

Development of Geovibesense for Position and Fall Detection for Total Station Instrument

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Abstract

Total station instrument are very important in achieving accuracy and precision in measurement work, especially cadastral and engineering surveying. However, it is very susceptible to damage and large data errors due to systematic, random and human errors, especially due to carelessness in handling the device. To mitigate this risk, this research paper presents the development of a system called "Geovibesense," a semi-intelligent monitoring system based on Internet of Things (IoT) technology designed to detect vibrations, shocks, and falls in real time. This system basically integrates an accelerometer to measure acceleration across the X, Y and Z axes, a GPS module for precise location tracking and a Wi-Fi module (ESP8266/ESP32) processed by an Arduino microcontroller to communicate with cloud data storage. Once the sensor detects falling activity or strong vibrations exceeding the set target value, the system will wirelessly transmit the instrument status and record the data to the ThingSpeak IoT platform for visualization in the form of graphs for further analysis. The results of the drop experiment confirmed the system's ability to accurately distinguish between vibration status conditions, namely a stable condition producing acceleration values below 10 m/s², while a condition where a drop occurs records a spike exceeding 15 m/s² (reaching 17.16 m/s²), triggering an automatic "FALL DETECTED" warning. This system innovation provides a low-cost and effective solution to improve the safety of all measuring equipment, most of which have relatively high prices, and ultimately reduce repair costs and ensure the accuracy and precision of data in field measurements.

Keywords: - Total station, Internet of Things (IoT), vibration detection, fall detection

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1. Introduction

In the field of geomatics, especially field engineering work, the Total Station is used to measure distances, horizontal and vertical angles, and determine point coordinates digitally and automatically (Tamimi & Toth, 2024). Data from Total Station is very important because it allows angle and distance measurements to be made with high accuracy, speeds up the field work process, minimizes human error, and facilitates data processing to produce accurate and high-resolution digital maps. The data can also be directly integrated with mapping software and Computer-Aided Design (CAD), making it a reliable basis in various engineering, construction, and topographic mapping projects (Sestras et al., 2023). Information from Total Stations can also be integrated into Geographic Information Systems (GIS) to analyse and visualize changes in position, elevation, and

topographic patterns of an area, thus assisting in the decision-making process related to construction planning, land management, and monitoring of earth surface changes for development and environmental protection purposes.

When conducting engineering surveying work, conventional installation and use of Total Stations can be a challenging and risky process. The process of setting up the instrument must be done at the appropriate time and environmental conditions to ensure stability and accuracy of readings. Uncertain weather conditions or uneven ground surfaces can make it difficult to install and align the instrument, as strong winds or unstable ground can cause the instrument to drift out of alignment, and atmospheric conditions can induce significant measurement errors (Hope & Chuaqui, 2007 & Zhou et al., 2021).

In addition, the area selected to set up the Total Station must be strong and stable to avoid movement or vibration that can affect the accuracy of angle and distance observations. Tripod stability problems and soft ground surfaces can cause small movements of the instrument, thus producing inaccurate readings. There are many cases of damage to Total Station instruments that are often reported by users in the geomatics field, especially when conducting field surveying work. This damage is caused by various factors such as careless handling, unstable ground conditions, the use of loose tripods, as well as weather influences such as strong winds and heavy rain that can affect the stability of the device. Among the most frequently reported causes is strong vibrations or shocks that cause the device to fall or fall during measurement operations. Such incidents not only cause physical damage to the internal components of the device, but also affect the accuracy of observation data, slow down the field work process, and increase the cost of maintenance and repair of the equipment (Witczak et al., 2024).

Therefore, the issue that arises requires immediate action through the development of a real-time monitoring system that is capable of detecting, recording and providing early warning of any vibrations and shocks that can affect equipment such as internal damage. To overcome this problem, a system is developed as an innovation based on the Internet of Things (IoT). The system developed must be able to detect vibrations and falls of Total Station equipment in real time (Battistoni et al., 2021). This system combines an acceleration sensor to. This system combines an acceleration sensor, GPS and Wi-Fi where the acceleration sensor is to detect any changes in movement. The GPS module determines the exact location point where the vibration or shock occurs on the Total Station device. While the Wi-Fi module functions to send data from the GPS and acceleration sensor wirelessly to cloud storage and displayed on IoT platforms such as Thingspeak. Through this combination of hardware, software and communication, continuous monitoring in detecting any vibrations and shocks then sends data such as the position and status of the device automatically and in real time without the need for manual observation and reporting. This innovation can reduce the risk of failure to report if there is a tremor or shock to the total station device.

