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Research paper

Automatic anesthesia regularization system (AARS) with patient monitoring modules

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Abstract

The administration of high/low dose of anesthesia during surgery may cause lethal effect to the patient. To avoid such situation, the anesthetist administers few milliliters of anesthesia at regular intervals to the patient. To overcome such tedi-ous problems, this project aims to design an effective microcontroller based automatically operated anesthesia machine. In the proposed Automatic Anesthesia Regularization System, anesthesia level is controlled by multi-task feedback and microcontroller system, based on patient's condition. The Automatic Anesthesia Controller designed using microcontroller aids to control anesthesia levels during the course of surgery. Mechanical syringe infusion pump is provided to deliver an-esthesia to the patient. The anesthetist can set the keypad to administer the dose of anesthesia in terms of milliliters per hour. The keypad transmits the analog signal to the microcontroller to control the required dose of anesthesia to be fed into DC motor to operate injection pump. The anesthesia was administered based on patient's body condition and movement of syringe in the forward or backward direction based on the rotation of DC motor. This module will play a major role in the field of medicine and useful to the physicians during major surgery to provide the desire amount of anesthesia.

Keywords: *Anesthesia; Automatic Regularization System; DC Motor; Infusion Pump; Microcontroller*

1. Introduction

A patient must be anesthetized before any major surgery by the doctors to start their surgical procedure. In case of major surgeries which could take upto 4 or 5 hours, the complete dosage of anesthesia could not be administered in single dose to patient. Since excess dose may cause critical condition to the patient which could lead to permanent unconsciousness (Misal et al 20016). To overcome this problem, the anesthetist need to designed automatic direction of anesthesia based on clinical parameters of patient to minimize future side effects. Anesthesia is very much essential to carryout painless surgery so an automatic direction of anesthesia is essential for a successful surgery (Hanumant Vani et al 2014). At present in clinical practices an anesthetist employs manual system of anesthesia administration to the patient. This may originate many complexities such as, dose of anesthesia getting varied and chances of getting adverse side effects in future life. Moreover anesthetist may fail to administer the accurate dose of anesthesia for the period of the predestined time which might be disturbed the patient during surgical procedure. The anesthetic processes are recurring and require keen attention of the anesthetist is always human errors. The incidence of error is drastically reduced due to automatic mechanism of drug administration. In this context there is a need to automate the processes related to anesthesia to minimize human error, disturbance from routine repetitive activities could be minimized and anesthetist may have more time to take direct care to patient (Kraft and Lees 1984).
Nowadays embedded system is used in many applications in medical industries to control various biological and biomedical parameters. Microcontroller is used to regulate the anesthesia machine automatically depending upon the various clinical parameters such as body temperature, heart rate and respiration (Manikandan et al 2013). The system investigates various clinical parameters obtained from the sensors to decide the direction of rotation of the DC motor. The rotary motion of the DC motor initiate the Infusion Pump to move in forward and backward direction and the anesthesia supplied in the syringe is injected to patient's body. Embedded based systems are applied in many applications in medical field for controlling various biomedical signals, biomedical parameters and monitoring patient's health (Durgadevi and Anbananthi, 2014). In the present design, micro-controller is used to control the anesthesia machine automatically, based upon the diverse biomedical parameters such as heart rate, body temperature, respiration rate etc., The main aim of this project is to control the drug injection speed depending upon the patient's state during the surgical procedure. The main reason for automating is the administration of anesthesia is to relieve the anesthesiologist so that they can dedicate their attention to other tasks as well fluid balance, ventilation, drug application etc thus to increase the patient's safety. The dosage given manually by doctors at times may vary from its standard value and result in ill effects on the patient. In order to achieve efficient injection of anesthesia by automatic anesthesia controller, the heart beat sensor plays an important role which takes into account the heart rate of the patient and injects anesthesia accordingly reducing the work of the doctors.

