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DEVELOPMENT OF MONITORING SYSTEM FOR NEONATES IN HOSPITALS USING IOT: CASE OF CHATINKHA NURSERY UNIT

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ABSTRACT

Hence, the high neonatal mortality rate in the facilities such as the Chatinkha Nursery Ward in low resource country like Malawi is a cause for concern and therefore, there is an urgent need for heightened neonatal care. The current system of monitoring neonates through the manual process is marred with issues of data inaccuracy which has made it difficult to deliver efficient care to the neonates. This project focuses in adding an IoT-based monitoring system to the current paper-based system in order to ease the monitoring of neonatal vital signs including; heart rate, oxygen level, temperature among others.

Accordingly, the research employed an experimental research methodology which entailed the creation of an IoT prototype to monitor neonates in real-time. Both primary and secondary methods of data collection will be employed and this will include survey, interviews and analysis. Interviews and questionnaires to Nurses and health Care providers will be used to obtain Qualitative data. The quantitative data will be derived from data gathered from different system's performance and from the different sensors installed. Survey approach used in the examine and assess the current course of work at the nursery ward and discover weaknesses of the manual assessment.

The development will involve iterative prototyping to ensure that feedbacks from the users are incorporated in the development of the system to maximize on its usability and functionality. Most of the analysis will focus on the qualitative responses through content analysis while the quantitative aspect will shed light on how well the system is performing. The final system will possess the features of modelling so that data will be sorted to check the integrity and further alert sounds will be generated the moment that the neonate's vitals go above the stipulated limits.

Anticipated consequences are a more precise and time-saving tracking of the neonates, less burden on the nurse, and a system that signals regarding deviations of the neonates' status. The objectives of this project are as follows: This project shall help enhance the neonatal care offers in settings that offers less of an infrastructure support.

Keywords: Neonate, Health Network, IoT technology, Neonatal, Healthcare, Real time Monitoring, Resource constraint area

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ACRONYMS AND ABBREVIATIONS

Preterm: Babies born before 37 weeks of gestation.

Neonate: Is a newborn whose age is less than **28 days** or whose is 1 month old or below.

BPM: Beats per minute.

SPO2: Peripheral Capillary Oxygen saturation.

SQL: Structured Query Language.

SPI: Serial Peripheral Interface.

I2C: Inter-Integrated Circuit.

ERD: Entity Relationship Diagram.

WHO: World Health Organization **NMR:**

Neonatal Mortality Rate.

NICU: Neonatal Intensive Care Unit.

MLCC: Midwife-led Continuity of Care.

QECH: Queen Elizabeth Central Hospital.

IOT: Internet of Things.

RH: Relative Humidity.

WAP: Wireless Access Point.

WSN: Wireless Sensor Networks.

IDE: Integrated Development Environment.

1.0 INTRODUCTION

1.1 Background Information

The World Health Organization (2024), defines neonates as live-born infants whose age is within **28 complete days of birth**. Neonatal mortality (NM) is defined as infant death, which occurred during the first four weeks of life after birth.

According to WHO a child's survival is mostly considered during its first month of birth because in this period the child is very vulnerable to many susceptible factors, with the numbers reaching **2.3 million** preterm deaths in the year of 2022 (WHO, 2024). In the year 2000 neonatal deaths have seen a decline of **44%** but unfortunately in 2022 there was an increase of **3%** leading to **47%** which is almost half of the total premature child births in the world leading to a need of **intensified quality intrapartum** and **newborn care.** Sub-Saharan Africa accounted for only 30% of live births worldwide in 2022, but for 57% of all under-5 deaths (2.8 million). With 27 deaths per 1000 live births, SubSaharan Africa had the highest neonatal mortality rate in the world. Central and southern Asia came in second with 21 deaths per 1000 live births. The main causes of neonatal deaths continue to be premature birth, birth complications (birth asphyxia/trauma), infections, and congenital abnormalities. Children who pass away within the first 28 days of life typically have illnesses and conditions linked to inadequate prenatal care or to inadequate postpartum and early life care. Midwife-led continuity of care (MLCC) recipients is 16% and 24% less likely to lose their babies, respectively, and to give birth before term, according to professional midwives trained and certified in accordance with international standards. The neonatal mortality rate (NMR) in Malawi is 22 deaths per 1,000 live births as of January 2024. This means that for every 1,000 babies born in Malawi, 22 die within the first 28 days of life.

1.2 Case Description

The Chatinkha Nursery is a special neonatal intensive care unit (NICU) located close to the delivery ward at Queen Elizabeth Central Hospital (QECH) in Blantyre, Malawi. This NICU provides immediate care for babies born or referred from other hospitals who require urgent medical attention. However, this ward experiences numerous challenges like high rates of premature deliveries, poor infection prevention and lack of proper control practices by healthcare workers and caregivers, and many outbreaks of neonatal sepsis as well as inadequate resources and infrastructure such as incubators also prevent the unit's ability to deliver quality care. In the chatinkha ward nurses and caregivers are still using manual means of checking and recording the vitals of the babies using plain documents. They are currently using what is known as a "Critical Care Path Way" also known as clinical pathway which is a management tool used in healthcare facilities to improve the quality of care in the newborns however, despite using this method nurses still find themselves overloaded with work when it comes to looking after the neonates, to take that into perspective the World Health Organization (WHO) recommends a nurse-to-patient ratio of 1:1000 for developing countries. However, in Malawi, the ratio is significantly higher, at 1:2300. This means that there is a shortage of nurses available to care for newborns hence leading to fatigue because the nurses have to look after all the preterm babies assuring that their vitals are in check hence leading to data integrity problems as well as the inconsistences in the data because of the manual paper-based system they are using.

1.3 Problem Statement

Neonatal mortality is quite high and resources are limited in Malawi, especially in Chatinkha nursery unit. One of the major challenges which needs immediate attention is monitoring systems for neonates. The current method of vital signs monitoring based on paper and manual record keeping is the core reason why inconsistencies and data integrity flaws are on the rise owing to long hours and heavy workload on registered nurses. Besides this, the poor infrastructure factor that has been the major cause of the fatal incubator's shortage is still a serious hindrance in the unit's ability to provide excellent care to premature infants. These difficulties underscore the pressing demand for a technological remedy that will automate and simplify the process of monitoring and provide assistance to overloaded nurses in data accuracy inducing a higher degree of quality in neonatal care delivery.

1.4 Aims and Objectives

The aim of this research project is to introduce a digital monitoring system to work alongside the traditional paper-based system for premature infants also known as neonates using internet of things (IOT).

To achieve this aim, the following objectives have been drawn.

1. To find out the current means of vital monitoring in premature babies.

2. To find out how IOT technology can be incorporated in the development of the new health monitoring system.
3. Design a monitoring and alert system.
4. Implement the system

2.0 RELATED LITERATURE

This literature review aims to explore the past artifacts and provide some analysis in the recent technological advancements in the development of monitoring systems for neonates, with a lasered focus on the applications in low resource countries like Malawi. By synthesizing findings from a selection of relevant articles, this review seeks out to find out the common trends, challenges and opportunities inform of gaps in this rapidly evolving field of study.

2.1 General Literature

2.2.1 Challenges Posed by infant incubators and their potential mitigation

Puppala (2023) claims that very low birth weights (less than 1000 grams), inadequate gestational age for the development of the mechanisms needed for the infant to cope with the environment outside the mother's womb, and heat loss through radiation, conduction, convection, and evaporation are the main causes of infant morality. Premature babies, or preemies, should be placed in a suitable microenvironment that resembles an artificial mother's womb because they are incapable of storing heat or altering their posture to prevent thermal stress. They should also not be kept in an open crib. A device that will house the infant and has controls to adjust different aspects of its microenvironment for the comfort and benefit of the child is called an infant incubator. By regulating temperature, relative humidity, weight gain, baby movements, and oxygen concentration inside, it can provide specialized care for the infant occupying it. Certain sophisticated neonatal incubators can also regulate incident light and sound intensity, block offensive Odors, and lower the risk of infection for the premature infant. The most recent baby incubators can inform the concerned physician and family members about the preemie's condition. There are essentially three kinds of baby incubators on the market. The first kind is a fixed incubator, which is expensive and immobile despite being able to carry out all necessary tasks. The second type is a mobile incubator, which is also quite costly but can carry out all necessary tasks and be moved to any desired location. The third kind of incubator is a transport incubator, which is capable of moving preemies around but may have serious issues like electrical shock hazards and failures in thermoregulation. Using infant incubators can lower the infant mortality rate by increasing the survival rate of premature babies. In his literature the following gaps were identified and there categorised into two **direct** and **indirect** challenges.

Direct challenges

There direct challenges are as follows;

- **Inaccurate thermoregulation:** Because most baby incubators do not account for all radioactive, conductive, convective, and evaporative exchanges with the surrounding environment, thermoregulation is not carried out efficiently in most of them. Generalized predictive control (GPC), which considers all factors involved in regulating the temperature inside a baby incubator, can be used to resolve this.
- **Absence of relative humidity (RH) standardization:** The RH level in the infant incubator has an impact on the conditions that preemies face, including infection, trans-epidermal water loss (TEWL), hypothermia, electrolyte imbalance, oxygen consumption, and skin integrity. The lack of RH standardization contributes to a practice gap for the nurses managing these incubators. The preemie suffers from the uneven application of these levels and the gaps in nursing practice. It is also discovered that wide variations in RH management in clinical practice result from non-standard use of high RH, even beyond the preemie's first week of life. By standardizing RH levels and providing practice guidelines that incubator handling nurses must follow, this challenge can be lessened.
- **Slow and non-homogeneous temperature distribution:** In order to protect the preemie from health risks, the infant incubator needs to be able to maintain a homogeneous temperature inside the hood. It also needs to be able to quickly restore the desired temperature because parents and medical professionals will inevitably disturb the microenvironment inside the incubator. Regretfully, current incubators aren't able to perform these functions; however, this issue can be

lessened by using a modular thermoelectric heat pump system (MTEHPS) in an infant incubator.

