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SaveTots: IoT System For Monitoring Children and Animal in Vehicles

SaveTots: Iot para monitoramento de crianças e animais em veículos.

SaveTots: sistema IoT para monitorizar niños y animales en vehículos.

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Abstract:
This article addresses the development of SaveTots, an IoT prototype designed to prevent children and animals from being left in passenger vehicles. The proposal arose in response to the increasing cases of vehicular heatstroke deaths and the lack of effective alert systems. The project integrates sensors and wireless communication technologies, employing the ESP32 microcontroller and the LoRa protocol, to detect the presence of occupants and the absence of the responsible person, triggering safety alerts in risk situations. A qualitative methodology, based on the work of Lakatos and Marconi (2003), was adopted to understand the human and technological factors contributing to these occurrences and to guide the development of the device. The results indicate that SaveTots is a viable, low-cost solution that is easily adaptable to different vehicle models. It is concluded that the device contributes to accident prevention and raises awareness about responsibility in the transportation of children and animals.

Resumo:
O presente artigo aborda o desenvolvimento do *SaveTots*, um protótipo *IoT* de dispositivo destinado a prevenir o esquecimento de crianças e animais em veículos de passeio. A proposta surgiu diante do aumento de casos de mortes por insolação veicular e da ausência de sistemas eficazes de alerta. O projeto tem como base a integração de sensores e tecnologias de comunicação sem fio, empregando o microcontrolador *ESP32* e o protocolo *LoRa*, capazes de identificar a presença do ocupante e a ausência do responsável, acionando alertas de segurança em situações de risco. Adotou-se uma metodologia qualitativa, fundamentada em Lakatos e Marconi (2003), com o intuito de compreender os fatores humanos e tecnológicos que contribuem para esse tipo de ocorrência e orientar o desenvolvimento do dispositivo. Os resultados indicam que o *SaveTots* é uma solução viável, de baixo custo e fácil adaptação a diferentes modelos de veículos. Conclui-se que o dispositivo contribui para a prevenção de acidentes e para a conscientização sobre a responsabilidade no transporte de crianças e animais.

Resumen:
El presente artículo aborda el desarrollo de *SaveTots*, un prototipo de dispositivo *IoT* destinado a prevenir el olvido de niños y animales en vehículos particulares. La propuesta surgió ante el aumento de casos de muertes por golpe de calor en vehículos y la ausencia de sistemas de alerta efectivos. El proyecto se basa en la integración de sensores y tecnologías de comunicación inalámbrica, utilizando el microcontrolador ESP32 y el protocolo LoRa, capaces de identificar la presencia de los ocupantes y la ausencia del responsable, activando alertas de seguridad en situaciones de riesgo. Se adoptó una metodología cualitativa, fundamentada en Lakatos y Marconi (2003), con el objetivo de comprender los factores humanos y tecnológicos que contribuyen a este tipo de ocurrencias y orientar el desarrollo del dispositivo. Los resultados indican que *SaveTots* es una solución viable, de bajo costo y fácilmente adaptable a diferentes modelos de vehículos. Se concluye que el dispositivo contribuye a la prevención de accidentes y a la concienciación sobre la responsabilidad en el transporte de niños y animales.

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1. Introduction

Forgetfulness of children and small animals left inside vehicles is a recurring problem with serious consequences, mainly due to mental overload, distractions, and changes in caregivers' routines. According to data from BBC News Brasil (2022), since 1988, the United States has recorded 906 deaths of children from heatstroke inside cars. In Brazil, although there are no official studies, researcher Driely Costa identified 59 occurrences between 2006 and 2018, according to a study published by the Metrópoles portal (2024).

A recent episode that underscores the seriousness of the situation was reported by G1 Goiás (2025): in the municipality of Nerópolis, a 2-year-old child was left inside a vehicle for approximately 4 hours in intense heat by the owner of a daycare center responsible for transportation. The case resulted in a critical increase in the victim's body temperature and, tragically, in his death. Situations like this highlight the urgency of preventive solutions and the essential role of technology in protecting lives.

