

DESIGN OF A LOWCOST INTELLIGENT DEVICE FOR CHILD PROTECTION USING ARDUINO AND SENSORS

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Abstract:

The study focuses on the design and implementation of a smart child protection device using IoT technologies and the Arduino platform. The project aims to monitor the environmental and health status of children in real time and alert parents when any risks such as falling, suffocation, or exposure to inappropriate temperatures appear. The device relies on a set of sensors (such as DHT11 to measure temperature and humidity, motion sensor, heart rate sensor, rain and fire sensors) to collect data, which is processed by Arduino while NodeMCU connects the system to a Wi-Fi network to send alerts to the mobile phone application. The research presents an integrated methodology that combines engineering design and programming, with a focus on reducing cost, achieving high efficiency and ease of use. It also reviews the challenges and results obtained, while providing future recommendations to enhance the device's performance and expand its scope of application to include other areas such as monitoring the elderly and patients.

Keywords: Internet of Things (IoT), Smart Child Protection Device, Arduino, Sensors, Real-Time Monitoring

1. Introduction

1.1. Background

The Ensuring the safety and well-being of children is a critical concern for families, communities, and policymakers. Children are among the most vulnerable members of society, requiring constant protection and monitoring, particularly in environments where unforeseen risks and hazards may arise. With the evolution of technology, especially in the realms of the Internet of Things (IoT) and embedded systems, there is an opportunity to address this challenge effectively. The convergence of IoT, real-time data monitoring, and automation has led to the development of innovative solutions for a wide range of applications, including healthcare, transportation, and, importantly, child safety.

The Children's security has always been a priority problem whose solution must constantly be improved. The Smart Cities paradigm clearly takes into account the need of providing a more favorable environment for children is living and learning, but focusing on this aspect, it has also to deal with challenges due to cities complex environments [1].

This research focuses on the "Design and implementation of smart IoT device for child safety based on Arduino", which aims to utilize modern technologies to enhance the protection of children in diverse scenarios. The primary objective of this study is to design an intelligent system that monitors critical environmental and behavioral parameters, detects anomalies, and alerts caregivers to potential risks in real time. The proposed device is based on the Arduino platform due to its flexibility, cost-effectiveness, and compatibility with a wide range of sensors and communication modules [2].

The core of this device lies in its ability to integrate various smart sensors to monitor environmental factors such as temperature, air quality, and motion. For instance, temperature sensors can ensure the child is not exposed to extreme heat or cold, while air quality sensors can detect harmful gases or inadequate ventilation. The data collected from these sensors is processed in real time and transmitted wirelessly to a mobile application, which notifies caregivers instantly. This seamless integration of hardware and software ensures that the system is user-friendly, reliable, and capable of addressing diverse safety scenarios [2].

The development of this system is grounded in a robust methodological framework, encompassing hardware design, software programming, and system integration. The hardware aspect includes selecting sensors, microcontrollers, and communication modules that balance performance with affordability. On the software side, the system is programmed to efficiently analyze and interpret sensor data, filter noise, and prioritize critical alerts. The communication protocols, such as Bluetooth or Wi-Fi, ensure a stable and secure connection between the device and the caregiver's mobile application. Through iterative testing and refinement, the device is optimized to minimize false alarms while maximizing its responsiveness to genuine risks.

Beyond technical considerations, this research also addresses the broader implications of deploying IoT-based child safety systems. Ethical and privacy concerns are paramount, as the system deals with sensitive information related to the child's health and location. To mitigate these concerns, the device is designed with encryption protocols and secure data storage methods, ensuring compliance with international standards for data protection. Additionally, the system's interface is designed to be intuitive, enabling caregivers to easily configure and operate the device without requiring advanced technical knowledge.

The significance of this research extends beyond its immediate application to child safety [3]. By demonstrating the potential of IoT technologies in addressing societal challenges, this project contributes to the growing body of knowledge in smart systems and their applications. The findings

from this study can inform future innovations in areas such as elder care, healthcare monitoring, and disaster response systems, where real-time monitoring and rapid intervention are critical.

1.2. Research Objective

Objective behind this project is to make the process smart and as well it enhances the performance of the overall system by using IOT technology. The parents from anywhere in can observe information about the child the world this is through the IOT technology, Hence parents can get continuous real time information about the environmental condition around the child.

