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IOT-Connected Parental Safety System

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Abstract— This paper shows a parental safety device that uses the Internet of Things. The device is built around an ESP32 microcontroller. The device uses a NEO-6M GPS module to get location information. A MAX30102 sensor measures heart rate. Estimates SpO_2 levels. An MPU6050 sensor checks for movement. A MAX4466 module measures sound levels around the device. The ESP32 uses Wi-Fi to send data to a monitoring interface. A passive buzzer and LED lights give alerts directly on the device.The paper describes how the parts work together. It also summarizes the tests done in the project report. The report does not have data to say anything about accuracy or how fast the system works. The system is meant to help parents stay aware. It is not a replacement for a grown-up watching over a child or for equipment.

Index Terms—Internet of Things (IoT), parental safety, ESP32, NEO-6M GPS, MAX30102, MPU6050, MAX4466, Wi-Fi, health monitoring, movement detection.

I. INTRODUCTION

Children often go to school go to classes or join activities without a parent being with them. At these times parents might want to know where the child is and if the device has picked up anything. A system that mixes location details with data from sensors can give better updates than a location tracker by itself.

In this project an ESP32 is used as the controller. It gathers data from the GPS module and the health, motion and sound sensors that are connected. The data is handled by the controller. Sent to a monitoring screen, through Wi-Fi. The device also uses a buzzer and LEDs to give warnings when the set conditions are met.

II. RELATED WORK AND DESIGN NEED

Iot monitoring work shows how connected sensors and small embedded devices can collect information and make it accessible to users. A GPS-device mainly reports location while a health sensor by itself cannot reveal where the user is. Bringing together types of readings can give parents a broader picture yet the quality of information still relies on sensor placement, signal conditions and reliable communication. The project adopts an approach, by combining the selected modules with an ESP32 and a Wi-Fi connection.

III. SYSTEM DESIGN

A. Hardware and Communication

The hardware is centred on the ESP32 development board. The NEO-6M GPS module provides location coordinates when it can receive satellite signals. The MAX30102 uses optical sensing to estimate heart rate and SpO_2. The MPU6050 measures acceleration and rotation, which can help the system recognise unusual movement. The MAX4466 provides an analogue output that can be used to observe the surrounding sound level. The ESP32 reads these inputs and controls the buzzer and LED indicators .The controller and its communication interfaces are described in the ESP32 technical documentation . The MAX30102 and MPU6050 functions are based on their respective device specifications while the NEO-6M receiver and MAX4466 microphone amplifier are documented .

During operation, the ESP32 acts as the central point for acquiring and coordinating the sensor information. The GPS receiver supplies latitude and longitude when a satellite fix is available. The MAX30102 provides optical pulse-related measurements from which heart rate and estimated oxygen saturation can be derived. Since the optical signal depends on stable contact, the readings may fluctuate when the device moves or is loosely positioned. The MPU6050 contributes acceleration and angular-motion information, allowing the program to observe sudden changes in activity. The MAX4466 supplies an analogue signal that varies with surrounding sound intensity. These inputs are different in nature, so each must be interpreted according to the role and limitations of its sensor.

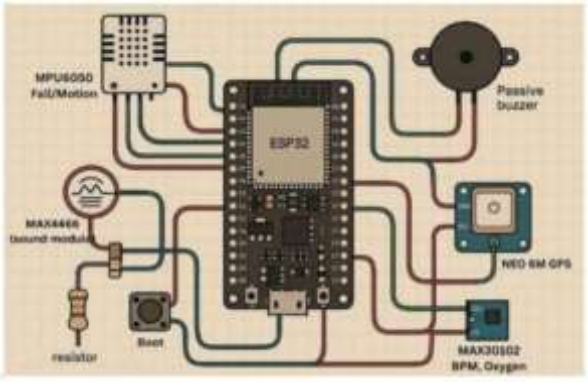


Fig. 1. Project hardware interconnection illustration showing the ESP32 and connected sensor and alert modules.

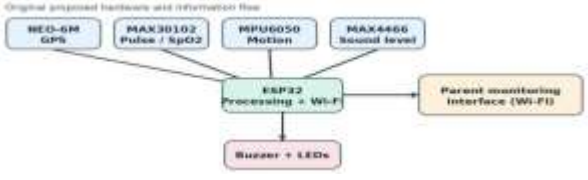


Fig. 2. Original proposed hardware and information flow.

The ESP32 uses Wi-Fi to send the available information to the monitoring interface. The way this works depends on the network arrangement used in the project. Wi-Fi coverage is therefore a

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practical requirement for sending updates. No cloud storage or Bluetooth link is included. The ESP32 Wi-Fi capability and software interface are documented by the manufacturer

B. Event Detection

Suddenly changing accelerometers, and changing orientation, could indicate a fall. Additionally, we can look at certain heart rate, SpO_2 and sound level factors. However, these are just indicators and not evidence of an emergency. Sometimes during normal play or sudden activity there can appear to be a fall.

