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Neo-Bedside Monitoring Device

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Abstract:

We depict the improvement of Neo, a minimal expense bedside gadget that can get basic information continuously by connecting with a few gadgets joined to children in NICUs. Premature infants in NICUs have many linked monitoring equipment, which collect several terabytes of data daily. Every hour, a record is made by hand of the constant essential data from these devices. This results in inaccurate results and the loss of precious detail. Clinicians additionally have a hard time visualising and detecting patterns of diagnostic value due to the inconsistent reporting of physiological data. The continuous information gathered by Neo is shipped off a cloud-based large information stage called iNICU [29,30], which is itself developed on an inexpensive IoT platform. In addition to reducing the likelihood of human mistake during documentation, the gadget also permits data capture at near-real-time rates, which may be used to show where each patient stands right now in the Neonatal Intensive Care Unit. Neo automatically graphs or charts the current state of vital signs and historical patterns, so doctors and nurses may check in from anywhere in the world. Diseases including sepsis, respiratory distress syndrome (RDS), necrotizing enterocolitis (NEC), and retinopathy of prematurity (ROP) are scored using Neo's physiological signal and clinical criteria. This score aids doctors in making decisions that promote prompt intervention and predicts the newborn's physiological health. INDEX TERMS Neonatal Intensive Care Units, Internet of Things, Aggregators of Cloud-based Device Data, Early Warning Scores, and Big Data.

Keywords:

Respiratory Distress Syndrome, Necrotizing Enterocolitis, Retinopathy of Prematurity, Neonatal Emergency unit, Neo Device

1. Introduction:

Premature birth, defined as occurring before 37 weeks of gestation, affects 15 million newborns annually throughout the globe [1]. This amounts to 10% of the 150 million annual births throughout the globe (or 1 in 10 births). These untimely newborn children have a very high demise rate and need serious consideration during the initial 27 days of life. The quantity of untimely births in India, at 3.5 million, is the highest in the world and accounts for 23% of all premature births [1]. In India, preterm birth problems kill close to 748K infants per year [2]. Prematurity (accounting for 35%) and newborn infections (accounting for 33%) are two significant causes of these fatalities in India [2]. The number of premature babies in India is outpacing the capacity of the healthcare system to care for them [3, 4]. Babies that make it through this frequently have impaired immunity and may have developmental delays or trouble communicating [5].

Very untimely newborn children (those brought into the world before 32 weeks of development) are viewed as health-related crises and should be really focused on in a particular, sterile region of the clinic known as the Neonatal Emergency unit [6]. Babies in the neonatal emergency unit are checked nonstop and given clinical treatment through an assortment of connected life-support bedside gadgets. Standard observing gear incorporates a heart and lung capability analyzer, a circulatory strain and temperature test, a heartbeat oximeter, a mixture siphon, a blood gas analyzer, a continuous positive airway pressure (CPAP) machine, and a ventilator. Clinicians need frequent measurements from these monitors of the newborn's vital signs in order to determine the infant's health and to schedule appropriate diagnostic procedures. Clinical professionals such as nurses and physicians physically check readings from all display units linked to a baby in order to capture vital information on a frequent typically hourly basis as shown in Figure.1.

