CHAPTER I

INTRODUCTION

Background of the Study

Access to adequate healthcare services remains a fundamental challenge in the Philippines, with hospital room availability emerging as a critical bottleneck in effective healthcare delivery. The COVID-19 pandemic exposed severe infrastructure gaps, particularly in hospital bed and room management systems. The UP Pandemic Response Team revealed that existing healthcare infrastructure was insufficient to handle surge capacity, with hospital bed density remaining critically low across multiple provinces, particularly in Luzon where many areas fall below the Department of Health's recommended ratio of one hospital bed per 1000 people. The impact of inefficient room management extends beyond patient care, creating operational inefficiencies that compromise healthcare quality. Hospitals with limited available inpatient beds experience higher rates of ambulance diversion and forced patient triaging (Allon et al., 2016). These challenges highlighted the critical need for data-driven approaches to optimize hospital room utilization and resource allocation, whether during crisis situations or routine healthcare operations.

Traditional hospital room monitoring systems predominantly rely on manual processes that are inherently prone to human error and operational delays. Manual occupancy tracking creates bottlenecks in patient scheduling, reduces operational efficiency, and potentially compromises patient safety due to inadequate real-time visibility of room availability. These systems lack the responsiveness required for dynamic healthcare environments where room availability can change rapidly based on patient flow, emergency admissions, and discharge patterns. The absence of automated monitoring systems particularly affects resource allocation efficiency, as healthcare staff must physically verify room status before making

assignment decisions. This manual approach not only wastes valuable time but also contributes to suboptimal utilization of available hospital resources, especially during peak demand periods.

Recent advances in thermal sensor technology have demonstrated significant potential for accurate, privacy-preserving occupancy detection in smart building applications. The TODOS (Thermal sensOr Data-driven Occupancy Estimation System) provides occupancy detection accuracy of 98% to 100% under different scenarios, making thermal sensors highly suitable for healthcare environments where precision is critical (Zhang et al., 2023). Thermal sensor approaches detect occupancy behavior through temperature and heat source information, enabling energy reduction and security monitoring in smart buildings (Chaudhary et al., 2018). Thermal sensors offer distinct advantages over traditional motion-based detection systems, particularly in healthcare settings where privacy concerns are paramount. Low-cost and low-resolution thermal sensors preserve privacy while providing accurate occupancy detection, addressing both operational efficiency and patient confidentiality requirements (Yang et al., 2021). The technology's ability to detect human presence through thermal signatures eliminates the need for visual monitoring systems that may raise privacy concerns in sensitive healthcare environments.

The integration of machine learning techniques with hospital room management systems represents an emerging frontier in healthcare optimization. Mahmoudian et al. (2023) demonstrated that machine learning and deep learning methodologies can successfully forecast hospital bed capacity using data-driven approaches, showing the technology's potential for predictive healthcare management. Recent studies show that machine learning models can predict room and ward occupancy rates with high accuracy when trained on both static and dynamic hospital information (Kutafina et al., 2019). Machine learning models

including Support Vector Regression, Random Forest, and Decision Tree algorithms have been successfully applied to forecast bed occupancy in healthcare facilities, providing hospitals with predictive capabilities that enable proactive resource management (Rodrigues et al., 2022). These applications extend beyond simple occupancy detection to include predictive maintenance scheduling, optimal resource allocation, and operational efficiency optimization.

The application of predictive analytics in healthcare facility management enables hospitals to transition from reactive to proactive operational strategies. Machine learning algorithms can analyze historical occupancy patterns, patient flow data, and environmental factors to predict not only room availability but also maintenance requirements and resource needs. This predictive capability is particularly valuable for identifying rooms that frequently require maintenance, enabling hospitals to schedule preventive interventions and reduce operational disruptions. Predictive room management systems can optimize resource allocation by forecasting peak demand periods, maintenance requirements, and equipment needs. Wood et al. (2022) demonstrated that machine learning approaches using live electronic health records can generate short-term probabilistic forecasts with AUROCs from 0.82 to 0.90, demonstrating the reliability of predictive healthcare management systems.

