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B.A.E. GUARD

B.A.E. GUARDA

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Abstract:
This study addresses the significant increase in the occurrence of fires over time, due to the lack of fire prevention and firefighting, partly caused by the high cost of existing fire safety systems. In this context, the aim is to reduce the damages caused by structural fires by developing a low-cost system for detecting fire incidents in residential buildings, with a focus on financial accessibility. The Internet of Things (IoT) technology is the base for the proposed system, enabling users to prevent accidents by providing detailed information about the monitored environment. To achieve this goal, conducting studies on embedded systems and mobile environments.. The research involved requirements analysis, diagram development, and prototyping of graphical interfaces and electrical schemes. In addition to that, a mobile application was developed to integrate sensors with the alarm system. The system was tested under realistic conditions to ensure its efficiency and compliance with safety regulations. It is expected that this system will contribute to the early detection of fires and the mitigation of their effects, enhancing residential safety.

Resumo:
Este estudo aborda a problemática do aumento abundante de ocorrências de incêndios ao longo do tempo, causados principalmente pela falta de prevenção e combate de incêndio e, em parte, devido ao alto custo dos sistemas existentes contra incêndio. Diante desse cenário, busca-se reduzir os danos causados por incêndios estruturais por meio do desenvolvimento de um sistema de detecção de princípios de incêndio em residências, com ênfase na acessibilidade financeira. O sistema proposto é baseado na tecnologia Internet das Coisas (IoT) e permite aos usuários evitar acidentes ao fornecer informações detalhadas sobre o ambiente monitorado. Para alcançar esse objetivo, foram realizados estudos sobre sistemas embarcados e ambiente *mobile*. A pesquisa envolveu a análise de requisitos, elaboração de diagramas e prototipação de interfaces gráficas e esquemas elétricos. Além disso, foi desenvolvida uma aplicação para dispositivos móveis, que integra sensores e uma câmera com sistema de alarme. O sistema foi testado em condições reais para garantir sua eficácia e conformidade com os regulamentos de segurança. Espera-se que esse sistema contribua para a rápida detecção de incêndios e a mitigação de seus efeitos, proporcionando maior segurança residencial.

Resumen:
Este estudio aborda la problemática del aumento abundante en las ocurrencias de incendios a lo largo del tiempo, causado principalmente por la falta de prevención y combate de incendios y, en parte, debido al alto costo de los sistemas existentes contra incendios. Ante este panorama, se busca reducir los daños causados por los incendios estructurales a través del desarrollo de un sistema de detección de principios de incendio en las viviendas, con énfasis en la asequibilidad. El sistema propuesto se basa en la tecnología de Internet de las Cosas (IoT) y permite a los usuarios evitar accidentes al proporcionar información detallada sobre el entorno monitoreado. Para lograr este objetivo, se llevaron a cabo estudios sobre sistemas embebidos y entorno móvil. La investigación consistió en el análisis de requerimientos, elaboración de diagramas y prototipado de interfaces gráficas y esquemas eléctricos. Además, se ha desarrollado una aplicación para dispositivos móviles, que integra sensores y una cámara con el sistema de alarma. El sistema ha sido probado en condiciones reales para garantizar su efectividad y el cumplimiento de las normas de seguridad. Se espera que este sistema contribuya a la rápida detección de incendios y a la mitigación de sus efectos, proporcionando una mayor seguridad residencial.

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1. INTRODUCTION

Fires in homes represent a significant risk to the safety and integrity of people, in addition to causing considerable material and economic damage (National Fire Protection Association, 2023). Given this challenge, the present study aims to develop a system for detecting the beginnings of fire in homes, using the Internet of Things (IoT) and a mobile application to control and monitor it.

The increase in the number of structural fires in recent years is a growing concern. It has brought attention to the need for more accessible and effective solutions for early detection. In this context, the hypothesis raised is that a fire detection device, combined with a mobile application, can help residents in early detection and fighting fires, providing a faster and more accurate response, regardless of the physical presence on site. Furthermore, the availability of detailed information about the monitored environment contributes to preventive decision-making and damage mitigation.

This work includes the research and selection of the best gas, smoke, and temperature sensors for fire recognition, the development of requirements and use case diagrams, state, sequence, activities, prototyping of graphical interfaces and electrical schematics, the development of a mobile application, the integration of sensors with the alarm system and ensuring compliance with safety regulations.
The approach adopted involves carrying out bibliographic and documentary studies to support the project, testing to verify the reliability of the device and application developed, and the use of technologies such as Kotlin, Jetpack Compose, C++, Firebase, and others presented later.

