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# The Making of a Safety Proximity Sensor with the Utilization of ESP32 and ESP32 Camera Integrated with Arduino Interface and a Buzzer Alert System

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**Abstract: Technology plays a crucial role in enhancing safety and security, especially in environments like schools, where developing innovative solutions to everyday challenges is becoming more vital. This research aimed to expand the use of safety proximity sensors into educational settings by providing an affordable and easy to implement system. This study utilized the quantitative method and experimental design with the objective to determine the feasibility of using ESP32 Camera integrated with Arduino interface as a safety proximity sensor in terms of distance, real-time feedback and the response time of the buzzer. This device was observed to be able to detect human figures or objects with a distance ranging from 1 to 4 meters away from the sensor. Moreover, the ESP32 Camera had a minimal delay time at presenting images with a mean value of 0.89 seconds. Furthermore, the buzzer's reaction time presented a swift response with a mean value of 0.15 seconds. The integration of ESP32 and Arduino interface provided a unique opportunity to repurpose existing technology, making the safety system more accessible for schools with limited budgets. The results of this study indicated that the Safety Proximity Sensor is effective at detecting nearby objects or humans swiftly and efficiently. The real-time speed of both the buzzer and the ESP32 camera had little to no delay. Future researchers may utilize this study as a guide in making more advanced innovations and can be improved by integrating the device to a dedicated app to provide more extensive data and features to further enhance the real-time images it captures and prevent accidents, crimes, and the likes.**

***Keywords**: Arduino Interface, ESP32, ESP32 Camera, Safety Proximity Sensor*.

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## I. INTRODUCTION

Technology plays an essential role in improving safety and security, particularly in settings such as schools, where finding innovative solutions to common challenges is becoming increasingly important. Similar to industrial and commercial spaces, schools must prioritize the protection of students, staff, and visitors to ensure a secure environment. Moreover, proximity sensors have proven to be a powerful tool in managing these risks. Proximity sensors satisfy the commitment of safe, reliable, and independent systems for industrial and daily use (Navarro et al., 2021). The same concept of early hazard detection and prevention can be applied to schools, preventing accidents, enhancing safety, and securing the premises.

This study focused on the feasibility of ESP32 cameras integrated with an Arduino interface to control a buzzer in order to create an affordable and effective alternative to traditional proximity sensors. Through utilizing readily available technology, this approach offers a cost-effective solution for schools looking to enhance their security systems while maintaining a focus on student and staff safety. The proposed sensor aimed to reduce incidents such as accidents in hallways, unauthorized access to restricted areas, and even theft of school property, creating a safer environment for everyone within the school premises.

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Furthermore, the integration of ESP32 and Arduino interface provided a unique opportunity to repurpose existing technology, making the safety system more accessible for schools with limited budgets.

The expansion of the use of proximity sensors into educational settings through an affordable and easy-to-implement system could serve as a model for other educational institutions to follow, promoting the adoption of safety technologies that can be tailored to each school's unique needs and challenges. Moreover, it is emphasized that the ability to repurpose existing technology for safety and security applications can lead to more widespread use of these solutions in environments that may otherwise lack the resources for expensive, specialized security equipment (Schwartz et al., 2016).

In addition to improving safety within schools, proximity sensors offer the potential to safeguard valuable assets and infrastructure from damage or misuse. For instance, monitoring entry points and detecting unauthorized movement can prevent theft or vandalism. It is suggested that the use of cost-effective proximity sensors for communication of intrusion events to security systems can provide real-time alerts, helping to protect both physical property and personal safety (Gokaraju et al., 2016). Furthermore, this research aligned with the increasing need for effective security measures in schools, where theft and unauthorized access are major concerns.

This research is beneficial for several reasons. Firstly, it aimed to capture images of potential intruders or unusual activities, thereby deterring theft and ensuring a swift response from security personnel. Secondly, by preventing accidents through timely alerts, the proposed system contributes to a safer educational environment, promoting better learning outcomes. Lastly, this research is aligned with the growing field of smart surveillance and automation to enhance security and automate monitoring in real-time. Therefore, making this research significant in terms of safety and security.

