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Enhancing Mortuary Practices in Rwanda's Hospitals: Integrating IOT Technology and Mobile Applications

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Abstract

In Rwandan hospitals, mortuary management faces significant inefficiencies that make effective service delivery difficult. Among those Key challenges are manual body recording processes that lead to body misidentification, inadequate notification of unfavorable storage conditions to mortuary staff, and access to mortuary delays. These inefficiencies compromise the integrity, traceability, and timely management of deceased bodies. The study proposes an event-driven system integrating Internet of Things (IoT) technology and mobile applications to address these issues and enhance mortuary operations. The system automates key events in body handling and monitors critical parameters. IoT-enabled sensors are deployed to monitor temperature, humidity, door status, and air quality (for odor detection). Upon detecting anomalies, the system triggers real-time mobile notifications to authorized personnel, such as mortuary staff and biomedical engineers. A mobile-based platform ensures continuous monitoring and digital record management, while an event-driven architecture facilitates streamlined communication among all stakeholders, including bereaved families. The smart mortuary system demonstrated the ability to protect the body from deterioration through continuous environmental monitoring, minimize human error by digitizing body tracking and records, improve responsiveness through real-time notifications and alerts, enhance coordination among hospital staff and other related departments, and promote transparency and data availability in mortuary operations. The proposed IoT-based, event-driven mortuary management system modernizes hospital mortuary practices in Rwanda at the implementation phase by enhancing operational efficiency, ensuring regulatory compliance, and fostering transparent communication among stakeholders. Ultimately, the system provides a scalable, technology-driven solution for improving the dignity and management of deceased individuals in healthcare institutions.

Keywords: *Mortuary Practices, Rwanda Hospitals, IoT Technology, Mobile Applications, Smart Mortuary Systems, Sensors, Real-time Notifications*

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1. Introduction

Still, nowadays, the management of funeral services and mortuaries in general is often an ignored essential aspect of society (Guidetti et al., 2021). There is a considerable ambition for innovative solutions that can enhance the efficacy and sense of mortuary activities (James et al., 2015a). As day-by-day technology progresses, the advent of IoT (Internet of Things) and mobile applications has also offered a unique opportunity to remodel how mortuaries operate and offer special support to depressed families (Gutierrez et al., 2021). This thesis aims to study the development and implementation of a mobile application to establish the management of a smart mortuary by integrating IoT notifications.

Manual documentation, human involvement, and limited communication methods are mortuary management aspects in the traditional period. The above methods result are inability, misjudgment, and emotional distress for the dispossessed families. In an area such as today's modern world characterized by smart technology and connectivity, it is necessary to modernize and streamline the mortuary management process (Ariyarathna & Htdw, n.d.).

The idea of a "Smart Mortuary" comprises the incorporation of IoT devices to invigilate, trace, and manage various aspects of mortuary operations (“Navigating the Internet of Things (IoT): Towards a Smart and Sustainable Future - Opportunities, Issues, and Challenges,” 2023). These devices can incorporate sensors for body tracing, environmental surveillance, and security awareness. By using IoT technology, mortuaries can become more interactive and offer mortuary staff accurate information relative to the mortuary room conditions, helping them in the monitoring process (Santosh Kumar et al., n.d.).

In addition, the development of a mobile application specifically customized to the needs of mortuary management is a central step in improving communication and clarity. Such an application can offer mortuary staff a way to gain notifications, access important information, and make necessary arrangements more conveniently (Kuznetsova, 2021).

This thesis is done to analyze the IoT technology (devices and sensors) that can be embedded with a smart mortuary to enhance operational efficiency, security, and data management. To design, generate, and implement an interactive mobile application with a graphical user interface that can serve as an intermediate for both mortuary staff and biomedical technicians, enabling current notifications on time, access to information, and suitable arrangements (Chataut et al., 2023; Mashayekhy et al., 2022). To treat the sensitive data focus on the mortuary nature and the role of maintaining rigorous security and privacy measures to safeguard the information and maintain the trust of the families (Zainab et al., 2021). Concentrating on the usability and user-friendliness of the mobile application, ensuring that it sustains the needs of diverse users, including grieving families and mortuary personnel (Röcker, 2013).

The development of a mobile application for managing a smart mortuary, enhanced with IoT notifications, holds the potential to transform mortuary operations and significantly improve the experience for grieving families (Yazid & Jantan, n.d.). This research aims to contribute to the evolving field of mortuary management and pave the way for more compassionate, efficient, and technologically advanced practices.

