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Smart Classroom: A Development of Electrical Control System with Internet of Things

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Abstract

The Internet of Things (IoT) is a dynamic breakthrough that has a huge impact on today's world and has the potential to simplify human life. The potential application of IoT is limitless, and it has been implemented in various industries, including medicine, engineering, computer science, space and technology, automotive, and more. This paper aims to develop a smart classroom electrical control system using IoT technology to regulate the classroom's electrical system and monitor student occupancy. This study chose to use the Rapid Application Development (RAD) method to develop the proposed system for reducing the waste of electricity resources in a classroom. The objectives of this research include identifying the main problems related to the waste of electricity in the classroom, developing an electronic project using IoT, and testing the functionality of the electronic project. The development of the proposed electrical control system uses Arduino and Infrared (IR) sensors. The IR sensors are used to detect the presence of students either entering or leaving the classroom. When human presence in the classroom is detected, lights and fans will automatically turn on. The approach benefits users by enabling a comprehensive understanding of the system through interactive evaluation, bringing it closer to meeting the requirements intended for this study.

Keywords: IoT, Arduino, electrical system, smart classroom

INTRODUCTION

The Internet of Things, more simply known as IoT, is a technology that evolved as part of the Industrial Revolution 4.0. The IoT concept can potentially influence how we live and work by increasing the efficiency and productivity of daily life activities. Unbeknownst to many, internet broadband services are now widely utilized, thanks to reduced consumption costs, the proliferation of Wi-Fi and sensor-enabled devices, affordable technology, and increasing smartphone penetration rates. These characteristics collectively produce a setting ideal for developing an IoT system. All devices equipped with ON and OFF buttons should be connected to the internet. This concept includes a wide range of items, including telephones, washing machines, lights, and even complex machinery like jet engines used in aircraft and other applications. The IoT has a large potential to initiate a revolution in many aspects of human life in the coming years. This technological revolution could help us redefine our living standards by providing automation, one of the most commonly used terms in the field of science and technology (Ghafar et al., 2023; Hasbullah et al., 2022; Sudin et al., 2022).

Automation allows us to have total control with minimal intervention over the electrical equipment that surrounds us at home or work. We are rapidly approaching the time when technology can interact with us in real time (Roslin et al., 2022, Tamrin et al., 2015). IoT is expected to aid in the development of intelligent systems that can recognize human needs and respond appropriately without even needing instructions. Its development depends on rapid technological developments in several key areas, including nanotechnology and wireless sensors. There is not a single definition for the IoT that is universally accepted; instead, several parties use multiple definitions to depict or advance their ideas about what the IoT is and what its key features are. Most definitions describe scenarios where network connectivity and processing power extend to various objects, devices, sensors, and everyday items not traditionally considered 'PCs.' This enables the devices to generate, exchange, and utilize information, often with minimal human intervention.

The terms "Internet of Things" and "IoT" frequently imply the spread of system networks and processing power to devices like gadgets, sensors, and other items that are not typically associated with computers. The primary focus of this research is leveraging IoT technologies to establish a smart classroom environment, with the overarching goal of reducing excessive energy consumption. The classroom setting was selected due to its observable issues, such as lights and fans being left on inadvertently by teachers and students. As such, the aim is to address these situations by implementing automated and controllable electrical systems within the classrooms. Recent advancements in computer systems have paved the way for the development of prerequisites for various types of devices. The initial plan was to employ sensors like the Arduino Uno and the Infrared Sensor (IR) to detect human presence and manage the classroom's electrical system. To comprehend the task, the researcher created a virtual representation of the actual environment. However, this approach has drawbacks, such as cost, absence of required sensors, wear and tear, and user discomfort. Nevertheless, these challenges do not deter researchers from progressing with the study (Sadeghi et al., 2018).

LITERATURE REVIEW

This section will follow a logical progression, starting with an exploration of the IoT, followed by an examination of IR sensor modules, a discussion of related work, and finally, a summary of related articles.

