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Prototype of movement monitoring Objects using Arduino Nano and SMS Notifications

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Abstract: Currently the development of information technology is very rapid, coupled with the development of the internet of things which is also very fast. This encourages many researchers to use information technology devices and internet of things devices to solve problems in the field. Internet of things is a device that can communicate between one device and another. Currently, there are many internet of things devices that have been used in everything, including Smart Home, Smart Office, Smart Campus and others. There is a problem, where currently there are a lot of theft of goods or the transfer of goods that are not known by the owner. This problem encourages researchers to conduct research, by making prototypes to be able to find out about objects that have moved. So that the owner of the goods will know, the goods have moved without notifying the owner. This research is to detect motion sensors using MPU6050. Where the sensor has two functions, namely accelerometer and gyroscope. Both sensors are able to find the coordinates of the x-axis, y-axis and z-axis. The most widely used and affordable microcontroller is the Arduino Nano or Arduino Uno. The purpose of this study is to detect motion with the MPU6050 sensor, then the detection results of the x-axis, y-axis and z-axis are sent via SMS media with the SIM900A device. The use of the prototype has many functions, it can be used to detect falling objects, detect falling motorcycles and others. This device is equipped with a SIM900A module which functions to transmit coordinate data via Shrot Message Service (SMS).

Keywords: MPU6050; SIM900A; Arduino Nano; Arduino Uno; Accelerometer; Gyroscope;

INTRODUCTION

Internet of Things, a technology that has been around for a long time, since the invention of radio and telecommunication devices, can actually communicate with other devices. But now the information about the Internet of Things sounds very powerful. Today device-to-device communication relies on the reuse, scalability and interoperability of services (Khodadadi & Sinnott, 2017). The Internet of Things (IoT) (Schröder & Diedrich, 2020), (Atzori et al., 2017) aims to provide an environment where smart devices can easily expose their services while providing clients with accurate service functionality. Devices that communicate with each other such as sensors, motors and actuators. One of the self-balancing applications is a robot that is used as a learning tool is Lego Robotic which is a product from Lego that can be assembled into a robot and can be programmed according to the desired needs. With the development of this technology, many researchers wish to develop robots that are more than two decades old, one of which is by adding a self-balancing feature (Gonzalez et al., 2017).

The self-balancing (Gandarilla et al., 2021) feature can work as a counterweight and the initial concept was based on the concept of an Inverted Pendulum which must balance the center of mass, in order to be in a balanced position. This PID control method aims to make the system output equal to its setpoint by processing the error signal value. In the PID control (Yun et al., 2022), there are 3 controls, namely the Proportional Controller, integral control and derivative control, each of which has an influence in helping the robot to stand upright. In the design of this PID control system, it is necessary to set the parameters Kp, Ki, Kd, where the parameter settings will be carried out by the trial and error method so that the system output signal response to the input signal is as desired. If applied to this system, the robot must balance the robot's body so that it does not fall. To balance the robot's body, a method is needed so that the robot can stand in balance.

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The balance device that can detect the x-axis, y-axis and z-axis is currently widely applied in various fields, such as detection of infrequent falls and for balancing the position of objects so as not to fall. Application on two-wheeled bicycles that are standing without rocking or falling, because they have a balancing sensor. One that can be used as a balanced detection sensor is the MPU-6050 (Casilari-Pérez & García-Lagos, 2019). The purpose of this study is to make a prototype that is used as a motion object detection tool and send the object's position using SMS. This prototype can be applied as motion detection to find out the position of the tool.

LITERATURE REVIEW

Several studies on the internet of things with the topic of motion sensor detection (Wang et al., 2021) using accelerometers and gyroscopes have been carried out in previous studies. Actually, the accelerometer and gyroscope sensors are already embedded in smartphones, where they are widely used for game programs.