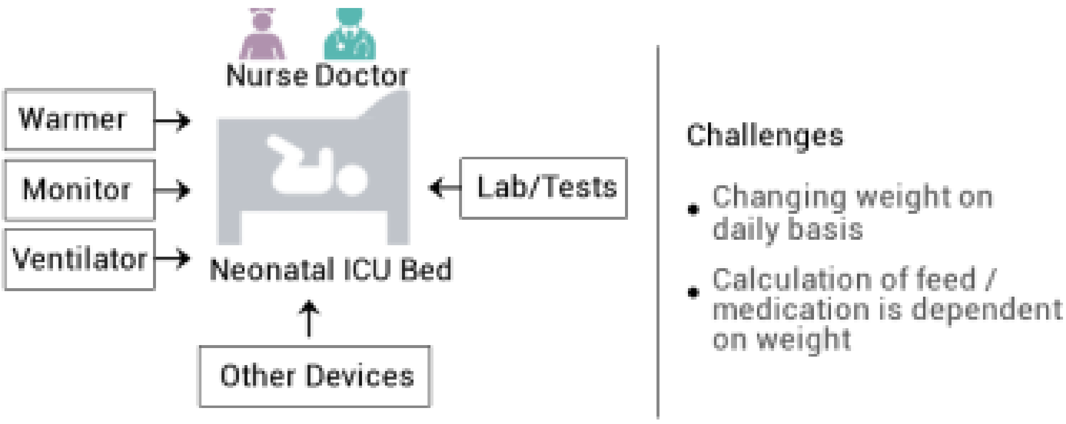


Figure.1: Data Sources in Neonatal ICU Environment for a Patient

There might be millions of rows of information generated by the monitoring equipment. The average day in the life of a patient with a cardiac monitor produces 86.4 million measurements, whereas a blood oxygen saturation monitor produces 0.08 million readings [7]. The monitors can't save records for more than a week, and they don't provide a summary that can be printed out and used to track vitals every hour. Along these lines, attendants really focusing on babies in basic consideration need to physically follow normal hourly patterns or significantly more modest step sizes. Human missteps might crawl into the documentation cycle as of now [8-12]. The utilization of an observation gadget at a patient bed associated with clinical gear in the NICU has been supported in late examination to diminish the probability of mix-up and increment patient security [13]. Devices utilized in the neonatal intensive care unit (NICU) produce asynchronously proprietary data on physiological parameters of therapeutic significance. Screen readings, imbuement siphon information, radiology reports, and lab test information boundaries are instances of time-series information that should be collected for direction (Fig. 2). The big number and heterogeneity of information across birth companions present extra troubles [14]. While involving measurable grouping for continuous information examination in clinical assessment, it is essential to represent possibly perplexing perspectives such as the kid's weight, gestational status, and orientation [15]. Fast digitization in these gadgets throughout recent many years has permitted them to give ongoing information focuses by means of different advanced interfaces like RJ-45 and RS232, which help in the production of computerized clinical records using standard medical services conventions like HL7 (Wellbeing Level 7) [16] or ASTM (American Culture for Testing Material) [17].

Central monitoring services for each modality are offered by all device manufacturers, but come at an additional license and hardware cost. Patient monitors, for instance, make monitoring easier by establishing a single location from which to oversee all devices. Information from different suppliers, for example, lab results, blood gas readings, or imaging studies, are not coordinated into their focal observing frameworks naturally. The Philips Intellispace Basic Consideration and Sedation (ICCA) framework [18] and the Draeger Innovian [19] are just two instances of data aggregator frameworks that give basic consideration data framework between operable with EMR arrangements. These choices permit clients to get information from Philips or Draeger gadgets continuously and discuss that information with different gadgets and an EMR utilizing HL7 principles. To total information from bedside gadgets and show on exclusive shows and convey information to EMR [18], there is a connection point module called Philips IntelliBridge. At the point when a medical clinic demands coordination with a gadget producer, it is the EMR seller's liability to keep up with the patient's well-being record and interface it with the gadget merchant's remarkable configuration. Current research suggests that only a small number of EMRs are able to record all vital signs. Their intricacy and expensive price have prevented their broad application in the emerging market [20]. In addition, the demands of the NICU are too particular to be met by these EMR-based systems, which were developed with the general needs of ICUs in mind [21].

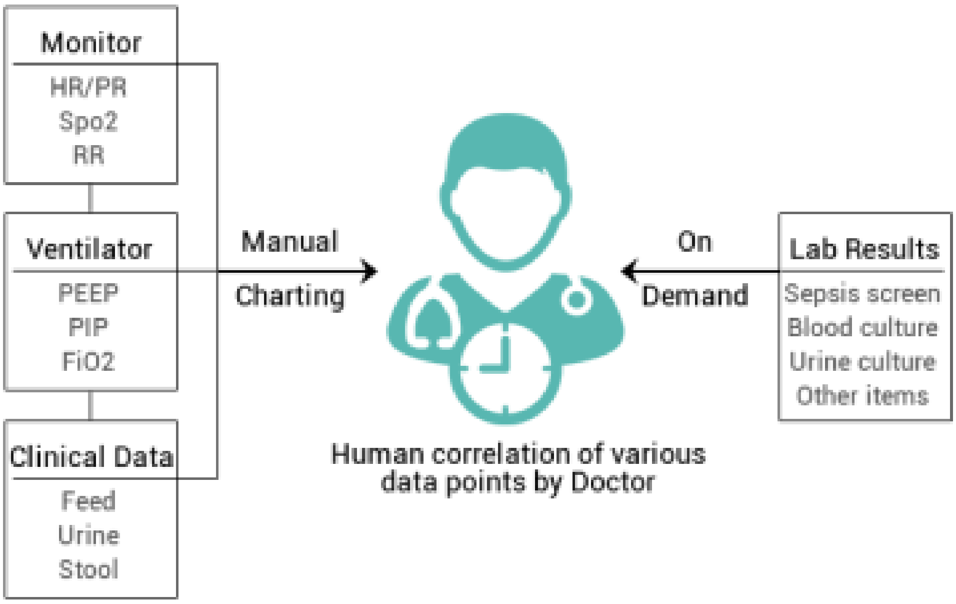


Figure.2: Human based correlation data

Clinical parameters developed from statistical analysis of constantly observed patient data have been demonstrated to be indicative of the health state of newborns in recent research. One such metric is the relative heart rate fluctuation [22, 23]. The exclusive framework Legend observing, which is available yet restrictively exorbitant, shows a critical decrease in fluctuation and log jam on account of various obsessive circumstances [24]. Diminished pulse inconstancy on review information is likewise announced by Suchi Saria et al. [25] as a sign of serious dismalness in newborn children. In different issues, for example, NEC and sepsis, varieties in physiological signs have been recognized as early signs of infant well-being status empowering constant order of patients [26].

We introduce Neo, a low-cost bedside safety monitoring system for neonates that can communicate with a wide variety of medical equipment, regardless of their manufacturer or brand. Neo utilizes a local area-empowered, minimal-expense, single-board miniature regulator stage in view of ARM innovation [28]. This stage is known as a Beaglebone Dark

(BBB) [27]. The Beaglebone can execute a Java program, bringing the total cost of integrating many devices down to about $100. The contraption gathers time-series data as a huge number of data of interest progressively from a wide assortment of gadgets of various makers. To make the clinical choice emotionally supportive network known as coordinated NICU or iNICU [29,30], it sends this information to a cloud-based information collector over a WiFi organization, where it is handled reasonably to make a summed up representation designed as a course of events that gives a speedy outline of the newborn child's wellbeing.

