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ORIGINAL CONTRIBUTION

IoT-Enabled Shoe-Embedded Safety Device for Child Protection

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ABSTRACT

This paper presents an IoT-enabled safety device embedded in shoes to enhance child protection through real-time tracking, fall detection, and emergency alerts. The World Health Organization (WHO) highlights the critical need for effective safety measures, as rapid urbanization, increased mobility, and changing social structures expose children to greater risks. By integrating these technologies into children's everyday footwear, the device ensures consistent usage, minimizes the likelihood of misplacement and enhances accessibility for caregivers or guardians. Performance evaluations, conducted through extensive testing, validate the system's effectiveness in providing reliable safety and monitoring for children. Furthermore, the final product is designed to balance functionality and cost-effectiveness, making it both competitive and affordable, ensuring it is accessible to a wide range of families.

KEYWORDS: Child Safety, Child monitoring, IoT, GPS Tracking, Emergency Alerts, Smart shoe, GPS tracking

1. INTRODUCTION

Child safety is a crucial global issue, with unintentional injuries—such as road accidents and falls—ranking among the leading causes of death for children under 18, according to the World Health Organization (WHO). Moreover, the threats of child abduction and exploitation are also on the rise. Despite existing safety measures, the risks faced by children in today's rapidly changing world continue to grow. Factors like urbanization and increased mobility have contributed to unpredictable environments, even in traditionally safe spaces like schools, playgrounds, and neighborhoods.

Technology offers promising solutions, mainly through the Internet of Things (IoT). IoT has transformed areas like home security and healthcare by enabling real-time data sharing. However, its application in child safety is still underdeveloped. This paper proposes the creation of an IoT-powered, shoe-embedded safety device that combines real-time tracking, fall detection, and emergency alerts. This device ensures consistent use and minimizes the risks associated with lost or forgotten safety devices.

2. Literature Review

Child safety devices, including wearable GPS trackers and smart watches, have shown effectiveness in location tracking and emergency alerting [1, 2, 3]. However, several challenges still need to be addressed, such as the potential for device removal, inconsistent usage patterns, and reliance on mobile phones. Research into IoT-enabled safety systems indicates promising avenues for enhancing response mechanisms in areas like healthcare and security, yet integrating IoT into everyday items, such as shoes, remains relatively uncharted. This shoe-integrated device seeks to fill these gaps by offering children a seamless, continually active safety solution. Various wearable technologies for child safety have been examined, with insights into their strengths and weaknesses discussed in [4]. The authors in [5] explored IoT-based safety monitoring systems and their applications in child

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safety, including case studies illustrating how these systems can be effectively implemented. A detailed analysis of real-time location tracking challenges in GPS-based systems was presented in [6]. Yang et al. [11] demonstrated the use of clever shoes. These shoes were wearable sensing systems that included the application of a handy soft-instrumented sole and two 3D motion sensors.

Authors in [7] also extensively review GSM-based alert systems and their applications. The authors in [8] focused on designing and optimizing power-efficient IoT devices. This paper reviews various innovative wearable technologies that prevent child abduction and enhance child safety through IoT applications.

3. System Design and Components

The shoe-embedded safety device integrates various hardware components for real-time tracking, alerting, and proactive monitoring. The system utilizes an Arduino Uno microcontroller and a GSM module to manage sensor interactions, ensuring reliable safety responses.

The shoe-embedded safety device integrates advanced hardware and software components to ensure real-time tracking, alerting, and proactive safety monitoring. As shown in Fig. 1(a), at the core of the system, an Arduino Uno microcontroller coordinates the functionality of the GPS module, GSM module, and pressure sensor, enabling reliable and timely safety responses. The embedded software optimizes system operations by managing continuous sensor data flow. It monitors the pressure sensor for anomalies, such as unexpected shoe removal, and regularly updates location data through the GPS module. Upon detecting an anomaly or manual activation via the emergency button, the GSM module is triggered to send a real-time SMS alert with precise location details to predefined contacts, ensuring rapid response in critical situations. The control flow diagram shows the details of the system of our proposed solution in Fig.1 (b). The proposed system also includes error-handling signal-loss protocols, ensuring reliability even in suboptimal conditions.