Table. 1 Previous research on accelerometer and gyroscope sensors

Author	Topic	Advantage	Disadvantage
(Nurfaizal et al., 2021)	Robot Control System Prototype ARM Gripper Manipulator using Flex Sensor And Internet Based MPU6050 of Things	The design for the control system on the ARM Gripper robot uses Flex Sensor and MPU6050 and communicates via a wifi connection	The weakness in the prototype has not used communication other than a wifi connection. So if there is no internet, the remote control from the smartphone cannot work.
(Firman, 2016)	Implementation of the MPU6050 IMU Sensor Based on Serial I2C on Self-Balancing Robot	Pembahasan mengenai Self Balancing yang diaplikasikan ke Robot untuk menjaga keseimbangan dari Robot tersebut.	The weakness of this study does not use communication with other devices. Such as the use of communication with wifi, bluetooth and other communications.
(Mangkusasmito et al., 2020)	GY-521 MPU-6050 Sensor Accuracy Improvement with Drift Factor Correction Method	The discussion about the MPU-6050 sensor improves with Drift correction factor. This method results in the accuracy of the MPU-6050 sensor.	The weakness of this research is that there is no communication from the device or this prototype uses device communication such as wifi, bluetooth or connection with a server.
(Samosir & Widodo, 2020)	Gyroscope and Accelerometer Sensor on the Lanange Jagad Dance Robot Balance System	Discussion about balance robot using Gyroscope and Accelerometer using MPU6050 and Arduino MEGA 2560 PRO.	The weakness of this research does not use communication modules such as the use of wifi, bluetooth and other communication modules.
(Fathoni et al., 2021)	Implementation of Motion Balance Control of Two Wheels Self Balancing Robot Using Fuzzy Logic	Discussion about the accelerometer and gyroscope of the MPU6050, plus Fuzzy Logic.	The weakness of this research does not use communication modules such as the use of wifi, bluetooth and other communication modules
(Setiawan, 2021)	Self-Balancing Two-Wheeled Robot With Pid . Method	The discussion on balance uses the PID method to adjust the balance of objects. Uses MPU 6050 sensor, Gyroscope sensor and Accelerometer for balance.	The weakness of this research does not use communication modules such as the use of wifi, bluetooth and other communication modules

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From previous research that has discussed about the MPU6050 sensor which is used for balance and detection of the x-axis, y-axis and z-axis. State-of-the-art in this study detects the coordinates of the x-axis, y-axis and z-axis is used to determine the coordinates and sends the data via SMS. Where the purpose of this research is to find out the position of the coordinates and send it via SMS and actually it is widely applied to the balance of objects.

METHOD

The method proposed in this study is a flowchart of the prototype Accelerometer and Gyroscope of the MPU 6050, which can be seen in Figure 1.

