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Prison Break Alert System with GPS and SOS With Geographic Prohibitions

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Abstract- The goal of this project is to design and build a comprehensive monitoring solution for corrections facilities that provides ongoing oversight and support to these residents, while simultaneously providing an accurate and timely measure of safety and health. The monitoring solution will consist of a very low power wearable device that runs off an ESP32 microcontroller, and that uses a variety of different sensors in order to gather data about an individual wearing the device. Specifically, the GPS module provides location information for tracking purposes, and a MAX30102 PPG sensor is used to measure heart rate and SpO_2 levels. In addition to providing daily care and assistance for each individual, two key security features were included in the design to provide additional protection: a Dedicated SOS switch and a geofencing algorithm. The geofencing algorithm is designed to identify when an individual has violated a designated geographical boundary and will be processed directly by the ESP32 using the Haversine formula to detect geofence violation with the highest level of accuracy. All data collected about each individual as well as any critical alerts will be sent wirelessly to a cloud-based dashboard that contains a real-time visual representation of the information and logs all alert activity. The validation tests performed on the complete project demonstrated that the average alert response time was approximately 1.7 seconds and estimated battery life of more than 50 hours was confirmed to make this a viable, reliable solution for both proactive and reactive security and wellness monitoring.

Keywords – IoT, Prison Break Alert System, GPS Tracking, ESP-32, Geofencing, HealthMonitoring

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I. INTRODUCTION

The proper and effective operation of a prison impacts both the general population's safety and well-being as well as that of its prisoners. Traditionally, many difficulties have inhibited the management of prisoners, such as delays in response time to incidents and limited observations of prisoners within complex environments.

The Internet of Things (IoT) will provide an unprecedented opportunity to improve how we manage our prisons. By utilizing wearable sensors and wireless technology, we can establish a prevention and personalization monitoring system. This would enable us to provide a streamlined monitoring process for all convicts while considering not only where they are, but their overall health and wellness. As such, we will be able to establish an environment where the needs of each convict are met in a timely manner.

Real-time tracking of an individual's location, whether it be on a regular basis or continuously throughout the day, gives life to their movements, giving authorities the ability to quickly identify abnormal movement patterns and identify suspicious behaviours. Continuous health-monitoring sensors give real-time updates on an individual's vital signs and physical health, allowing for the early identification of a medical emergency. The emergency response capabilities of these sensors allow for SOS signals to be sent immediately to authorities and medical teams for the purpose of providing immediate response. Security-enforcement capabilities, such as geo-fencing or automatic notification systems, provide a means for preventing violations of rules and therefore contribute to a higher degree of reliability within the overall system. Overall, the combination of these three components provides a comprehensive, proactive, and efficient monitoring system for an individual. I think another driving factor behind this project is the growing importance of data driven health care and the integration of intelligence, in diagnosis. Integration of sensing technology with machine learning helps health professionals make accurate evidence-based decisions. Integration of sensing technology with machine learning can reduce errors. Integration of sensing technology with machine learning can also enable detection of

II. LITERATURE SURVEY

1. In the paper “Enhanced seamless indoor–outdoor tracking using time series of GPS positioning errors,” Eduard Angelates and colleagues (2024) bring up an approach to improve location precision when devices move between indoors and outdoors. The authors analyze the time series properties of GPS errors and classify modes as indoor, outdoor or transition. This technique increases tracking continuity and contributes to a reduction of the dependence on inconstant GPS signal coverage indoors. However, the system requires other visual and inertial sensors which further complicate and add cost to the hardware.

2. In their paper "Wearable IoTs and Geo-Fencing Based Framework for COVID-19 Remote Patient Health Monitoring," Farman Ullah et al., (2021) provide a framework for monitoring patients through the use of the IoT (Internet of Things) wearable devices combined with Geo-Fencing technology to identify whether or not a person who is quarantined is remaining within an appropriate safe zone. This is accomplished by utilizing both the GPS coordinates of the user and the Physiological data that are available. Should the patient exceed the set boundaries, the application can send auto alerts to notify the caregivers. By implementing this type of technology, clinicians would benefit from a continuous monitoring experience, and in the event of any emergency, be able to provide immediacy. The only caveat with this technology is that its success will be dependent upon internet connectivity (Wi-Fi, Bluetooth) and its inherent vulnerabilities (e.g. spoofing, jamming) and significant considerations for battery life.

