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Smart Safety System for Fishing Vessels: GPS, Gyroscope, and Accelerometer-Based Real-Time Monitoring

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ABSTRACT

Fishing is a vital economic sector in Indonesia, but fishermen face significant risks from unpredictable sea conditions. An integrated safety system has been developed to mitigate these hazards using GPS, gyroscope, and accelerometer technology for real-time vessel monitoring. The system incorporates an MPU6050 sensor to measure the vessel's orientation, a GPS module for position tracking, and a SIM808 GSM module for data transmission, all processed by an Arduino Uno microcontroller. System testing demonstrated that the GPS module achieved positioning accuracy within 3 meters, while the MPU6050 sensor successfully detected excessive tilting with a response time of under 1 second. Additionally, the system's data transmission had a success rate of 98%, ensuring timely alerts even with moderate GSM signal interference. This integrated system enhances safety by providing early warnings for hazardous conditions, reduces accident risks, and promotes more sustainable fishing practices through improved operational monitoring.

1. Introduction.

Fishing is one of Indonesia's most important economic sectors, providing livelihoods for millions of people and contributing to food security and foreign exchange earnings (Choiron, 2024). Every day, fishermen face unpredictable challenges on the high seas, where the risk of accidents and natural hazards can threaten their lives and livelihoods (Ratnawati, 2023). Safe vessels are important to protect fishermen's lives and ensure the sustainability of operations that support communities that depend on marine products. Fishing vessels that can withstand storms and strong currents at sea symbolize resilience in facing natural challenges and proof of the importance of supporting technology that ensures that vessels can operate optimally even in bad conditions because ship accidents can have serious consequences, such as loss of life, economic losses, and environmental damage (Wu, 2024).

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An efficient ship safety system is important in providing early warning of other hazards, allowing fishermen to take preventive measures and reduce the risk of loss, both to the vessel and to life (López & González, 2020). One innovation that can support this system is the integration of GPS, gyroscope, and accelerometer technology that provides real-time data on the vessel's position, orientation, and condition. With this kind of monitoring, the ship can detect dangerous situations, such as excessive tilting or shaking due to strong currents, giving fishermen time to act quickly and avoid accidents. Fishing vessels equipped with modern monitoring technology make it possible to follow responsible fishing practices, thereby reducing the risk of overfishing and maintaining the balance of the marine ecosystem (Thurston & Smythe, 2018).

Fishing vessel activities often pose risks to fishermen, but a ship safety system based on modern technology can provide significant added value. A system that can monitor the location and tilt of the ship in real time not only provides the presence of large ships around to prevent potential collisions but also provides an early warning system. Thus, the implementation of a ship monitoring system integrated with GPS, gyroscope, and accelerometer technology not only provides direct protection for the safety of fishermen but also supports more efficient, sustainable, and environmentally friendly ship operations.

2. Materials.

2.1. Sensor MPU6050.

The MPU6050 sensor combines a 3-axis accelerometer and gyroscope in one module, allowing simultaneous monitoring of linear acceleration (±2g to ±16g) and ship rotation (±250°/s to ±2000°/s). The accelerometer detects linear acceleration and inclination based on gravity, while the gyroscope measures angular velocity to detect changes in ship orientation (pitch, roll, yaw) (Zhou, 2018).

2.2. Modul GSM SIM808.

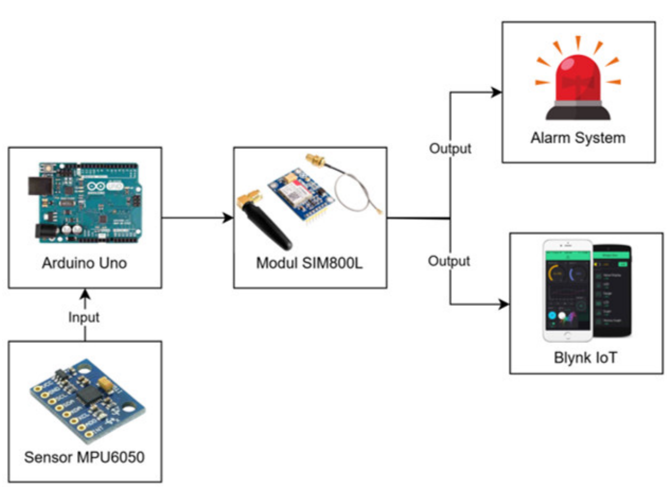
The GSM SIM808 module is a versatile communication device that combines GSM, GPRS, and GPS functions in one module, with the ability to transmit data over a cellular network (Ali, 2016). This module supports serial communication with microcontrollers such as Arduino Uno. It has a GPS antenna that can determine accurate geographic positioning and provide user position information anywhere in the world (Zaky, 2018). GPS antennas are the eyes and ears of a ship's navigation system (Maradona, 2021). Using satellite signals, GPS antennas accurately determine the ship's location. This information is essential for navigation and routing and vital when the ship needs help (Ratnawati, 2023). In bad weather conditions or when an engine fails, the accurate location provided by GPS can speed up the response of rescue teams.

