

## Theft alarm system using Arduino Uno's PIR motion and tilt ball switch sensors

Villanueva, Michelle Joy S. ✉

Divine Word College of San Jose, Philippines ([michellejoysalesvillanueva@gmail.com](mailto:michellejoysalesvillanueva@gmail.com))

Bacorro, Dominica M.

Guilas, Yasmin Faith H.

Khoe, Julienne Jaya D.

Madarcos, Marielle A.

Pastrana, Zen Kreyieline G.

Bautista, Josephine N.

Limos-Galay, Jenny A.



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### **Abstract**

This applied experimental research aimed to enhance a theft alarm system that will be installed in the doors, cabinets, and lockers of homes and buildings to promote security and nurture a safer and thief-free community by combining PIR motion and Tilt Ball Switch sensors into a single device. Descriptive statistical methods were used to evaluate the level of effectiveness of the alarm system in terms of distance from the source and type of place, as well as the level of efficiency of the product utilizing the GSM module and sim card. The researchers also used the linear regression model to characterize the relationship between the speed of other living organisms entering the vicinity of the PIR motion sensor and the theft alarm system detection time. The study's findings revealed that the level of effectiveness of the theft alarm system depends on how close an individual is to the source, the theft alarm system has a very high level of effectiveness in terms of any type of place, there is a high level of production efficiency using the GSM module and sim card in the theft alarm system, there is a significant difference in the level of effectiveness of the theft alarm system in detecting the motion of individuals in terms of the distance from the source, and the detection capability of the PIR motion sensor is affected by the speed of organisms within its vicinity. The researchers recommend considering using other types of sensors or technologies that may be better suited to detecting organisms moving at high speeds.

**Keywords:** applied experimental research, PIR motion, GSM module, theft-alarm, effective

## **Theft alarm system using Arduino Uno's PIR motion and tilt ball switch sensors**

### **1. Introduction**

The COVID-19 pandemic that has been happening for the past three years has forced people to stay and do their work and study at their respective homes. Even though this caused a decrease in crime rates in the country, the total number of crime incidents recorded in the Philippines in 2021 is still high, with 375 thousand cases, and the most prevalent crime that occurred was theft (Statista Research Department, 2022). Region 4B- MIMAROPA has been facing a lot of theft and robbery cases not only before, but also during the pandemic, despite the reduction in crime rates. According to "An Analysis on the Location and Type of Index Crimes in the Philippines" by Baculinao and Ceballos (2017), Region 4B- MIMAROPA has ranked 8th out of 17 regions on the theft rates with 24.0%, a total of 2,826 cases. The region also ranked 10th on the robbery rates in the country with 8.1%, a total of 955 cases. The current reports of the Philippine National Police (PNP) have stated that from January 1- May 31, 2022, there were 3,219 criminal incidents in the MIMAROPA region. The eight focus crimes that have occurred this year were murder, homicide, physical injuries, rape, theft, robbery, carnapping, and motor napping. Though they also disclosed that carnapping, rape, and physical injuries have shown a remarkable decrease, it can be concluded from these statements that theft and robbery cases in the region and province are still prevalent.

As reported by the San Jose Municipal Police Station of the Occidental Mindoro Police Provincial Office in their Crime Clock and Crime Mapping from January to December 2021, index crimes, which include theft, robbery, and burglary, commonly happen in the town during the daytime rather than during the night in Brgy. San Roque, one of the places where crimes frequently occur. According to their data, index crimes occur between 8:00-8:59 A.M., 9:00-9:59 A.M., 11:00-11:59 A.M., 7:00-7:59 P.M., and 10:00-10:59 P.M. San Jose Police Station (2022). Indeed, the eagerness of people to gain profit, property, and other assets for their own sake, has urged them to commit transgressions like property crimes. It is well known that crimes like theft, robbery, and burglary generally decrease safety, disturb social order, cause confusion within the community, and greatly affect the lives of people. In accordance with Flatley et al. (2011), households with 'less than basic' home security measures were six times more likely to have been victims of burglary (5.8%) than households with 'basic' security (0.9%) and ten times more likely than households with 'enhanced' home security measures (0.6%). Over time, many studies and inventions have been developed and produced in terms of preventing property crime. Yet, to this day, thefts are still everywhere in the community and may bombard other people's property.

