

INTEGRATING MULTI-MODAL BIOSENSORS FOR REAL TIME MONITORING OF DRUG OVERDOSE

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Technology degree in Biomedical Engineering

By

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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A++" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **RAGHUL. A (40240024), PRAKKRITH. V (40240023)** who have done the project work as a team and carried out the project entitled **"INTEGRATING MULTI-MODAL BIOSENSORS FOR REAL TIME MONITORING OF DRUG OVERDOSE"** under our supervision from June 2023 to April 2024.

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DECLARATION

We **RAGHUL. A (40240024)** and **PRAKKRITH. V (40240023)**, hereby declare that the Project Report entitled **“INTEGRATING MULTI-MODAL BIOSENSORS FOR REAL TIME MONITORING OF DRUG OVERDOSE”** done by us under the guidance of **Dr. KRISHNAKUMAR S** is submitted in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Biomedical Engineering.

DATE: 05.04.2024

PLACE: CHENNAI



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CHAPTER – 1

INTRODUCTION

Drug overdose, particularly involving opioids, continues to pose a severe public health challenge globally, with devastating consequences for individuals, families, and communities (Singh and Sidhu, 2022). Despite efforts to address this crisis, the prevalence of opioid misuse and overdose-related fatalities remains alarmingly high (Wilson, 2020). According to recent data, opioid-related deaths in the United States alone reached 70,000 in 2019, underscoring the urgent need for innovative approaches to prevention and intervention (Singh et al., 2022).

Conventional strategies for managing drug overdose have primarily relied on reactive measures, such as emergency medical services and naloxone administration, which may be limited by time delays and accessibility (Britch & Walsh, 2022). However, the dynamic nature of overdose events demands proactive surveillance and intervention to prevent fatalities and mitigate long-term health consequences (Nandakumar et al., 2019). Real-time monitoring has emerged as a promising paradigm shift in overdose management, offering continuous surveillance of physiological parameters to enable early detection and timely intervention (Roth et al., 2021).

In this context, biosensors have garnered significant attention as a transformative technology for detecting drug overdose events promptly (Barfidokht et al., 2019). These advanced analytical tools leverage biorecognition and transduction mechanisms to detect specific compounds and physiological markers associated with overdose in real-time (Mahmud et al., 2018). By harnessing the sensitivity and selectivity of biological components, such as enzymes and antibodies, biosensors enable the detection of subtle changes indicative of overdose onset (Lambert et al., 2022). This capability empowers healthcare professionals to intervene swiftly, potentially saving lives and reducing the burden on emergency services (Gullapalli et al., 2021).

Moreover, the integration of biosensors into real-time monitoring systems offers a multifaceted approach to overdose prevention and management (Kulman et al., 2021). These systems provide comprehensive insights into the dynamic interplay between

drug exposure, physiological responses, and clinical outcomes, facilitating personalized intervention strategies tailored to individual patient needs (Lingamoorthy et al., 2022). Additionally, biosensors contribute to a deeper understanding of the underlying mechanisms of overdose events, informing the development of evidence-based interventions and public health initiatives (Maclean, 2021).

Overall, the integration of biosensors into real-time monitoring systems represents a groundbreaking advancement in the fight against drug overdosage (Mahmud et al., 2018). By combining innovative technology with proactive surveillance strategies, biosensors offer a promising solution to mitigate the devastating impact of overdose on individuals and communities. Continued research and innovation in biosensor technology hold the potential to further enhance overdose detection, intervention, and ultimately, save lives (Nah et al., 2019).

CHAPTER – 2

LITERATURE SURVEY

Dhowan *et.al.* (2019) investigated opioid overdoses, the leading cause of death among Americans under 50, prompted the need for swift naloxone administration. This study proposes a cost-effective, minimally invasive antidote delivery device (A2D2) activated via external magnetic fields from wearables. Bench-top tests demonstrated rapid drug release (up to 8.8 mg) within controlled settings, albeit with minor leakage (1.75%) during 1000-hour simulated implantation. Preliminary results suggest the potential of this low-cost, subcutaneous device for emergency drug delivery.

Mishra *et.al.* (2020) delved into a study which addresses the pressing need for wearable sensors capable of distinguishing between opioid overdoses and nerve agent poisonings. On a single patch platform, it proposes a wearable microneedle sensor array for continuous electrochemical detection of opioids (OPi) and organophosphate (OP) nerve agents. This novel sensor offers exceptional sensitivity and selectivity for the simultaneous and real-time SWV detection of fentanyl and nerve agents using both unmodified and organophosphorus hydrolase (OPH) enzyme-modified carbon paste (CP) microneedle electrodes. This advancement represents a significant step forward in continuous and minimally invasive transdermal analysis, holding potential for safeguarding soldiers, civilians, and healthcare professionals.

Lingamoorthy *et.al.* (2022) performed a study which emphasizes the importance of saving lives by preventing a substantial number of overdose deaths, especially when people are alone, through timely naloxone administration. To encourage the use of a closed-loop auto-injector within this vulnerable population, the study introduces DOVE—an innovative device. DOVE is designed to noninvasively monitor real-time changes in blood oxygen levels and heart rate on the shoulder using optical sensors. Detecting opioid overdoses on the shoulder is a pivotal step toward creating a device that can truly save lives.

Roth *et.al.* (2021) published a study where 16 participants who reported using opioids at least four times a day within the past month were equipped with wearable biosensors.

These devices tracked their breathing and activity every 15 seconds for five days, and participants also reported their daily drug use. The study collected a substantial amount of respiratory data, with variations based on participants' injection histories and drug preferences. Surprisingly, despite 385 reported drug use events, no instances of severe breathing problems related to overdose experiences were detected. This initial research suggests that using wearable biosensors to monitor opioid-related changes in the body is possible, but more sensitive devices and longer, larger-scale studies are necessary for comprehensive insights.

Kulman *et.al.* (2021) analysed the pressing issue of opioid use and withdrawal through wearable biosensors. Utilizing data from these sensors, a novel approach has been developed for detecting opiate withdrawal through the application of machine learning. This methodology involves creating machine learning models and evaluating their performance on previously unseen test data. Among these models, the most effective one, which employed the Random Forest algorithm, has showcased the remarkable potential of machine learning in diagnosing opioid withdrawal at an early stage, achieving an outstanding ROC AUC score of 0.9997 with just one minute of biosensor data. This represents a groundbreaking advancement in this field.