The issue addressed in this study is the lack of efficient, accessible systems that notify responsible parties when vulnerable occupants are in vehicles, especially when a hectic routine compromises caregivers' attention. The study is based on the hypothesis that these episodes of forgetfulness result from the mental overload of those responsible, changes in caregivers, and the limitations of warning systems in conventional vehicles, all of which contribute to the persistence of this problem and its serious consequences.

Given this reality, the SaveTots project emerges as a technologically and socially relevant proposal to prevent children and small animals from being left behind in passenger vehicles. The prototype is based on the principles of the Internet of Things (IoT). It integrates smart sensors in a microcontroller, enabling automatic detection of occupants in the child seat cushion or booster seat and sending real-time alerts when the guardian moves away from the vehicle. The system was designed to be accessible, versatile, and low-cost, with easy integration into different car models. The initiative aims to protect lives and promote a culture of attention and responsibility in the transportation of vulnerable passengers.

In this context, the specific objectives include identifying the presence of children or animals inside the vehicle, recognizing the presence of the person responsible both while driving and in the vicinity of the vehicle, issuing intelligent alerts quickly and reliably, and structuring the device's hardware to ensure its integration with different vehicle models, making it adaptable and effective in preventing accidents. The study is delimited to the analysis of situations involving children and small animals in passenger vehicles, as well as the development of an IoT device with presence sensors and intelligent alerts.

The methodological approach adopted is qualitative, based on Lakatos and Marconi (2003), which aims to understand the social and behavioral phenomena related to forgetfulness, providing subsidies for the improvement of the technological solution.

The technical rationale is based on authors such as Eduardo Magrani (2018), who discusses the importance of connectivity and distributed intelligence, and José Morais (2023), who proposes guidelines for developing accessible and sustainable solutions. The ESP32 was selected as the core of the system owing to its versatility and Wi-Fi/Bluetooth connectivity, which enable multiple functions to be integrated into a single device while maintaining low cost and high energy efficiency. Wireless communication is established through the LoRa protocol, recognized for its low energy consumption and long range, according to Sérgio Oliveiro (2021), enabling monitoring even in remote or low-coverage areas and in environments without a conventional network.

Given the urgency of protecting lives before risky situations involving these potential victims, a central question this study seeks to answer is: how can an intelligent system prevent children and animals from being left behind in vehicles, ensuring greater safety for users and peace of mind for those responsible?

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2.Theoretical Foundation

In this section, the research problem that motivated the development of the SaveTots prototype is presented, along with the concepts employed in its conception, thereby providing the theoretical basis for an intelligent solution to prevent children and animals from being left in vehicles.

2.1 Forgetfulness of Children and Animals in Vehicles: Risks and Consequences

According to a report published by the digital newspaper AutoPapo (2021), Ford experimented to warn people about the danger of leaving children and animals in cars, showing that the interior can heat up quickly to 50°C, which can lead to death from heatstroke.

In 2025, another tragic accident was reported in Brazil, in Videira, Santa Catarina, where a 3-year-old child died after remaining locked inside a vehicle for ten hours, as reported by G1 (2025). Another similar case involving forgotten animals was also reported, according to Metrópoles (2024), two dogs died from asphyxiation after being forgotten in a pet shop car, in Goiás. These actions can be considered crimes under Article 133 of the Brazilian Penal Code, Law No. 2,848, of December 7, 1940:

> Art. 133 — To abandon a person under one's care, custody, supervision or authority, and, for any reason, unable to protect themselves from the risks resulting from abandonment (BRAZIL, 1940, Art. 133).

Furthermore, according to a report in the newspaper *O Tempo* (2023), no foolproof technologies have yet been implemented to address this problem. Solutions that alert drivers to the presence of children inside the vehicle still have limitations, but this has been widely discussed among car manufacturers in the United States. These solutions are not widely available and are limited to new models.

Therefore, the main focus of the project is to meet caregivers' safety needs, reducing the risk of forgetfulness and preventing tragedies through an accessible, efficient technological solution.

