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Design of a Fire Alarm System and Its Integration into Building Automation System Trainer at Makassar Aviation Polytechnic

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ABSTRACT

Fire Alarm Systems and their integration into Building Automation System Trainers can be used as a learning medium for practical devices in the form of automation system trainers. The problem raised in this research is how to design, integrate, and test the feasibility of the devices created in this research. The research aims to find out how to design devices, integrate devices with other equipment, and test the feasibility of the devices that have been made. The research method used in this research is the waterfall research and development model, which consists of the stages of requirements analysis, system design, implementation, integration and testing, implementation, and maintenance. At the needs analysis stage, identification of what is needed to make the device is carried out. The system design stage includes designing the device architecture and user interface. Implementation involves developing hardware and software according to predetermined specifications. The device was then examined for suitability using an instrument in the form of a questionnaire given to 2 experts in their fields at the integration and testing stage to ensure the device's suitability. Once implemented, the device is accompanied by a user guide in the form of a module, which plays a crucial role in ensuring that students can use the device effectively and understand its functionality. The maintenance phase is carried out continuously to correct errors and update as needed. The results of this research showed that the device could function well according to the design that has been made, its feasibility has been tested by two experts in the field who stated that this device is very suitable based on Likert scale calculations, and this device was successfully integrated with other devices to become a building automation system. This device will provide students with experience in operating a fire warning system and how this device is integrated with other equipment to become an automation system.

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INTRODUCTION

An automation system refers to the use of technology to perform tasks automatically without significant human intervention (Amstrabena, 2018). Advances in automation technology have made major contributions to various fields including safety and security. The use of sensors, intelligent software, and system integration are key building blocks for developing solutions that can respond effectively to emergencies. Security automation systems refer to the use of automated technology to monitor, control, and respond to situations

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related to security aspects. This system is designed to protect people, property, and the environment from potential hazards and dangerous events (Prabowo et al., n.d.).

Groover (2015) defines automation as the use of control systems to operate equipment with minimal or no human intervention. An automation system consists of the integration of several components or devices and also software that is controlled or managed by a system without human intervention (Chasta et al., 2016). Where one of the device that can be integrated to create an automation system is the Fire Alarm System which has the function of warning people to take evacuation action in the event of a fire or other emergency (Yendri & Tiffany, 2017).

Avillo (2014) highlights that fire alarm systems play a crucial role in building fire safety strategies, with the main function of detecting fires at an early stage and providing warnings. Christopher J. Naum explains that a fire alarm system is an important component of building safety designed to detect fires and provide early warning to occupants and firefighters. Naum emphasized the importance of integrating fire alarm systems with other building safety systems to ensure effective and efficient responses to fire incidents (Naum, 2016). The Fire Alarm System has two main systems, namely the detection system and the alarm system. The detection system uses detectors in the form of heat detectors and smoke detectors. Heat detectors are used to detect a significant increase in temperature which may indicate a fire will occur and smoke detectors are used to detect particles in the form of gas around the room, where the detector will give a signal to the control center when it detects an indication of a fire then the alarm system will give a warning to take immediate evacuate action (Ali, 2016).

In research related to making a Fire Alarm System, it is known that the device that has been made can detect fires in several rooms by using fire sensors, smoke sensors, and temperature sensors whose values will be monitored on a 16x2 LCD where the buzzer used as an alarm will active if the sensor detects a fire in the room (Bayu Purbo Wartoyo, Syahrir Rasyid, 2023). The Fire Alarm System in other research also detects potential fires by using PLC-controlled smoke detectors and heat detectors, and the water pump will be activated if a fire occurs (Darmawan et al., 2022). In other research, it was also explained that the device that has been created will provide notifications to Telegram if the sensor used detects a fire (Dr. Osamah Ibrahim Khalaf, 2019).