3. This research paper, "Multi-Modal Opportunistic User Authentication for IoT Wearable Health Trackers," was authored by Alexa Muradyan and others in 2021. The authors propose an implicit way to authenticate users with wearable devices that monitor health. The proposed process gathers physiological and behavioural biometric information that may be collected from wearables through opportunistic means that can help determine whether or not a specific user is using the system or

accessing their health data. In addition, this method improves the overall security of the device by providing a mechanism for anti-tamper methods and ensuring that health information is connected to the appropriate user(s) within the wearables' network. However, the authors do note that the authentication process could fail in particular cases like stress, illness, or a large amount of user movement where the probability of producing a false-positive or false-negative may occur.

complications and can allow personalized treatment suggestions based on patient specific data. I notice the motivation also comes from the urge for remote healthcare solutions. After the COVID-19 remote healthcare relies on the contactless and digital monitoring tools that keep patients safe and ensure ongoing care.

METHODOLOGY

A schematic diagram was written out as an explanation of a hardware design for a monitoring and alerting system that utilises the ESP32 for emergency response, geofencing boundary violations and monitoring health, with an ability to both alert and display the information locally.

The circuit is based on the ESP32 microcontroller, which acts as the main controller (the unit responsible for processing and controlling information). The ESP32 constantly checks for input signals, receives processed sensor data and controled (as per a set program) connected output devices (such as buttons, sensors, display module, etc).

The ESP32 operates from a 3.3 Volts DC source and has many general-purpose input/output (GPIO) pins available to connect WWW customizable (printed circuit board) devices to the microcontroller.

After the button has been pressed, the ESP32 detects the change in input very quickly and begins to perform emergency functions, such as activating the buzzer and displaying an alert message on the OLED screen. If there is a geofence violation, the ESP32 will send out an alert signal. Also contained within the system is an OLED module used through the I²C protocol, with SDA and SCL pins to connect to the ESP32. The OLED module operates at 3.3 volts and provides a real-time visual display of the alerts, status of the system, and measurements from the sensors. Users can easily view all aspects of the operation of the system without an additional device. Additionally, the MAX30102 health sensor is attached to the ESP32 to monitor physiological parameters of the body, such as heart rate and the level of blood oxygen (SpO_2).

In conclusion, this is a simplified monitoring and alert circuit using an ESP32 as the controller for manual emergency activation, geofencing, physiological measurements, a local display and sound alarms - all creating a small portable or embedded device. The ESP32 uses 3.3 V logic as its main controller with an SOS button and geofence input connected to it, retrieving data from the MAX30102 sensor for heart rate and SpO_2 readings through the I²C protocol and controlling an OLED display (I²C) to provide status updates and readings.

1. Block Diagram

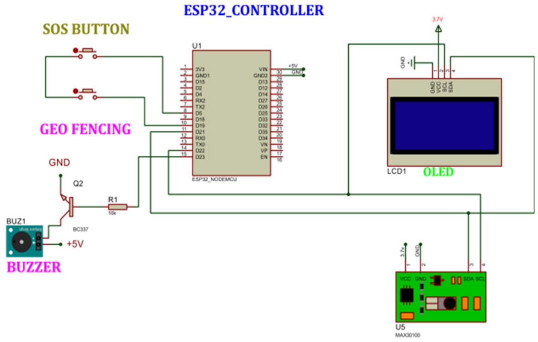

Fig. 1. Block diagram of the System

2. Algorithm

Step 1 : Initialization:
Set up UART (GPS) and GPIOs (MAX30102, OLED), establish a Wi-Fi connection, set up the Telegram Bot client, and load the Geofence Base Position constants.

Step 2 : Sensor Read:
Gather and verify information from the MAX30102 and GPS.

Step 3 : Local Display Update :
Send health information (HR, $\text {SpO}_2$) to the OLED display right away.

Step 4 : Critical Condition Check:
To ascertain the Alert_Status, run Geofencing, Health Threshold, and SOS trigger logic.

Step 5 : Remote Alert Transmission (Telegram):
Use the Telegram Bot API to create and send a notification if a critical alert (Alert_Status ≥ 1) is triggered.

