Migration Letters

Volume: 21, No: S7 (2024), pp. 956-966

ISSN: 1741-8984 (Print) ISSN: 1741-8992 (Online)

www.migrationletters.com

Integrating Iot With Ai-Enabled Wireless Sensor Networks For Landslide Monitoring And Early Warning Systems

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ABSTRACT

Monitoring landslides is essential to understand their dynamics and to reduce the risk of human losses by raising warnings before a failure. Monitoring natural environments presents significant challenges, particularly in areas lacking infrastructure. Wireless Sensor Networks (WSNs) have emerged as a practical solution for data collection in such environments. Landslides, among the most devastating natural disasters worldwide, are often triggered by heavy rainfall or seismic activity, particularly prevalent in regions like India. This paper proposes an innovative landslide monitoring system aimed at mitigating link failures in routing protocols. The system incorporates a diverse range of sensors including soil moisture, rainfall, vibration, and humidity sensors, coupled with GSM sensor connectivity through ESP8266 modules. Data collected from these sensors is processed using AI techniques to enhance sensor node lifespan and facilitate real-time assessment of landslide magnitudes. By comparing collected data against predefined threshold values, the system enables timely warning and mitigation strategies. This integrated approach offers a promising solution for effective landslide monitoring and early warning systems in challenging environments.

Keywords: *AI techniques, ESP8266 modules, Landslide monitoring, Soil moisture sensor, Wireless Sensor Networks.*

I. INTRODUCTION

A devastating natural disaster, landslides endanger people, buildings, and ecosystems all throughout the world. Climate ch[1]ange, urbanization, and deforestation are only a few of the variables that are increasing their devastating potential. To combat this, early warning systems and good monitoring are very necessary [1]. Coverage, precision, and timeliness are three areas where traditional landslip monitoring techniques fall short, calling for new approaches that make use of cutting-edge technology [2]. Modern advancements in artificial intelligence (AI), wireless sensor networks (WSNs), and the Internet of Things (IoT) have created exciting new opportunities for landslip early warning and monitoring systems [3]. It is now possible to gather real-time data from hard-to-reach places, analyze it intelligently, and provide early warnings to lessen the impact of possible catastrophes by combining Internet of Things (IoT) devices with WSNs enabled by artificial intelligence [4-5].

In order to better monitor landslides and provide early warning systems, this research presents a thorough architecture for combining the Internet of Things (IoT) with WSNs that

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are enabled by artificial intelligence (AI) [6]. There are a number of benefits to using these technologies in tandem as opposed to more conventional methods [7]. To start, a wide range of environmental variables, including soil moisture, rainfall, seismic activity, and slope stability, can be easily measured with the use of wireless sensors that have Internet of Things (IoT) capabilities [8-9]. To provide thorough coverage, these sensors can be strategically positioned in locations prone to landslides, such as inaccessible or rough terrain. Second, using AI algorithms makes it easier to intelligently analyze and analyze the data that has been acquired [10]. It is possible to train machine learning algorithms to spot trends, outliers, and warning signs of upcoming landslides [11]. These AI algorithms can learn from past data and input from sensor networks to become better predictors over time, making early warning systems more accurate and reliable [12]. To add to that, stakeholders can react quickly to changing landslip hazards thanks to real-time monitoring and decision-making made possible by AI and the Internet of Things [13]. The efficient transfer of data between sensor nodes, data processing centres, and end-users is made possible by modern communication protocols and cloud-based platforms. This allows for the quick distribution of warnings and advisories [14–15].

A. Motivation of the paper

This study discusses the urgent need for early warning systems and monitoring systems for landslides, especially in areas vulnerable to such natural catastrophes. The suggested approach gets over problems like poor infrastructure and communication breakdowns by combining Wireless Sensor Networks (WSNs) with IoT devices and AI methods. It uses a number of sensors to measure things like soil moisture, rainfall, vibration, and humidity, among other things. Timely alerts and mitigation methods are made possible by processing this data using AI algorithms that identify prospective landslip occurrences in real-time. One potential way to make communities more resistant to landslip risks is to use the novel strategy outlined in this research.