- **Ineffective thermoregulation:** The resistive heating element in existing incubators consumes approximately 85% of the total electrical power used, and they also have temperature fluctuations (± 0.8°C) in the hood. These systems are primarily made to operate at room temperature and only have a temperature-raising mechanism. If the incubator is being transported or moved, and the temperature is high during the transition, they are not set up to lower the temperature so that the preemie won't become hyperthermic. An improved modular thermoelectric heat pump system in an infant incubator can help solve this issue.
- **Existing baby incubators are unable to function when the outside temperature (Tamb) exceeds the ideal temperature (Tdes):** Commercial Resistance Incubators (CRI) are the type of infant incubators that are currently being produced. They use a resistive heating element and can only control temperature and relative humidity (RH) when the ambient temperature (Tamb) is below the desired temperature range (Tdes). When Tamb>Tdes, which is quite possible in many parts of the world, these incubators are unable to provide the microenvironment that the preemie needs to be comfortable. On sunny days during the day, when infant incubators are being transported from one location to another, it is also possible to contract Tamb>Tdes.Using a modular infant incubator powered by a thermoelectric heat pump system can help to lessen this difficulty.

2.2 Related Work on IOT technologies

2.2.1 Design of smart neonatal health monitoring system using SMCC

De and Mukerjee (2016), implemented wireless means of infant monitoring using **Wireless sensor networks (WSN)** and **Cloud Storage** in order to monitor and record the vitals of the baby in **radiant warmers**, they also developed an android app that will be receiving information from the wireless sensor's nodes. In their experiment they measured **temperature**, **heart rate**, **acceleration** of the baby in relation to the environment, they did this by implementing wireless sensor technology to measure the vitals. Their system aims to eliminate the wired sensors because they say it is too complex to keep on implementing the wired approach as well as it causes discomfort to the baby due to limited range of motion the baby has. The caregivers need to have extra care in order to handle the baby because of the wired sensors hence, they created a system that will have wireless sensors attached on to the neonate and each of those sensors will send data to a **sensor base station** that will aggregate all the data together and send it a **wireless Access Point (WAP) or Wi -Fi Hotspot** from there the data will transmitted to the cloud storage with the help of **Message queuing telemetry transport protocol** used in the system where transport layer security and secure socket layer are used to achieve secured communication. There system achieved the following results,

I. If the temperature is high or low, an alarm is generated in the health professional's device to alert him or her for taking initiatives. The normal ambient temperature varies from 32 to 35 degrees Celsius depending on the age and weight of the neonates.

2.2.2 Remote monitoring of a premature infant's incubator

Shabeeb et al (2020) developed a monitoring system centred around humidity and temperature readings using an Arduino microcontroller as their base controller with different sensors attached to it and they also used an open-source internet of things (IOT) applications known as 'Thinkspeak'. The system is connected to a network via Wi-Fi connection to be linked to an application on the smart phone or computer. The system was developed using Arduino microcontroller, DHT11/DHT22 sensor for measuring the body parameters such as temperature and the humidity, LCD monitor for displaying the readings, ESP8266 Wi-Fi module as well as NodeMCU-v3 for wireless connection. Their methodology, was to use an Arduino to control the whole system but later on they later changed to the NodeMCU-v3 microcontroller because it has a more powerful processor with 4 Mib flash memory and much more random access memory (RAM) than a normal Arduino uno's Atmega328 chip as well as it has inbuilt Wi-Fi capabilities hence eliminating the need for an external Wi-Fi module to send the data to the cloud than they connected sensors like the DHT11/DHT22 as well as the LCD monitor for display and than send the data directly to the ThingSpeak application servers.

There results for their proposed monitoring system experiment shows that the location sensor placement within the incubator matters, and as a result can give different readings with a certain degree of difference but here the results explained in detail, firstly when placing the sensor at the left hand side above the incubator heater the temperature was 40 degrees Celsius, while the temperature was reduced to 34 degrees Celsius when placed on the centre of the incubator, which is considered as a more optimum measuring point inside the incubator. The conclusion for this proposed literature was that when using the NodeMCU-v3 as wireless module has aided the work and provided more accuracy than using the ESP826 Wi-Fi module. The proposed system has shown accurate and reliable temperature and humidity level measurements and transmitting via IOT module. The remote monitoring is achieved using smart mobiles or computers which provided low-cost method for remote monitoring with very small tolerance compared to the incubator built-in sensors.

In summary, the general literature outlined the challenges in most recent incubators as well as highlighted that the major gaps that mostly focused around thermal and humidity monitoring and regulation as well as inadequate competences of the nurses due to lack of proper training. In the IoT technology section highlighted on the ways in which IoT has already been incorporated in the monitoring and alerting of the vitals but there consist a gap in which most of the components used where microcontrollers like Arduinos in which they have low computational power, as well as memory bandwidths and also lacks computational ability to muti-task like most microprocessors have so in order to address the following gaps my research is going introduce a component better than the microcontroller which is the Raspberry pi as well as develop a user friendly system that will work hand in hand with the nurses and caregivers that even if they are not fully competent the system and interface will be easy enough to follow.

2.3 THEORECTICAL FRAMEWORK

The theoretical background of this research work is therefore utilised to anchor the research work and incorporate applicable theories and models in designing the IoT based neonate monitoring system. The following framework will help facilitate the achievement of the identified aims and objectives because it will provide a more focused roadmap on how to handle challenges likely to be encountered in monitoring newborns at the Chatinkha nursery unit.

2.3.1 Technology Acceptance Model (TAM)

According to the TAM model, perceived usefulness and perceived ease of use of new technology affects the users' decision on whether or not to embrace the technology (Davis, 1987). To succeed, the IoT-based neonatal monitoring system has to be highly perceptive among the healthcare staff and should not at all be cumbersome in terms of operation. Thus, this model will guide the design and implementation of the system in order to ensure that it meets the needs and abilities of the users to increase usage rates.

2.3.2 Systems Theory

Based on the systems theory, all the components of a single system are organized in the most effective way when they are in tune with each other. This theory focuses on various elements such as the sensors, data communication as well as monitoring interfaces when specializing in neonatal monitoring. It ensures it is not only a technically optimal solution for the implementation of the Internet of Things system but also fully integrates into the contemporary healthcare system providing a holistic approach to newborn care.

2.3.3 Health Belief Model (HBM)

The Health Belief Model or abbreviated as HBM centres on people's perceptions on certain health threats or hazards, and the benefits of not getting threatened or being threatened by those. The intent behind this model is to understand and alleviate the concern that different healthcare providers may have concerned the software of the new IoT monitoring system. The perceived barriers of the new monitoring practices can be tackled and the perceived benefit can be built in the system, which mean high level of adherence to the new practice that can enhance the neonatal health outcomes.

3.0 METHDOLOGY

3.1 Strategy

This research project took an experimental approach that involved proposing and implementing a proof-of-concept IoT neonate monitoring system. Some of the essential aspects that the system was intended to track included pulse rates, oxygen saturation, and temperature. But for reasons of ethical issues the above sensors were not fixed on real neonates. Thus, the testing was made with the involvement of the researcher, hence, providing the real-life scenario of the process.

Both qualitative and quantitative research data collection and analysis techniques were employed in this study. The quantitative data was collected from the prototype system by simulating the researcher's vital parameters which helped in assessing the effectiveness of the system in terms of precision, response and reliability.

For gathering the qualitative data, semi-structured interviews, and observations were carried out with the healthcare professionals which include nurses and doctors at the chatinkha nusery ward. These interactions proved helpful in understanding the nature of the existing paper-based system and improved features and functionality of the IoTbased monitoring system.

Given the innovative nature of the work, the prototyping process used in the project supports refinement of the system through the feedback gathered from the targeted healthcare staff and the system performance. Since the actual neonatal data was not captured because of ethical issues, the testing approach used offered insight into the capability of the system in an actual true and realistic hospital setup.

3.2 Sampling

In this study, convenience sampling was used to recruit participants for collecting user specifications and opinions on the model IoT-based neonatal monitoring system. Convenience sampling was selected for this study because of the availability and ease of reaching out to the healthcare professionals in the context of the Chatinkha Nursery Ward.

The subjects of this study were the qualified and non-qualified staff members who are involved in the care process of the babies at the ward. The members comprised of nurses, healthcare assistants, and doctors.

The study sample frame was from all staff members who frequently dealt with neonates at the Chatinkha Nursery Ward. Because of the time constraint and accessibility to the intended set of participants, the participants who happened to be available and willing to participate in the study constituted the sample frame.

The final sample comprised of a group of 10 of which 6 are nurses, 2 are healthcare assistants, and 2 are doctors. Participants in this study were purposively sampled because of their availability during data collection period and involvement in neonatal care. The responses elicited were used to identify the user needs of the prototype for instance, the features of the IoT system, usability issues and the anticipated gains from the system.

Furthermore, for ethical reasons, no neonates participated in the actual testing of the system. Instead, the prototype was tested with synthetic data that mimics real use cases, whereas the healthcare professionals gave a qualitative estimate of how the system can be incorporated into practice.

3.3 Data Collection

3.3.1 Interviews

Semi structured interviews were held with the healthcare professionals that consisted of nurses and doctors as well as the care-givers who are working in the ward. The interview questions were designed to collect qualitative data on the issues faced by the current method of monitoring babies as well as the inefficiencies of the paperbased system, and the participants anticipation of the proposed IOT-based neonatal monitoring system.

The interviews' semi-structured nature provided flexibility, allowing participants to elaborate on their personal experiences and points of view while making sure that all pertinent subjects were covered. Important user needs, like the need for automated alerts, real-time monitoring, and ease of use, were revealed in the interviews.

In order to minimize disruptions to the participants' work, the interviews were conducted at times that worked best for them, such as lunch breaks or shift changes. Ten healthcare professionals in all took part in the interviews, contributing high-quality qualitative data that influenced the prototype's design and iteration.

3.3.2 Observations

Observations were conducted in a way that did not disturb the work-flow of the healthcare professionals the aim of the observation was to understand the daily routines conducted at the ward and also observe how the nurses interact with the current system. The observations focused mainly on identifying the inefficient workflow of the nurses when it comes to the measurements and record taking of the vital parameters of the neonates, alongside this other parameter were observed like the time delays in the recording of vital signs, data inconsistencies, and the workload impact on nurses and healthcare staff.

Important features that were taken into account was the frequency of recording vital signs, management of data, and the reactions of medical staff to modifications in the conditions of the newborn.

This method provided invaluable insights into the manual system’s short falls, like the labour-intensive paper-work process and the possibility of human error. These discoveries facilitated in the establishment of the specifications for the Internet of Things (IOT) system, including real-time alerts and automated data logging.

3.3.3 Document Analysis

Document analysis was also used in order to examine the patient records, monitoring logs, as well as incident reports. This aided my understanding in how the data of the neonates is currently recorded, kept and retrieved.