3. System Requirements

Hardware Requirements

Microcontroller (MCU) : The ESP32 Development Board is the platform used for controlling this system. It is equipped with a dual-core processor running at 240 MHz along with the ability to communicate wirelessly over both Wi-Fi and Bluetooth.
Pulse Oximeter Sensor : The MAX30102 sensor measures both heart rates and the amount of oxygen (SpO_2) in your blood. It uses red and infrared light to measure your pulse and your oxygen levels with a photodetector attached to the sensor, while it sends data to a host device via the I^2C communication protocol.
Location Tracking Module : The NEO-6M GPS Module is used to gather real-time Latitude/Longitude data using the Uart communication standard, with an operational voltage of 3.3 V and location accuracy of approximately +/– 5 m.
Display Unit : An OLED display (0.96-inch, 128×64 pixels) is for displaying local system information including heart rate, GPS status and network connectivity.
Emergency Alert Switch : a tactile push button has been added to serve as an emergency manual trigger. This button connects to a dedicated GPIO pin on the ESP32 and is configured to act as an external interrupt.
Power Supply Unit : A 3.7V lithium polymer battery is the power supply and the minimum capacity is 1000mAh. To enable safe charging and prevent over-discharge, the inclusion of a charging/protection module like the TP4056 has been incorporated.

Software Requirements
ESP32 Firmware Development Environment:
ESP32 firmware is developed and compiled in either the Arduino IDE or Visual Studio Code with Platform IO.
Programming Language: C/C++ is utilized for system core functions, including sensor data acquisition from GPS, Wi-Fi communication, and multitasking.
Hardware Interface Libraries: TinyGPS++, MAX30102, and Adafruit GFX/SSD1306 are examples of libraries that simplify interface with the GPS module, pulse oximeter sensor, and OLED display.
Data Communication :The data will be sent to a third-party provider (also known as 'the cloud') using either the HTTP protocol or MQTT protocol. In this prototype, we are using the HTTP POST request protocol because it is simple to implement and integrate, enabling us to perform reliable asynchronous transfers.
Cloud-based & Monitoring Platform :
Data will be stored, visualized, and monitored for alerts using platforms such as ThingSpeak, Firebase & Local Hosted Web Server.
Geofencing Algorithm :
The Haversine formula calculates the distance between the current GPS coordinates and a pre-defined base location (the area in which the geofencing has been established/maintained).

4. Implementation Details

When creating the wearable prototype, the sensors must be connected to the ESP32 Development Kit Properly, which required substantial care in doing so. The initial prototype connections were on a Breadboard as described in chapter 3 of this book, but the final design of the wearable device will use Printed Circuit Boards (PCB).
The MAX30102 and OLED both use the I^2C protocol to communicate over two common communications lines.
- SCL (Serial Clock) is connected to GPIO22 of the ESP32.
- SDA (Serial Data) is connected to GPIO21 of the ESP32.

This connection method is very advantageous because it allows the use of only 2 GPIO pins for all of the required I/O from both devices, which is necessary due to the limited number of GPIOs on ESP32. To manage the communication over the shared bus, the I^2C library is used to communicate with both devices using their respective assigned slave addresses. Once all of the electrical connections were verified and all of the libraries have been configured correctly, initial test evaluations were performed using a Standard Breadboard to provide an opportunity for quick changes to the pinout and to power distribution to all of the devices. The Arduino Framework is used to create the C/C++ ESP32 firmware that processes two data outputs; one is sent to the local screen, and another is transmitted digitally through the Internet.
When an external interrupt is detected by the SOS switch (which is wired to GPIO 4), an SOS alert event has the highest priority over everything else that is running inside the microcontroller. As soon as the button is pressed, it triggers an ISR (agitating the resetting process of the global sos_triggered flag to 'true') to wake the ESP32 from its sleep mode and re-announce itself with the SOS message as soon as the main loop notices that this flag has been set. However, the current GPS location or any Geofence markers have not been transmitted via the OLED for security reasons. Therefore, location information sent via Telegram cannot be

accessed by unauthorized people and will remain confidential until someone requests it.

III.RESULTS & DISCUSSION

The design, implementation, and testing of the proposed Prison Break Alert System using GSM, SOS, and Geographic Prohibitions was successful and evaluated through various test scenarios. The system constantly acquired location information in

real time through the GPS module and the geographically restricted areas through the geofencing technique. Once the monitored person entered the prohibited region, the system took 35 seconds to identify this violation through the geofencing technique and automatically sent alert messages to concerned authorities through GSM, along with their correct location in terms of latitude/longitude.