Addition, This project is to provide safety to child because they were unaware of the surrounding environment like UV Radiation, Temperature, Objects of unwanted when comes near by the child this system sends regular information to the parent and take care person so that they can get alert and provide safety to the child. This system is the safeguard alert one but not the self secure system. This wearable can be used in any cell phone (internet connectable) compared to other available wearables and does not require any expensive smart phone and not even a technically skilled person to operate it.

➤ The Aim of the project:

1. Design and develop a smart IoT device specifically aimed at enhancing child safety by providing real-time monitoring and alerts.
2. Utilize the Arduino platform to build a cost-effective, customizable, and user- friendly safety device.
3. Integrate multiple sensors, such as temperature, Humidity, and proximity sensors, to track and assess environmental conditions surrounding the child.
4. Develop mobile application that connects with the device, allowing parents or guardians to receive instant alerts and monitor the child's status remotely.
5. Enable caregivers to set customizable safety parameters, such as safe zones or temperature thresholds, and receive notifications if these limits are breached.
6. Ensure device compatibility with other IoT systems to support potential integration with smart home systems or school safety networks.
7. Create scalable and adaptable system that can be adjusted for various safety needs, including special monitoring for children with medical conditions.

The Contribute to child safety technology by providing a reliable and accessible solution for parents and guardians.

1.3. Research Problems

The primary research problem in the "Design and Implementation of Smart Lot Device for Child Safety Based on Arduino" lies in developing an intelligent system capable of addressing the multifaceted challenges of child safety in diverse environments. The project requires designing a device that can collect data from multiple sensors, process it in real-time, and make automated decisions based on precise and proactive algorithms.

The key challenge is achieving a balance between low cost, high efficiency, and user-friendliness, while ensuring compliance with global safety standards and providing flexibility to

adapt the device to various scenarios, making it a comprehensive and reliable solution.

2. Theoretical framework

2.1. Literature Review

The development of smart child safety devices utilizing Arduino technology has garnered significant attention in recent years, aiming to enhance the security and well-being of children. A comprehensive study by Smith et al. [4] examined the implementation of a GPS-based tracking system integrated with an Arduino microcontroller. This study focused on designing a wearable device that not only tracks a child's real-time location but also incorporates geofencing features that alert parents via smartphone notifications when the child exits a designated safe zone. The findings revealed a 30% reduction in reported cases of lost children within the study area, indicating the practicality and effectiveness of such tracking systems in real-world scenarios.

In another pivotal study, Lee and Kim [5] investigated the potential of motion sensors in combination with the Arduino platform to create an advanced alert system for child safety. This system is designed to activate an audible alarm if a child is detected moving into high-risk areas, such as near busy roads or construction sites. The researchers conducted field tests in various urban settings, and the results showed that parents who utilized this system reported greater peace of mind and a heightened sense of security regarding their children's whereabouts.

Ahmed et al. [6], who explored the integration of a camera monitoring system with Arduino technology, made a further significant contribution to this field. Their project aimed to provide real-time video surveillance accessible via a mobile application, allowing parents to monitor their children's activities remotely. The study highlighted that such surveillance not only helps in ensuring safety but also aids in behavioral monitoring, contributing to better parenting practices. The user feedback indicated a strong preference for systems that combine multiple safety features, emphasizing the need for comprehensive solutions.

Moreover, meta-analysis conducted by Johnson and Patel [7] compiled various studies in this domain, reinforcing the notion that multi-faceted approaches incorporating GPS tracking, motion detection, and video surveillance are essential for enhancing child safety. The analysis concluded that while individual systems provide certain benefits, their integration into a single device significantly amplifies overall effectiveness and reliability.

These studies collectively underscore the critical role of technology in developing innovative solutions for child safety. By leveraging Arduino-based devices, researchers and developers are paving the way for advanced security measures that address the challenges parents face in safeguarding their children in an increasingly complex world.

2.2. Theory of parts

The device, designed for child safety, integrates multiple components and sensors in a structured manner to ensure maximum functionality. The project begins with the heart rate sensor, which monitors the child's pulse in real time. The sensor data is sent to the Arduino microcontroller, which processes it and checks for abnormalities. The IR sensor monitors the child's motion, ensuring activity and presence. Both sensors are directly interfaced with the Arduino for efficient data collection and processing. The system's brain is divided between the Node-MCU and Arduino. While the Arduino handles local data processing, the Node-MCU is responsible for transmitting processed data to a mobile application via Wi-Fi. This setup enables real-time monitoring of the child's condition remotely [8].