From the references and previous research described, it is known that the device made have not been integrated with other devices, so this research will be developed by integrating the device made with other devices to create an automation system in the form of a Building Automation System Trainer. This is also supported by the conditions at the Makassar Aviation Polytechnic, which currently does not have learning media for automation systems, where understanding the automation system is very important to understand because the automation system allows flexibility in adapting functions according to changing needs. Additionally, it can be easily integrated with the latest technologies or updated to meet new requirements. This is also supported in the journal "Building Automation Systems: Concepts and Technology Review".

The fire alarm system is a system that utilizes gas and temperature sensors to detect fires. This system is integrated with communication devices to provide notifications to the security system and building occupants (Suryani & Wijaya, 2019). Fire alarm system is defined as a system designed to detect the first signs of fire through the use of various sensors and communication technologies. This system aims to provide early warning so that building occupants can evacuate safely (Hidayat, 2021). Based on the explanation in the journal, a fire alarm system is a device used to detect fires and provide warnings to immediately evacuate if a fire occurs.

Building Automation Systems (BAS) is a system that controls various electrical, electronic and mechanical systems throughout the building in one control center. BAS functions as a computer network system that monitors and controls various electronic and other mechanical systems. This allows disparate systems to communicate across platforms, software, and languages (Domingues et al., 2016).

An expert in innovation and technology management, explains that technology integration is a process that combines various information technology systems to increase operational efficiency and effectiveness. Schilling emphasized the importance of integration in ensuring that various technologies can work together to achieve strategic goals (Schilling, 2016). Marc Lankhorst, an expert in enterprise architecture, states that system integration is the process of connecting various subsystems and applications in an organization so that they can function coherently. Lankhorst emphasized the importance of integration in creating efficient information flows and improving organizational performance (Lankhorst, 2017). Inmon and Linstedt (2015) explain that data integration is the process of combining data from various sources to provide an integrated and consistent view. Integration is an important process that involves bringing together various elements or systems to ensure that they can work together efficiently. According to experts such as Joseph A. Schilling, Marc Lankhorst, Inmon and Linstedt, the integration of technology, information, and systems is the key to increasing efficiency, effectiveness, and coordination in various organizational and technological contexts.

Banzi and Shiloh (2014) explain that Arduino is a device that allows individuals to create interactive projects and is designed to be simple and affordable. Michael Margolis, in his book on Arduino programming, states that Arduino is a flexible development platform and can be used for a variety of applications, from simple projects to complex industrial applications. Margolis emphasized Arduino's power in combining hardware and software in one easy-to-access platform (Margolis, 2020). Simon Monk, an author of books on electronics and programming, explains that Arduino is a platform designed to make microcontroller programming easier for beginners and professionals. Arduino allows users to create devices that can interact with the physical environment through sensors and actuators (Monk, 2019). Arduino is an easy-to-use and flexible electronics development platform, designed to enable anyone, from beginners to professionals, to create interactive projects. According to experts such as Massimo Banzi, Michael Margolis, and Simon Monk, Arduino combines hardware and software in one platform that makes it easy to develop a variety of applications, from simple to complex projects.

Jacob Fraden, an expert in the field of sensor technology, defines a sensor as a device that measures a physical quantity and converts it into a signal that can be read by an observer or instrument. Sensors are used to measure various parameters, including temperature, pressure, light, and humidity (Fraden, 2016). John Turner and Martyn Hill stated that sensors are devices that detect changes in the physical or chemical environment and convert this information into electrical or optical signals. They also highlight the importance of sensors in a variety of modern technology applications, including robotics, automation, and health systems (Turner & Hill, 2016). Clarence W. de Silva, a professor, and expert in the field of control systems, defines sensors as devices that respond to physical stimuli such as heat, light, pressure, and movement, and produce signals that can be measured. De Silva emphasized the role of sensors in data collection and process control (De Silva, 2016). Sensors are devices that detect and measure changes in the physical or chemical environment, converting this information into signals that can be analyzed or read by instruments. According to experts such as Jacob Fraden, John Turner, Martyn Hill, and Clarence W. de Silva, sensors play an important role in various measurement and control systems, enabling accurate data collection and effective process control.