3. Method.

3.1. System Design.

The safety system is designed by integrating the GSM GPS module, gyroscope, and accelerometer. These components are made according to the block diagram in Figure 1.

Figure 1: Block Diagram.



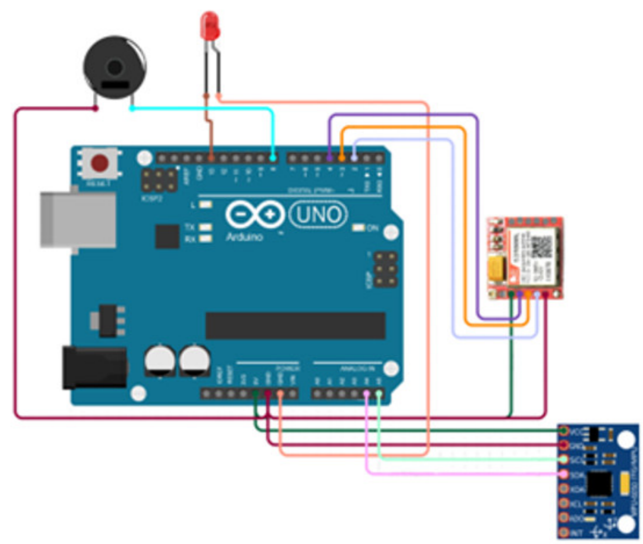
Source: Authors.

Data from these three pieces of hardware will be processed using a microcontroller that functions as the main processing unit. This system also has an alarm that warns fishermen early on if dangerous conditions are detected.

3.2. System Design.

Figure 1 shows the system design. It involves installing and integrating various electronic components to create an Internet of Things (IoT)- based fishing vessel safety monitoring unit. This system is designed to automatically monitor vessel conditions and provide real-time data to fishermen and the monitoring center.

Figure 2: System Design.

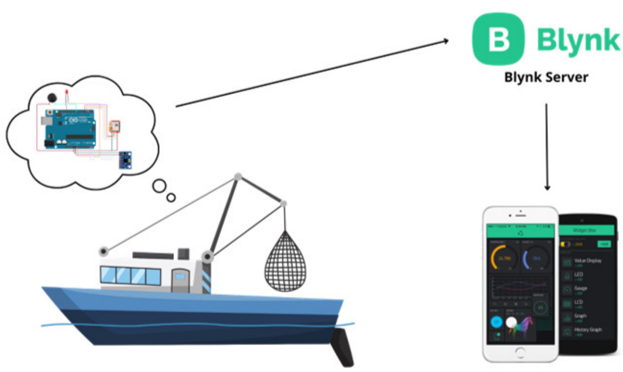


Source: Authors.

In Figure 2, the SIM808 GSM module functions for GSM/GPRS communication and is connected to the Arduino via a serial port. This module is placed on top of the system with an external antenna to amplify cellular communication signals, facilitating data transmission and reception.