Considering all of those concerns and to aid in the reduction of theft occurrences in the province, the researchers intend to enhance a theft alarm system with the use of the Arduino Uno's P.I.R. Motion and tilt ball switch sensors. This theft alarm works with the help of specified sensors. When a human's thermal energy is detected by the PIR Motion Sensor, a few minor noises, that may be modified, will be audible. For instance, Cavas and Baballe (2019) stated in their study that many households, industries, schools, and organizations today are now primarily broken into by force, either by criminals destroying a window, entering via a cut ceiling, or even breaking through a locked door or occasionally even an open window. In the P.I.R. motion sensor, people can save power, and achieve effective management at a low cost, and it requires little memory space. The Passive Infrared Sensor (PIR) is responsible for detecting the change in infrared radiation levels when an intruder or human is passed through the system or space where it is arranged. Depending on the change in radiation levels the change in voltages occurs and then with the voltage the signal is amplified and hence the sound will be produced (Umamaheswari, 2020). Therefore, in contrast to other alarm systems available or being sold now on the market, the researchers decided to employ a Tilt Sensor to detect unauthorized handling of objects and trigger the sound of an alert. The purpose of the study is to produce a theft alarm system to be

implemented in the doors, cabinets, and lockers of households and buildings to increase security and help promote a safer and theft-free community.

**Statement of the Problem** - The aim of this study is to produce a theft alarm system that will make future situations and scenarios safer for everyone and to verify the product's efficacy and long-term viability. Specifically, the researchers sought to answer the following questions: (1) What is the level of the effectiveness of the alarm system in terms of distance from the source, type of place, and use of GSM Module and sim card? (2) Is there any significant difference in the level of efficacy of the alarm system based on its distance from the source? (3) Is the detection capability of the PIR motion sensor affected by the speed of organisms within its vicinity?

**Significance of the Study** - In order to assist in improving the existing conditions for everyone's safety, this research study will assess how effective the product is in the Philippines today. The researchers want to monitor product usage to ensure the product's efficacy and to be able to sustain its invasion. The various sectors that benefit from the study are as follows: this research will look into a significant issue that might result in a valuable tool for households to help disperse security. The research study will be more valuable to consumers if it can prevent household intruders. The study's findings will be put to good use to keep the owner's belongings safe from an unexpected incident. This could increase everyone's security in all aspects. To the students, this research will look into a significant issue that might result in a valuable tool for school essentials to help disperse security. The research study will be more valuable to consumers if it can prevent theft. To the community, this study will help enhance security inside the establishment to prevent intruders. This research study will broaden the act of safety to be valuable for consumers. To future researchers, this study will continue to test the effectiveness of enhancing everyone's safety and will broaden the act of service in any aspect of securing properties. The result of the study will turn out to be knowledge in the future.

**Scope and Delimitation of the Study** - This research study focused on the theft alarm system using the Arduino Uno's P.I.R. motion and tilt sensors. The P.I.R. motion sensor allows the users to sense the motion and also detect human movement in or out of the sensor's range, which helps to improve the product's liability. The tilt sensor, on the other hand, responded to the change of position or presence of motion in an object by tilting. These two sensors make the products more possible and usable for a theft alarm. Also, this research is limited to the thermal energy of animals that can be detected by the P.I.R motion sensor, as well as the organisms' speed of movement within the sensor's vicinity. In this case, the product was adjusted or changed by the researcher based on the perspective of the use of the product. The researcher started collecting materials in September 2022 and processed the product in the same month as the materials needed were delivered and completed. The theft alarm system was conducted in a place where there is power due to a power interruption problem in Occidental Mindoro: school, home, and the I Love Milktea coffee shop located in J.P. Rizal Street, San Jose, Occidental Mindoro. The product was finished in April 2023, as the researcher processed it completely. This study enhanced the effectiveness of the product to protect any type of place from thieves. The researchers came up with this study to upgrade the security and safety of consumers against intruders.

## 2. Methodology

**Research Design** - The development of this study utilized an applied research design that developed practical solutions to form the theft alarm system. It is a type of research method that focuses on using scientific principles, theories, and knowledge to solve practical problems or develop new products, processes, or technologies that can be used in real-world settings. According to Baimyrzaeva (2018), "Applied research" is defined as research conducted in an everyday context to solve specific problems of individuals, organizations, and/or industries. Applied research typically employs a combination of several data collection methods from various sources, as well as a mix of qualitative and quantitative data processing methodologies. This study used a quantitative approach to research. Unlike qualitative research, quantitative research emphasizes precise, objective, and generalizable findings. Quantitative methods are based on numerous probability and statistical theories, with rigorous proofs and support from both simulated and empirical data. Quantitative methods can be employed in all stages of a scientific

inquiry, ranging from sample selection to final data analysis (Guo, 2013).