METHOD

This research uses the "Development Research" or Research and Development (R&D) method. According to Borg and Gall (1989: 634), what is meant by Research and Development research is "a process used to develop and validate educational products". Apart from developing and validating educational results, Research and Development also aims to discover new knowledge through basic research or to answer specific questions about practical problems or applied research, which is used to improve educational practices. The R&D method is a systematic research process that aims to develop new products or improve existing products. This method includes stages such as needs assessment, product design, development, and evaluation (Kustijono, 2020). Creswell (2014) explains that the R&D method is used to develop new products or improve existing products through a systematic process, including needs identification, design, testing, and evaluation.

The type of the research method used is the waterfall method. (Winston W. Royce, 1970) who was a software engineer who first introduced the waterfall model in his paper entitled "Managing the Development of Large Software Systems" in 1970. In this paper, Royce outlined a development model with linear stages, describing the process like a waterfall. Ian Sommerville, in his book "Software Engineering," defines the Waterfall Method as a software development model that involves a series of stages carried out sequentially, with each stage requiring the results of the previous stage. The Waterfall model is suitable for projects with clear and unchanging needs (Pressman, 2014). Waterfall is a type of application development model and is included in the classic life cycle, which emphasizes sequential and systematic phases. For the development model, it can be analogous to a waterfall, where each stage is carried out sequentially from top to bottom.

There are 5 stages in the waterfall method, the first is a requirement, in this stage explains the understanding of the needs needed in the design which includes hardware and software in designing the device. The second is design, at this stage, the author creates a device design that can help determine the hardware, namely the components in this research and the requirements that help in defining the system architecture in designing the device. The third is implementation, at this stage, the device is first designed by designing hardware and software and will then be developed in a small program called a unit, which is integrated in the next stage. Each unit is developed and tested for functionality which is called unit testing. Next is verification, at this stage, the device design will be verified and tested to see whether it meets the feasibility values with a feasibility test by experts so that the device that has been made can follow the objectives of this research. The last is maintenance, the device that has been created will be run and maintained. Maintenance includes correcting errors that were not found in previous steps.

The author uses the waterfall research method because this method has a clear structure and is easy to understand. Apart from that, this research also uses software, namely Arduino IDE, to program the hardware. This research is an experiment using a simulation model. The planned research results are in the form of a prototype.

Device Design

In designing a Fire Alarm System, it is of course supported by other components such as fire sensors, smoke sensors, temperature sensors, and Arduino Uno. 3 inputs enter the Arduino, where the first input is from the fire sensor, the second input is from the smoke sensor, and the third input is from the temperature sensor. When the three sensors detect a potential fire, they will turn on the buzzer, and LED, and display a warning on the LCD module. The first step in this design is to create a block diagram which is the basic image in this system. So it will produce a device that can work and function under the research objectives. Below is the block diagram created.