After, conducting a thorough study of the paper-based records, I noticed that the areas where the IOT-based monitoring system could shine is on the improvement of data accuracy and integrity. For example, the system is designed to automatically log in sensor readings and maintain a digital record of the neonatal vitals, hence decreasing the dependency of manual data entry.

Input used to assess the IOT system included monitoring logs and patient records from the Chatinkha Nursery ward. Comparing the accuracy and efficiency of the new system against the old method was made possible by the baseline that the existing records offered.

3.3.4 Questionnaire

The participants were medical professionals who were asked to fill in structured questionnaires about their expectations towards the IOT based system and their experience and attitude towards the current monitoring system. Quantitative and qualitative data were sought through the use of the questionnaire. In addition to closed-ended questions, open-ended questions were included in the questionnaire in order to assess respondents' satisfaction with the current system, perceived difficulties, and desired features in the new system.

These included;

- A statement reflecting the current discontent of the nurse with the current paperbased system.
- These perceived problems and sub-optimality in monitoring neonates.
- Imagined expectations for the new IOT-based neonatal monitoring system.
- Fears that come with the implementation of a new digital system.
- The anticipated improvement that may be achieved with the new system.

The findings obtained from the questionnaire made it possible to refines the system design in order to meet the requirements and expectations of healthcare professionals.

3.4 Data Analysis

3.4.1 Content Analysis:

The content analysis will be adopted for text data collected from the documented interviews, observational notes, documentation, and user feedback related to the prototype real-time IoT monitoring system. This technique consists of the development of a systematic process to group and label written data in order to obtain response themes, patterns, or keywords that may repeat. The data interpretation will aim at the quantification and generality of key themes throughout the text, which will make clear the participants' opinions, feelings, and attitudes towards neonatal monitoring and the IoT system.

3.4.2 Descriptive Statistics:
The involved descriptive statistics will analyse the quantitative data derived from the sensor readings and the system metrics generated by the IoT-based monitoring system. Along the same lines, there are a variety of operations, such as the calculation of mean, median, standard deviation, and frequency distributions, that are aimed at describing and summarizing the characteristics of this data. Quantitative descriptive statistics will enable me to do quantitative summaries of interesting variables, thus finding generalizations about trends, patterns, and variability in the data.

3.5 Prototyping

Scrum was the chosen development approach which I used in my project prototyping because it enabled me to follow an iterative approach focused on continuous improvements through user feedback and testing.

3.5.1 Software Development Approach:

This chosen approach aided me to perform the following tasks;

- Make incremental delivery of system features.
- Get frequent feedback from health professionals.
- Make adjustments on the system based upon real-time testing and user needs.

3.5.2 Stages of prototyping:

The following stages were undergone during the development of the prototype;

Requirements Gathering:
During gathering of the requirements, I conducted Interviews with various hospitals staffs in the ward including medical doctors, nurses, nurse assistants and mid-wives as well as administered questionnaires. The requirements helped shape the features of the system which were real-time monitoring, ease of use and integration of sensors.

System Design:

The system architecture was designed to incorporate various sensors such as the heartbeat sensor, oxygen/saturation sensor, humidity sensor, room temperature sensor and the body temperature sensor. The system also had a GUI inform of a dashboard to provide central monitoring and data flow between the two.

The design included basic components such as:

- Sensors for vital signs monitoring.
- A real-time display of vital signs.
- A user-friendly interface to reduce nurses' workload.

Prototype Development:

- **Phase 1- Integration of sensors into the system:**
  Sensors were integrated together with the system in order for real-time data such as heart rate and temperature readings to be captured.

- **Phase 2 - Monitoring Dashboard integration:**
  A basic monitoring dashboard was designed and created in order for the readings to be displayed in a more user-friendly less technical way. The dashboard was made to enhance the UI/UX of users to make it easier for them to interact with the system by providing an appropriate amount of data abstraction.

Testing and Refinement:

During this stage, simulated data was used instead of actual readings from the babies due to ethical considerations and concerns. Initial feedback from healthcare professionals pointed out that they were some issues with accuracy of some the sensors like the heart rate sensor as well as they also noticed that the user interface needed some more clarification.

Based upon the responses and feedback, refinements were undergone in order to improve the system especially in the areas of concern which were the user interface the sensors inaccuracies.

3.6 Ethical Considerations

During the research there was a high code of ethics that had to be followed particularly to the involvement of healthcare professionals and the sensitivity of neonatal care. The research abided to the ethical principles in order to assure the protection of all participants involved in the study. The project ensured that the rights of the research participants were respected as well as the integrity of the data that was collected was fully maintained and not tampered with. Although the prototype was not actually tested on the neonates, safety precautions still had to be put in place to ensure that all processes adhered to the ethical guidelines.

The key ethical considerations in this project included voluntary participation, informed consent, anonymity, confidentiality, minimizing potential harm and results communication to the department in charge of then ward.

3.6.1 Voluntary Participation

Everyone who took part in the research including the healthcare professionals, participated on a voluntary basis. The participants were given the free will to either join or not in the research study without any obligation or coercion. They were told that their participation is not at a mandatory level which means that they have the right to withdraw from the study at any point without any consequences.

The involvement of the participants in the healthcare setup was of uttermost importance because it enabled me to conduct interviews, questionnaires, and observations and get feedback on the IOT system. Their voluntary involvement ensured that the information provided was unbiased and genuine.

3.6.2 Informed Consent

Before any sort of data was collected there had to be an informed consent, which in my case was obtained from the participants as well as the head of chatinkha unit. Healthcare professionals were fully made aware of my objective of the research, the purpose of the interviews and observation, and the intended use of the data collected. They were also briefed on how the IOT system would be tested and that it would not involve any direct interaction with the neonates.

3.6.3 Anonymity

Anonymity was maintained throughout the whole research. The actual healthcare professionals who took part in the interviews, observations and questionnaires remained hidden and undisclosed in the report instead, they are given unique identifications such as pseudonyms which were used to refer to the participants in the analysis and findings.

This assured me that the participants responses and personal details remained a secret hence reducing potential discomfort or repercussions that might arise from sharing their feedback.

3.6.4 Confidentiality

The confidentiality and privacy of the participants was strictly followed within the research procedures. All the data collected from interviews, questionnaires, and observations were treated with the utmost confidentiality that it deserved.

3.6.5 Minimizing Potential Harm

The participant's safety was closely monitored for any potential risks or harmful outcomes during the course of the study. This included ensuring the safety and comfort of the preemies during data collection and in the testing of the prototype. Additionally, measures were put in place to prevent any psychological issues or distress.

3.6.6 Results Communication

The findings of the research were conveyed precisely and faithfully, upholding principles of integrity and honesty. Any potential risks and limitations associated with this research were clearly highlighted, and the findings were shared in a manner that respected participants rights and dignity.

4.0 REQUIREMENTS ANALYSIS

During the phase of gathering requirements for the IoT monitoring system, nurses and healthcare practitioners at chatinkha unit expressed their needs for what they would want the system to have and incorporate. Through various methods, including interviews, questionnaires as well as observations, critical user requirements were highlighted, analyzed, and prioritized for the prototype development.

4.1 User Requirements Gathering

4.1.1 Interviews

The interviews were semi-structured with nurses and doctors taking part in the study, the aim of the interviews was to grasp an understanding of the day-to-day problems and challenges that comes with the existing paper-based system.

As a result of conducting the interviews, I discovered that nurses indeed were struggling with how the existing system was working as a result it led to decrease in the quality of care provided to the infants which was mainly caused by nurses being overworked as well as nurses being understaffed, on an average day the nursetopatient ratio can be quite high and this can lead to errors or gaps occurring when recording vital signs of babies.

The participants also emphasized the need for a real-time monitoring system that can help in reducing the workload on the nurses due to the manual paper-based system as well as a robust alarming system for detecting abnormalizes within the readings.

4.1.2 Questionnaires

Questionnaires were handed out to nurses in order to get their feedback on specific features they would love to have in the new system. It was discovered that 85% of the respondents wanted a real-time monitoring system for the vital signs measurements, 75% agreed that a simplified interface would aid them in their daily tasks and make their workflow more efficient and finally, 90% expressed their interest in receiving training for the newly introduced system as many lacked experiences with IoT devices as well as how to handle them.

4.1.3 Observation

As I was carrying out the observations on the nurses' workflows I gathered some useful insights into the manual entry processes, showing how time-consuming and error prone the current system was. Nurses were usually multi-tasking a lot, leading to inconsistencies in the manual documentation entries for the vital signs.

As a result, the need for a system that can automatically record and store vital signs data without manual input is of paramount importance.

4.2 Requirements Analysis

Once the user feedback was gathered, it was analyzed to prioritize the most critical requirements for the system.

4.2.1 Core User Needs Identified

- Real-time monitoring of heart rate, oxygen saturation, and temperature.
- A user-friendly interface that allows easy access and interpretation.
- A reliable system that reduces the risk of data entry errors and automatically records data.

4.2.2 Additional Findings

- Nurses expressed the need for a system that works with limited resources, acknowledging the infrastructural constraints in the hospital.
- Training emerged as a high priority for the successful adoption of the system.

4.3 Prioritizing Requirements

The requirements were prioritized based on the criticality and feasibility of implementation within the scope of the project.

4.3.1 High Priority

- Real-time monitoring of the vital signs.
- Simple and intuitive interface designed to reduce the workload of healthcare professionals.

4.3.2 Medium Priority

- A potential alert system for critical cases (future implementation).
- Data Storage for historical patient records.

4.4 Results in the prototype

4.4.1 Real-time Monitoring

- The prototype included basic sensors for heart rate and temperature monitoring, displaying the data in real time on the dashboard.
- This directly addressed the need for faster and real-time decision-making.

4.4.2 User-friendly interface

- Based on user feedback, a simple and easy-to-navigate dashboard was created, reducing the steps needed for nurses to monitor

4.4.3 Data Accuracy

- While the system reduced manual errors, some sensors showed inconsistent readings, particularly with heart rate monitoring, highlighting the need for calibration in future iterations.

The requirements analysis process was successful in translating user needs into functional system features, although some challenges

Below is a table highlighting the functional and non-functional requirements of the system as specified by the stakeholders.