1.1. Background of the study and motivation

Manual record-keeping, poor communication channels, and a lack of technological modernization have characterized traditional mortuary management practices (Miranda et al., 2021). The inefficiencies, miscommunications, and emotional distress for grieving families were the results of these practices (Näppä et al., 2016). Scholars have shown the pressing need for modernization in this sector, emphasizing the potential for IoT technology and mobile applications to transform operations and communication (Orton et al., n.d.).

The adoption of IoT technology in healthcare settings has been widespread due to its ability to enhance operational efficiency and security (Rejeb et al., 2023). Within the context of mortuary management, researchers have explored the application of IoT sensors for body tracking, environmental monitoring, and security measures (Kelly et al., 2020). These innovations promise to streamline the handling of the deceased and improve overall workflow (Azzawi et al., 2016; Rejeb et al., 2023).

The power of mobile applications in healthcare and sensitive environments has been outstanding while providing interactive platforms for communication and data access (James et al., 2015b). The development of mobile applications designed to the unique needs of mortuary management is an area of research (Tamrat et al., n.d.). Such applications aim to facilitate real-time notifications and improve user experience for both mortuary staff and grieving families (Frasier et al., 2008).

The management of sensitive information in healthcare and mortuary settings requires strict data security and privacy measures (Labrique et al., 2013). Safeguarding personal and medical data, especially considering the increasing prevalence of data breaches has an importance highlighted by the research (Seh et al., 2020). This issue is one of the important concerns within the scope of our project.

User-centered design principles in healthcare technology promote the development of interactive interfaces that address the needs of diverse users, including grieving families (Dabbs et al., 2009). Ensuring a sensitive, intuitive, and accessible user experience is vital in the context of mortuary management (Turner et al., 2023).

Effective communication and support for grieving families are crucial components of mortuary management. Existing research has explored strategies for providing timely and empathetic notifications to families during the grieving process, recognizing the emotional sensitivity of this context (Weber Falk et al., 2022).

The integration of technology in traditionally conservative industries, such as mortuary management, has been met with challenges and opportunities. Previous studies have examined cases of technology adoption and the potential for innovation within such (Murdoch, 2021).

Research on the cost-effectiveness and benefits of technology integration in healthcare and related industries is relevant to our project's economic implications. These studies consider factors such as resource savings, operational efficiency, and improved user satisfaction.

Thinking about the long-term success of technology solutions in healthcare, scalability, and sustainability are critical keys to consider. Cases of scalable and sustainable healthcare technology implementations offer insights into the adaptability and enduring relevance of our project (Ayalew et al., n.d.).

The collection, storage, and sharing of sensitive medical and personal information are of utmost importance within healthcare settings governed by legal and regulatory frameworks. Understanding these frameworks is crucial for compliance with data protection laws and ethical standards (Lysaght et al., 2023).

1.2. Problem Statement

Thinking on modern mortuary management, the existing techniques and technologies used to handle the deceased and support-grieving families often lack efficiency, transparency, and sensitivity. Current mortuary practices are based on papers or registers, manual record-keeping, traditional (verbal or written) communication channels, and outdated infrastructure. Delayed alerts, miscommunications and misunderstandings, data inaccuracies, and emotional agitation for grieving families are a range of problems that can be generated by this traditional approach. Moreover, the lack of effective IoT integration and dedicated mobile applications tailored to the unique requirements of mortuary management further aggravates these challenges.

The faced problem is the urgent need to provide a comprehensive solution that leverages IoT technology and mobile applications to strengthen the management of smart mortuaries. The absence of such a solution result in several urgent problems, such as the absence of efficient management of mortuary facilities, which leads to delays in the handling of the deceased and disruptions in the overall workflow. The absence of timely access and accurate information by mortuary staff about the body status inside mortuary rooms. This failure to receive notifications or updates contributes to grieving emotional distress during an already challenging time and can lead to medical legal cases. Time-consuming and heavy processes in data management and retrieval are risks resulting from reliance on manual record-keeping methods. Highly sensitive and personal data in mortuaries, which are not adequately protected, cause significant privacy and security risks. The lack of technological tools that enable mortuary staff to manage and communicate about the mortuary, or the missing of an adequate mobile application specific to responding to the needs of mortuary staff, further intensifies the issue of this kind of staff who are central in providing support to grieving families. Mortuary management activities have been slow to meet technological advances, limiting the power of innovation in this crucial sector.