When used together, Neo and iNICU provide a "safety net" by improving the efficiency and effectiveness of data exchange between various biomedical devices and the clinical management system. Neo automates the NICU's daily vital chart generation by collecting data from a variety of medical equipment. This eliminates documenting mistakes made by hand and gives doctors and nurses access to a patient's time series data whenever they need it. We've also created an adaptive mathematical model that uses iNICU data to forecast infant morbidity, and it gets better the more data it receives. We have gathered constant pulse information from 92 children in two NICUs to verify the effectiveness of the merged Neo and iNICU designs. This research builds on PhysiScore's [25] analysis of historical data and applies the same methodology to signals in real time. The findings demonstrate that a reduction in HR variability is a crucial, continually observable signal of the newborn's criticality. This means that HR, together with other important distinguishing features, might help physicians anticipate illnesses early on and intervene sooner.

2. System Design

All medical data is acquired, integrated, and analysed by the system as a whole. Neo, which acts as the system's data collection component, is liable for catching information from various patient-associated clinical hardware and sending it to a cloud information beneficiary for collection, examination, and notice to a tablet gadget provided to clinical staff. In this article, we'll go through the parts that make up Neo, for example, the presentation connection point and information social affair and transmission units. We likewise discuss the cloud information beneficiary module, which takes time-series information from Neo and shows it in various examinations on a tablet application.

2.1. Architecture of Neo Device

Different clinical gear is connected to Neo (Fig.3) utilizing different information trade conventions and connection points.

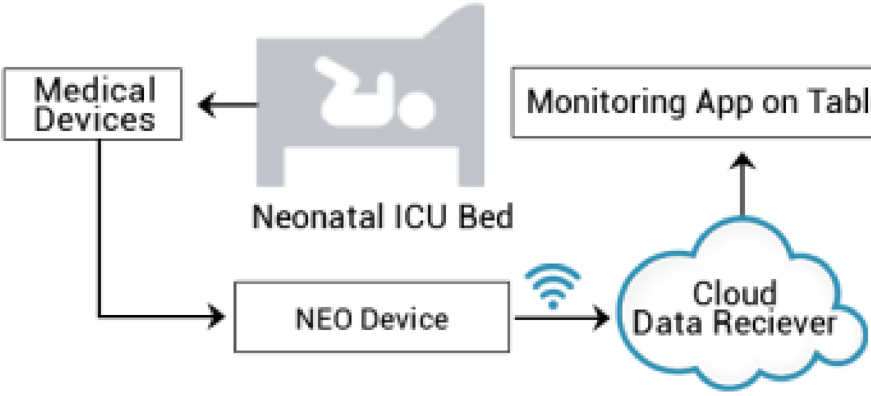


Figure.3: Solution components for NICU bed integration

In Figure. 4, we see a tangible depiction of Neo's placement in the NICU. The Neo data collection module pulls data from a wide variety of medical devices in real time, processes it, and then uploads it to a server through Wi-Fi and the Internet. To keep tabs on how much a baby is moving about, an IP (internet protocol) camera is stationed beside the cot. Live infant feeds from the webcam are also fetched by Neo and sent to the iNICU. The camera may be removed at the option of the clinician or the parent.

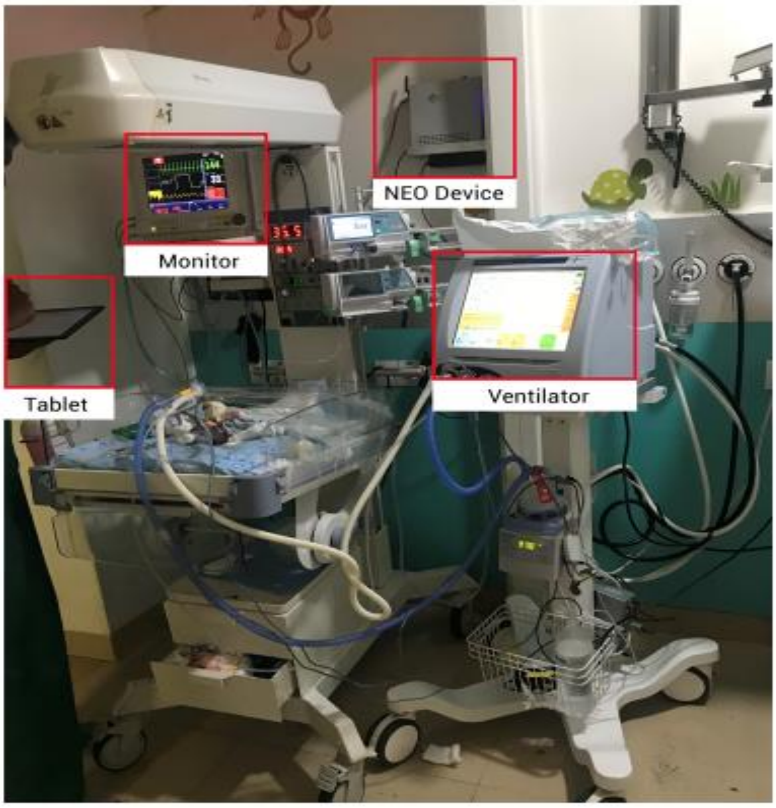


Figure.4: Neo device aggregates the real-time data from devices connected with patients

Neo is comprised of a data-gathering Module, a data-sending Module, and an information-displaying Interface, as shown in Fig.5. The real Neo hardware is seen in Figure 6. The three components of the Neo gadget are described below.