Despite the broad availability of monitoring and imaging technology, the potential for leveraging ESP32 cameras to enhance safety standards in a range of settings, including industrial facilities, public spaces, and home automation systems, deserves further investigation. These technologies could discover and warn users about unanticipated events such as just-in-time warnings about the distractions, and potential impending dangers. The classification algorithm makes use of the temporal tracking results and the shape of the detected objects to accurately classify objects into classes such as human, human group, and vehicle (Wong & Leow, 2014). Moreover, as mentioned in a study, comprehensive image databases and flexible interfaces are highly desirable for environmental analysis and of human movement (Bradley & Clarke, 2011). Due to the sensor's programming flexibility and comprehensive surveillance database, this study can be further expanded in the future.

In the educational sector, safety proximity sensors are integral to expand security within school premises through advanced monitoring and proper access control. Visible surveillance technologies deter theft and increase safety among students and staff (Adiyono et al., 2024). ESP32 cameras support automating the attendance system by facilitating ease of monitoring with high-quality motion detection and image capture (Kumar et al., 2022). Furthermore, ESP32 cameras are a highly adaptable and efficient platform, it embeds video and image processing into systems for enhanced real-time data acquisition and analysis (Cameron, 2023). In the industrial sector, highway workers are exposed to risks due to the close contact of workers to moving traffic. However, sensor technologies including GPS, radar, and infrared sensors, have demonstrated efficiency in detecting intrusion and proximity hazards that minimizes the possible dangers (Liu et al., 2024). Furthermore, laboratories equipped with proximity sensors have an advantage as these sensors can operate in environments that are harmful to humans, such as areas with toxic leaks or corrosive chemicals (Al-Okby et al., 2021).

A study with a similar objective has also investigated the adaptive behavior of security systems, by which the addition of other elements, like door or window sensors, and smoke detectors, can provide enhanced security in educational environments (Surantha & Wicaksono, 2018). Moreover, combined with the IoT devices and the smart cameras as well as the motion detectors, the integration could automatically perform the security responses, and then send alerts to the teachers or school management in case of suspicious behaviors (Kodali et al., 2016).

This study utilized ESP32 which has become a popular, cost-effective, and versatile solution for home monitoring and control systems, offering Wi-Fi connectivity to allow remote management of devices through smartphones (Pravalika & Prasad, 2019). Beyond home automation, the ESP32 plays a critical role in IoT surveillance systems, where it is paired with cameras to transmit image data wirelessly. Furthermore, the ESP32-CAM module, which integrates a camera and PIR sensor, facilitates real-time human presence detection and image capturing. These innovations showcase the ESP32's significant potential for enhancing both security and home automation applications, improving functionality and user experience in IoT environments.

The prospect of executing basic machine learning processes right on the device without depending on generally cloud-based services promises quicker response times and higher levels of privacy (Dokic, 2020). The ESP32-CAM is an integration between a microcontroller and a camera, offering a practical and adaptable solution for many IoT applications. Its features keep evolving, supporting developers and researchers in developing innovative solutions for surveillance, smart home systems, and more (Cameron, 2023).

Arduino is an open-source hardware that has gained massive popularity among students to develop embedded systems and a working model with open-source software (Yogesh, 2021). Moreover, Arduino has been used in a variety of innovations to improve lives through smart homes, energy management, and healthcare applications. An example is Arduino-based smart home systems that automate lighting control, temperature regulation, and security monitoring (Hasanin et al., 2022; Real et al., 2021). Recent studies show that Arduino's adaptability in the educational setting has allowed it to become a user-friendly learning platform (Tselegkaridis & Sapounidis, 2024). Its modular and alterable nature supports a wide range of applications, from easy-to-do hobby projects to research experiments (Prabowo & Irwanto, 2023). Additionally, Arduino has been employed in cost-effective experimental setups, such as pressure-sensing systems in thermoacoustic research, demonstrating its adaptability in innovative solutions (Iniesta et al., 2024; Manaois et al., 2023). Capacitive proximity sensors that are used with Arduino show their capability to detect objects at various ranges with precision-enhancing safety applications (Hosseini et al., 2022). Furthermore, integrating Arduino into platforms like remote laboratories supports the deployment of many Arduino-based experiments, allowing students to have opportunities to bridge the gap between knowledge and hands-on experience (Martin et al., 2023).