1.1. Embedded system

Embedded system is a special type of computer system designed to perform one or few functions, often with real time computing constraints. It is usually composed as part of a complete device including hardware and mechanical components. Embedded systems read data from input sensors and provide several functions to monitor the environment. This data finally processed and the outcome is displayed in digital format to the users. Embedded systems classically execute applications such as finite state machines,

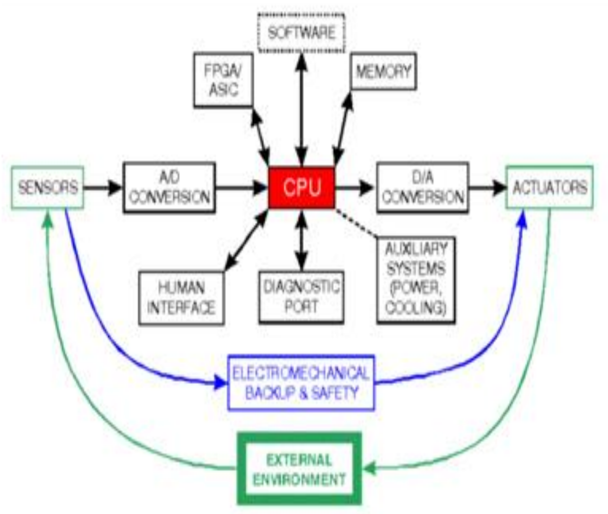

Fig. 1: Block Diagram of Embedded System.

Control laws, and signal processing algorithms.
Block diagram of typical embedded system is displayed in figure 1. An embedded system usually.
Contains an embedded processor and digital interface. Some of the embedded system includes operating systems. Others are very specialized implemented as a single program. These systems are embedded into some tool for some specific function to provide general purpose computing. Embedded systems are characterized by a unique set of characteristics. Each of these characteristics compulsory have a specific set of design control on embedded systems designers. The challenge to designing embedded systems is to conform the specific set of limitation for the application. Embedded system designs are characterized for a specific application. Many of the performance analysis characteristics are known prior to the hardware is designed. Some embedded systems require the flexibility of reprogram ability of digital signal processing.

2. Materials and methods

2.1. Proposed method

In the present proposed system, microcontroller based system is used for injecting the drug to maintain the level of anesthesia administered to the patient. The dose of anesthesia must be known in advance, as a predefined value is programmed as input for the anesthetic control. The actual dose of anesthesia is predetermined based on the body temperature, heart beat and respiration rate of the patient. The microcontroller is programmed using embedded system to regulate the dose of anesthesia.

2.2. Sensors

The heart beat sensor, respiration sensor and the thermister (473) are used to sense the heart beat, respiration and temperature of an individual respectively. These sensors give corresponding analog values to signal conditioning. Signal conditioning circuit gives the binary value to the microcontroller depending on the controller drives motor. Syringe placed in motor will inject the drug to the patient based on the patient's body condition.

2.3. Automatic anaesthesia regularization system

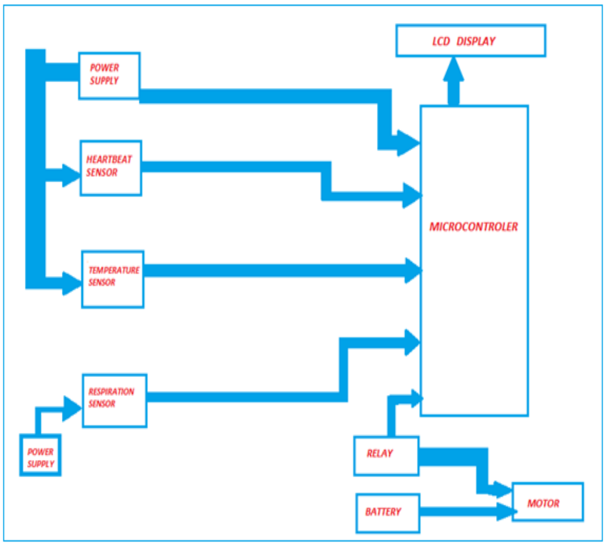

Fig. 2: Block Diagram of Automatic Anesthesia Regularization System.

2.4. Working technology

Anesthetist can determine the dose of anesthesia to be governed to the patient in terms of milliliter per hour ranging from 1ml to 1000ml using keypad provided along with the microcontroller. After getting the anesthesia level from the keypad regulator, the microcontroller set the system to administer anesthesia at the previously prescribed level of drugs. This dosage analyses various based on biomedical parameters received from the sensors to determine the direction of revolution of the DC motor. The revolution of the DC motor induces the infusion pump to move in forward or backward direction. The anesthesia loaded in the syringe is injected into the patient's body.