II. BACKGROUND STUDY

Bressani, L. et al. [2] the management and safety of geotechnical operations, as well as the prevention and mitigation of landslip incidents, rely heavily on monitoring systems. New opportunities and difficulties have arisen for geotechnical engineers as a result of the convergence of inexpensive sensors with powerful data processing capabilities. There was a difficulty that has to be addressed: how to efficiently comprehend enormous data sets generated by Big Data. The potential quality of a vast amount of data should not be disregarded, even if it was not synonymous with an efficient system. As a result, improving the data quality obtained from big data systems necessitates the creation of new methods. One such method that, when designed and implemented properly, can synthesize massive amounts of data into crucial information for right decision making was artificial intelligence.

Harsa et al. [4] these authors' research shows that ML and AI performed better once input data was appropriately pre-processed. During the model development phase, the author distinguish between two approaches to ML and AI model creation. In contrast to the second one, the first one was pre-processed. In addition, the second strategy achieved better results than the first, and it did so with fewer explanatory factors. In order to prepare the data for the second technique, the author used PCA and log-transformation as pre-processing steps. The first method's optimal model was given by the GLM, whereas the second one was given by the DL. Using rainfall characteristics retrieved from satellites, the models predicted the likelihood of landslides occurring one day in the future.

Khoa, V. V., & Takayama, S. [6] An event-driven system, the Landslip Monitoring System aims to lessen the likelihood of landslip damage. The system's measurement components were a wireless sensor network, making it a telemetric system. Sensors allow for the analysis of field state, network status, and individual nodes in both normal and emergency scenarios. Despite the system's limitations in catastrophe prediction, landslip monitoring in real-time enables further data analysis.

Ofli, F. et al. [8] An interdisciplinary team consisting of computer scientists from the Qatar Computing Research Institute (QCRI), earthquake experts from the European-Mediterranean Seismological Centre (EMSC), and landslip experts from the British Geological Survey (BGS) worked together to develop the system that was showcased in this paper. Using cutting-edge AI methods, the created system automatically identifies information relevant to landslides by using real-time data from online social media.

Shutimarrungson, N., & Wuttidittachotti, P. [10] these authors research proposes the creation of propagation models for landslip management systems that use wireless sensor networks. The measurement data and preexisting propagation models were used to build the models. The development's measuring setup included two primary cases: one with ground-based antennas and one with antennae placed one metre above ground. Both the first scenario's propagation model and the second scenario's multi-ray tracing model were built using these authors experimental data in conjunction with the log-normal model and the log-normal model, respectively.

Sruthy et al. [12] In the realm of geophysical research, one of the current, demanding study fields was the real-time monitoring of landslides. The goal of an Internet of Things (IoT) landslip detection system was to identify potential danger signs, alert authorities in a timely manner, and ultimately prevent casualties. The existing methods for detecting landslides were not as precise.

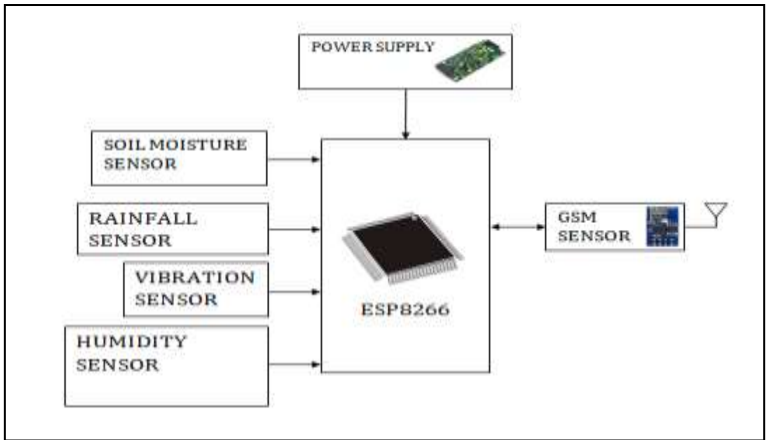
Valade et al. [14] Using data downloaded and processed automatically from Sentinel-1 SAR, Sentinel-2 SWIR, and Sentinel-5P TROPOMI, the author provide a functioning volcano monitoring system. The data that has been retrieved was intended to provide important metrics that can provide information on the level of volcanic activity. These parameters include changes in surface reflectance, surface heat anomalies, surface deformation, and SO_2 gas emissions.