2. Literature Review & Gap Analysis

Table 1 demonstrate the novelty of Geovibesense, a gap analysis of existing vibration and monitoring systems. Total Station instruments are critical for precision in cadastral and engineering surveying. However, these devices are highly susceptible to damage from human error, unstable ground, and environmental vibrations. Current literature highlights that tripod instability, and soft surfaces often lead to significant observation errors. While robotic total stations have advanced, there remains a need for low-cost, real-time monitoring to prevent physical damage from falls. This paper introduces 'Geovibesense,' an IoT-based system

using an accelerometer, GPS, and Wi-Fi to provide immediate "FALL DETECTED" warnings.

Table 1: Gap analysis of surveying instrument monitoring systems

| Research Study | Focus Area | Real-Time IoT | Fall Detection |
|---------------------------|----------------------|---------------|----------------|
| Al-Hameedawi (2019) | Accuracy impacts | No | No |
| Lienhart et al. (2016) | Bridge vibrations | No | No |
| Pasha (2018) | General monitoring | Yes | No |
| Geovibesense (This study) | Total Station Safety | Yes | Yes |

3. Methodology

3.1 Hardware

Fig. 1 shows an Accelerometer Sensor that functions to detect changes in movement, vibration, or shock on a device. This sensor operates by measuring acceleration on three main axes, namely X, Y, and Z, to determine the direction and magnitude of movement of an object. When a vibration or shock occurs, the reading values on these axes will change, indicating the presence of movement or shock. This change data will be sent to the Arduino board to be processed and identified whether the device is experiencing normal vibration or a strong shock, thus allowing the system to automatically warn or send information to the user (Dhadwe & Kathale, 2017).

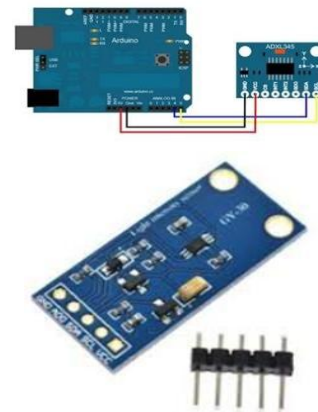


Fig. 1: Accelerometer sensor

Fig. 2 shows the GPS Module (GY-NE06MV2) for coordinate tracking. The Integration of Wi-Fi and GPS Modules in this system functions to monitor and transmit current status information of the Total Station in real time (Kumari & Komati, 2021). Fig. 3 shows NodeMCU V3 Development Board with integrated Wi-Fi. The system integrates an ADXL345 accelerometer for 3-axis motion detection. Data is processed via an Arduino-based NodeMCU (ESP8266/ESP32) which handles cloud communication. Wi-Fi modules such as ESP8266 or ESP32 are connected to the Arduino board as the main hardware in this IoT innovation and configured with a network Service Set Identifier (SSID) via a password to enable wireless data transmission to a

server or monitoring system via protocols such as Hypertext Transfer Protocol (HTTP) or Message Queuing Telemetry Transport (MQTT). At the same time, GPS modules such as GY-NE06MV2 are used to determine the exact position of the device when vibration or shock is detected by the acceleration sensor. This location data is then sent along with vibration information to the monitoring system so that users can quickly identify the location and impact level of the incident. To ensure stable and reliable data transmission, power supply and Wi-Fi connection need to be maintained, and connection tests should be performed periodically (Manchala et al., 2023).

The accelerometer is programmed to sample data at a rate of 10 Hz (10 readings per second). This rate was selected to ensure high-speed impact detection while maintaining low power consumption and stability for the ESP8266 Wi-Fi module (Villa & Casilari, 2025).

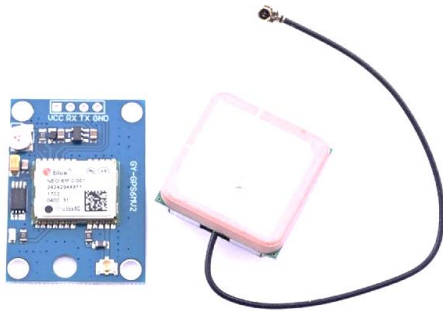


Fig. 2: GPS Module (GY-NE06MV2) for coordinate tracking



Fig. 3: NodeMCU V3 development board with integrated Wi-Fi

3.2 Software

The Arduino Integrated Development Environment (IDE) is used to write, compile, and upload code to the Arduino board, as shown in Fig. 4. The code is written using the simplified C/C++ programming language to make it easier for users to control the microcontroller functions. In the sensing system, the Arduino IDE is used to program the interaction between the accelerometer sensor, GPS module, and WiFi module, so that each component can communicate seamlessly. The code uploaded to the Arduino board controls how vibration, shock, and location data are detected, when the device is dropped, processed, and sent to the monitoring server in real time. In addition, the Arduino IDE also allows users to test and store data received

from the sensors for future analysis and system improvements.