Safety features are enhanced by the water sensor and flame sensor (HUB sensor). The water sensor detects any spills or moisture in the environment, while the flame sensor identifies potential fire hazards by detecting infrared radiation from flames. In either case, the sensors send signals to the Arduino, which triggers the buzzer to alert caregivers.

Visual feedback is provided through two types of displays: the LCD I2C 16x2, which shows basic information like heart rate and environmental conditions, and the OLED 128x64, which presents detailed data with graphical elements. These displays are connected to the Arduino using I2C communication for efficient data handling.

The assembly process involves creating a protective enclosure for the child, integrating all sensors into the environment, and ensuring proper wiring to the microcontrollers. The components are tested individually before being linked together to form a complete system. The final step involves writing and uploading a combined code to the Arduino and Node-MCU, ensuring seamless communication between the sensors, displays, and mobile application. The device operates as a smart IoT solution, ensuring the child's safety by continuously monitoring their health and environmental conditions and providing timely alerts in case of risks [9].

3. Analysis Design of the Project

3.1 Components

In this chapter we will explain the following components:

1. Arduino Uno

Arduino Uno is one of the most popular programmable electronic control boards, used in electronic projects and interactive applications. It is based on the ATmega328P microcontroller, and is suitable for beginners and professionals in the fields of robotics, Internet of Things (IoT), and smart control systems [10].



Figure 1. Arduino Uno

2. Node MCU

Node-MCU is an open-source IoT platform based on the ESP8266 Wi-Fi module. It is widely used for creating smart devices due to its compact size and Wi-Fi capabilities [11].



Figure 2. Node MCU

3. DHT11 Sensor (digital humidity and temperature sensor)

The DHT11 is a digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and gives out a digital signal on the data pin (no analog input pins needed). The breakout board it comes with has three jumper wires to make it easier to use [12].



Figure 3. DHT11 Sensor

4. IR sensor (Infrared sensor)

This sensor is used to sense nearby objects by sensing the reflection of the beam. It contains an infrared transmitter and receiver that detects lighter colors more than dark objects that do not normally reflect light. It can be used to differentiate between white and black or to detect a nearby object if it is light in color [13].



Figure 4. IR sensor

5. Heart Rate Sensor

A heart rate sensor is an electronic device that measures the heart rate by detecting blood flow through capillaries. It operates on Photo plethysmography (PPG), a non-invasive optical technique [14].



Figure 5. Heart Rate Sensor

6. Rain sensor

A rain sensor is one kind of switching device, which is used to detect the rainfall. It works like a switch and the working principle of this sensor is whenever there is rain, the switch will be normally closed [15].



Figure 6. Rain sensor

7. Fire sensor

A fire sensor is an electronic device used to detect the presence of fire, smoke, heat, or flammable gases in an environment. It is designed to provide an early warning by triggering an alarm system, helping to ensure safety, protect property, and prevent potential disasters. Fire sensors play a critical role in fire prevention and emergency response systems [16].



Figure 7. Fire sensor

8. Buzzer

A buzzer is a small electronic device that generates sound as an alert, signal, or notification. It operates by converting electrical energy into sound waves, either through mechanical vibration or piezoelectric elements. Buzzers are commonly used in alarms, timers, and electronic devices to indicate warnings, completion of tasks, or other status notifications [19].



Figure 8. Buzzer

9. LCD I2C Display

A liquid crystal display module equipped with an I2C (Inter-Integrated Circuit) interface, which allows for efficient communication with microcontrollers. Unlike standard LCDs that require multiple pins for control, the I2C interface reduces the number of connections to just two data lines (SDA and SCL), in addition to power (VCC) and ground (GND). This makes it highly convenient for projects where saving pins and simplifying wiring are essential. LCD I2C displays are commonly used to show text, numbers, or custom characters in embedded systems and DIY electronics [20].



