An INTELLIGENT SYSTEM for PATIENT MONITORING & CLINICAL DECISION SUPPORT IN NEURO-CRITICAL-CARE

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Abstract - *Acute monitoring and timely treatment are extremely crucial in Neuro Intensive/Critical Care Units (NICUs) to prevent patients from secondary brain damages. So we developed an integrated and intelligent system to enhance the effectiveness of patient monitoring and clinical decision makings in NICUs. The requirements of the system were investigated through interviews and discussions with neurosurgeons, neuroclinicians and nurses. Based on the summarized requirements stem is developed. This system integrates and stores crucial patient information ranging from demographic details, clinical & treatment records to continuous physiological monitoring data. This system enables remote and centralized patient monitoring and provides computational intelligence to facilitate clinical decision makings.*

***Key Words*: Microcontroller, PC (VB), Power supply**

1.INTRODUCTION

Neurocritical care or neurointensive care is a branch of medicine that emerged in the 1980's and deals with life-threatening diseases of the nervous system, which are those that involve the brain, spinal cord and nerves. The Neurocritical Care Society was founded in San Francisco in 2002 to promote quality patient care, professional collaboration, research, training, education with the goal of improving outcomes for patients with life threatening neurologic diseases. The doctors who practice this type of medicine are called neurointensivists, and can have medical training in many fields, including neurology, anesthesiology, or neurosurgery. Most neurocritical care units are collaborative effort between neurointensivists, neurosurgeons, neurologists, radiologists, pharmacists, physician extenders (such as nurse practitioners or physician's assistants),critical care nurses, respiratory therapists, and social workers who all work together in order to provide coordinated care for the critically ill neurologic patient. Common diseases treated in neurointensive are units include strokes, brain and spinal cord injury from trauma, seizures, swelling of the brain, infections of the brain, brain tumors, and weakness of the muscles required to breathe. The modern intensive care units (ICUs) typically employ continuous hemodynamic monitoring (e.g., heart rate (HR) and invasive arterial BP measurements) to track the state of patients. Hemodynamic instability is most commonly associated with abnormal or unstable blood pressure (BP), especially hypotension, or more broadly associated with inadequate global or regional perfusion. [4]. Patients in Neuro Intensive/Critical Care Units (NICUs) often suffers from certain levels of brain damage. Some of the patients who now survive severe head injury due to intensive therapy in the acute stage make a satisfactory recovery. [7] The major challenge in patient monitoring and treatment in NICUs is that the primary brain damage is often compounded by secondary damages that occur during the patient's stay in NICUs [1]. The secondary brain damage, formally known as "the secondary insult", can be caused by intracranial hypertension or insufficient oxygen and nutrition supple to the brain. Secondary insults can potentially be reduced and prevented with the help of continuous patient monitoring and timely treatments. [5].[6]In the current NICU practice, patient monitoring & treatment mainly rely on manual inspections and experience- based judgments from clinicians and nurses. The current approach is labor-intensive, prone to human errors and ineffective. To address this, we developed an integrated and intelligent system to enhance the effectiveness of patient monitoring and clinical decision makings in NICUs. The system is named as an intelligent System for Neuro-Critical-Care. This system provides an integrated platform that gathers a wide spectrum of patient information, which includes demographic data, clinical records, continuous treatment records and multi-modal physiological monitoring data. Based on the integrated data, this system analyses and forecasts patients' changing physiological status and generates alerts for impending changes of the status. In addition, this system also predicts patients' recovery outcome, which serves as a reference for clinical decision makings. Management of intracranial pressure (ICP) following a traumatic brain injury (TBI) is an essential aspect of minimizing such secondary brain injuries as intracranial hypertension and cerebral hypoxia. Intracranial hypertension (IH) episodes were identified along with slow wave segments.ICU management of ICP elevations is reactive in nature [6]