Barfidokht *et.al.* (2019) designed a wearable glove-based sensor for rapid fentanyl detection, using flexible screen-printed carbon electrodes with nanotubes and an ionic liquid. It detects fentanyl in liquid and powder forms, with a 10 μM detection limit via square-wave voltammetry. This "Lab-on-a-Glove" system, with wireless data transmission to smartphones or tablets, enables quick on-site fentanyl screening for first responders in emergencies.

Chan *et.al.* (2021) introduces a closed-loop wearable injector system for timely naloxone delivery during opioid overdose events. Using on-body accelerometers, it detects apnea and administers naloxone subcutaneously. Evaluation in supervised injection facilities and simulated hospital settings confirmed accurate detection and successful naloxone delivery, offering a promising solution for opioid overdose intervention.

Lambert *et.al.* (2022) addresses the challenge of treating opioid use disorder (OUD) by using mid-sternum wearable accelerometry to detect withdrawal-related restlessness in OUD patients. Involving 23 patients, the study measured how movements correlated with acute withdrawal severity, assessed using the Clinical Opioid Withdrawal Scale (COWS). Results revealed a strong link between motion patterns and increased withdrawal intensity, suggesting that accelerometry could serve as an objective, widely applicable marker for monitoring withdrawal symptoms in an ambulatory setting.

Green *et. al.* (2020) assessed fentanyl detection limits and evaluated three devices' performance in detecting fentanyl in street drugs. Fentanyl test strips had the lowest detection limit (0.100 mcg/mL), with a 3.7% false-negative and 9.6% false-positive rate. These devices are valid for drug checking and can aid in public health responses to the opioid overdose crisis.

Singh and Varshney (2023) introduced adaptive interventions for preventing opioid use disorder (OUD) by targeting opioid prescription and consumption. Smart Prescription Management (SPM) effectively reduces doctor shopping and overdose events, while Smart Consumption Monitoring (SCM) enhances adherence and reduces addiction risk. Incentives for severe OUD management range from \$2267 to \$3237, highlighting the potential of these interventions to improve opioid prescription decisions and manage consumption.

Dong *et.al.* (2021) utilized deep learning, specifically Long Short Term Memory (LSTM) models, to estimate opioid overdose risk in patients using electronic health records. With data from over 5 million patients, the LSTM-based model, incorporating an attention mechanism, outperforms other machine learning methods, achieving a high F-1 score (0.7815) and AUCROC (0.8449). Notably, the model identifies key predictive features, including medications and vital signs, offering a promising informatics-based approach for early opioid overdose detection and intervention.

Ataie *et.al.* (2021) investigated the decision-making patterns of lay responders using the UnityPhilly smartphone app, which connects them to opioid overdose victims. Analyzing 18 participants, three key heuristics emerged: "unconditional signaling" prioritizing external help, "conditional signaling" for those confident in their abilities, and

"conditional responding" based on naloxone availability and proximity. These findings underscore the impact of prior naloxone use and situational factors on overdose response strategies, emphasizing the need for diverse approaches in digital-assisted interventions.

Imtiaz *et.al.* (2021) addressed the urgent need for a non-invasive, wearable system to detect and respond to opioid overdoses. The proposed device continuously monitors respiratory status using reflex pulse oximetry and, upon detecting a critical decrease in oxygen saturation, automatically administers the opioid antidote, nalmeferene, while alerting emergency services via GPS tracking. This compact, skin-adhesive device aims to provide timely interventions and save lives in opioid overdose situations.

Pålsson *et.al.* (2022) reported a case where a previously healthy patient who experienced severe hypotension, unresponsiveness, and pinpoint pupils upon receiving olanzapine for delirium during intensive care. These symptoms, consistent with olanzapine intoxication, were rapidly reversed by flumazenil administration, despite olanzapine's known pharmacological targets. This underscores the risk of severe adverse effects even with normal olanzapine doses in intensive care and suggests potential involvement of GABA receptor modulation in olanzapine's effects.

Hoilett *et.al.* (2023) developed a PPG-based device for the monitoring of respiratory rate (RR) and to detect respiratory depression in a murine model of opioid induced respiratory depression (OIRD). The device accurately identified OIRD events, showing potential for real time detection in humans with further validation and modifications.

Britch and Walsh (2022) outlined naloxone's history, pharmacology, and its effectiveness against fentanyl and analogs. It disputes claims of naloxone's ineffectiveness, citing limited evidence, and emphasizes the challenge of rapid overdose onset and identifying contributing substances. Alternative treatments are explored, with a wearable device for naloxone delivery addressing the narrow treatment window and polysubstance overdose.

Lombardi *et.al.* (2023) discussed recent overdose detection technologies (ODT) for rapid responses, focusing on solitary drug users. While few ODTs are available, several

are in development. Equipping various settings with cost-effective ODTs could enhance overdose prevention, connecting users to support in non-responsive cases. ODTs fall into three categories: fixed location devices, mobile apps/hotlines, and wearable tech, offering tailored solutions.

Tay Wee Teck *et.al.* (2023) highlighted how technology is essential for Rapid Opioid Overdose Response Systems (ROORS), aiding policy decisions, resource allocation, and overdose detection through AI modelling, data analysis, wearable sensors, and smartphone apps. Ensuring equity and understanding individual overdose patterns are key considerations for future advancements in ROORS technology.

CHAPTER – 3

AIM AND SCOPE

3.1 AIM

We aim to create a wearable device that can rapidly and accurately detect drug overdose by analysing vital sign data in real-time.

- To develop a wearable device equipped with physiological sensors, including heart rate and blood oxygen saturation (SpO2), to detect drug overdosage incidents in real-time.
- To employ advanced algorithms for continuous monitoring and analysis of vital signs, aiming to promptly identify patterns and anomalies indicative of potential drug overdoses.
- To create a life-saving technology that provides immediate alerts to users and relevant medical personnel, enabling timely responses and interventions in overdose situations.