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Internet of Things (IoT)

Initially, the internet was intended for communication, where it allows computers to view websites, download files, and interact with other users. However, as technology advances, we get quicker, more capable, and more powerful gadgets. Advances in networking technology have profoundly contributed to how IoT devices produce, exchange, and perceive data (Al-Masri et al., 2020). The potential to establish massive networks of sensors with the capacity to gather information, process it, and take appropriate action is made possible by advances in electronics technology, which simultaneously produce smaller devices with low power consumption. This is where the concept of the IoT first appears. Under this concept, technologies and computers operate discreetly around users, collaborating and adjusting their behavior to the environment. The seamless integration allows users to engage with technology without disrupting their daily lives (Zhang et al., 2023). In this way, the idea of a computer as a piece of hardware is diluted to include linked gadgets in users' daily lives. The data created by people through their interactions with things accounts for a significant portion of the information we have today. When the phrase "Internet of Things" first debuted, it was assumed that there would be devices that could know every detail about such items or things. In brief, using IoT, we would be able to monitor and manage everything and determine when changes need to be made thanks to the already acquired data.

Infrared (IR) Sensor

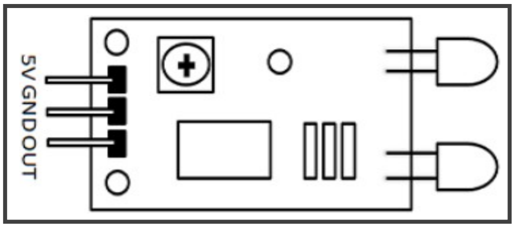

Figure 1: IR Sensor Module Pinout

Figure 1 shows the pinout of the IR sensor module, which is straightforward to use for detecting infrared objects. It features an internal potentiometer for adjusting sensitivity. Since it outputs a digital signal, it can be easily interfaced with any microcontroller, including Arduino UNO, Mega, Leonardo, Zero, 101, as well as Raspberry Pi or Raspberry Pi Zero. Additionally, it is compatible with all other controller boards, such as CIKU, CT-UNO, CT-ARM, and others. This IR sensor enables swift and effortless obstacle detection through IR reflection without requiring direct contact. However, detection may vary depending on the reflective properties of different surfaces. Moreover, the presence of any IR sources could potentially interfere with the detection process.

The sensor module can adapt to ambient light conditions as it has a pair of infrared emitting and receiving tubes. When the sensor detects an obstacle's presence (via reflected infrared light), the reception tube receives the reflected signal. After processing through a comparator circuit, the green light is on, indicating that the signal output interface produces a digital signal (a low-level signal). The effective distance range of the detecting distance knob potentiometer is 2 to 30 cm, and the operating voltage range is 3.3 to 5 V. The sensor's detection range may be adjusted using a potentiometer, and it has additional advantages, including low interference, ease of assembly, and ease of use. It is commonly employed in applications such as robot obstacle avoidance, vehicle collision avoidance, line counting, black-and-white line tracking, and numerous others. Numerous studies on energy conservation and smart classrooms have been conducted concerning related works. Patil (2018) proposed an energy-efficient smart classroom using an Arduino microcontroller. The sensors utilized in the classroom have the ability to measure temperature, humidity, light intensity, and human presence. The classroom's lighting and fan are both controlled by the parameter sensors. For improved outcomes and energy savings, this system uses a smart option. The technology may also be used to assess the amount of noise at a certain location, and when that level exceeds a certain threshold, an SMS will be sent to the designated party. Nonetheless, some of the drawbacks of this method are high maintenance costs and system complexity. Meanwhile, Mao and Zhang (2022) proposed a smart and intelligent power-saving system for Indian universities. The PIR sensor was used in the project to detect individuals in the hallway or room. Two PIR sensors were placed at the entrance to detect people entering and leaving the room.