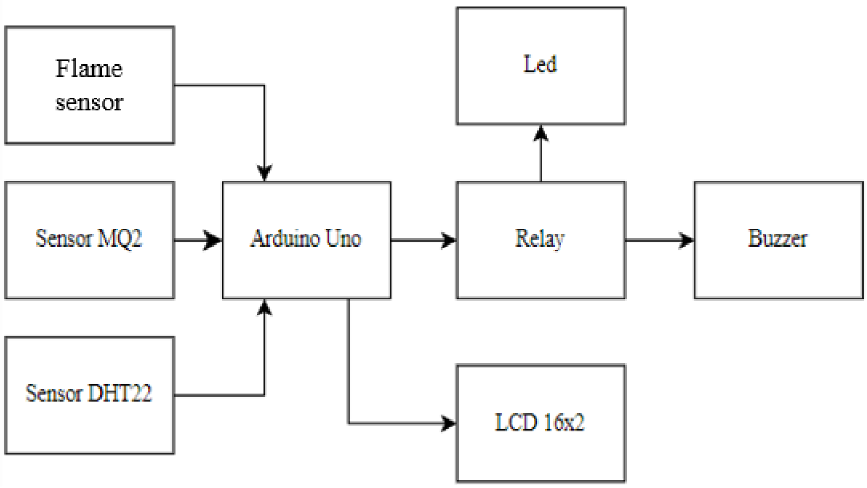

Figure 1. Block Diagram

The fire sensor is a sensor that will detect the potential for a fire, where if the sensor detects a parameter that exceeds the threshold, the sensor will send a signal to Arduino. The smoke sensor is a sensor that will detect smoke parameters in the form of gas that is around, where if the parameters exceed the threshold, the sensor will send a signal to Arduino. The temperature sensor is a sensor that detects the surrounding temperature, where if the temperature exceeds a threshold, the sensor will send a signal to Arduino. When the fire sensor, smoke sensor and temperature sensor detect a fire, the Arduino will send a command to the relay to activate the buzzer, turn on the LED and display the dangerous status on the LCD.

When the Fire Alarm System block diagram has been designed, the next step is to design the block diagram of all the equipment that is integrated into the Trainer Building Automation System, below is the block diagram that has been created.

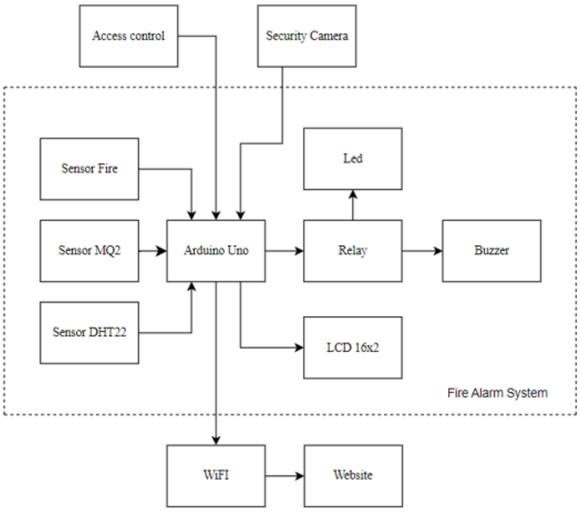

Figure 2. Integrate Block Diagram

The device will be integrated with Access Control and Security Camera so the devices will be controlled by one brain, namely a microcontroller and will be monitored on the website. The components in the dotted line are components of a device created by the author, namely the Fire Alarm System, then those outside the dotted line are devices created by other researchers who are in the same group, where Access Control and Security Camera are in the block diagram above is a device created by another researcher which will be integrated with a device created by the author then the website in the block diagram above is a website created by another researcher to monitor the devices that have been integrated so that all the equipment created will be controlled by one centralized control and monitored by one website.

System Overview

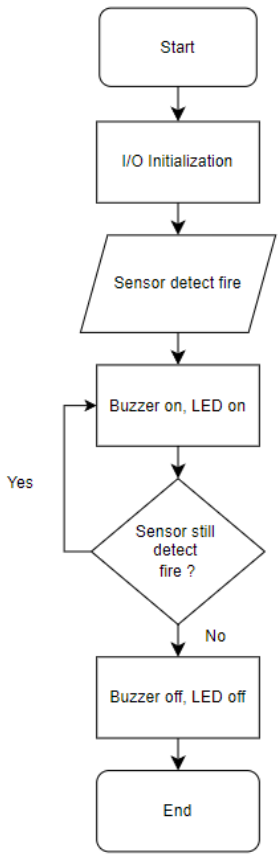

Figure 3. Flow Chart

The way this device works is to first initialize what inputs are used in this device, where the inputs in the design of this device are fire sensors, smoke sensors, and temperature sensors. Then when the sensor detects a fire, the output from the Arduino Uno will activate the buzzer and turn on the LED. When the sensor still detects a fire, the buzzer and LED will remain on, but if the sensor does not detect a fire, the buzzer and LED will turn off.

Testing Techniques

At this stage, a feasibility test was carried out on the Design of a Fire Alarm System and Its Integration Into a Trainer Building Automation System Based on the Internet of Things (IoT) at Makassar Aviation Polytechnic using a quantitative approach in the form of a questionnaire as an assessment instrument. This questionnaire will be given to two experts who have relevant expertise and experience in their fields, to gather their views and assessments regarding the feasibility of the device that has been designed.