This study utilizes a buzzer which is an audio signalling device used to alert individuals (Sirumalla, 2021). Furthermore, the active buzzer plays a crucial role in safety proximity systems by providing immediate auditory alerts when users enter potentially hazardous zones, which is essential for preventing accidents in environments with high-risk factors. Buzzers are important because they provide a distinct, attention-grabbing signal that can be heard over background noise, ensuring that workers are immediately aware of their surroundings. These auditory signals are particularly valuable in environments with limited visual cues, ensuring that workers are promptly warned and reducing the likelihood of accidents (Huang & Sun, 2022).

Proximity sensors, necessary for non-contact detection, are needed to increase safety in robotics, healthcare, and intelligent environments. Inductive, capacitive, photoelectric, and magnetic sensors ensure accuracy and flexibility for different applications (Wu et al., 2024). In the healthcare sector, proximity sensors provide critical support for contactless patient monitoring and assisting with medical transport (Krishnamurthi et al., 2020). They also contribute to the safety of patients and personnel by monitoring restricted areas, warning staff about possible unauthorized access, and preventing contamination risks (Hassani & Dackermann, 2023). In smart homes, proximity sensors have better accuracy and privacy than video-based systems. Proximity sensors can ensure that operations are safe from collisions and facilitate a seamless workflow (Sishoda et al., 2020) while automating key safety functionalities-intrusion detection and lighting control, for instance, a secure environment (Javaid et al., 2021). Their public safety applications range from monitoring traffic flow and noticing anomalies in otherwise restricted areas to enhancing security policies (Muller et al., 2020). Collectively, proximity sensors provide an adaptable methodology to enhance the safety of several industries by bringing together the concepts of precision, adaptability, and advanced technologies.

This study can be beneficial to Philippine School Doha, the Filipino and Qatari communities residing in Qatar, local and international workers, and future researchers. The findings of this study will help the students, teachers, and non-teaching staff of Philippine School Doha by offering cost-effective solutions for accident prevention and promoting enhanced security. To add to that, proximity sensors could be integrated with the access control systems that will alert the school personnel when an individual approaches restricted areas or attempts to enter premises without authorization. Areas like electrical rooms, laboratory storage rooms, and other restricted areas, are only some of the incident-prone areas in a school campus. With proximity sensors, authorities will be able to prevent and mitigate accident-causing situations.

## II. RESEARCH QUESTIONS

### A. *Research Questions*

The objective of this study was to determine the feasibility of using ESP32 cameras and ESP32 integrated with Arduino interface as a Safety Proximity Sensor. Specifically it sought answers to the following questions:

- What is the distance of detection of the Safety Proximity Sensor?
- What is the real-time feedback of the camera in the Safety Proximity Sensor when monitoring approaching movement?
- What is the response time of the buzzer in the Safety Proximity Sensor?

### B. *Maintaining the Integrity of the Specifications*

H1: It is feasible to create an alternative Safety Proximity Sensor with the use of ESP32 and ESP32 cameras integrated with Arduino Interface.

## III. METHODOLOGY

This study utilized the experimental design of research. An experimental research method follows strict controls of the researchers as it is more likely a field research rather than theoretical (Zubair, 2023). This type of research design aims to establish causal relationships by manipulating one or more variables and observing their effects on the dependent variables whilst controlling for extraneous factors. In this research study, the ESP32 and ESP32 cameras integrated with an Arduino interface were the independent variables, while the alternative safety proximity sensor was the dependent variable. Moreover, the quantitative method was utilized to properly ensure that the experiment was organized in a proper and thorough manner in order to acquire accurate data. In a study conducted, it is said that recent experimental designs—like those that involve many levels of randomization—offer improved control and precision, which makes them very suitable for study designs that seek to find causal correlations systematically (Bajari et

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al., 2023). It was vital to use this type of research method as it provided a systematic, reliable, and objective approach to data collection and analysis.

*A. Research Locale*

This research was conducted in the school of the researchers. Specifically, it is located at Mesaimeer Area (Zone 56), Al Khulaifat Al Jadeeda Street (St. 1011), as the researchers are enrolled in this school and require the facilities and expertise of the school to conduct and develop the experiment.