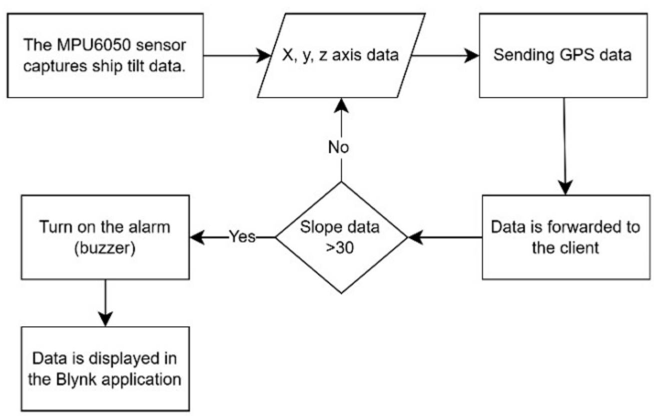
This fishing boat navigation and stability system combines several key components to monitor the position and movement of the boat. A GPS antenna connected to a SIM808 GSM Module receives satellite signals to determine the boat's position. It transmits location data in real time, provided the antenna is installed in an open location. The MPU6050 sensor, which combines an accelerometer and a gyroscope, measures the boat's movement, including linear (roll) and rotational (pitch) acceleration, to monitor the boat's stability relative to the sea surface. An Arduino Uno R3 microcontroller processes data from these sensors, which runs algorithms to analyze the boat's condition and take necessary actions. The Arduino is placed in a safe location to protect it from the elements. This system automatically monitors the fishing boat's position and stability, improving operational safety and efficiency. The design of the system implementation on a fishing boat is shown in Figure 3, and the system flowchart is shown in Figure 4.

Figure 3: Design of Implementation on Fishing Vessels.



Source: Authors.

Figure 4: System flowchart.



Source: Authors.

Overall, this system's design considers factors such as resistance to harsh maritime conditions, ease of maintenance, and long-term reliability. All components are installed in a way that allows efficient communication between components and easy access for maintenance or replacement when necessary. In addition, the system is designed to withstand humidity, salt, extreme temperatures, and other maritime environmental factors, such as ship shaking and seawater splashes. The selection of corrosion-resistant materials and protective coatings on sensitive parts are also significant concerns in this design to ensure the reliability and durability of the system in the long term.

3.3. System Testing.

A. MPU6050 Sensor Calibration Testing.

The MPU6050 sensor is mounted on a stable and flat test platform. The platform is then placed in a stationary position. Data from the sensor is collected for several minutes to obtain the average value on each axis (X, Y, Z) under static conditions. This average value is considered as the offset value. Furthermore, the platform is moved slowly in various directions to measure changes in sensor values. These changes in value are used to calculate the sensitivity of the sensor. The calibration results are then used to compensate for the offset value and adjust the data scale in the program.

B. GPS Accuracy Testing.

The GPS module will be tested, and the reference GPS will be installed at the exact location with a clear sky view. Both devices are turned on simultaneously, and position data is recorded at specific intervals. The position data from both devices is then compared. The difference between the coordinates obtained from both devices is calculated to determine the accuracy level of the GPS module being tested. Testing should occur at several locations and times to get more representative results.

C. Packet Loss Blynk Testing.

Packet loss testing on the Blynk system is carried out by monitoring data communication between devices (Arduino and MPU6050, GPS, SIM808 sensors) with the Blynk application via two types of networks: Wi-Fi and GSM. Tests are carried out under various network conditions, such as stable Wi-Fi with a strong signal, Wi-Fi with interference (e.g., blocked by walls or long distances), GSM with a strong signal, and GSM with a weak signal. Each scenario is tested for 10 minutes with data transmission measurements every second, where measurements are taken to calculate the number of successfully sent and lost packets.

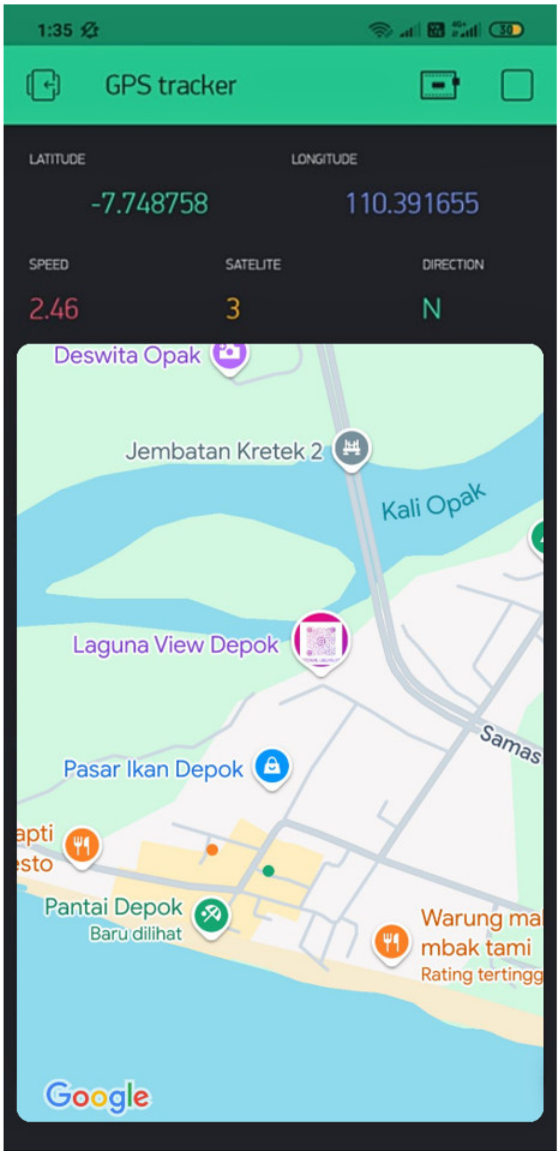
4. Results and Discussion.