A. Problem definition

The need of early warning systems and efficient landslip monitoring is the issue at hand, especially in areas vulnerable to such natural calamities. We need creative solutions that use new technologies like AI, the Internet of Things (IoT), and Wireless Sensor Networks (WSNs) because traditional methods have problems like inadequate infrastructure, communication breakdowns, and data collection and analysis delays.

III. MATERIALS AND METHODS

The proposed landslip monitoring system's essential components and processes are detailed in the paper's materials and techniques section. The technique for collecting, processing, and analysing data for landslip detection and early warning purposes is detailed in this part. It includes the selection of sensors, setting of wireless communication protocols, integration of AI algorithms, and overall approach.



1: Block diagram

A. IoT (Internet of Things)

In this context, "thing" refers to any inanimate object that has the ability to execute an action (e.g., control the brightness of a light, the speed of a motor, etc.) and is also equipped with sensors that collect data that can be sent across a network. Included in this wide group are appliances, buildings, automobiles, streetlights, industries, and rehabilitation equipment. It is not always necessary to physically connect sensors to devices; in some instances, it is sufficient for them to just monitor their immediate surroundings.

WSN (Wireless Sensor Networks) gather data on soil moisture, rainfall, vibration, and humidity by placing a network of wireless sensors in locations prone to landslides. Especially in areas without infrastructure, these sensors are set strategically to cover the area of interest efficiently. In order to continuously monitor circumstances that might cause landslides, the WSN is vital since it allows for the gathering of data in real-time from distant or inaccessible places.

B. ESP8266

For wirelessly connecting embedded devices to the internet or local networks, the ESP8266 from Espressif Systems is a great choice since it combines a microcontroller unit (MCU) with Wi-Fi connection referred by Thopate, K. et al. (2024). Its many GPIO (General Purpose Input/Output) pins make it ideal for Internet of Things (IoT) applications that include connecting to a broad variety of sensors, actuators, and other peripheral devices. The low power consumption of the ESP8266 is one of its main benefits; this makes it a good choice for battery-operated devices and applications that prioritise energy economy. On top of that, the ESP8266 is quite customisable and can be readily programmed using tools like the Arduino IDE and Lua.

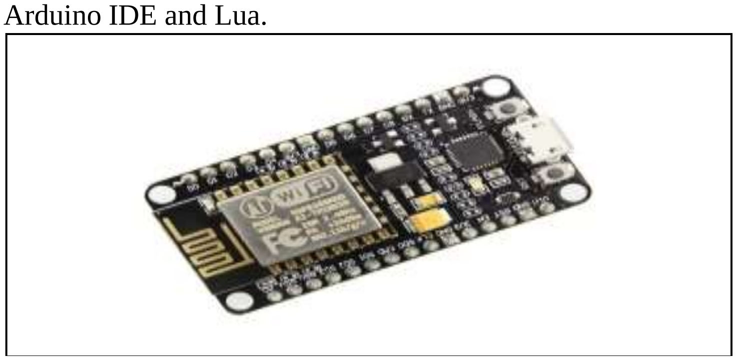


Figure 2: ESP8266

C. Soil Moisture Sensor

One way to find out how much water is in the dirt is to use a soil moisture sensor. Essential for optimising irrigation schedules, avoiding plants from being over- or under-watered, and measuring soil health, it provides vital data on soil moisture levels, making it a key tool in agriculture, gardening, and environmental monitoring Shaukat, H. et al. (2024). Soil moisture sensors usually work by inserting two electrodes into the dirt. The dielectric constant, or electrical conductivity, of the soil is measured by these electrodes, and it is proportional to the soil's moisture content. A change in soil moisture can be detected by the sensor because electrical conductivity rises with increasing soil moisture. Resistive, capacitive, and frequency domain soil moisture sensors are all available, and each has its own set of pros and cons. Different sensors can detect different degrees of moisture; some measure the resistance between electrodes, while others employ capacitance changes. Soil moisture can be measured via frequency domain sensors by the use of electromagnetic waves. Spot measurements or periodic monitoring are done with others. Soil moisture sensors can also be linked to data loggers and internet of things platforms, allowing for remote control and monitoring, or even automated wagering systems.