The gravity of the above challenges requires the development of a mobile application communicating with IoT notifications to modernize and enhance the management of smart mortuaries. This project aims to handle these issues by embedding IoT solution that improves the efficacy of operations, provides better communication channels, ensures data security, and offers a user-friendly interface for both mortuary staff and grieving families.

1.3. Research objectives

1.3.1. General Objective

This research aims to investigate the potential of integrating IoT technology and mobile applications to enhance efficiency, communication, and the overall experience in mortuary management, ultimately establishing a new standard for compassionate and technologically driven mortuary practices.

1.3.2. Specific Objectives

This research attempts to achieve the following objectives:

1. To develop an integrated mortuary solution using IoT devices and a mobile application.
2. To analyze its impact on efficiency, communication, and stakeholder experience.
3. To provide recommendations for future enhancements and implementations.

2. Methodology

The study follows a structured methodology to develop and implement a smart mortuary management system for Rwandan hospitals. It begins with a rigorous assessment of current mortuary practices to pick out key challenges and stakeholder needs. Referring to these insights, an event-driven system architecture is designed, integrating IoT temperature, humidity, door status, and odor detection sensors, combined with a mobile application for real-time monitoring and alerts. The system is developed through iterative software and hardware integration, followed by testing to ensure functionality, reliability, and usability. After successful deployment in a hospital setting, staff are trained to operate the system effectively. Continuous monitoring and user feedback guide system enhancements, while strict adherence to health regulations and data protection standards ensures compliance. The entire process is documented to support scalability and future implementation.

2.1. System design or model

The system design outlined for the research project aims to Enhance Mortuary Practices in Rwanda's Hospitals through the integration of IoT Technology and Mobile Applications. The design encompasses various components such as a mobile application, IoT devices, a central system, user authentication, real-time notifications, data encryption, integration with mortuary operations, user training, scalability, compliance with regulations, data backup, and testing.

The expected results of the research project include improved efficiency in mortuary operations, enhanced communication with grieving families, real-time data monitoring and analysis, the development of a user-centered mobile application, compliance with data security and privacy standards, high user adoption rates, cost savings, long-term scalability and sustainability, positive user feedback, and a significant contribution to mortuary management practices.

Overall, the research is anticipated to revolutionize smart mortuary management, offering practical, compassionate, and technologically advanced solutions that improve the experiences of both mortuary staff and grieving families. The expected outcomes have the potential to set new industry standards and positively impact mortuary management practices.

This flowchart represents the process of managing a system that registers devices and deceased individuals, ensuring that data is stored efficiently. The process follows a structured approach, beginning with system management and proceeding through various decision-making steps.

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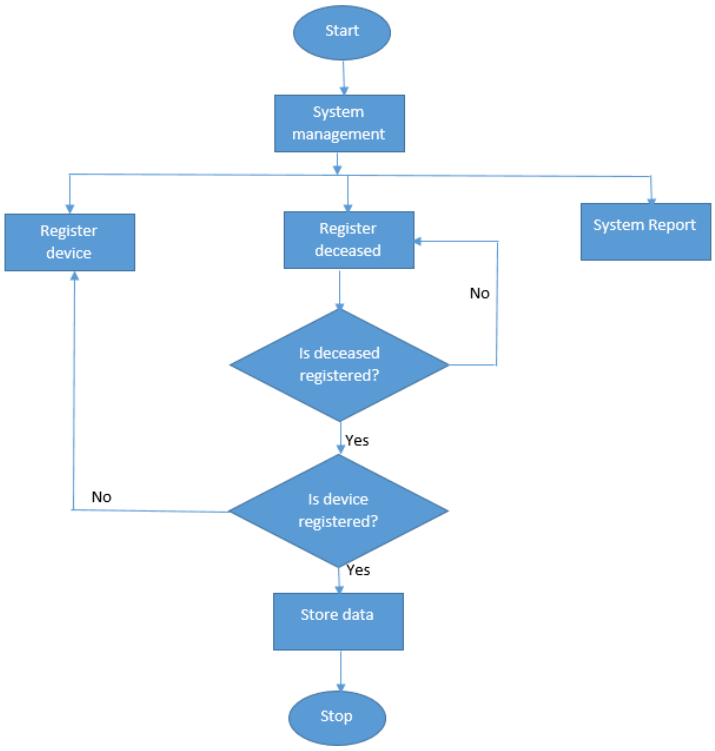

Figure 1: System design (Flowchart)

The process starts with System Management, which is responsible for overseeing the registration of devices and deceased individuals, as well as generating system reports. The System Report branch allows users to access stored data and insights.