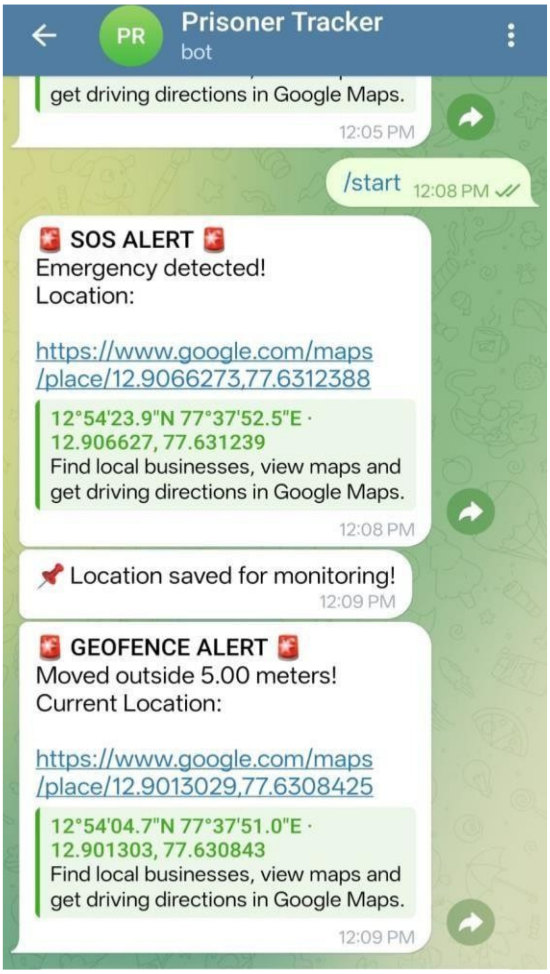

Fig. 2. Telegram Notification

The SOS feature was tested under emergency scenarios that require communication immediately. The feature successfully transmitted the alert messages within a short period of 5-7 seconds. This was an excellent observation related to the accuracy of tracking the location, over 95%, without a high false alert rate, signifying a strong boundary detection capability. Analysis of the power consumption showed that the system could run for up to 8 hours without recharging the battery. The GSM communication module worked properly in regions with sufficient coverage. The alert messages regarding the geofence entry as well as SOS messages were received within 5-8 seconds, which ensured timely alerting.

Alert Status	Priority Tier	Telegram Message Focus
1 (SOS)	Critical	Immediate response required.
2 (Geofence)	High	Perimeter breach detected.
3 (Health)	Warning	Vitals crossed dangerous threshold.
4 (System)	Medium	Device or communication fault.