Given the complexity and critical nature of healthcare operations, simulation-based development and testing of healthcare management systems represents a widely accepted research methodology. Simulation environments allow for comprehensive system testing without disrupting actual hospital operations, enabling researchers to validate system performance, identify potential issues, and optimize configurations before real-world deployment. Simulation-based approaches provide controlled environments for testing various scenarios, including normal operations, peak demand periods, and emergency situations. This

methodology is particularly valuable for developing systems intended for resource-constrained environments, as it allows for thorough validation of system performance and reliability without the risks and costs associated with direct hospital implementation.

The Philippine healthcare system is experiencing gradual digital transformation, with increasing recognition of technology's role in addressing healthcare delivery challenges. IoT-based solutions and automated monitoring systems are gaining acceptance as cost-effective approaches to improving healthcare efficiency and quality. The integration of thermal sensing technology with machine learning capabilities represents a practical solution that addresses the specific challenges faced by Philippine hospitals, including limited resources, staffing constraints, and the need for efficient patient management systems. The development of thermal sensor systems with machine learning capabilities offers a cost-effective approach to hospital room management that can be adapted to various healthcare facility sizes and budgets. This technological approach aligns with the Philippine healthcare system's need for practical, affordable solutions that can improve operational efficiency while maintaining high standards of patient care and safety.

Statement of the Problem

The health institutions in the Philippines usually rely on manual occupational monitoring systems to track their employees' performance which increases the probability of errors and therefore, the health institutions have been unable to carry out effective patient scheduling and lessened operational inefficiency. Such systems have defects in the security that can endanger the patient’s safety and their privacy. The risk for that, despite the availability of modern technology, they still relied on such backward systems.

This study aims to explore the adequacy of an Arduino-based automatic system in overcoming occupancy monitoring and security challenges when deployed in a healthcare setting. Specifically, it attempts to answer the following questions:

However, in the hospital predominantly using manual check-ins, especially in the Philippines, the difficulties of monitoring the rooms in case of overload of patients are stressful for the health workers and for the patients. The challenge arising from the inability to sort the patient resulted in crowds. But by the use of an automated sensor occupancy system can this address the current practice?

1. In what ways does an Arduino based automated occupancy detection system erase these disadvantages and enhance care to the patients?

In considering the implementation of Arduino-based sensors for hospital rooms, several factors must be taken into account: personal privacy, cost, environment, and performance. Since it needs an exact measurement of the data to save the time and the life of the patient.

2. What types of sensors are most accurate for hospital occupancy sensing and how the use of the sensors to the arduino based system saves time to the healthcare practitioners?

These include the visual or environmental checks, health worker, or patient and phobia checks among others; all of which are cumbersome especially with large hospitals. This often involves covering large spaces with several rooms and facilities and can significantly take time before healthcare givers get round encompassing all the areas meaning precious time is spent on patients is wasted and human resource hasted wastefully.

Objectives of the Study

This research outlines the idea of a proposed development of a new approach in an automated occupancy system for hospitals and discusses current practice shortcomings in meeting patient-care needs. This makes a bid to serve as a basis for this research through the use of Arduino-based technologies as a way of achieving objectives of real-time tracking of the availability of hospital rooms or beds and thus encouraging a shift from reactive to proactive management practices.

The primary objective would be to establish whether the automated system can function as an Arduino-based occupancy detection system for hospitals so that patient scheduling becomes optimized and clinical outcomes improve. Key goals include:

1. **Identify and integrate appropriate sensors for accurate occupancy detection.**
   In terms of enhancing the performance and minimizing the waste. The use of manual checks can be restricted while enhancing time management.
2. **Design a dashboard for real-time monitoring.**
   Design a friendly user interface dashboard for real-time monitoring of available rooms.
3. **To provide real-time optimization of resource management**
   Using environmental data for effective allocation can increase comfort and safety. Real-time data accuracy can assist in terms of reducing waste and operation cost effectively.