For motivation to do this work, there is the need to reduce the damage caused by residential fires, which have shown significant growth, especially during the quarantine. The search for more accessible and efficient solutions is necessary to assume the extreme cost of traditional fire detection systems. Furthermore, the ability to provide accurate information about the occurrence of fires enables a faster and more effective response, contributing to the safety of residents.

The system developed has the potential to reduce damage caused by fires, as well as encourage the adoption of safety measures and efficient combat actions.

2. THEORETICAL FOUNDATION

The next subchapters refer to the theoretical foundation based on research, which will be necessary to understand the article presented.

2.1. FIRES AND HIGH COST

In 2022, the São Paulo Fire Department responded to 6,291 cases of fires in buildings, of which 2,161 occurred in areas regulated by the RSCI and reached 265,246 square meters. There is no information about the affected area in buildings not regulated by RSCI. (SÃO PAULO STATE FIRE DEPARTMENT, 2022)

The quarantine caused a 60% increase in fires in 2020, with São Paulo recording 2,560 incidents in March 2019 and 4,089 in the same period in 2020. In April, there were 2,589 incidents, an increase of 18%. (BBC NEWS BRAZIL – FELIPE SOUZA, 2020). According to Cronoshare, conventional fire stations have an average cost of between R$1,500 and R$5,800. Devices for more advanced systems may have prices above this range. (Chronoshare - Isabella Barbosa, 2023).

In October 2022, occurrences of structural fires increased. The Sprinkler Institute registered 165 cases, an increase of 8.6% compared to the same month of the previous year, which had 152 reports. (Instituto Sprinkler Brazil, 2022). In this scenario, the growing increase in fire cases arising from the lack

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of an adequate fire prevention project is evident, due to their excessive cost. This project aims to reduce the damage caused by fire cases in different situations, in addition to reducing the cost of a fire detection system.

2.2. B. A. E. GUARD: IOT FOR FIRE DETECTION

The project consists of an electrical system and an application developed based on the Android Jetpack Compose toolkit. The primary purpose of the electrical system is the detection and monitoring of fire hazards. To achieve this goal, it incorporates high-quality sensors designed to capture accurate information related to potential fires. Below, you can find an image of the electrical circuit.

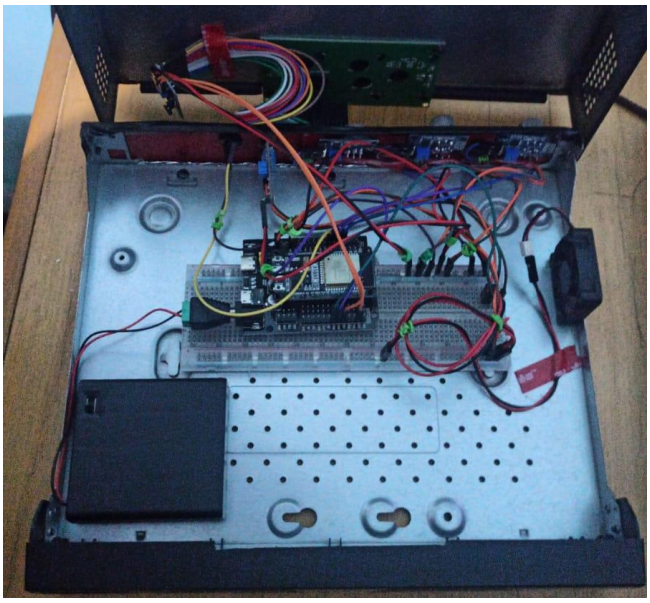

Figure 1 – Electrical circuit
Source: From the author (2023)

Below, we can see the device and the arrangement of its sensors, including gas, smoke, temperature, humidity, carbon monoxide, and fire sensors. Additionally, the device features an easily accessible audible alarm for data capture, along with a display for quick and efficient information presentation. It also includes a camera to enable the viewing of the environment in which the device is installed via your smartphone.

Figure 2 - Device Case
Source: From the author (2023)

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The application's main purpose is to alert its users about potential fire incidents, providing detailed information to safeguard their homes. In the image below, you can see the main interface, where you can access this information from anywhere you are, ensuring the safety of your home.

