International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

A Novel Approach in Surgical Management, for Anesthesia Controlling

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Abstract: ***Modern Medical science has shown the usage of Engineering in medical applications. Many Surgeries will require anesthesia applying to the patient to reduce/prevent pain during surgery. In several situations it is not possible to have anesthesiologist during surgery, and moreover the presence of anesthesiologist will increase the cost of the surgery. It is inevitable to apply anesthesia during surgery. In this paper we propose a method for automatic injecting of anesthesia into patient body based on his/her response to the anesthesia drug dose.***

Keyword: ECG, EEG, BIS, HR, RR Tachycardia, Bradycardia & Labview

1. Introduction

Assessment of depth of anesthesia is fundamental to anesthetic practice. Depth of anesthesia depends on mainly two factors; one is type of the compound, degree of anesthetic drug amount used, and other is response of the patient to the injected amount of anesthesia. In history, many people defined anesthesia in many ways; we define here, in simple manner it is defined as a substance which is used to prevent the pain of the patient by temporary disabling of some/few sensory organ system of human body [1].

Since anesthetic drug disables the sensory system of the patient temporary, so small over-amount of drug than threshold can induce a damage to organs of patient, also can potentially lead to patient death. Even the small less quantity than threshold can cause the pain for the patient, which can cause abnormal mental behavior of the person will impact surgery efficiency [3].

The threshold amount of the drug is different based on several factors, like age, sex, patient condition, compound used for the anesthesia. An expert like anesthesiologist is very essential for any surgery to inject anesthesia into body. Many times complete amount of the drug dose won't be applies in single shot, rather than applied in multiple times for a long time surgeries like which continues for beyond 3-4 hours.

To overcome such hazardous problems, in this paper we proposed an automatic intelligent system which inject the given drug of anesthetic compound into patient body by continuously monitoring patient response.

2. Problem Description & Priory Work

Anesthesia controlling can be done effectively by monitoring few key parameters of patient. In general Anesthesia state can be measured using a metric called BIS (Bi spectral Index). BIS Index is a processed EEG parameter with extensive validation and demonstrated clinical utility. It is derived by utilizing a composite of measures from EEG signal processing techniques including bi-spectral analysis, power spectral analysis and Time domain analysis. These measures are combined via an algorithm to optimize the correlation between the EEG and the clinical effects of anesthesia, and quantified using the BIS Index range.

In 1996, the U.S. Food and Drug Administration cleared the BIS Index as an aid in monitoring the effects of certain anesthetic agents. In 2003, the Food and Drug Administration cleared an additional indication which states: "Use of BIS monitoring to help guide anesthetic administration may be associated with the reduction of the incidence of awareness with recall in adults during general anesthesia and sedation". The use of BIS monitoring to guide anesthetic administration and monitor patient status is a clinical decision. It is the responsibility of each clinician to make clinical practice decisions that are in the best interest of the patient.

Today, the BIS Index remains the most validated form of consciousness or brain function monitoring used within the clinical context of anesthesia and sedation care [2,3]. BIS Index values are the result of two particular innovations: bi-spectral analysis and the BIS algorithm. Bi-spectral analysis is a signal processing methodology that assesses relationships among signal components and captures synchronization within signals like EEG. By quantifying the correlation between all the frequencies within the signal, bi-spectral analysis yields an additional EEG factor of brain activity.

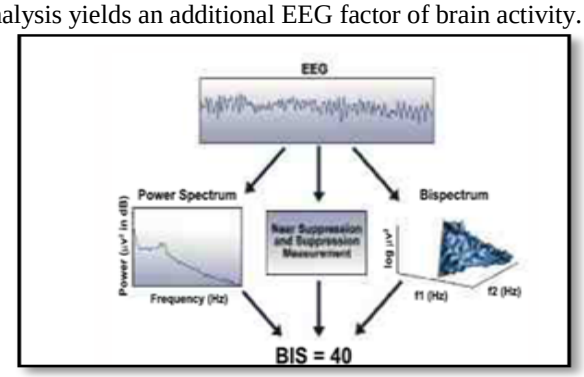


Figure 1: The BIS algorithm, developed through statistical modeling, combines the contribution of each of the key EEG features to generate the scaled BIS Index

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The BIS algorithm was developed to combine the EEG features (bi-spectral and others) which were highly correlated with sedation/hypnosis in the EEGs from more than 5,000 adult subjects. The four key EEG features that characterized the full spectrum of anesthetic-induced changes were the degree of high frequency (14 to 30 Hz) activation, the amount of low frequency synchronization, the presence of nearly suppressed periods within the EEG, and the presence of fully suppressed (i.e. isoelectric, "flat line") periods within the EEG [2,3]. The algorithm enables the optimum combination of these EEG features to provide a reliable processed EEG parameter of anesthetic and sedative effect – the BIS Index (Figure 1). The BIS Index is a number between 0 and 100 scaled to correlate with important clinical endpoints and EEG states during administration of anesthetic agents (Figure2). BIS values near 100 represent an "awake" clinical state while 0 denotes the maximal EEG effect possible (i.e., an isoelectric EEG).