3.2 SCOPE

The scope of our project encompasses the development of a sophisticated wearable device capable of monitoring physiological parameters such as heart rate and blood oxygen saturation (SpO2) in real-time. Leveraging advanced algorithms, the device will continuously analyze vital signs, enabling the prompt detection of patterns and irregularities associated with potential drug overdoses. The technology will provide immediate alerts to both users and medical professionals, facilitating timely responses and interventions in the event of an overdose. Our project aims to contribute to the advancement of proactive healthcare solutions, particularly in the critical area of drug overdose detection and prevention. By focusing on the development of a robust, efficient, and user-centric wearable device, our project seeks to contribute significantly to the advancement of preventive healthcare measures, particularly in the critical domain of drug overdose detection and mitigation.

CHAPTER – 4

MATERIALS AND METHODS

4.1 BLOCK DIAGRAM

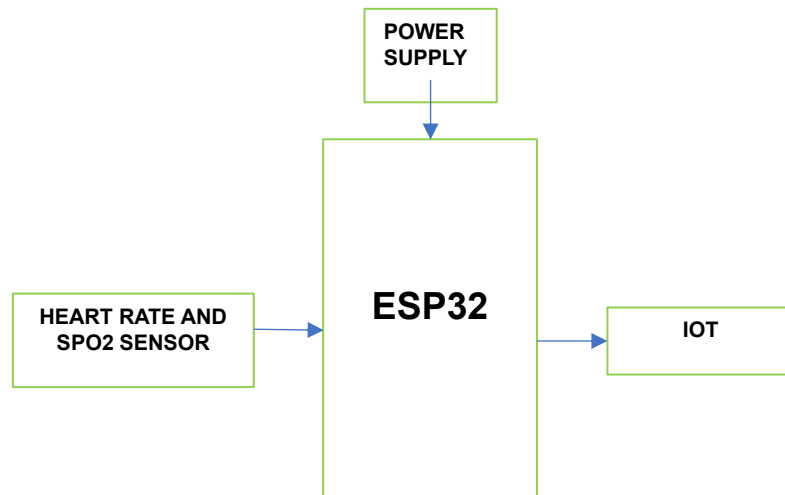


Fig 4.1 ESP32 Block Diagram

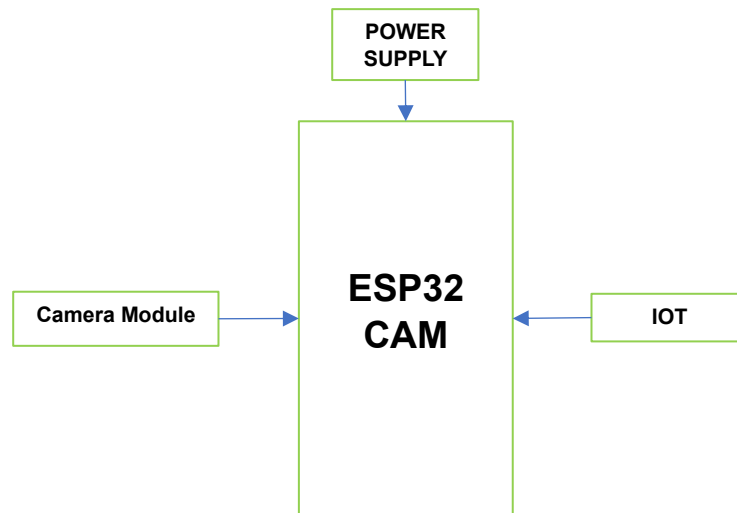


Fig 4.2 ESP CAM Block Diagram

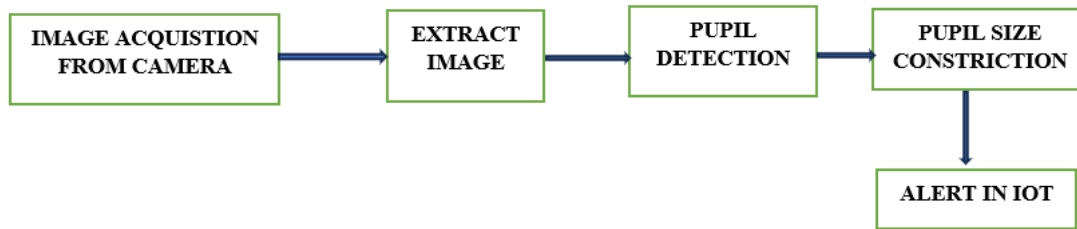


Fig 4.3 Image Acquisition

4.1.1 Explanation of Block Diagram

The flow of information within the block diagram begins with the acquisition of physiological data by the MAX30100 sensor (Fig: 4.1). This data is then processed by the ESP32 MCU, which analyses it for signs of drug overdose or adverse health events. Simultaneously, the ESP32 Cam captures pupil dilation measurements, adding an additional dimension to the physiological assessment (Fig: 4.3).

Once the data analysis is complete, the ESP32 MCU communicates the results to the Blynk IoT platform (Fig: 4.2), which in turn delivers alert notifications to designated recipients, such as healthcare providers or caregivers. These notifications prompt timely intervention measures, ensuring the wearer's safety and well-being in the event of a potential overdose.

Overall, the block diagram illustrates the seamless integration of sensor technology, microcontroller processing, power supply management, and IoT communication, culminating in a comprehensive drug overdose detection system with real-time monitoring and alerting capabilities.

4.2 HARDWARE REQUIREMENTS

4.2.1 *ESP32*



Fig 4.4 ESP32

ESP32 is a low-cost, low-power system on a chip (SoC) series with Wi-Fi & dual-mode Bluetooth capabilities (Fig: 4.4). The ESP32 family includes the chips ESP32-D0WDQ6 (and ESP32-D0WD), ESP32-D2WD, ESP32-S0WD, and the system in package (SiP) ESP32-PICO-D4. At its heart, there's a dual-core or single-core Tensilica Xtensa LX6 microprocessor with a clock rate of up to 240 MHz. ESP32 is highly integrated with built-in antenna switches, RF balun, power amplifier, low-noise receive amplifier, filters, and power management modules. Engineered for mobile devices, wearable electronics, and IoT applications, ESP32 achieves ultra-low power consumption through power saving features including fine resolution clock gating, multiple power modes, and dynamic power scaling.