The project's microcontroller, a Micro ATMEGA (ATMEGA 328P), is utilized to manage its operations. The light will turn on automatically when PIR Sensor 1 and PIR Sensor 2 detect human movement entering the room, and it will turn off automatically when PIR Sensor 2 and PIR Sensor 1 detect human movement leaving the room. Furthermore, Patel et al., (2020) proposed an automatic classroom lighting controller and energy saving based on a microcontroller unit. In this project, the PIR Sensor is used to detect the presence of people within a room in order to turn on lights and fans when there are people around. This project system also makes use of the campus cards that students already have. The IR Sensor and the campus card are both used to measure the brightness of the inner chamber's light. The PIC 16F877A microcontroller, along with the Light Dependent Resistor (LDR) and the PIR Sensor, is utilized in this project. The signal will be sent to PIC 16F877A to compare the recorded light intensity from the inner chamber's PIR Sensor and LDR. If both sensors detect human movement and the light intensity is below the preset level, the PIC 16F877A will automatically activate the lamp and fan.

Moreover, Shao et al. (2017) proposed the application of an intelligent device and method for detecting the dynamic and static human body in energy-saving control of schools. In the classroom, the pyroelectric sensor is utilized to monitor student attendance and mobility. The lights in the classroom will automatically go out if no one is in attendance. Only a student's movement may be detected by this pyroelectric sensor, which has a detection range of up to 14 micrometers. The MOC3041 and SCR BCR20AM photoelectric connection circuit is the equipment control module utilized in this project. The MOC3041 photoelectric is used to separate the strong grounding electrical system from the weak electrical conducting system. Avoiding electromagnetic interference is beneficial; the SCR

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BCR20AM, a flexible switch consuming less power than a relay, exemplifies this principle. Last but not least, Mubarok et al. (2022) proposed an IoT-based smart classroom. This project's major goal is to provide a productive learning environment. The Raspberry Pi has been integrated with an LCD monitor and an internet-controlled smartphone to create the smart degree booth model. This model automates attendance, displays the tour on a real board, stores spare parts online, and records lectures to organize the class and enhance its intelligence in real life.

METHODOLOGY

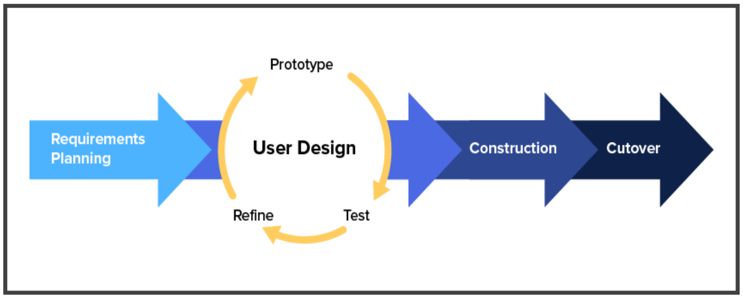

Figure 2: Phase of Rapid Application Development Methodology

The Rapid Application Development Model was initially proposed by IBM in the 1980s. The utilization of strong development tools and methods is a key component of this strategy. Prototyping and iterative models with no (or less) detailed preparation are the basis of this methodology. In general, the RAD method of software development places greater focus on prototyping and development jobs and places less emphasis on planning duties. The RAD technique focuses on building on continually shifting needs, in contrast to the waterfall model, which places an emphasis on thorough definition and preparation. As the development process moves forward, more and more lessons are learned. A software project can be divided into manageable modules, and each module can be individually allocated to different teams (Alazzawi et al., 2023). The model may be used to implement the project. The finished product may then be created by combining these parts. Figure 2 illustrates the fundamental phases of each module's development: requirements analysis, user design, construction, and cutover. The short period of this model, or the time box, which is typically 60-90 days, is another eye-catching aspect (Montalbo & Enriquez, 2020).

Requirements Planning

The project's demands, scope, problems, and requirements are planned and agreed upon by all key participants (managers, IT personnel, users, etc.) in the first phase. In this aspect, RAD differs from other models since it establishes wide criteria to maintain flexibility throughout time. RAD distinguishes itself from conventional software development approaches right away (Zamzuri et al., 2024). It only asks for a general demand; it does not require a researcher to sit down with end users and obtain a comprehensive set of requirements. A researcher can separate certain requirements at various stages of the development cycle thanks to the broad nature of the criteria.