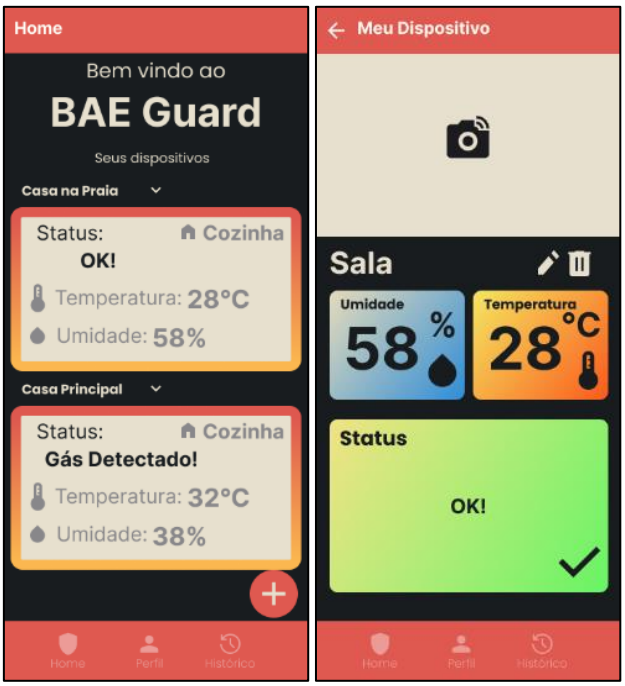

Figure 3 — High Fidelity Wireframe: Home and Device Details
Source: From the author (2023)

3. MATERIALS AND METHODS

Explore the materials and methods employed in the creation of B. A. E. Guard:

3.1. MATERIALS

Check out the physical devices that were used in the development of B. A. E. Guard:

3.1.1. ESP32

In the realm of microcontrollers, one standout device is the ESP32. This microcontroller is prized for its versatility, offering strong processing power and the ability to handle data transfer both locally and remotely. It's a popular choice for rapid prototyping and product applications (Bertoleti, 2019). The ESP32 is notable for its built-in modules supporting various communication protocols, including I^2C, I^2S, Wi-Fi, Bluetooth, UART, SPI, and more. This extensive module support sets it apart from other microcontrollers, eliminating the need for external modules (Santos, 2016).

When it comes to programming the microcontroller, there are two primary methods: using the official Espressif SDK with the C programming language or the Arduino IDE software with C or C++. The latter option is favored due to its user-friendliness and is widely adopted by independent developers and for educational purposes (Bertoleti, 2019).

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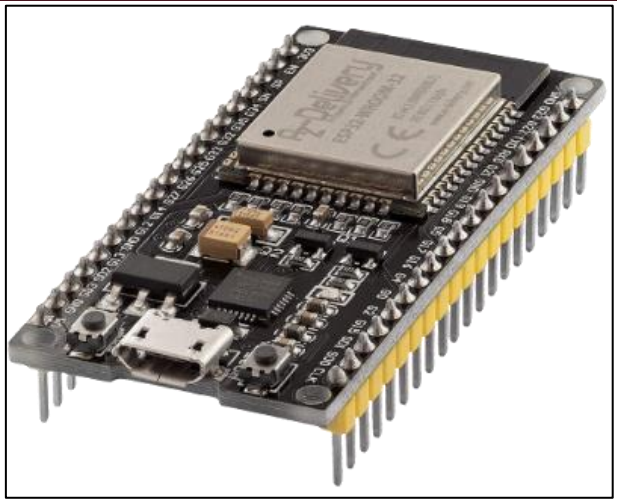

Figure 4 – ESP32
Source: (Robocore, 2023)

3.1.2. ESP32CAM

The ESP32CAM is a significant version of the development board based on the ESP32WiFi module, proving to be a highly technological electronic module developed especially to connect robotic makers or home automation projects to the Internet with greater ease and low cost.

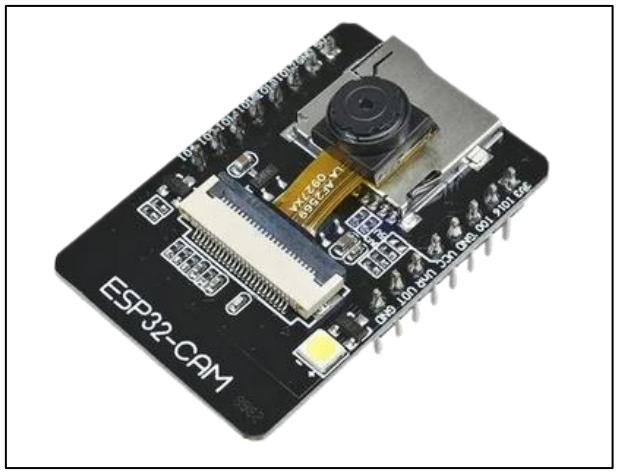

Figure 5 – ESP32Cam
Source: (Robocore, 2023)

3.1.3. BUZZER

The 5V Active Buzzer is a small speaker designed to emit sound signals by supplying DC power to the module, without varying the emission frequency.