If a new deceased individual needs to be registered, the Register Deceased process is initiated. A decision check, "Is deceased registered?", determines whether the individual is already in the system. If No, the system loops back to allow registration. If Yes, the process proceeds to the next step.

The next step is to check "Is device registered?", which verifies whether the monitoring device associated with the deceased is in the system. If No, the process directs users to the Register Device step, ensuring the device is correctly linked. If Yes, the system proceeds to Store Data, ensuring that all relevant information is saved in the database.

Once the data is stored, the process reaches the Stop point, indicating that all required information has been recorded successfully. This structured approach ensures that every deceased individual and their corresponding device are properly registered before storing data, preventing errors and missing records.

2.2. Conceptual Framework (Block Diagram)

The following block diagram represents a sensor-based monitoring system using ESP8266, integrating multiple sensors to collect environmental data and trigger appropriate responses through output devices. The system consists of input devices (sensors), a microcontroller (ESP8266), and output devices (displays and alerts).

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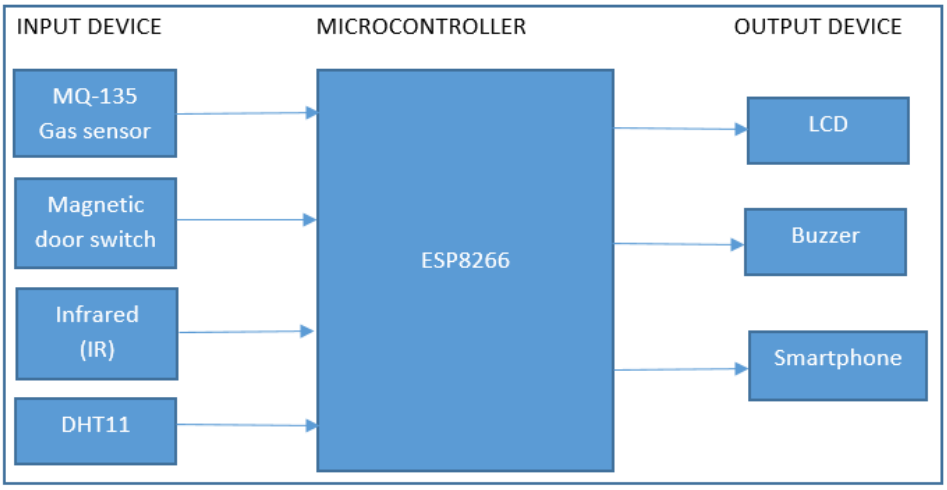

Figure 2: Block diagram

The input devices include four sensors that feed data into the ESP8266. The MQ-135 gas sensor detects harmful gases such as ammonia (NH_3), carbon dioxide (CO_2), and other air pollutants, making it useful for monitoring air quality in controlled environments. The magnetic door switch is responsible for detecting whether a door is open or closed, ensuring security and controlled access to restricted areas. The infrared (IR) sensor detects motion or obstacles, which can help in detecting unauthorized access or the presence of people in a monitored area. Additionally, the DHT11 temperature and humidity sensor measures temperature and humidity levels, ensuring that environmental conditions remain within desired thresholds.

The ESP8266 microcontroller serves as the central processing unit, receiving data from the input devices, analyzing the information, and determining the appropriate actions. The ESP8266 is particularly advantageous due to its built-in Wi-Fi module, which allows it to communicate data remotely, making real-time monitoring possible through a smartphone.

The output devices provide feedback based on the processed sensor data. The LCD display presents real-time readings of gas concentration, temperature, humidity, and door status, allowing users to monitor conditions at a glance. The buzzer generates audible alerts in critical situations, such as when gas levels exceed safe limits or an unauthorized door opening is detected. Additionally, the system can send alerts and data to a smartphone via Wi-Fi, enabling remote monitoring and timely intervention.

This system has several practical applications. In mortuaries and hospitals, it helps ensure air quality, maintain temperature control, and monitor security. Smart home systems can detect gas leaks and unauthorized access and maintain optimal indoor conditions. In industrial safety settings, it can help prevent hazardous gas exposure and alert personnel to potential risks.

2.3. Circuit Diagram

This circuit diagram represents a sensor-based monitoring system using the NodeMCU ESP8266, which integrates multiple sensors and output devices for security and environmental monitoring applications. The system is designed to detect gas levels, temperature, humidity, movement, and door status, providing real-time data on an LCD display, triggering a buzzer when necessary, and sending information to a smartphone via Wi-Fi.

