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Research Article

Server Room Temperature Remote Monitoring System

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ABSTRACT

The COVID-19 pandemic creates more significant opportunities to develop more Internet of Things-based systems. IoT has been helpful in remote monitoring and control of connected devices. This research aims to develop a Room Temperature Remote Monitoring System using an Arduino Board and Cloud storage. It provides remote room temperature monitoring, real-time reports and graphs, and a 3-way alert/alarm system when the observed temperature is out of range. The prototype developed is compared to the room thermometer and provides accurate results.

Keywords: *IoT, Remote Monitoring, Temperature Monitoring, Arduino, Cloud-storage, Sensor, Server Room Temperature Remote Monitoring System*

Introduction

Technology has undeniably been valuable across various industries even before the COVID-19 pandemic (Yunita et al., 2022; Shaun et al., 2023; Mukesh et al., 2022). Before the pandemic, technology was crucial in facilitating remote work, enhancing communication through digital services, and enabling e-commerce (Logsdon, 2022). During the COVID-19 pandemic, technology plays a vital role in the continuity of everyday life and business processes. Businesses invest in ICT infrastructure to sustain their businesses amidst the COVID-19 pandemic. Because of the costly equipment inside a server room, it is vital to ensure its maintenance. The server room must be monitored constantly; one crucial factor that must be observed is temperature. An ideal room temperature should be maintained for the equipment to operate efficiently. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has recently updated their recommended temperature range to be from 18°C-27°C (64.4°F-80.6°F). Because of the work-from-home arrangements and the uncertainty brought about by the COVID-19 pandemic, there is no regular checking of the server room temperature; thus, if there is an increase or decrease in the temperature that is drastic in the server room, the ICT staff cannot monitor. The Internet of Things (IoT) concept has helped control and monitor things remotely. Thus, this paper aims to develop a temperature monitoring system for the server room using the Internet of Things. Furthermore, the device provides the convenience of automatically recording the temperature in the server room using Google Spreadsheets. The

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proposed IoT-based temperature monitoring system addresses the critical need for reliable and efficient server room maintenance, particularly in the context of increased remote work and pandemic-related challenges. The system enhances ICT infrastructure's resilience and operational efficiency by providing real-time monitoring, automatic data recording, and remote access. This research contributes to the field by demonstrating the practical application of IoT in server room management, highlighting its potential to improve business continuity and equipment longevity amidst evolving work environments.

Objectives of the Study

This paper developed a Server Room Temperature Monitoring System with the following features:

1. Monitors the temperature of the server room remotely.
2. Record temperature readings of the server room three (3) times a day using Google Spreadsheet.
3. Queries and generates reports and graphs.
4. Provides access control for intended users.
5. Email alert/ message warning when the observed temperature is out of range.

Methodology

Activities are enumerated in this part of the paper to meet the study's objectives, which is the development of server room temperature monitoring using the Arduino Integrated Development Environment (IDE) programming, Arduino Uno board, driver board, and temperature sensor.

Phase 1. Identifying the requirements. In this phase of the project, the researchers identified both hardware and software requirements to develop the prototype. Availability and compatibility of the identified requirements This was taken into consideration in this phase. The following were identified during this phase:

Software requirements:

a. Arduino IDE
b. Google Spreadsheet
c. Script Editor
d. Windows Operating System (Windows 7 or higher version)

Hardware requirements

: a. CPU with Intel Core i3 and a 4GB RAM
b. Module of LM35DZ
c. Real-time Clock Module
d. Breadboard
e. 16x2 LCD

Phase 2. Prototyping. After identifying the required requirements, the researchers proceeded to develop the prototype. Figure 1 Context Diagram of the project was used in the study. A temperature sensor scans the environment, in this case, inside the Server Room. The temperature reading will be recorded in the cloud, particularly Google Spreadsheet. Shared files can be accessed through the cloud without going to the Server Room on-site. The file can produce reports that can be filtered by dates when needed.

