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Internet of Things (IoT)

Detecting Potential Dangers in Elderly Bathrooms using a PIR-Based Notification System and Magnetic Sensor

Dwi Arfi Ananda *, *Farid Akbar Siregar*

Department of Information Technology, Faculty of Computer Science and Information Technology, Universitas Muhammadiyah Sumatera Utara, Medan, 2028, North Sumatera, Indonesia

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CORRESPONDENCE

Phone: +62 853-7244-8022
E-mail: dwiarfiananda@gmail.com

A B S T R A C T

Bathrooms represent one of the most hazardous environments for elderly individuals due to the high risk of falls, prolonged inactivity, and delayed emergency response. Early detection of potentially dangerous situations is therefore crucial to improve safety and reduce injury risks. This study proposes a notification system for detecting potential dangers in elderly bathrooms using a Passive Infrared (PIR) sensor and a magnetic door sensor. The PIR sensor is utilized to monitor human presence and movement patterns, while the magnetic sensor detects door status to identify abnormal conditions, such as prolonged bathroom occupancy or lack of movement after entry. The system is designed to automatically trigger notifications to caregivers when predefined risk conditions are detected. The proposed system was implemented using a microcontroller-based platform and evaluated through a series of controlled experiments simulating typical and abnormal bathroom usage scenarios. Performance evaluation focused on detection accuracy, response time, and system reliability. The experimental results indicate that the system is capable of effectively identifying potentially dangerous situations and delivering timely alerts to caregivers. The integration of PIR and magnetic sensors provides a simple, low-cost, and non-intrusive solution for enhancing elderly safety in domestic environments. This research demonstrates the potential of sensor-based notification systems to support assisted living and improve the quality of care for elderly individuals.

INTRODUCTION

According to Dewi SR (2019), the risk of falls in the elderly tends to increase with age. Each year, approximately 30% of seniors aged 65 and over experience falls, while in the 80 and over age group, this figure rises to 50% worldwide. Falls in the elderly can have serious consequences, increasing morbidity and mortality rates.

The risk of falls in the elderly can be caused by two types of factors: intrinsic and extrinsic. Intrinsic factors relate to the elderly's physical condition, while extrinsic factors relate to the surrounding environment, such as poor lighting, slippery floors, and objects that could potentially trip them [1,2].

Most falls in the elderly occur around the bed (approximately 66.7%), while in the bathroom (approximately 29%). However, in the elderly care unit at the St. Theresia Dharma Bhakti Kasih Nursing Home, this situation is actually the opposite [3,4]. The bathroom is one of the most common accident locations for the elderly. Unfortunately, elderly who fall in the bathroom do not receive immediate assistance due to a lack of direct supervision.

Therefore, based on the results and suggestions from previous studies, this study aims to demonstrate that sensor-based notifications can provide early warnings of potential hazards, allowing caregivers to respond more quickly in emergencies.

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Furthermore, this study also aims to develop a hazard detection system in bathrooms for the elderly using PIR sensors and Internet of Things (IoT)-based magnetic sensors. According to [5,6] a PIR (Passive Infrared) sensor is a sensor that detects infrared light. This sensor is passive, meaning it does not emit infrared light itself but instead captures infrared radiation from the surrounding environment. As the name suggests, "Passive," this sensor responds to energy from passive infrared light emitted by surrounding objects. Generally, the object detected by this sensor is the human body.

A magnetic sensor, often referred to as a magnetic sensor or door sensor, is a device that responds to changes in the surrounding magnetic field by producing a change in its output state. This sensor works similarly to a two-position switch (on/off) that is activated by the presence of a magnetic field [7,8]. A PIR sensor is used to detect the presence and movement of the elderly in the bathroom. If there is no movement within a certain period of time, the system will assume there is a potential danger, such as falling or fainting. The magnetic sensor functions to monitor the status of the bathroom door (open or closed). If the door remains closed for a long time without detecting movement, the system will send an alert to the caregiver. This system will later be developed with web-based notifications, so that caregivers can immediately respond when the elderly are indicated in an emergency.