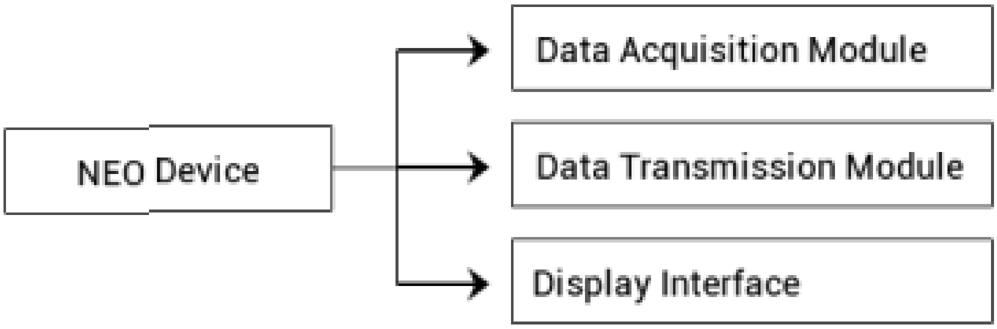


Figure.5: Neo device architecture showing hree conceptual design components

Figure.6: Actual hardware image of Neo device

2.1.1. Data Acquisition Module:

This part is responsible for social occasion data from a clinical device over the accessible organization ports. It uses two programmable Beagle Bone black (BBB) microprocessors with the Debian [31] operating system and a Java 1.8-based program. Each BBB is equipped with a 1 GHz CPU, a NEON floating-point accelerator, and two 32-bit PRUs. The BBB platform is ideal for Neo because it (a) has a robust Cortex A9 CPU and (b) 512 MB of DDR3 RAM, both of which are sufficient for running complicated healthcare data-collecting applications. In order to gather information from various medical equipment and cameras, each BBB is equipped with one USB, one RJ45, and many GPIO pins. Data is collected via medical equipment

(Supplementary Table II) or a bedside camera (Fig. 7) and sent to a cloud-based data receiver through a multi-threaded embedded Java program. In order to collect information from numerous sources, embedded Java software communicates with them through network interfaces (HL7 and RS232 ports). HAPI (HL7 API) [32], an open-source project, is used. It is compatible with HL7 versions 2.X and 3.X.

The RS232 interface is handled via the Java-based RXTX [33] communication API. The logic of a Java application built on the BBB architecture is seen in Figure 8. It begins by identifying the kind of connected device and then using the appropriate handshake protocol for that device. After initialization, data is sent to the cloud data receiver on a periodic basis. OpenCV, a Python package, was used to integrate a camera into an embedded Java programme. The camera at the patient's bedside sends footage to the server in real time using the RTSP protocol.

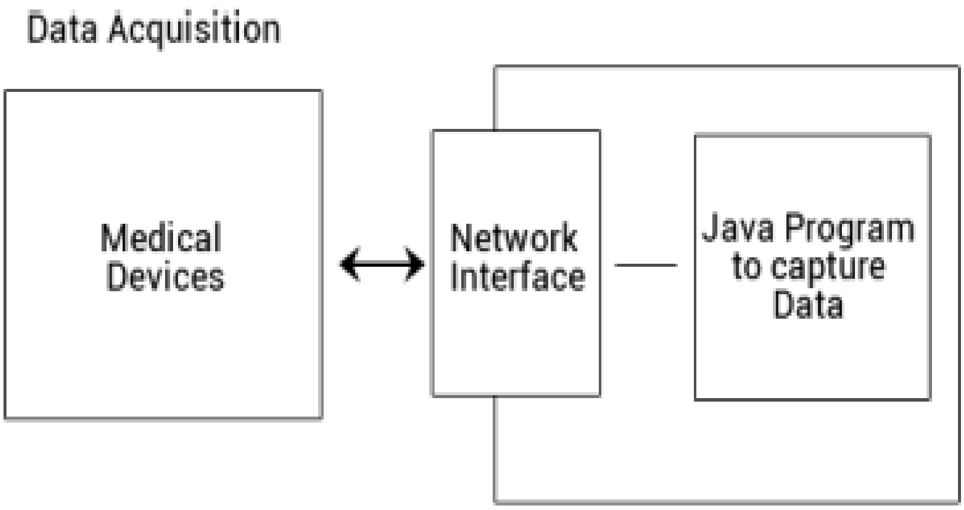


Figure.7: Embedded Java Application for data acquisition

2.1.2. Data Transmission Module:

The data collected by the BeagleBone is uploaded to the cloud using a Wi-Fi USB adapter. The data from the medical device is received by an embedded Java programme, which then, at that point, changes it to JSON prior to conveying it to the cloud-based information collector. The JSON files include information on the acquisition time, Neo's name, the BBB's MAC address, the model of the medical equipment, and the manufacturer. Gained PNG information is compacted into JPEG design and handled into a twofold JSON design on account of a camera feed.