3. Hardware requirement

3.1. PIC16F877A microcontroller

Microcontroller integrates a number of components of a microprocessor system onto single chip. It has inbuilt CPU, memory and peripherals to make it a mini computer. The heart of the microcontroller is the CPU core. A microcontroller combines onto the same microchip with CPU, memory (both ROM and RAM) and parallel digital i/o. Microcontrollers also combine with other devices such as timer module allow performing tasks for certain time periods. Serial I/O ports allow the data to flow between the controller and other devices such as PIC or another microcontroller. An ADC to allow the microcontroller to accept analogue input data for processing. The specifications of pin description of PIC 16F877 is presented in Table 1.

Table 1: Specification of PIC16F877

DEVICE	PROGRAM FLASH	DATA MEMORY	DATA EEPROM
PIC 16F877	8K	368 Bytes	256 Bytes

3.2. Memory organization

There are three memory blocks in each of the PIC16F87XA devices. The program memory and data memory have separate buses to access concurrently. Additional information on device memory is found in the Pismire® Mid-Range MCU Family Reference Manual (DS33023).

3.3. Program memory organization

The PIC16F87XA devices have a 13-bit program counter capable of addressing 8K word x 14 bits of flash program memory space. Accessing a location above the physically implemented address will cause an envelope around. The reset vector is at 0000h and the interrupt vector is at 0004h.

3.4. Temperature sensor

LM35 temperature sensor is employed to detect the body temperature in the present study. The LM35 series are accuracy integrated circuit temperature sensor, output voltage is linear proportional to the temperature in Celsius (Centigrade). The LM35 devices have advantage over linear temperature sensors calibrated in degree Kelvin. The LM35 does not need external calibration to provide typical accuracies of $\pm 1/4^\circ$ C at room temperature and $\pm 3/4^\circ$ C over temperature range of from −55 to +150°C. It can be operated by single power supplies. LM35 sensor is appropriate for remote application and cost effective due to wafer level trimming and operates from 4 to 30 volts. The LM 35 temperature sensor wired on a circuit board is depicted in fig 6. The white wires go to the power supply. The resistor and the black wire go to the ground. The output voltage would be measured from the middle pin to ground.

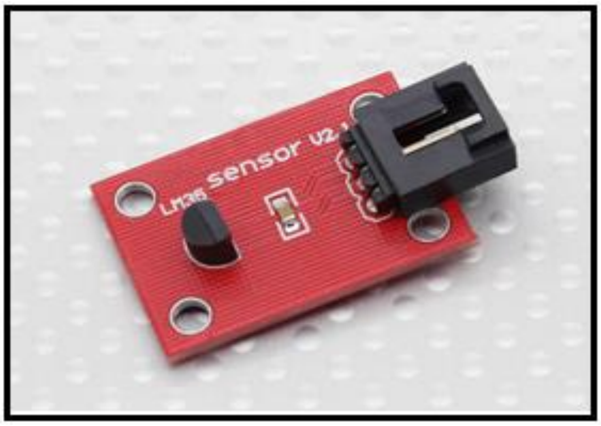

Fig. 6: Temperature Sensor.

3.5. Heart beat sensor

The heart beat sensor is made to shine an infrared led through patient's finger. The infrared sensor on the other side can pick up slight changes in the light transmittance through finger when blood is pumped. The device composts of an infrared (IR) transmitter LED and an infrared sensor phototransistor. The transmitter sensor is clipped on any one of patient's finger. The fixing position of the heart beat sensor is displayed in fig 7. The LED bombards infrared light to the finger of the patient. The phototransistor detects the light rays and calculates the change of blood volume from the finger artery. The signal in the form of pulses is amplified, filtered and finally fed to the microcontroller for display. The microcontroller counts the total number of pulses over a defined time interval to obtain the heart rate of the patient. Several readings are received over a specific period of time to get mean accurate reading of heart rate. The calculated heart rate is displayed on LCD in beats per minute using the following format:
Rate is equal to nnn bpm
Where, nnn is an integer between 1 and 999

Fig. 7: Heart Beat Sensor.

