Review on Microcontroller based Anesthesia Machine

Akshay Sharma A S[1], Chetan Ravindra Kabade[2], Hitesh K B[3], Sourabh R[4], Bhanu H S[5]

[1]Akshay Sharma A S, Student, Department of Electronics and communication Engineering,Vidyavardhaka College of Engineering,Mysore, India
[2]Chethan Ravindra Kabade,Student, Department of Electronics and communication Engineering,Vidyavardhaka College of Engineering,Mysore, India
[3]Hitesh K B, Student,Department of Electronics and communication Engineering, Vidyavardhaka College of Engineering, Mysore, India
[4]Sourabh R, Student, Department of Electronics and communication Engineering, Vidyavardhaka College of Engineering, Mysore, India
[5]Bhanu H S, Professor, Department of Electronics and communication EngineeringVidyavardhaka College of EngineeringMysore, India

---

ABSTRACT: Anesthesia usage is very effective and common in most of the surgeries performed. The dosage of Anesthesia and the flow rate is usually determined by anesthetist. The aim of this paper has been to develop an automated system that delivers the precise amount of anesthetic drug at a desired flow rate by monitoring patient parameters like Heartbeat, body temperature, breathing rate, blood pressure. It is also crucial to analyze other parameters required for proper operations which also includes signal acquisition, signal conditioning, amplification. The prerequisites of this paper includes usage of microcontroller, heartrate sensors, pressure transducers, software like MATLAB, and also usage of reconfigurable devices like FPGA .The microprocessor used will analyze the data of the patient and the drug is injected at a particular rate by movement of a stepper motor. An alarm is also sounded whenever the drug in the syringe gets emptied.

Keywords:

Anesthesia, Heartbeat, Blood Pressure, Sensors. (key words)

1. INTRODUCTION

Anesthesia means without sensation or lack of sensation, which has 3 stages namely Hypnosis, Analgesia, and Immobility. Anesthetic drugs are used very much popularly for painless and hassle free surgeries and operations, but it is safe only when used in a right dosage and correct flow rate, else may cause complications and even death of a patient. Proper dosage and also proper flow rate are very important for easy and harmless surgeries. Usually the anesthesia dosages are estimated by anesthetists and also injected at a required flow rate by them, and also for long surgeries like open heart surgery, brain tumor removals. A single dose of anesthesia is insufficient and needs an additional dosage, which the anesthetist must be aware. Since there might be chances of overdoses, underdoes, an automated anesthetic injector can be used which takes over the job of an Anesthetist in the operation theatre.

Anesthesia is a state of controlled, temporary loss of consciousness or sensation that may be persuaded for medical purposes like operations. There are 3 stages of Anesthesia namely Hypnosis, Analgesia and Muscular Immobility. Hypnosis represents the degree of unconsciousness; Analgesia is basically the degree of suffered pain and Muscular Immobility is relaxing the muscles so that they do not contract or move while doing an operation. Anesthesia is of 3 types, Local anesthesia: Numbs only the required area to be operated, where patient stays conscious. Regional Anesthesia: Here, certain areas of the body like hands or legs are made insensitive to pain. It includes epidural, spinal Anesthesia. General Anesthesia: It makes the patient or the person to go completely unconscious. Anesthetics are generally introduced in the body intravenously or by inhalation. Commonly used types of drugs are Propofol, Sevoflurane, Ketamine, Methohexital, Amobarbital and Etomidate. Pain killers like Lidocaine, Morphine, Codeine, and Tramadol are also used during surgery to provide analgesic effects.

2. LITERATURE REVIEW

In this paper the main objective is to maintain the degree of unconsciousness a constant for a longer time [1]. Fuzzy Logic and Genetic Algorithms are used for adaptive drug infusions to patients. Fuzzy logic is defined as analysis of input variables in terms of logical variables. The components like temperature sensor, Blood pressure sensors, and Pulse rate sensor are used for analyzing the body parameters. The anesthetist enters the value of the drug to be infused using the keypad. The microcontroller used here is PIC165877, which analyses the bodily parameters and also reads the input from the keypad. The stepper motor is rotated to move the syringe back and forth to inject the drug. The alarm is also given whenever the drug in the syringe gets empty. Advantages include handling of interpatient and intrapatient variabilities,

fuzzy logic control gives active control of the level of anesthesia, infusion rates are also displayed here. Disadvantages are it doesn't show SpO2, Blood pressure, Temperature and cannot handle overdoses if any.