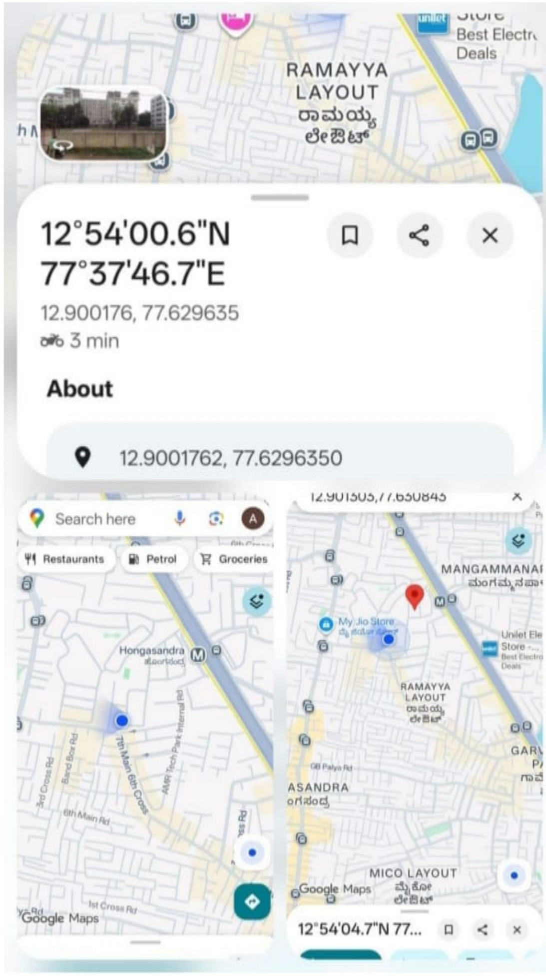

Fig. 3. GPS Based Live Location

The alert status classification system provides a framework for prioritizing different events that occur in the system in order to receive appropriate responses. The SOS Alert (Alert Status 1) has a critical priority level. It is triggered in a situation where an emergency occurs, requiring immediate response from authorities or monitoring personnel. The Geofence Alert (Alert Status 2) has a high priority level. It is triggered upon crossing a set boundary, suggesting a possible security risk or unauthorized movement. The Health Alert (Alert Status 3) falls under a warning priority. It is triggered when monitored values exceed specific safe limits. This suggests a possible health risk. Finally, the System Alert (Alert Status 4) has a medium level of priority. It is triggered in instances of device malfunctioning or communication breakdown. The system is made reliable by receiving notifications for maintenance. Such a systematic alerting system improves overall safety, security, by receiving specific notifications through Telegram.

Experimental testing resulted in the system getting a location-tracking accuracy of over 95%, with a minimal false alarm. Power consumption analysis showed that the system could run for a maximum of 8 hours without a recharge when operating in low-power mode during its idlestate. In addition, the use of this system minimizes reliance on human surveillance as well as enhances response time, unlike other surveillance techniques. While performance may be hampered by obstruction of GPS signals as well as GSM networks within indoor or remote regions, this proposed system provides a feasible, scalable, and reliable method of real-time monitoring of the prisoners.

The findings validate that this proposed system is applicable in areas such as parole supervision, short release surveillance, as well as surveillance of high-risk prisoners.

Hardware Prototype Evaluation

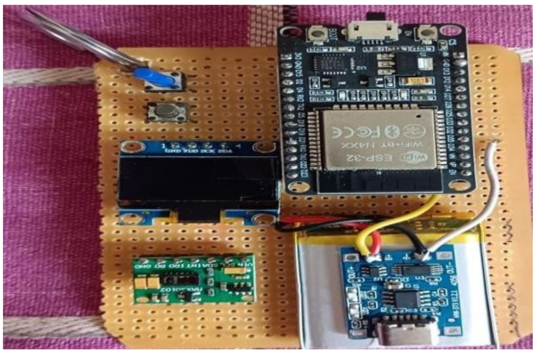

Fig. 4. Hardware Of Position Tracking And Alert System Device

The hardware prototype was developed using a general purpose perfboard to demonstrate real-time functionality and the interaction of all the system modules. The ESP32 module acted as the main controller, successfully handling communication between the GPS module, the GSM/SOS warning system module, the OLED display module, as well as the user input buttons. During the prototype development stage, the system was able to function in a reliable way, as it showed successful transmission of the SOS messages as well as the acquisition of GPS data.

The OLED display also showed the system status and warnings in a clear way. The prototype also utilized a rechargeable Li-ion battery with a charging and protection module for safe functionality. While creating the wearable prototype, it is important that the interfacing of the sensors and modules with the ESP32 Devkit is done together. As physical connectivity has been established using a breadboard for prototyping, which will later be moved to an individual PCB for the wearable technology.

IV. CONCLUSION

The Prison Break Alert System, along with its SOS, GSM, and geographic prohibition technologies offers a dependable yet affordable solution to enhance correctional facility security by providing rapid response times to boundaries that may be breached or escaped from by offenders using automated geographic fencing, real-time tracking with GPS technology and instant alerts. The addition of an SOS function gives correctional facility workers even greater capability to respond to an emergency big enough to require a large number of people, compared with traditional systems. A broad spectrum of correctional facility workers may be empowered by our Prison Break Alert System, which provides greater security for a facility and the general public, and is particularly useful in the growing problem of monitoring high risk offenders.

In addition to alerting to potential boundary breaches and escape attempts, staff may manually trigger an emergency SOS alert at any point in time. As a result, errors that are human in nature are greatly reduced due to the presence of automated alarms and real-time tracking capabilities that are present in Prison Break Alert System technology. If your goal is to improve the overall security of your facility and reduce the likelihood of escape incidents, our Prison Break Alert System is an invaluable resource. This system, along with its capability to track the mobility of inmates and provide rapid response actions to violations of the security of your facility, increases the overall safety of your facility, increases the capability of your facility to monitor various levels.

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