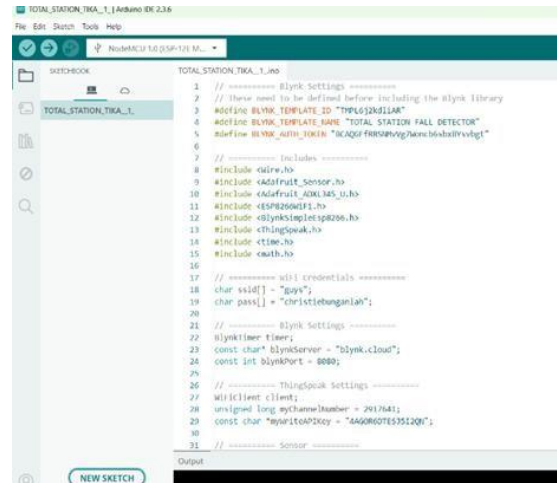


Fig. 4: Arduino IDE

ThingSpeak is an IoT platform that allows users to collect, store, analyze and visualize data from IoT devices in real-time as shown in Fig. 5. It is very popular for small-scale IoT projects, academic research and prototyping due to its ease of use and ability to integrate with other software such as MATLAB (Pasha, 2018).



Fig. 5: IoT platform

3.3 System Production Process

The Geovibsense system was developed as an innovation based on IoT (Internet of Things) technology which functions to detect vibrations or unusual shocks on measuring instruments such as Total Station. This system is designed to help users detect any vibrations in real time and send information about the location of the incident via Wi-Fi connection and GPS module, making equipment monitoring efficient and safe.

In its production process, the Geovibsense system uses accelerometer sensors to detect any movement or vibration that exceeds a certain threshold. Data from these sensors will be processed by Arduino microcontrollers, which then transmit the information wirelessly via ESP8266 or ESP32 Wi-Fi modules. The information sent includes GPS location coordinates, which allows users to accurately identify the position of the equipment in the event of a tremor or fall.

This system is powered using portable power banks or battery 9V, allowing it to be used in the field without relying on a fixed power source. The transmitted data can be accessed via IoT platforms such as ThingSpeak,

where users can monitor the status of the tool and record vibration activity in the form of graphs and digital reports.

After all connections are tested and working properly, system components such as Arduino, Wi-Fi module, GPS and accelerometer sensors are neatly arranged in a DB protective box that is resistant to heat, rain and shock shown on Fig. 7. This is important to ensure that the system can operate stably in various weather conditions in the field. With Geovibsense, the safety and durability of surveying equipment can be improved, thus reducing the risk of damage and loss due to accidents or negligence during surveying work.



Fig. 7: Circuits arranged in the DB box

Fig. 8 shows a schematic of the Geovibsense innovation system, which is a Total Station vibration and fall detection system based on IoT (Internet of Things) technology. The concept or way this system works is by connecting a power source to an Arduino microcontroller and setting up a Wi-Fi connection and a GPS module so that any vibration or shock detected by the accelerometer sensor can be recorded and sent wirelessly to a server or monitoring platform such as ThingSpeak.

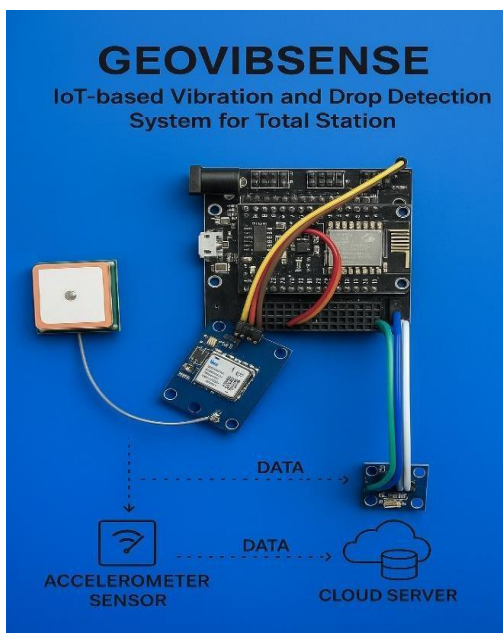


Fig. 8: Schematic of the proposed Geovibsense innovation system

When the device detects a tremor or falls, the system will automatically send a warning signal along with the exact location of the incident to the user via the Wi-Fi network. The recorded and stored data can be accessed in real time for monitoring, analysis, and maintenance purposes in the field. With this system, users can monitor the condition of the Total Station more effectively, thus reducing the risk of damage and loss of equipment during measurement work.

