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Design of Wireless Sensor System for Neonatal Monitoring

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Abstract

A vital effort to improve care quality and outcomes for newborn babies is the development of wireless sensor systems for neonatal monitoring. We showcase the use of wireless sensor technology and its inherent benefits for newborn care and monitoring in newborn Intensive Care Units (NICUs) in this study. The proper transmission, detection, and presentation of data are our goals in creating this prototype system. A smart neonatal jacket created at TU/e is one example of a non-invasive monitoring platform that might benefit from the wireless system's architecture. The smart jacket with textile electrodes can transmit ECG data wirelessly, as shown in the experiments. Modern sensor technology has brought about a sea change in newborn monitoring with the introduction of wearable form factors and photoplethysmography (PPG) sensors, which provide patients with high-fidelity data in an easy-to-understand format.

Keywords: Neonatal, Wireless transmission, Hospital, Jacket, Monitoring

I.Introduction

To ensure the safety of the most defenseless group of people—newborn babies—the development of a wireless sensor network for neonatal monitoring is an important area where medical science and engineering are coming together. Continuous monitoring of newborns' vital signs and physiological parameters is of the utmost importance in clinical settings for neonatal monitoring. This allows for prompt interventions to reduce risks and provide optimum care by providing crucial insights into the neonates' health condition. To create a smooth and efficient monitoring solution, the design of such a system must painstakingly include state-of-the-art sensor technologies, wireless communication protocols, algorithms for processing data, and ergonomic considerations. In order to determine a newborn's health state, it is essential that important physiological indicators be recorded and analyzed precisely using a neonatal monitoring system. Typical examples of such measures include pulse rate, respiration rate, temperature, SpO_2, and, on rare occasions, blood pressure. It is critical to keep an eye on these vital signs in order to spot any irregularities or warning indications like apnea, bradycardia, hypoxemia, or hyperthermia. These might be symptoms of more serious health problems that need medical attention right away. Therefore, in order to identify abnormalities in a timely manner, it is essential that these physiological measures be designed with a wireless sensor system that prioritizes accuracy, dependability, and the capacity to monitor in real-time.

With so many sensitive factors to consider while developing a wireless sensor system for newborn monitoring, one of the biggest obstacles is guaranteeing reliable and accurate data collection. Neonates need specific sensor technologies that can accommodate their unique physiological traits, including as smaller anatomical features, fast physiological changes, and heightened vulnerability to external effects. For example, in order to keep constant and precise readings without irritating or harming the delicate newborn skin, sensors should not be invasive, pleasant, or minimally obtrusive. In order to guarantee continuous monitoring and data integrity, it is

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necessary to carefully handle the extra issues that arise from the wireless nature of the system, such as signal interference, power consumption, and data transfer dependability.

Recent developments in sensor technology have changed newborn monitoring forever, opening the door to new sensor modalities that may provide non-invasive, high-fidelity physiological data. Because of its great precision in recording vital signs including heart rate and SpO2, as well as their non-invasive nature, photoplethysmography (PPG) sensors have become an essential part of newborn monitoring equipment. The use of non-invasive probes to detect body temperature is another way that temperature sensors based on thermistors or infrared technologies improve patient safety and comfort. Wearable sensor technology has also advanced to the point where several sensors may be integrated into small, portable forms, enabling continuous monitoring without restricting the movement of neonates or causing them pain.

Wireless newborn monitoring system designs should take sensor technologies and the selection of suitable wireless communication protocols for dependable data transmission and connection into account. Medical monitoring systems often use wireless protocols such as Wi-Fi, Zigbee, Bluetooth Low Energy (BLE), and cellular networks. These protocols have different benefits and drawbacks in terms of range, battery consumption, data rate, and compatibility. The best wireless protocol to utilize is contingent upon a number of criteria, including the scenario at hand, the surrounding environment, power limitations, and any applicable regulations. Wearable medical devices, for example, have benefited from Bluetooth Low Energy's (BLE) low battery consumption, low latency, and extensive connectivity with cellphones and other consumer devices, all of which provide easy data integration and remote monitoring. On the other hand, Zigbee is well-suited for large-scale deployments in clinical settings because to its increased range and scalability, which allows several monitoring devices to connect with a centralized monitoring station.