The installation of the SIM808 GSM Module, MPU6050 Sensor, and GPS Antenna on the Arduino Uno platform was successfully carried out. The connectivity between these components proved stable and reliable during testing. The SIM808 GSM Module can send and receive data to the monitoring center smoothly, including GPS coordinate information, ship tilt status, and other vital data. The messages sent did not experience significant interference. The MPU6050 sensor provides accurate data on the orientation of fishing boats, including detecting tilts that exceed the safety threshold, which indicates a potential risk of accidents. The GPS antenna successfully provides high-precision ship location data per the known location during testing, which shows the system's reliability in geographic mapping. The location of the fishing boat can later be seen through the Blynk application, as in Figure 5.

Before the MPU6050 sensor was used in the system, it was calibrated and showed excellent results. The MPU6050 sensor was calibrated as a gyroscope and accelerometer. Accelerometer calibration ensures the sensor can provide accurate acceleration readings in various orientations. The results of the accelerometer calibration are shown in Table 1.

The calibration results show that the accelerometer sensor on the MPU6050 can provide accurate results at various orientations. Testing in vertical and horizontal positions shows results that are very close to the expected values, with slight deviations still within acceptable tolerances. The calibration results are also excellent in the tilted position, indicating the sensor's ability to detect acceleration accurately at various angles.

Figure 5: Blynk Interface.



Source: Authors.

Gyroscope calibration aims to reduce drift or bias in rotation measurements. The results of the gyroscope calibration are shown in Table 2.

The results of the gyroscope calibration test show that the sensor can provide very accurate rotation angle readings with minimal deviations. In each rotation test, the sensor detected high-precision angular changes. The minor deviations in the 360° rotation were still within acceptable tolerance limits, indicating that the gyroscope was stable and reliable.

In shipping theory, ship stability is critical in preventing accidents due to excessive tilting (Rajasekhar, 2018). The metacenter and metacentric distance (GM) determine how stable the ship is against shaking and tilting (Doerry, 2008/0. The greater this distance, the more stable the ship. This monitoring system functions to detect changes in the ship's roll and pitch through the sensor, providing early warning if the ship's tilt reaches a

Table 1: Accelerometer Calibration Results.

No.	Sensor Position	Expected Acceleration	Test Result
1	Vertical position (X=0, Y=0, Z=9.81 m/s²)	0 on the X and Y axes, 9.81 m/s² on the Z axis	X: 0.02, Y: 0.01, Z: 9.81
2	Horizontal position (X=9.81 m/s², Y=0, Z=0)	9.81 m/s² on the X axis, 0 on the Y and Z axes	X: 9.80, Y: 0.01, Z: 0.01
3	Tilted position (X=7.0 m/s², Y=7.0 m/s², Z=7.0 m/s²)	7.0 m/s² on all axes	X: 6.95, Y: 6.98, Z: 7.02

Source: Authors.

Table 2: Gyroscope Calibration Results.

No.	Sensor Position	Expected Rotation (degrees)	Test Results
1	Fixed position (no rotation)	0° (no rotation)	0.1°
2	Rotate 90° (X-axis)	90°	89.9°
3	Rotate 180° (Y axis)	180°	179.8°
4	Rotate 360° (Z axis)	360°	359.5°

Source: Authors.

risky level.

GPS testing is carried out to measure the position accuracy provided by GPS on the GSM module and compare it with standard position measurement tools such as GPS handheld. In this test, measurements were taken in the open field to obtain more accurate data. The results of the GPS accuracy test are shown in Table 3.