2.2 Field Research: Perceptions Collected

To gain a deeper understanding of the public's needs and perceptions regarding the SaveTots project proposal, and given the study's qualitative methodology, field research was conducted. This stage played a key role in collecting real data to guide the system's development, ensuring that its functionalities aligned with user expectations.

The survey was conducted via an electronic form. It involved 78 participants who answered 11 objective questions described below, which sought to understand transportation habits, levels of concern about forgetting in vehicles, and understanding of the use of smart devices to prevent such incidents.

1. Do you have: small children (ages 0 to 6), small pets (up to 15 kg), both, or neither?
2. Do you own a car or use a vehicle frequently?
3. How often do you transport your child(ren) or pet(s) in the car: daily, a few times a week, rarely, or never?
4. Have you ever forgotten, or do you know someone who has forgotten, a child or pet inside a car, even for a short time?
5. On a scale of 0 to 10, how concerned are you about the possibility of forgetting a child or pet inside a car?
6. Do you usually use child seats or pet carriers in your car: yes, sometimes, or no?
7. Were you already familiar with or had you heard of this type of technology before?
8. On a scale of 0 to 10, how useful do you think a smart key fob that alerts the driver when it detects a baby or pet in the vehicle is?
9. Would you feel safer with this type of device installed in your car: yes, maybe, or not at all?
10. Do you think this type of device should be required by law, just like car seats: yes, maybe, or no?

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11. Would you like to receive more information about this project or participate in future testing?

Among those interviewed, the majority stated that they have small pets, while a smaller proportion reported having children or both. It was also observed that almost all own or frequently use a vehicle, reinforcing the topic's relevance in the context of family and daily transportation. Likewise, most participants transport children or pets in their vehicles daily or a few times a week, highlighting frequent exposure to situations that could pose a risk if they are distracted.

Despite this routine, only a small proportion reported having witnessed cases of children or animals becoming forgetful in vehicles. Even so, significant collective concern was evident, as most participants gave high scores (8-10) when asked about the risk of forgetting. This result shows that even among those who have not directly experienced this type of situation, there is a clear awareness of the problem's seriousness and the importance of preventive measures.

However, it was noted that most respondents do not consistently use child seats or pet carriers, which points to the need for greater awareness regarding vehicular transportation safety policies.

Regarding prior knowledge of technologies similar to SaveTots, most respondents stated that they were unfamiliar with this type of solution. Nevertheless, the proposed device was widely recognized as helpful and functional, with predominantly positive evaluations and strong interest from participants. Moreover, most said they felt safer with the device installed in the vehicle, reinforcing their perception of the importance of technological resources for safety.

2.3 SaveTots: IoT System For Monitoring Children and Animals in Vehicles

SaveTots is an IoT system designed to assist in monitoring children and animals inside vehicles, preventing situations where they might be forgotten due to hectic routines, unexpected route changes, or the caregiver’s overloaded schedule. The project was conceived to offer an accessible and efficient solution capable of acting as an additional layer of safety in real-world scenarios, where small lapses can lead to severe consequences. Thus, the system was developed not only as a technological product but also as a preventive tool that supports everyday care.

The prototype consists of two devices developed through 3D modeling: a seat-attached structure equipped with integrated sensors and a smart key fob carried by the user. The cushion module is responsible for detecting the presence of the child or animal and monitoring whether the guardian remains near or walks away, using its connection to the key fob. This key fob acts as an alert transmitter, receiving notifications whenever the system identifies that the caregiver has moved away while the vehicle occupant is still inside. Through this interaction, the system aims to prevent accidents by offering immediate and reliable warning mechanisms.

Both devices communicate through ESP32 and LoRa modules, ensuring continuous supervision of the guardian’s presence after confirming that a child or animal is seated. Each device includes a battery indicator, charging port, and power switch, making the system autonomous, portable, and easy to handle, even for users with minimal technical experience. The integration between hardware and wireless communication was carefully planned to ensure extended range, signal stability, and low power consumption.