3.6. Respiration sensor

Thermistor respiratory monitor is a low cost easy to use device to monitor breathing rates of patients. This portable device was designed for low resource environments and is shown in fig 8. The component op-amp (IC 741) is used to amplify the sensed respiratory signals and displayed using TTL (transistor to transistor logic) using transistor (BC 547). The device calculates the breathing rate by detecting changes in temperature when the patient breaths through the mask. The device comprises an alarm through a buzzer which beeps when the patient stops breathing or has a low breathing rate (<15bpm) or a high breathing rate (>22bpm). Here analog to digital conversions of sample readings take place for both thermistor and battery for timer to beep the buzzer. The thermister used here for respiratory sensor is thermister 473 which is the NTC (negative temperature coefficient) thermister. NTC thermistors provide the design engineer with desirable sensor performance which is found advantageous in a variety of applications.

Fig. 8: Thermistor 473.

Two thermistors connected to the resistor bridge network are used for respiration measurement as displayed in fig 9. The bridge terminals are connecting with inverting and non-inverting input terminals of the comparator. The LM 741 operational amplifier constructs the comparator. The amplified voltage is converted from +12v to -12v of square wave pulse through the comparator. Then square wave pulse is converted from 5v to 0v TTL pulse throughout the transistor Q1 (BC 547). Finally, TTL pulse is given to the microcontroller to monitor the respiration rate.

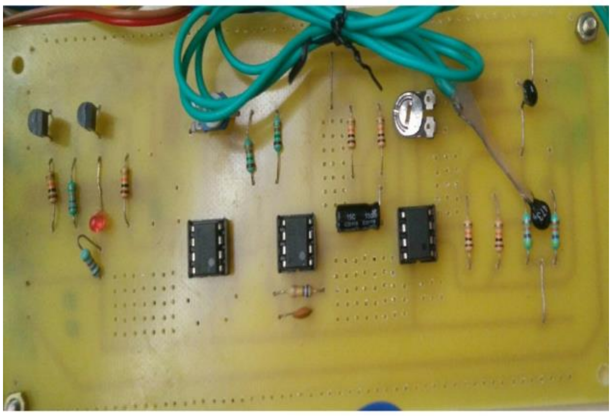

Fig. 9: Respiration Sensor.

3.7. LCD (liquid crystal display)

A liquid crystal display (LCD) is depicted in fig 10 is a thin, flat panel used for electronically displaying information such as text, images, and moving pictures. LCD includes Pin-1 Vss - Ground, Pin-2 VDD Power 5V, Pin-3 VEE - LCD Contrast Adjustment Control Signals and RS- Register Select. The enable Pin is used by the LCD to handle information at its data pins. When the data is supplied to data pins, high to low pulse must be applied to this pin in order to latch the data present in the data pins to display the LCD.

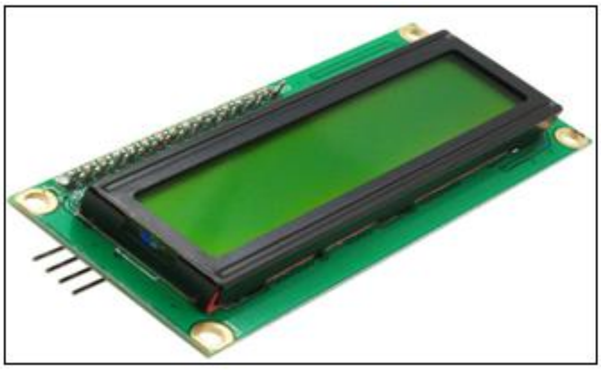

Fig. 10: LCD Display.

3.8. Description of MP LAB

The MP LAB Integrated Development Environment (IDE) runs as a 32-bit application on Microsoft Windows includes several free software machinery for application development, hardware component and debugging. MP LAB IDE also provides as a single, integrated graphical user interface for additional Microchip, third party software and hardware development tools. C programming languages have been used with MP LAB IDE supported through the use of third party programs. MP LAB IDE does not support Linux, UNIX and Macintosh based operating system.