**Data Gathering Procedure** - To assess the effectiveness of the product, the researchers used convenience sampling as the technique for obtaining data from the 18 respondents and used sel-constructed questionnaires, since this technique offered the researchers the choice of choosing a respondent that they considered eligible to test their device. The main reason for utilizing this technique is the time constraint for conducting tests with respondents, along with the various time allotments of the said respondents for participating in the survey. The researchers needed to get a consensus from the respondents before completing the test and survey properly. The testing of the product involved the Anti-theft alarm system. The testing went on for a week to acquire vital information and insights supplied by the respondents for the researchers to better grasp the conflicts, as well as the advantages the device gives. For respondents' data collection, the researchers took respondents from the Divine Word College of San Jose and asked for their approval to participate in the study. Respondents were required to try the product for themselves and answer the survey. After testing the product, the researchers gathered, organized, and analyzed the results.

**Research Process; Stage 1 Preparation and Gathering of Materials** - To be able to enhance an effective product, this project needs innovative materials. The following resources are required to finish the proposed product; researchers chose to use reliable and reasonably priced sources, and the following pictures came from Cybergibbon 2013 and MikroElektronika (n.d).



Figure 1. 9V Battery



Figure 2. Adjustable AC/DC Power Supply Adapter



Figure 3. Arduino Uno R3

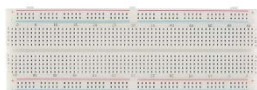


Figure 4. Breadboard



Figure 5. Breadboard Jumper Wire/Cable



Figure 6. GSM Module



Figure 7. Light Emitting Diode (LED)



Figure 8. Passive Infrared Motion Sensor



Figure 9. Piezo buzzer, 5V



Figure 10. Resistor



Figure 11. Tilt Ball Switch Sensor



Figure 12. Sim Card

The materials were ordered by the researchers online. The budget was approximately two thousand pesos

(2,000 PhP).

**Stage 2: Construction and Development of the Product** - The researchers aimed to decrease the number of intruders and robbers that are occurring in many places today by using a theft alarm system that alerts the owner of the establishment and its surroundings when intruders and robbers try to steal valuable objects. In this experiment, the infrared and tilt ball switch sensors were used to detect if a robber is trying to steal valuable objects. The infrared sensor detected unwelcome guests with a certain range of wavelengths, while the tilt sensor detected if the door, cabinet, or lockers are being forced to be opened and the light-emitting diode and piezo buzzer corresponded to it. These components alarmed the surroundings and made the owner of the establishment objects aware if there was any theft. This was done and simulated through the researchers' programming and encoding of pins. In assembling this, the prototypes were wired using jumpers and connectors. Furthermore, the application of the GSM module and sim card was used. This notified the owner if anyone is trying to get into their household or building. And as the project was constructed, the measurements and components, as well as how the owner managed and set up the system would still be enhanced by the researchers.



Figure 13. Actual Product Theft Alarm System Using Arduino Uno's P.I.R Motion and Tilt Ball Switch Sensor

**Stage 3: Experimental Stage** - To evaluate whether the theft alarm system is operable, the researchers began by creating the product in Tinkercad, an online 3D modeling tool that includes most of the parts present in the Arduino package. The components required were purchased from an online store. The researchers then obtained and finalized all of the materials before assembling the product based on the model they created in Tinkercad. Because the software application lacked a GSM module, the researchers investigated how the material would be connected to the theft alarm system. The PIR motion sensor, tilt sensor, piezo buzzer, and LED light bulbs were plugged into the breadboard, while the GSM module was plugged directly into the Arduino Uno R3. The program that the researchers had coded was then transferred to the application Arduino IDE, which implements the program into the actual product. The application identifies the errors in the code and therefore has helped the researchers fix the program for the theft alarm system to work.