Table 1.1 Functional Requirements

Category	Requirement	Description
Functional Requirements	Real-time Monitoring of Neonatal Vitals	Continuously collects and displays real-time vitals (heart rate, oxygen levels, temperature) from sensors attached to neonates
	Automated Alert System	Triggers alerts when vital sign thresholds are exceeded and sends notifications to nurses or other healthcare providers.
	Patient Record Management	Allows nurses to view, update and retrieve neonatal patient records, including health history and vitals.
	Data Logging	Logs all sensor readings and store them in the system for later analysis and review, including timestamps for every reading.
	Login and Authentication	Provides a secure login system to authenticate users (nurses, system admin) based on their roles, limiting access to critical features.

	Set and Modify Alert Parameters	Enable authorized users (e.g., system admin) to set and modify the alert thresholds based on the condition of the neonates.
	Generate Reports	Generate reports summarizing neonatal heath trends, alerts, and sensor data for analysis, presentation, or archiving.
	Sensor Management	Manages the connection and monitoring of sensors, including status checks for battery life, signal strength, and data accuracy.
	View Sensor Readings	Allows nurses and healthcare providers to access real-time sensor data for monitoring vitals.
	Manage Nurse Details	Enables system admins to manage nurse profiles, including adding, updating and removing
		nurse credentials and contact details.
	Record Patient Data	Nurse and healthcare providers can input, update, and track patient data including vitals and other relevant information.

Table 1.2 Non-Functional Requirements

Category	Requirement	Description

Non-Functional Requirements	Usability	The system will have an intuitive and user-friendly interface for nurses and healthcare providers, requiring minimal training for effective use.
	Performance	The system should display sensor data in real-time, with less than 2 seconds of latency between data collection and display.
	Reliability	The system must ensure continuous operation with at least 99.9% uptime, ensuring that vital monitoring continues without disruption.
	Scalability	The system should scale to support more sensors and neonates without performance degradation, making it suitable for larger neonatal units.
	Security	All data (including patient records and vitals) must be encrypted in transit and at rest to ensure patient confidentiality and comply with healthcare data regulations.

	Maintainability	The system should allow easy maintenance and updates without downtime, ensuring that nurses and staff can continue to monitor patients uninterrupted.
	Data Storage and Backup	The system must support efficient data storage with automated backups to prevent data loss and ensure data integrity, even in case of the system failures.
	Interoperability	The system should integrate easily with other hospital systems and healthcare devices, allowing for the exchange of patient data and seamless operation with different types of sensors.

5.0 SYSTEM DESIGN

The aim of this section is to provide a detailed description of the technical design and structure of the neonatal monitoring system. The primary objective of this system is to continuously monitor neonatal vitals in real-time, issue timely alerts when critical thresholds are crossed, and ensure that data is accessible to nurses and administrators for effective patient care. This section includes the architecture, main components, data flow, use cases, security and database design of the system.

5.1 Overview of the System Architecture

5.2.1 Block Diagram

The block diagram below provides a high-level overview of the key components of the neonatal monitoring system and their interactions:

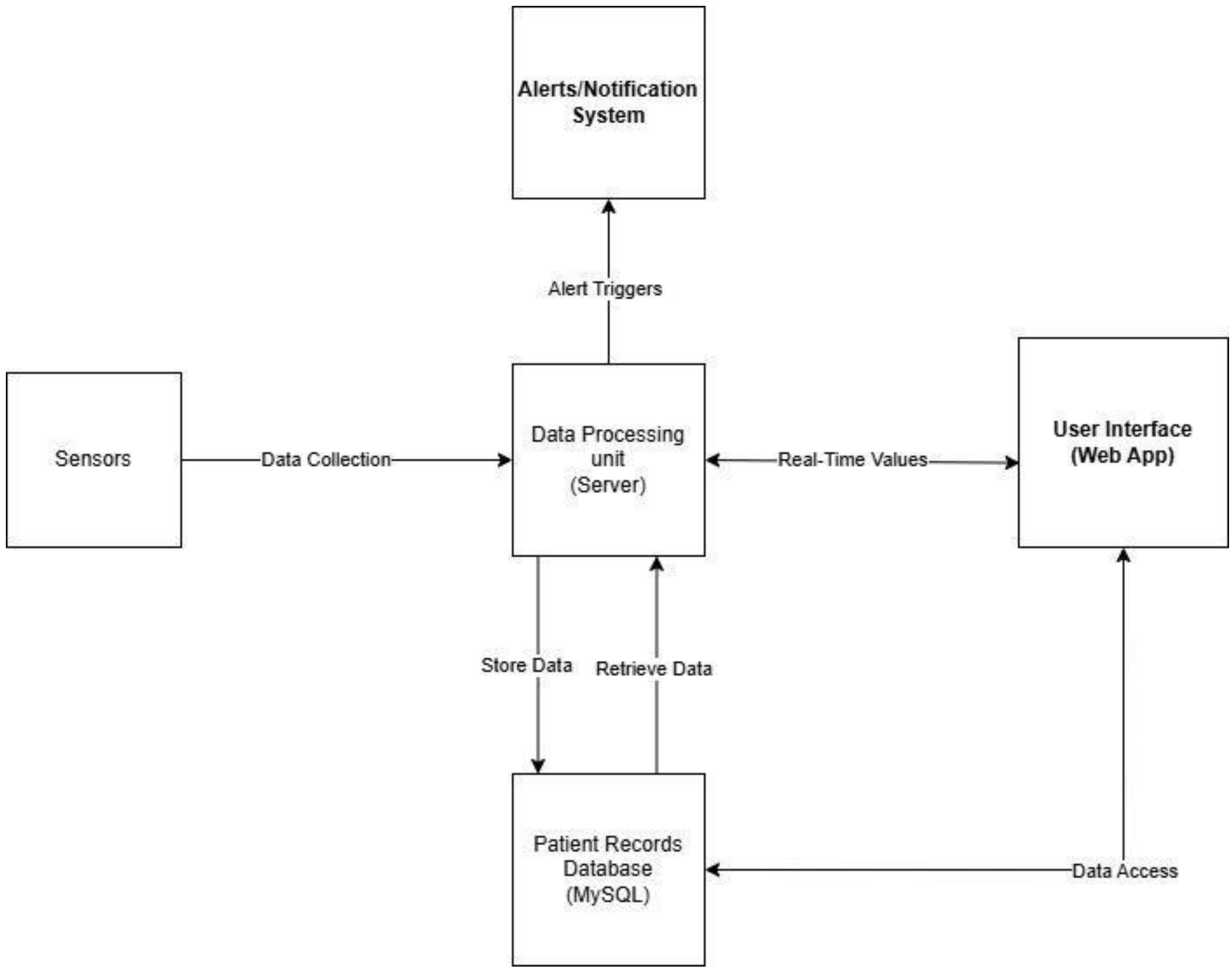

Figure 1: Shows an architecture of a neonatal monitoring inform of a block diagram.

Components:

- **Sensors:** Collect vitals such as heart rate, SpO2, temperature, and humidity.
- **Data processing unit (Server):** Receives data from sensor readings, and alerts, allowing for retrieval by the user interface.
- **Alerts/Notification System:** Monitors the data for critical thresholds and triggers alerts to the nurses' user interface when necessary.
- **User Interface:** Provides a graphical interface for nurses and administrators to view real-time vitals, alerts, and historical data.

Data Flow:

- The Sensors collect data and send it to the Data processing Unit.

- The Data Processing Unit process this data and stores it in the Patient Records Database.
- The Alerts/Notification System monitors data for abnormal values and triggers alerts to the User Interface if thresholds are crossed.
- Nurses and administrators access the User Interface to monitor patients in real-time and retrieve stored records.

Key System Components

Sensors

The neonatal monitoring system uses various sensors to measure essential neonatal vitals, including heart rate, SpO2, temperature, and humidity. These sensors continuously collect data and transmit it to the data processing unit via **I2C (Interintegrated circuit)** or **SPI (Serial peripheral Interface)** communication protocols, depending on the sensor type. The data collection frequency is set to ensure timely updates without overwhelming the system.

Data Processing Unit (Server)

The data processing unit acts as the system's central hub, receiving data from all connected sensors. This unit validates and processes the data to ensure accuracy and format consistency. Once processed, the data is stored in the patient records database for long-term storage and retrieval. The server also interfaces with the alerts/notification system to check incoming data against predefined thresholds.

Patient Records Database

The patient records database stores all sensor readings, patent demographics, and timestamps. This relational database is designed with structured tables and relationships to ensure data integrity and quick retrieval. Each patient's records are uniquely linked by identifiers, facilitating easy lookup and monitoring of historical data.

Alerts/Notification System

The alerts/notification system is responsible for monitoring data in real time and triggering alerts with vital signs exceed or fall below specified thresholds. The notifications are sent to the user interface, alerting nurses to take immediate action if necessary. Alerts are designed to be context-sensitive and include different alert types, such as visual or auditory notifications, depending on the system configuration.

User Interface (Nurses and Admin)

The user interface provides a dashboard for nurses and administrators, allowing them to monitor patient vitals, view alert notifications, and access historical data. Nurses use the interface to view real-time data for each patient, while administrators have additional controls for managing user accounts, setting threshold parameters, and generating reports. The interface includes sections for patient selection. Real-time monitoring, and access to patient records.

5.3 System Interactions and Data Flow

5.3.1 Data Flow Diagram

Level 0 DFD

The Level 0 DFD shows the high-level overview of system's major processes and data flows. It shows how data flows between sensors, the data processing unit, the patient records database, the alert system, and the user interface.