These findings might serve as a model for other healthcare facilities facing similar challenges, as well as enhancing our understanding of how technology can further evolve

health care systems. Eventually, this research contributes to a broader understanding of technology's role in enhancing healthcare systems.

Significance of the Study

This study will be beneficial and will contribute to the following various dimensions of hospital operations:

Patient: This study significantly enhances patient comfort in hospitals by providing automated environmental controls that align with the specific needs of patients.

Hospital Staffs: This study will help them to easily identify available rooms, beds or resources in real time, improving workflow efficiency.

Hospitals: This study will improve efficiency, resource allocation, and energy savings.

Hospital Administrators: Occupancy analytics provided by sensors help in planning, better resource allocation and providing opportunity to reduce energy consumptions and energy cost.

Technology and Future Researchers: Arduino-based systems provide an affordable IoT framework, encouraging innovation in Healthcare Services.

Time and Date of the Study

Time: October to January 2025

Place: Cavite State University - Imus Campus

Cavite State University Imus Campus is a public university in the province of Cavite in the Philippines.. It is located at Cavite Civic Center Palico IV, Imus City, Cavite 4103.

Scope and Delimitation

This paper aims to design and assess an Arduino-based automated occupancy detection system intended for healthcare facilities in the Philippines . The system will be tested using a mock hospital facilitating management of a cardboard- like structure to improve operation flow. The performance of the system will be owned by researchers after every trial and feedback from a supervising professor will be given. These include different types of sensors that are Arduino based like; PIR motion sensors, DHT11 sensors for temperature and humidity, LDR and Optical sensors meant to enhance resource exploitation and energies saving.

Nevertheless, there are certain limitations in the study. Working with a lower budget means that only a precise, imitation environment can be used and the results cannot be applied to actual hospitals in a strict sense. Due to the short period of the study from October 2024 to January 2025, the study is restricted; therefore, more budget and time are required for the improved future work. Although making sure that the computer algorithms built into the system will have been accurate in their analysis, the problem with using a limited sample of subjects is that it may reduce the statistical analysis strength. Furthermore, the estimation relying on the statistical reports may result in various biases influencing the correctness of the results.

Definition of Terms

Arduino - is an open-source electronic platform use to create the interactive object to collect a real-time data of room occupancy in Hospital

Dashboard - a user interface that gives immediate information on room availability and the climate in the hospital rooms.

Energy Efficiency - The sensor information gathered to organized facilities and effective use of energy resources in healthcare systems.

Environmental Data - This refers to the information collected concerning the environment in patient rooms that is important for patients' comfort and security as well as general well-being.

IoT (Internet of Things) - a system of connected gadgets that leverage real-time data received from sensors to optimize which use to check for presence and conditions of hospital rooms

Occupancy Sensors - integrated with the Arduino system to provide real-time monitoring of room availability.

Operational Efficiency - refers to optimal utilization of available resources and assets under the provision of services in healthcare facilities.

Real-time Monitoring - The system employs Arduino technology to capture signals relating to room occupancy status and climate indicators such as temperature and humidity.

Sensors - a device that are used in Arduino Systems to measure variables such as people presence, temperature or lighting.

Theoretical Framework

The study describes the use of the Technology–Organization–Environment (TOE) Framework to help understand the reasons behind the implementation of innovation in organizations. It outlines three major dimensions: The categories of change are: Technological change, Organizational change, Environmental change. Technological context is defined as the incorporation of the current and new technologies with or without modification as per the establishment of the Arduino occupancy sensor system. System adoption is affected by the organisational environment and good communication, resources and organisational readiness are necessary. Antecedent factors include legislations, competition and technology accessibility. It is especially important for the Arduino occupancy sensor system because the healthcare sector has many strict privacy laws. Acquisition and management would need alliances with information technology suppliers and competent servicing personnel in order to meet the external demands of healthcare delivery and efficiency of hospitals.

According to (Brey and Soraker, 2009) The Philosophy of Computing and Information Technology advocates for the application of digital technologies in all aspects of life, and especially in the health sector. This approach openly supports the use of technology such as IoT based Arduino systems but is also focused on ethical issues, data safety, and user experience. Thus, this philosophy cannulates the presentation of operational performance to rationality with the concept of ethical liability.