In designing the key fob, the goal was to create an object that visually represented the project while remaining simple and practical for everyday use. Based on this concept, a heart-shaped mold was chosen, directly referencing the SaveTots symbol and reinforcing its association with care and protection. Beyond its emotional appeal, the distinctive shape makes the accessory easy to spot among personal items, strengthening the project’s visual identity and overall usability.

The key fob features a dedicated battery compartment, isolating the component to avoid interference and ensure stable performance. On the right side, there is a button that allows the user to manually

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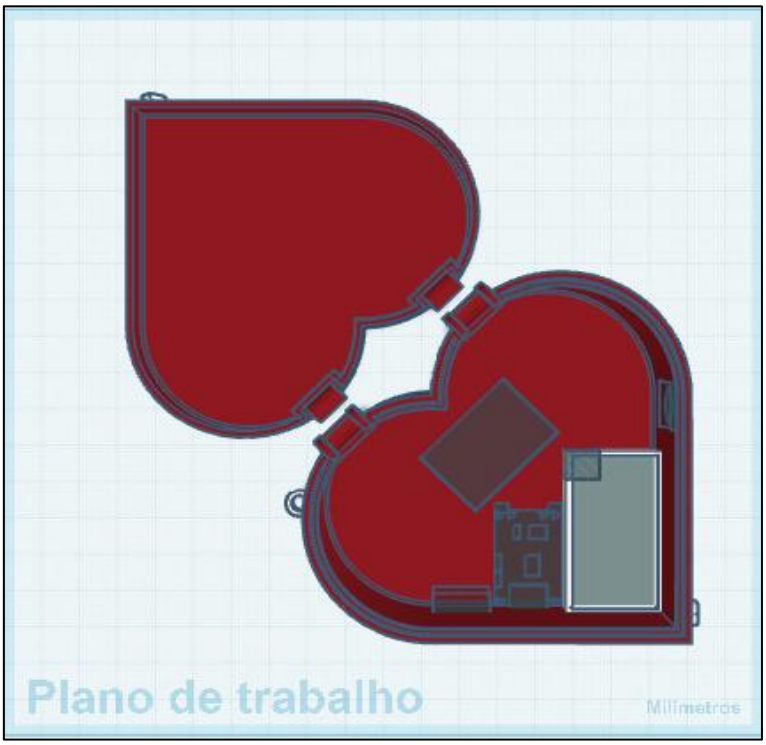
deactivate the buzzer's audible alert in critical situations. On the opposite side, the power switch, charging port, and battery level indicator are arranged in an intuitive layout, providing quick and convenient access. This design approach sought to balance ergonomics, aesthetics, and functionality.

The main challenge in this development stage was accommodating all electronic components within the structure, which required several rounds of resizing, mold adjustments, and repeated testing until the final configuration was reached. This process involved reorganizing the internal layout, reinforcing structural points, and optimizing the space to prevent component overlap while maintaining full system functionality. As each test cycle revealed new improvement opportunities, the prototype gradually became more stable, durable, and better suited for the automotive environment, significantly increasing its robustness and expected lifespan.

Figure 1 - 3D Modeling of the Heart-Shaped Keychain



Source: Own authorship (2025)

The choice of red for the device designs was carefully planned to maintain consistency with the intended visual identity of the SaveTots project. This shade, featured in the logo, strengthens the connection between the physical prototype and the institutional image, ensuring harmony between the concept and its practical application and making the set more attractive and easier to recognize in presentations and exhibitions.