Data Analysis Technique

The Author will use data analysis techniques using quantitative analysis using instruments in the form of questionnaires. This questionnaire will be given to two experts in their fields and will be assessed using a score classification according to a Likert scale. Where the answers will be given a score as follows :

Table 1. Eligibility table

Category	Score
Strongly Agree	5
Agree	4
Neither Agree / Disagree	3
Disagree	2
Strongly disagree	1

The formula used to calculate the percentage on the Likert scale is as follows :

$$xi = \frac{\sum s}{smax} \text{ x } 100\%$$

Information :

$smax$ = Maximal score

$\sum s$ = Total score

xi = value of each aspect

To classify the results as worthy of passing the test or not, you can use the following categories:

Table 2 eligibility category

Eligibility interval	**Category**
81%-100%	Very Worthy
61%-80%	Worthy
41%-60%	Less Worthy
21%-40%	Unworthy
0%-20%	Very Unworthy

Place and Time of Research

The place of research was carried out at the Makassar Aviation Polytechnic. Data was taken from February to March, then preparation of devices and materials in April. Design and manufacture of device is carried out from May to June, device testing is carried out in July.

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RESULTS AND DISCUSSION

The following is a schematic circuit of the device that has been created.

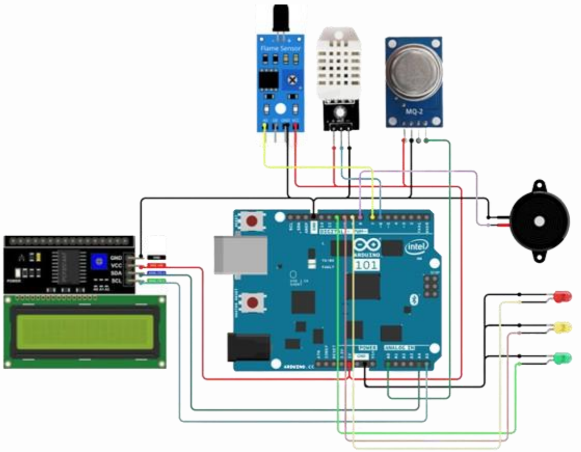

Figure 4 Device circuit

Based on the picture above, the Arduino UNO is the control center for the device being made. Input to the device includes a fire sensor connected to pin 7, a DHT22 sensor connected to pin 6, and an MQ2 sensor connected to pin A0. Pin 9, pin 10, and pin 11 initialize to control the LED. The I2C module on the 16x2 LCD is connected to pins A4 and A5. The buzzer as a warning is connected to pin 8. The data obtained from the sensor will be processed then the Arduino will provide output on the 16x2 LCD which will display whether the condition is dangerous or not, the buzzer will light up if there is an indication of fire, and the LED light will light up based on existing conditions.

The LCD will display an indicator when a condition on the three sensors is met. The three sensors, namely the temperature sensor, smoke sensor, and fire sensor, will work to detect the surrounding conditions which will trigger an alarm to activate when a condition is met. The LCD will display 8 condition statuses, where each condition will be displayed according to the conditions obtained from the three sensors. 5 LED lights will light up according to the conditions that are met, the green LED will light up when conditions are normal, the yellow LED will light up when one or both sensors detect an indication of fire and the red LED will light up when all three sensors detect a fire. The buzzer will turn on when the three sensors detect a fire. At the testing stage, testing will be carried out on each sensor.

Table 3. Test result 1

No.	Parameter	Indicators of Success	Test Result
1.	LCD 16x2	Displays the condition of the presence or absence of fire.	The LCD can display 8 status conditions according to the data obtained from the sensor. The LCD also displays conditions in clear and easy-to-read letters.
2.	Flame Sensor	Detect fire well	The test results were declared successful because it could detect when there was a fire and send a signal if the fire was detected.
3.	MQ2 Sensor	Can detect gas/smoke well.	The test results were declared successful because it could detect gas/smoke and send a signal if the detected gas/smoke exceeded the threshold.
4.	DHT22 Sensor	Can detect temperature well	The test results were declared successful because it could detect the surrounding temperature and would send a signal if the temperature exceeded the specified threshold

5.	Buzzer	Active when fire conditions are met	The test results were declared successful because the buzzer will turn on when the three sensors detect it.
6.	LED	The LED will light up if the conditions are met.	The test results are declared successful because the green, yellow, and red LEDs will light up when each condition is met.
7.	Arduino UNO	Arduino UNO as the brain of the device.	The test results were declared successful because the Arduino UNO was able to receive data from the input, process the data, and produce output.