2. PROPOSED SYSTEM

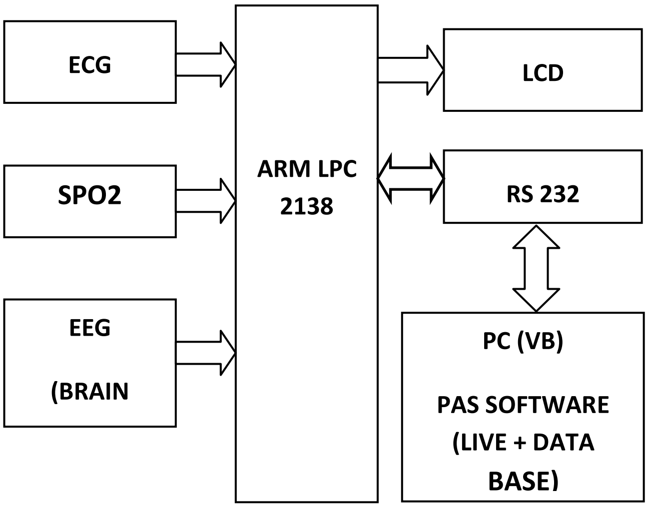

Chart -1: -System Block Diagram

The chart-1 gives the general description of system block diagram in which each block has following description.

2.1ECG:

The circuitry will consist of protection circuit, a instrumentation amplifier, isolation circuit, a high-pass filter, low pass filter, amplifier, notch filter, and adder.

1)Electrode:

In clinical ECG measurements, three electrodes are attached to the body: left Chest (LC), right Chest (RC) and right leg (RL). The electrode on RL is usually grounded while ECG is measured as the voltage drop from LC to RC.

2) Protection circuit:

Diode (D1, D2, D3, D4) are used to protect IC from over voltage when input voltage reaches to 0.7V then Diode get clamped and over voltage condition is avoided.

3) AD620:

Instrumentation Amplifier : The second stage is an instrumentation amplifier (Analog Device, AD620), which has a very high CMRR (90dB) and high gain (1000), with power supply +9V and -9V.

4) Isolation circuit (IC: MCT2E):

For checking the ECG signals on CRO we measure the ECG signals via CRO probes if the CRO ground is not properly earthed then the patient may get a Shock so for this reason we are interfacing a opto isolator which provides a optical insulation between the Electrode circuit and the Output circuit.

5) High Pass/Low Pass Filter:

ECG signal is in frequency range of 0.5Hz to 35Hz. Therefore lower cut-off frequency for HPF is 0.5 Hz. Low pass filter allow signal below 35Hz only.

Fc = 1/2*pi*RC

6) Amplifier (OP07):

This non-inverting amplifier is used for signal conditioning purpose, gain provided by amplifier is 143. Total gain required for ECG circuit is 1000.Using variable resister gain adjust to 143.

7)Notch Filter:

Notch filter is used to provide zero output at particular freq. It eliminates power line noise at 50Hz. It contains H.P.F and L.P.F called twin-T network. Signal having freq between 47HZ to 53HZ. Output of notch filter is+2.5v.

8)Adder Circuit:

Output of notch filter is ±2.5V. It connects to input of adder circuit. Adder circuit shifts the signal from ±2.5V to 0-5V. And this output gives to ADC.

- Normal ECG waveform

  The Fig.2 shows two complete cycles of a normal ECG waveform.

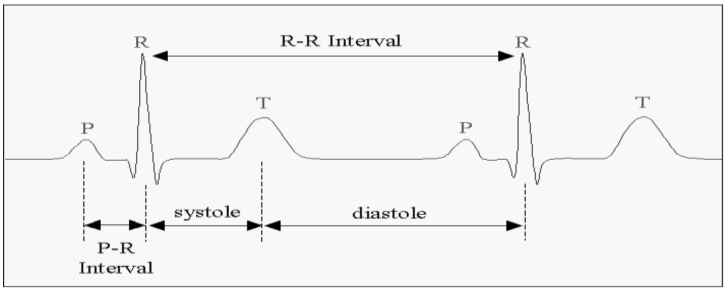

Fig 1– Normal ECG waveform

P-wave is produced by muscle contraction of atria. ***R-wave*** marks the ending of atrial contraction and the beginning of ventricular contraction. Finally, ***T-wave*** marks the ending of contraction. The magnitude of the R-wave normally ranges from 0.1 mV to 1.5 mV.[4]A narrow and high ***R-wave*** indicates a physically strong