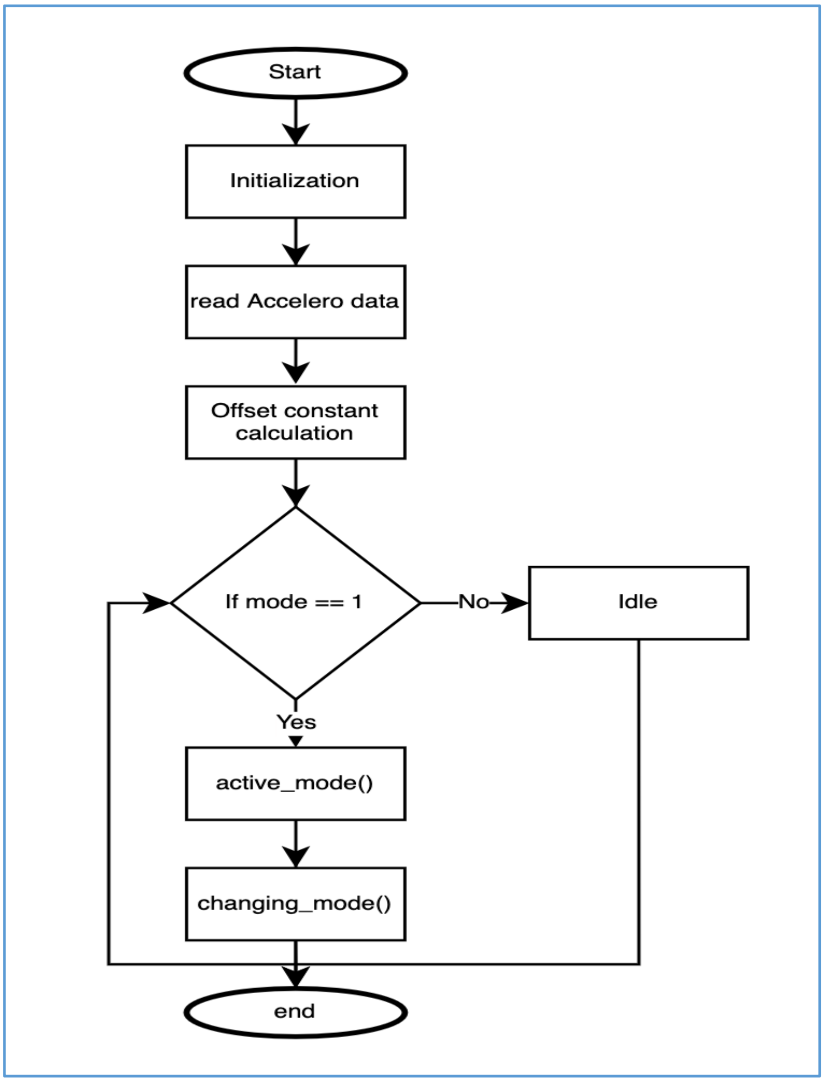

Figure. 1 Flowchart untuk Accelerometer.
Source : researcher property

In figure 1. on the flowchart of the MPU6050 module, it starts with the initiation process of all the variables that will be used. Then proceed with reading the accelerometer sensor. The results of the sensor reading and calculating the offset constant. Next there is a mode checking condition. If mode = 1, then continue the process mode becomes active. The next stage is making changes to Changing mode and done. If the mode check condition = 0 then the process will be idle.

Poses active_mode() adalah melakukan proses, membaca data dari accelerometer. Tahap berikutnya adalah offset cleaning dan filtering signal. After that perform the fault detection process. If there is a condition where the fault is greater than or equal to the limit in the time period, it will send an SMS. If the condition is not greater then it is a clear counted fault.

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Change_mode will change if the operation mode = 1, then if the button is pressed 4 times and within time period if it is true then it stops. if the button pressed 4 time is wrong then the operation mode = 0 and stop the process. If the operation mode = 1 is false, then if the button is pressed 2 times and within the time period, then the operation mode = 1, if it is false, the process will stop.

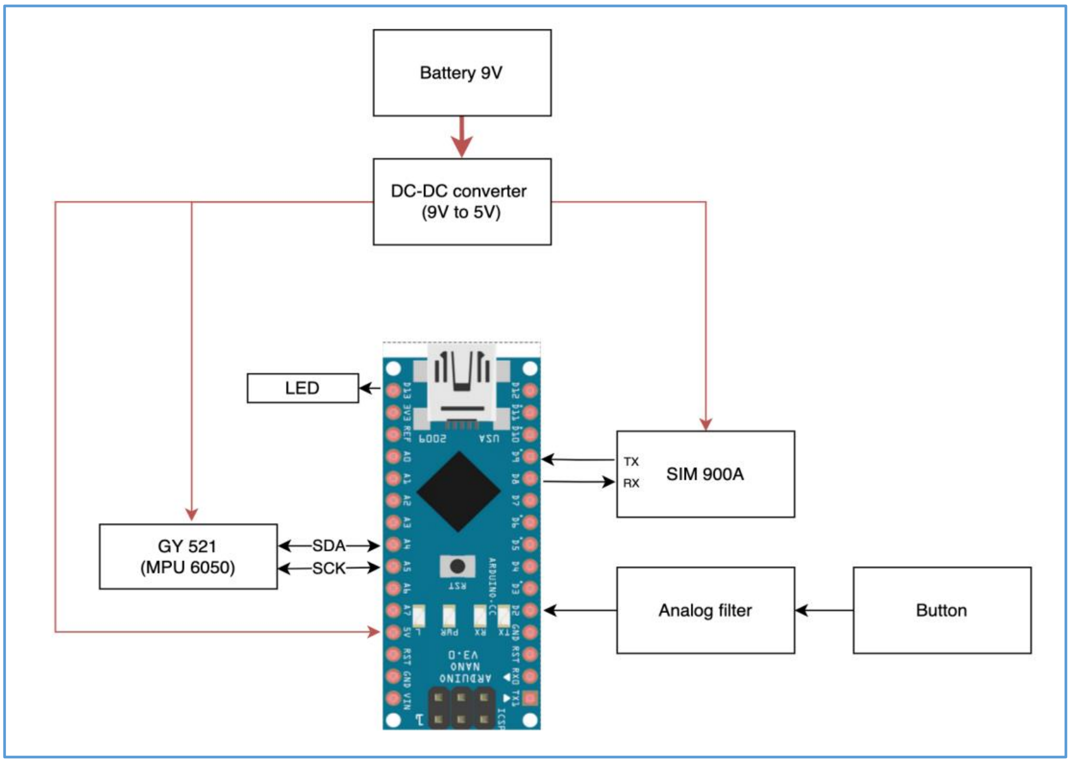

Figure. 2 Configurasi prototype accelerometer.
Source : researcher property

Figure 2. Describes the configuration of the prototype accelerometer using the MPU6050. The SDA and SCK pins on the MPU6050 are connected to the A4 and A5 pins of the Arduino Nano. The SIM 900A module on the Tx pin is connected to the Arduino Uno's D9 pin, while the Rx pin is connected to the Arduino Uno's D8 pin. Because of cursing the 9V DC battery, it is necessary to do a DC to DC Converter module which functions to change the 9V to 5V voltage. In the series of prototype accelerometer and gryoscope using a voltage of 5 Volt DC.