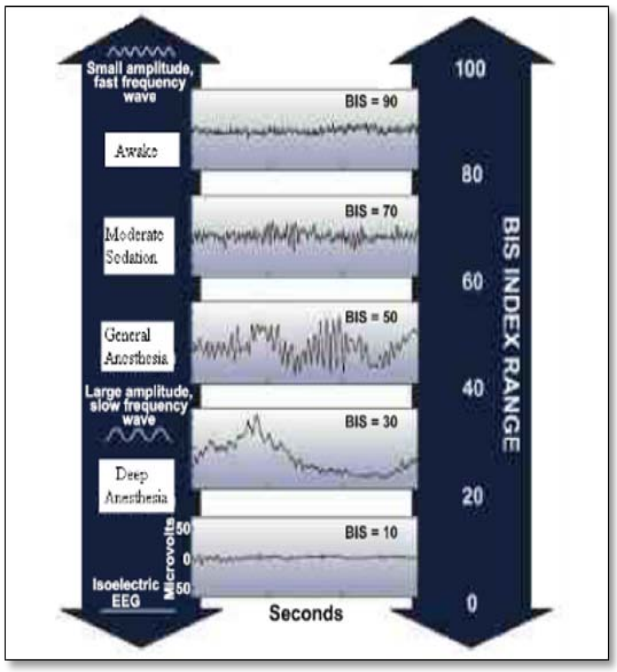


Figure 2: The BIS Index is scaled to correlate with important Clinical endpoints during administration of anesthetic agent

Since usage of BIS index is a difficult parameter for a small scale surgeries, hence we propose a novel method for small scale surgeries using monitoring of heart rate (HR), body temperature and respiration rate (RR).

3. Proposed Solution

In this paper we propose an algorithm which takes different vital signs as input and detects the response of the patient based on that the Anesthesia will be injection will be turned on or off. Vital signs are nothing but the Heart Rate (HR) measurement, Respiratory Rate (RR), and temperature of the patient body.

A. Heart Rate (HR) Measurement

Heart rate monitoring is performed by using pulse oximetry. The principle of pulse oximetry is as follows, "difference in absorbance of the IR signal by passing through the oxygenated blood as shown in figure 3. The Volume of the blood flowing through arteries varies during each heart-beat. Hence infrared radiation is incident on it, the absorbance of IR also varies according to heartbeat. These variations are determined by placing photo detector at receiver end [4].

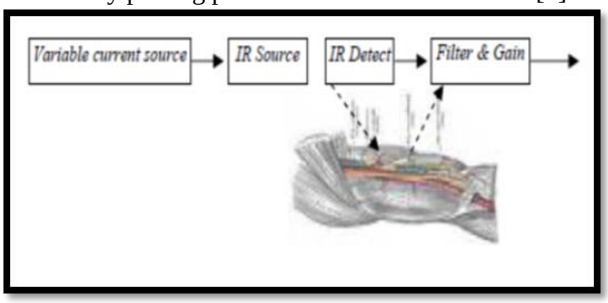


Figure 3: Principle of HR measurement

The received signal from photo detector will be passed through signal conditioning circuitry, as shown in figure 4. The o/p of the signal conditioning circuit is given to DAQ system to measure the analog voltage. The o/p signal, average voltage is 120mv, when it passed through oxygenated blood the signal undergoes for attenuation becomes 70-80mv.