During this step of the system, we are looking at certain factors that have been programme into the controller. We are looking at the pattern of movement to see if there has been any sudden changes to acceleration and orientation. We are comparing the health related factors to our set thresholds. Finally we are looking at the sound sensor to see if there has been any increase in sound around them. These are all indicators to the user and do not give us evidence of what has caused an event. An increase in sound does not tell us if someone is speaking. Also, if there has been an indicator of a fall we need to look at the context available to us and decide on what needs to be done by the caregiver.

C. Data Handling and Output Indication

The controller is used to collect and process the data coming from the sensors. Each module provides specific data; GPS provides location data, optical sensor provides data about pulses, inertial sensor provides movement data and the microphone module provides a signal representing the sound level. The ESP32 processes the available data along with any programmed conditions and updates the monitoring interface. There is also a buzzer and LED to give indication locally meaning there is an alert regardless of if it is being monitored through the interface.

Each sensor provides specific data which should be shown clearly. GPS provides the estimations of the location of the device, MAX30102 provides estimates of physiological data, MPU6050 provides movement data. MAX4466 provides the intensity of sounds around the microphone however it does not know what the sound is. Keeping the data separate when displaying using the monitoring interface allows a caregiver to understand exactly what has been measured. It will not show any changes in the sound level or movement as confirmed emergencies. The controller is able to link the available data to any programmed alert conditions, however the quality and recentness of the data will affect how the data is interpreted..

IV. IMPLEMENTATION METHODOLOGY

The hardware is tested for each module individually. Once everything is connected to the ESP32 we test the GPS to make sure it outputs coordinates, MAX30102 and MPU6050 to check if they are outputting sensor data, and MAX4466 to ensure that it outputs changing sound levels. We then combine these readings into the ESP32 program. The values are processed to trigger the buzzer or LEDs once the desired conditions are met.

A. Integration Procedure

Once the circuitry and interfacing are confirmed, the GPS module will send location information to the controller. The sensor modules will then send their values from their respective inputs. The firmware will constantly read these values and check if any of the chosen conditions are met. This provides a way to check that there are no issues with the circuitry or sensors. If an unexpected output is produced it can be easily identified if it is caused by the sensor, controller program or wi-fi connection.

Finally, when the controller is started it needs to be initialised along with any modules connected to it. The GPS module might need to wait a while and have a clear view to get a correct position. Whilst waiting do not consider the coordinates to be correct if they are not present. The other sensors can be checked by seeing if they produce a changing output depending on the input. Once the values are available the firmware will constantly read them and check if any conditions are met. This means that the device can constantly update the monitoring interface with any new sensor values.

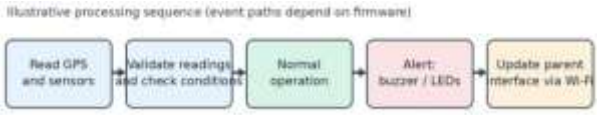


Fig. 3. Illustrative processing sequence; event paths depend on firmware.

The monitoring aspect will show the most recent values provided by the device and the most recent GPS location. If an SOS or any pre-programmed situation is triggered then the device can provide local alerts whilst also updating via its Wi-Fi. If there is no GPS signal or Wi-Fi connection then the user should be made aware that there may be no or outdated data from the location/sensor.

Typically, once the device is powered on the controller will start to gather data from the modules connected. If there is a valid GPS location then it can be sent to the monitoring aspect via Wi-Fi. Whilst the health and motion sensors are providing data, if there is a pre-programmed situation detected then the buzzer and LED can provide local alerts. The data that is available can then be sent to the interface whilst the network is active. The parent can then look at the data they have received and get in contact with or check on the child. This shows how the device can be monitored but does not guarantee any emergency services.

The communication aspect uses the ESP32 and Wi-Fi network. The controller will format the latest sensor data and send it to the monitoring aspect using the communication setup within the project. The parent/guardian can then see the data and location that has been received. It is only useful to update remotely if the Wi-Fi is working and there is up-to-date sensor data. If these are not available then there may be delays or incomplete data shown. The buzzer and LEDs can provide local alerts.

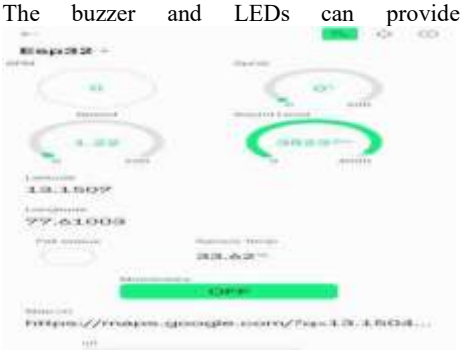


Fig. 4. Example monitoring dashboard captured from the project implementation.

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V. TESTING AND DISCUSSION

This section of the project report details the functionality testing performed on the sensor values, GPS tracking, Fall detection, sound level and alerts. It also details some testing on chosen communication and device issues, giving an overview of the monitoring interface. This shows that the main components of the prototype have been connected and tested.