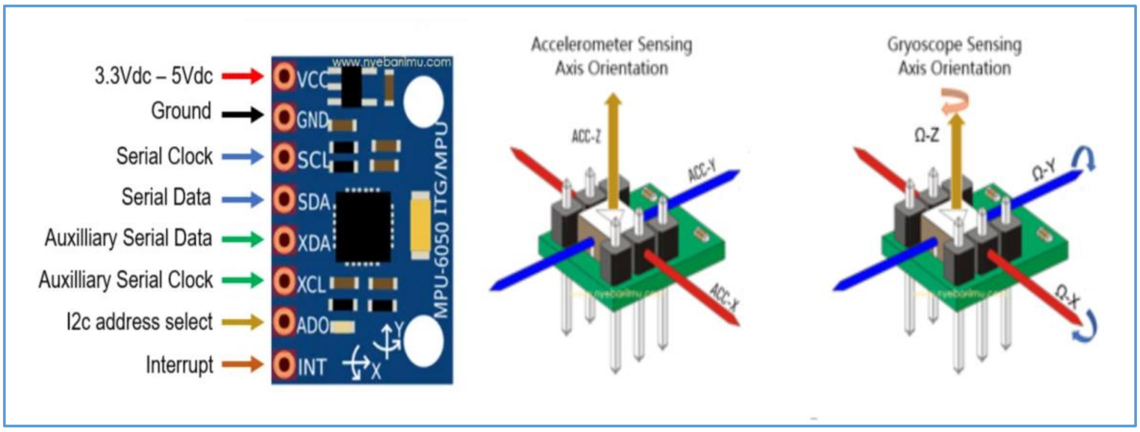

Figure. 3 MPU-6050 consists of Accelerometer and Gyroscope.
Source : researcher property

Accelerometer MPU6050

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This sensor is used to measure the acceleration of objects that move dynamically or statically (Lim & Jeong, 2020). Dynamic measurement (Perelman, 2022) is a measurement of acceleration of a moving object, while static measurement is a measurement of the acceleration of an object due to gravity. The accelerometer is more often used to measure the angle of inclination and the working principle of the accelerometer is to use the principle of acceleration. On the accelerometer in everyday life, the smartphone's shake control function. Where with this function you can take quizzes, for example held by online shop marketplaces. This function can be applied to the music player where to change the song to the next song by moving the smartphone. Change the screen display from portrait to landscape.

Gyroscope MPU6050

Gyroscope is a sensor that determines the orientation of motion by resting on a wheel that rotates rapidly on an axis based on angular momentum. Before use, the gyroscope is calibrated using a pendulum. Calibration process to obtain the value of the calibration factor. The gyroscope has an output in the form of angular velocity from the direction of three axes, namely, the x-axis which will later become the phi angle (right and left) of the y-axis which will later become the theta angle (up and down), and the z-axis will later become the psi angle (front and back).

Gyroscopes (Kim et al., 2020), (Pajaziti & Gara, 2019) are often used in robots or helicopters and other sophisticated equipment. Gyroscope in the form of a gyro sensor to determine the orientation of motion by resting on a wheel or disk that rotates rapidly on an axis. By using a combination of Accelerometer and Gyroscope in a system, Accelerome provides angle measurement when the system is at rest. Meanwhile, when the system rotates the accelerometer cannot work optimally because it has a slow response. This weakness can be overcome by the Gyroscope because this sensor can read dynamic angular velocity. However, the gyroscope also has a weakness, namely the process of moving the angular velocity over a long period of time becomes inaccurate due to the refractive effect produced by the gyroscope. An applicative example of the combination of Accelerometer and Gyroscope is an iPhone device that combines 2 sensors.

From the combination of accelerometer and gyroscope, 6 detection axes are obtained, namely 3 rotation axes (x, y, z) and 3 linear axes (up-down, right-left, front-back). The output of this sensor combination is a very detailed image and smooth movement compared to smartphones that only use the Accelerometer. The Vertical Measurement Unit (IMU) is a tool that utilizes measurement systems such as gyroscopes and accelerometers to estimate the relative position, speed, and acceleration of motor motion. The IMU is part of a navigation system known as an Inertial Navigation System (INS) (SONG et al., 2020), (Qazizada & Pivarčiová, 2016), (Grochowski et al., 2018). IMU became a common navigational component of the shipping industry.

