of GPS satellite signals $vt_i\,(i = 1, 2, 3, 4)$ is provided by the satellite ephemeris, vt_0 is the time difference of each satellite, and the clock difference of the receiving device can be solved by the above 4 equations, three-dimensional coordinates xy, z, and the time difference of the receiving device vt_0.

3.3. Data Transmission System. Landslide monitoring data transmission subsystem is generally divided into monitoring site transmission and remote real-time transmission.

Monitoring site transmission is the process of aggregating data collected from various monitoring points in the monitoring site, and GPRS hierarchical transmission mechanism is generally adopted in the monitoring site. The monitoring data is transmitted from the lowest monitoring point (level II monitoring point) to the upper monitoring point (level II monitoring point), and then centrally transmitted to the remote transmission equipment through level II monitoring point. Remote real-time transmission is to transmit the data aggregated to the remote transmission equipment to the monitoring center through the remote transmission mechanism [20]. The data transmission subsystem needs to meet the standards of uninterrupted data transmission, complete data, the timely transmission of key data, and safe and effective data.

At present, ZigBee technology, GPRS technology, and BeiDoumessage communication technology are commonly used in the landslide monitoring and warning system. ZigBee technology communication distance of 10–1000 m, bandwidth of 250/kbps can be extended to 65000 child nodes, is mainly used in sensor networks. The communication distance of GPRS is more than 1000 m, and the bandwidth is 10–1000/kbps, which is suitable for long-distance communication; BeiDou message communication transmits up to 120 Chinese characters at a time through satellite communication and is not restricted by mobile signals. Communication positioning frequency is less than 1 time per minute. The interface transmission rate reaches 1200–115,200 bits per second. Table 1 shows the performance and characteristics comparison of the three [21].

3.4. Analysis of Satellite Positioning Error. The positioning principle of BeiDou II adopted the four-star positioning algorithm, namely, the four observation equations as follows:

$$\rho_i(x_u)=\sqrt{\left(x_u-x_{s_i}\right)^2+\left(y_u-y_{s_i}\right)^2+\left(z_u-z_{s_i}\right)^2}+n_i+c^*\delta t. \tag{5}$$

Here, ρ_i is the pseudometric observation quantity $(i = 1, 2, 3, 4)$, $[x_{s_i}, y_{s_i}, z_{s_i}]$ represents the position of the satellite; $x_u = [x_u, y_u, z_u, \delta t]$ is the 4 unknowns to be solved, $x_u = [x_u, y_u, z_u]$ is unknown to users, and δt is the clock difference.

The positioning accuracy of the satellite navigation and positioning system is represented by Geometric Dilution of Position (GDOP), which represents the vector magnification factor between the receiver and the space satellite caused by the satellite ranging error. GDOP includes PDOP (positioning dilution of precision), TDOP (time dilution of precision), HDOP (horizontal dilution of precision), and VDOP (vertical dilution of precision) [22].

$$\begin{aligned} HDOP^2+VDOP^2&=PDOP^2,\\ HDOP^2+VDOP^2+TDOP^2&=PDOP^2. \end{aligned} \tag{6}$$

The corresponding relationship between GDOP value and positioning accuracy grade is shown in Table 2:

4. Interpretation of Results

4.1. Algorithm Efficiency Analysis. The original four-star positioning method for the selected 4 equations from all visible satellite positioning satellites, set a number of N star

Table 1: Comparative analysis of data transmission technology.

Project	ZigBee	GPRS/GSM	BeiDou communication
Transmission rate	Average transmission rate	Average transmission rate	Low transmission rate
Coverage area	Covers most of the area	Covers most of the area	Large coverage
Construction cost	Low construction cost	Low construction cost	High construction cost
Communication cost	Low communication cost	Low communication cost	High communication cost
Instantaneity	Bad real-time performance	Real-time performance is a bit poor	Good real-time performance
Reliability	Reliability is low	Relatively low reliability	Good reliability
Security	Low security	Moderate security	High security

Table 2: The corresponding relationship between GDOP value and positioning accuracy grade.

GDOP value	1-2	2-3	3–6	6–9	9–20	More than 20
Positional accuracy	Ideal	Excellent	Good	Moderate	Mediocre	Bad
Grade	Best	Excellent	Good	Moderate	Qualified	Bad

Table 3: Algorithm complexity comparison.