4. Results and discussion

4.1. Results

Automatic Anesthesia Regularization System controls drug infusion depending upon the patient's body state. Temperature sensor, heartbeat sensor and respiration sensor senses the temperature, heartbeat and respiration respectively and gives corresponding analog values to signal conditioning circuit. The Signal conditioning circuit then provides the binary value to the microcontroller depending upon the binary value given to the controller to drive the syringe pump motor. Syringe placed in motor for injects the drug to patient based on the patient's condition. Every 30 seconds all the parameters were sensed to check the patient's condition, which were monitored and intimated in the display whether normal or abnormal as shown in the fig 11 and fig 12. Infra red heart beat monitor was kept between the fingers to detect the heart rate. If the heart beat rate exceeds 40 beats per 30 seconds, it was intimated as abnormal condition and the pump infused according to the programmed condition. Respiration sensor attached with the mask kept on the nose sensed the exhalation and the abnormality was intimated on the display is shown fig 13 when the respiration exceeds 12 per 30 seconds. Similarly the temperature sensor placed between two fingers sensed the patient's body temperature. The abnormal condition was intimated according to the programmed condition when the temperature reduced to 22°C. The coding were written in C language, the VB code is compiled and simulated in MP Lab.

Fig. 11: Normal Condition Heart Beat and Respiration.

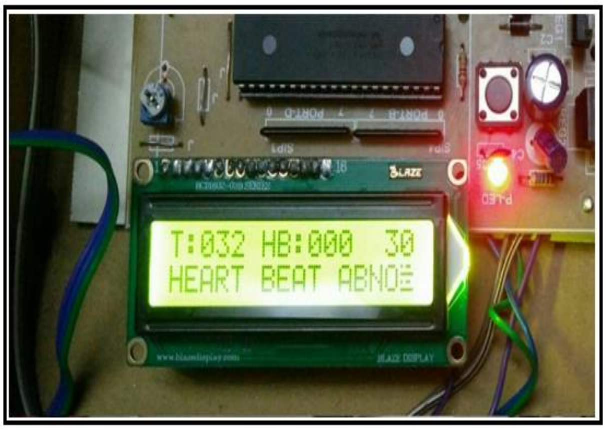

Fig. 12: Abnormal Condition of Heart Beat.

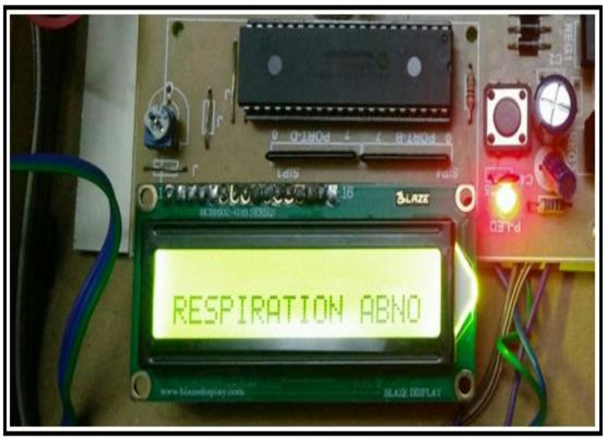

Fig. 13: Abnormal Condition of Respiration.

The utilization of Automatic Anesthesia Regularization System increases patient's safety and comforts the anesthesiologist by providing direct attention to other physiological variables under his control. This helps to protect the environment by using optimum anesthetic agent and cost effective operation. This machine can be fixed along with anesthesia ventilator which will be easier to control the medicine level to be regularized.

The proposed system is based on Graphical User Interface of static parameters such as height, weight of the patient undergoing the surgery by the physician.

The system calculates the initial dose of drugs to be injected to the subject thereafter the essential parameters of the patient are continuously monitored by the device. If any parameters deviate from the normal range at any moment during the surgical procedure the system recalculates the required dosage of the anesthesia and the same must be injected by using syringe infusion mechanism. The important clinical parameters are stored in real time as database for future reference and analysis.