The purpose of this GPS accuracy test is to represent when the system is in the actual field, passing through roads with open conditions or in closed conditions (Amanaf, 2019). The results in Table 3 show that the GPS performance on the SIM800L Module is excellent in open locations, with adequate accuracy. In this condition, the average position deviation was recorded at around 1-2 meters, with the slightest deviation below 1 meter, indicating a reasonably high accuracy level for applications that require reliable position data. In open locations, the GPS signal is received well without any interference so that the module can detect the position very accurately. However, in tests carried out in locations with obstacles, such as inside buildings or densely populated areas, the test results showed a significant decrease in GPS signal quality. This is due to the obstruction of the GPS signal path by physical structures, such as walls or ship roofs, which hinder communication between the GPS module and the

Table 3: GPS device accuracy testing SIM808 module.

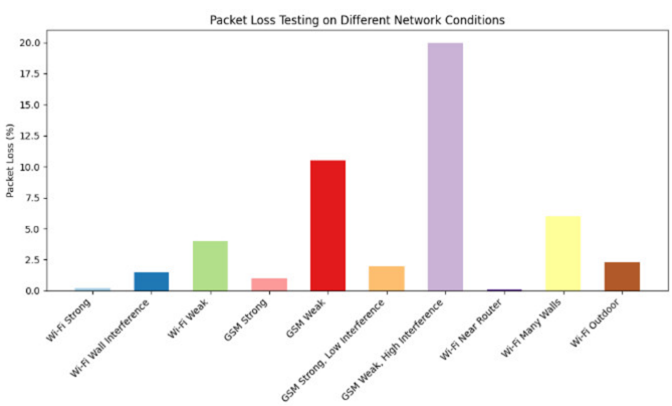
No	Testing Locations	GPS (GSM Module)	GPS Coordinates	Deviation(m)
1	Location A (open field)	-8.013795, 110.291665	-8.013789, 110.291660	0,869
2	Location B (waters near the coast)	-8.013908, 110.291357	-8.013904, 110.291350	0,896
3	Location C (roadside)	-8.013056, 110.291079	-8.013066, 110.291073	1,297
4	Location D (inside the building)	-8.012545, 110.291335	-8.012582, 110.291323	4,123
5	Location E (dense settlement)	-8.001387, 110.304061	-8.001396, 110.304056	1,145

Source: Authors.

satellite.

Packet loss testing provides valuable insights into the stability and reliability of data delivery between the Blynk system and application, especially on low-quality networks (weak Wi-Fi or GSM). Packet loss can affect application performance, and this test shows the importance of ensuring good signal quality using a Blynk-based ship monitoring system. The results of the Blynk packet loss test are shown in Figure 6.

Figure 6: Packet Loss Test Results.



Source: Authors.

The test results highlight the critical role of network quality in determining packet loss and the overall reliability of the Blynk communication system used in the IoT-based ship safety monitoring system. A strong Wi-Fi signal performs best with minimal packet loss (0.1%), ensuring smooth communication. However, packet loss increases with Wi-Fi interference (1.5%) and weak signals (4.0%), making it less reliable in environments with obstacles or poor signal strength. In contrast, while GSM networks offer broad availability, they exhibit higher packet loss, particularly in weak signal areas (10.5%) and when subject to interference (up to 20%). Even with a strong GSM signal, packet loss is still noticeable (1.0%), highlighting GSM's limitations compared to Wi-Fi. These findings underscore the importance of selecting a network with strong and stable signal quality, as packet loss can severely affect real-time monitoring and the system's effectiveness, especially in critical applications like ship safety.

Conclusions.

An IoT-based fishing vessel safety monitoring system that integrates GPS, MPU6050 sensors (gyroscope and accelerometer), and SIM808 GSM modules has proven effective in improving vessel operational safety. Tests show GPS positioning accuracy with an average deviation of 1-2 meters in open locations, as well as the ability of the MPU6050 sensor to detect vessel tilt with a fast response of less than 1 second. Data transmission has a success rate of 98%, even in weak GSM network conditions. Data packet tests revealed that network quality significantly affects communication stability, with Wi-Fi providing the best performance, while GSM showed a higher packet loss rate. Overall, this system provides early warning of dangerous conditions, reduces the risk of accidents, and supports more sustainable fishing practices, thereby improving fishing vessels' safety and operational efficiency.

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