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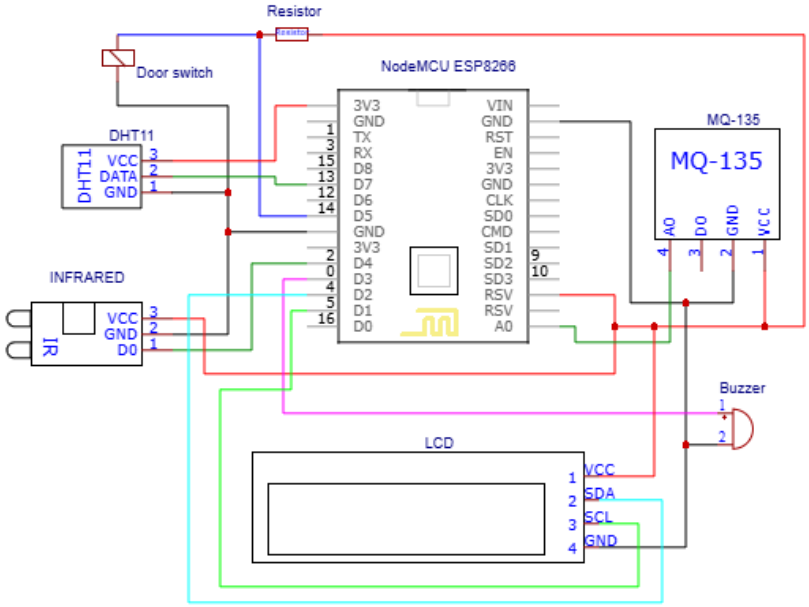

Figure 3: Circuit diagram

The input devices in the circuit include an MQ-135 gas sensor, a DHT11 temperature and humidity sensor, an infrared (IR) sensor, and a magnetic door switch. The MQ-135 gas sensor is responsible for detecting harmful gases such as CO_2 and NH_3. It is connected to the A0 analog input of the ESP8266, while its VCC and GND are connected to the 3.3V and GND of the NodeMCU. The DHT11 sensor measures temperature and humidity, with its data pin connected to D3 of the ESP8266, and power connections provided by the 3.3V and GND pins. The infrared (IR) sensor, used for movement detection, has its D0 output connected to D4 of the ESP8266, and its VCC and GND connected to the 3.3V and GND pins. Lastly, the magnetic door switch is wired with a pull-up resistor, allowing the ESP8266 to detect door status via pin D5.

At the center of the system is the NodeMCU ESP8266, which acts as the microcontroller, processing sensor inputs and controlling the output devices. It is responsible for making decisions based on sensor readings, activating alerts, displaying data on the LCD, and transmitting information via Wi-Fi for remote monitoring.

The output devices in this system include an LCD display, a buzzer, and Wi-Fi communication to a smartphone or server. The LCD is connected via the I2C protocol, with its SDA pin connected to D1 and SCL pin connected to D2 of the ESP8266. This LCD displays real-time readings from the sensors, providing a quick and easy way to monitor environmental conditions. The buzzer, connected to D6, is used to generate an audible alarm when dangerous gas levels are detected or when unauthorized movement occurs. Additionally, the ESP8266 sends sensor data over Wi-Fi, allowing users to remotely monitor the system via a smartphone or web interface.

The working principle of this system is straightforward. The MQ-135 gas sensor continuously measures air quality, and if the gas concentration exceeds a predefined threshold, the buzzer is activated to alert users. The DHT11 sensor regularly updates temperature and humidity readings, which are displayed on the LCD. The IR sensor detects motion, which can be used

for security purposes. The magnetic door switch helps in monitoring door status, triggering an alert when the door is opened unexpectedly. All collected data is displayed on the LCD and transmitted via Wi-Fi for remote monitoring.

This system has various applications, including mortuary gas monitoring, where it can detect ammonia and other harmful gases, ensuring a safer environment. It can also be used in home security systems to detect unauthorized access, industrial safety monitoring to prevent gas leaks, and smart IoT-based environmental tracking. By integrating ESP8266 with sensors, the system provides a cost-effective and efficient solution for real-time monitoring and alerting.

The above conceptual framework outlines the processes and variables implicated in anticipating a smart mortuary management system with IoT notifications and a mobile application.

2.4 Mobile application

The mobile application serves as an intelligent interface connecting the hospital mortuary staff to a centralized mortuary management system. In our research, we designed a mobile application that facilitates the sharing of data from the sensor between the cloud server and the mortuary staff through the use of the HTTP protocol.