*B. Data Gathering Procedure*

The procedure shows the step-by-step process that guides and instructs how to create a Safety Proximity Sensor with the usage of ESP32 and ESP32 Camera Integrated with Arduino Interface.

Below is the procedure in guaranteeing protection and maintaining safety.

- Wear protective equipment such as safety gloves, safety goggles, and a laboratory coat prior to the procedures below to avoid any hazardous circumstances.

Below is the procedure in preparing and gathering the needed materials.

- Prepare all the required materials and equipment.
- Ensure care in handling materials and equipment to prevent danger to the researcher.

Below is the process of assembling and coding the device

- Wire the ESP32 camera board module to the ESP32 board using jumper wires following the pinout diagram and schematic.
- Run the ESP32 camera module example code in the Arduino IDE.
- Modify the code with your Wi-Fi credentials.
- Compile and upload the code to the ESP32 board.
- Open the serial monitor in Arduino IDE in order to receive the IP address of the ESP32 camera.
- Put the IP address in a web browser to check out the streaming video live.
- Modify settings in the code or physical connections.
- Implement an ESP32 to process camera data and identify proximity.
- Add the additional components such as the ultrasonic sensor.
- Modify the Arduino code to incorporate camera and sensor capabilities.
- Design a log circuit or software function to steer buzzer activation according to a proximity data set.
- Attach the buzzer to the circuit.
- Test the buzzer by activating it manually using the Arduino code.
- Connect the ESP32 board to the battery/power source.
- Ensure the on/off switch is functioning correctly.
- Design and build a protective casing.
- Assemble the components into the protective casing.
- Insulate exposed wires and reinforce weak connections.

Below is the procedure in testing the accuracy of the Safety Proximity Sensor

- Make sure that the proximity sensor is on and ready for testing.
- Lay out a measuring tape on the floor to measure the sensitivity of the Safety Proximity Sensor in terms of distance.
- Take note of the feedback and reaction of the Safety Proximity Sensor.

Below is the procedure in measure reliability of danger detection of the Safety Proximity Sensor:

- Slowly walk towards the sensor in patterns of 5 centimeters each.
- Take note of the feedback and reaction of the Proximity Sensor.
- Repeat this process 2 more times or as necessary until the alarm goes off. If the alarm goes off, the Safety Proximity

➢ *Sensor is Efficient In Monitoring the Distance of a Person.*

In order to determine the effectiveness of the Safety Proximity Sensor, its detection range, real-time feedback, and buzzer response time were tested using a series of trials. The detection range was assessed by placing an object or human figure at increasing distances from the sensor, starting from 1 meter up to 5 meters. The sensor's ability to detect the object was recorded for each distance. The maximum detection range was determined by identifying the farthest distance at which the sensor could consistently detect an object.

Furthermore, to evaluate the real-time feedback of the ESP32 Camera, the delay in image transmission was measured. A stopwatch was used to record the time taken for the camera to capture and display an image after an object entered the detection range. The delay time was calculated by subtracting the time of actual movement from the time the image appeared on the display. Five trials were conducted, and the average delay time was obtained by dividing the sum of all measured delays by the number of trials.

Additionally, to measure the response time of the buzzer, a stopwatch was used to determine how quickly the buzzer activated upon detecting an object. The time of activation was recorded for each trial when the sensor detected proximity. The response time was calculated by measuring the duration between the moment an object entered the detection range and the moment the buzzer was triggered. The experiment was repeated across five different distances—1 meter, 2 meters, 3 meters, 4 meters and 5 meters—to ensure accuracy. The average response time was then computed by dividing the total sum of recorded times by the number of trials.

## IV. RESULTS

This study is aimed at creating a Safety Proximity Sensor with the use of ESP32 and ESP32 Camera integrated with Arduino Interface. This section includes the results and interpretations of the data that were collected during the testing procedure, wherein the answers to the research questions were sought, such as the distance of detection, real-time feedback, and the response time of the buzzer in the safety proximity sensor.