Module MPU6050

The ability of this sensor can be said to be accurate because there is hardware that works to convert analog data to digital which has 16-bit resolution on each channel. So this module is able to read data from channels X, Y, and Z simultaneously in 1 time. The I2C (Del Corso et al., 1987), (Joglekar et al., 2018) communication system requires only two data lines, namely Serial Data (SDA) and Serial Clock (SCL). natural resources is the path used for data transmission, while SCL is the path used as a clock source during data transmission. There is a special format for data transfer between master and slave. When viewed from the special format, I2C is divided into several signal conditions. The first is START and STOP conditions, START conditions are signals to start all commands marked by a change in SDA voltage from “1” becomes “0” when SCL is “1”. STOP condition is a signal to end all commands marked by a change in the SDA voltage from “0” to “1” when SCL is “1”. The second condition is data transmission between master and slave, generally data sent by 8 bits that are transmitted over SDA. Data is divided into two, namely 7 bits slave address and 1 bit to select read mode (value “1”) and write (value "0"). The third condition is Acknowledgment (ACK) and Non-Acknowledge (NACK), are responses signal given by during the data transmission process between master and slave. The ACK or NACK signal will be appears at the 9th bit after data transmission between master and slaves (Deynu et al., 2020), (Huang & Bao, 2020) happen. ACK condition occurs after data transfer by master is successfully accepted by slave then slave will responds to the ACK signal, i.e. when SDA is “0” for 9th clock cycle. If the slave is no longer receiving data sent by the master, the slave will respond to the NACK signal which describes SDA when the value is “1”.

Specifications of the MPU6050 module:

- MPU6050 IC chip.
- DC operational voltage, range between 3V – 5V.
- Using I2C communication interface (SCL, SDA).
- Range of Gyroscope : 250 500 1000 2000 / s.
- Chip built-in 16bit AD converter, 16-bit data output.

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- There are accelerometer and gyroscope sensors.
- Module size: 2.2cm x 1.7cm.

The MPU6050 sensor has a rotation or tilt position. Roll, pitch, and yaw are the reference points of the slope of the system (Awad & Wang, 2016), (Li et al., 2001). Rotating sideways is the term for Roll. Then the downward and upward circular motion constitutes the pitch. As well as a sideways twisting motion is a yaw. There are 16 analog pins that are carried out for conversion first to determine the axis, so that this sensor can work optimally. The values of the x, y, and z axes on this sensor can be taken simultaneously at one time. This sensor uses an Inter Integrated Circuit (12C-bus interface) (Frenzel, 2016) as a connection between the sensor and Arduino.

RESULT

The results of this study are to determine the x-axis, y-axis and z-axis and send data via SMS, the prototype display can be seen in figure 4. This prototype is used as object detection when a displacement occurs, the SIM 900A sensor can provide the position of the object that is moving. All coordinates are complete and will be sent via SMS. Therefore, this prototype can be applied to various objects, and can also be used for self-balancing objects such as robots and two-wheeled bicycles that can stand without an object as a backrest.

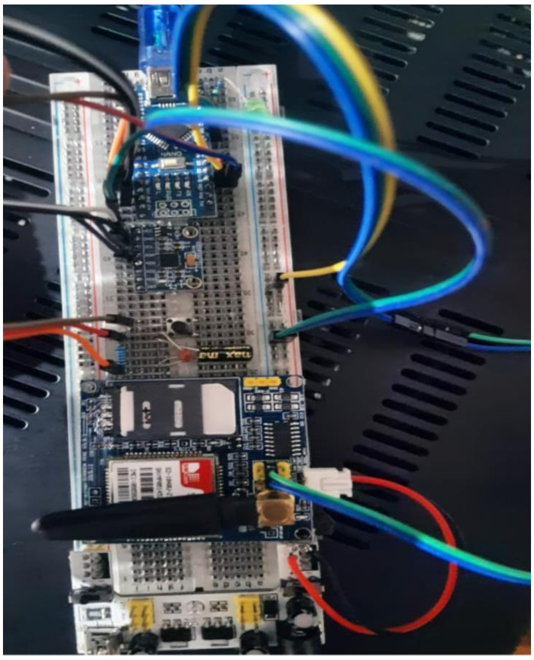

Figure. 4 Motion sensor detection prototype with MPU6050
Source : researcher property