Key Components:

- **Arduino Uno**: The central component of the system, coordinating inputs from sensors and triggering alerts via the GSM module.
- **GPS Module**: Provides real-time location updates, enabling caregivers to track the child's whereabouts.
- **GSM Module**: Transmits critical alerts and location data via SMS to registered contacts in case of emergencies.
- **Pressure Sensor (FSR)**: Detects whether the shoe is being worn and flags its removal, triggering alerts to parents.
- **Emergency Button**: Allows the child to manually send SOS alerts along with location details.

The circuit design has been refined for durability and efficiency. The Arduino Uno interfaces with the GPS and GSM modules using UART. At the same time, the pressure sensor is connected to an analog pin, and the emergency button is linked to a digital pin. A rechargeable lithium-ion battery powers the entire system, supported by a voltage regulator to ensure stable performance.

Moreover, the design integrates power-saving features, such as sleep modes for both the Arduino and peripheral modules, to enhance battery life. The device is encased in a waterproof, flexible housing embedded in the shoe sole, providing reliability and comfort.

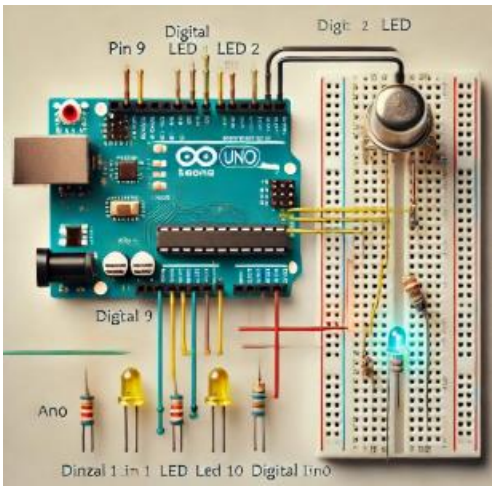

Fig.1. Circuit diagram of our proposed system with required components.

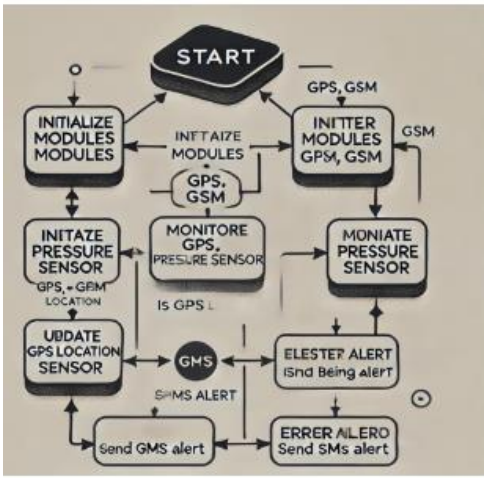

Fig.2. Proposed system design flowchart.

4. Results and Discussion

Scenario Testing:

- **Continuous Tracking**: The GPS module provided an accuracy range of 3-5 meters, consistent in both urban and semi-urban environments.

- **Shoe Removal Alerts**: The pressure sensor detected shoe removal within 5 seconds, with alerts being sent within 8 seconds.
- **Manual SOS Activation**: The emergency button successfully triggered SMS alerts within 6-8 seconds, ensuring rapid response during emergencies.

Quantitative Results:

- **GPS Accuracy**: 95% accuracy in location tracking.
- **Alert Time**: An average of 7 seconds to send alerts after a trigger event.
- **Battery Life**: The device operated for 12 hours continuously, extendable to 18 hours using power-saving modes.

5. Conclusion

The system significantly enhances child safety through an integrated GPS module that provides precise location tracking, complemented by a reliable GSM alert system with minimal latency. Key features include a pressure sensor, an emergency button, and efficient power management, all housed in a durable waterproof casing. Designed for shoes, this IoT-enabled device offers real-time tracking, fall detection, and SOS alerts, ensuring it is practical and frequently utilized. The functionality and cost-effectiveness of this solution make it accessible and appealing to a wide range of families. Future enhancements may include voice communication capabilities and integration with smart home systems. Finally, there is a crucial need for further research into the long-term use and maintenance of smart shoe systems designed for children. Understanding the durability and reliability of these systems over time is essential, along with the resources and necessary support for their sustenance.

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