ESP32 DEVKIT V1 – DOIT version with 36 GPIOs

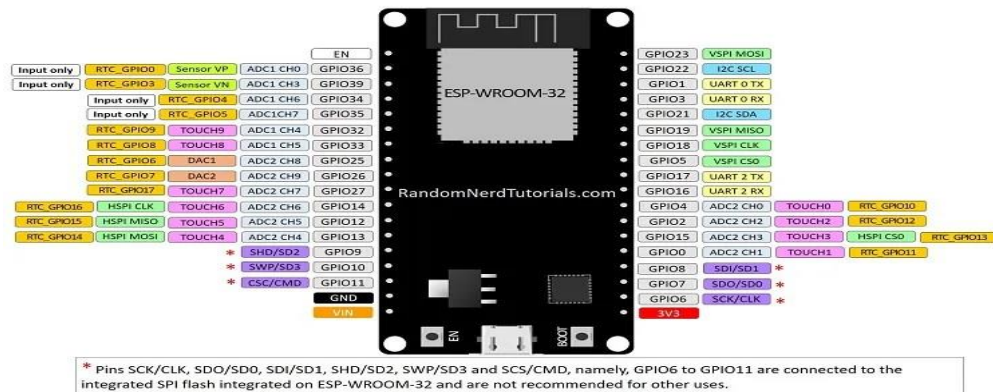


Fig 4.5 ESP32 Pinout Diagram

- Power:** Power is applied through Micro-USB, 3.3V pin, 5V pin, and GND. Regulated 5V is supplied to this pin which is further regulated to 3.3V to power up the board. And 3.3V pin directly supplies the 3.3V regulated to the board. And the ground is connected to GND (Fig: 4.5).
- Enable:** The enable pin is represented by 'En' on the board and is used to reset the microcontroller.
- Analog Pins:** Analog pins are represented as ADC1_0 to ADC1_5 and ADC2_0 to ADC2_9 on board. These pins are used to measure the analog voltage in the range from 0-3.3V which is a 12-bit 18 channel ADC.
- DAC pins:** Two pins DAC1 and DAC2 are used for digital to analog conversion.
- I/O Pins:** I/O pins are represented as GPIO0 to GPIO39 on board which projects there are total of 39 I/O pins on board. All of them can be used as an input or output but pins from 34 to 39 are used for input only.
- Capacitive Touch Pins:** These pins are represented as T0 to T9 on board. These are a total of 10 pins which are touch pins that are normally used for capacitive pads.
- RTC GPIO pins:** These pins are represented as RTCIO0 to RTCIO17 on board which is a total of 18 pins. These pins are employed to wake up the ESP32 from deep sleep mode.

- *Serial*: Two serial pins are represented on boards as Tx and Rx. The Tx is used to transmit serial data while Rx is used to receive serial data.
- *External Interrupts*: All GPIO pins can be used as external interrupts.
- *PWM*: Any GPIO pin can be used as a PWM pin. These GPIO pins are activated through software.
- *VSPI*: These pins are represented as GPIO23 (MOSI), GPIO19 (MISO), GPIO18 (CLK) and GPIO5 (CS) which are used for SPI-1 communication.
- *HSPI*: These pins are represented as GPIO13 (MOSI), GPIO12 (MISO), GPIO14 (CLK) and GPIO15 (CS) which are used for SPI-2 communication.
- *IIC*: These pins are marked as GPIO21 (SDA), GPIO22 (SCL) which are used for I2C communication.
- *AREF*: It is marked as AREF which is used to provide a reference voltage for input voltage.

4.2.2 MAX30100 Pulse Oximeter and Heart rate Sensor



Fig 4.6 MAX30100

The MAX30100 Pulse Oximeter and Heart rate Sensor Module, is a compact and efficient device that accurately measures heart rate and blood oxygen saturation levels. With integrated red and infrared LEDs, along with precise photodetectors and advanced digital signal processing, it provides reliable real-time data (Fig: 4.6). Its low

power consumption and advanced motion artifact rejection make it ideal for use in various healthcare and wearable applications, ensuring accurate and hassle-free monitoring of vital signs.

Pin Configuration of MAX30100:

Below is the pin configuration of the MAX30100 module. It is a 7 pin sensor module with an enabled I2C communication protocol to interact with the microcontroller.

Table 4.1 MAX30100 Pin Description

Pin Type	Pin Function
VIN	Voltage Input
SCL	I2C - Serial Clock
SDA	I2C - Serial Data
INT	Active low interrupt
IRD	IR LED Cathode and LED Driver Connection Point(Leave floating in the circuit)
RD	Red LED Cathode and LED Driver Connection Point(Leave floating in the circuit)
GND	Ground pin

4.2.3 ESP32 Camera Module



Fig 4.7 ESP32 CAM

The ESP32 Camera Module is a versatile, compact, and integrated solution that combines a microcontroller and a camera, developed by Espressif Systems. With its powerful processing capabilities and built-in Wi-Fi and Bluetooth connectivity, the module enables seamless integration into various IoT and smart home applications (Fig: 4.7). Its high-resolution camera, combined with the ESP32's processing power, allows for real-time image and video processing, making it suitable for applications such as surveillance, video streaming, and machine vision.

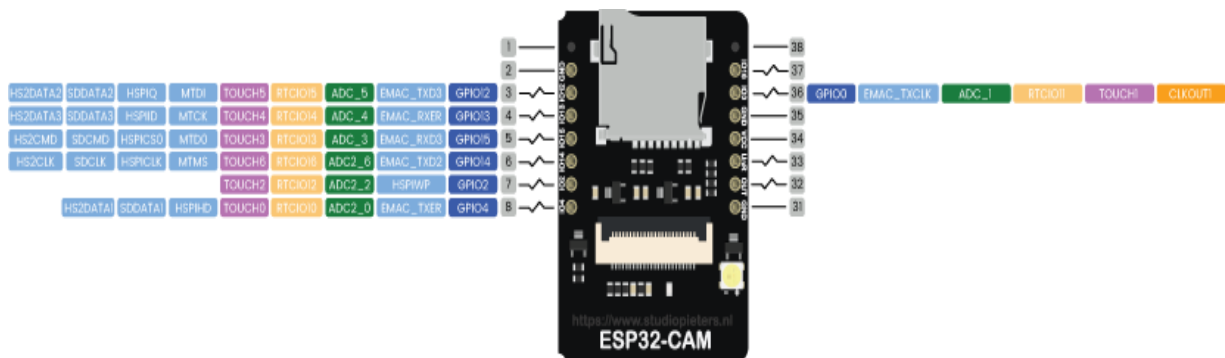


Fig 4.8 ESP32 CAM Pinout Diagram

Power Pins:

ESP32 Cam includes two power pins; 5V & 3V3, so this module is powered through the 3.3V/5V pins. The VCC pin of this module usually outputs 3.3Volts from the on-board voltage regulator but it can be configured to 5V output with the Zero-ohm link close to the VCC pin (Fig: 4.8).