Number of visible stars	17	18	19	20	21	22	N
The number of times calculated by the old algorithm	2380	3060	3876	4845	5985	7315	C_N^4
New algorithm calculation times	84	120	165	220	286	364	C_N^3
Efficiency improvement multiple	27.3	24.5	22.4	21	19.9	19	C_N^4-C_N^3

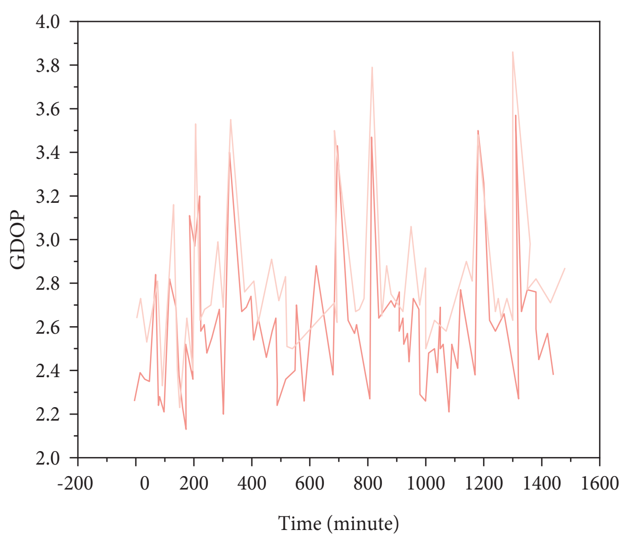

Figure 3: GDOP comparison curve of simulation results.

visible, it made star algorithm C_N^4, and through the star way for its star algorithm C_N^3, which every calculation GDCP need to perform this matrix multiplication and the complexity of old and new star selection algorithms is shown in Table 3.

As can be seen from Table 3, the efficiency of the algorithm decreases with the increase of the number of visible satellites, but the overall efficiency of the algorithm increases significantly. When the number of visible satellites is 28, the algorithm times decreases from 20,475 to 1,140, and the efficiency of the algorithm increases by 16.9 times [23].

4.2. Algorithm Emulation. A receiver was set in a certain place with the latitude and longitude of [121.1°, 31.1°, and 15°] and the satellite position information of the whole BeiDou constellation was generated by STK software. 1 minute was taken as the sampling period, and the comparison curve of 24-hour GDOP simulation results is shown in Figure 3.

As shown in Figure 3, the maximum value of GDOP of the original star selection scheme is 3.6080, the minimum value is 2.1612, the average value is 2.6387, and the variance is 0.1009. The maximum GDOP of the new star selection algorithm proposed in this paper is 3.8366, the minimum value is 2.1612, the mean value is 2.7684, and the variance is 0.0937. The GDOP simulated by the fast star selection algorithm proposed in this paper is all less than 3.9, reaching an excellent grade [24, 25].

5. Conclusion

In recent years, landslide geological disasters often occur, which causes threat to the safety of people's life and property. With the development of BeiDou industry in China, BeiDou will definitely replace GPS, so this paper adopts the positioning mode of BeiDou and WSN fusion. Internet of Things technology Smart Earth is the inevitable trend of future development; wireless sensor network in recent years shows a strong vitality, but there are also many problems to be solved. On the basis of the two methods, this paper conducts relevant research on landslide monitoring and early warning technology. The work content is as follows:

(1) Firstly, the definition of landslide, the principle of landslide classification, the characteristics and laws of landslide development process, and landslide

monitoring technology are studied, which lay a good theoretical foundation for the design of landslide monitoring and warning system based on BeiDou, GPS, and Internet of Things technology.

(2) The landslide monitoring and early warning system is summarized in detail, and the hardware and software of the system are analyzed and designed in detail, and the system is built by participating in the practice, which lays a good foundation for the reliability research of the system.

(3) On the basis of system design and practice, the reliability of landslide monitoring system is studied.

The positioning accuracy of WSN monitoring points in the landslide monitoring and warning system integrated with BeiDou and WSN needs to be further improved. In addition, the landslide monitoring and early warning system is a part of the remote real-time monitoring system.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] Y. Shi and Y. Zhou, "Gene extraction of leizhou kiln porcelain patterns based on safety internet of things and its application in modern design," *IETE Journal of Research*, vol. 2, no. 3, pp. 1–8, 2021.

[2] R. F. Mansour, M. M. Althobaiti, and A. A. Ashour, "Deep Learning for Internet of things," in *Proceedings of the Internet of Things and Synergic Deep Learning Based Biomedical Tongue Color Image Analysis for Disease Diagnosis and Classification*IEEE Access, Beijing, China, 2021.

[3] T. Wei, W. Feng, Y. Chen, C. X. Wang, N. Ge, and J. Lu, "Hybrid satellite-terrestrial communication networks for the maritime internet of things: key technologies, opportunities, and challenges," *IEEE Internet of Things Journal*, vol. 8, no. 11, pp. 8910–8934, 2021.

[4] M. Keuschnig, A. Schober, R. Delleske, K. Brandner, and G. H. Ollinger, "Scale-oriented landslide monitoring and early warning system for uranium legacy complexes in mailuu suu, Kyrgyzstan," *Geomechanics and Tunnelling*, vol. 14, no. 1, pp. 47–53, 2021.

[5] J. Cai, H. Jia, G. Liu et al., "An accurate geocoding method for gb-sar images based on solution space search and its application in landslide monitoring," *Remote Sensing*, vol. 13, no. 5, 2021.

[6] Z. Gojcic, L. Schmid, and A. Wieser, "Dense 3d displacement vector fields for point cloud-based landslide monitoring," *Landslides*, vol. 18, no. 12, pp. 3821–3832, 2021.