Device Integration

The following is a schematic image of a series of devices that have been integrated into a Building Automation System.

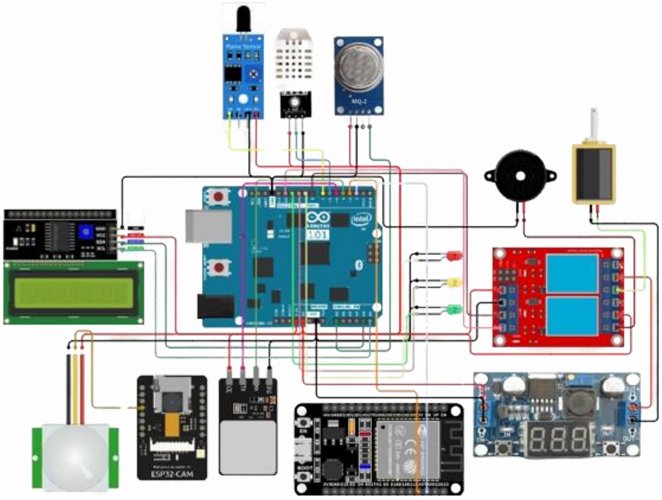

Figure 5 Integrate Circuit

Based on the picture above, the Arduino UNO is the control center for the device being made. Input to the device includes a fire sensor connected to pin 7, a DHT22 sensor connected to pin 6, an MQ2 sensor connected to pin A0, a fingerprint sensor connected to pin 4 and pin 5, a PIR sensor connected to pin IO13 on the ESP32 cam. Pin 9, pin 10, and pin 11 initialize to control the LED. The I2C module on the 16x2 LCD is connected to pins A4 and A5. The buzzer as a warning is connected to pin 1 on the relay. The door lock solenoid as a door lock is connected to pin 2 on the relay. The 2-channel relay module is connected to the Arduino UNO where VCC and ground are connected to ground and 5v on the Arduino UNO, pin 1 of the relay is connected to pin 8 on the Arduino UNO to control the buzzer, and pin 2 of the relay is connected to pin 12 on the Arduino UNO to control the door lock solenoid. Pin 2 and pin 3 on the Arduino UNO are connected to the RX and TX pins on the ESP32 for serial communication. The data obtained from the sensor will be processed then the Arduino will provide output on the 16x2 LCD which will display whether the condition is dangerous or not, a buzzer will light up if there is an indication of fire, an LED light will light up based on existing conditions, and the door lock solenoid will open if the presence of verified fingerprints or the required conditions are met. The Arduino UNO will send data from the sensor to the ESP32 serially, then the ESP32 which is connected to an internet connection will send the data to the database on the website.

Based on the picture above, it can be seen that the device created by the author has been successfully integrated with devices created by other researchers in one group to become a Building Automation System Trainer. The entire device will be controlled by Arduino UNO as the data processing brain and will be monitored on the website. When the device is given a 5v voltage supply, the device will turn on and work according to the program given. The integrated devices, namely the Fire Alarm System, Access Control, and Security Camera, will work according to their respective functions.