To ensure the effectiveness of the Theft Alarm, the researchers tested the product first by attaching it to areas or objects within establishments that open and close, especially doors, windows, and cabinets. The range of the PIR motion sensor was tested by enacting different instances and scenarios that would trigger the alarm. For the safety of the respondents, the researchers examined every aspect and functionality of all materials before executing the final part of the experimental stage. During the experimentation stage with the volunteers, every result was recorded, from positive to negative outcomes. The Theft Alarm System was installed in certain areas of an establishment that has valuable properties, and the test started by passing by the alarm and attempting to force open their door, window, or cabinet. After the experiment, the researchers gave the respondents a survey form to gather their feedback about the theft alarm system. They answered the survey through a printed survey sheet. A separate experiment was conducted by the researchers to test whether other living organisms would be detected by the Theft Alarm System. A camera was set up just outside the vicinity of the PIR motion sensor which is 10 meters. Every reaction of the device was recorded and observed.

**Stage 4: Observation and Data Recording** - The researchers used self-made questionnaires to determine the effectiveness of the proposed product. Observational study findings have high validity because the researcher gathered extensive data regarding a specific activity. There were, however, drawbacks. Both generalizability and

dependability have issues. According to faculty.washington.edu, reliability describes the extent to which observations can be replicated. To determine the effectiveness of the said product, the researcher monitored the alarm system's results each time it was used. To make it more valuable, they wrote it down and identified the benefits and disadvantages. The data collection process was performed by the researcher to improve the alarm system's quality and efficiency.

**Statistical Treatment of the Data** - For statistical treatment, the researchers used the central tendency of frequency distribution to determine the level of satisfaction of the respondents based on the observed outcome of the theft alarm system. It also visualized or illustrated the results of the data collected. It proved that the Theft Alarm System is beneficial for public safety and consumption. It can provide the number of aspects that this study wants to aim to meet its purpose. The central tendency was performed and calculated in the Statistical Data Analysis to determine the accuracy of the PIR Motion and Tilt Ball Switch Sensor, used in the theft alarm system in order to reach the expected output of this research study. The Linear Regression model was used by the researchers to describe the relationship between the speed of other living organisms that entered the vicinity of the PIR motion sensor and the detection time of the theft alarm system.

### 3. Results and Discussions

**Table 1**

*Mean level of Effectiveness of the Theft Alarm System*

Indicators	Strongly Agree (4)		Agree (3)		Disagree (2)		Strongly Disagree (1)		Total	
	F	%	f	%	f	%	f	%	Σf	%
1. The GSM Module promptly sends notifications when someone attempts to steal something.	18	100%	0	0	0	0	0	0	18	100%
2. The P.I.R. Motion Sensor is effective in activating the LED whenever it detects any attempt at stealing.	15	83.33%	3	16.67%	0	0	0	0	18	100%
3. The LED switches on when a person tries to steal.	17	94.44%	1	5.56%	0	0	0	0	18	100%
4. The product can detect anyone attempting to steal no matter where I placed it.	8	44.44%	9	50.00%	1	5.56%	0	0	18	100%
5. If someone tries to steal something, the piezo buzzer is activated.	15	83.33%	3	16.67%	0	0	0	0	18	100%
6. The piezo buzzer is loud enough for me to be alerted to a thief.	7	38.89%	8	44.44%	2	11.11%	1	5.56%	18	100%
7. The PIR Motion and Tilt Sensors are functioning and can detect any attempts at theft	12	66.67%	6	33.33%	0	0	0	0	18	100%
8. The overall product is functioning according to its purpose.	16	88.89%	2	11.11%	0	0	0	0	18	100%
9. I would recommend this product to be implemented in facilities in my area.	16	88.89%	2	11.11%	0	0	0	0	18	100%

Table 1 below presents the perceptions of respondents on distance from the source and type of place utilizing the theft alarm system using Arduino Uno's P.I.R. motion and tilt ball switch sensor. Eighteen (18) or 100 percent of the respondents strongly agreed that the GSM module promptly sends notifications and enhances awareness in terms of being alert when someone attempts to steal something. By a review, the majority of the

respondents have positive feedback when it comes to the distance from the source and type of place utilizing the Theft Alarm System using Arduino Uno's P.I.R. Motion and Tilt Ball Switch sensor. Such findings conform to the study of Abdulrahman et al. (2019) which proves that the GSM module promptly sends notifications when someone attempts to steal something. The component is meant for wireless monitoring and quick response to an emergency warning. The GSM module is tested to send alert SMS whenever the radiation measured exceeds the threshold value. This feature is beneficial for prompt or early emergency alerts in radiation monitoring and safety.