The ***R-R interval*** measures the period of heart beat. Its inverse is the heart rate:

$$HR = \frac{60000}{R-R} \text{ (bpm)}$$

Where HR is the heart rate measured in beat-per-minute (bpm),R-R is the R-R interval measured in millisecond (ms).

B) SPO2:

To estimate the burden of critical hypoperfusion and ischemia across the entire brain, such an approaches requires tissues based upon voxel measurement. Voxel based approaches are used to define distribution of oxygen extraction fraction(OEF) across the entire brain, to measure the variability of OEF. These data are used to integrate voxel above a these hold OEF value to produce an region of interest (ROI) based upon coherent physiology rather than is schematic brain volume. [1]

C) EEG:

The Brain Trauma Foundation and the Neurotrauma Foundation, in concert with the American Association of Neurologic Surgeons (AANS) and the Congress of Neurologic Surgeons(CNS) guidelines and options for the medical and surgical management of TBI (Traumatic Brain Injury) [2] Electroencephalograpy is an electrophysiological monitoring method to record electrical activity of the brain. EEG measures voltage fluctuations resulting from ionic current within the neurons of the brain. In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a period of time. Diagnostic applications generally focus on the spectral content of EEG, that is, the type of neural oscillations (popularly called "brain waves") that can be observed in EEG.EEG is most of to be valuable tool for research & diagnose sleep, disorders, coma, , and brain death. But this has decreased with magnetic resonance imaging (MRI) and computed tomography (CT). CT has primary diagnostic test in the acute evaluation of TBI [2] EEG continues to and diagnosis, especially when millisecond-range temporal resolution (not possible with ct or MRI) is required. EEG technique includes evoked potentials (EP), which involves averaging the EEG activity time-locked. The circuitry will consist of protection circuit, a instrumentation amplifier, isolation circuit, a high-pass filter, low pass filter, amplifier, notch filter, and adder.

1]Electrodes:

In clinical EEG measurements, three electrodes are attached to the body: left Chest (LC), right Chest (RC) and right leg (RL). The electrode on RL is usually grounded while EEG is measured as the voltage drop from LC to RC.

2) Protection circuit:

Diode (D1, D2, D3, D4) are used to protect IC from over voltage when input voltage reaches to 0.7V then Diode get clamped and over voltage condition is avoided.

3) AD620:

The second stage is an instrumentation amplifier (Analog Device, AD620), which has a very high CMRR (90dB) and high gain (1000), with power supply +9V and -9V.

4) Isolation circuit (IC: MCT2E):

It is NPN silicon planar phototransistor optically coupled to a gallium arsenide infrared emitting diode. Isolation circuit is used to provide isolation between input and output. It protects patient from shock. For checking the EEG signals on CRO we measure the ECG signals via CRO probes.

5) High Pass/Low Pass Filter:

ECG signal is in frequency range of 0.04Hz to ~35Hz.

Therefore, lower cut-off frequency for HPF is 0.5 Hz. Low pass filter allow signal below 35Hz only.

Fc = 1/2*pi*RC

6) Amplifier (OP07):

Purpose is gain provided by amplifier is 143. Total gain required for ECG circuit is 1000.Using variable resister gain adjust to 143.

7) Notch Filter:

Notch filter is used to provide zero output at particular freq. It eliminates power line noise at 50Hz. It contains H.P.F and L.P.F called twin-T network. Signal having freq between 47HZ to 53HZ. Output of notch filter is+2.5v

8) Adder Circuit:

Output of notch filter is ±2.5V. It connects to input of adder circuit. Adder circuit shifts the signal from ±2.5V to 0-5V. And this output gives to ADC. Three factors predicting high guideline compliance: 1) Neurosurgical residency program, 2) State designation 3) Established hospital-based protocol based on the Guidelines for the Management of TBI [2].