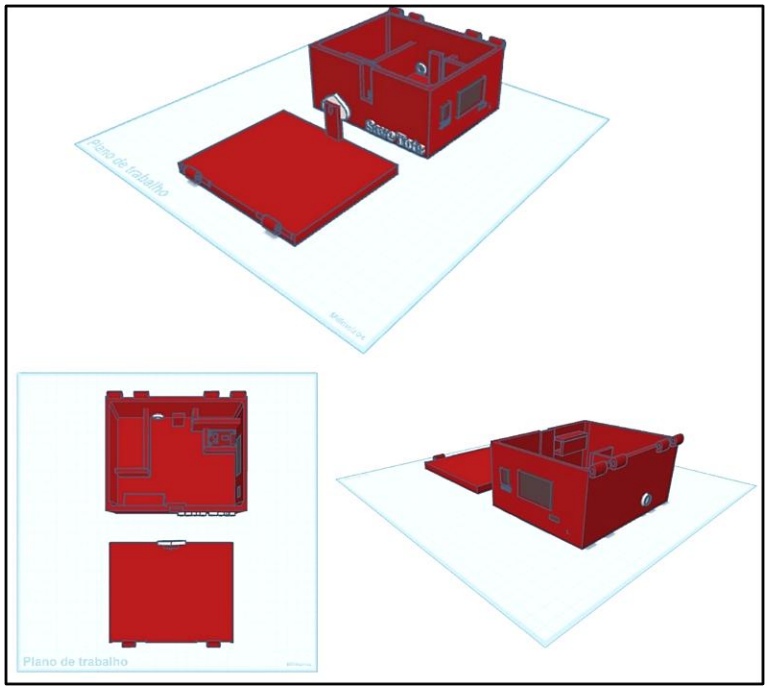
Red also carries symbolic meaning related to protection, attention, and care, principles that reflect the initiative's essence, focused on safety and the preservation of life. Hence, the color goes beyond aesthetics, reinforcing the project's identity and conveying values of responsibility, innovation, and commitment to user well-being.

For the seat, a protective side structure was designed to prevent damage to components, even when a child or animal sits on it. To ensure stability and safety, a rectangular shape with internal partitions was adopted, where each element is positioned according to predefined measurements. Strategic openings were also included, which are essential for the proper functioning of the weight and motion sensors.

This modeling houses the processor, LoRa module, battery, and circuits responsible for charging and monitoring energy. From this perspective, SaveTots was developed to assist in the care of children and

animals in vehicles, preventing forgetfulness and reducing the risk of accidents, especially in hectic situations.

Figure 2 - 3D Modeling of the Complementary Vehicle Structure

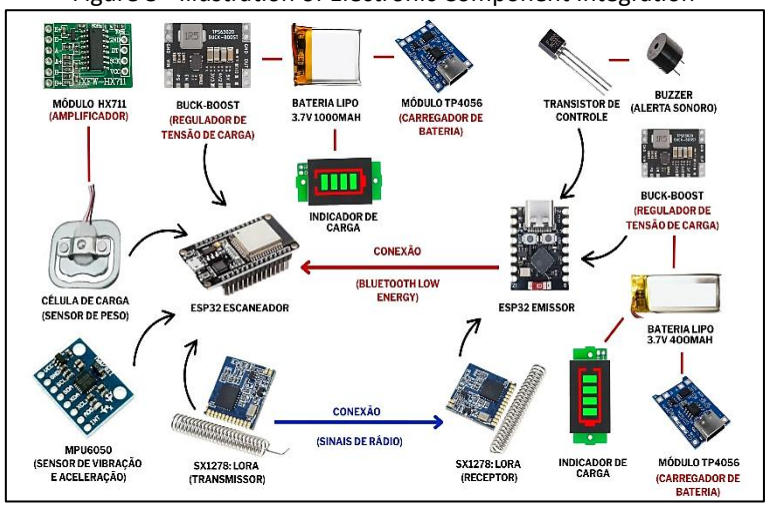


Source: Own authorship (2025)

3. Method

This section describes the methods applied in developing the SaveTots project, grounded in the qualitative approach proposed by Lakatos and Marconi (2003), which supports the interpretation of social and behavioral factors associated with forgetfulness. The qualitative method was selected for its ability to capture contextual details and user experiences that directly influence system requirements. It also outlines the system's components and the key technologies selected for the IoT solution, highlighting how each choice contributes to the system's reliability, efficiency, and alignment with the project's objectives, ensuring a coherent development process.

Figure 3 - Illustration of Electronic Component Integration



Source: Own authorship (2025)

The figure above illustrates the interconnection of all elements, including subsequently discussed components and additional modules integrated into the prototype. This visual organization offers a

clearer view of the system architecture and the functional relationships between the parts, helping to demonstrate how the modules operate together to ensure accurate monitoring and consistent performance.