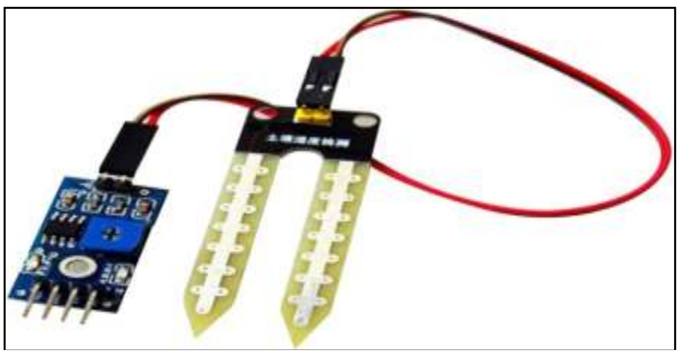


Figure 3: Soil Moisture Sensor

D. Rainfall Sensor

One way to keep track of how much rain falls and how hard it falls is using a rainfall sensor. Its data on rainfall patterns is vital for weather forecasting, flood prediction, and water resource management; hence, it is an important part of hydrology, environmental monitoring, and meteorology referred by Nielsen, J. et al. (2024). There is a wide variety of rainfall sensors available, each developed to meet the needs of a unique application or measurement standard. Acoustic rain sensors, optical rain sensors, and tipping bucket rain gauges are some of the most common kinds of rainfall sensors. One kind of rain gauge is the "tipping bucket," which is essentially a funnel that empties into a smaller container using a pivoting bucket. A mechanical or electrical sensor is used to record the tip of the bucket as it fills up with water, and then it tips over to drain the water. Rainfall is directly proportional to the quantity of tips received during a certain time frame. Raindrops falling across a detecting region can be detected by optical rain sensors using infrared or laser beams. The sensor records a rainfall event whenever droplets block the beam. The automated regulation of windscreen wipers in automobiles and the measurement of rainfall intensity in weather stations are two common uses for optical rain sensors. Sensor membranes or piezoelectric elements are used by acoustic rain sensors to detect raindrops impacting a surface. Rainfall intensity and duration are determined by analysing the acoustic signals generated by the impact of raindrops.

Figure 4: Rainfall Sensor

E. Vibration Sensor

An accelerometer, seismic sensor, or vibration sensor is a device that can detect and quantify mechanical oscillations or vibrations in a physical system. Its ability to measure vibrations' amplitude, frequency, and duration makes it an indispensable tool for environmental, structural, and industrial monitoring applications. There is a wide variety of vibration sensors available, each designed to meet the unique needs of various measuring tasks and environments. Vibration sensors often used in everyday life include piezoelectric accelerometers, velocity sensors, and accelerometers made by MEMS (Microelectromechanical Systems). A piezoelectric crystal or ceramic element attached to a mass constitutes a piezoelectric accelerometer. The piezoelectric material compresses under the force of mechanical vibrations, producing an electric charge that is directly proportional to the acceleration. After that, the charge is transformed into a voltage signal, which can be used for processing and analysis to identify the vibrational properties. Miniature sensing components, such piezoresistive or capacitive structures, are integrated into a silicon chip using microfabrication processes in MEMS accelerometers. These sensors are ideal for structural health monitoring, consumer electronics, and automotive systems because to their small size, light weight, and low cost. When vibrated, velocity sensors determine how fast an item or surface is moving. A coil or magnet held in a magnetic field is the standard component. Vibrations cause the coil to shift in relation to the magnetic field, which in turn induces a voltage that is directly proportional to the vibrational speed.