[7] B. Zeng, Y. Zheng, J. Yu, and C. Yang, "Deformation calculation method based on fbg technology and conjugate beam theory and its application in landslide monitoring," *Optical Fiber Technology*, vol. 63, no. 6, Article ID 102487, 2021.

[8] R. C. S. B. Allil, L. A. C. Lima, A. S. Allil, and M. M. Werneck, "Fbg-based inclinometer for landslide monitoring in tailings dams," *IEEE Sensors Journal*, vol. 21, no. 15, pp. 16670–16680, 2021.

[9] Z. Xiong, G. Feng, Z. Feng et al., "Pre- and post-failure spatial-temporal deformation pattern of the baige landslide retrieved from multiple radar and optical satellite images," *Engineering Geology*, vol. 279, no. 11, Article ID 105880, 2020.

[10] A. Wakai, G. Sato, T. V. Tran, J. Karnjana, and J. Komori, "Special issue on e-asia jrp: development of a landslide monitoring and prediction system in monsoon asia," *Journal of Disaster Research*, vol. 16, no. 4, pp. 483-484, 2021.

[11] R. Macciotta and M. T. Hendry, "Remote sensing applications for landslide monitoring and investigation in western Canada," *Remote Sensing*, vol. 13, no. 3, p. 366, 2021.

[12] Y. S. Song, B. G. Chae, K. S. Kim, J. Y. Park, H. J. Oh, and S. W. Jeong, "A landslide monitoring system for natural terrain in korea: development and application in hazard evaluations," *Sensors*, vol. 21, no. 9, 2021.

[13] P. Mazzanti, P. Caporossi, and R. Muzi, "Sliding time master digital image correlation analyses of cubesat images for landslide monitoring: the rattlesnake hills landslide (USA)," *Remote Sensing*, vol. 12, no. 4, p. 592, 2020.

[14] G. Aslan, M. Foumelis, D. Raucoules, M. De Michele, S. Bernardie, and Z. Cakir, "Landslide mapping and monitoring using persistent scatterer interferometry (psi) technique in the French alps," *Remote Sensing*, vol. 12, no. 8, 2020.

[15] X. Liang, L. Gui, W. Wang, J. Du, F. Ma, and K. Yin, "Characterizing the development pattern of a colluvial landslide based on long-term monitoring in the three gorges reservoir," *Remote Sensing*, vol. 13, no. 2, p. 224, 2021.

[16] G. Dhiman, V. Vinoth Kumar, A. Kaur, and A. Sharma, "Don: deep learning and optimization-based framework for detection of novel coronavirus disease using x-ray images," *Interdisciplinary Sciences: Computational Life Sciences*, vol. 13, no. 2, pp. 260–272, 2021.

[17] N. Yuvaraj, K. Srihari, G. Dhiman et al., "Nature-inspired-based approach for automated cyberbullying classification on multimedia social networking," *Mathematical Problems in Engineering*, vol. 2021, pp. 1–12, 2021.

[18] D. Selva, B. Nagaraj, A. Rajendran, A. Nair, and A. Nair, "Intelligent network intrusion prevention feature collection and classification algorithms," *Algorithms*, vol. 14, no. 8, p. 224, 2021.

[19] X. Liu, C. Ma, and C. Yang, "Power station flue gas desulfurization system based on automatic online monitoring platform," *Journal of Digital Information Management*, vol. 13, pp. 480–488, 2015.

[20] R. Huang, *Framework for a smart adult education environment*, vol. 13, no. 4, pp. 637–641, 2015.

[21] E. Guo, V. Jagota, M. E. Makhatha, and P. Kumar, "Study on fault identification of mechanical dynamic nonlinear transmission system," *Nonlinear Engineering*, vol. 10, no. 1, pp. 518–525, 2021.

[22] X. Huang, F. Guo, M. Deng, W. Yi, and H. Huang, "Understanding the deformation mechanism and threshold reservoir level of the floating weight-reducing landslide in the three gorges reservoir area, China," *Landslides*, vol. 17, no. 12, pp. 2879–2894, 2020.

[23] L. Longoni, V. Ivanov, M. Ferrario, M. Brunero, M. Papini, and D. Arosio, "Laboratory tests with interferometric optical

fibre sensors to monitor shallow landslides triggered by rainfalls," *Landslides*, vol. 19, no. 3, pp. 761–772, 2022.

[24] S. Kumar, S. Duttagupta, V. P. Rangan, and M. V. Ramesh, "Reliable network connectivity in wireless sensor networks for remote monitoring of landslides," *Wireless Networks*, vol. 26, no. 3, pp. 2137–2152, 2020.

[25] C. Zhang, Y. Yin, H. Yan, H. Li, Z. Dai, and N. Zhang, "Reactivation characteristics and hydrological inducing factors of a massive ancient landslide in the three gorges reservoir, China," *Engineering Geology*, vol. 292, no. 1, Article ID 106273, 2021.