3.1 Internet of Things (IoT)

According to IBM (2025), the Internet of Things (IoT) is a network of physical devices integrated with sensors, software, and internet connectivity that enable the collection and sharing of data.

Everyday devices that use sensors to capture factors around us, such as pressure and weight, and later use this information intelligently, are considered part of this concept (MAGRANI, 2018).

3.2 Programming Language for Embedded Systems

C++ is a programming language derived from C, developed to build highly efficient systems, created by Bjarne Stroustrup in 1979. Its purpose was to assist in the management of programs that required an increasing level of sophistication (SCHILDT, 2002).

An application developed in C++ requires compilation after coding, a process that converts source code into one or more machine-language files, generating an executable file that the computer can interpret and run (MICROSOFT LEARN, 2023).

The figure below shows an annotated example of C++ code that controls an LED by alternating its state between on and off.

Figure 4 - C++ Code Example

```
#include <Arduino.h>  // ESSENCIAL - inclui as funções do Arduino

void setup() {
  // Configura o pino do LED
  pinMode(2, OUTPUT);  // O número 2 representa o pino do LED interno
}

void loop() {
  // Liga o LED
  digitalWrite(2, HIGH);
  delay(1000); // Espera 1 segundo

  // Desliga o LED
  digitalWrite(2, LOW);
  delay(1000); // Espera mais 1 segundo

  // Isso se repete para sempre!
}
```

Source: Own authorship (2025)

3.4 ESP32

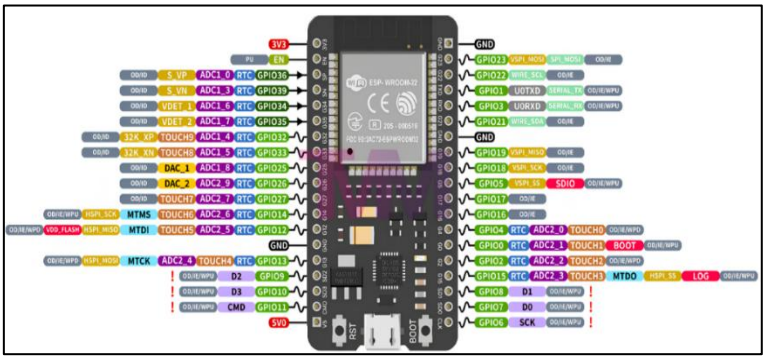
The ESP32 stands out for not requiring external boards for wireless communication, such as Wi-Fi and Bluetooth, even Bluetooth Low Energy, as it has integrated features in its own structure for these purposes (RALL; LEITE; MIRANDA, 2023). Among the microcontrollers available on the market, it is recognized for its high performance and high connectivity, offering extremely advantageous cost-effectiveness, as described by Morais (2023).

BLE is a wireless communication technology widely used in battery-powered devices, as it stands out mainly for its energy efficiency, making it ideal for devices that do not need to transmit large volumes of data (FERREIRA; ANTUNES, 2022). As Eichner, Da Silva, and Rizzetti (2019) demonstrate, Bluetooth Low Energy (BLE) can scan nearby devices and establish connections upon request. It is easily integrated with various sensors and devices, including the ESP32.

It has 38 physical pins, 25 of which can be used for Pulse Width Modulation (PWM). These pins carry inputs and outputs; the inputs are like buttons that send signals to the microcontroller and can activate outputs such as LEDs, buzzers, and motors (ELETRÔNICA ÔMEGA, 2021).

The ESP32 pin description is illustrated in the figure below.