The PIR motion sensor detected the respondents' motion within its vicinity during the experiment, with at least five meters of distance when pointed directly to the individual. According to the research of Darmawan & Taufan (2019), the range of the PIR sensor itself can be adjusted as needed. The maximum distance is 10 meters and a minimum of 30 cm. Fifteen over eighteen, or 83.33% of the respondents, strongly agreed that the PIR motion sensor is effective in activating the LED whenever it detects any attempt at theft, while three over eighteen, or 16.67% of the respondents, agreed with its effectiveness. Meanwhile, the majority of the respondents agreed that the Theft Alarm System can detect anyone attempting to steal regardless of the device's location, with nine or 50% in the results of the survey. Eight or 44.44% of the respondents strongly agreed with this statement, and one, or 5.56% disagreed with its effectiveness regarding the location or type of place.

**Table 2**

*Mean level of Perceptions of Respondents*

Indicators	Weighted Mean
1. The GSM module promptly sends notifications when someone attempts to steal something.	4
2. The PIR motion sensor is effective in activating the LED whenever it detects any attempt at stealing.	3.83
3. The LED switches on when a person tries to steal.	3.94
4. The product can detect anyone attempting to steal no matter where I place it.	3.38
5. If someone tries to steal something, the piezo buzzer is activated.	3.83

*Legend:* 3.25 - 4.00 - Very High; 2.50 - 3.24 - High; 1.75 - 2.49 - Fair; 1.0 - 1.74 - Low

The Theft Alarm System's characteristics, applications, and judgments received are all covered in the first set, which is presented in Table 2. The descriptive ratings for the 9 indications were all rated as very high after computing the weighted mean by the use of frequencies. As a result, the product appears to meet the needs of the respondents after receiving a very high overall descriptive rating, with the exception of the indicator stating that the buzzer is loud enough for a probable theft to be alarmed. The consistency of data, in which each indicator has been observed by respondents to be precise and satisfying, tells an aspect of the project's success, as reflected by its overall weighted mean of 3.7, which is assessed as very high. In the study of Cavas & Baballe (2019), they stated that the installation of a security alarm system may assist in avoiding the loss of assets and property, which might cause enormous monetary loss. As a result, having one of these alarm systems in houses, industries, and other locations increased an individual's sense of security and comfort.

**Table 3**

*Observations of Researchers on the Distance from the Source in the Level of Effectiveness of the Alarm System*

Long Range (>10m)	Short Range (<10m)
0	1
0	1
0	1
0	1
1	1

*Legend:* 0 - the alarm system didn't react; 1 - the alarm system reacts

Throughout the experiment, the observers test if the PIR motion sensor can detect them by standing in front of the theft alarm system with varied distances. When the individual is 11m, 16m, 18m, and 24m far from the alarm system, detection of the organism occurs wherein the researchers observe that the longer the range with the distance of more than 10 meters of the source from the theft alarm system, the low probability of detection. On the contrary, when the individual is 1 m, 3m, 5m, 8m, and exactly 10 m near the alarm system, the detection

of an organism occurs in the shorter range with a distance of less than 10 meters from the source from the Theft Alarm system, the higher probability of detection. However, there is an if only if when the individual is approximately 10 meters away from the alarm system, the detection would not occur. In accordance with the study of Darmawan & Taufan (2019), they stated that the maximum distance is 10 meters and a minimum of 30 cm. Surantha & Wicaksono. (2018) designed and set into use a PIR sensor-based home security system that took an average of 2 seconds to detect an intruder with an accuracy of 89%.

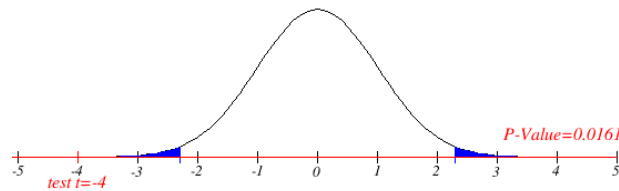


Figure 14. T- test Distribution Graph on the Distance from the Source in the Level of Effectiveness of the Alarm System

As the researchers gathered data from Table 3 and used the data analysis in the Microsoft Excel computer program, they got a P-value of 0.00395 which is less than 0.05. Therefore, the result of the experiment made the researchers was to reject the null hypothesis and accept the alternative hypothesis. This led them to conclude that the distance from the source has a significant difference in the level of effectiveness of the alarm system.