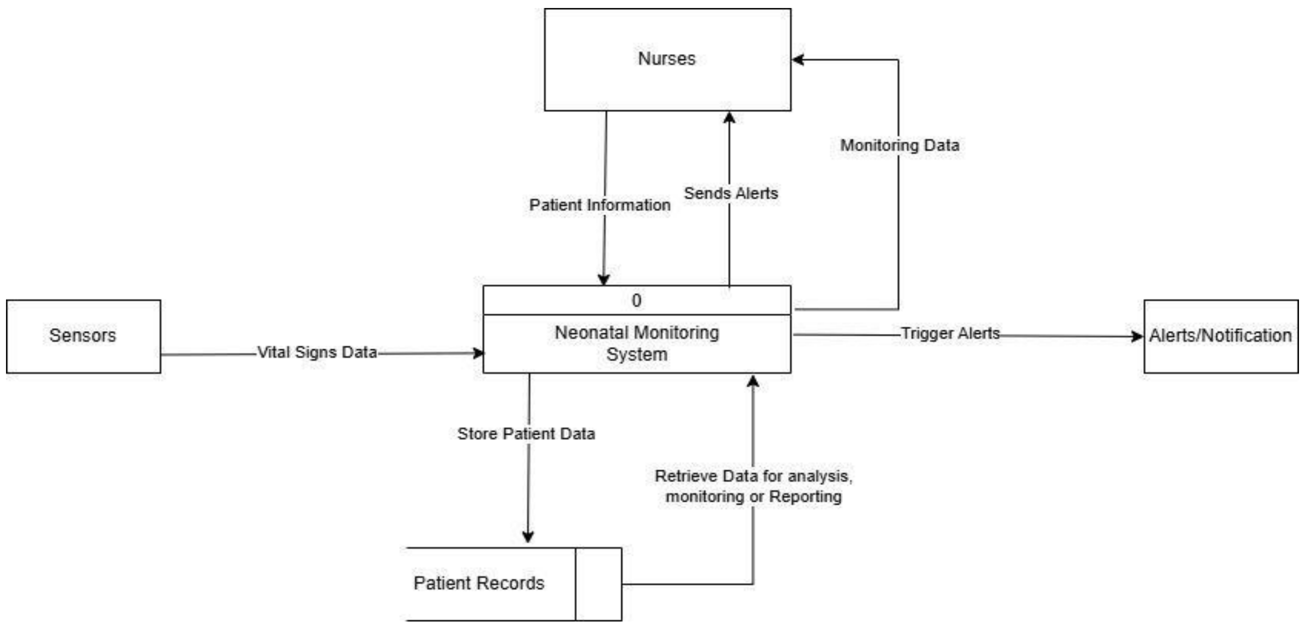

Figure 2: Shows a Level 0 (High level overview) DFD of the system, showing all the necessary data flows.

Level 1 DFD

Level 1 DFD provide a detailed view of specific processes. In level 1, data flow between the sensors and the data processing unit is broken down into data collection and validation steps.

Level 1 DFD

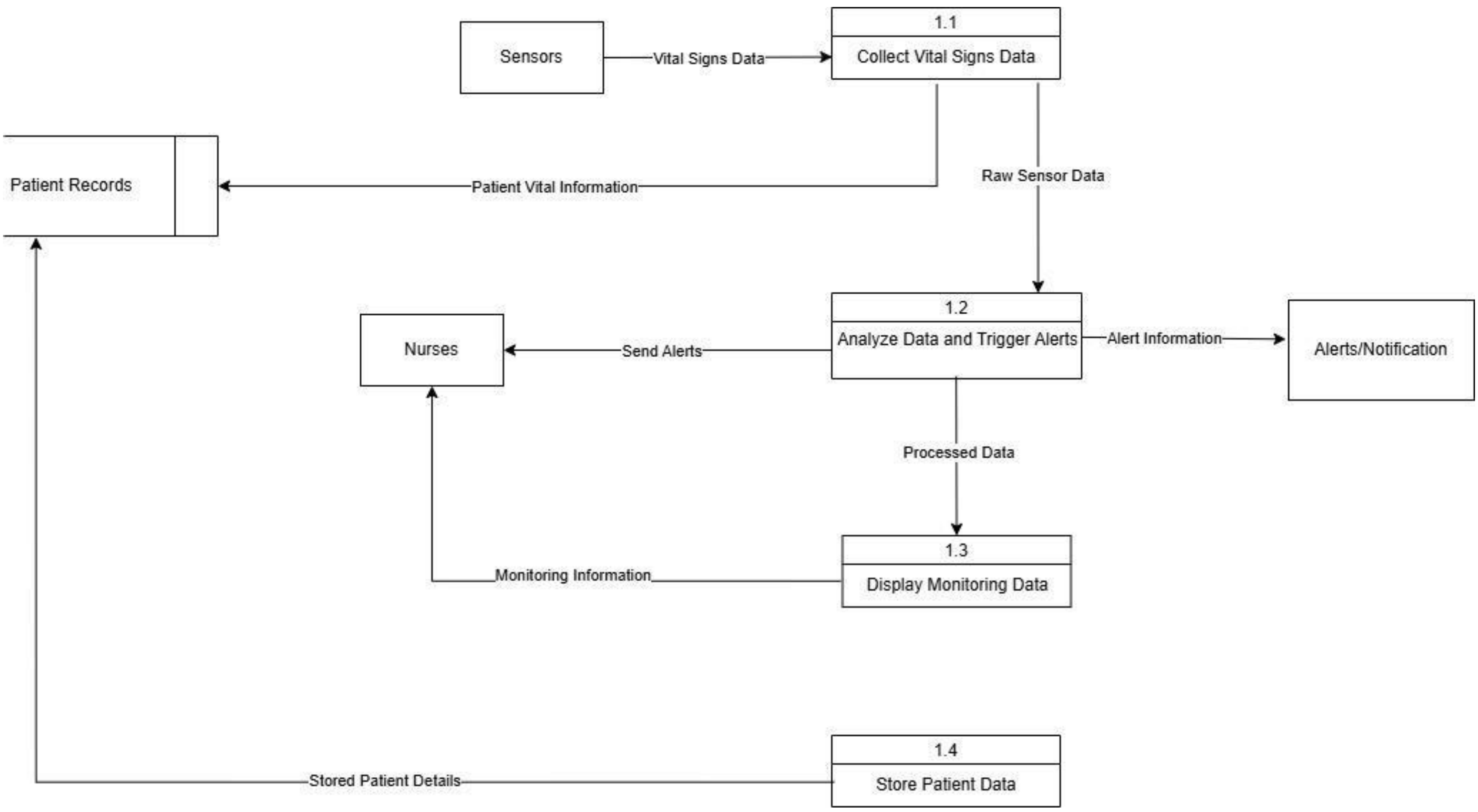

Figure 3: Shows a detailed overview of the system in form of a level 1 DFD.

Description of Data Flow:

- Sensors collect data and send it to the data processing unit.
- The data processing unit processes and stores the data in the patient records database.
- The alerts/notification system continuously monitors the data, checking against threshold limits.
- If an alert is triggered, the notification is sent to the user interface, where nurses and administrators can view and respond to it.
- The user interface also retrieves historical data from the database for review and analysis.

5.4 System Use Cases

5.4.1 Use Case Diagram

The use cases diagram represents the primary interactions between the system's actors, including Nurse, Admin, Sensors, Alerts/Notification System, and Patient Records Database.

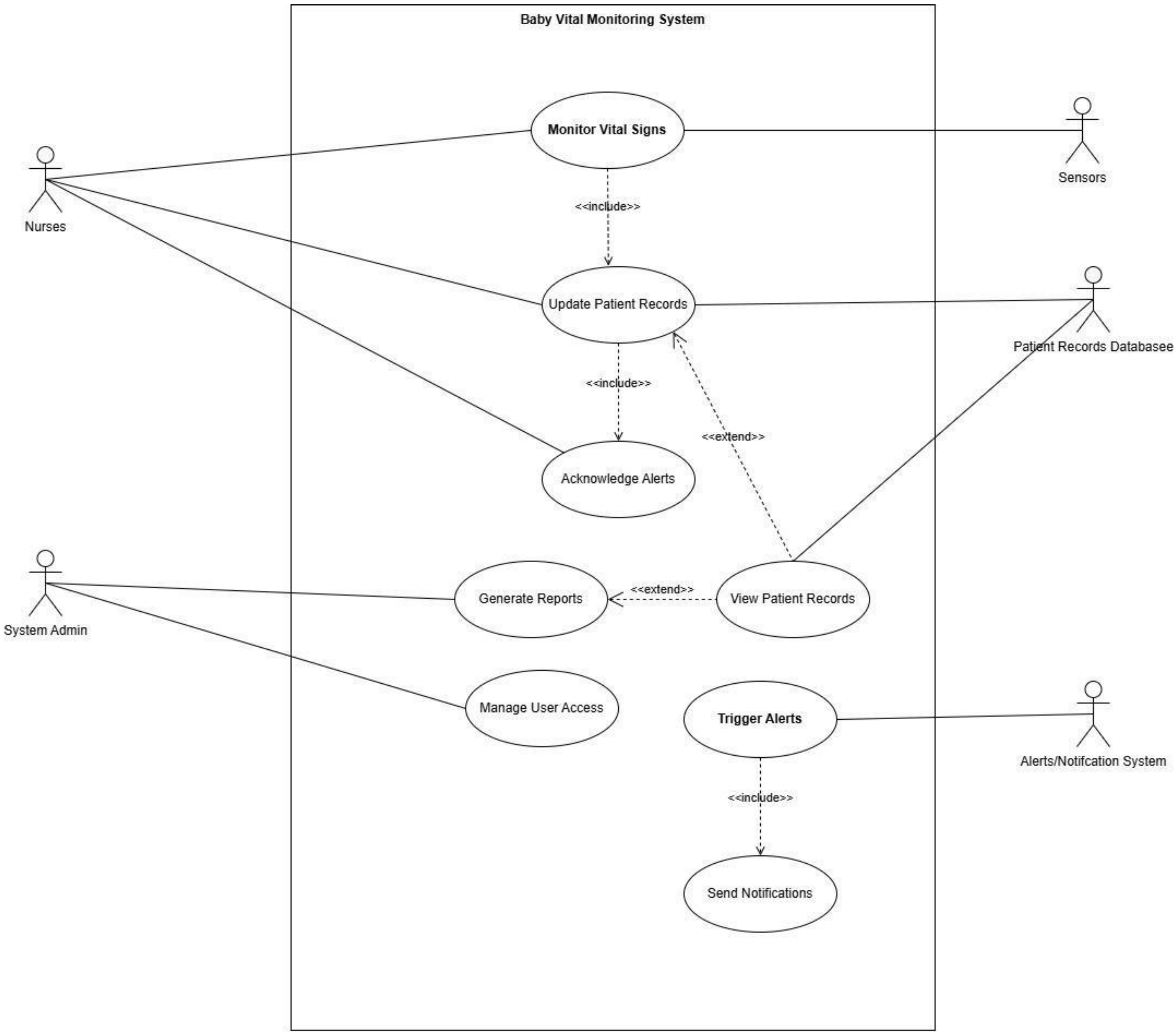

Figure 4: Shows a use case diagram that shows how users are interacting with the system.

Detailed Use Case Description

1. **Monitor Vital Signs (Nurse):**
    - Actors: Nurse, Sensors
    - Preconditions: Nurses is logged in; patient records are available.

- Steps include that the Nurse has to log into the system and the system retrieves data from the sensors and displays it on the interface.
- Postconditions: Nurse views the patient’s current vital.

