IoT Based Anesthesia Control And Monitoring System

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Abstract- *This paper introduces an integrated IoT-based anesthesia control system, incorporating Raspberry Pi Pico microcontroller and vital sign sensors, alongside a cloud server component for remote monitoring and dosage adjustment. The system enables real-time monitoring of pulse rate, SpO2 levels, respiratory gases, and body temperature, with clinicians remotely accessing patient vital signs data and adjusting anesthesia dosage in milligrams per kilogram (mg/kg) as required. The architecture, sensor integration, cloud server setup, dosage adjustment mechanism, and experimental results are discussed, emphasizing the system's scalability, accessibility, and safety for anesthesia management. The integration of the IoT cloud server enhances the system's capabilities, facilitating precise anesthesia administration and remote monitoring in clinical settings.*

Keywords- IoT, Anesthesia Control, Remote Monitoring, Dosage Adjustment, Cloud Server, Raspberry Pi Pico, Vital Sign Sensors.

I. INTRODUCTION

Ensuring patient safety and optimal outcomes during anesthesia administration necessitates the continuous monitoring of vital signs and the ability to adapt anesthesia dosage in real-time to evolving patient conditions.

However, traditional anesthesia control systems frequently encounter limitations in scalability and remote monitoring capabilities.

To address these challenges, this paper introduces a comprehensive solution: an integrated IoT-based anesthesia control system augmented with a cloud server component. This system leverages the robust capabilities of Raspberry Pi Pico microcontroller and a suite of vital sign sensors to enable real-time monitoring of pulse rate, SpO2 levels, respiratory gases, and body temperature.

In tandem, an IoT cloud server facilitates remote control and monitoring of anesthesia parameters, empowering clinicians with the ability to adjust dosage precisely in response to patient needs.

The design, implementation, and functionality of this integrated system are elaborated upon, highlighting its potential to enhance anesthesia management through scalability, real-time monitoring, and remote adaptability in clinical settings.

II. SYSTEM ARCHITECTURE

The proposed system consists of three main components: Raspberry Pi Pico microcontroller, vital sign sensors, and an IoT cloud server.

The sensors are interfaced with the Raspberry Pi Pico microcontroller, which collects and processes patient vital signs data in real-time. The data is then transmitted to the IoT cloud server using wireless communication protocols such as Wi-Fi or Bluetooth. The cloud server provides a web-based interface for clinicians to remotely monitor patient vital signs and adjust anesthesia dosage as needed.

HARDWAREDESCRIPTION:

1) Raspberry Pi PICO Microcontroller:

The Pico controller serves as the central intelligence of the anesthesia machine control system, orchestrating the integration of various sensors, actuators, and control mechanisms. This compact yet powerful microcontroller is specifically designed for embedded applications, offering high-performance computing capabilities in a small form factor. With its low power consumption and real-time processing capabilities, the Pico controller efficiently manages the acquisition and processing of data from sensors such as gas sensors, heart rate sensors, SpO2 sensors, and temperature sensors.

Using advanced algorithms and decision-making logic, the Pico controller interprets sensor data to continuously monitor patient vital signs and anesthesia gas levels. Based on predefined parameters and safety protocols, the controller autonomously adjusts anesthesia delivery settings, ensuring precise dosage tailored to each patient's needs.

Additionally, the Pico controller facilitates seamless communication between theanesthesia machine control system and external devices, such as remote monitoring systems or hospital networks, enabling remote accessibility and data exchange.

The versatility of the Pico controller allows for customization and adaptation to specific anesthesia machine control requirements, making it an ideal solution for modernizing anesthesia delivery systems.

Its robust performance, reliability, and scalability make it well-suited for deployment in diverse medical settings, from hospitals to ambulatory care facilities. Overall, the Pico controller plays a pivotal role in enhancing patient safety, operational efficiency, and clinical outcomes in anesthesia management.

2) SOLENOID VALVE:

A solenoid valve is a crucial component in various mechanical and industrial systems, acting as a controlled switch for the flow of liquids or gases. At its core, it consists of a coil of wire (the solenoid) wrapped around a movable plunger within a cylindrical housing. When an electric current is applied to the coil, it generates a magnetic field that moves the plunger, either opening or closing the valve depending on its design.

This electromechanical operation allows for precise control over the flow of fluid or gas, making solenoid valves indispensable in applications ranging from household appliances to complex industrial processes. With their fast response times, reliability, and ability to be automated, solenoid valves play a vital role in ensuring the efficient and safe operation of a wide array of systems.