Additionally, it is essential that wireless neonatal monitoring systems have strong data processing algorithms built in. These algorithms should be able to analyze the massive volumes of physiological data produced by the sensors in real-time, draw meaningful conclusions, and notify healthcare providers of any crucial events or abnormal trends. Understanding intricate physiological signals, recognizing patterns that may indicate negative occurrences, and creating timely alarms or warnings to initiate action are all tasks that are greatly assisted by machine learning algorithms, signal processing methods, and pattern recognition algorithms. Remote monitoring, trend analysis, and predictive analytics may help foresee and avoid future health concerns in neonates. This is made possible by the integration of cloud-based data analytics systems, which allows the aggregation of data from different monitoring devices.

Because the device's comfort and ease of use have a direct bearing on its adoption and efficacy in clinical settings, ergonomics and user experience are also major factors to be considered when designing a wireless neonatal monitoring system. To make the monitoring device easy to use for healthcare practitioners and caregivers, optimize its form factor, size, weight, and interface design. This will guarantee that the device can be seamlessly integrated into current workflows without hampering patient care. Healthcare practitioners are empowered with actionable information and may enable prompt interventions to improve newborn outcomes thanks to the system's adjustable alarm settings, remote monitoring capabilities, and intuitive user interfaces.

II.Review Of Literature

In the present work, a special monitoring system is designed to take care the health condition of the Infants. An Arduino Uno board is used in implementing the work. An Arduino board is inter-faced with the GSR sensor, MQ135 sensor, Pulse rate sensor and AM2315 sensor. The emotions of the Infant are identified by the GSR sensor, CO gas & smoke concentrations are recorded and analyzed using MQ135 sensor. The heartbeat of the infant is ontinuously recorded and monitored using pulse rate sensor. The temperature and the moisture content are monitored using AM2315 sensor. The alert message is sent to the doctors and parent whenever infant condition is identified as abnormal.

Ingale, Aniket et al., (2021) Parents who are always on the go may still keep an eye on their little ones with the help of this paper's baby monitoring system. Therefore, we need to come up with a novel solution that can assist parents in keeping an eye on their baby and alert them when necessary. Because of this, we have decided to develop an Internet of Things (IoT) smart baby monitoring system to assist parents in keeping tabs on their newborn. Various technologies are used, such as Raspberry Pi and other Internet of Things (IoT) modules, temperature and humidity sensors, a cry detector, and live video monitoring. Live video of the baby's cradle position, temperature, and the sound of his or her cries are all within our capabilities. Any parent, from anywhere in the world, may keep tabs on their child at all times with the live streaming of their location and activity shown on their computer browser. The swinging mechanism of the cradle can be activated when the baby cries, the fan can be switched on or off in response to an increase in temperature, the camera can be turned on to record live video, and the music system may be set to play music whenever the baby cries.

Vk, Karthik et al., (2019) this study details the development of a wireless newborn monitoring system for use in preterm babies. An effective and dependable infant monitoring system is created as a prototype, which may greatly contribute to better child care. Using a GSM network, this device transmits data to parents about their infant's vital signs, including their temperature, heart rate, cries, and movements. It is possible to assess these critical characteristics and then notify parents via SMS of a potential danger so that they may take the necessary precautions.