2. **Alert/Notify Nurse:**
    - Actors: Alerts/Notification System, Nurse
    - Steps involve the system detecting any abnormalities as well as alerts being generated and displayed on the nurse’s dashboard.
    - Extend Relationship: Alerts include extended types (visual, sound) for severity levels.

3. **Manage Nurse Details (Admin):**
    - Actors: Admin
    - Include Relationship: Authentication is included as part of the process.

4. **Generate Reports (Admin):**
    - Actors: Admin
    - Steps include the admin designing a customized report and the system retrieves data and compiles a report based upon the alert.

5.4 Conceptual, Logical Model of the System

The Conceptual Model represents a high-level view of the Neonatal Monitoring System. It is designed to capture and understand the critical entities in the system and their relationships. The purpose of this model is to outline the fundamental components of the system in a way that is clear and intuitive, providing insight into how different parts of the system interact with each other.

Below is the diagram of the conceptual model of the system;

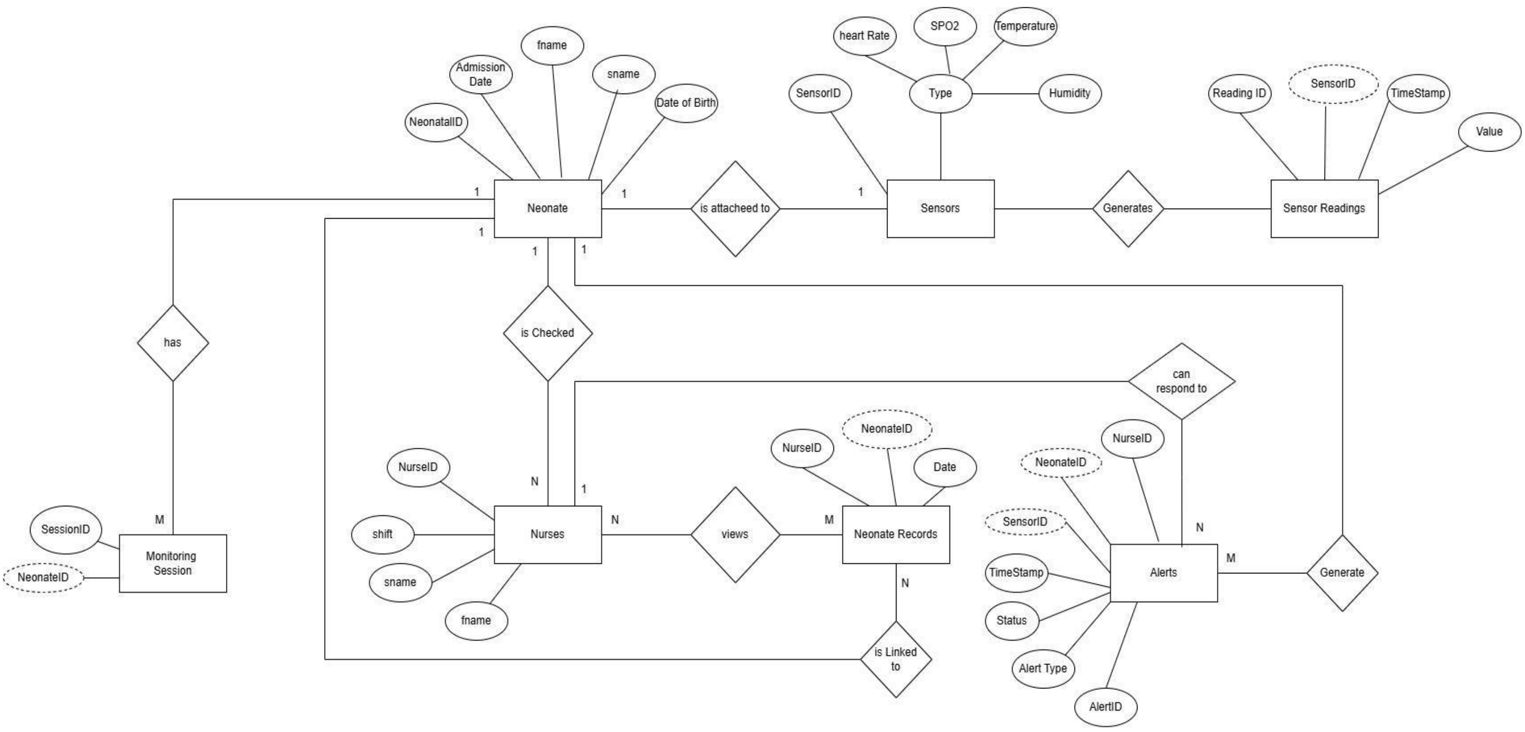

Figure 5: Shows a conceptual overview using ER model of the system.

The ER Model for this system includes the following main entities:

1. **Neonate**: Represents each newborn under monitoring, identified by a unique NeonateID. A neonate has basic attributes like first name, surname, date of birth, and admission date. Each neonate can have multiple Monitoring Sessions and is connected to various Sensors to measure vitals.

2. **Sensors:** These devices are attached to each neonate to collect vital information such as heart rate, oxygen saturation (Sp02), temperature and humidity. Each sensor has a unique SensorID and records different types of data. Sensors generate Sensor Readings that reflect the neonate’s current condition.

3. **Sensor Readings:** These are data entries produced by sensors, containing values for each type of reading (e.g., heart rate, temperature) along with a

timestamp. Each reading is associated with a specific SensorID, making it easy to trace data back to the sensor that generated it.

4. **Nurses:** Medical staff responsible for monitoring neonates. Each nurse is identified by a NurseID and has attributes like first name, surname, and shift. Nurses have access to Neonate Records and can respond to Alerts when necessary.

5. **Neonate Records:** These records capture a neonate’s health and monitoring details overtime. Each record is linked to a specific neonate, nurse, and date, enabling easy tracking of the neonate’s progress and carehistory.

6. **Monitoring Session:** Represents each instance of neonate observation, uniquely identified by a SessionID. Each session is connected to a neonate and documents periods of continuous monitoring.

7. **Alerts:** Notifications generated by abnormal sensor readings, such as high or low vitals. Each alert has an AlertID and is associated with a specific neonate, nurse, sensor, timestamp and alert type. Nurses can respond to alerts to ensure time intervention.

Below is the ERD that is representing the logical model of the system which now shows the cardinalities between the entities.

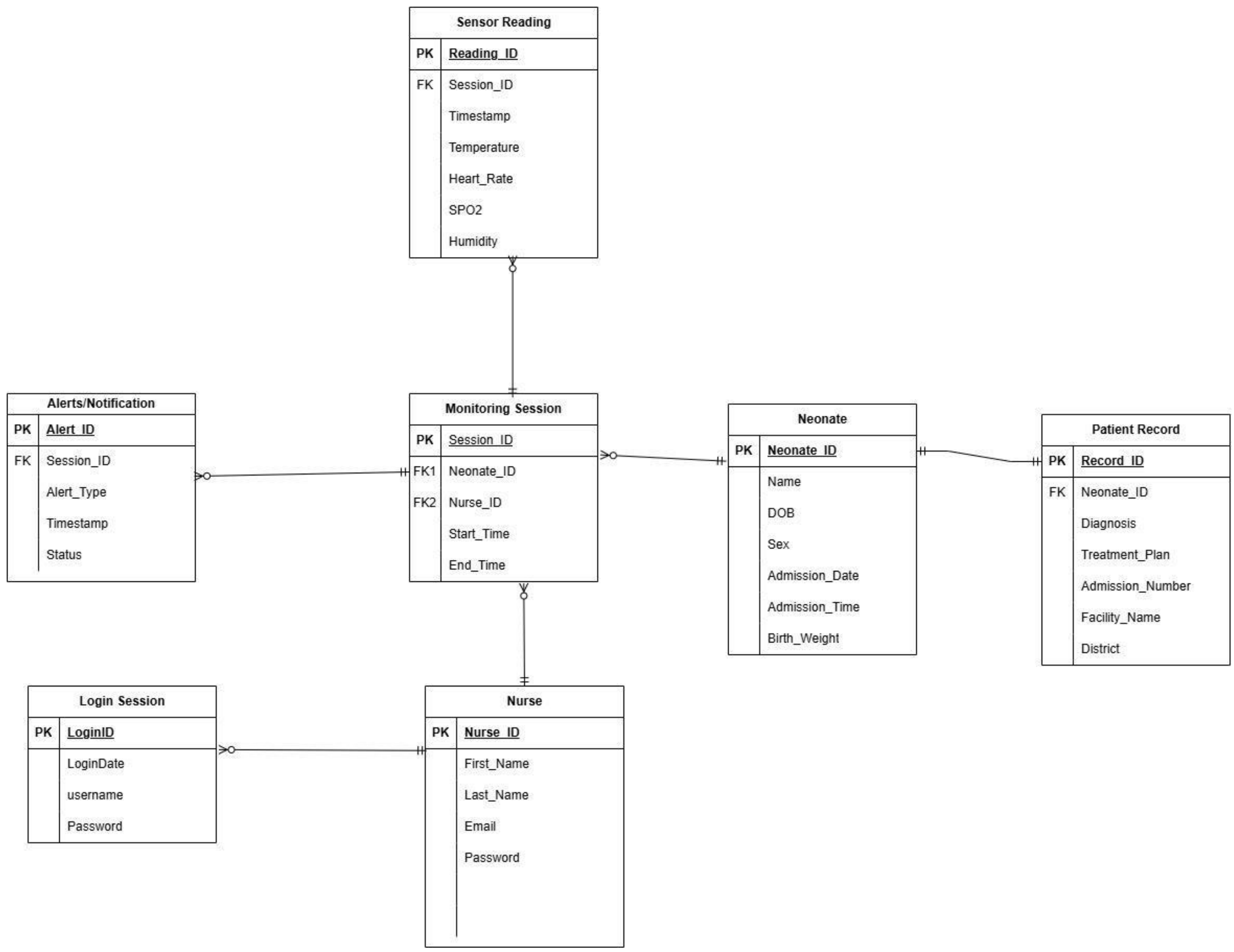

Figure 6: Shows an Entity Relationship Diagram (ERD) of system's database.