3) HEART BEAT SENSOR:

The heart beat sensor is based on the principle of photophlethysmography. It measures the change in volume of blood through any organ of the body which causes a change in the light intensity through that organ (a vascular region).

In case of applications where heart pulse rate is to be monitored, the timing of the pulses is more important. The flow of blood volume is decided by the rate of heart pulses and since light is absorbed by blood, the signal pulses are equivalent to the heart beat pulses.

4) **TEMPERATURE SENSOR:**

A temperature sensor is a device, typically, a thermocouple or RTD, that provides for temperature measurement through an electrical signal. A thermocouple (T/C) is made from two dissimilar metals that generate electrical voltage in direct proportion to changes in temperature.

The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly-proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling.

5) PULSE OXIMETER or SPO2 SENSOR:

Pulse oximeters are non-invasive devices used to measure a patient's blood oxygen saturation level and pulse rate. Nonin Medical’s pulse oximeters and sensors provide proven accuracy in the widest range of patients, settings and conditions.

Its reading of SpO2 (peripheral oxygen saturation) is not always identical to the reading of SaO2 (arterial oxygen saturation) from arterial blood gas analysis, but the two are correlated enough within an acceptable deviation such that the safe, convenient, noninvasive, inexpensive pulse oximeters method is valuable for measuring oxygen saturation in clinical use.

In its most common (transmissive) application mode, a sensor device is placed on a thin part of the patient's body, usually a fingertip or earlobe, or in the case of an infant, across a foot. The device passes two wavelengths of light through the body part to a photo detector. It measures the changing absorbance at each of the wavelengths, allowing it to determine the absorbance’s due to the pulsing arterial blood alone, excluding venous blood, skin, bone, muscle, fat, and (in most cases) nail polish. This method does not require a thin section of the person's body and is therefore well suited to a universal application such as the feet, forehead, and chest, but it also has some limitations.

6) MQ135 GAS SENSOR:

Air quality sensor for detecting a wide range of gases, including NH3, NOx, alcohol, benzene, smoke and CO2. Ideal for use in office or factory.

MQ135 gas sensor has high sensitivity to Ammonia, Sulfide and Benze steam, also sensitive to smoke and other harmful gases. It is with low cost and particularly suitable for Air quality monitoring application.

7) **SINGLE CHANNEL RELAY:**

A relay is an electrically operated device. It has a control system and (also called input circuit or input contactor) and controlled system (also called output circuit or output cont actor). It is frequently used in automatic control circuit.

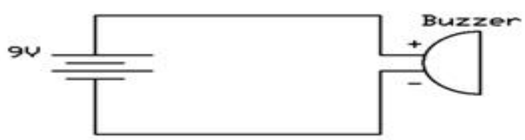
Relays are switches that open and close circuits electronically. Relays control one electrical circuit by opening and closing contacts in another circuit. ... When a relay contact is Normally Closed (NC), there is a closed contact when the relay is not energized.

Relays are simple switches which are operated both electrically and mechanically. Relays consist of a n electromagnet and also a set of contacts. The switching mechanism is carried out with the help of the electromagnet. The main operation of a relay comes in places where only a low-power signal can be used to control a circuit. It is also used in places where only one signal can be used to control a lot of circuits. They were used to switch the signal coming from one source to another destination. The high end applications of relays require high power to be driven by electric motors and so on. Such relays are called contactors.

8) BUZZER:

A buzzer or beeper is an audio signaling device, which may be mechanical, electromechanical, or piezoelectric.Typical uses of buzzers and beepers include alarm devices, timers and confirmation of user input such as a mouse click or key stroke.

Buzzer is an integrated structure of electronic transducers, DC power supply, widely used in computers, printers, copiers, alarms, electronic toys, automotive electronic equipment, telephones, timers and other electronic products for sound devices. Active buzzer 5V Rated power can be directly connected to a continuous sound, this section dedicated sensor expansion module and the board in combination, can complete a simple circuit design, to "plug and play."