D) Liquid Crystal Display:

LCD is used in a project to visualize the output of the application. LCD can also have used in a project to check the output of different modules interfaced with the microcontroller. Thus LCD plays a vital role in a project to see the output and to debug the system module wise in case of system failure in order to rectify the problem.

E) RS 232:

RS 232 is a serial communication cable used in the system. Here, the RS 232 provides the serial communication between the microcontroller and the outside world such as display, PC or Mobile etc. So it is a media used to communicate between microcontroller and the PC. Many devices today work on RS 232 logic such as PC, GSM modem, GPS etc. so in order to communicate with such device. RS 232 ic is a driver IC to convert the µC TTL logic (0-5) to the RS 232 logic (+-9v). We have to bring the logic levels to the 232 logic (+/-9v). In our project the RS232 serves the function to transfer the edited notice (or data) from PC (VB software) to the microcontroller, for the further operation of the system.

F) Power Supply:

The basic step in the designing of any system is to design the power supply required for that system. The steps

involved in the designing of the power supply are as follows:
1) Determine the total current that the system sinks from the supply.
2) Determine the voltage rating required for the different components.
We have used Regulator IC 7805 that gives output voltage of 5V. The minimum input voltage required for the 7805 is near about 7v. Therefore, we have used the transformer with the voltage rating 230v-15v/12v and current rating 500 mA/750mA/1A. The output of the transformer is 15V AC. This Ac voltage is converted into 12 V DC by Bridge rectifier circuit.
The reasons for choosing the bridge rectifier are

a) The TUF is increased to 0.812 as compared the full wave rectifier.
b) The PIV across each diode is the peak voltage across the load $=V_m$, not $2V_m$ as in the two diode rectifier.

G) RESET DESIGN:

Reset is used for putting the microcontroller into a 'known' condition. That practically means that microcontroller can behave rather inaccurately under certain undesirable conditions. In order to continue its proper functioning, it has to be reset, meaning all registers would be placed in a starting position. Reset is not only used when microcontroller doesn't behave the way we want it to, but can also be used when trying out a device as an interrupt in program execution, or to get a microcontroller ready when loading a program.

In order to prevent from bringing a logical zero RESET pin accidentally, RESET has to be connected via resistor to the positive supply pole AND a capacitor from RESET to the ground. Resistor should be between 5 and 10K and the capacitor can be in between 1µf tp 10 µf. This kind of resistor capacitor combination, gives the RC time delay for the µc to reset properlyThe ARM µC has an active low reset, therefore we connect an RC circuit.

3 SYSTEM REQUIREMENT ANALYSIS

After interviews and discussions with neurosurgeons, neuroclinicians and nurses in NICU, the key requirements for our intelligent system are summarized as follows.

[1] Data Acquisition:

In NICU, multiple physiological readings of patients are continuously measured with various monitoring devices. A data acquisition unit is required to collect the physiological reading from all monitoring devices.

[2] Data Storage:

A database is required to store various patient information, which includes demographic details, clinical data, physiological monitoring data and NICU. Since patients' data come from multiple sources, collected data must be integrated and synchronized.

[3] Data Transmission:

A data transmission network must be employed to transfer collected monitoring data to the database server. The transmission network must ensure collected data is transmitted reliably without any loss or distortion. The transmission network should also avoid any interference with other transmission network in NICU.