User Design

In this stage, users collaborate with developers to design and build a prototype that satisfies the listed system requirements. Users engage with the prototype throughout this phase and offer input until a real final product is authorized. The real construction takes place here. Developers work quickly to produce prototypes with a variety of features and functions rather than adhering to a strict set of specifications (Azman et al., 2024). The clients are then given these prototypes, and they determine what they like and do not. These prototypes are frequently rapidly created to function in order to highlight only the most important characteristics. This is typical since the final product is only developed when the customer and the developer are on the same page about the result or during the finalist on stage.

Construction

This is the third ongoing phase, and it depends on user feedback. The main goal of this stage is to implement user input through coding, testing, and any other necessary development tasks. Until the users approve the product, the second and third stages complement each other. We now fully understand what needs to be done: the system must be developed and tested to ensure readiness for production use. Emphasis is placed on quality, reliability, and maintainability; there will be no more cutting corners. Even at this stage, stakeholders remain engaged, providing feedback on improvements. Fine-tuning is still possible in this phase of rapid application development (Modarresi et al., 2021).

Cutover

This last phase includes user training, rollover, and acceptability testing. Once the product is accepted, developers add certain final touches, such as testing, conversion, interface work, or user training. The product is prepared for delivery once stability and lifespan have been thoroughly evaluated.

DESIGN AND DEVELOPMENT

Project development includes planning and arranging every aspect of a project, including selecting resources, establishing a budget, and assigning team members roles. It also includes the procedures required to finish a project, such as altering the plans as work progresses and locating potential areas for improvement to make the project operate more smoothly.

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Block Diagram

A customized, high-level flowchart used in engineering is called a block diagram. It is utilized to define and enhance current systems as well as to create new ones. Its organizational structure gives a high-level picture of the main system parts, critical process actors, and key working relationships. A block diagram offers a fast, high-level picture of a system that helps quickly pinpoint key features or potential problem areas. It might not provide the level of information necessary for more thorough planning or implementation due to its high-level perspective. A circuit diagram's function is to depict every wire and switch in detail; a block diagram does not do this. A block diagram places more emphasis on a system's input and output. It is less concerned with what occurs in the transition from input to output. Engineering professionals refer to this concept as a "black box." The components that bring us from input to output are either unknown or not significant. Figure 3 shows the block diagram of the smart classroom of this project.

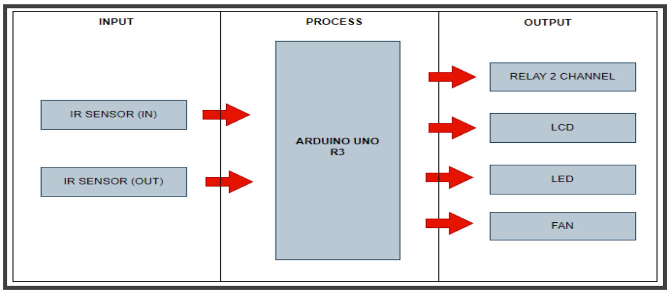

Figure 3: Block diagram of smart classroom electrical control system

According to Figure 3, the input for this project consists of an IR sensor that serves both as an 'IR sensor (in)' and an 'IR sensor (out),' utilized in the smart classroom for power conservation. Two IR sensors will be installed at the door to track the movement of students and teachers entering and leaving the classroom. Both IR sensors function similarly in detecting the presence of objects and belong to the same category. The project's processor, the Arduino Uno R3, outputs data straight to a Relay 2 Channel, a fan, an LED, and an LCD once it has been processed.