DISCUSSIONS

The discussion in this discussion section has been tested by testing the prototype values for the x-axis, y-axis and z-axis. After the x-axis, y-axis and z-axis values, the results will be sent via SMS via the SIM900A module. The following is a snippet of the script from the prototype accelerometer and gyroscope using the MPU6050 sensor.

```
void send_message()
{
   // Procedure to send SMS from Arduino to Mobile phone using sim900A

    Serial.println ("Sending Message");
    SIM900A.println("AT+CMGF=1");                          //Sets the GSM Module in Text Mode
    delay(500);
    Serial.println ("Set SMS Number");
    SIM900A.println("AT+CMGS=\"+6287771687768\"\r");      //Mobile phone number to send message
    delay(500);
    Serial.println ("Set SMS Content");
    SIM900A.println("Somebody try to get your luggage");   // Messsage content
    delay(100);
    Serial.println ("Finish");
    SIM900A.println((char)26);// ASCII code of CTRL+Z
```

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```
	delay(1000);
	Serial.println ("Message has been sent ->SMS Selesai dikirim");
}

void get_data()
{
	// procesure for fetching data from GY-521 (IMU Sensor)

	Wire.beginTransmission(MPU_ADDR);
	Wire.write(0x3B);
	Wire.endTransmission(false);		// the parameter indicates that the Arduino will send a restart.
						// As a result, the connection is kept active.
	Wire.requestFrom(MPU_ADDR, 7*2, true);	// request a total of 7*2=14 registers

	// "Wire.read()<<8 | Wire.read();" means two registers are read and stored in the same variable
	accelerometer_x = Wire.read()<<8 | Wire.read();
	accelerometer_y = Wire.read()<<8 | Wire.read();
	accelerometer_z = Wire.read()<<8 | Wire.read();
	temperature = Wire.read()<<8 | Wire.read();
	gyro_x = Wire.read()<<8 | Wire.read();
	gyro_y = Wire.read()<<8 | Wire.read();
	gyro_z = Wire.read()<<8 | Wire.read();
}

void offset_calculation()
{
	// offset constant calculation
	digitalWrite(13,HIGH);
	digitalWrite(LED_MODE,HIGH);
	Serial.println("offset calculation");

	for(int i = 0; i<=init_iteration;i++)
	{
		get_data();
		// filtering accelero read data
		filtering_accel(accelerometer_x, accelerometer_y, accelerometer_z);
		delay(100);
	}
	digitalWrite(13, LOW);

	// offset setting
	offset_x = fax.output;
	offset_y = fay.output;
	offset_z = faz.output;

	// reset output and prev_output value
	fax.reset();
	fay.reset();
	faz.reset();
}

void alert()
{
	// procedure for sending alert to user

	if ((fault_count >=2) && (prev_alert==0))
	{
		alert_mode = 1;
		send_message();
		last_alert=millis();
	}
}

void active_mode()
{
	// procedure containing function that must be activated when system is operate actively

	if (prev_mode == 0)
	{
		offset_calculation();
	}

	get_data();
```

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```
        offset_cleaning();
        led_operation();

        //filtering signal
        filtering_accel(filtered_ax, filtered_ay, filtered_az);

        Serial.print(convert_int16_to_str(fax.output));
        Serial.print("\t");
        Serial.print(convert_int16_to_str(fay.output));
        Serial.print("\t");
        Serial.print(convert_int16_to_str(faz.output));
        Serial.println();

        fault_checker();
        alert();
}

void setup() {
        SIM900A.begin(9600);                    // Setting the baud rate of GSM Module
        Serial.begin(9600);

        // Open transmission with GY-521 (IMU sensor)
        Wire.begin();
        Wire.beginTransmission(MPU_ADDR);       // Begins a transmission to the I2C slave (GY-521 board)
        Wire.write(0x6B);                       // PWR_MGMT_1 register
        Wire.write(0);                          // set to zero (wakes up the MPU-6050)
        Wire.endTransmission(true);

        // pin Setting
        pinMode(LED_MODE, OUTPUT);
        pinMode(13, OUTPUT);
        pinMode(2,INPUT);

        attachInterrupt(digitalPinToInterrupt(2), mode_selection, RISING);      //external interrupt
        Serial.println("ax,ay,az");
}
void loop() {
        clearing_fault();
        clearing_button_count();
        Serial.println("mode");
        Serial.println(mode);
        Serial.println(btn_count);
        Serial.println(fault_count);
        // operation mode
        if (mode == 0)
        {
                get_data();
        }
        else if (mode == 1)
        {
                active_mode();
                Serial.println(last_btn);
        }
        prev_mode = mode;
        prev_alert = alert_mode;
        delay(100);
}
```