In this paper the anesthetic drug dosage is calculated using fuzzy logic considering the physiological parameters [2] like arterial pressure, Blood pressure, End tidal CO2. Here, fuzzy controller is used to control the mean arterial pressure, Cardiac output by drug administration like Dopamine, Sodium Nitroprusside, Phenylephrine which commonly increases the Cardiac output, decreases and increases blood pressure respectively, which uses mathematical model to mimic human cardiovascular system. The paper is mainly for inhalation and also the intravenous types. When the program is runned, it asks the patient's height, weight, and calculates the body surface area using formula $BSA(m^2)=[(Weight(inKg))^{0.425}*(height(incm)^{0.725}]/139.2$. The bodily parameters like Systolic BP, Diastolic BP, and body temperature is calculated automatically. The data is transformed into digital signals for the microcontroller using analog to digital converter(ADC) using the internal ADC of Atmega 32 microcontroller, these functions are done by one fuzzy controller and another fuzzy controller calculates the precise dosage required and also detects and gives messages for hypothermia and hyperthermia detection. Advantages include the best usage of anesthetic agent, improving the patient safety, carry out smooth infusions, makes best use of an anesthetic agent. Disadvantages include increased time delay, lesser precision, no displaying of bradycardia, tachycardia (Low and High heart rates), Hyperplexia (Very high fever of temperature of 106.7^{o}F or more). Major disadvantage is that lesser dosage is injected than actual needed dosage.

In [3], the objective is to use computer assisted drug delivery system to give best results in terms of recovery and also healthiness. Here an anesthesia regulation paradigm is used for detection and quantification of pain using mathematical model and hence control the drug regulatory loop for hypnosis control which is done using bispectral index which basically uses EEG (Electro Encephalo Gram) to determine brain activity which is 0 for unconsciousness and 100 for full consciousness which basically works by measuring skin impedance and also uses hemodynamic model with nociceptor stimulation. The value of extracellular and intracellular medium resistance is noted and accordingly the syringe pump is runned. Advantages include effective pain relief during surgery, usage of a safe noninvasive skin impedance method, usage of closed loop system rather than manual control which cross verifies unconsciousness from bispectral index (BIS). Disadvantages include need of proper technician, anesthetist to analyze level of hypnosis and give no warning signals.

In [4], the main objective is to monitor the sentience of patient by periodically observing various biological parameters, which are given to re-configurable device known as Field Programmable gate array (FPGA) reducing overdosages by effective observation and also parallel processing. The automated FPGA is used instead of a conventional microprocessor or controller as it has a greater parallel processing and hardware is very easily reconfigurable as required. Multiple biomedical signals like pulse, respiration, body temperature, EEG signals are obtained and monitored. These signals are analyzed by the FPGA and accordingly the syringe pump is runned to administer the drug to the patient. However the syringe infusion pump must be designed so that it distributes the drug in controlled fashion and since the parameters varies from patient to patient, the dosage required is entered into FPGA using a normal keypad. An alarm system alerts whenever the drug in the syringe gets emptied. The notable point here is that among the monitored biological parameters, Bispectral index obtained from the EEG is very much effective to monitor the consciousness and also the depth of anesthesia. In FPGA, unlike conventional processors, the logical array blocks are arranged according to the needs of the project, almost like emulation of hardware or software. Advantages include the reduction of overdosage due to parallel processing, monitors the biological parameters for better precision, gives an indication whenever abnormalities are detected like empty syringe. Disadvantage is presence of unwanted artifacts in EEG.