Narayana, M. et al., (2017) the current effort focuses on developing a specialized monitoring system to attend to the well-being of infants. To put the plan into action, an Arduino Uno board is used. The GSR, MQ135, pulse rate, and AM2315 sensors are connected to an Arduino board. The GSR sensor detects the infant's emotions, while the MQ135 sensor records and analyzes the concentrations of CO gas and smoke. Using a pulse rate sensor, the baby's heart rate is constantly recorded and monitored. An AM2315 sensor is used to track the humidity and temperature. Whenever an abnormality is detected in an infant's condition, an alarm message is delivered to the physicians and the parent.

De, Debashis et al., (2016) to keep an eye on newborns' vitals, this study developed a specialized monitoring device. The task is carried out using an Arduino Uno board. Every one of these sensors—GSR, MQ135, pulse rate, and AM2315—is linked to an Arduino board. The MQ135 sensor records and analyzes concentrations of CO gas and smoke, while the GSR sensor identifies the infant's emotions. A pulse rate sensor records and monitors the baby's heartbeat in real time. An AM2315 sensor measures both the temperature and the humidity. When anything out of the ordinary happens with a newborn, an alarm message is sent to both the parents and the physicians.

Rao, Hiteshwar et al., (2015) In this book, we outline the blueprints for a wearable health tracker that can keep tabs on newborns' vitals for the first few weeks after delivery. The primary function of the gadget is to detect the beginning of hypothermia in infants by continually monitoring their skin temperature. A microcontroller with an integrated Bluetooth low energy radio is responsible for temperature monitoring, and a medical grade thermistor is directly interfaced to it. In addition to the previously mentioned features, the gadget additionally has an inertial sensor that allows for the monitoring of respiratory rate. Information that has been sensed is safely sent to a nearby gateway using Bluetooth low energy radio. The gateway then transfers this information to a central database, allowing for real-time monitoring. Extended runtime on a single charge is possible because to software and circuit level improvements that minimize power consumption. You can quickly sterilize and reuse the gadget, and it comes in a baby-friendly, water-proof case.

Ganesan, Rajesh et al., (2014) Cases of Sudden Infant Death Syndrome (SIDS) include the inexplicable and unexpected passing of a baby while they are sleeping, which cannot be explained by the baby's medical history and which persists despite extensive forensic autopsies and investigations into the cause of death. We created a method that addresses these issues by integrating wireless sensor networks (WSN) and mobile phones into the crib. Live video monitoring; alerts for crib fencing and awakening, temperature and light intensity readings, vaccination reminders, and weight tracking are all features of the system.

Chen, Wei et al., (2010) in the neonatal intensive care unit (NICU), monitoring the temperature of preterm newborns is an important part of keeping tabs on their health. In this study, we present and showcase a design for wearable sensors that monitor neonatal temperature non-invasively. The tiny and precise negative temperature coefficient (NTC) resistor is used as the temperature sensor. The incorporation of sensors into a non-invasive monitoring platform, such a neonatal smart jacket, is made possible with the use of conductive textile wires. To maximize practicality, patient comfort, and the potential for aesthetic elements, the placement of the sensor, the materials used, and the overall look are all carefully considered. To showcase the temperature monitoring, a belt prototype is constructed from gentle bamboo materials and equipped with an NTC sensor. The experimental findings demonstrate that the prototype belt accurately monitors temperature compared to the typical patient monitor. The testing was conducted on newborns at the Neonatal Intensive Care Unit (NICU) at Máxima Medical Center (MMC) in Veldhoven, the Netherlands.

Das, & Bag, Rajib (2010) the development and cooperation of communication and computer technologies have opened up several new fields of study, one of which is the wireless sensor network (WSN). The versatility of WSNs in sensing various types of data has led to their widespread use. When connected to the WSN, the computer system will take any safety measures it thinks are required. In addition to introducing the reader to the basic architecture of WSN, this article provides a broad overview of WSN-based monitoring systems in a variety of sectors, including healthcare, transportation, power, and early warning systems used to indicate geological hazards. There are a variety of WSN power management challenges covered in this study. Based on the study, this report promotes the use of WSN micro-level applications for tracking, monitoring, and observing systems in underdeveloped nations.