Here is brief explanation of following Entities of ERD above;

1. **Neonate:** Stores information about each newborn admitted at the chatinkha ward.
2. **Patient Record:** Contains additional details related to the neonate's medical information, such as **Diagnosis, Treatment_Plan, Admission_Number, Facility_Name,** and **District**. It is linked to the Neonate and Nurse entities through foreign keys (Neonate_ID and Nurse_ID).
3. **Monitoring Session:** Symbolizes each session in which a neonate's vitals are monitored. It includes **Session_ID (Primary Key)**, **Start_Time,** and it is linked

to the Neonate and Nurse entities through foreign keys (**Neonate_ID** and **Nurse_ID**).

4. **Nurse:** Stores nurse information, including **Nurse_ID(Primary_key), First_Name, Last_Name** and **Email.** Nurses are responsible for overseeing monitoring sessions.
5. **Login Session:** Tracks each nurse's login activity, with fields like **LoginID (Primary key), LoginDate, username** and **Password**. This is connected to the Nurse table to verify login credentials.
6. **Sensor Reading:** Records various vital signs for each monitoring session, including **Temperature, Heart_Rate, SpO2,** and **Humidty.** It has a foreign key link to **Monitoring Session** through **Session_ID.**
7. **Alerts/Notification:** Manages system alerts with details like **Alert_ID (Primary Key), Alert_Type, Timestamp,** and **Status.**It is linked to the **Monitoring Session** table to track alert specific to a session.

6.0 PROTOTYPING AND TESTING

This section is going to describe how the prototype was developed and tested. It will provide an overview of the tools used, the methods that were taken and finally the processes used to create a functional model, along with the evaluation conducted to ensure that it meets the project's objectives.

6.1 Prototype Development

The purpose of the prototype is to demonstrate the core workings of the proposed system and validate its capabilities in a real-world setting. This prototype includes key features such as sensor integration, data collection, user interface display, and data storage, which collectively simulate the final system.

Tools and Technologies used

The prototype was developed using a combination of hardware and software tools;

- **Hardware:** Esp32 Microcontroller as the data processing unit, sensors (such as max30100 for heart rate and SPO2, and max30914x and dht22 for temperature and humidity).

- **Software:** Programming languages like C++ for the hardware and JavaScript inform of node JS for the web application and PHP for the backend integration.
  • **Development Platform:** IDEs and development tools, such as Arduino IDE and visual studio code.

Challenges and Solutions

During development, challenges such as sensor calibration and data accuracy were encountered. These issues were addressed by recalibrating sensor and optimizing the data processing code to improve accuracy.

Prototype Versions and Improvements

Few versions of the prototype were developed. Each iteration introduced adjustments based on the feedback from testing, such as refining the user interface or adjusting sensor placement for more accurate readings.

6.2 Prototype Testing

Testing aimed to ensure the prototype met functional requirements providing accurate data collection and user-friendly experience.

Testing Objectives

The main of tests were to ensure;

- **Accuracy of sensor Readings:** Verifying that the prototype could reliably measure and display correct data from each sensor.
- **System Integration:** Ensuring that all components functioned smoothly together.
- **User Usability:** Evaluating the ease of use for end-users and gathering feedback to improve the interface.

Results

The prototype worked as expected and it met its performance objectives, providing close to accurate data for some sensors and other sensors inaccurate and it also managed to achieve an easily accessible user interface. Testing confirmed that each component operated smoothly, and the system was able to display real-time data reliably. User feedback was positive, with suggestions for minor adjustments to improve usability.

Following testing, several improvements were made, including adjusting sensor calibration in order to improve some of the sensor’s accuracy, enhancing interface clarity, and refining the data display format. These changes optimized the prototype’s performance and user experience.

7.0 CONCLUSION

To conclude, the project has proven to be successful and it demonstrated the potential to become a solution that can actually solve the identified problem. Through careful research, design and testing, a functional prototype was developed incorporating the essential features such as real-time data collection, display, and storage. The testing phase validated the prototype’s effectiveness in capturing accurate a sensor data and providing a user-friendly interface. Feedback from users and iterative testing enabled continuous improvement, ensuring the system met its intended objectives.

The development process highlighted both the challenges and solutions involved in creating a system that integrates multiple hardware and software components. Issues like sensor calibration and interface usability were resolved through recalibration and interface adjustments, improving overall accuracy and ease of use.

Overall, this project provided valuable insights into the feasibility and practicality of implementing a solution using a prototype, laying a strong foundation for further development. This experience emphasizes the importance of iterative design, user feedback, rigorous testing in creating effective, user-centered technological solutions.

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APPENDIX

Informed Consent Form for Participation in Research Study

Project Title:
Development of an IoT-Based Monitoring System for Neonates in Hospitals: Case of Chatinkha Nursery Unit

Researcher:
Nyasha Mpinda
Malawi University of business and applied sciences (MUBAS)
+265(0) 998 790 208

Purpose of the Study

You are being invited to participate in a research study aimed at developing a prototype of an IoT-based neonatal monitoring system. The system is intended to help improve the accuracy and efficiency of monitoring vital signs (e.g. heart rate, oxygen levels, temperature etc) in neonates within the Chatinkha Nursery Unit at Queen Elizabeth Central Hospital. Your valuable input and feedback as a healthcare provider will help me better understand the current monitoring practices and identify ways to enhance neonatal care through the use of digital technologies.

Note: The developed prototype will not actually be tested on the actual babies at the ward.

Why You Are Being Asked to Participate

You are being asked to participate because of your experience and involvement in neonatal care. Your feedback will contribute to understanding the current challenges in neonatal monitoring and how the proposed IoT system could be integrated into the hospital's workflow.

Participation Involves

If you agree to participate in this study, you will be asked to:

Take part in semi-structured interviews or fill out a questionnaire regarding your experiences with the current neonatal monitoring system and your expectations for the proposed IoT-based system.

Allow the researcher to observe your normal routine in the neonatal ward to gain insight into current practices.

Provide feedback on the usability and functionality of the prototype IoT system based on simulated data.

Participation will take approximately 10-15 minutes of your time for the interviews or questionnaires. Observations will be conducted without interfering with your workflow.

Voluntary Participation

Your participation in this study is entirely voluntary. You have the right to refuse to participate or withdraw from the study at any time, without any consequences or affecting your role at the hospital.

Confidentiality and Anonymity

All data collected will remain confidential. Your identity will not be revealed in any reports or publications resulting from this study. Any personal identifiers will be removed, and your responses will be reported in aggregate form to ensure anonymity. The data will be securely stored and only accessed by the researcher.

Potential Risks and Benefits

There are no known risks associated with participation in this study. The benefit of your participation is the potential improvement in neonatal care through the development of a more efficient monitoring system. Your feedback may help shape a system that reduces nurse workload and improves patient care.

Questions and Contact Information

If you have any questions or concerns about this research, you may contact me at: email: **bit20-nmpinda@mubas.ac.mw** or nyasha20mpinda@gmail.com phone: +265(0) 998 790 208

You may also contact my supervisor at rbanda@mubas.ac.mw

Consent

By signing this form, you acknowledge that you understand the nature of the study, your rights as a participant, and you voluntarily agree to participate in this research.

Participant Name : ____

Signature of Participant: ____

Date: ____

Researcher Signature: ____

Date: ____

Thank you ....

Questionnaire for Data Collection

Closed-Ended Questions (Multiple Choice, Yes/No, Likert Scale)

1. Demographic Information

What is your role in the Chatinkha Nursery Unit?

a) Nurse

b) Doctor

c) Technician

d) Administrator

e) Other (please specify)

How many years of experience do you have in neonatal care?

a) Less than 1 year

b) 1-3 years

c) 4-6 years

d) More than 6 years

2. Current Monitoring System

How effective do you find the current paper-based monitoring system?

a) Very effective

b) Effective

c) Neutral

d) Ineffective

e) Very ineffective

How often do you encounter inconsistencies or errors in the current system? a)

Always

b) Often

c) Sometimes

d) Rarely

e) Never

How reliable is the current system in terms of data accuracy and integrity? a)

Very reliable

b) Reliable

c) Neutral

d) Unreliable

e) Very unreliable

3. Challenges and Efficiency

How often do you experience challenges related to inadequate infrastructure and resources at the Chatinkha Nursery Unit?

a) Always

b) Often

c) Sometimes

d) Rarely

e) Never

How would you rate the overall efficiency of nurses in managing neonatal care with the current system?

a) Very efficient

b) Efficient

c) Neutral

d) Inefficient

e) Very inefficient

How significant is the impact of heavy workload on the performance of nurses?

a) Very significant

b) Significant

c) Neutral

d) Insignificant

e) Very insignificant

4. Perception of IoT-based Monitoring System

Do you believe an IoT-based monitoring system could improve neonatal care? a)

Yes

b) No

c) Unsure

How important is real-time monitoring of neonatal vital signs to you?

a) Very important

b) Important

c) Neutral

d) Unimportant

e) Very unimportant

5. Implementation and Usability

How user-friendly do you expect the IoT-based monitoring system to be?

a) Very user-friendly

b) User-friendly

c) Neutral

d) Not user-friendly

e) Very not user-friendly

How confident are you in using new technology for neonatal monitoring?

a) Very confident

b) Confident

c) Neutral

d) Not confident

e) Very not confident

Open-Ended Questions (Structured Questions)

What are the main challenges you face with the current paper-based monitoring system?

How do you think an IoT-based monitoring system could address these challenges?

What features would you consider essential in an IoT-based neonatal monitoring system?

How would you suggest the system handle cases where a sensor fails or provides inaccurate readings?

In what ways do you think the new system could support the workload and efficiency of healthcare providers?

What concerns do you have about the implementation of an IoT-based monitoring system in the Chatinkha Nursery Unit?

How do you think the new system could improve data accuracy and integrity in neonatal care?

Can you provide any specific examples or scenarios where real-time monitoring could have made a significant difference in neonatal care?

How do you envision the training process for the staff to use the new monitoring system effectively?

What additional support or resources would you need to ensure the successful adoption of the new system?

What general problems do you face in the Chatinkha Nursery Unit that affect neonatal care?

How do you think these problems could be resolved with better monitoring and technological solutions?

How does the workload and current monitoring system impact your ability to provide quality care?

Instructions for Respondents

Please answer all questions honestly and to the best of your knowledge.

For multiple-choice questions, select the option that best represents your view or experience.

For open-ended questions, provide detailed responses to help us understand your perspective.

This questionnaire will help gather valuable insights into the current challenges and expectations for the new IoT-based neonatal monitoring system, ensuring that the system meets the needs of healthcare providers and improves neonatal care at the Chatinkha Nursery Unit.