CONCLUSION

From the results of this study, that the x-axis, y-axis and z-axis can be known from the SMS results. This research produces a prototype for motion detection which is represented by the position of the x-axis, y-axis and z-axis. This prototype can be used as consideration for detecting objects that are moving or moving from one location to another. The position can be known from the results of sending location data via SMS. The application of this prototype can also be used as an object that can stand upright without the support of other objects around it. Developments and modifications can also be made to produce a prototype object that is better than a robot that has wheels but can be used for two-wheeled bicycles that can walk and stand without a backrest.

SUGGESTION

This research can be developed further by modifying the self-balancing object on a two-wheeled bicycle. So the bicycle does not need to have a backrest to stand. Development and modification will produce prototypes that are more useful and easier to use to help with everyday life.

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REFERENCES

Atzori, L., Iera, A., & Morabito, G. (2017). Understanding the Internet of Things: definition, potentials, and societal role of a fast evolving paradigm. *Ad Hoc Networks*, *56*, 122–140. https://doi.org/10.1016/j.adhoc.2016.12.004

Awad, A., & Wang, H. (2016). Roll-pitch-yaw autopilot design for nonlinear time-varying missile using partial state observer based global fast terminal sliding mode control. *Chinese Journal of Aeronautics*, *29*(5), 1302–1312. https://doi.org/10.1016/j.cja.2016.04.020

Casilari-Pérez, E., & García-Lagos, F. (2019). A comprehensive study on the use of artificial neural networks in wearable fall detection systems. *Expert Systems with Applications*, *138*. https://doi.org/10.1016/j.eswa.2019.07.028

Del Corso, D., Civera, P. L., Reyneri, L., & Sansoè, C. (1987). An integrated controller for modified inter-integrated circuit protocol. *Microprocessing and Microprogramming*, *19*(2), 153–166. https://doi.org/10.1016/0165-6074(87)90267-5

Deynu, F. K., Xu, B., & Akpari, E. W. (2020). Design of feedforward master–slave carrier phase recovery in frequency comb-based superchannel coherent transmission systems with nonlinear phase noise. *Optics Communications*, *459*. https://doi.org/10.1016/j.optcom.2019.124898

Fathoni, K., Pratama, A. P., Salim, N. A., & Sulistyawan, V. N. (2021). Implementasi Kendali Keseimbangan Gerak Two Wheels Self Balancing Robot Menggunakan Fuzzy Logic. *Jurnal Teknik Elektro*, *13*(2), 89–97. https://doi.org/10.15294/jte.v13i2.33414

Firman, B. (2016). Implementasi Sensor Imu Mpu6050 Berbasis Serial I2C Pada Self-Balancing Robot. *Jurnal Teknologi Technoscientia*, *9*(1), 18–24.

Frenzel, L. E. (2016). Inter-Integrated Circuit (I2C) Bus. *Handbook of Serial Communications Interfaces*, 65–68. https://doi.org/10.1016/b978-0-12-800629-0.00013-9

Gandarilla, I., Santibáñez, V., Sandoval, J., & Romero, J. G. (2021). PID passivity-based control laws for joint position regulation of a self-balancing robot. *Control Engineering Practice*, *116*(September), 104927. https://doi.org/10.1016/j.conengprac.2021.104927

Gonzalez, C., Alvarado, I., & Peña, D. M. La. (2017). Low cost two-wheels self-balancing robot for control education. *IFAC-PapersOnLine*, *50*(1), 9174–9179. https://doi.org/10.1016/j.ifacol.2017.08.1729

Grochowski, M., Schweigler, M., Alrifaee, B., & Kowalewski, S. (2018). A GPS-aided Inertial Navigation System for Vehicular Navigation using a Smartphone. *IFAC-PapersOnLine*, *51*(10), 121–126. https://doi.org/10.1016/j.ifacol.2018.06.247

Huang, Y., & Bao, H. (2020). Master-slave synchronization of complex-valued delayed chaotic Lur'e systems with sampled-data control. *Applied Mathematics and Computation*, *379*. https://doi.org/10.1016/j.amc.2020.125261

Joglekar, M. R., Mejias, J. F., Yang, G. R., & Wang, X. J. (2018). Inter-areal Balanced Amplification Enhances Signal Propagation in a Large-Scale Circuit Model of the Primate Cortex. *Neuron*, *98*(1), 222-234.e8. https://doi.org/10.1016/j.neuron.2018.02.031