Chen, Wei et al., (2009) The survival of sick and frail newborns admitted to a hospital's neonatal intensive care unit (NICU) depends on close monitoring of their vital signs. However, patients experience pain and parent-child contact is hindered by the sticky electrodes and cables. In this study, we provide a solution for newborn monitoring in NICUs using wireless transmission technology. An Arduino Pro Mini and BlueSMiRF wireless transmission system prototype is constructed to illustrate the design idea. Correct data transfer, detection, and presentation are the goals of software development. A smart neonatal jacket or other non-invasive monitoring platform would be an ideal fit for the system's design. The prototype system is able to send and receive data from various sensors within a 20 m range, according to the experimental findings.

III.Proposed Methods

The prototype's execution focuses on the core functionality of the system as it is used in real-world scenarios. To meet both functional and non-functional needs, development was necessary for hardware implementation. A TDMA network protocol was used to accomplish the wireless transfer. Using this protocol, a maximum of three sensor nodes may exchange data across a network. With two channels of data transmission per sensor node, the network can support up to six distinct channels of data. In this proof-of-concept implementation, the 1-lead ECG signal was sent via a single data channel. Each data channel had six samples included in the data package, and the data was sampled at 198 Hz. And then, at a frequency of 33 Hz, the data packets were sent continually.

In MATLAB, software is used to read data, handle signals, and create the user interface. We used default hardware for the test setup for the first step, which is establishing the connection. Following connection establishment, the microcontroller executes the previously described process of reading all active sensor inputs and appending headers to them. The information is thereafter sent in a sequential fashion to the central processing unit (CPU), where it is deciphered and allocated a specific data array for every sensor. The raw ECG signal was filtered using algorithms for a notch filter, a high pass filter, and a low pass filter. To better analyze the supplied raw data, an extra logging method was included. Lastly, a screen that is connected to the central processing unit shows the data. Here, medical staff can decipher the sent data, draw conclusions, and respond appropriately.

IV.Results And Discussion

The overarching goal of the clinical trial was to determine, through data analysis, whether and to what extent the

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Smart Jacket's integrated Holst-Center ECG amplifier, wireless communication, and silver Medtex textile electrodes work in a neonatal intensive care unit (NICU) setting when worn by a premature infant.

In order to get permission for clinical testing, the suggested equipment and system were thoroughly examined in accordance with the hospital's regulations. Infection and hygiene concerns, potential current leakage, interference with other devices, wireless system frequency, etc. are among the items that are examined. Research protocols were greenlit by the MMC's ethical review board. In order to gather data and capture video and photographs for review reasons, parental permission was also acquired. To guarantee the baby's safety, a member of the medical team must be there to monitor the baby's vitals while the data is being collected.

The testing and data gathering were conducted during a one-hour recording session of the electrocardiogram signal sent by the recently created wireless monitoring system on a healthy, preterm infant weighing around 2 kg in a neonatal intensive care unit. While the infant was lying supine, we recorded a series of ECG derivations using the silver Medtex textile electrodes that were embedded into the Smart Jacket. The prototype transmission system with the smart jacket was tested on a newborn in the NICU at MMC (Fig. 1) in an instance.

Figure 1: Testing of the prototype transmission system with the smart jacket on a neonate in the NICU

The data from the log file was processed and plotted using a MATLAB application. In order to get the raw data, the application was used to process the data at the right sampling rate. To eliminate the DC component and high frequency noise, a low pass filter was used, followed by a high pass filter. Finally, the infant was measured from various angles to get the filtered ECG data.

Figure 2 shows the filtered electrocardiogram data collected from the baby's chest, and Figure 3 shows the data collected from the baby's back using the Smart Jacket. Figure 4 displays the filtered electrocardiogram data acquired using gel electrodes. The data transmission from the prototype wireless sensor system was successful. Additionally, we can see that the signal detected by the sticky gel electrodes is more stable than the signal detected by the jacket. Textile sensing relies on specialized design to optimize skin-electrode contact and on specialized signal processing techniques to decrease motion artifacts and improve smart textile signal quality.