In [5], noninvasive technique is used where current pulses are used to numb a particular area instead of using anesthetic drugs, which uses a microcontroller based nerve locator to locate nerves in limbs of humans and also animals. The components used include a constant current source /sink using a pulse width modulation technique using OPAMP and Darlington pair. Boost converters are used to boost 9V DC supply to 100V DC supply using IRF540N Transistor. The pulse duration is decided by microcontroller which is 8 bit here in this case. An opto electrical circuit is used for open circuit detection to ensure that current is passed through patient. It also gives low battery indications in case of Battery operated system. The microcontroller used Is PIC16F877A with 368B RAM, 8KB flash memory, 10 bit ADC. A 20Kohm resistor is used to limit the current to 5mA. The pulses had rectangular waveform with small rise and fall time <1us with absence of overshoot and undershoot. Advantages includes Most functionality of nerve locator which is used extensively here, but on the counterpart the disadvantages are inaccurate current intensities at the values less than 1mA, lack of display for current intensity delivered, impulse duration and also impedance, Usage of an 8 bit microcontroller reduces the functional aspects

In [6], the system was basically designed for sevofluorane, a type of gaseous anesthetic agent used commonly by anesthetists, which has a lesser blood solubility and easier volumetric control during emergency operations and surgeries.

The depth of anesthesia is analyzed by measuring physiological parameters like blood pressure, heart rate. It works by recording the Blood pressure, heart rate and also rate of anesthetic drug flow for every 5 minutes. The membership functions an fuzzy logic's rule base are determined previously by specialists by following data base information. Here, the fuzzy logic works on if then conditions, which is equivalent to a PI controller, depending on the output the controller is either PI or PD controller s both derivatives and integrals are considered as input. The rules for the controller are made by a specialist or an anesthetist as several biomedical parameters are nonlinear in nature. The final output is controlling the depth of anesthesia by controlling the dosage of gaseous anesthetic drug. Advantages include better tracking of anesthesia depth using fuzzy logic, a simple 8 bit microcontroller can be used to obtain the required functionalities, biological parameters are recorded frequently, hence offers a better reliability, safety and accuracy in drug delivery. Disadvantage is it's maintenance cost since Sevofluorane is highly volatile and requires special type of storage.

In [7], an EEG based processor is used to analyze the Anesthesia Depth during the operation period. It uses Machine learning for extracting the original features of patients. The decision taken by the processor is based on 7 features of EEG signals and also removes the EMG artifacts which corrupt the original EEG. For efficient feature extraction 128 point Fast Fourier Transform which achieves reduction in area and also energy by 39 percent and 58 percent respectively. The workings is basically recording the EEG, extracting the 7 features of EEG and reduces or remove the EEG artifacts by using Machine learning, 128 point FFT algorithm is used for data compression. The compressed or reduced dataset is compared with the original and decision tree is used to perform classification of the anesthesia depth, initially the system was synthesized on 65nm technology and implemented using FPGA. Advantages include Data compression techniques which improve energy saving and accuracy, Anesthesia Depth is analyzed perfectly. Disadvantages include poorer Depth of anesthesia (DoA) classification, with more latency when compared to other anesthesia depth analyzing systems. The system is quite complex since usage of machine learning and 128 points FFT is complex itself.

In [8], the objective is development of a system for monitoring the depth of anesthesia using middle latency auditory evoked potential(MLAEP), an evoked potential is response in an electrical potential in specific pattern recorded from specific parts of the brain when a stimulus like sound or light flash is applied to the eyes and ears respectively. The PIC microcontroller is given a low level control and data is sent through serial link to PC where data processing is done by MATLAB software. An auditory evoked potential is generated by giving an audio pulse using headphone or earphone. The signals are detected using 3 electrodes mainly Cz as signal source, mastoid as reference and forehead as ground. The signals obtained are amplified using amplifier having CMRR>110dB and frequency response of 100Hz, electrical impedance of the electrode is carried out for every 10 epochs. A moving window representing 8 traces was applied to the auditory evoked signals ,where an variable span near real time Finite Order filter (VSNFIR filter) with an adaptive nose cancellation abilities were used. The data is sent to a standard PC using UART link, where the PC performs the filtering operations. The code was successfully implemented using 16F series microcontroller coded in a standard C language code. Here, each output is weighed sum of the input signals; hence we have greater performance for greater number of variables. Other software also includes Active X, Dynamic Link library. The user interface plotted the Level of arousal score (LAS) which was basically used to measure the consciousness of a particular patient or subject. Advantages include Use of adaptive harmonic filters for noise cancellation which is very much useful, and also uses EEG in certain region of brain, which gives correct estimation of the region of brain stimulated. Disadvantages include inclusion of ECG and other artifacts even though adaptive filters are used, the results may vary from lab to actual tests.