With the implementation of this system, the potential for accidents in senior bathrooms can be significantly minimized through early detection of risky situations, such as prolonged inactivity or doors remaining closed. Furthermore, this system also plays a role in increasing safety and comfort for seniors, as they can feel more at ease when using the bathroom without worrying about falling without anyone noticing. For nursing staff and caregivers in nursing homes, this technology provides easy real-time monitoring, so they can immediately respond to emergencies, ensuring the safety of residents remains optimal.

METHODS

Sensor Configuration and Data Acquisition

The PIR sensor is installed inside the bathroom to continuously monitor movement patterns, while the magnetic sensor is mounted on the bathroom door to detect entry and exit events. Sensor data are recorded at fixed time intervals and transmitted to the microcontroller for processing. Threshold values for inactivity duration and bathroom occupancy time are defined based on common elderly behavior patterns and safety considerations. These thresholds are used to distinguish normal activity from potentially dangerous situations.

In the flowchart above, it starts with a PIR sensor that emits a reflection to the object. The program reads data from the PIR sensor and the magnetic sensor. The ESP32 will process the data received from the PIR sensor and the magnetic sensor. The program will check whether the sensor has successfully read the data, the program will wait until the sensor has successfully read the data, if the sensor fails to read the data, the program will wait until the sensor has successfully read the data, If the timer reaches 5 minutes without movement, the program will send the data to the website. The program is complete.

Danger Detection Algorithm

A rule-based detection algorithm is implemented to identify abnormal conditions. When the magnetic sensor detects that the bathroom door is closed and the PIR sensor registers initial movement, the system starts a monitoring timer. If no movement is detected by the PIR sensor for a specified period while the door remains closed, the system classifies the situation as potentially dangerous. Similarly, prolonged bathroom occupancy beyond a predefined time threshold triggers an alert. These rules are designed to minimize false alarms while ensuring timely detection of emergency situations.

Equipment Circuit Schematic

The circuit diagram illustrates the model of the device to be used. The circuit diagram for the potential hazard detection device in the elderly bathroom consists of an ESP32 microcontroller, a PIR sensor to detect movement, and a magnetic sensor to detect door movement.

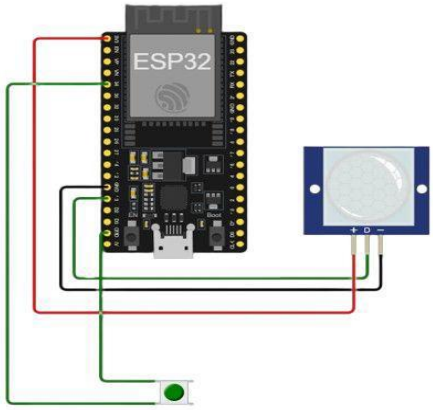

Figure 1. Equipment Circuit Schematic

The circuit above contains several tools for assembling a potential hazard detection system in the elderly's room, the presence of ESP32 as a microcontroller for other tools, then there is a PIR sensor to detect the movement of the elderly, and then a magnetic sensor to detect the movement of the door (open or closed).

RESULTS AND DISCUSSION

Research result

This study aims to monitor elderly people in bathrooms using an Internet of Things (IoT)-based hazard detection system developed using PIR and magnetic sensors. This system is expected to provide real-time notifications to caregivers, enabling a rapid response to emergencies. The developed system consists of several main components, namely:

1. PIR Sensor
   PIR sensors are used to detect human movement in the bathroom. These sensors work by detecting changes in infrared radiation emitted by the human body. If there is no movement for a certain period of time, the system will interpret this as a potential hazard (for example, an elderly person has fallen and is not moving).
2. Magnetic Sensor
   A magnetic sensor is installed on the bathroom door and functions to detect the door's status (open or closed). This sensor consists of two parts: one mounted on the door and one on the frame. When the two parts are separated (the door is open), the sensor will emit a signal.
3. Website-Based Monitoring Platform
   This platform is a user interface that allows caregivers, nurses, or family members to monitor bathroom conditions in real time. The website displays information from door and motion sensors, where the door sensor status indicates whether the door is open or closed, while the motion sensor status indicates movement or rest. Based on data from these sensors, the system displays a graph of movement activity trends over a specified time period. This platform functions to present sensor data in real time, providing visual information about bathroom activity, and can be accessed via a computer or smartphone connected to the internet.
4. Notification
   This detection system is also equipped with an automatic notification feature that will activate when a potentially dangerous condition is detected. For example, if the bathroom door is closed for a certain period of time without any movement being detected, the system will treat this situation as an emergency. Notifications will then be automatically sent to relevant parties, such as nurses. The notification delivery medium is on the website. The main function of this feature is to provide real-time alerts to responsible parties, so they can immediately take action if something undesirable occurs. With this notification feature, the system able to increase the responsiveness and safety of residents, especially the elderly who use the bathroom independently.