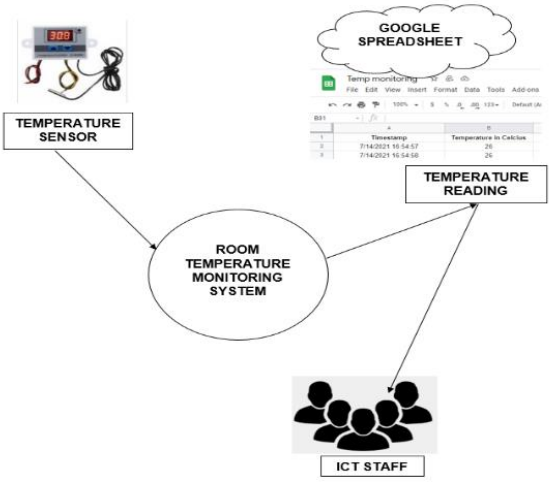

Figure 1. Context Diagram for Room Temperature Monitoring System

A schematic diagram in Figure 2 was drawn following the context diagram to guide the researchers on how the hardware requirements will interface. Furthermore, a circuit diagram in Figure 3 depicts the physical arrangement of the wires and the components identified in the project's first phase.

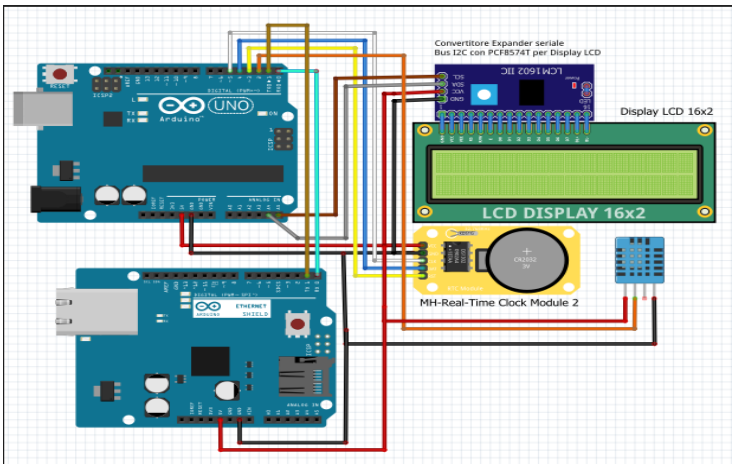

Figure 2. Schematic Diagram of the Arduino Board

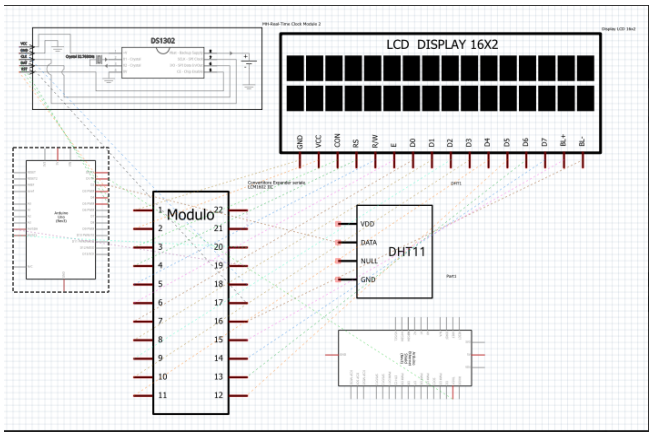

Figure 3. Circuit Design/Diagram

The LM35 sensor is connected to the Arduino in the system's design. This is then coded to take temperature readings from the sensor and display the results in the Serial Monitor. Next, the Arduino's built-in 1.1 V reference voltage is used to get more accurate readings. This is followed by the procedure to display the temperature on a 16x2 LCD to create a standalone thermometer.

Phase 3. Development and Integration. Arduino IDE software is used to program the sensors' settings. The researchers also ensured the schedule of temperature readings, which was set to three (3) times a day. The timestamp and temperature readings in degrees Celsius are recorded in the Google Spreadsheet.