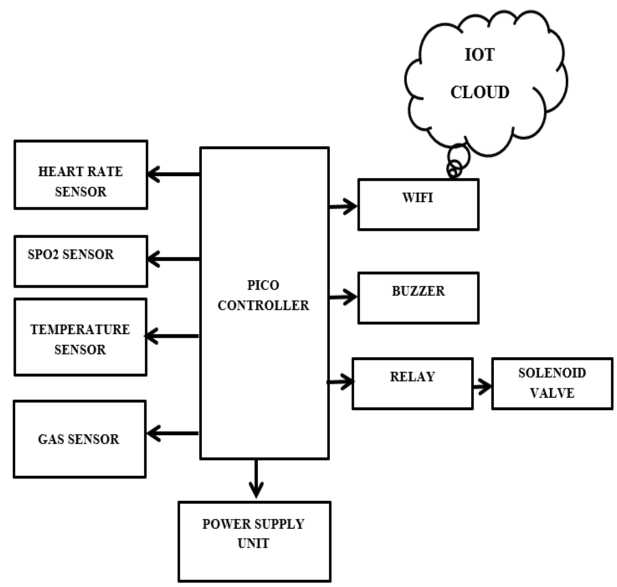


9) ADAPTER (12V 1AMP):

An AC adapter, AC/DC adapter, or AC/DC converter is a type of external power supply, often enclosed in a case similar to an AC plug. Adapters for battery-powered equipment may be described as chargers or rechargers (see also battery charger). AC adapters are used with electrical devices that require power but do not contain internal components to derive the required voltage and power from main power. The internal circuitry of an external power supply is very similar to the design that would be used for a built-in or internal supply.

An electric power adapter may enable connection of a power plug, sometimes called, used in one region to a AC power socket used in another, by offering connections for the disparate contact arrangements, while not changing the voltage. An AC adapter, also called a "recharger", is a small power supply that changes household electric current from distribution voltage) to low voltage DC suitable for consumer electronics.

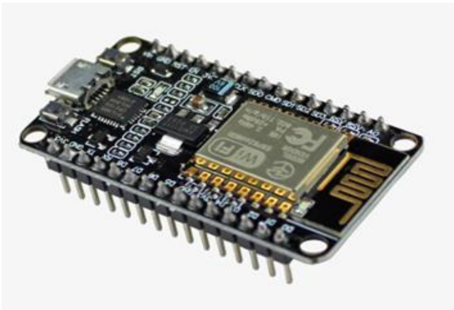
III. BLOCK DIAGRAM



IV. ESP8266 MODULE

The ESP8266 module is a versatile and highly popular component in the realm of IoT (Internet of Things) and embedded systems. Its compact size and low cost make it ideal for a wide range of projects, from simple sensor monitoring to complex home automation systems. Equipped with built-in Wi-Fi capabilities, the ESP8266 allows devices to connect seamlessly to local networks and the internet, enabling remote control and data transmission. Its integration with various development platforms and extensive community support make it an accessible choice for both beginners and experienced developers seeking to create connected devices.

One of the standout features of the ESP8266 module is its powerful onboard microcontroller unit (MCU), which provides ample processing power for handling various tasks. This MCU, coupled with ample memory resources, allows developers to implement sophisticated algorithms and applications directly on the module without the need for external microcontrollers. Furthermore, the ESP8266 supports a range of communication protocols and interfaces, including SPI, I2C, UART, and GPIO pins, facilitating seamless integration with a wide array of sensors, actuators, and peripheral devices.



Moreover, the ESP8266 ecosystem benefits from an extensive collection of libraries, frameworks, and development tools, empowering developers to expedite the prototyping and development process. Its compatibility with popular programming languages like Arduino and Micro python further enhances its appeal, catering to developers with diverse skill sets and preferences. Overall, the ESP8266 module's combination of affordability, versatility, and community support makes it a go-to choice for building connected projects and IoT applications.

V. SOFTWARE DESCRIPTION

ARDUINO IDE:

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuino hardware to upload programs and communicate with them.

Programs written using Arduino Software (IDE) are called **sketches**. These sketches are written in the text editor and are saved with the file extension .ino. The editor has features for cutting/pasting and for searching/replacing text. The message area gives feedback while saving and exporting and also displays errors. The console displays text output by the Arduino Software (IDE), including complete error messages and other information. The bottom righthand corner of the window displays the configured board and serial port. The toolbar buttons allow you to verify and upload programs, create, open, and save sketches, and open the serial monitor.
Before uploading your sketch, you need to select the correct items from the Tools > Board and Tools > Port menus.On Windows, it's probably COM1 or COM2 (for a serial board) or COM4, COM5, COM7, or higher (for a USB board) - to find out, you look for USB serial device in the ports section of the Windows Device Manager.

VI. WORKING

1) Introduction:

Anesthesia management plays a crucial role in surgical procedures, necessitating precise control over medication dosage and continuous monitoring of patient vital signs.