Implementation results showed that the system successfully reads and periodically sends sensor data to the server, displaying this information in graphical and numerical formats. The system is also capable of sending alerts if an

untoward event occurs. This system implementation has been shown to increase the sense of security and comfort for the elderly and facilitate ongoing monitoring by nursing staff.

Hardware Implementation

The circuit in Figure 4 so that it can be understood well, the following is an explanation of the circuit schematic and the function of the parts contained in the IoT elderly bathroom potential hazard detection system schematic that has been created:

Figure 2. Schematic of the Internet of Things System

By understanding the function of each component and how they are interconnected, the author can gain a comprehensive understanding of how this IoT-based bathroom hazard detection system works. The PIR (Passive Infrared) sensor detects human movement within the bathroom, allowing the system to recognize any activity or presence. Meanwhile, a magnetic sensor detects whether the door is open or closed. The combination of these two sensors allows the system to monitor the situation in real time and provide a warning if a potentially dangerous condition is detected, such as someone remaining motionless in the bathroom with the door closed for too long.

IoT Code Implementation

The IoT code implementation in this system uses a NodeMCU ESP8266 connected to a PIR (motion) sensor and a magnetic (door) sensor. The code is written using the Arduino IDE with the ESP8266WiFi.h and ESP8266HTTPClient.h libraries to connect the device to WiFi and send data to the server.

The PIR sensor is installed on pin D5 and the magnetic sensor on pin D4, while the indicator LED is on pin D2. The system periodically reads the sensor status and sends the data to the server in JSON format via HTTP POST. If there is no movement for a long period while the door is closed, the system triggers an alert by turning on the LED and sending data.

Client Implementation (Website)

The client-side implementation of this bathroom monitoring system uses the React.js library combined with TypeScript to create a responsive, modular, and dynamic user interface. This website displays real-time sensor data and notifies users if a dangerous condition is detected, such as the absence of movement in the bathroom when the door is closed. The data displayed on the interface includes the status of the door sensor and the motion sensor, each of which is updated directly via socket communication using the socket.io-client library. To maintain access security, the website is equipped with a cookie-based token authentication system, which automatically redirects users to the login page if the token is not found.

The main page of the website presents sensor information in the form of cards that display the current sensor values and the last updated time. Additionally, there is an area graph that visualizes the change in motion sensor data over a specific time period, where the "MOTION" value is converted to 1 and "STAY" to 0 for easy visual interpretation. The interface is also designed to automatically display a warning dialog when a dangerous condition is detected by the system, such as a combination of a closed door and no movement for a certain period. Users can also log out of the system by pressing

the log out button, which will delete the authentication token and redirect to the login page. The overall implementation of this interface aims to present sensor information intuitively and assist in monitoring bathroom conditions efficiently and timely.

The following displays the results of implementing a website (client) that serves as a user interface for monitoring bathroom conditions in real time. The website displays sensor status, movement graphs, and alert notifications in real-time and is designed for user-friendliness. The resulting website interface is documented in the following screenshots as evidence of the implementation process.

Figure 3. Display of Door Open and Motion Detected Operational Conditions

The IoT monitoring dashboard shown in this image is specifically designed to monitor activity and status within a bathroom, providing both a real-time overview and a brief history of the environment. At the very top, the title "Bathroom IoT Monitoring" clearly states the dashboard's primary function, while an "Exit" button in the upper right corner allows the user to end the monitoring session. Below the main title, the dashboard presents key information from two key sensors: the Door Sensor and the Motion Sensor. For the Door Sensor, the dashboard directly displays the status as "OPEN," meaning the bathroom door is currently unlocked. This information is accompanied by a timestamp of "Last updated: May 23, 2025 6:25:52 PM WIB," indicating the last time the door's status was updated and sent to the dashboard, ensuring the data displayed is up-to-date.