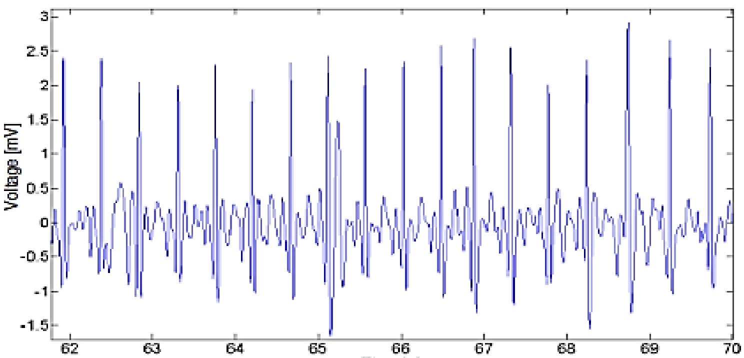

Figure 2: Data measured from position LA2 and RA2 (front)

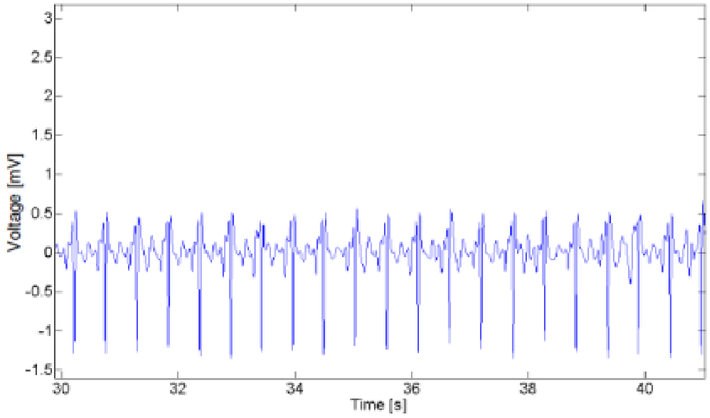

Figure 3: Data measured from position LL3_RA3 (back)

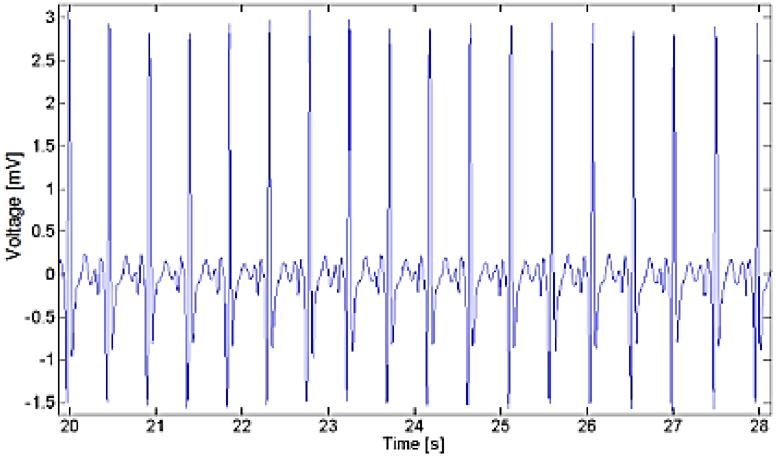

Figure 4: Data measured from gel electrodes

V.Conclusion

New wireless sensor systems for neonatal monitoring have been developed, which is a huge step forward in healthcare technology. These systems provide a complete answer to the problem of how to continuously monitor newborns' physiological characteristics and vital signs. These systems enable healthcare personnel to identify and handle possible health issues in newborns by addressing the particular difficulties of monitoring them, such as their fragile physiology and the requirement for non-invasive monitoring technologies. The experimental findings demonstrate that the prototype system can receive and send data from electrocardiogram (ECG) sensors in neonatal intensive care units (NICUs), and that the smart jacket can wirelessly monitor and transmit ECG signals from a preterm newborn. Additional clinical validation, software feature enhancements, and testing for system robustness are next advancements.