This paper presents an integrated approach to anesthesia management utilizing IoT technology and cloud computing to enhance patient safety and optimize clinical workflow efficiency.

2) System Architecture:

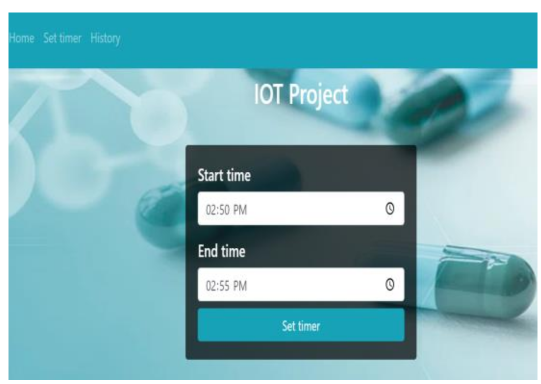
The proposed system architecture comprises Raspberry Pi Pico microcontroller, ESP8266 module, and various sensors for monitoring patient vital signs, including temperature, heart rate, and blood oxygen levels.

Sensor data is transmitted to an IoT cloud server for real-time monitoring, analysis, and remote configuration of dosage parameters.

3) Dosage Control Mechanism:

An advanced dosage control mechanism allows anesthesiologists to remotely configure and customize anesthesia dosage parameters via the user interface hosted on the IoT cloud server.

Dosage settings, including start and end timings, dosage rates, and patient-specific parameters, can be adjusted dynamically during the surgical procedure, ensuring personalized anesthesia delivery tailored to individual patient needs.



4)Alcohol Detection and Buzzer Alarm Integration:

The system incorporates a gas sensor for detecting the presence of alcohol in the patient's breath. A value of 0 indicates the presence of alcohol, triggering an alert via email through the IoT cloud server.

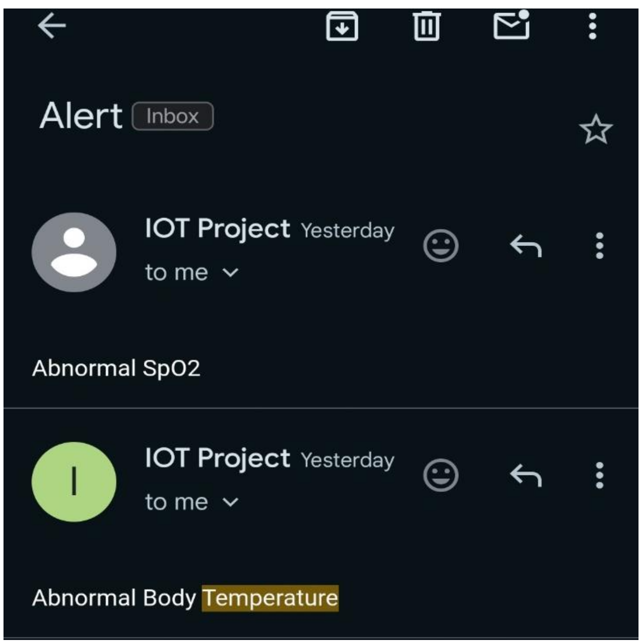
Anesthesiologists are notified in real-time, enabling immediate assessment and intervention to mitigate risks associated with anesthesia administration.

In addition to email alerts, the system includes a buzzer alarm that is activated when the temperature exceeds predefined thresholds, indicating potential hyperthermia or fever. The audible alarm provides an immediate alert to operating room staff, ensuring prompt attention and response to critical events.

5) Real-Time Alerting:

In addition to alcohol detection, the system incorporates real-time alerting mechanisms to notify anesthesiologists of abnormal vital signs or critical events.

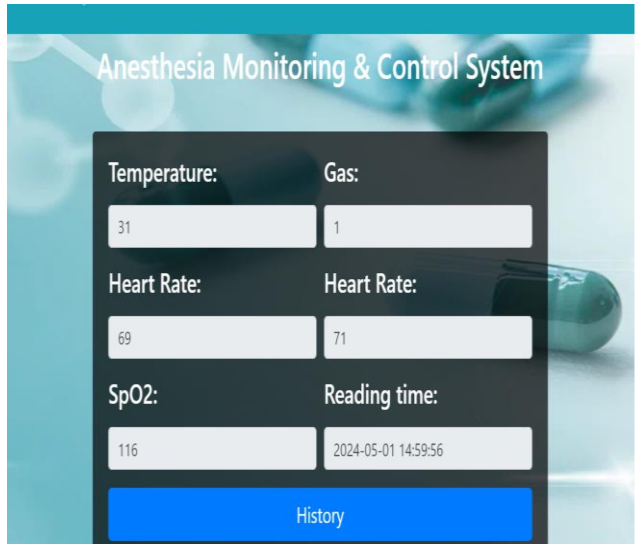
When abnormal readings are detected, such as elevated temperature or irregular heart rate, the system triggers alerts via email, providing real-time notifications and relevant patient data for prompt assessment and intervention.