[4] User Interface:

User interface of the system should allow clinicians and nurses to interact with the system and perform the following actions: 1) real-time observation of patient monitoring data, 2) review of historical monitoring data, 3) record treatment details and clinical events, and, most importantly, 4) visualize data-driven analytic & predictive results generated by the intelligent system

4. SYSTEM DESIGN & IMPLEMENTATION

A. Overview Of of System Architecture:

This system designed to be modular-based. This gives us the flexibilities to update, enhance, modify or change the modules of the system. The front-end of the system consists of the "Data Acquisition" module, which ensures continuous data collections and transmission, and the "User Interface" module, which allows clinician and nurses to interact with the system. The back-end of the system is then composed with the "Database" module, for data integration and storage, and the "Computational Intelligence" module to perform data-driven analytic tasks to enhance patient monitoring and clinical decision makings. The front-end and back-end modules communicate through a local wireless network. The system is not directly connected to the internet, due to privacy and data security concerns.

B) Data Acquisition:

In NICU, multiple physiological readings of patients are continuously measured with various monitoring devices. A data acquisition unit is required to collect the physiological reading from all monitoring devices. The main task of the "Data Acquisition" module is to continuously collect physiological monitoring data from multiple devices. In our NICU setting, patients' intracranial pressure (ICP) is monitored with the Codman ICP monitoring system, and brain tissue oxygen (PtiO2) and brain temperature are measured with the Licox CMP Brain Tissue Oxygen and Temperature Monitor. The other physiological readings are then monitored using the Philips Intellivue system.

The data acquisition unit will first decode all signals from various monitoring systems, and it will further synchronize the data based on their time stamps. The collected data will be transmitted to the back-end database server through the wireless transmission network.

C) Data Storage:

A database is required to store various patient information, which includes demographic details, clinical data, physiological monitoring data and records of continuous treatment that patients have received during their stay in NICU. Since patients' data come from multiple sources, collected data must be integrated and synchronized. The back-end "Database" module is the centralized node of this system. Through the wireless transmission network, the database server receives continuous monitoring data from the data acquisition module and event data from the user interface module. The database server also collect patients' demographic data and clinical & treatment records from hospital's existing database. The database server integrates various types of patient data and stores it into a relational database. In particular, the database is implemented using Microsoft SQL server 2008. The integrated data is then feed to the computational intelligence module to support data-driven analytic tasks. The analytic results from the computational intelligence module will also be stored in the database server. Upon request, both collected data and analytic results will be transmitted, through the wireless network, to the user interface module for visualization and inspection. The database server stores multiple types of patient data from various data sources. All the collected data are integrated with respect to the patients' *Admission ID*. Note that, instead of *Personal ID*, *Admission ID* is used as the primary key to link up various data. This is because one patient may be admitted to the NICU for more than once and for different reasons. Only the *Admission ID* can uniquely identify one particular NICU stay of one patient.

The various types of collected patient data can be classified into three categories:

1) One-time data, e.g. demographic information and clinical records;

2) Continuous periodic data, e.g. continuously recorded physiological monitoring data and forecasting data;

3) Continuous episodic data - data that is continuously updated but on irregular basis, e.g. clinical treatment records, generated alters, diagnostic information. For, the continuous periodic and episodic data, time information is crucial, for, without the underlying time information, the data is meaningless. Therefore, the continuous periodic and episodic data are all coupled and synchronized with time stamps.

D) Data Transmission:

A data transmission network must be employed to transfer collected monitoring data to the database server. The transmission network must ensure collected data is transmitted reliably without any loss or distortion. The transmission network should also avoid any interference with other transmission network in NICU. A local wireless transmission network is proposed to support communication between the front-end and back-end modules of the proposed system. Wireless network is chosen to avoid laying of long data cables, which is time-consuming and cost ineffective, and to enable remote and centralized patient monitoring.

E) User Interface:

User interface of the system should allow clinicians and nurses to interact with the system and perform the following actions:

1) Real-time observation of patient monitoring data,

2) Review of historical monitoring data,

3) Record treatment details and clinical events, and, most importantly.

4) Visualize data-driven analytic & predictive results generated by the intelligent system.

Fig.3, Fig.4. & Fig.5 are the VB platform results of the patient in which the "User Interface" module communicates with the back-end database server through the local wireless network.