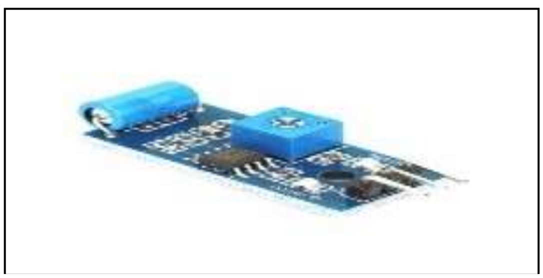


Figure 5: Vibration Sensor

F. Humidity Sensor

Operators can make real-time adjustments to improve production efficiency and product quality with the help of IIoT-integrated sensors that provide continuous monitoring. According to Bi et al. (2021). Several products used in industry are sensitive to changes in humidity and temperature. By enabling more precise control of HVAC systems, temperature and humidity sensors contribute to energy management. Reduced energy waste and costs are achieved by the use of real-time data, which allows for adjustments in reaction to environmental conditions.

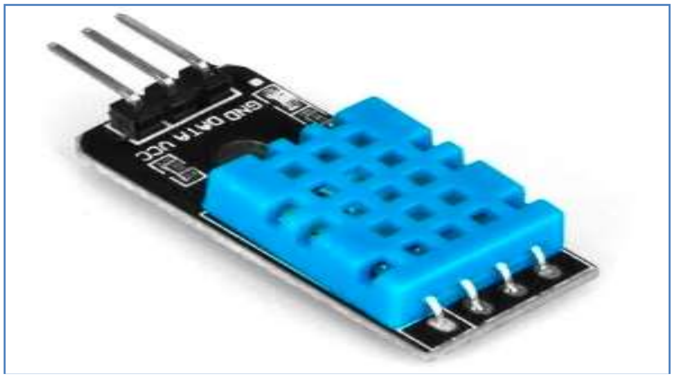


Figure 6: Temperature & Humidity Sensor

G. GSM sensor

A GSM (Global System for Mobile Communications) sensor is a type of sensor device that integrates GSM technology for wireless communication. Unlike traditional sensors that can transmit data using local wireless protocols like Wi-Fi or Bluetooth, GSM sensors utilize cellular networks to transmit data to remote servers or monitoring stations. The GSM sensor typically consists of a sensor element for detecting physical or environmental parameters, such as temperature, humidity, pressure, or motion, along with a GSM module for wireless communication. The GSM module is equipped with a SIM card, allowing it to connect to cellular networks and transmit data via SMS (Short Message Service), GPRS (General Packet Radio Service), or other GSM-based communication protocols. GSM sensors are commonly used in applications where real-time monitoring and remote data access are required, especially in locations where Wi-Fi or other local wireless networks are not available. These applications can include environmental monitoring, industrial automation, security systems, and asset tracking.


Figure 7: GSM sensor

H. Power supply

An AC voltage source, usually 120V root mean square (rms), is linked to a transformer in this circuit arrangement. The main winding of the transformer is linked to the AC source, and the secondary winding is responsible for reducing the voltage to the required level for the output. A diode rectifier circuit receives this AC voltage after it has been stepped down. A full-wave rectified voltage, which is pulsing DC, is created by converting the alternating current (AC) voltage using a diode rectifier. Because rectification is inherently imperfect, the rectified voltage still exhibits ripples and variations. Using a basic capacitor filter, we can reduce these ripples and get a more consistent DC voltage. The capacitor filter lessens the ripple's intensity by accumulating charge at the rectified voltage's peaks and releasing it at its troughs. This causes the DC voltage across the capacitor to be somewhat constant. This direct current voltage, however, can still fluctuate somewhat depending on the input alternating current voltage and the load. A voltage regulator circuit is used to make sure the output voltage is steady and controlled. This function is often performed by means of voltage regulator integrated circuit (IC) components, including linear and switching regulators.

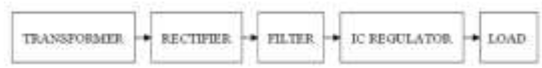


Figure 8: Power supply flow diagram

I. Bank end and Network Connectivity

PHP is a server-side scripting language with many potential applications beyond web development and general-purpose programming. As of January 2013, PHP was installed on more than 2.1 million servers and over 240 million sites, accounting for 39% of the domains examined. The PHP group, founded in 1994 by Rasmus Leerdorf, is responsible for creating the widely used PHP programme, which is powered by the Zend engine. Recursively abbreviated as "php: web preprocessor," the term has evolved from its original meaning "personal website".