This data transmission and sharing is done following these steps:

1. At the mortuary reception desk, the hospital mortuary staff register all the deceased's information using the mobile application. A unique identifier code is assigned to the dead body.
2. The ESP8266 is used to provide an HTTP connection and establish an internet connection for the sensor model.
3. The sensors fetch data from the mortuary room environment and send that data to the central system.
4. The central system shares data with the mortuary staff through the mobile app, within which the mortuary staff on the other side inserts deceased information.
5. The mobile application displays this data on the LCD screen and on a mobile device.

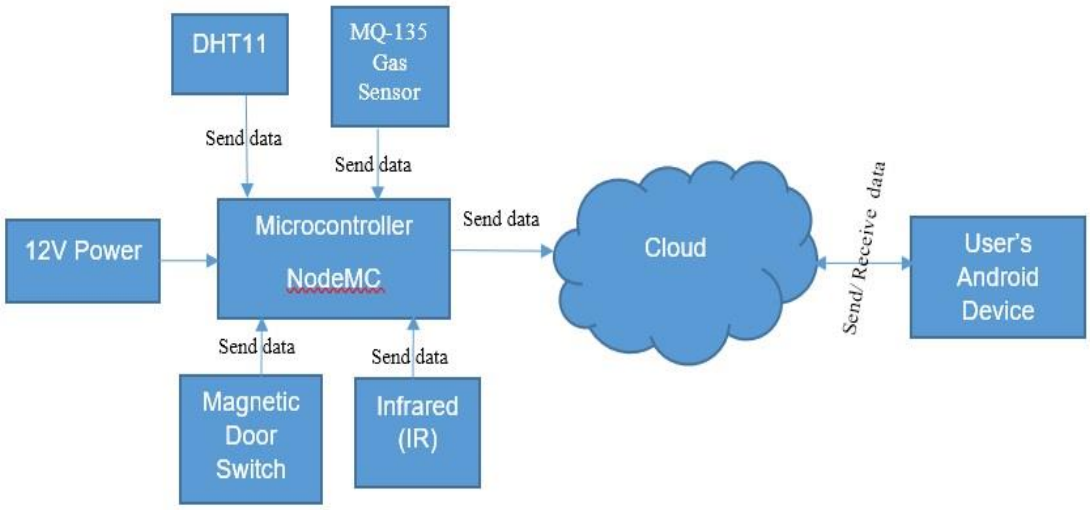

Figure 4: Sensors and a mobile application communication

3. System Integration Results

The integration of IoT hardware, cloud infrastructure, and mobile applications in our system was successfully achieved by ensuring that all operations are coordinated across all components of the system. Results show that the data flow and processing among these elements were efficient, by enabling real-time monitoring, updates, and notifications immediately. The above has simplified workflow, and enhanced system reliability, and user experience, by supporting the effective management of mortuary operations. The system ensured strong integrity of data in storage, by maintaining accurate and reliable records while complying with privacy regulations. Security audits have proven effective measures for encryption, user authentication, and access control, safeguarding sensitive information from unauthorized access. These results confirm the system's commitment to secure and compliant data management practices.

Integrating IoT hardware, cloud systems, and mobile applications was smooth, ensuring efficient data flow and processing. The system is also at high management standards and security standards, with strong encryption, authentication, and access to data control measures related to privacy regulations. Moreover, the system has proven its capabilities of optimizing mortuary operations, improving communication, and ensuring data security, allowing it to be implemented across Rwanda's hospitals.