References: -

1. Ingale, Aniket & Kshirsagar, Somnath & Nikam, Sonal & Nagalkar, Vinay. (2021). BABY MONITORING SYSTEM. 7.

2. M. Abd El Aziz, Rasha & Taloba, Ahmed. (2021). Real Time Monitoring and Control of Neonatal Incubator using IOT.

3. Vk, Karthik & Miheal, B & Kumar, T & Prabaharan, Manoj & Pallakku, Selvaprasanth. (2019). Automated Health Monitoring System for Premature Fetus. Current Journal of Applied Science and Technology. 3. 17-23.

4. Najib, Suhaila & Hassan, Norshahida & Shair, Nur & Rahim, N & Ab Wahab, Norfariza. (2019). Intelligent Neonatal Monitoring System Based on Android Application using Multi Sensors. 131-135. 10.1109/ISCAIE.2019.8743867.

5. Narayana, M. & Dusarlapudi, Kalyan & Kasi, Uday & Kumar, Sakthi. (2017). Neonate monitoring system.

6. De, Debashis & Mukherjee, Anwesha & Sau, Arkaprabha & Bhakta, Ishita. (2016). Design of smart neonatal health monitoring system using SMCC. Healthcare Technology Letters. 4. 10.1049/htl.2016.0054.

7. Hongyu, Chen & Xue, Mengru & Mei, Zhenning & Bambang-Oetomo, Sidarto & Chen, Wei. (2016). A Review of Wearable Sensor Systems for Monitoring Body Movements of Neonates. Sensors. 16. 2134. 10.3390/s16122134.

8. Rao, Hiteshwar & Saxena, Dhruv & Saurabh, Kumar & Sagar, G. & Amrutur, Bharadwaj & Mony, Prem & Thankachan, Prashanth & Shankar, Kiruba & Rao, Suman & Bhat, Swarnarekha. (2015). Design of a Wearable Remote Neonatal Health Monitoring Device. 34-51. 10.1007/978-3-319-26129-4_3.

9. Zhu, Zhihua & Liu, Tao & Li, Guangyi & Li, Tong & Inoue, Yoshio. (2015). Wearable Sensor Systems for Infants. Sensors. 15. 3721-3749. 10.3390/s150203721.

10. Sumathi, O.M. & Mudigonda, Malini & Vikram, Tula. (2015). Wireless Data Acquisition System For Vital Sign Monitoring of Neonates. 10.1109/ICCCT2.2014.7066734.

11. Ganesan, Rajesh & R, Arun & L., Hari & R, Chandira. (2014). BABY MONITORING SYSTEM USING WIRELESS SENSOR NETWORKS. ICTACT Journal on Communication Technology. 05. 963-969. 10.21917/ijct.2014.0138.

12. Chen, Wei & Dols, Sietse & Bambang-Oetomo, Sidarto & Feijs, Loe. (2010). Monitoring Body Temperature of Newborn Infants at Neonatal Intensive Care Units Using Wearable Sensors. Proceedings of the 5th International ICST Conference on Body Area Networks, BodyNets 2010. 10.1145/2221924.2221960.

13. Das, & Bag, Rajib. (2010). Wireless Sensor Network Based Monitoring Systems: A Review and State-of-the-art Applications. 3. 142-151.

14. Chen, Wei & Nguyen, Son & Coops, Roland & Bambang-Oetomo, Sidarto & Feijs, Loe. (2009). Wireless transmission design for health monitoring at neonatal intensive care units. 1 - 6. 10.1109/ISABEL.2009.5373671.