Figure 5 - ESP32 Pin Specifications



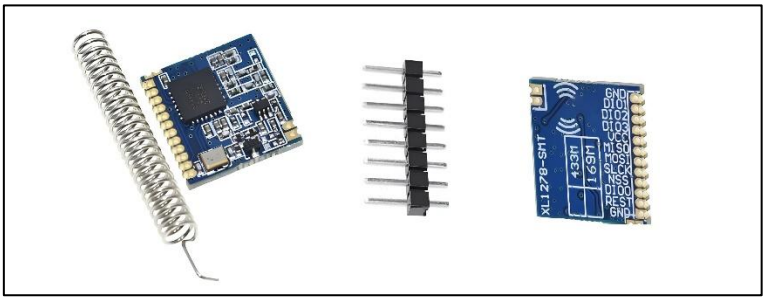
Source: Teach Me Micro (2025)

3.5 LoRa

In response to the need for a technology to cover long distances, a device called LoRa was developed in 2015, which, through radio frequency, permit long-range communication of up to 15 kilometers, according to Oliveira (2021).

It is used via a transceiver to transmit and receive signals over a frequency range of 150 MHz to 960 MHz. In Brazil, unlicensed frequencies regulated by the National Telecommunications Agency (ANATEL) are available in the 915-928 MHz band, according to Bertoleti (2023).

Figure 6 - SX1278: LoRa Communication Module for Applications



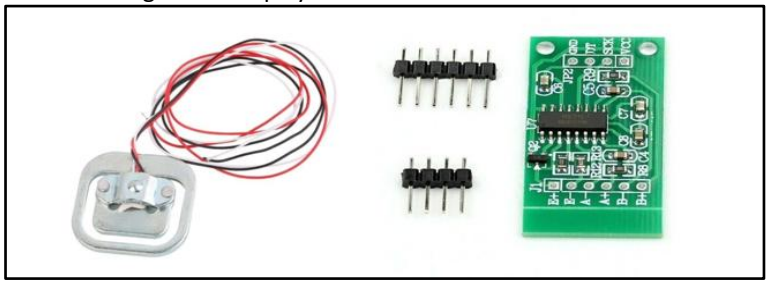
Source: Fermarc (2025)

3.6 Load Cell

Load cells undergo small but significant deformations in their metallic structure when subjected to an applied load or force, and their operation is based on the variation of ohmic resistance detected by a strain gauge, which senses the deformation and converts it into a measurable electrical signal proportional to the applied weight (THOMAZINI; ALBUQUERQUE, 2011).

The representation of these components can be seen in the following figure.

Figure 7 - Display of load cell and HX711 module



Source: Robocore (2025)

As demonstrated by Paixão, Santos, and Almeida (2021), the electrical signals generated by load cells are extremely small. They thus cannot be directly interpreted by a microcontroller. For this reason, the HX711 module is essential, as it serves as both a signal amplifier and an analog-to-digital converter, ensuring that even trivial variations in resistance are accurately detected and processed.

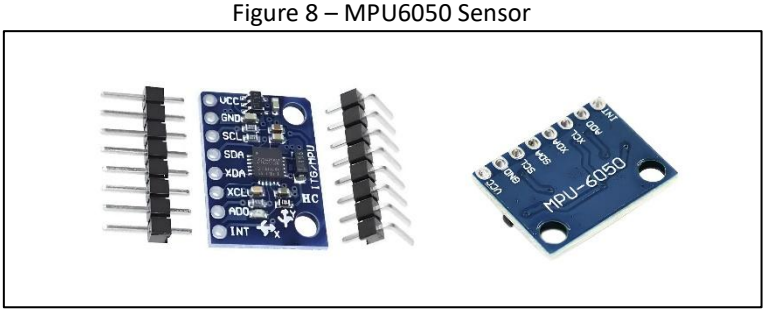
According to Oliveira et al. (2020), this module facilitates effective communication and integration between the sensor and the microcontroller, enabling the construction of reliable and efficient monitoring systems.

3.7 MPU6050 Sensor

The MPU6050 combines a 3-axis accelerometer and a 3-axis gyroscope on a single chip, being capable of capturing data from applications involving motion, tilt, and vibration detection (MATHIAS; JUNKES; VIANA, 2024). For acceleration, the sensor can be operated in the ranges of ±2 g, ±4 g, ±8 g, and ±16 g, and for rotation, it operates in selectable scales of ±250, ±500, ±1000, and ±2000 °/s, making it versatile for several different implementations (MIRANDA et al., 2022).