Schematic Diagram

An electronic schematic to electronics is what a recipe is to a chef. It will instruct on how to organize and link the materials as well as what ingredients to utilize. An electrical device's assembly is shown via a schematic diagram rather than by providing detailed instructions. Digital electrical symbols that represent each of the used components are utilized in electronic schematics. The symbols on the schematic illustration of an electrical device are connected by lines to demonstrate the connections between the components. To create a circuit based on the schematic, whether on a breadboard or a

PCB (printed circuit board), you can use a tool that can link the schematic to the actual layout. Fritzing software is an excellent option for this purpose, as it is user-friendly and capable of handling both breadboard and basic PCB layouts. The researcher initiated the Smart Classroom project by constructing a scheme. Assembling the breadboard was akin to solving a puzzle. Fritzing's standout feature is its ability to provide an immediate visual representation of the breadboard layout before wire cutting and stripping begin. When designing a circuit schematic, researchers will notice that Fritzing includes information about every pin on the device. The following screenshot in Figure 4 depicts that each pin is appropriately connected to the device or component used in the Smart Classroom project. However, some physical pins may remain unconnected, as Fritzing aims to facilitate breadboarding. Nonetheless, all physical pins are represented in the symbol (Venkatasamy et al., 2022).

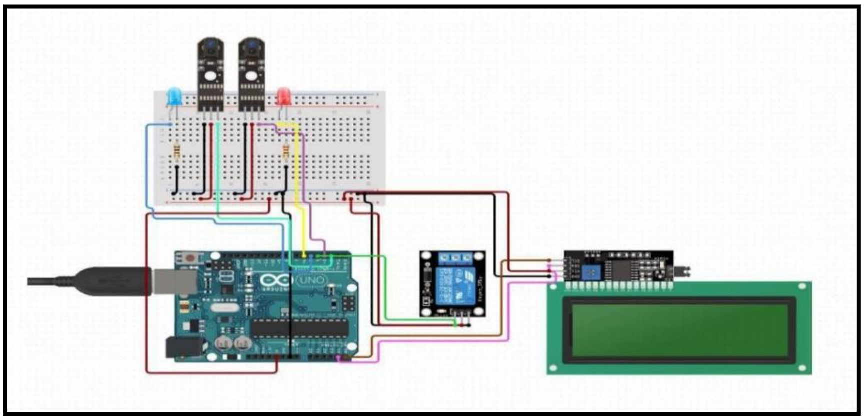

Figure 4: Schematic smart classroom electrical control system

Prototype Modelling

A prototype is a work-in-progress sample, model, or version of a product made to test a theory or procedure. A prototype is typically used to test a new design in order to increase the accuracy of analysts and system users. It is the stage following the formalization but before the notion has been evaluated. All design disciplines employ prototypes as a significant component of the design process. A prototype serves as a physical representation of the difficulties that have previously been identified and addressed by the designers during the concept/idea stage. Prototypes enable designers to verify their concepts by presenting an early iteration of the solution in front of real users and gathering input as rapidly as feasible, as opposed to going through the full design cycle based on a presumed answer. The smart classroom project prototype is illustrated in Figure 5.

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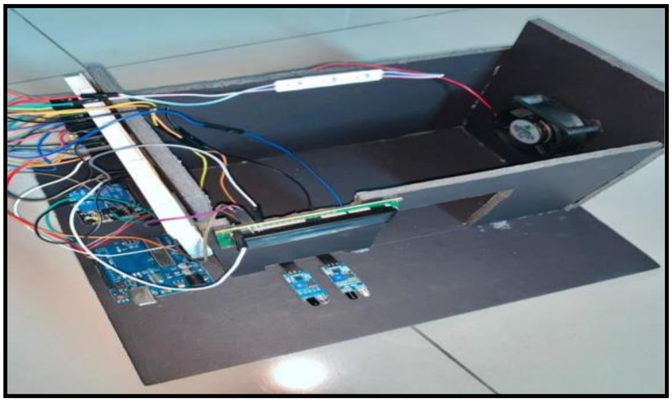

Figure 5: Prototype of smart classroom electrical control system

Based on the prototype in Figure 5, the main hardware is Arduino Uno and an Infrared sensor. The lamps use a 12-volt input voltage, the fans use 12-volt AC, and the Arduino uses 5 volts. Arduino is the hardware that processes the output on the LCD and the inducer of a response to the change of the lamp (LED) and the fan. This occurs because the Infrared sensor works to detect the presence of student movement when entering and leaving class.