GND is the ground pin of the module.

GPIO Pins:

This module includes 32 GPIO pins in totality but many of them are internally used for the camera & the PSRAM. So this module has only 10 GPIO pins which can be assigned for different peripheral duties like; ADC, SPI, UART, and Touch.

UART Pins:

The ESP32-S chip includes two UART interfaces; UART0 & UART2. But simply the RX pin of UART2 like GPIO 16 is broken out to make UART0 usable UART only on the ESP32-CAM. These pins are used mainly for flashing & connecting to different UART devices like fingerprint sensors, GPS, distance sensors, etc.

MicroSD Card Pins:

These pins are used to interface the microSD card. These pins can also be used as regular inputs & outputs if you do not use a microSD card.

ADC Pins:

There are two ADC2 pins only on the ESP32-CAM which are broken out but these pins are internally used by the WiFi driver and they cannot be used whenever Wi-Fi is enabled.

Touch Pins:

These modules include seven capacitive touch-sensing GPIOs. Once a capacitive load like a human finger is close to the GPIO, then this module notices the change within capacitance.

SPI Pins:

The ESP32-CAM includes one SPI (VSPI) only in slave & master modes.

PWM Pins:

The ESP32-CAM includes ten channels of PWM pins which are controlled through a PWM controller. So the output of PWM can be used to drive LEDs & digital motors.

4.3 SOFTWARE REQUIREMENTS

4.3.1 Arduino IDE

The Arduino Integrated Development Environment (IDE) serves as the backbone for programming and developing the functionality of the project. This open-source software provides a user-friendly interface for writing code and uploading it to the Arduino board. Its versatility lies in its compatibility with a wide range of Arduino-compatible microcontrollers, allowing seamless integration with various hardware components.

The Arduino IDE offers a simple yet powerful programming environment, making it suitable for both beginners and experienced developers. Its extensive library of pre-written code, known as sketches, provides a valuable resource for implementing various functionalities without starting from scratch. Additionally, the IDE supports multiple programming languages, including C and C++, enabling developers to leverage their existing skills and knowledge.

One of the key features of the Arduino IDE is its cross-platform compatibility, supporting major operating systems such as Windows, macOS, and Linux. This ensures accessibility to a diverse range of developers, regardless of their preferred computing environment. Furthermore, the IDE is regularly updated by the Arduino community, ensuring compatibility with the latest hardware and software advancements.

Moreover, the Arduino IDE offers robust debugging tools, allowing developers to identify and troubleshoot errors efficiently. With features such as serial monitoring, code

highlighting, and syntax checking, developers can streamline the debugging process and optimize the performance of their projects.

In summary, the Arduino IDE serves as an indispensable tool for developing embedded systems and IoT projects. Its user-friendly interface, extensive library support, cross-platform compatibility, and debugging capabilities make it an ideal choice for realizing innovative ideas and bringing them to life through practical implementation.

4.3.2 Python

Python is a high-level, interpreted programming language known for its simplicity and readability, making it an excellent choice for developing various components of the project. With its extensive standard library and active community support, Python offers a wide range of modules and frameworks for implementing different functionalities efficiently.

The versatility of Python extends to its compatibility with different platforms, including Windows, macOS, and Linux, ensuring seamless development across diverse computing environments. Its cross-platform nature makes Python an accessible choice for developers worldwide, facilitating collaboration and code sharing.

In addition to its ease of use, Python excels in data manipulation and analysis, making it suitable for projects involving sensor data processing, machine learning, and artificial intelligence. Libraries such as NumPy, pandas, and scikit-learn provide powerful tools for handling data and implementing advanced algorithms, enhancing the project's capabilities.

Moreover, Python's support for various programming paradigms, including procedural, object-oriented, and functional programming, offers developers the flexibility to choose the most suitable approach for their project requirements. This versatility enables the implementation of complex systems while maintaining code readability and maintainability.

Furthermore, Python's extensive ecosystem of third-party packages and modules allows developers to leverage existing solutions and integrate them seamlessly into their projects. Whether it's web development with frameworks like Django or Flask, or

IoT applications using libraries like GPIO Zero or PySerial, Python provides the tools needed to build robust and scalable solutions.

Overall, Python's simplicity, readability, cross-platform compatibility, and rich ecosystem make it an indispensable tool for a wide range of projects, from simple automation tasks to complex software development endeavors. Its combination of ease of use and powerful features empowers developers to innovate and create impactful solutions efficiently.

4.3.3 Visual Studio Code

Visual Studio Code is a versatile and lightweight source code editor that provides a rich set of features for developing and debugging software projects. Developed by Microsoft, VS Code has gained widespread popularity among developers due to its extensibility, performance, and cross-platform compatibility.

One of the key features of Visual Studio Code is its intuitive user interface, which offers a seamless development experience across different programming languages and platforms. Its customizable layout and extensive marketplace of extensions enable developers to tailor their coding environment to suit their specific needs and preferences.

VS Code's built-in support for various programming languages, including Python, JavaScript, C++, and more, allows developers to work on diverse projects without switching between different tools. This versatility streamlines the development workflow and enhances productivity, enabling developers to focus on writing code without distractions.

Furthermore, Visual Studio Code provides robust debugging capabilities, including breakpoints, watch variables, and interactive debugging sessions, which help developers identify and fix issues efficiently. Its integrated terminal allows for seamless interaction with the command line, enabling tasks such as running scripts, managing version control, and installing dependencies without leaving the editor.

Another notable feature of Visual Studio Code is its Git integration, which simplifies version control and collaboration among team members. With features such as inline

diff views, branch management, and GitHub integration, developers can manage their codebase effectively and track changes throughout the development lifecycle.