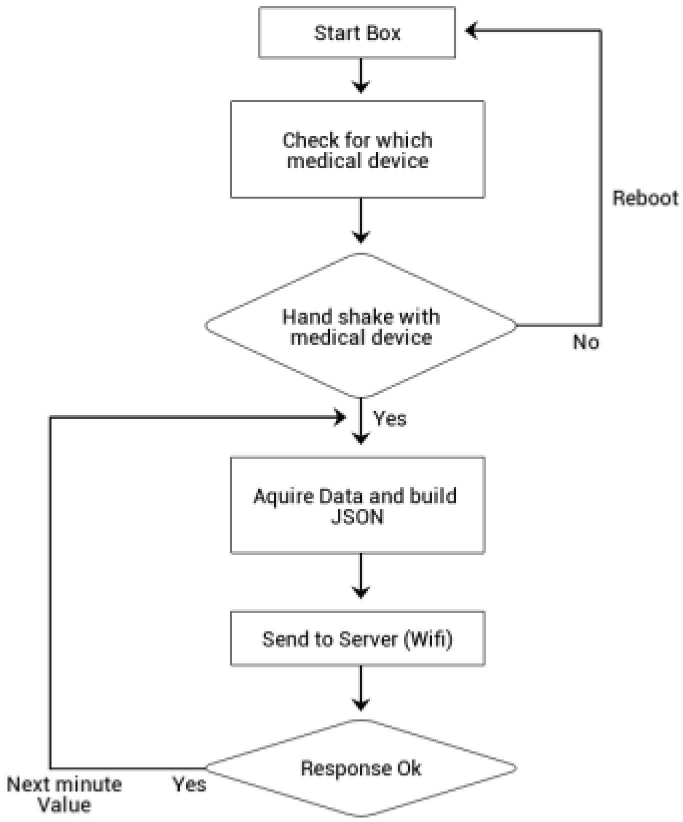


Figure.8: Data flow of Neo data acquisition module

2.1.3. Display Interface:

The Neo box has four LEDs that each represent a distinct status. When the BBB is activated, a single LED will light up. When Neo is getting information from his medical gadgets, he will blink twice. If Neo's Wifi dongle is transferring data to the cloud, the third LED will light up, and the fourth LED will blink when Neo gets confirmation from the iNICU server. The PCB's power switch pulls the BBB's shutdown pin low, allowing for a gentle shutdown.

2.2. Cloud data receiver:

The time series information sent from Neo is aggregated by the cloud's information recipient module. To make an infection explicit classifier, this information is investigated for examples that match pathologies utilizing a neonatal space dictionary. The early warnings provided by these classifiers are sent to the tablet computers held by physicians and nurses. The four components of a cloud-based data receiver are the "receiver object module," "Neo communication," "tablet communication," and "real-time analytics."

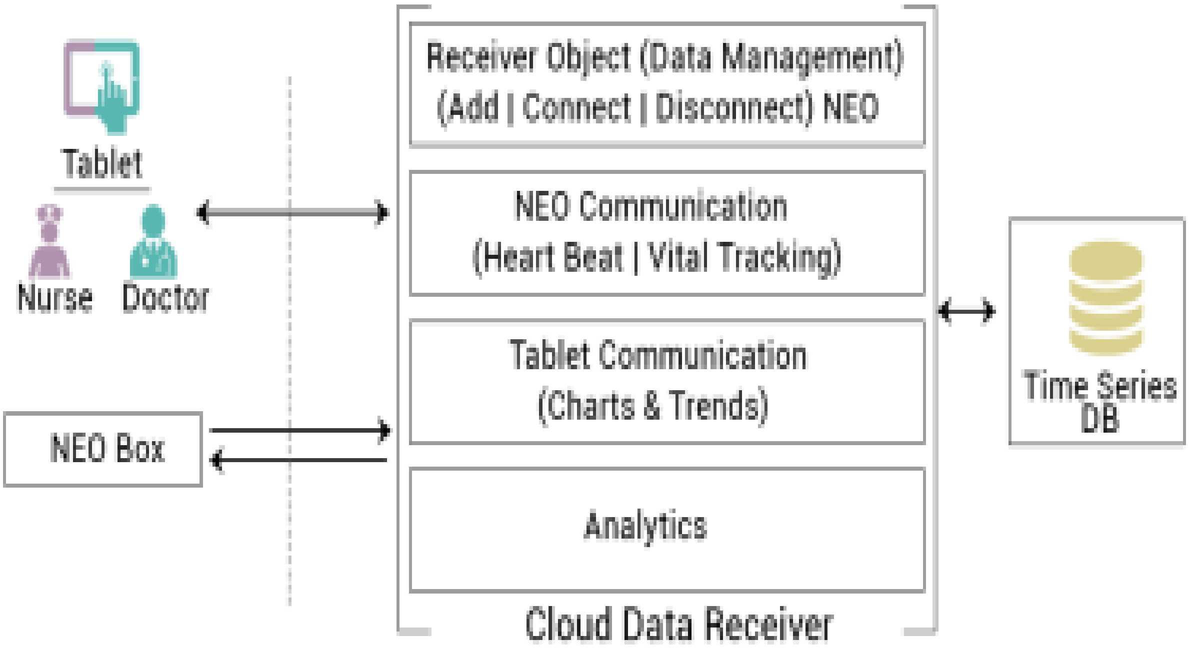


Figure.9: Cloud data receiver's logical components

2.2.1. Receiver Object:

The receiver object configures the tablet app for use with different Neo devices and maps the data received from them. Neo devices may be added to the web interface in a number of different ways, such as clinical brand, model, baud rate, network port, etc. The medical caretaker or specialist may then connect the proper hardware to the patient and relegate the subsequent information stream to the perfect individual (Fig. 10). As patients in the neonatal intensive care unit (NICU) often go down or up a level dependent on their severe condition, nurses frequently attach and unhook a variety of Neo devices from the same child. The data from the devices is gathered by the Receiver Object and stored in a database as a time series. It is written in Java and deployed to the cloud utilising the open-source Spring-Boot and Postgres frameworks. Apache Cassandra is used to store time series continuous device data.