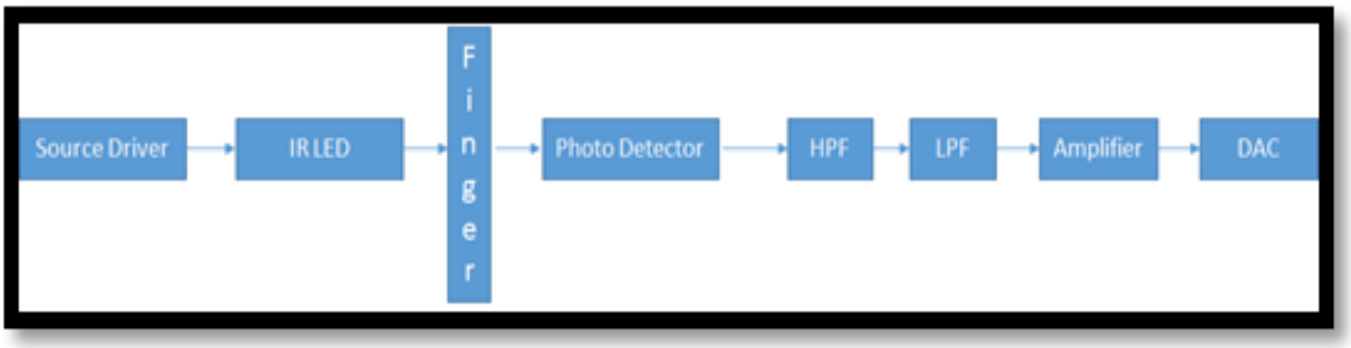


Figure 4: Block diagram of HR measurement

B. Temperature and Respiratory Measurement

TMP100 temperature sensor is used for the respiratory measurement. Principle here is temperature of the body will vary for every inhale and exhale during respiration by nasal activity. Change in temperature will be very small (~0.5^{o}C), hence we had used a high precision temperature sensor. TMP100 sensor is interfaced to NI USB 8451 through I2C interface.

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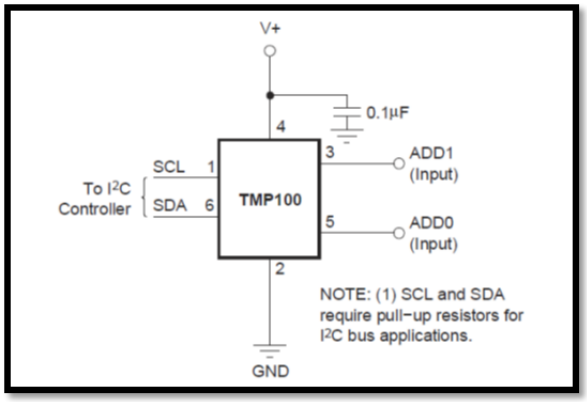


Figure 5: TMP100 temperature sensor

TMP 100 provides 9-12 bits of output, which can be interpret as a temperature by selecting the output resolution through Configuration register. Below we explain the internal register organization of TMP100. It consists of Pointer Register, Temperature register, Configuration register, T_{Low} register, T_{high} register and I/O control interface for I2C as shown in figure 6.

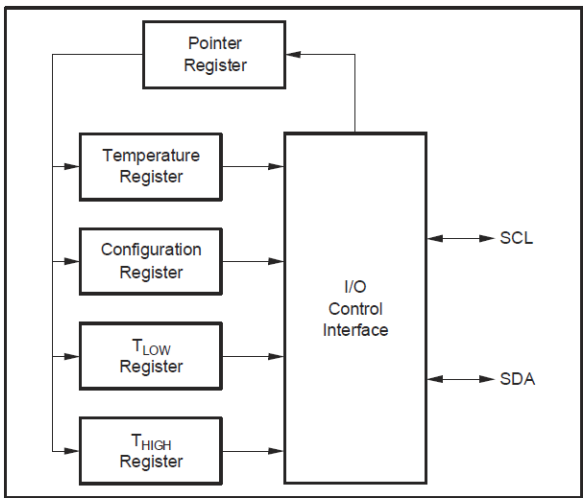


Figure 6: Internal structure of TMP100

TMP100 is configured to output of 12-bits using configuration register. The resolution of the output bits is 0.0625^{o}C per step. The maximum temperature (128^{o}C) can measured as 0111 1111 1111 bits from the Temperature register.

The temperature measurement of the body is given by Let **"T"** be temperature of the body and **"O_c"** output bits in decimal value [5, 6];

$T = O_c * 0.0625$ (^{o}C)

Respiratory measurements can be done using the difference in temperature. If the temperature difference is ~0.5^{o}C indicates the process of breathing. Read the temperature for temperature & respiratory measurements at sampling rate of 1 KHz [7].