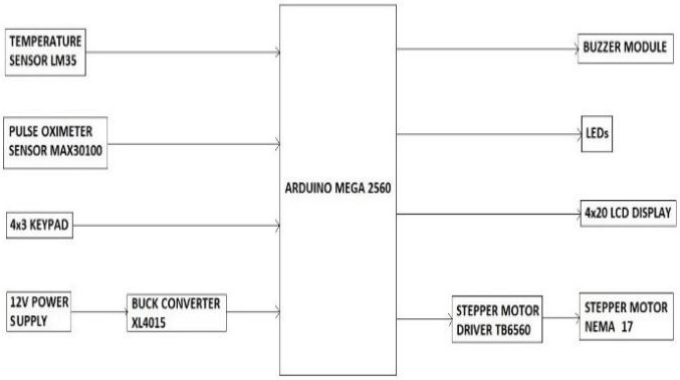
In [9], the main objective is to create a microcontroller based anesthesia injector that takes the input from anesthetist, the dosage of drug required for a particular patient and also analyze the biological parameters like heart rate, body temperature, blood pressure to regulate the drug flow. Since, a small misinterpretation of dosage of anesthetic agent or drug can lead to complications and also eventually death of a patient, all these parameters are correctly analyzed here. The working is very simple; it uses sensors like heart rate, respiration, temperature sensors, whose signals are converted into digital form for the microcontroller. The keypad is used by the anesthetist to set the dosage of anesthetic drug to be injected to a patient in mL per hour. After analyzing the biomedical parameters of a patient including body temperature, heart rate, etc, the stepper motor is controlled to move in both the front and backward direction and causes the syringe to be moved forward and inject the drug to patient. If the drug gets emptied, then alarm is given and also opposite blood flow will be detected. The microcontroller that is used here is Atmel 89C51, a simple 8 bit microcontroller with 4KB ROM, 256B RAM, external interrupts, timer interrupts and also serial port interrupts. ADC used is ADC0808/09 for analog to digital conversion. Advantages include High accuracy, excellent temperature dependence and also minimal power consumption of the setup. Disadvantages include the requirement of technical expertise, and also an anesthetist to continuously monitor the setup or the injector.

In [10], the objective is to design a method for intelligent noninvasive method of monitoring the anesthesia machine. The system consists of data acquiring terminal, a communication module and PC monitoring platform. The data collection terminal uses MSP430F149 microcontroller as the central control center consisting of power supply, reset, airway pressure detection, oxygen concentration and flow detection module in the system, where a simple C language code is used to control signal acquisition, processing, and initializations. These monitored data is sent to the monitoring platforms using serial ports for recording and analysis. The specified protocol data is confirmed to be received from an upper layer protocol and then data is detected from the sensors. If the parameters are okay, then only the data is sent constantly, else an interrupt will trigger an alarm whenever the parameters are not in the designated values. Advantages include usage of XML Http request and server sent event technologies which realize the expert diagnosis. We also get an effective non invasive anesthesia machine monitoring and also controls the concentration of drug injected successfully. Disadvantages include the lesser physiological parameters that are noted down and also lesser technological content.

In [11], the objective is both controlling and monitoring of the depth of anesthesia. Here a neural network is developed along with the usage of fuzzy logic controller for a nonlinear and compartmental system for having a closed loop drug administration control. The above method is desirable for noncardiac type surgeries. The working uses large time varying values of a patient during the entire duration of the operation. Neural network and fuzzy logic work together creating an ideal framework for adaptive controllers. While other methods use BIS (Bi spectral index) for measuring the level of anesthesia, this on the other hand uses generalized predictive control algorithm along with fuzzy logic control using the mean arterial pressure (MAP) to deliver isoflurane, a volatile anesthetic drug. But the level of hypnosis is analysed using BIS in the paper mentioned. A compartmental model and neural network design based radial basis function and fuzzy controller work hand in hand to control the anesthesia depth in a surgery. Advantages include the reduction of drug utilization and also reduce the reversal of drugs needed in an operation. Disadvantages are that this method is only useful for a noncardiac based surgeries, which cannot be used for heart or heart related operations, classification is slow and also each Radial Basis Function (RBF) contains a hidden layer beneath, which also must not be ignored an must be calculated.