### *A. The Distance of Detection of the Safety Proximity Sensor*

Table 1 Distance of Variable Proximity Detection

| **Trial** | **1st** | **2nd** | **3rd** | **4th** | **5th** |
|---|---|---|---|---|---|
| **Measured distance (in meters)** | 1 meter | 2 meters | 3 meters | 4 meters | 5 meters |
| **Detection (Yes or No)** | YES | YES | YES | YES | NO |

Table 1 shows the maximum distance measuring capability of the Safety Proximity Sensor made from ESP32 and ESP32 Camera integrated with Arduino Interface in terms of distance using meters as the unit of measurement. The results of table 1 was obtained by measuring how far from the sensor can the safety proximity sensor detect proximity between the variable and the sensor. Moreover, a measuring tape was utilized to measure the distance, as it is an accurate tool to determine the data. For reliable results, a total of five trials were conducted with an addition of 1 meter as the trials progressed. In the first trial the measured distance to be tested was 1 meter, in which it triggered the buzzer. In the second trial, the detection was also successful with a distance of 2 meters. In the third and fourth trial, with the distance of 3 meters and 4 meters respectively, the Safety Proximity Sensor was also able to detect the human figure. In the fifth trial, the Safety Proximity Sensor made from ESP32 and ESP32 Camera integrated with Arduino Interface was not able to detect the human figure standing 5 meters away from it. Therefore, the maximum distance capacity measurable by the Safety Proximity Sensor is 4 meters away from the sensor.

Analyzing the results of the trials, the Safety Proximity Sensor is reliable at detecting figures at certain distances. The trials show that the Safety Proximity Sensor is capable of detecting figures from distances with the range of 1 to 4 meters. In a school setting, it is significant for the Safety Proximity Sensor to be able to detect human or variable proximity at a reasonable distance wherein it is not too far and be a reason for false alarms, and it is also not too near to the point where it is too late to provide immediate action to the situation. It is a necessity for a proximity sensor to detect approaching humans or objects at a distance approximately 4 meters allowing an extended range to ensure safety and efficiency to provide alerts in a timely manner. With its broad detection capabilities, the results indicate that the proximity sensor is capable of detecting humans in large-scaled applications (Hosseini et al., 2022).

### *B. The Real-Time Feedback of the Camera in the Safety Proximity Sensor when Monitoring Approaching Movement*

Table 2 Real-Time Feedback of the Camera in Monitoring Approaching Movement

| **Trial** | **1st** | **2nd** | **3rd** | **4th** | **5th** | **Average** |
|---|---|---|---|---|---|---|
| Delay (in seconds) | 0.81s | 0.79s | 0.94s | 0.92s | 0.97s | 0.89s |

Table 2 illustrates the real-time feedback of the camera in capturing images based on its real-time feedback in seconds. The delay in real-time feedback was determined through a stopwatch and physical testing. The stopwatch was started the moment a hand was swiped in front of the screen and the stopwatch ends once the hand has disappeared. To provide reliable results, five trials were done in which the delay in seconds was then averaged. In the first trial, the delay time was 0.81 seconds. Followed by which with a delay time 0.03 seconds less than the first trial. In the third trial, more delay was experienced with a measured value of 0.94 seconds. In the fourth trial, a delay time 0.02 seconds less than the previous trial was recorded. And lastly in the fifth trial, a delay time of 0.97 seconds was recorded, making it 0.05 more delayed than the fourth trial.

Analyzing the results of the five trials, the average delay time of the Safety Proximity Sensor has a mean value of 0.89 seconds. The results show that the Safety Proximity Sensor had a minimal delay in providing real-time feedback of images detected. Minimal delays in security systems play a crucial and critical role in protecting personnel and machinery in situations where humans and systems interact (Beuster et al., 2024).