2.2.2. Neo communication module:

The handshakes that occur between Neo devices and the cloud data recipient take place at this layer. It analyses how well Neo devices transmit data and alerts the user if any information is lost. All infants' anticipated and actual vital signs are shown in Figure. 11.

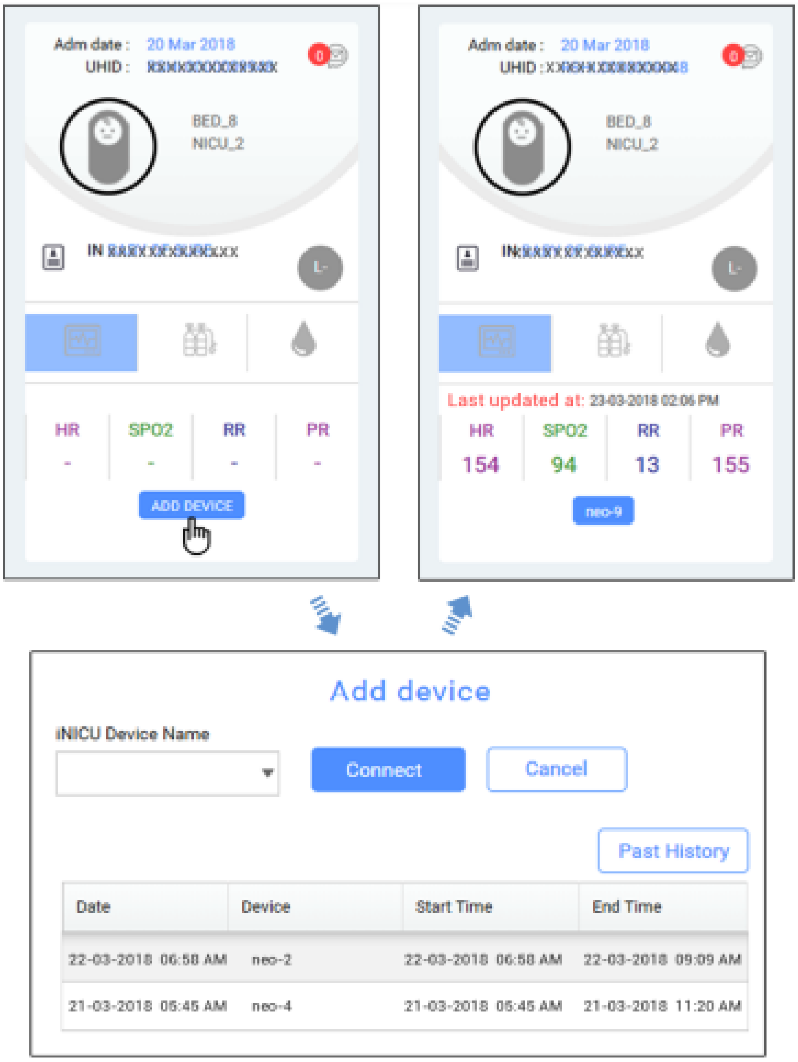
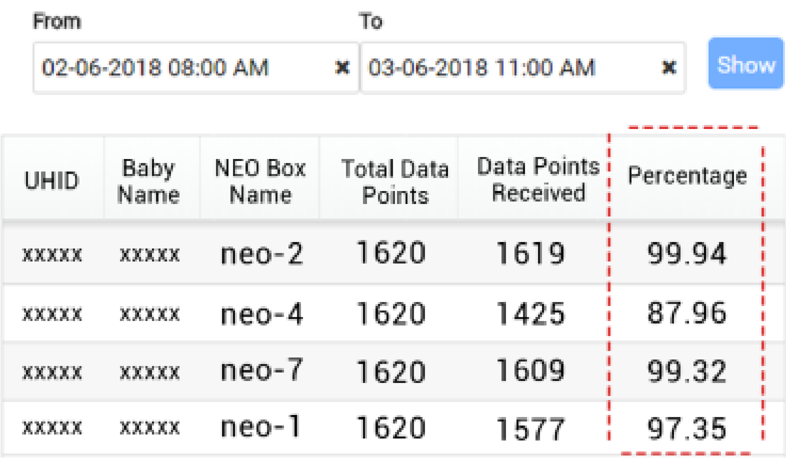


Figure.10: Connecting and disconnecting a baby with Neo device



UHID	Baby Name	NEO Box Name	Total Data Points	Data Points Received	Percentage
xxxxx	xxxxx	neo-2	1620	1619	99.94
xxxxx	xxxxx	neo-4	1620	1425	87.96
xxxxx	xxxxx	neo-7	1620	1609	99.32
xxxxx	xxxxx	neo-1	1620	1577	97.35

Figure.11: Vital tracking data monitoring screen

For every baby, it is easy to see and track the lowered percentage or missing data count. To see when certain information focuses were absent for a specific patient, this module likewise shows a heartbeat diagram for each Neo gadget (Fig. 12). In the heartbeat graph, 1s represent successful data transfers and 0s represent unsuccessful ones; the graph updates every minute. In addition, the error and its cause are recorded in the event log.