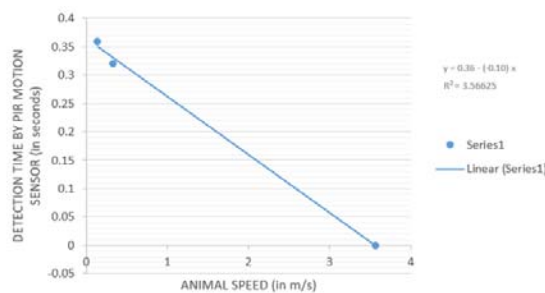


Figure 15. Linear Regression Between Other Living Organisms and the Detection Time of the PIR Motion Sensor

In order to test the detection capability of the PIR motion sensor depending on the speed of organisms within its vicinity, the researchers conducted a separate experiment. The results had shown a negative relationship between the speed of the animal and the detection rate of the PIR motion sensor. During the experiment, two cats and a small mouse passed by. The PIR motion sensor detected the two cats, while the small mouse that ran by the sensor was not detected.

The researchers have observed that living organisms are detected by the PIR motion sensor in the theft alarm system depending on how long they stay within its vicinity. The detection by the PIR motion sensor was predicted by the living organism's speed of movement. The experiment showed that the first cat stayed within the PIR motion sensor's vicinity for precisely 73.5 seconds, and the sensor was immediately triggered after 0.36 seconds. With the PIR motion sensor's detection range of 10 meters, the researchers were able to calculate the first cat's speed as 0.14 m/s. The second cat entered the vicinity and left after 30.36 seconds, and the sensor was immediately triggered for 0.32 seconds. Its calculated speed was 0.33 m/s. The small mouse, however, only ran by the sensor, and the house mice's approximate speed is 3.57632 meters per second. To determine the time it took the mouse to leave the vicinity, the distance or range of the PIR motion sensor, which is 10 meters, is divided by the speed of the mouse, which is therefore equal to 2.796170365 seconds. The researchers initially applied the study by Darmawan and Taufan (2019) in observing the detection, wherein each object with a temperature above 0 degrees Celsius produces passive infrared rays, which are used by PIR sensors to detect heat, but after the experiment, it was observed that the study by Narayana et al., (2015) provided more accurate information regarding the response of the PIR motion sensor to living organisms, as they have discovered that



the speed of the moving object affects the duration and amount of infrared rays falling on the sensor element.

According to an article by Weir (n.d.), the normal temperature range for cats is between 38.1°C and 39.2°C, which is relatively higher than the normal human temperature range. On the other hand, mice have a temperature range between 34°C and 38°C (Gordon, 2017). This proves that temperature alone is not the sole reason for the difference in the PIR motion sensor's sensitivity to detect passive infrared rays, but rather their speed. If a living organism that moves slower passes by the theft alarm system, there is a high probability that it will be detected by the PIR motion sensor. If a living organism that moves faster passes by the theft alarm system, there is a lower probability that it will be detected by the PIR motion sensor. Therefore, the result of the experiment made the researchers was to reject the null hypothesis and accept the alternative hypothesis that the detection capability of the PIR motion sensor is affected by the speed of organisms within its vicinity. Although the researchers have determined the relationship between the two variables, the data would be more concrete if there were more animals detected during the experiment, but due to time constraints and the constant power outage in Occidental Mindoro, the researchers had to make use of the few data points gathered in the experiment.

#### 4. Conclusions and Recommendation

Based on the findings of the study, the researchers have made the following conclusions: The level of effectiveness of the theft alarm system depends on how close an individual is to the source. The theft alarm system has a very high level of effectiveness in terms of any type of place. There is a high level of product efficiency using the GSM module and sim card in the theft alarm system. There is a significant difference in the level of effectiveness of the theft alarm system in detecting the motion of individuals in terms of the distance from the source. The detection capability of the PIR motion sensor is affected by the speed of organisms within its vicinity. Hence, the faster the living organism is, the less responsive the alarm system's PIR sensor becomes.

In light of the conclusion of the study and the findings from the data gathered, the recommendations are as follows: The researchers recommend not placing the theft alarm more than 10 meters away from the specific item or place that the user wants to protect in order for the product to function effectively. The researchers recommend placing the theft alarm in a location that is not easily noticeable by a person, as the device is not small enough to go unnoticed. The researchers recommend placing the theft alarm in an area with good signal reception, as this will enable the GSM module to promptly send a message and make a call when the tilt ball switch sensor detects a suspicious motion. The researchers recommend putting the tilt ball switch sensor in an area where the force can be strongly detected, to ensure that the alarm functions effectively. The researchers recommend considering using other types of sensors or technologies that may be better suited to detecting organisms moving at high speeds.

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