RESULTS AND DISCUSSION

The primary hardware consists of the Arduino, an open-source microcontroller board based on the Microchip ATmega328P microcontroller. It serves as a development board specifically designed for IoT-based applications, along with the IR sensor. The IR Sensor Principle, which consists of an IR Led and an IR Photodiode known as an Opto-Coupler, is used as an object sensor for detection. The lights and fan will turn on when the first student enters the classroom, and the LCD display will show the number of students present. Furthermore, the lights and fan will switch off when the last person leaves the room, and the LCD will indicate an empty room upon detection by IR sensor 2. The fans and lamps will automatically turn on when the first student enters the classroom, and the 'number of students displayed on the LCD screen will increase. There is no restriction on how many students may be shown on the LCD display as they enter and leave the classroom. Additionally, after the final student leaves the room, the LCD display's "number of students" drops, and the fans and lamps turn out automatically. The goal of energy conservation is to avoid wasting electricity by having students leave the classroom without turning off the fans and lamps. In the era of IR4.0, this system plays a significant role and can be applied in real-world classroom settings. As indicated in Table 1, this approach has been tested with 5 students.

Table 1: Result of smart classroom electrical control system implementation

Number of students	IR sensor 1	IR sensor 2	Display on LCD	Appliances
STUDENT_1 IN	1	0	1	ON
STUDENT_2 IN	1	0	2	ON
STUDENT_3 IN	1	0	3	ON
STUDENT_4 IN	1	0	4	ON
STUDENT_5 IN	1	0	5	ON
STUDENT_4 OUT_TOILET	0	1	4	ON
STUDENT_4 IN_CLASS	1	0	5	ON
STUDENT_1 OUT	0	1	4	ON
STUDENT_2 OUT	0	1	3	ON
STUDENT_3 OUT	0	1	2	ON
STUDENT_4 OUT	0	1	1	ON
STUDENT_5 OUT	0	1	0	OFF

Table 1 demonstrates that when the first student enters the classroom, the IR sensor 1 will be enabled, turning ON all of the classroom's appliances. The LCD displays the number '1', signifying the presence of a single student in the classroom. It will continuously track and display the number of pupils entering and leaving the classroom. When someone exits, the number on the LCD decreases, and IR sensor 2 is activated. The LCD will show "0" after the final student exits the room, indicating that it is empty and that all of the appliances have been switched off automatically.

Based on the results, energy may be conserved by having all electrical equipment turned off immediately and automatically after usage. For instance, if a classroom has four 1-horsepower air conditioners that consume 860 Watts per hour and are not switched off for two hours, there might be 6880 watts of electricity waste. The power cost will be considerable if the same thing occurs again. In order to decrease power waste, this work was created using IoT technology.

CONCLUSION

In conclusion, this paper has demonstrated the successful application of IoT technology in developing a smart classroom electrical control system designed to effectively manage electrical usage and monitor student occupancy. The implementation of Arduino and infrared (IR) sensors enabled real-time tracking of student movements, thereby ensuring that electrical appliances such as lights and fans are only activated when needed. This approach has not only provided a technical solution to the problem of electricity wastage in classrooms but has also highlighted the potential of IoT in automating and optimizing energy consumption in educational environments.

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The results from our tests confirm that the system functions as intended, with the IR sensors accurately detecting student presence, thereby controlling the classroom appliances efficiently. The use of the Rapid Application Development (RAD) method facilitated a swift and flexible development process, allowing for iterative testing and modifications that aligned closely with the project's requirements. Future research could expand on this work by integrating additional features such as temperature control, further automation of classroom devices, and perhaps a mobile application for remote monitoring and management by faculty. Additionally, the scalability and security aspects of the IoT system could be examined more thoroughly to ensure that such implementations can be safely and effectively applied in larger educational settings. Overall, the Smart Classroom project serves as a promising model for the broader adoption of IoT solutions in academia, potentially leading to significant energy savings and enhanced educational experiences.

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