The active motion sensor detects movement, while empty or dark areas indicate no movement has been detected. The pattern on the graph shows multiple instances of movement, with two clear peaks indicating significant activity. Overall, this dashboard provides an intuitive and informative interface for monitoring door conditions and movement activity within the bathroom, which can be leveraged for a variety of intelligent applications such as security, energy efficiency with lighting automation, or attendance monitoring.

This bathroom IoT monitoring dashboard is designed to provide an overview of the current condition and historical activity within the bathroom, utilizing data collected from smart sensors. At the top, the title "Bathroom IoT Monitoring" clearly indicates the system's primary focus. Immediately next to it, a red "Exit" button provides basic navigation functions for users.

At the heart of the dashboard are two main information panels that display real-time sensor status. The first panel, "Door Sensor," indicates the status of the bathroom door. Currently, its status is "OPEN," meaning the door is not closed. This information is accompanied by a timestamp of "Last updated: May 23, 2025 6:25:52 PM WIB," indicating that this data is very recent and relevant. The second panel, "Motion Sensor," currently shows the status of "MOTION," indicating that movement has been detected in the bathroom. Like the door sensor, this information was also updated at the same time, May 23, 2025 6:25:52 PM WIB, indicating that both sensors are sending their latest data in sync.

Below the real-time sensor information is the "Current movement" section, which focuses on visualizing the motion detection history. The "Inside the bathroom" label highlights the area monitored by this graph. The graph presented is an area chart with the horizontal axis displaying "May 23" repeatedly, indicating the time span over the course of May 23rd. The vertical axis of this graph has no explicit numeric label, but the height of the light gray area clearly represents the presence of movement. Periods where the light gray area appears indicate times when the motion sensor was actively detecting movement, while empty or dark areas indicate no movement was detected. The pattern of the graph clearly shows several significant peaks in movement, indicating activity within the bathroom at specific times. This graph not only verifies the "MOTION" status displayed on the motion sensor panel but also provides historical context about when and how frequently movement occurred throughout the day.

Overall, this dashboard offers an efficient monitoring solution for bathrooms, allowing users to instantly access information about door status and movement. With the ability to track movement history through graphs, the system can provide valuable insights for a variety of applications, such as improving security, optimizing cleanliness (e.g., scheduling cleaning based on usage levels), or even intelligent energy management (e.g., activating lighting only when there is a presence).

Write results in logical sequence. Results with important findings should be present first. When presenting results in a table or figure, do not repeat all those contents in the text. Present only the summary of the text. Describe only new and important aspects of the study. Do not repeat all information from results section or any section above. Present limitations of the study. Write the issues that are new or unsolved, for future research. This section consists of the information on What/How the presented data were produced, no raw data should be present in the article. The produced data are presented in tables, or figures with an explanation of what is the result/findings from the work. The section will also need to address connections between findings and basic concepts or hypothesis made earlier. Authors should also express whether any arguments were needed relating to other works from other researchers. Write implications made by the work related to theoretical or applications.

In addition to real-time monitoring of door sensor status and motion detection, there are situations where the system detects potential danger, which will then generate an emergency notification to the user, such as:

Figure 4. Potential Hazard Detection Pop Up Warning Condition Display

This message indicates that the IoT system has detected an anomaly or unusual data pattern, which is interpreted as an accident risk. The most likely trigger for this notification is a combination of the motion sensor status being "QUIET" after previous activity, indicating someone has been in the bathroom and has now been silent for an abnormal or suspicious amount of time. With bathrooms often slippery and at high risk for incidents like slips, a sudden silence after a presence could be interpreted as an indicator that someone may have fallen or fainted.