Table 4 Test Result 2

No.	Parameter	Indicators of success	Test Result
1.	LCD 16x2	Displays the condition of the presence or absence of fire.	The test results were declared successful because they could display the conditions in clear and easy-to-read letters
2.	Flame Sensor	Can detect fire well.	The test results were declared successful because it could detect when there was a fire and send a signal if the fire was detected.
3.	Smoke Sensor	Can detect gas/smoke well.	The test results were declared successful because it could detect gas/smoke and send a signal if the detected gas/smoke exceeded the threshold.
4.	Temp Sensor	Can detect temperature well.	The test results were declared successful because it could detect the surrounding temperature and would send a signal if the temperature exceeded the specified threshold.
5.	Fingerprint sensor	Can verify fingerprints well.	The test result is declared successful because it can verify the fingerprint properly and will send a signal to the Arduino to unlock the door.
6.	PIR Sensor	Can detect movement well.	The results of the test were declared successful because it could detect movement and would send a signal if movement was detected.
7.	Relay 2 channel	Can perform switching well.	The results of the test were declared successful because the relay will switch when it gets a signal from Arduino.
8.	Buzzer	Active when fire conditions are met.	The test results were declared successful because the buzzer will turn on when the fire sensor, temperature sensor and smoke sensor detect fire, high temperature and excessive smoke.
9.	Solenoid door lock	Can lock and unlock when getting a signal.	The results of the test were declared successful because the door lock will lock and open when the relay switches when it gets a signal from Arduino.
10.	ESP32	ESP32 as a component to send data obtained from Arduino to the database.	The test results were declared successful because the ESP32 was able to send data from Arduino to the database when connected to the internet.

11.	ESP *Cam*	ESP Cam is used to take pictures if conditions are met.	The test results were declared successful because the ESP Cam was able to take pictures when given a command and when the PIR sensor detected movement it then sent it to Telegram as a notification.
12.	Arduino UNO	Arduino UNO as the brain of the device.	The test results were declared successful because the Arduino UNO was able to receive data from the input, process the data, and produce output.

Feasibility Test Result

On July 2, 2024, and July 3, 2024, the feasibility testing instrument in the form of a questionnaire was submitted to Mr. Muhammad Agung Raharjo, S.Kom., M.A.P. and Mr. Heru Prasetyo, M.Kom as a lecturer at the Makassar Aviation Polytechnic, whom the author appointed as experts 1 and 2, the results of the test show values of 92% and 84%, if seen from the feasibility table, the test results show that the device is very suitable for use.

This research focused on the design and development of a Fire Alarm System Trainer integrated with a Building Automation System (BAS) at Makassar Aviation Polytechnic. The system was evaluated based on its operational functionality, feasibility, and integration capabilities. Functionality and design suitability. The device functioned effectively as per the design specifications, meeting the requirements for real-time fire detection and alert. This aligns with the findings by Al-Janabi and Hadi (2022)**,** who emphasized the importance of intelligent fire alarm systems in enhancing operational safety and response times through IoT integration. Similarly, Chen and Li (2010) demonstrated that systems with fire control linkage features significantly improve safety protocols in intelligent buildings.

Feasibility Assessment. Two experts evaluated the system's feasibility, concluding it to be highly suitable based on Likert scale calculations. Such expert validation underscores the practical applicability of the system, akin to the performance evaluation metrics discussed **by** Tan and Wong (2018)**,** which highlighted the importance of expert reviews in assessing reliability and system effectiveness.

Integration with Other Systems. The successful integration of the fire alarm system with other devices into a unified BAS demonstrates the system's capability to function as a cohesive safety solution. This integration is consistent with the work of Singh and Sharma (2021)**,** who showcased how embedded systems could enhance fire detection and prevention in smart environments. Moreover, Zhao and Huang (2017) emphasized the role of protocols like BACnet in ensuring seamless communication and interoperability in such integrated systems.

Application in Educational institutions. Given its successful implementation in an educational setting, the system offers significant potential for broader adoption. This finding aligns with Williams and Taylor (2023)**,** who documented a similar success story in integrating fire alarm systems into BAS within educational institutions. Advancements and Future Potential. The research underscores the growing relevance of integrated systems in enhancing building safety and operational efficiency. Kumar and Roy (2021**)** highlighted those smart technologies and automation offer scalable solutions for building fire safety, making systems like the one developed at Makassar Aviation Polytechnic highly relevant in the context of modern infrastructure.