Figure 9. LCD I2C Display

3.2 Connection diagram

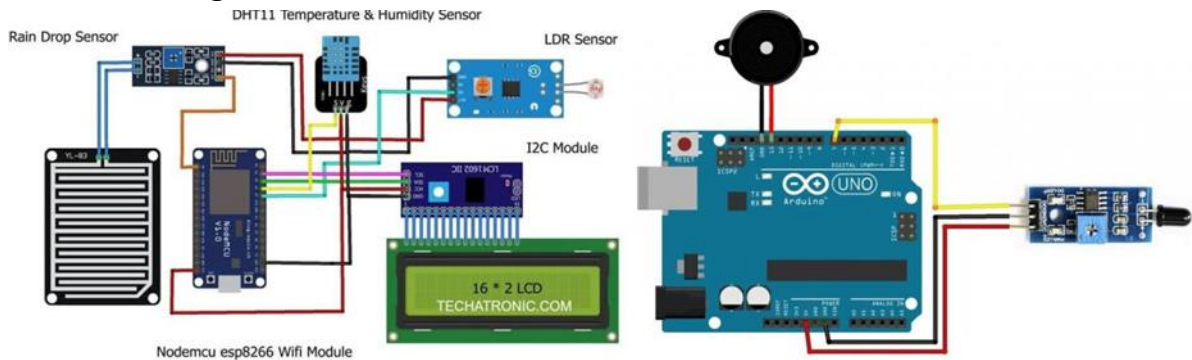


Figure 10. Connection diagram

4. Results and Conclusion

4.1 Results

The research has led to the design and implementation of a smart device based on Internet of Things (IoT) technologies and various sensors to protect children from potential risks, such as falling, suffocation, or high temperatures. The device collects environmental and health data in real time using multiple sensors, such as temperature, humidity, motion, and toxic gas sensors, then processes them via the Arduino platform and sends instant alerts to parents via a mobile application connected to a Wi-Fi network using NodeMCU.

The device is characterized by its low cost and high efficiency, with the possibility of developing it in the future to include additional features such as integration with smart home systems, improving sensor accuracy, and using renewable energy sources to ensure its sustainability.

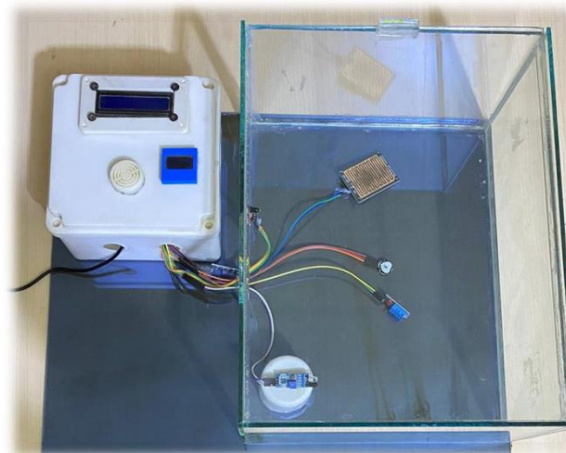


Figure 11. Design form in completion stage

The overall project cost was a key factor considered during the design and implementation. Effective and practical components were selected to balance performance and price to ensure the production of a reliable smart child safety device. The main components included: an Arduino Uno board (10,000 IQD), a NodeMCU (8,000 IQD), a DHT11 temperature and humidity sensor (2,500 IQD), a MAX30102 heart rate sensor (5,000 IQD), a PIR motion sensor (5,000 IQD), a rain sensor (3,000 IQD), a fire or smoke sensor (5,000 IQD), an I2C LCD display (4,000 IQD), an OLED display (6,500 IQD), and a buzzer (500 IQD). Additional costs were added, including programming, structural materials, a rechargeable battery, a charger, wires and resistors, a protective box, an initial subscription to the mobile app, and a portable power source, bringing the total project cost to approximately 225,000 Iraqi dinars (approximately \$150). This cost is reasonable considering the device's capabilities and multiple features, making it an effective and economical solution for enhancing child safety in various environments.

4.2 Advantages

1. Real-time monitoring: The device allows continuous monitoring of the child's condition and sending instant alerts when any danger is detected.
2. Low cost and high efficiency: It is based on the Arduino platform, making it an economical and easy-to-implement solution.
3. Ease of use: It does not require advanced technical knowledge, making it suitable for all users.
4. Mobile connectivity: The device sends notifications to parents via an application connected to the Wi-Fi network using NodeMCU.
5. Flexibility for expansion and development: It can be integrated with smart home systems or enhanced by adding new sensors such as surveillance cameras or toxic gas sensors.
6. Enhanced security: The device relies on encryption protocols to protect the child's data and ensure their privacy.