4.2. Discussion

Administration of anesthesia pharmacologically induced temporary loss of sensation and reversible state of loss of responsiveness, loss of skeletal muscle reflexes provided simultaneously. These conditions allow patient to undergo surgery and other painful procedures without the sense of pain. Surgical procedure involves giving anesthetic drugs to patients to induce unconsciousness to ensure safe surgery by the surgeon without any untoward incidence (Jung Kim et al 2012). Some of the surgical procedures are fixed and predetermined whereas some process are based on the patient's response to the interventions like altering anesthetic drug infusions or inhaled concentrations or to maintain hemodynamic etc. The important parameters to be monitored for minor operations are ECG, pulse rate, blood pressure, respiration. So with these parameters the anesthesia can be regulated for either minor or major operations. Collins (1993) reported that anesthesia has to be given to the patient considering the various parameters such as heart rate, respiratory rate, temperature etc.

Isaka (1993) developed an automatic blood pressure control system has been used in operation theater during major surgery.The system monitors the blood pressure of patients at low level during operation using a hypotensive drugs substantially. This deliberate hypotension reduces the risk of intra-operative bleeding and also brought two major desirable effects. First, detailed anatomical structures of the patient in the operative field are revealed and thus more accurate and speedy operation has been facilitated. Second, blood transfusion is safe, and thus the risk of side effects such as sepsis, organ failure and other adverse conditions are decreased. The general anesthesia can be either as gases or vapours or as injections. It is possible to distribute anesthesia solely by inhalation or injection. The most commonly two forms are combined, with an injection given to induce anaesthesia and a gas used to maintain it. So the infusible medicine can be in liquid form that can be vaporized after being regulated to the vaporizer through solenoid pump (Vickers et al 1991). Tavakol et al (2012) developed a blood pressure sensor to monitor blood pressure using invasive technique which has certain disadvantages like arterial obstruction and distal ischaemia. This occurs due to thrombus, haematoma, infection when injection of drugs to the patient. So the pressure sensor is modified as belt sensor which measures the pressure by the movement of the diaphragm. This belt sensor is also becomes a failure method when the surgery is done on the chest part and hence the functioning and monitoring of pressure sensor is replaced by the other important parameter respiration sensor.

Prashanth et al (2014) suggested that anesthetist administers regulated dose of anesthesia to the patient during surgery. According to their concept the dose of anesthetic injections are given together too closely or too quickly, the patient might suffer from some side effect due to overdose. On the other hand, suppose the anesthesia is too less than the optimum dose, then the patient might feel pain and wake up during the surgery. These result comfortless of patient due to severe pain and shock leading to unexpected complications. Anesthesia must be administered by correct dosage and time depends on the basis of vital parameters of the patient such as body temperature, heart rate etc. Usually, in current clinical practices anesthesia is administered manually which may lead to adverse complications due to overdose or less dose. To reduce the risk of such complications, a devise is automatically administers anesthesia to the patient at regular intervals of patient's body interest. Vishnoi and Roy (1991) proposed that Closed Circuit Anesthesia (CCA) is more safe and economical than open circuit anesthesia. However, gas concentrations control regulations are more difficult to control. Computer control of CCA has been proposed for positive efforts to facilitate the control of anesthetic gas concentrations have been limited to small group of patients. Some of these procedures are predetermined based on the patient's response to the intrusions like altering anesthetic drug infusions or inhaled concentrations.

5. Conclusions

Modern Technologies have developed automation in every sphere of biomedical instrumentation. This project is also based on automation drug regulation system will be very much useful to surgeon to check the current position of anesthesia so that the proper anesthesia will be injected to patients. Protection is intelligent than prevention and cure. This project on automatic anesthesia regularization system is one of the efficient protecting systems in medical industries. This system is very useful to the anaesthesiologists who monitor the particular parameter for the patient and regularize the anesthesia. This module can be connected along with the syringe pump or the anesthesia ventilator for future implementation. They can also connect with the EEG parameters for major operations. Advantages of using the proposed system are physical presence of anesthetist is not always required, the required level of anesthesia is exactly calculated and administered so that future side effects due to variations in anesthesia levels are eliminated. IR detector is included in the present system for monitoring the total anesthesia level throughout surgery period.

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