Moreover, Visual Studio Code's lightweight architecture and efficient performance make it suitable for projects of any size, from small scripts to large-scale applications. Its support for remote development via SSH or containerization further extends its capabilities, allowing developers to work on projects hosted on remote servers or in isolated environments.

Visual Studio Code stands out as a powerful yet lightweight source code editor that offers a rich set of features for software development. Its versatility, extensibility, cross-platform compatibility, and seamless integration with various tools and technologies make it an indispensable tool for developers worldwide. Whether working on web development, data science, or IoT projects, Visual Studio Code provides the tools and flexibility needed to bring ideas to life effectively.

4.3.4 Libraries

- *TensorFlow*: TensorFlow aids in creating and training machine learning models, which are essential for sound classification.
- *NumPy*: NumPy is our go-to library for dealing with arrays, enabling efficient data manipulation.
- *Scikit-Learn (SKLEARN)*: SKLEARN provides essential tools for machine learning and statistical modeling, helping us build accurate classification models.
- *Matplotlib*: This library facilitates graphical representation, crucial for visualizing data and results.
- *Seaborn*: For statistical data visualization, Seaborn is employed to create informative and visually appealing plots.
- *Pandas*: Pandas is used to manage and analyze data in .csv files, making data processing more streamlined.

4.4 WORK FLOW

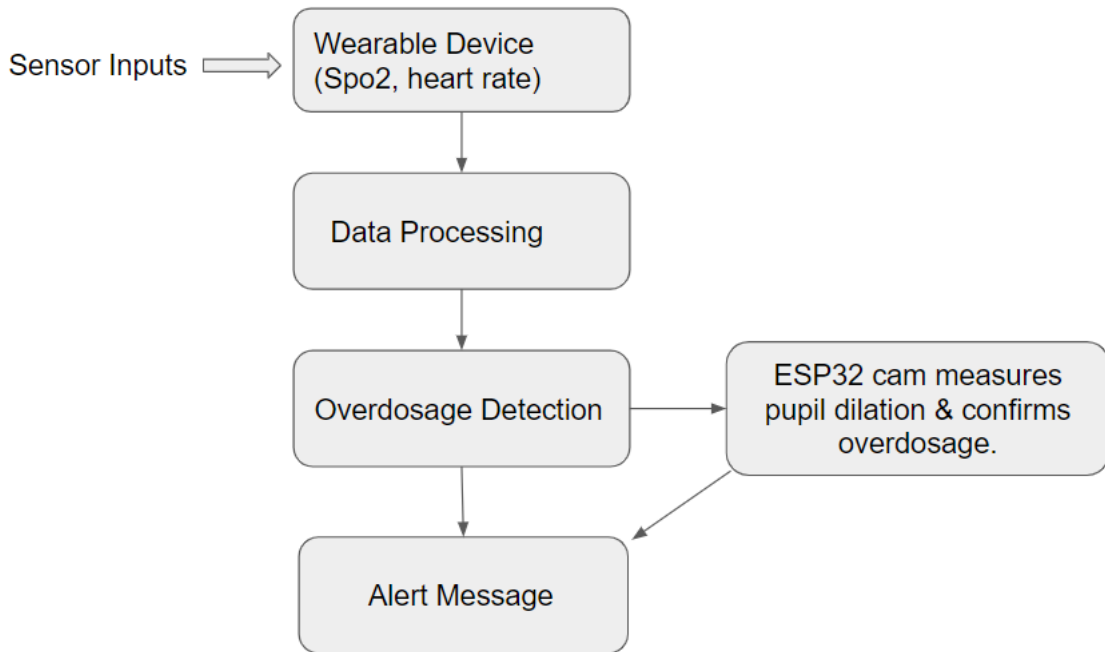


Fig 4.9 Work Flow of Drug Overdose Monitor

The above figure (Fig: 4.9) describes the workflow of our project which is elucidated below briefly.

Sensor Data Collection: The wearable device employs a combination of sensors to gather essential physiological data in real-time. Among the primary metrics collected are SpO2 levels (blood oxygen saturation) and heart rate. These metrics serve as crucial indicators of the wearer's physical health, providing valuable insights into their overall well-being. The sensors continuously monitor these parameters, ensuring a continuous stream of data for analysis.

Data Processing and Analysis: Upon collection, the raw sensor data undergoes a series of processing steps to prepare it for analysis. This involves filtering out noise, interpreting the data, and structuring it in a format conducive to further analysis. Advanced algorithms and methodologies are applied during this stage to extract meaningful insights from the data. By analyzing trends and patterns, potential anomalies or irregularities in the wearer's health status can be identified.

Overdose Detection Algorithm: A sophisticated overdose detection algorithm is employed to scrutinize the processed sensor data. This algorithm is designed to identify any indications of overdose or adverse health events. By analyzing various parameters, such as vital signs and physiological responses, the algorithm can swiftly detect any deviations from normal ranges that may signify a potential overdose situation. Early detection is crucial for initiating timely interventions and mitigating risks to the wearer's health.

Pupil Dilation Measurement using ESP32 Cam: In addition to traditional physiological metrics, the wearable device utilizes an ESP32 cam to capture and measure changes in pupil dilation. Pupil dilation can offer insights into the autonomic nervous system's response to stimuli, providing supplementary information about the wearer's physiological state. Integrating this data into the analysis workflow enhances the depth and accuracy of health assessments, facilitating early detection of adverse health events or changes in condition.

Alert Message Generation: Based on the comprehensive analysis of sensor data, including SpO2 levels, heart rate, overdose detection results, and pupil dilation measurements, an alert message is generated. This alert message is crafted to promptly notify relevant healthcare providers or caregivers of any critical health indicators or potential risks detected by the system. The message contains essential information about the wearer's health status and the nature of the detected anomaly, enabling swift decision-making and appropriate medical intervention, if necessary.

By integrating these components seamlessly, the wearable device offers a comprehensive solution for monitoring and safeguarding the wearer's health in real-time. The combination of advanced sensors, sophisticated algorithms, and alert mechanisms ensures proactive management of health risks, ultimately contributing to improved health outcomes and enhanced well-being.