Khodadadi, F., & Sinnott, R. O. (2017). A Semantic-aware Framework for Service Definition and Discovery in the Internet of Things Using CoAP. *Procedia Computer Science*, *113*, 146–153. https://doi.org/10.1016/j.procs.2017.08.334

Kim, C. H., Kim, J. S., & Cho, D. Il. (2020). Harsh-environment visual odometry for field robots using data fusion of gyroscope & magnetometer. *IFAC-PapersOnLine*, *53*(2), 9566–9570. https://doi.org/10.1016/j.ifacol.2020.12.2440

Li, W., Dallal, N., & Matin, L. (2001). Influences of visual pitch and visual yaw on visually perceived eye level (VPEL) and straight ahead (VPSA) for erect and rolled-to-horizontal observers. *Vision Research*, *41*(22), 2873–2894. https://doi.org/10.1016/s0042-6989(01)00165-1

Lim, H., & Jeong, S. (2020). Effect of bedrock acceleration on dynamic and pseudo-static analyses of soil-pile systems. *Computers and Geotechnics*, *126*(May), 103657. https://doi.org/10.1016/j.compgeo.2020.103657

Mangkusasmito, F., Tadeus, D. Y., Winarno, H., & Winarno, E. (2020). Peningkatan Akurasi Sensor GY-521 MPU-6050 dengan Metode Koreksi Faktor Drift. *Ultima Computing : Jurnal Sistem Komputer*, *12*(2), 91–95. https://doi.org/10.31937/sk.v12i2.1791

Nurfaizal, H., Makhsun, M., & Djaksana, Y. M. (2021). Prototype Sistem Kendali Robot Arm Gripper Manipulator Menggunakan Flex Sensor Dan Mpu6050 Berbasis Internet of Things. *Faktor Exacta*, *13*(4), 191. https://doi.org/10.30998/faktorexacta.v13i4.6598

Pajaziti, A., & Gara, L. (2019). Navigation of self-balancing mobile robot through sensors. *IFAC-PapersOnLine*, *52*(25), 429–434. https://doi.org/10.1016/j.ifacol.2019.12.576

Perelman, C. C. (2022). On maximal acceleration, strings with dynamical tension, and Rindler worldsheets.

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DOI : https://doi.org/10.33395/sinkron.v7i2.11413
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Physics Letters B, *829*, 137102. https://doi.org/10.1016/j.physletb.2022.137102

Qazizada, M. E., & Pivarčiová, E. (2016). Mobile robot controlling possibilities of inertial navigation system. *Procedia Engineering*, *149*(June), 404–413. https://doi.org/10.1016/j.proeng.2016.06.685

Samosir, A. S., & Widodo, N. S. (2020). Gyroscope and Accelerometer Sensor on the Lanange Jagad Dance Robot Balance System. *Buletin Ilmiah Sarjana Teknik Elektro*, *2*(2), 51. https://doi.org/10.12928/biste.v2i2.922

Schröder, T., & Diedrich, C. (2020). Formal definition of the term "semantics" as a foundation for semantic interoperability in the industrial internet of things. *IFAC-PapersOnLine*, *53*(2), 8276–8282. https://doi.org/10.1016/j.ifacol.2020.12.1957

Setiawan, A. (2021). Self-Balancing Robot Beroda Dua Dengan Metode Pid. *JST (Jurnal Sains Dan Teknologi)*, *10*(1), 52. https://doi.org/10.23887/jst-undiksha.v10i1.32407

SONG, J., YANG, S., & XIONG, F. (2020). Control failure of the roll-isolated inertial navigation system under large pitch angle. *Chinese Journal of Aeronautics*, *33*(10), 2707–2715. https://doi.org/10.1016/j.cja.2019.08.026

Wang, S., Zhou, G., Watson, A., Xie, L., Sun, M., & Jung, W. (2021). Wearable motion sensor-based chewing side detection. *Smart Health*, *21*(May), 100205. https://doi.org/10.1016/j.smhl.2021.100205

Yun, J., Sun, Y., Li, C., Jiang, D., Tao, B., Li, G., Liu, Y., Chen, B., Tong, X., & Xu, M. (2022). Self-adjusting force/bit blending control based on quantitative factor-scale factor fuzzy-PID bit control. *Alexandria Engineering Journal*, *61*(6), 4389–4397. https://doi.org/10.1016/j.aej.2021.09.067

*name of corresponding author