End of Questions

Interview Questions for Data Collection

Closed-Ended Questions:

1. How long have you been working at the Chatinkha Nursery Ward?

   - Less than 1 year
   - 1-3 years - 4-6 years
   - More than 6 years

2. How often do you monitor the vital signs of neonates?

   - Every 30 minutes
   - Every hour
   - Every 2-3 hours
   - As needed

3. Are you familiar with the current monitoring systems used in hospitals?

   - Yes - No

4. Do you believe a digital monitoring system could improve your workflow?

   - Yes - No

5. How often do you encounter technical difficulties with monitoring equipment?

   - Rarely
   - Sometimes
   - Often

- Always

6. Do you feel that current monitoring methods provide timely and accurate data?

    - Strongly Agree
    - Agree
    - Neutral
    - Disagree
    - Strongly Disagree

7. Would you be willing to adopt a new system if it improved patient care?

    - Yes
    - No

Open-Ended Questions:

1. Can you describe a typical day at the Chatinkha Nursery Ward in terms of patient monitoring?

    - Follow-up: What challenges do you face during this process?

2. What are the most critical challenges you encounter when monitoring neonates?

    - Follow-up: How do these challenges impact patient care?

3. How do you think technology could help in overcoming the challenges you face in neonatal care?

    - Follow-up: Are there specific features you believe would be beneficial in a monitoring system?

4. Can you share an experience where the current monitoring methods were inadequate or failed?

    - Follow-up: How was the situation managed, and what could have improved the outcome?

5. What are your concerns about implementing a new digital monitoring system in the ward?

   - Follow-up: How can these concerns be addressed?

6. In your opinion, what are the essential features that a monitoring system should have to support your work effectively?

   - Follow-up: How would these features improve your daily tasks?

7. How do you ensure that the vital signs data you collect is accurate and timely?

   - Follow-up: What methods do you currently use to verify this data?

8. What would be your preferred method for receiving training on a new system?

   - Follow-up: How do you think the training process could be made more effective?

General Questions on Efficiency and Challenges:

1. How do you think the current monitoring system affects the overall efficiency of the ward?

   - Follow-up: Are there any specific areas where efficiency could be improved?

2. What do you believe are the most significant challenges in neonatal care at Chatinkha Nursery Ward?

   - Follow-up: How do you think these challenges can be mitigated?

3. Do you feel that the workload is evenly distributed among the staff during a shift?

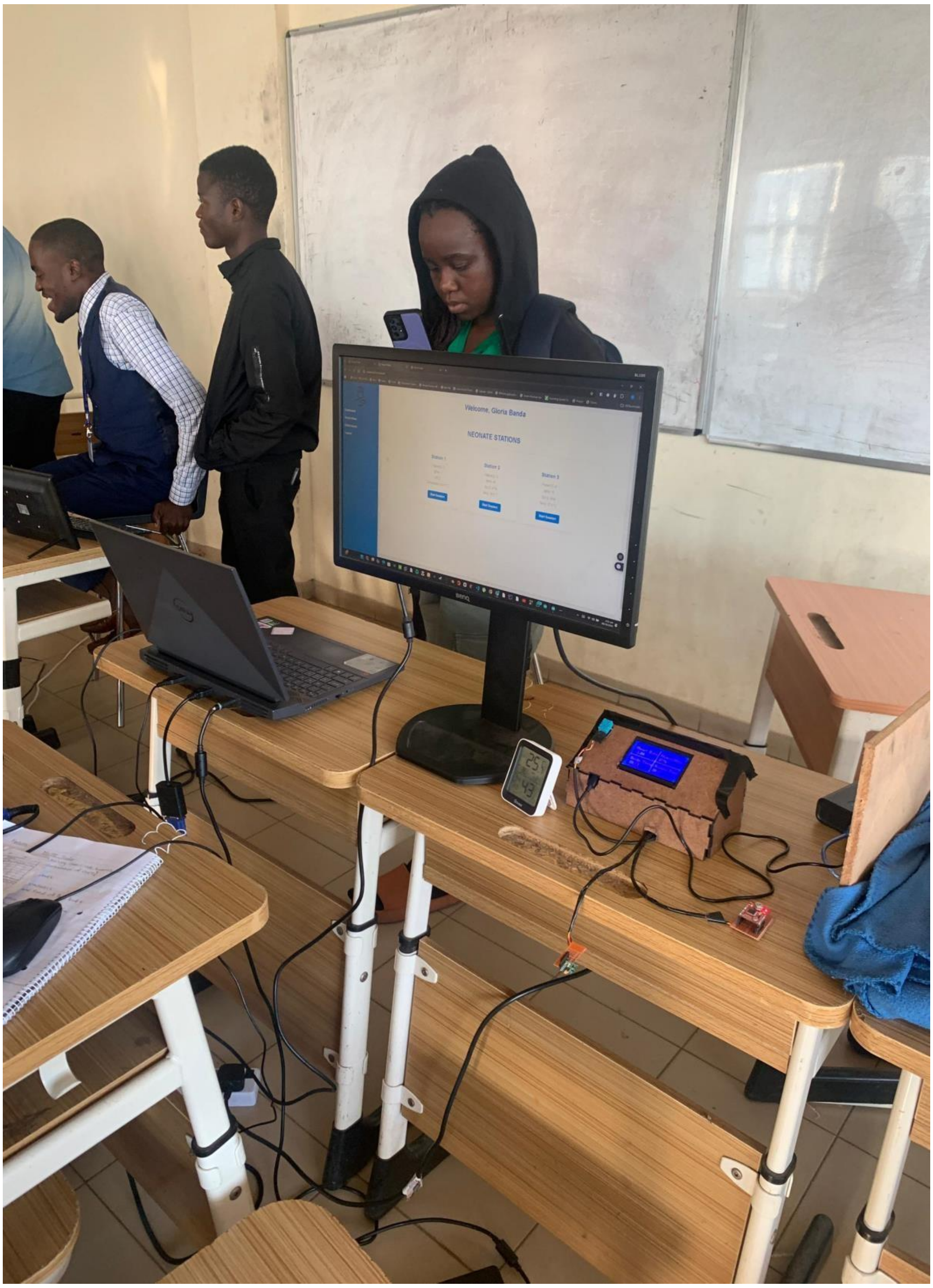
   - Follow-up: How could technology assist in balancing this workload?

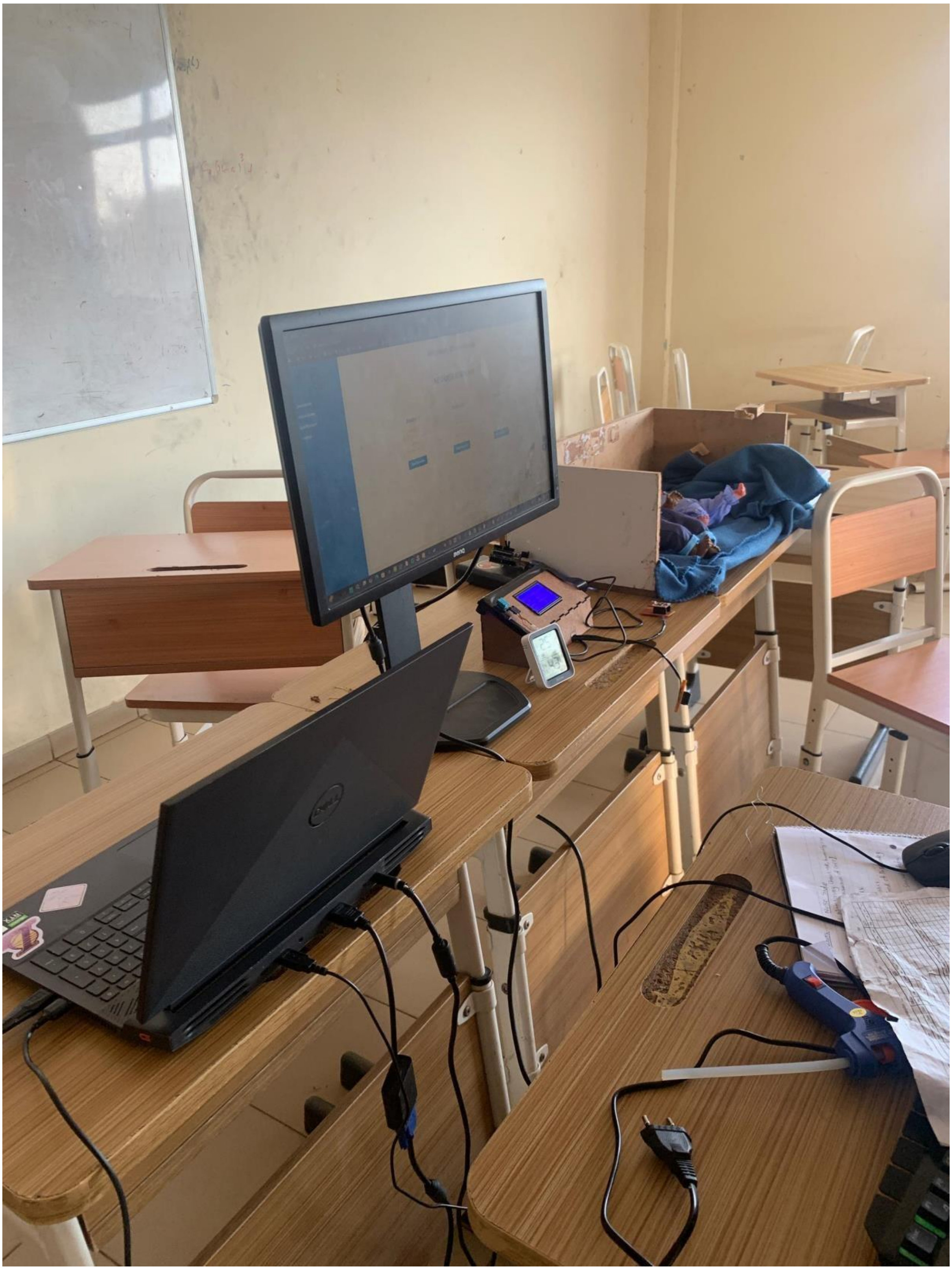
4. How often do you collaborate with other healthcare professionals regarding neonatal monitoring?

   - Follow-up: What tools or systems do you currently use to communicate and share data?

End of Questions ....

PROTOTYPE DEMONSTRATION






Welcome, Gloria Banda
NEONATE STATIONS
Station 1
Station 2
Station 3