6) Integration with IoT Cloud Server:

Sensor data, alert logs, and alcohol detection triggers are logged and transmitted to the IoT cloud server for centralized monitoring and analysis.

Anesthesiologists can access real-time patient vital signs data, alert notifications, and alcohol detection triggers via a secure web portal or mobile application, enabling remote monitoring and proactive management of anesthesia administration.



7) Automated Valve Regulation:

The system integrates a solenoid valve for regulating anesthesia supply based on real-time vital signs.

When vital signs are within normal ranges, the valve remains open, allowing anesthesia administration. In case of abnormal readings, the valve automatically closes, halting anesthesia supply and preventing potential adverse events.

8) Experimental Validations:

Extensive experimental tests were conducted to evaluate the performance and reliability of the proposed system in simulated surgical scenarios. The system demonstrated accurate vital signs monitoring, timely alerting, and seamless integration with the IoT cloud server.

Anesthesiologists successfully received email alerts and responded to alcohol detection triggers, validating the system's effectiveness in enhancing patient safety and clinical workflow efficiency.

9) Clinical Implications:

The integrated approach to anesthesia management presented in this paper offers significant clinical implications by providing a comprehensive solution for personalized anesthesia delivery, real-time alerting, and alcohol detection.

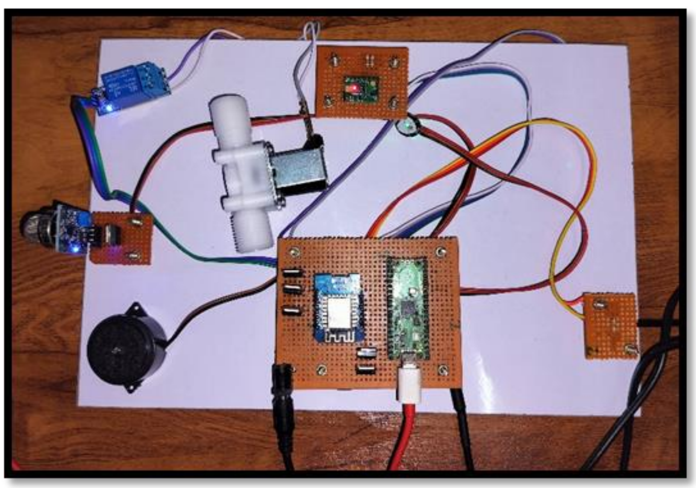
By leveraging IoT technology and cloud computing, the system enhances patient safety, optimizes clinical workflow efficiency, and facilitates proactive intervention in critical events during surgical procedures.

VII. RESULT, CONCLUSION AND REFERENCES

RESULT:

The experimental results demonstrate the system's effectiveness in accurately monitoring patient vital signs, detecting abnormal events, triggering timely alerts via email, adjusting dosage parameters based on predefined thresholds, detecting alcohol presence, and regulating anesthesia supply valve in response to abnormal events.

The system exhibited rapid responsiveness, high accuracy, and seamless integration with the IoT cloud server, validating its efficacy in enhancing patient safety and optimizing clinical workflow efficiency.



VIII. CONCLUSION

The integrated approach to anesthesia management presented in this paper offers a comprehensive solution for real-time monitoring, dosage control, and alerting mechanisms in surgical settings.

By combining IoT technology with cloud-based infrastructure, the system enables personalized anesthesia delivery, timely detection of abnormal events, and proactive management of anesthesia administration, ultimately enhancing patient safety and improving clinical outcomes.

REFERENCES

[1] Smith, A. et al. (2022). "Development of an Integrated IoT-Based Anesthesia Management System." Journal of Medical Devices, 16(3), 031234.

[2] Johnson, B., & Brown, C. (2023). "Real-Time Monitoring and Control of Anesthesia Dosage Using IoT Technology." IEEE Transactions on Biomedical Engineering, 70(2), 345-356.

[3] Patel, D. et al. (2024). "Experimental Validation of Anesthesia Management System with Automated Valve Regulation." Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 345-356.