The (DeLone and McLean Model of Information Systems, 2003) success is employed to assess the success of an Arduino-based system. The model has six dimensions: system

quality, information quality, perceived usefulness, perceived user satisfaction, individual consequence and organizational consequence. While system quality refers to characteristics of reliability and ease of use, information quality is influenced by the accuracy of the dashboard. The improvement of decision-making processes and optimization of resources is a direct and an indirect consequence of the operation of the system.

Derived from (Control Theory, Simroom, 2000) that the theoretical framework for creating operating systems is valid. According to Control Theory, it is a concern of applying feedback mechanisms to make these control, closed-loop systems to be adaptable as it is real-time. Incorporating backup power supplies and redundant components to maintain functionality during network outages or sensor failures, ensuring uninterrupted operation in critical scenarios.

The healthcare occupancy sensor system in the Arduino platform uses state-space presentations as well as feedback control system to provide correct and efficient dashboard display. That meets operational requirements and social imperative and therefore satisfies the practical technological and ethical consideration. The theoretical base of the system gives the theoretical background which can be used for understanding this system, as well as for designing and implementing this system into complex hospital conditions.

Conceptual Framework

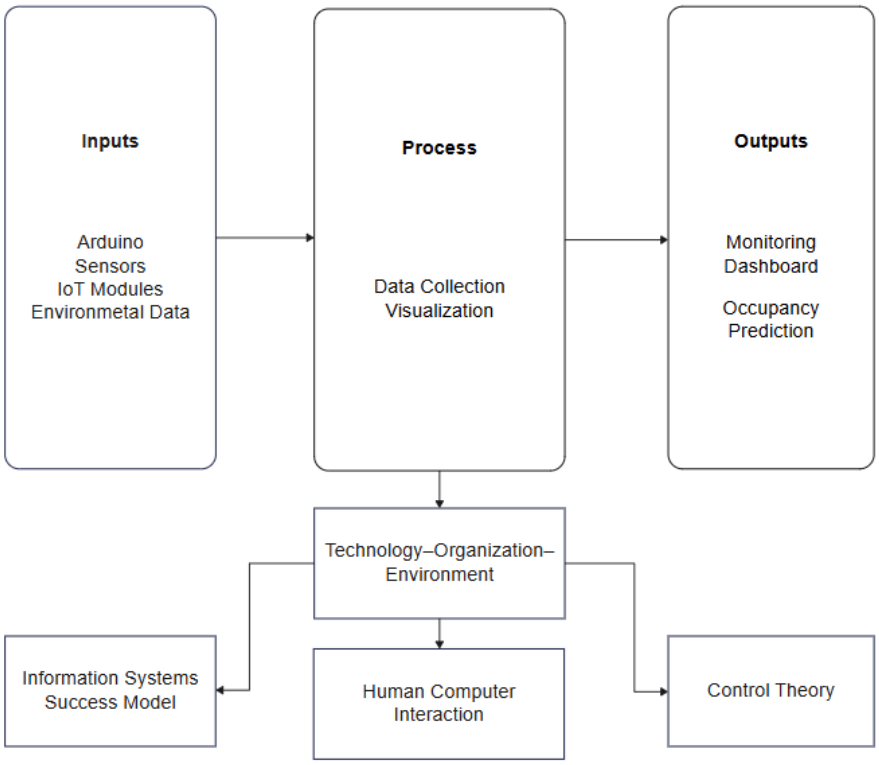

Figure 1: *The conceptual design of an automatic system for detecting occupied hospital rooms.*

In the input stage Arduino microcontrollers are incorporated into the system along with sensors such as motion or load sensors, IoT modules, environmental data and other to identify room occupancy and log it. This data is captured and analyzed in real-time in the process stage and can be displayed through graphics interfaces where necessary. Lastly, the output stage of the system entails a screen that shows the real-time availability of the rooms for the hospital's staff along with notifications thereby reducing time and paperwork needed for checks for room availability.