Beyond, it contains a digital motion processor (DMP) capable of performing complex sensor fusion calculations internally, reducing the processing load on the microcontroller to which it is connected (STUHLER, 2022).

Figure 8 – MPU6050 Sensor



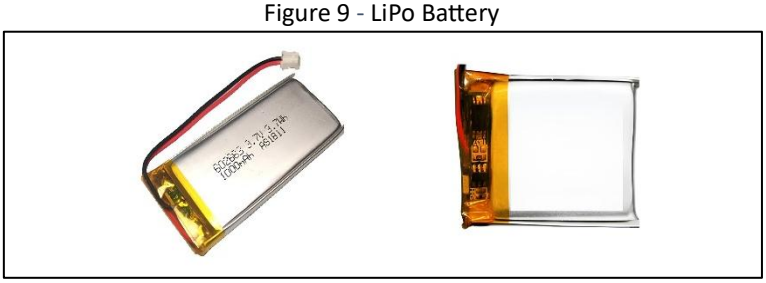
Source: Robocore (2025)

3.8 LiPo battery

According to Torres (2018), batteries are fundamental electronic devices that store electrical energy through electrochemical principles and provide direct current to power electronic circuits and systems.

According to Brito and Delatore (2022), lithium polymer (LiPo) batteries, introduced to the market in 1999, use a solid electrolyte instead of a liquid, which significantly reduces the risk of explosions and ensures greater structural flexibility, in addition to offering an excellent relationship between energy density and safety, standing out for being lighter and thinner, although they have a higher cost.

Figure 9 - LiPo Battery



Source: Mercado Livre (2023)

4. Results and Discussions

The SaveTots system was designed to assist in monitoring children and animals transported in vehicles, targeting guardians with busy routines or who experience frequent route changes.

Each component underwent unit testing to ensure proper functioning. Subsequently, the integrated system was evaluated for power management, electrical and logical compatibility between the ESP32 and LoRa modules, and the physical organization of the elements, to reduce interference and facilitate future maintenance.

The tests demonstrated stable communication between the modules, ensuring continuous and reliable data transmission between the cushion and the keychain. Presence detection proved to be accurate, triggering the sound alert whenever the mobile device moved away from the vehicle. The battery life was considered satisfactory, and the response time between detection and alert transmission remained fast and consistent, demonstrating efficiency and reliability.

The integration of the modules allowed the system to operate in a coordinated manner, fully meeting the proposed requirements. The optimized layout of the circuits and connections reduced failures and simplified future adjustments. These results demonstrate that SaveTots can detect the presence of children or animals, issue immediate alerts, and operate stably for extended periods.

The performance analysis confirms the technical feasibility of the prototype and its alignment with the project's objectives. Application in real-world contexts will allow the identification of improvement opportunities, such as adjustments to response time, enhancements to the interface, and optimization of energy autonomy. These advancements may consolidate SaveTots as a reliable and efficient tool for preventing accidents and promoting safety in the transportation of children and animals.

Figure 10 – Final System Prototyping

Source: Own authorship (2025)

5. Conclusion

The SaveTots project highlights the importance of using technology as a tool for protection and care in everyday life. The proposal goes beyond creating an electronic device, seeking to prevent children and animals from being left in vehicles and to avoid tragedies that could be avoided with simple, accessible solutions.

The study also highlights the potential of IoT technologies as allies in building a safer, more connected future capable of responding to contemporary societal demands. Further, the development of SaveTots provided continuous learning about the research process and the practical implementation of the solution, from conception through testing.

That way, it can be concluded that SaveTots represents not only a technical advance but also an initiative with strong social relevance, paving the way for new improvements and future applications that can expand its reach. We are excited about the possibility of applying the system in real-world settings and contributing to the prevention of cases of forgetfulness and risk, promoting greater safety for children and animals, and providing peace of mind for parents and pet owners.

Hence, the project's purpose is reaffirmed: SaveTots, because forgetting your tots is not an option.

Figure 11 - Logo

Source: Own authorship (2025)

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