The novelty of this research lies in several key aspects that distinguish it from existing studies. First, the integration of a fire alarm system into a Building Automation System (BAS) trainer is a significant innovation, particularly as it is designed specifically for educational purposes at Makassar Aviation Polytechnic. While many studies focus on fire alarm systems or building automation separately, this research bridges the gap by creating a trainer device that replicates real-world functionality, offering students hands-on experience. Second, the system's feasibility was validated by experts using quantitative Likert scale calculations, a structured approach that enhances the reliability and credibility of the findings. While expert evaluations are common, combining this method with a focus on educational applications adds a unique dimension.

Moreover, the research addresses a specific gap in education by tailoring the system to the needs of a polytechnic institution, thus equipping students with practical knowledge in fire safety and building automation

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principles. Achieving successful integration in an educational institution, often characterized by limited resources, further highlights the adaptability and cost-effectiveness of the developed system. Additionally, the regional focus of this research provides localized relevance, addressing the specific requirements of Makassar Aviation Polytechnic and Indonesia's education system. This contextually relevant innovation has the potential to be scaled to similar institutions in other developing regions. Collectively, these factors underline the novelty of the research by combining technical innovation, educational relevance, and practical feasibility in an integrated system.

CONCLUSION

The findings of this research contribute to the growing body of knowledge on integrating fire alarm systems with building automation technologies. The device not only demonstrated high functionality and feasibility but also showcased successful integration, supported by expert validation. These results are consistent with global research trends, further cementing the system's potential for real-world applications. In this research, the author succeeded in designing a Fire Alarm System with Arduino UNO as a microcontroller that works according to the design that has been made and knows how to make a design for this device. The design of this device begins with making the hardware and then installing the software so that this device can detect indications of a fire and provide a warning when a fire occurs by the design that has been made previously. The data analysis technique used in this research is a quantitative analysis using an instrument in the form of a questionnaire given to 2 experts to test the feasibility of the device created by the author and if seen from the feasibility interval, the results of the feasibility test by 2 experts show that this device is very suitable. In this research, the author succeeded in integrating the devices created by the author with devices created by other researchers in one group to become a Trainer Building Automation System where this integration was carried out by combining the three devices in one control center and connecting them to the internet so that they could monitor the equipment on the website using The aim is that devices that previously worked with their respective functions can work simultaneously and be controlled by one control center. The creation of the device in this research is also supported by several related journals, where these journals not only provide a strong theoretical basis but also present relevant empirical data. Previously existing journals were used as references by the author to conduct this research, enabling the author to identify existing research gaps and develop better methods. Thus, this research not only strengthens previous findings but also makes significant new contributions to the field.

This research presents several notable benefits that contribute to both education and practical applications. First, the development of a Fire Alarm System integrated into a Building Automation System (BAS) trainer provides students with invaluable hands-on experience, bridging the gap between theoretical learning and real-world applications. This enhances students' understanding of fire safety and building automation, making complex systems more accessible and comprehensible. Additionally, the research contributes to improved safety and preparedness by simulating realistic fire detection and automation scenarios, thus preparing students to handle such situations in actual environments. Furthermore, the cost-effective nature of the system makes it an ideal educational tool, particularly in institutions with limited resources, while its scalability ensures that it can be adopted by other educational institutions, training centers, or industries.

The integration of fire alarm systems into BAS also contributes to the body of knowledge in this field, offering insights into effective system integration, performance evaluation, and the application of advanced technologies. Looking ahead, the hope is that this trainer will be implemented in other educational institutions, broadening access to essential fire safety and building automation training. Future versions of the system could incorporate emerging technologies such as artificial intelligence and machine learning, allowing for predictive fire safety management and more efficient decision-making processes. Additionally, there is potential for this trainer to be standardized for training and certification programs, ensuring consistent, high-quality education across various institutions. Beyond education, there is potential for this system to be adapted for industrial applications in sectors such as aviation, healthcare, and smart cities. Ultimately, this research hopes to inspire further collaboration between educational institutions, industries, and government bodies to advance fire safety technologies and improve training methods on a larger scale

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