It was beneficial to perform some functionality testing. This involved first testing each individual module and then testing the whole circuit together. The GPS tracking can be tested by ensuring it is providing a valid co-ordinate and that the monitoring interface is displaying the same information. The MAX30102 can be tested by ensuring the pulse related values and estimated SpO_2 are being displayed. The MPU6050 can be tested by observing what happens when there is normal movement and intentional changes of orientation. The MAX4466 can be tested by comparing the output when there is less noise around. Finally, the buzzer and LED outputs can be tested to ensure they are responding to the conditions that have been programmed.

Not all the values were recorded for GPS error, fall detection accuracy, false alerts, Wi-Fi transmission times and battery life. Therefore no specific percentage accuracy or response times can be stated in this paper. Further testing should be done to ensure that the GPS value matches known positions, using normal movements and fall like movements. The number of Wi-Fi messages that are received by the monitoring interface should also be recorded.

A. Test Conditions and Interpretation

The functional checks aim to provide assurance that the modules and core functions are working together and not a full clinical or safety check. Finger positioning, movement and pressure will alter the heart rate and SpO_2 values. GPS will vary based on satellite visibility. Sound level measurements will vary depending on the distance and direction of the sound. The alert should be used to make the caregiver aware that they should check the situation. It is not a confirmation of medical condition or that an accident has occurred.

B. Practical Considerations

The device needs to be fixed so that the sensor has good contact without causing discomfort. The controller and wires need to be protected from being pulled and waterproofed. Wi-Fi connectivity is an important consideration. Without it, the buzzer and LED will still work, however there may be issues with remote monitoring. This needs to be recorded in future testing so that it is clear if the sensor is not available or out of range.

The device needs to be regularly checked. Before using the device the caregiver needs to make sure that the device is working. This includes checking that the sensors are connected, there is power to the device, and that the monitoring screen is showing current data. The GPS should be checked to ensure that there is a location available. The optical sensor should be placed correctly and the wearable should not cause discomfort by pressing. The casing should protect the electronics but allow the correct sensors to work. Whilst this does not overcome any issues with the prototype, it can help identify any basic issues with the device. For example if there is a loose connection, poor contact with the sensors or no network available.

VI. LIMITATIONS AND FUTURE SCOPE

There are limitations to the system. GPS signals can be weak indoors and MAX30102 values can fluctuate due to movement and poor contact. It cannot always be assumed that sudden movement will have been caused by a fall. The high sound levels do not tell us why there was a high sound level. The system will require power and a Wi-Fi signal to upload data. Potential improvements could be made to the wearable casing, reduce power consumption, improve the alert conditions and carry out more detailed testing.

A more thorough testing can be carried out. This can include tracking how many successful GPS updates were achieved in open and blocked areas, comparing the coordinates shown against a known location, and testing different movement patterns. Testing can be carried out multiple times to find the amount of missed events and false alerts. Testing with Wi-Fi can track how many data uploads were received whilst the system was in normal operation and when there was a momentary loss of signal. Tracking how much power is used can give an indication of how much battery would be required for the system to operate for a set amount of time. Overall this will give a better understanding of how reliable the system is.

The system is a prototype to assist with monitoring and not a guarantee for emergency situations. Sensor data can vary depending on movement, position and surrounding environment. If there is a loss of network then the system will not receive the data upload remotely. The sound module is only an input for sound levels and the project should not be seen as recording conversations or speech recognition. The heart rate and SpO_2 are estimates from an optical sensor and should not be used for medical diagnosis. The alert should be confirmed by the caregiver directly or through an appropriate communication method.

VII. CONCLUSION

The IoT Connected Parental Safety System allows parents to monitor and increase their children's safety by continuously monitoring their location, health, movement and surrounding sounds. This is achieved using the ESP32 microcontroller to collect data from the following components: NEO 6M GPS Module, MAX30102 Heart Rate & SpO_2 Sensor, MPU6050 Movement Sensor and MAX4466 Sound Sensor. The components allow important data to be collected and any issues flagged. The GPS module allows location to be tracked, the MAX30102 allows heart rate and estimated oxygen saturation to be tracked, the MPU6050 tracks any movement and potential fall activity and the MAX4466 tracks surrounding sounds.

This data is then processed by the ESP32 to send relevant data using Wi-Fi. A passive buzzer and LED lights are included to allow for local alerts to be given if any set conditions are met. This shows how useful embedded systems can be along with sensor technologies in creating a real life solution to monitoring children. The circuit layout has been created to keep everything neat and compact.

This system can help increase parent awareness of where the child is and any potential emergency situations. It adds another level of monitoring to the system by including multiple sensors. However, sensor accuracy can vary depending on where they are placed, what the environment is like, how good the GPS signal is and the network connection. The heart rate and SpO_2 should be seen as estimates when monitoring. Any movements detected should be seen as potential falls.

The system can be improved in the future by including more advanced ways of analysing the sensor data, more efficient alerts, better GPS accuracy and a more user friendly parental monitoring system. It can also be tested under various environmental and

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operating conditions to see how reliable the whole system is. Overall, this project shows how IoT, embedded systems, GPS and health monitoring sensors can be used to create a prototype to monitor children's safety. This can be used as a base to improve smart parental monitoring.

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