Finally, after the development of the interface, the temperature readings are stored in Google Spreadsheet. This is done by publishing the Arduino code to the Google Spreadsheet and deploying it as a web application. The time recording depends on the computer's system clock where the prototype is installed. The server room maintains a temperature range between 10 and 30 degrees Celsius; once the temperature reading is outside the given range, a warning message will be displayed in the Google Spreadsheet, and an email will be sent to the ICT.

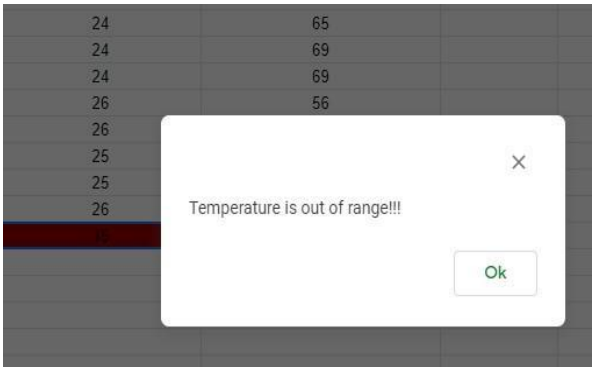

Figure 4. Message Warning in Google Spreadsheet

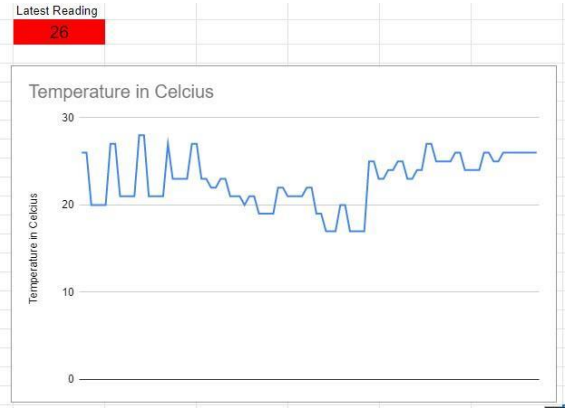

Figure 5. Example Reading with Temperature out of Range

The record is also highlighted in red for easy identification and reference. A graphical representation of the temperature reading provides a visual scan for easy data comparison.

Results and Discussion

Similar to the studies of Ridwan et al. (2020) and Wijaya et al. (2019), researchers compared the readings of the sensor and thermometer. The researchers took the readings from the room thermometer and the installed prototype for a week. The data is presented in Figure 6.

TimeStamp	Sensor Reading (°C)	Thermometer Reading (°C)	Difference in (°C)	Error (%)
7/15/2023 7:54:52	20	20.6	0.6	2.91
7/15/2023 16:54:52	27	27.3	0.3	1.10
7/16/2023 2:54:49	21	21.5	0.5	2.33
7/16/2023 7:54:46	21	21.5	0.5	2.33
7/16/2023 16:54:45	28	28.2	0.2	0.71
7/17/2023 2:54:41	21	21.3	0.3	1.41
7/17/2023 7:54:41	21	21.3	0.3	1.41
7/17/2023 16:54:39	27	27.4	0.4	1.46
7/18/2023 2:54:35	23	23.2	0.2	0.86
7/18/2023 7:54:34	23	23.2	0.2	0.86
7/18/2023 16:54:35	27	27.3	0.3	1.10
7/19/2023 2:54:29	23	23.2	0.2	0.86
7/19/2023 7:54:28	22	22.2	0.2	0.90
7/19/2023 16:54:29	23	23.2	0.2	0.86
7/20/2023 2:54:22	21	21.2	0.2	0.94
7/20/2023 7:54:21	21	21.2	0.2	0.94
7/20/2023 16:54:23	21	21.3	0.3	1.41
7/21/2023 2:54:16	19	19.3	0.3	1.55
7/21/2023 7:54:15	19	19.3	0.3	1.55
7/21/2023 17:00:16	21	21.2	0.2	0.94
Average			0.31	1.40