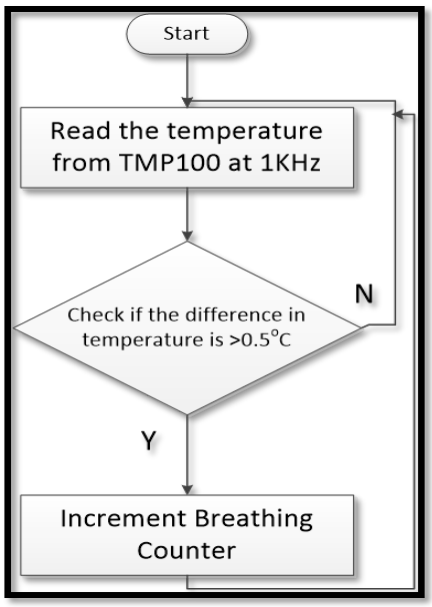


Figure 7: Flow chart for respiratory measurement

C. Algorithm for Controlling Anesthesia Syringe Infusion Pump Motor

In this section we will discuss about the how we control the Anesthesia syringe infusion pump motor, for the simplicity we assumed DC servo motor, similar to infusion pump motor. Heart rate in normal healthy persons will be given below in the table vs age [8].

Age	HR (Bpm)
<1 year	80-160
1-3 Years	80-130
3-5 Years	80-120
5-7 Years	75-15
7-10 Years	70-110
>10 years	60-100

The normal heart rate in adults is 60-100. Abnormal heart rate can be caused due to several factors during surgery. Typical medical names for the abnormal heart rate are **Tachycardia** (heart is beating too fast at rest usually over 100 Bpm) and **Bradycardia** (heart is beating slowly at rest less than 60Bpm). When a person is under sleep condition the heart rate will be less compared to normal HR (usually close to 50). If the HR is over 120, then it is treated as serious condition as per the medical science. Temperature of the body under normal conditions is given as 37^{o}C or 98.4^{o}F. The abnormal temperature of body and their consequence are given below [9].

Temperature (^{o}C)	Effect
44	Almost Death, patient can sometimes survive up to 46.5
43	brain damage & cardio collapse
41-42	Very fast heart rate, Fainting
38-40	Severe Sweating, dehydration headache
37	Normal temperature
36	Mild shivering , may be normal temperature
34-35	Intensive shivering, Heart irritability
29-33	very slow heartbeat & loss of memory
28	Breathing stop, almost Death

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Respiratory rate (RR) of the normal person is listed as 12-17 beats per minute. If the RR is above 20 bpm it is treated as Tachypnea and RR is below 10bpm it is called as Bradypnea.

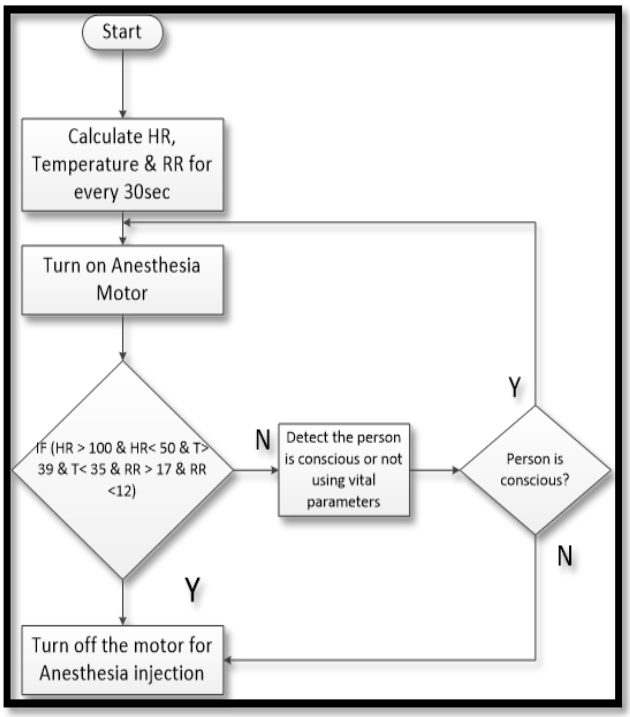


Figure 8: Algorithm to control pump motor

4. Real Time Implementation

In this paper we implemented a prototype for the real time implementation. The Heart rate is acquired pulse oximetry principle by using an analog input of USB NI DAQ 6289, the output bits of the TMP100 is acquired using USB NI 8451[10] and the output syringe infusion pump (DC Servo motor) is controlled using Analog output through H-Bridge [11]. Software program written in Labview acquires the HR, temperature & RR data and calculates the control for Servo motor configuration.

5. Conclusion

In this paper we proposed a novel method to control the anesthesia infusion pump based on the measured real time response of a patient. The algorithm here handles the case of a normal person, whereas this can also be improved by adding more data set of the vital parameters to control the anesthesia dose.

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