In [12], the depth of anesthesia is analyzed using an artificial neural network and back propagation algorithm to simulate a model of patient under the influence of an anesthetic drug by performing regression analysis of the surgical data. An artificial neural network is computing systems inspired by the biological neural system constituting the animal brains. Regression analysis is a statistical process, which is used for estimating the relationship between a dependent and an independent variable often referred as outcome variables and predictors or features respectively. The back propagation algorithm is supervised ANN learning phase which uses a gradient descent to produce a gradient of the error function for a given error function. The working is very much simple; the Back propagation algorithm has an initial learning phase used to train the program. The algorithm produces multiple layer for example an input, output and hidden layer. The error is simply is the function that defines the difference between the actual output and network's present output. To get the required results, weights of the links are established by continuously adjusting the error function by back propagating the error values for the output. The adjustments are calculated using derivatives of hidden function used to adjust weights of the output layer. Due to weight adjustment, the internal hidden layers represent features of the task domain; the task is completed by interaction between these units. The result of back propagation and nonlinear regression are developed. The drug controllers are usually connected to other programs that model the patient using the techniques like ANN or regression analysis. Advantages include use of ANN for modelling the patient, which gives an equivalent comparison of human under anesthetic without actually doing human trails. The setup used here is more robust and gives very high performance efficiency. Disadvantages include the lack of equivalent comparison, only a part of comparison is provided by the algorithm. Another potential disadvantage is that it doesn't consider the patients under influence of other drugs like morphine or other related painkiller drugs.

3. METHODOLOGY



Temperature sensor LM35 and Pulse Oximeter sensor MAX30100 are used to measure temperature and pulse and oxygen saturation of a patient respectively. A Keypad is used to enter the parameters such as weight, age, blood pressure and dosage of an anesthetic drug that should be injected to a patient. Buck Converter is used for driving a load of 5V from 12V. Arduino Mega, a microcontroller board is used to calculate the dosage of an anesthetic drug and to control the whole operation of anesthesia. The output is seen using a stepper motor NEMA 17, which in turn moves the syringe fixed to it and the pulse, drug dosage, age, blood pressure parameters are visualized on Liquid Crystal Display (LCD). It displays error message; buzzer is activated and red Light Emitting Diode (LED) glows when an interruption in the process is found. The Stepper Motor Driver TB6560 is used for axis control of stepper motor.

4. RESULT & DISCUSSIONS

In the above paper, the microcontroller development platform Arduino Mega 2560 is used along with LM35 Temperature sensor, MAX30100 Pulse oximeter, Keypad for entering the weight, height and blood pressure is entered manually. The output will be seen using a stepper motor which in turn moves a syringe to inject the anesthetic drug properly at a pre-defined rate for a proper and safe surgeries. A buzzer is used in order to indicate an empty syringe during an operation. Testing of the components for proper working is done to ensure it's proper functionality. Arduino Mega is tested by making a simple LED glow, Temperature sensor, stepper motor, buzzer were also tested.

5. CONCLUSION

From the above paper, the things to be noted is that proper flow rate of anesthetic drug can be achieved only if all the biomedical parameters are recorded, analyzed, and interpreted properly. The factors that hurdles the signal acquisition must be filtered out by signal conditioning techniques like FIR Filtering using MATLAB or by using hardware filters and amplified for microprocessor analysis. The microcontroller must be programmed to analyze the parameters and decide the required flow rate accordingly. The method of analysis and the algorithms used to program the processor is also dependent on the proper flow rate achievement and also for monitoring and control purposes.