IV. RESULTS AND DISCUSSION

The results and interpretations from the assessment and execution of the proposed landslip monitoring system are presented in the results and discussion portion of this article. Important results, such as sensor performance, AI algorithm efficacy in landslip detection, and system capacity to provide early alerts and mitigating techniques, are detailed in this part.

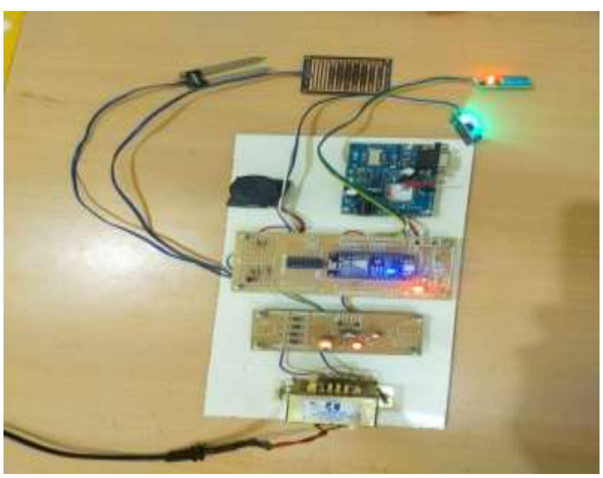


Figure 9: Industrial setup

Figure 9 shows an industrial setup. An industrial setup is a complex environment for various industrial operations, such as manufacturing, production, and processing. It typically combines machinery, equipment, infrastructure, and processes to achieve specific production goals.

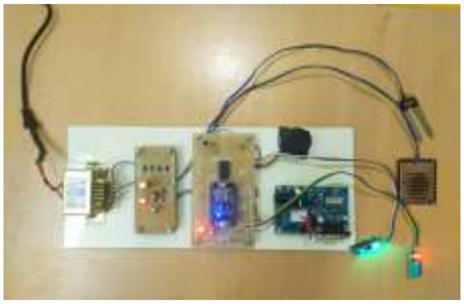


Figure 10: Sensors in industrial

Figure 10 shows sensors in industrial Sensors play a crucial role in industrial settings by enabling the measurement and monitoring of various physical parameters and environmental conditions. They provide valuable data for process control, quality assurance, safety monitoring, and overall operational efficiency.

Figure 11: Login page

Users access the application described in the paper via the login page, as shown in Figure 11. Typical elements of such a page include login boxes where users can enter their username and password and authentication buttons such as Login.

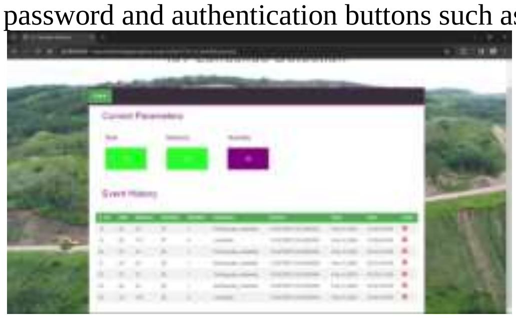


Figure 12: Current parameters

Current Parameters in figure 12 probably shows data acquired in real-time from different sensors in the system. Any environmental conditions pertinent to landslip monitoring can be included in these parameters, which could include measurements of soil moisture, rainfall intensity, vibration frequencies, and humidity.

V. CONCLUSION

To sum up, the suggested landslide monitoring system is a huge step forward in dealing with the problems of environmental monitoring, especially in areas vulnerable to landslides but without the necessary infrastructure. Integrating AI approaches, Internet of Things (IoT) devices, and Wireless Sensor Networks (WSNs), the system provides a complete and dependable solution for real-time landslip risk detection and assessment. Strong data collecting and transmission capabilities, even in harsh conditions, are achieved by integrating a variety of sensors and connecting them over GSM sensor using ESP8266 modules. In addition, landslip detection is made more efficient and accurate with the use of AI approaches, which allows for the implementation of mitigation plans and early warnings. Ultimately, this integrated method offers a potential answer for early warning systems and landslide monitoring, which can help preserve lives and infrastructure in places prone to landslides across the globe. Communities at risk of landslides and other natural catastrophes can be made even more resilient through ongoing innovation and multidisciplinary cooperation.

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