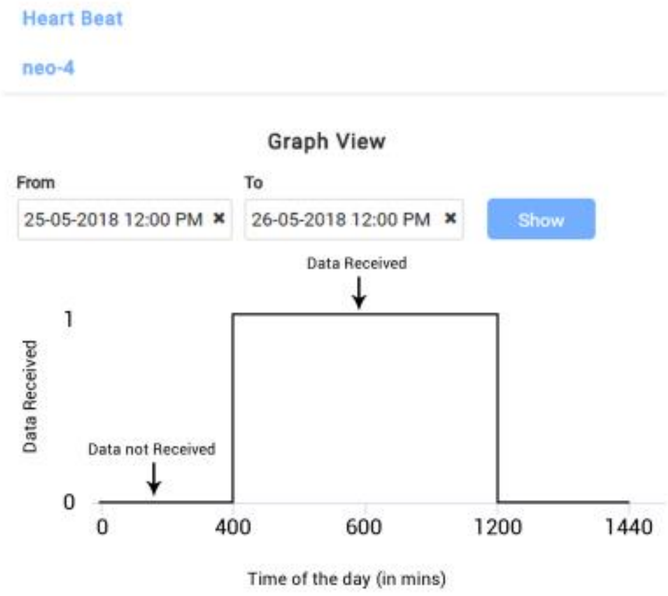


Figure. 12: Heartbeat graph for identifying missing data time points

2.2.3. Communication with Tablet Application:

This module feeds information to the tablet app, which is written in HTML5. Neo collects data from several sources (monitors, ventilators, etc.), and this information is shown in real-time on a single HTML5 graph on the tablet. Physiological data is shown on a trend screen (Figure 13), with the user having the option of selecting between an hourly or a minute sampling rate. Several physiological indicators are available for comparison and visualisation. With the help of this visualisation, doctors may do a time-based examination of physiological data. Some Heart Rate (HR) data is shown in Fig.13.

The most recent value received by Neo is instantly reflected at the nurse charting screen through the tablet application (Fig. 14). Medical caretakers might record this data on an hourly premise and use it to make even nursing diagrams. The automated vital chart prepared using Neo is illustrated in (a) in Supplemental Figure 2 and (b) in the actual nurse vital record for a random patient. Vital signs recording by hand is a time-consuming and error-prone process. Neo automated charts will help eliminate human mistakes in the NICU by relieving nurses of the burden of creating daily records.