3.1 LCD Displaying Sensors Results

Figure 5: Sensor results

3.2 Mobile application Login interface

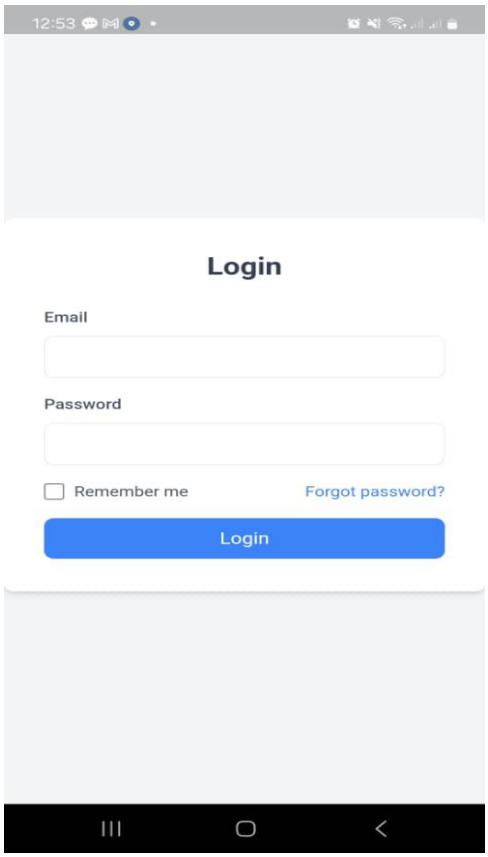

Figure 6: User identification

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3.3 Notification Results

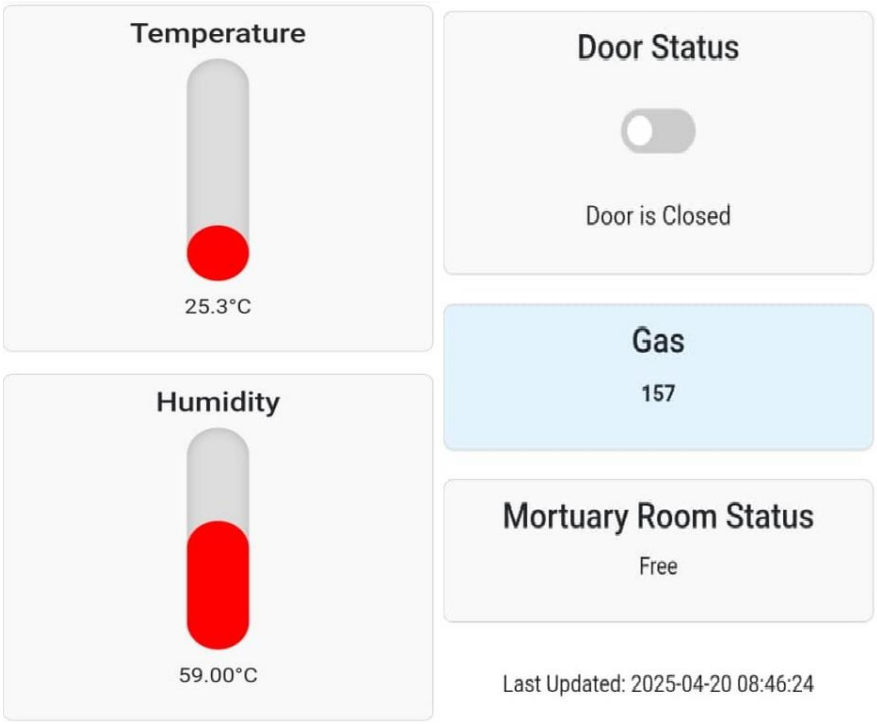

Figure 7: Notifications via the Mobile application

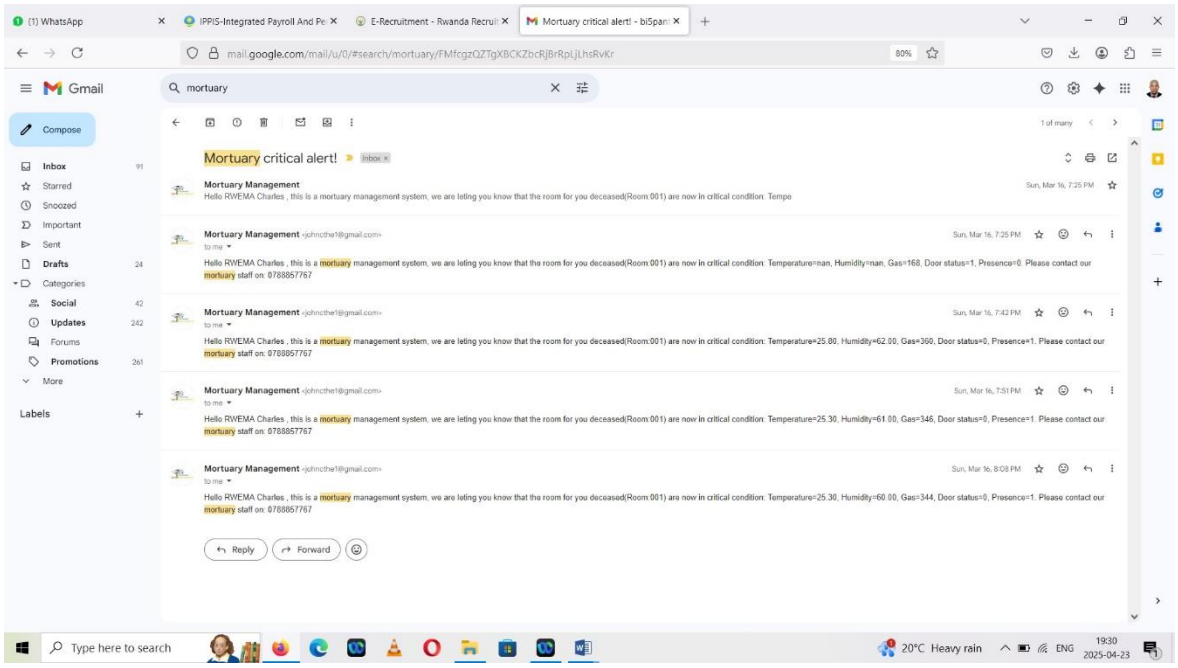

Figure 8: Notification via email

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3.4 Deceased Recording and Management Results

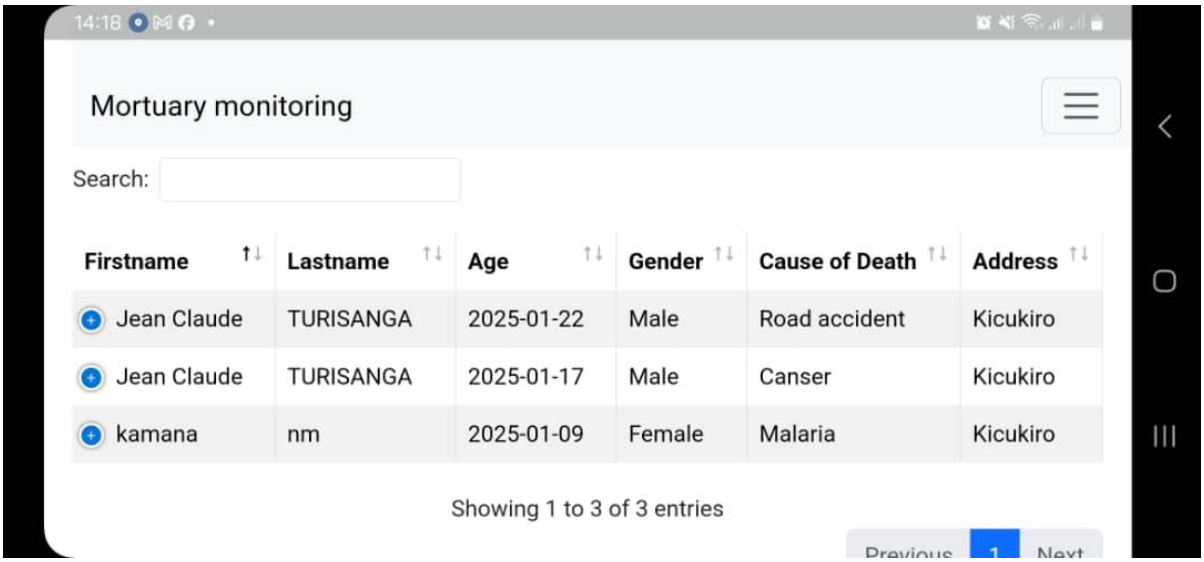

Figure 9: Deceased records

Figure 10: Deceased management

4. Conclusion

Referring to the success of our project at the selected pilot hospital through testing and implementation of the solution, we recommend expanding it to other health facilities to standardize operations and achieve similar benefits for all Rwandans. For continuous monitoring and maintenance, we recommend establishing a robust system for ongoing maintenance, monitoring, and calibration of IoT sensors to make sure performance and reliability are maintained. Moreover, regular staff training on the use of mobile applications and system monitoring is recommended to maximize user engagement and minimize operational challenges. We suggest that feedback from staff and families be integrated to allow iterative improvements to the system and to ensure user satisfaction. For predictive analysis, resource planning, and further optimization of processes, we recommend leveraging the data collected through IoTs sensors and mobile applications.

5. Recommendations for Future work

Our study was to find solutions to address inconsistencies in mortuary environmental monitoring and inefficiencies in the workflow as challenges. After the implementation of our solution, there is enhanced compliance with preservation standards, systematic processes in mortuary operations, and improved satisfaction levels among grieving families and staff. For future improvement, we suggest exploring additional technological advancements, such as AI-driven analytics and advanced reporting tools, to further enhance decision-making and operational efficiency.

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