6. REFERENCES

1. D Hemapriya, K Amrudha Shree, S Deepika, R Karthiyayini "Feedback Control approach in Controlled Sedation for Intensive Care Unit", IEEE international conference on innovations in green energy and healthcare(ICIGEHT), 2017.
2. D Y Pawade, T S Diwase, T R Pawade "Designing and Implementation of Fuzzy Logic Based Automation System to Estimate dose of Anesthesia" Confluence 2013,the next generation information technology summit(4th international conference), 2013.
3. Clara M Ionescu "Computer assisted drug delivery for general anesthesia: Completing the puzzle" SAMI, IEEE 17th World symposium on applied medicinal intelligence and information, 2019
4. Deepfranklin P, Krishnamoorthi M "Monitoring multiple biomedical parameter to
5. automate anesthesia injector using FPGA" 2nd international conference on computer, communication and Signal Processing (ICCCSP), 2018
6. H A Alzomor, B K Ouda "Low cost, Compact and Pulsated Constant Current Microcontroller based Nerve Locator", Cairo International Biomedical Engineering conference (CIBEC), 2012
7. A Yardimci, A Ferikoglu ,N Hadimioglu "Depth Control of Anesthesia with Microcontroller based Fuzzy Logic System", Proceedings of 23rd Annual EBMS International conference, 2001.
8. Ashra, Muhamma Awais Bin Altaf, Wallah Saadeh "A patient-specific machine learning based EEG processor for accurate estimation of Depth of Anesthesia", IEEE Biomedical Circuits and system conferences (BioCAS), 2018.

9. A C Fisher, A F G Takatk, G.Sidaras, A.G.Jonesand S.M.Mostaf "Deriving a real time depth of anesthesia index from the middle latency auditory evoked potential (MLAEP)" IET 3rd international conference MEDSIP advances in medical signal and information processing, 2006.
10. Engr Rana Muhammad Shakeel "Microcontroller based anesthesia injector" 2007
11. Ming Huang, Zhenjuan Zhang "Design and Implementation of the Anesthesia Machine Monitoring System", 8th international conference on biomedical engineering and informatics (BMEI) 2015.
12. N Engshi, M Aliyari, M Tehshenlab "Anesthesia Control based on Intelligent Controllers" IEEE 978-1-4244-2902, 2009.
13. D A Linkens, H U Rehman "Nonlinear control for anesthesia depth using neural network and regression" Proceedings of IEEE international symposium on intelligent control, 1992.

AUTHORS

Akshay Sharma A S, is a student of Vidyavardhaka College of Engineering, Mysuru, Karnataka. He was born on 6th of June, currently pursuing bachelor of engineering (B.E) Degree in Electronics and communication from Vishveshvaraya Technological University, Belagavi, Karnataka, India. Power Electronics and Networking is his area of interest.

Chetan Ravindra Kabade, is a student of Vidyavardhaka College of Engineering, Mysuru, Karnataka. He was born on 17th of March, currently pursuing bachelor of engineering (B.E) Degree in Electronics and communication from Vishveshvaraya Technological University, Belagavi, Karnataka, India. Internet of Things and Blockchain Technology is his area of interest.

Hitesh K B, is a student of Vidyavardhaka College of Engineering, Mysuru, Karnataka. He was born on 5th of August, currently pursuing bachelor of engineering (B.E) Degree in Electronics and communication from Vishveshvaraya Technological University, Belagavi, Karnataka, India. . Instrumentation and Digital electronics is his area of interest.

Sourabh R, is a student of Vidyavardhaka College of Engineering, Mysuru, Karnataka. He was born on 21st of July, currently pursuing bachelor of engineering (B.E) Degree in Electronics and communication from Vishveshvaraya Technological University, Belagavi, Karnataka, India. Printed Circuit Board and Augmented Reality is his area of Interest

Bhanu H S, is an Assistant Professor at Vidyavardhaka College of engineering. She was born on 25th of February, completed her Bachelor of Engineering in Electronics and communication at Ghousia College of Engineering, Ramanagara from Vishveshvaraya Technological University, Belagavi, Karnataka in the year 2016. She has also completed her M.Tech in Biomedical Signal Processing and Instrumentation at Sri Jayachamarajendra College of engineering (SJCE), Mysuru from JSS Science and Technology University(JSSTU), Mysuru ,Karnataka in the year 2018. Her areas of interests are Signal Processing, Electronic Devices and Communication.