Therefore, this system serves not only as a passive monitoring tool but also as a proactive warning system. Its ability to analyze sensor data and identify concerning patterns makes it a vital safety tool, especially for households with potentially vulnerable individuals, such as the elderly or those with certain medical conditions. By immediately notifying potential dangers and suggesting checks, this dashboard enables a rapid response to emergency situations, potentially preventing serious injuries or even saving lives.

Having previously shown a potential accident detection scenario that triggered an emergency notification, Figure 7 now shows the bathroom IoT monitoring dashboard in a different state. Although the emergency notification has disappeared, the dashboard still provides essential real-time monitoring, with sensor status and movement graphs updated according to the current situation:

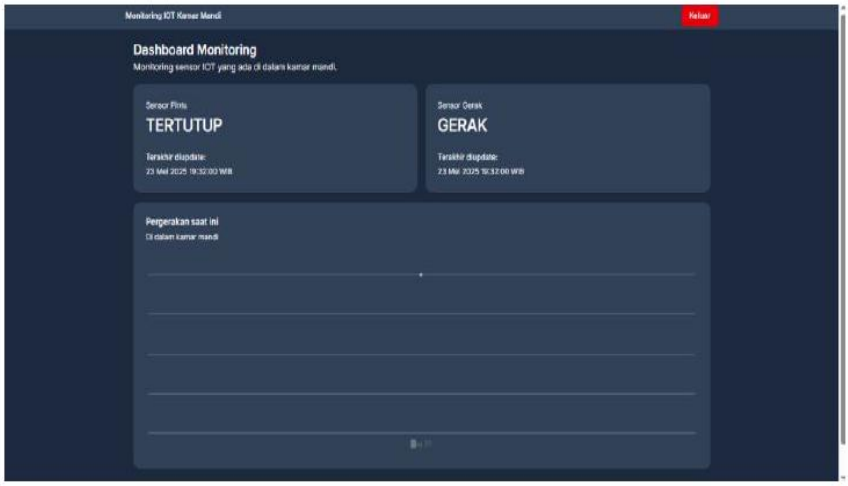

Figure 5. Display of Door Closed and Motion Detected Operational Conditions

Showing the IoT monitoring dashboard for a bathroom under normal operating conditions, following the previous emergency notification scenario. In this view, the dashboard clearly displays the current status of the key sensors. The "Door Sensor" is listed as "CLOSED," while the "Motion Sensor" shows "MOTION," indicating activity or presence in the bathroom at the moment. Both sensor statuses were updated simultaneously on May 23, 2025, at 7:32:00 PM WIB, confirming that the displayed data is the most up-to-date and synchronized information.

At the bottom of the dashboard, the "Current Movement" panel displays a graph of historical activity. Although the motion sensor indicates movement detection, the area representing the movement history graph appears nearly empty, with only a small white dot and the label "May 23" on the horizontal axis. This likely indicates that movement was recently detected after a period of inactivity, so there isn't much data to visualize on the graph's scale. Overall, this image depicts a properly functioning monitoring system, with the bathroom door closed and movement detected inside, indicating active and up-to-date monitoring functionality.

CONCLUSION

Based on the research conducted on "DETECTING POTENTIAL HAZARDS IN ELDERLY BATHROOMS WITH A PIR AND MAGNETIC SENSOR-BASED NOTIFICATION SYSTEM," several key points can be concluded as follows: The detection system successfully captured and recorded data from the available sensors, namely a passive infrared (PIR) motion sensor and a magnetic door sensor, with a high degree of accuracy. Testing showed that both sensors were able to identify status (motion/still and open/closed) with a 100% authentication success rate. The system was able to transmit sensor status data to the server and update the display on the user interface dashboard in a responsive manner, less than 1 second. This indicates that the system provides users with real-time information on bathroom conditions quickly and efficiently. The main hardware components, such as the microcontroller, PIR sensor, and magnetic sensor, functioned well according to specifications. These sensors proved reliable in detecting changes in conditions relevant to potential hazards in the elderly bathroom. The system successfully implemented a potential hazard detection logic in the bathroom (e.g., an abnormally "silent" state after a presence is detected), which was proven to automatically trigger an emergency warning pop-up notification and urge the user to check immediately.

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