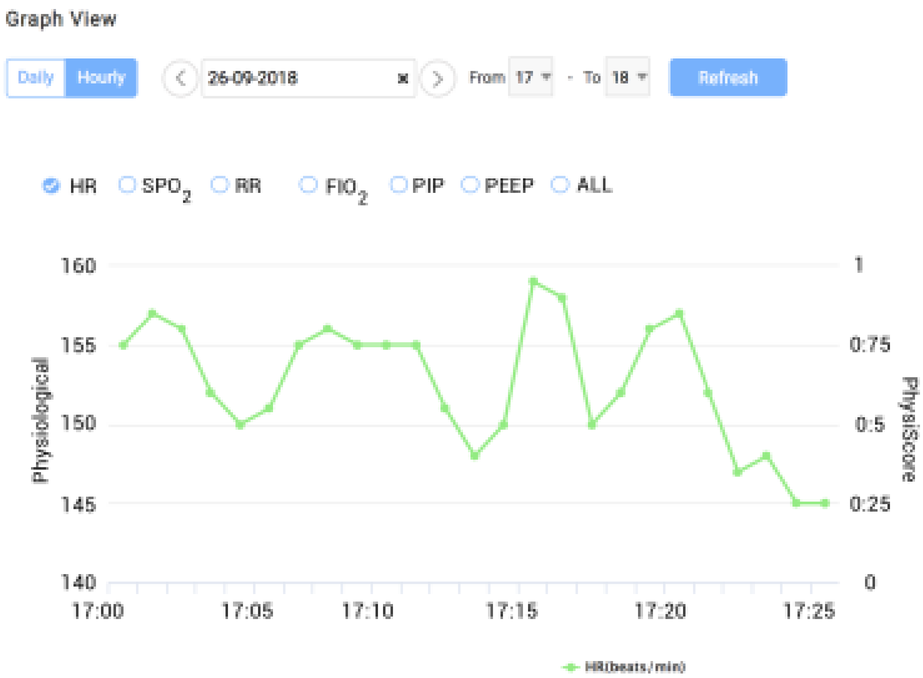


Figure. 13: Trend screen shows real time data streams for a baby

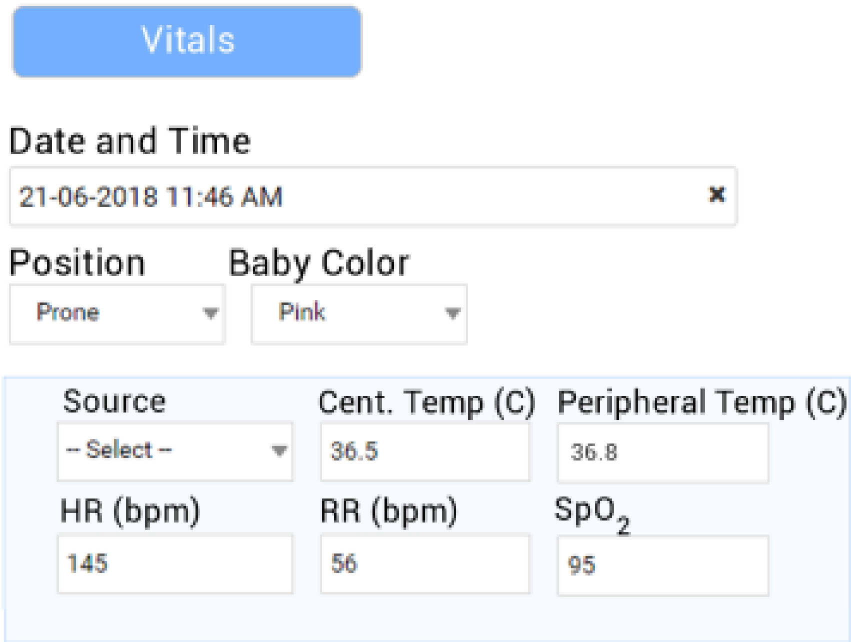


Figure. 14: Vital charting with acquired data by Neo device

2.2.4. Analytics:

The chance that a patient is in a sick condition is computed by the analytics module using time series physiological data stored in the cloud by the data receiver (Fig. 15).

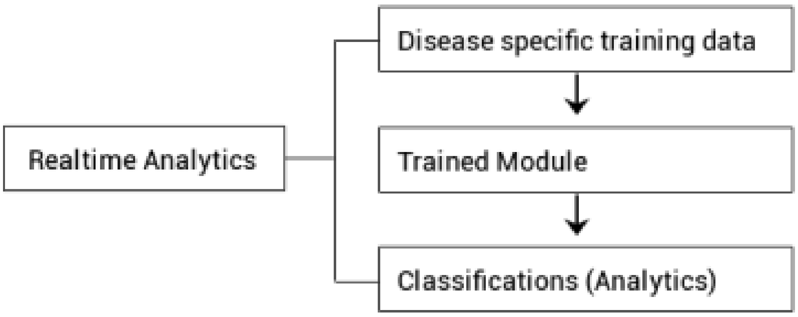


Figure.15: Design of analytics module

3. Data synchronization and security:

Different medical devices have different data transfer rates. While neonates' blood gases are checked twice daily on average, cardiac monitors are constantly sending data every millisecond. Patients' individual CPAP and ventilator setups are monitored in real-time with millisecond to second precision. Because of its flexible hardware design, BBB may collect information based on how often a certain device is used in conjunction with a given protocol. BeagleBone Black, BBB's entry-level product, has a solitary center and can run each errand in turn, but it is still an affordable industrial-grade device. Data transmission resolution is optimised by setting it to one minute. Therefore, the data gathering module collects and sends as much data as possible in a single minute. The Neo device is used for data collecting, while the tablet is used for data input in the present iteration. Since the tablet has its own CPU, this adds to the initial investment. The quad-core BeagleBone X15 model will be used in the next generation of these devices, which will increase the data transfer resolution to milliseconds and enable a bespoke touchscreen. The health care industry is heavily regulated, and HIPAA (the Health Insurance Portability and Accountability Act) must be followed when handling patient information. Neo uses a secure protocol (HTTPS, 256 bits) to encrypt any data transferred from your device while in transit. Each Neo box communicates with a server through an assigned IP address and port. When a device is plugged into one of Neo's ports, just that port is activated. Remote access protocols like SSH need private keys backed by PKI (public key Infrastructure). Roles and permissions provide users access to just the data they are supposed to see in the server database (Cassandra and Postgres). Human readable forms of the demographic data are not available. Firewalls and disaster recovery systems are in place to safeguard the servers. Each data repository is spread over three distinct physical locations.

4. Conclusion:

There are several different kinds of medical equipment in the NICU, all of which are linked to the infants. A newborn's health may be gauged in part by tracking the evolution of a number of important characteristics that can be shown on a number of different devices. Due to the limited capacity of these devices, documentation must be done manually, which introduces several opportunities for mistake. As a result, preventive clinical measures will be postponed. Better information on the health of newborns may be gained if many metrics are synchronised. So, in this paper, we introduce the Neo device, an open IoT-based equipment and programming based development in the mix, catch, collection, and capacity of clinical information at a sensible expense. Device agnosticism allows the Neo device to save money while also integrating data from any and all sources and aligning data with varying sampling rates. Neo uploads the information to the cloud and has it received by the iNICU clinical decision system. The gathered information is displayed to the client as a solitary pattern chart that incorporates the entirety of the fundamental measurements. Automatically produced daily nurse vital charts assist reduce the need for human intervention. Doctor-Nurse Panels and the Neo's built-in consistency checks catch discrepancies in the baby's condition and prevent nurses from accidentally ignoring the doctor's directions. To additionally show the significance of pulse fluctuation in foreseeing infant's wellbeing, we provided a case study based on data gathered from 92 babies using the Neo system. Additionally, this pipeline was developed and connected to the Neo-cloud information retrieval system. The collected data, combined with laboratory and clinical aspects unique to neonatal care, may then be utilised to develop more accurate and efficient real-time prediction algorithms. The earlier this is detected, the better the clinical results of the therapy will be.

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