Figure 6. Comparison Result

Figure 6 shows the comparison results between sensor and room thermometer readings. It can be noted that the difference between sensor and room thermometer readings are closely similar. The error results for each experiment are also smaller than 5%. The accuracy results are obtained using the accuracy formula, and the obtained accuracy results is 98.6% using the formula:

$$\text{Accuracy} = 100\% - \text{Average Error}$$
$$\text{Accuracy} = 100\% - 1.40$$

Conclusions

In this study, the Room Temperature Monitoring System is designed and developed to monitor the server room remotely and efficiently. Expressly, the following features are provided by the developed system:

The server room's temperature is monitored remotely. Google spreadsheets allow real-time monitoring of the server room temperature. With internet connectivity, ICT staff can monitor the site anytime and anywhere without going to the site.

Record temperature readings of the server room three (3) times a day using Google Spreadsheet. Programmed to provide three (3) times a day recording of the temperature, there is no need for the ICT staff or roaming guard to visit the server and record manually the temperature. Furthermore, mistakes in recording due to manual entry will be eliminated, and accurate readings will be recorded. Queries and generates reports. Queries and reports are readily available upon request for generation, printing, archiving, and sharing when needed. This provides access control for intended users. Only the ICT coordinator and staff are initially given access to the Google Spreadsheet file to ensure authorized people will have access to the file. Additionally, users can be given access upon approval by the ICT coordinator. Sends alert/ message warning via email when the observed temperature is out of range. If the system records a change from its average temperature, a 3-way alert system can be observed:

Google Spreadsheet will display a warning message. A particular cell in Google Spreadsheet will automatically change its back color into red to signify alert or waning. An alert message will be sent via email to the ICT staff.

Recommendations

Based on the conclusion of the study, the following enhanced recommendations are provided:

Integration of SMS Module: To further improve the notification system, integrating an SMS module will ensure that ICT staff receive alerts even without internet connectivity. This adds a layer of reliability, ensuring that critical temperature changes are communicated promptly.

Incorporation of a Calibration Module: Adding a calibration module will enhance the accuracy and reliability of the temperature sensors. This module can automatically calibrate the sensors, adjust data acquisition rates, and maintain sensor accuracy over time.

Expanded Deployment: The system should be deployed in critical areas beyond server rooms, such as science laboratories, chemical storage facilities, and any other sections that require precise temperature control. This will extend the system's benefits to various departments within an organization.

Temperature Control Integration: Future developments can include features for monitoring and controlling the temperature. This can be achieved by integrating systems that allow remote temperature adjustments via applications like Telegram or fuzzy logic controllers. This will provide a comprehensive solution for maintaining optimal environmental conditions.

Energy Efficiency and Sustainability: Implement features that monitor and optimize energy consumption in the server room. By analyzing temperature data and adjusting cooling systems dynamically, the system can contribute to energy savings and reduce the environmental footprint of the ICT infrastructure.

Data Analytics and Reporting: Enhance the system's advanced data analytics and reporting features. This will enable ICT staff to generate detailed reports, analyze temperature trends, and make informed preventive maintenance and infrastructure upgrade decisions.

User Training and Documentation: Provide comprehensive training and

documentation for ICT staff to ensure they can effectively utilize and maintain the system. This includes user manuals, troubleshooting guides, and regular training sessions.

Security Enhancements: Implement robust security measures to protect the integrity and confidentiality of the temperature data. These measures include encryption, secure access controls, and regular security audits.

IoT Device Management: Develop a centralized management platform for overseeing all IoT devices within the organization. This will streamline device maintenance and firmware updates and ensure seamless integration of new sensors and modules.

By adopting these recommendations, the developed temperature monitoring system can be significantly enhanced, providing a more robust, efficient, and comprehensive solution for maintaining optimal server room conditions and extending its benefits to other critical areas within the organization.

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