4.3 Disadvantages

1. Internet dependency: Requires a stable internet connection to ensure real-time alerts.
2. Possibility of false alarms: The sensitivity of some sensors may result in false alerts, which may cause inconvenience to parents.
3. Limited battery life: Relies on a rechargeable battery that needs to be recharged periodically.
4. Requires extensive field testing: To ensure the accuracy of the sensors and the effectiveness of the device in different environments.
5. Inability of the device to directly intervene: The device only acts as a warning tool without the possibility of actual intervention to protect the child.

4.4 Suggestions & Recommendations

1. Expanding the scope of functionality: Additional sensors, such as toxic gas sensors (such as carbon monoxide) and sound sensors, can be integrated to improve the device's ability to respond to environmental hazards.
2. Enhancing integration with smart devices: It is recommended to develop applications compatible with different operating systems (iOS and Android) and the ability to link the device with smart home systems such as Google Home and Amazon Alexa.
3. Improving ease of use: Developing a simple user interface for the mobile application, and designing a structure resistant to environmental factors such as water and dust to increase the device's durability.
4. Using sustainable energy sources: Replacing traditional batteries with renewable energy sources, such as small solar panels, to reduce the need for frequent charging.

5. Expanding coverage: Improving communication technologies by integrating protocols such as LoRaWAN to ensure that the child can be monitored even in outdoor environments such as parks and schools.
6. Conducting extensive field tests: Conducting experiments in different environments, such as homes, schools, and nurseries, to collect user feedback and improve the device's performance based on real-world experiences.
7. Supporting children with special needs: Adapting the device to provide additional features that meet the needs of children with chronic diseases or disabilities, such as special medical alerts.
8. Enhancing cybersecurity: Developing advanced encryption protocols to protect children's and parents' data from cyber breaches and threats, with regular updates to the security system.
9. Increasing reliability and reducing false alarms: Improving algorithms for analyzing data from sensors to ensure the accuracy of alerts and reduce unnecessary notifications.
10. Expanding areas of use: Studying the possibility of using the device in other applications, such as monitoring the elderly or patients who need continuous care, which increases the practical benefit of the project.

4.5 Conclusion

This project represents a significant milestone in leveraging IoT and Arduino technologies to address critical child safety challenges.

The proposed device offers an innovative, cost-effective, and user-friendly solution to monitor and ensure the safety of children in real time. By integrating various sensors, such as temperature, humidity, motion, and environmental sensors, the system can detect potential risks like extreme temperatures, harmful gases, or proximity to hazardous areas, providing immediate alerts to caregivers through both visual and audible alarms, as well as a mobile application.

The project's development involved meticulous hardware and software design to ensure reliability and efficiency. The hardware incorporated advanced yet affordable components like Arduino and NodeMCU platforms, complemented by robust sensor arrays. The software side was equally comprehensive, focusing on seamless data processing, real-time monitoring, and secure communication protocols to protect sensitive information about the child and their environment.

The combination of these elements resulted in a compact, efficient, and adaptable device capable of meeting diverse safety requirements.

The research also considered broader implications, including ethical concerns and usability. Security measures, such as encryption protocols, were integrated to ensure data privacy. The device's intuitive interface ensures accessibility for caregivers with varying levels of technical expertise. Additionally, the project highlighted the potential for scalability, offering opportunities for integration with smart home systems or expansion to monitor children with special needs or specific health conditions.

This work lays the groundwork for future innovations in child safety technology. Recommendations for further development include integrating more advanced sensors (e.g., toxic gas or sound detection), enhancing the device's resilience to environmental conditions, and adopting sustainable energy sources like solar panels.

Moreover, testing the system in real-world environments, such as schools or daycare centers, could further refine its effectiveness and adaptability.

In conclusion, the "Design and Implementation of a Smart IoT Device for Child Safety Based on Arduino" combines modern technology with practical application to create a powerful tool for protecting children in various scenarios. It not only addresses immediate safety concerns but also opens pathways for broader applications in healthcare, eldercare, and disaster response systems. This project is a testament to the transformative potential of IoT technologies in improving the quality of life and ensuring the safety of vulnerable population.

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