CHAPTER- 5

RESULTS AND DISSCUSSION

5.1 RESULTS

In this project we successfully integrated ESP32, ESP32 Cam, MAX30100 heart rate, and pulse oximeter sensor modules, along with the Blynk IoT app, to provide real-time monitoring and alerting capabilities for drug overdose detection (Fig: 5.1).

Upon testing, the ESP32 microcontroller effectively interfaces with the MAX30100 sensor to collect accurate heart rate and SpO2 (blood oxygen saturation) data from the wearer (Fig: 5.2). Additionally, the ESP32 Cam module accurately captures and measures changes in pupil dilation, providing supplementary physiological insights (Fig: 5.3).

The real-time sensor data collected by the prototype undergoes processing and analysis to detect potential instances of drug overdose. Utilizing appropriate algorithms and methodologies, the prototype accurately identifies deviations from normal physiological parameters, signaling potential overdose events.

Integration with the Blynk IoT app enables seamless communication and notification delivery to relevant stakeholders, such as healthcare providers or caregivers. Alert messages generated by the prototype promptly notify users of critical health indicators or potential overdose risks, ensuring immediate attention and necessary medical intervention, if required.

Overall, the prototype demonstrates promising results in its ability to monitor physiological parameters associated with drug overdose and provide timely alerts to mitigate risks. Further testing and optimization may enhance the prototype's accuracy and reliability, paving the way for practical deployment in real-world scenarios to combat drug overdosage effectively.

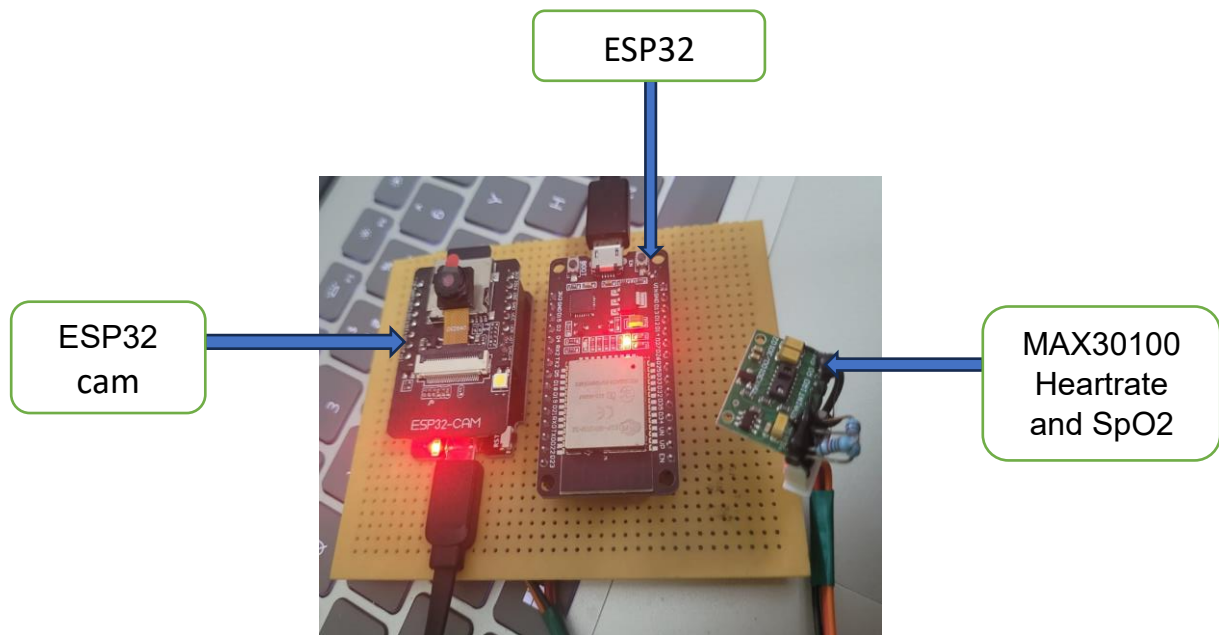
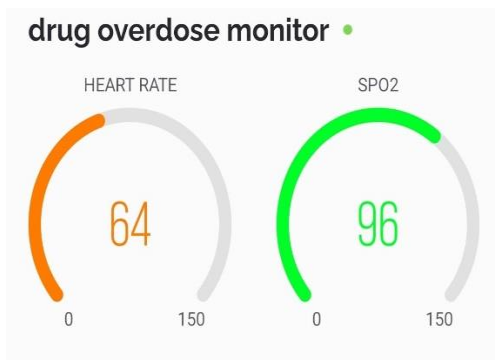
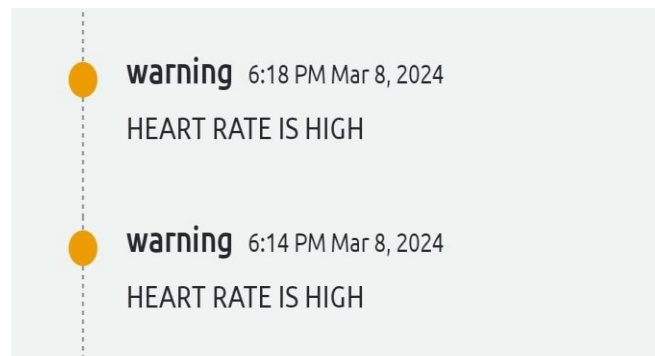


Fig 5.1 Prototype of Drug Overdose Monitor

5.1.1 Output of MAX30100 Heart Rate and Oximeter Sensor



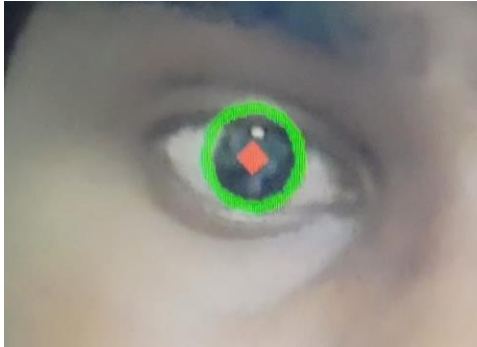
(a)