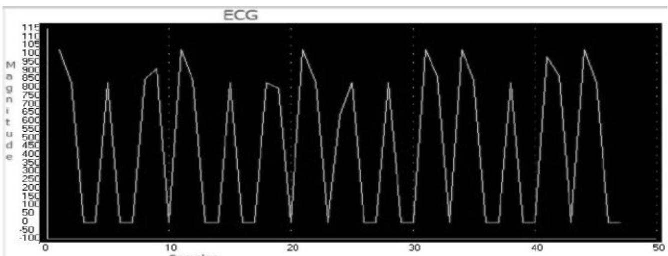

Fig.3-Information of Heart Beats

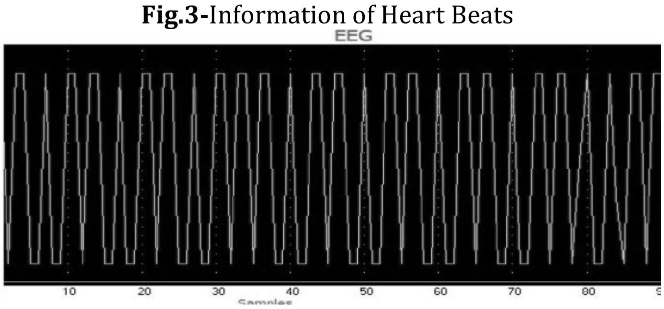

Fig.4- Information of Brain Waves

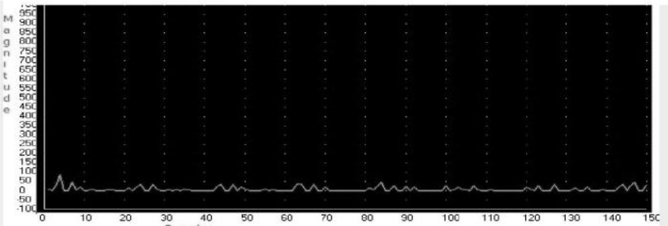

Fig.5-Information of SPO2

The user interface module sends various requests and input data to the back-end database server and receives monitoring data and analytic results from the back-end server. The user interface module is to be deployed in hand-held devices of clinicians and nurses. This enables remote and centralized patient monitoring, which greatly improves the labor efficiency in NICUs. Moreover, the user interface module also allows clinicians and nurses to review historical monitoring data, to record significant medical events and to visualize analytic and decision support results generated by the system.

The Graphical User Interface (GUI) of the system under the "real-time" view. In the real-time view, the main GUI window is split into 5 Data Visualization Panels. These panels allow clinicians and nurses to monitor 5 different physiological readings at the same time. Moreover, forecasted reading values are also displayed in the main visualization panel. This allows clinicians to observe the development trends of patients' physiological readings and get prepared if any dramatic changes are predicted. Besides the real-time view, users can switch to the "event" view and the "history" view. In the "event" view, users can review and edit the details of recorded events. All the recorded events coupled with their time stamp will be sent to the back-end database server for storage. In the "history" view, users can review and analyze the historical monitoring data of patients.

5 CONCLUSION

This paper has proposed an integrated and intelligent system, this system enhances the effectiveness of patient monitoring and clinical decision makings in NICUs. The requirements of the system were investigated through interviews and discussions with Neurosurgeons and Neuroclinicians. Based on the summarized requirements, this system is designed to be a modular system. This system integrates and stores patient information, which includes demographic data, clinical records, treatment records and multi-modal physiological monitoring data. This system also enables remote & centralized patient monitoring in NICUs. Moreover, data-driven predictive and analytic results from this system can be used to generate alerts for impending changes of patient's neurological and physiological status and to facilitate clinical decision makings. In short, with the help of this system, the efficiency of patient monitoring and treatment in NICUs can be greatly improved

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BIOGRAPHIES

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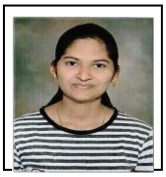

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