3.4 Threshold Selection and Justification for 3D Acceleration Magnitude

The Geovibesense system utilizes the 3D acceleration magnitude (*Accel*) to continuously monitor and define the operational status of the surveying instrument. Under normal, static conditions, the accelerometer primarily measures the constant downward pull of Earth's gravity, which is approximately 9.81 m/s^2 . To account for this standard gravitational force alongside minor environmental noise such as light wind or nearby foot traffic, the system establishes a stable threshold of $<10 \text{ m/s}^2$. This calculated margin ensures that the system remains reliable and does not trigger false alarms during routine, stable operations. Conversely, if the equipment experiences a drop, the sensor detects a sudden and drastic change in velocity upon impact. Therefore, a fall threshold is set at $> 15 \text{ m/s}^2$. As established by Bourke et al. (2007), an acceleration spike exceeding this level clearly distinguishes a severe physical fall from a standard environmental tremor, ensuring that emergency alerts are only activated during genuine, high-impact incidents.

4. Result and Discussion

The test process was conducted to assess the sensor's sensitivity to vibration, the stability of data transmission via Wi-Fi, and the accuracy of GPS coordinates. Tests were also conducted to ensure the system was able to provide immediate warnings when the device experienced unusual vibration or a fall.

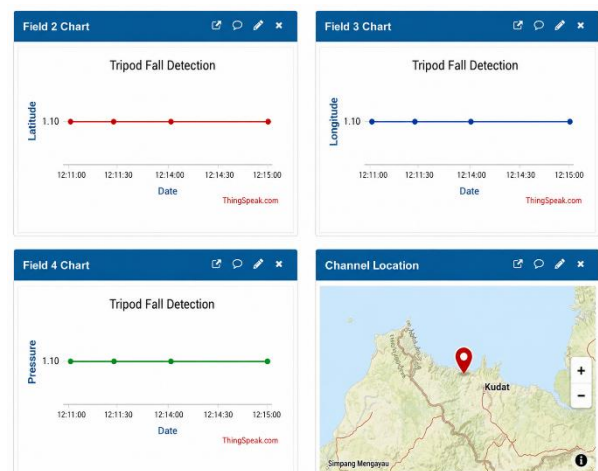


Fig. 9: Example of data display in Thingspeak

Table 2 and Table 3 show the data recorded by the accelerometer sensor that detects vibrations on the measuring equipment if it falls. The data is recorded in the form of acceleration readings on three axes (X, Y, Z) and the overall magnitude value (Accel). All this data is displayed on the Serial Monitor and sent to the IoT platform ThingSpeak for remote monitoring. This data is also sent in real-time which shows the time the tool falls and the time the tool stabilizes again. The data shows how well the system is working. It also shows the readings recorded according to the test conditions that have been set according to the desired shock strength. In addition, the system can show an alarm indicator if a shock occurs with a message displayed on the user's phone device. Based on Table 2, during the fall event at 12:13:15, a significant spike in the Z-axis (-16.67 m/s^2) was recorded. This indicates a rapid downward acceleration followed by impact, triggering the emergency alert.

Table 2: Sensor reading data during falling events (GeoVibSense)

| Time | X m/s ² | Y m/s ² | Z m/s ² | Accel. | Status |
|----------------------|-----------------------|-----------------------|-----------------------|--------|------------------|
| 11/04/25 12:13:14 | -5.22 | -5.02 | -4.24 | 8.39 | FALL DETECTED |
| 11/04/25 12:13:15 | -0.59 | -4.04 | -16.67 | 17.16 | FALL DETECTED |
| 11/04/25 12:13:16 | -0.63 | -5.30 | -6.81 | 8.72 | FALL DETECTED |