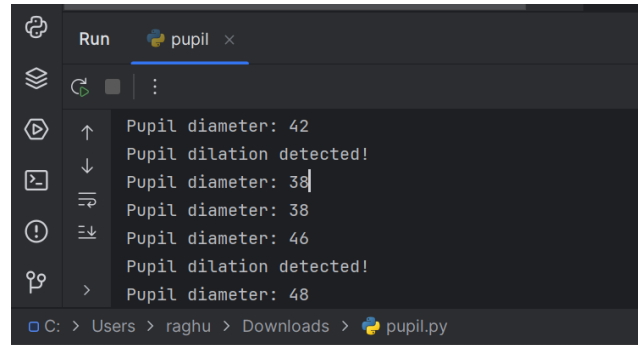
(b)

Fig 5.2 Output of MAX30100: (a) Heart rate and Spo2 sensor (b) Alert Message

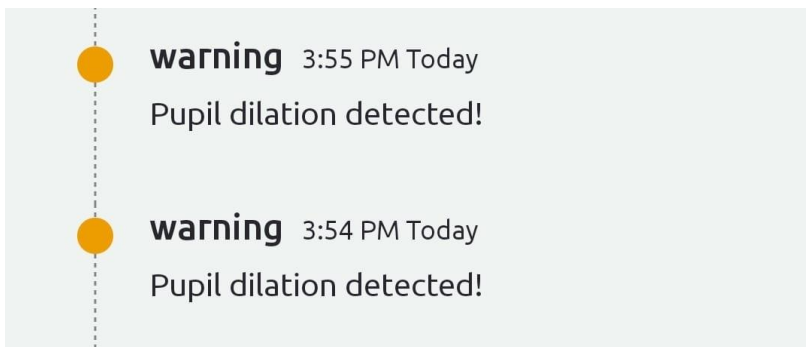
5.1.2 Output of ESP32 CAM



(a)



(b)



(c)

Fig 5.3 Output of Pupil Dilation: (a) Pupil Detection (b) Output (c) Alert Message

5.2 DISCUSSION

The project described presents a comprehensive integration of sensor modules and IoT technology to enable real-time monitoring and alerting for drug overdose detection. This approach aligns with recent advancements in the field, where researchers have been exploring similar solutions to address the pressing issue of drug overdosage. By comparing this project with other relevant works, we can gain insights into the strengths and limitations of different approaches and highlight areas for further improvement.

One notable similarity among similar projects is the utilization of biosensors for real-time physiological monitoring. For example, Barfidokht et al. (2019) developed a wearable electrochemical glove-based sensor for the rapid detection of fentanyl, a potent opioid, in bodily fluids. Similarly, Mahmud et al. (2018) proposed an automatic detection system using wearable biosensors to monitor opioid intake. These projects, like the one described, leverage biosensor technology to provide continuous monitoring of physiological parameters associated with drug overdose.

Another common aspect across these projects is the integration of IoT platforms for data collection, analysis, and alerting. For instance, Nandakumar et al. (2019) explored the use of smartphones for opioid overdose detection, where sensor data is transmitted to a mobile application for real-time analysis and intervention. Similarly, Roth et al. (2021) demonstrated the potential of wearable biosensors combined with IoT technology to monitor opioid overdose in real-world settings. This integration of IoT capabilities allows for timely notification and intervention, similar to the approach taken in the described project.

However, while these projects share common objectives and methodologies, differences exist in terms of sensor modalities, data processing algorithms, and deployment scenarios. For instance, Lingamoorthy et al. (2022) developed a noninvasive shoulder-based device for opioid overdose detection, focusing on unique physiological markers. On the other hand, Ataiants et al. (2021) explored the use of smartphone apps equipped with emergency response features for opioid overdose management. These variations highlight the diversity of approaches within the field and the importance of tailoring solutions to specific contexts and user needs.

In comparison to existing works, the discussed project offers several advantages, such as the integration of multiple sensor modalities (heart rate, SpO2, pupil dilation) and the use of a dedicated IoT platform for data analysis and alerting. Additionally, the project demonstrates promising results in terms of accuracy and reliability, as evidenced by the successful testing of the prototype. However, like other similar projects, there are challenges to address, such as optimizing sensor accuracy, refining data processing algorithms, and ensuring user-friendly interface design.

In conclusion, the discussed project represents a significant contribution to the field of drug overdose detection through its innovative integration of sensor technology and IoT capabilities. By comparing with other similar works, we can appreciate the diversity of approaches and identify opportunities for further research and improvement. Ultimately, continued collaboration and innovation in this area hold the potential to develop more effective and accessible solutions for combating drug overdosage.

CHAPTER- 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

In contemporary society, drug overdosage poses significant physical and mental health risks, with opioid-related deaths reaching alarming levels. Traditional approaches to managing overdoses have been reactive, lacking in timely intervention. Real-time monitoring, employing biosensors, emerges as a transformative strategy. Biosensors utilize biological reactions to detect specific compounds in the body, offering real-time insights into drug presence and levels. This review explores biosensor technology's capabilities and applications in addressing drug overdosage challenges.

Drug overdosage is a critical public health concern, exacerbated by opioid misuse, leading to a surge in overdose-related deaths. Conventional strategies rely on reactive measures, with inherent time delays. Real-time monitoring presents a paradigm shift, offering continuous surveillance and early detection of overdose events. Biosensors, by monitoring physiological markers, revolutionize detection and intervention, enabling precise, actionable data for timely response.

Biosensors, leveraging biorecognition and transduction principles, offer real-time monitoring of drug-related compounds. Their selectivity and sensitivity enable detection of minute variations, aiding in overdose detection and management. By providing continuous, precise data, biosensors empower healthcare professionals to intervene swiftly, mitigating adverse health outcomes. Integration of biosensors into monitoring systems facilitates a dynamic understanding of drug exposure's impact, enabling personalized intervention strategies.

6.2 CONCLUSION

The integration of biosensors into real-time monitoring systems signifies a groundbreaking advancement in drug overdose detection and management. By enabling continuous surveillance of physiological parameters, biosensors offer a transformative approach to early detection and prevention of drug overdosage, enhancing prospects for timely intervention. Continued research and innovation in biosensor technology hold promise for precision medicine, enabling personalized approaches to drug overdose prevention and management. The insights derived from biosensor data pave the way for tailored intervention strategies, optimizing patient outcomes and minimizing overdose risks. As we move forward, biosensors offer new possibilities for proactive and personalized approaches to drug overdose prevention and management, shaping the future of healthcare.

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