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*C. The Response Time of the Buzzer When an Object or Person is Detected*

Table 3 Response Time of the Buzzer in the Safety Proximity Sensor

| Trial | 1st | 2nd | 3rd | 4th | 5th | Average |
|---|---|---|---|---|---|---|
| **Distance Tested** | 1 meter | 2 meters | 3 meters | 4 meters | 5 meters | |
| **Time (in seconds)** | 0.08s | 0.14s | 0.15s | 0.21s | N/A | 0.15s |

Table 3 discusses the time it took for the buzzer to respond when an object or a person is detected. Moreover, to ensure that reliable data was obtained, a total of five trials with distance detections ranging from 1 meter to 5 meters was conducted and the results of the said trials were then averaged by dividing the summation of the time in seconds by the number of trials. Furthermore, with the use of the Clock app in a cell phone the reaction time of the buzzer was measured in terms of seconds based on certain distance detections. In the first trial, the buzzer in the Safety Proximity Sensor took 0.08 seconds before the alarm was set off with a distance of 1 meter. In the second trial, a time of 0.14 was recorded at 2 meters, with a difference of 0.06 seconds from the first trial. In the third trial, the buzzer went off at 0.15 seconds at 3 meters, which is 0.01 second slower than the second trial. In the fourth trial, the buzzer speed recorded at 4 meters away from the Safety Proximity Sensor took 0.21 seconds to react , making it 0.06 seconds behind from the third trial. And lastly, in the fifth trial, the researchers tested the device, however after a minute the buzzer never went off. This result supports the data in table 1 indicating that the maximum distance detection of the Safety Proximity Sensor is 4 meters.

Based on the results of the trials, the average response time of the buzzer in the Safety Proximity Sensor has a mean value of 0.15 seconds. The quick response time of the buzzer will allow authorities to be alerted in a swift manner in order to respond to situations quickly. Furthermore, sensors that provide rapid feedback allow prompt responses to human movements and actions, which is crucial for efficiency and security (Wu et al., 2024).

## V. DISCUSSION

Proximity sensors have demonstrated their effectiveness in mitigating risks. These devices identify nearby objects or people, helping to prevent unfortunate events. Additionally, proximity sensors have been essentially utilized to monitor the risk of collision events (Ventura et al., 2023). Moreover, utilizing a safety proximity sensor helps mitigate the issue of safety and security in different environments and sectors. As a result, this research aimed to assess the effectiveness of the Safety Proximity Sensor in terms of the maximum distance the Safety Proximity Sensor can detect approaching humans or objects in meters, the real-time feedback of the camera in image-capturing in terms of seconds, and the response time of the buzzer once triggered in seconds in certain distances. Based on the findings of the study, the Safety Proximity Sensor was able to trigger the alarm accurately when it detected human figures and objects up to 4 meters away from it. From the first to the fourth trial, the detection was successful. However, in the fifth trial, at 5 meters, the detection started to be inconsistent. Therefore, the maximum distance the Safety Proximity Sensor can detect from is 4 meters. Moreover, the real-time feedback of the camera in detecting movement in terms of seconds had minimal delay with the least delay measured at 0.79 seconds during the second trial, and had the most delay during the fifth trial with a feedback time of 0.97 seconds. Lastly, the device exhibited a swift reaction time in triggering the alarm when an object or human is detected, with the fastest time recorded at 0.08 seconds during the first trial with a distance of 1 meter and the slowest detection time was measured at 4 meters with a recorded time of 0.21 seconds. While at 5 meters, the buzzer did not respond to the approaching human figure. The Safety Proximity Sensor proved to be functional and precise by exhibiting promising results in all of the given trials.

## VI. CONCLUSION

The findings of the study indicate that the Safety Proximity Sensor is an effective and reliable tool for detecting human presence within a 4-meter range, ensuring quick alerts and enhanced safety. The ESP32 Camera provides real-time images with a minimal delay of 0.89 seconds, while the buzzer responds almost instantly at 0.15 seconds, allowing authorities to act fast in case of potential threats. These results highlight the practicality of using ESP32 and Arduino technology to create a budget-friendly yet highly responsive security system. By delivering accurate, real-time proximity detection, this system can help prevent accidents, unauthorized access, and other security risks, making it a valuable addition to safety measures in various environments.

Based on the findings, it is recommended that future researchers may utilize this study as a guide in making more advanced innovations with a similar objective and functionality. The researchers greatly suggest the future researchers to integrate the device to a dedicated app to provide more extensive data and features that can further enhance the real-time images the device captures and effectively alert individuals and prevent accidents, crimes, and the likes.

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