Table 3: Sensor reading data during stable events (GeoVibSense)

| Time | X m/s ² | Y m/s ² | Z m/s ² | Accel. | Status |
|------------------------|-----------------------|-----------------------|-----------------------|--------|--------|
| 11/04/2025 12:13:02 | -0.31 | 5.69 | 6.75 | 0.83 | STABLE |
| 11/04/2025 12:13:03 | -0.35 | 5.69 | 6.79 | 0.86 | STABLE |
| 11/04/2025 12:13:04 | -0.30 | 5.88 | 6.83 | 9.01 | STABLE |
| 11/04/2025 12:13:05 | -0.10 | 5.84 | 6.83 | 9.99 | STABLE |
| 11/04/2025 12:13:06 | -0.20 | 5.77 | 6.75 | 8.88 | STABLE |

Table 4 shows that the instrument maintains an Accel value below 10 m/s^2 . The Z-axis remains highly consistent (6.75 to 6.83 m/s^2), which confirms the tripod is level and stationary.

Table 4: Analysis for stable data reading

| Parameter | Value Range | Observation |
|----------------------|-------------------------------|-----------------------|
| X-axis | -0.35 to -0.10 | Small variation |
| Y-axis | 5.69 to 5.88 | Consistent readings |
| Z-axis | 6.75 to 6.83 | Very stable |
| Acceleration (Accel) | 0.83 to 9.99 m/s ² | Normal condition |
| System Status | STABLE | No vibration detected |

The recorded data shows no major changes in X, Y, or Z values, indicating that the instrument is static and stable. The Accel value remains below the vibration threshold ($<10 \text{ m/s}^2$), confirming a steady state. The threshold value of 10 m/s^2 is the magnitude of 3D acceleration, while scalar magnitude is a scalar value that represents the total rate of change of an object's velocity to determine the "strength" of the overall motion. Gravitational fall generally has a value of 9.81 m/s^2 . Therefore, a threshold value of 10 m/s^2 is used in this technical study.

The system is functioning normally, making it suitable for use in surveying operations or structural monitoring where instrument stability is critical.

Table 5: Analysis for fall data reading

| Parameter | Value Range | Observation |
|----------------------|--------------------------------|--|
| X-axis | -5.22 to -0.63 | Sharp change — indicates sudden movement |
| Y-axis | -5.30 to -5.02 | Negative values show tilt or reversal of direction |
| Z-axis | -16.67 to -4.24 | Strong downward acceleration — fall impact |
| Acceleration (Accel) | 8.39 to 17.16 m/s ² | Drastic increase |
| System Status | FALL DETECTED! | Emergency alert triggered |
| ThingSpeak Code | 200 | Data successfully transmitted to IoT cloud |

The readings show a sudden and strong change in all three axes. The Accel value spiked up to 17.16 m/s^2 , far above the stability limit, indicating a strong impact or drop. The system correctly detected the abnormal motion and displayed "FALL DETECTED!". The ThingSpeak response code 200 confirms that the data was successfully uploaded to the IoT platform for alert and monitoring. The sensor and microcontroller remained operational after the fall, showing durability and reliable data transmission.

The Geovibesense system offers an advancement over traditional surveying methods. Unlike the work of Meng et al. (2020), which focuses on construction-induced vibration for structural health, Geovibesense specifically addresses the safety and physical integrity of the Total Station. By using the ThingSpeak IoT platform, the system achieves a successful data transmission rate (Response Code 200) similar to industry-standard predictive maintenance models, but at a significantly lower hardware cost.

4. Conclusion

In both stable and falling or vibration tests, NodeMCU will constantly send sensor data to ThingSpeak using WiFi at a set interval. A consistent response code of 200 confirms successful data logging to the cloud storage. Users can view and download the vibration reading history, analyze graphs and receive notifications remotely via the ThingSpeak dashboard. The system successfully distinguishes between stable and falling conditions using acceleration data. Acceleration values below 10 m/s^2 have been

programmed to indicate normal or stable conditions, while values above 15 m/s² indicate strong vibration or falling. An automatic warning notification will be given to the administrator "FALL DETECTED" on media platforms such as the Whatsapp application. IoT data transmission shows that this system is capable of real-time monitoring and automatic reporting. This system is suitable for monitoring measuring tools during field work, detecting vibrations or sudden movements that occur to the tool and also the current location of the equipment for safety monitoring purposes.

Overall, the Geovibsense innovation system has successfully achieved its intended objectives. This system demonstrates how open-source technology based on Arduino, vibration sensors, and GPS modules can be effectively utilized to monitor the stability and position of the total station in real time at a low cost. The Geovibsense system has the potential to be widely used by students of Politeknik Kuching Sarawak during field surveying activities. In the future, this system will continue to be improved and adapted to meet the needs and challenges of real industry applications beyond the polytechnic environment.

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