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Figure 6 – Buzzer
Source: (Robocore, 2023)

3.1.4.PROTOBOAR

A Protoboard/ Breadboard, also known as Test Board or Contact Matrix, is a board with holes and conductive connections for assembling experimental electrical circuits.

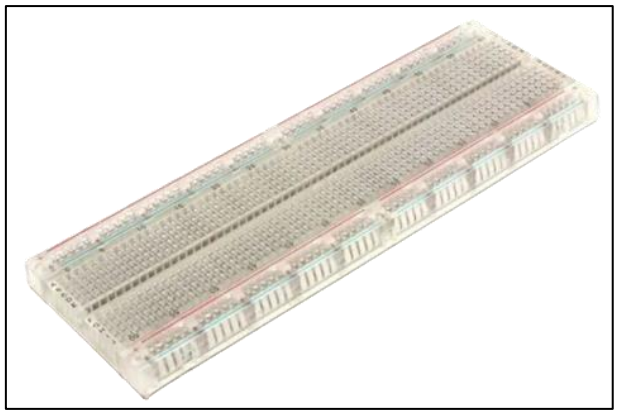

Figure 7 – Protoboard
Source: (Robocore, 2023)

3.1.5.20X4 LCD DISPLAY

The 20x4 LCD Display is a device with a blue background that can support the display of up to 20 characters per line on a 4-line screen, being especially suitable for those developing projects with ESP32.

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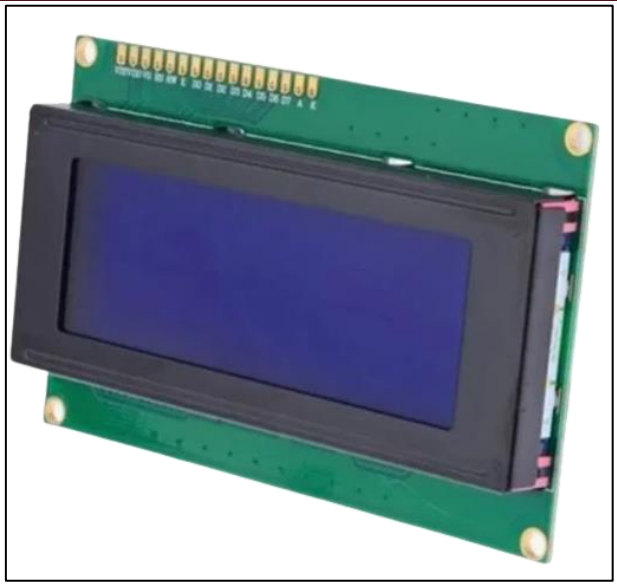

Figure 8 – 20x4 LCD Display
Source: (Robocore, 2023)

3.1.6.MQ-7 MONOXIDE GAS SENSOR

The MQ-7 Carbon Monoxide Gas Detector/Gas Sensor is a safety device widely used in domestic projects (home automation).

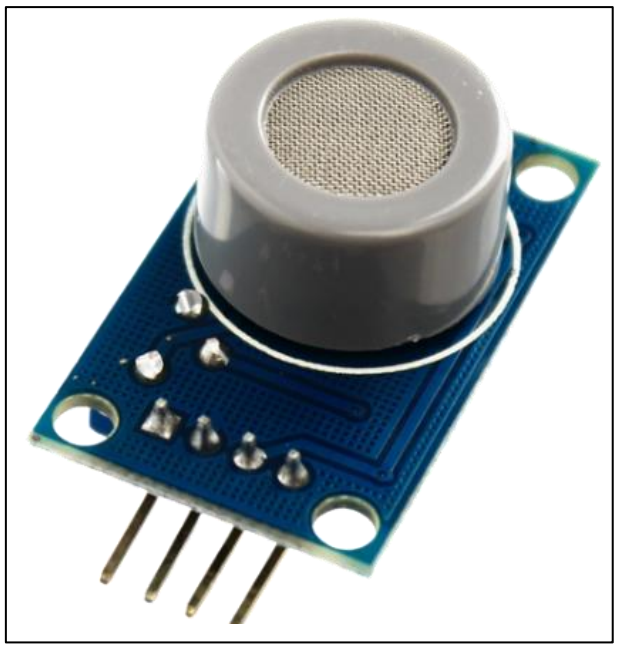

Figure 9 – MQ-7 Monoxide Gas Sensor
Source: (Robocore, 2023)

3.1.7.MQ-5 GAS SENSOR

The Gas Detector / Gas Sensor LPG (Cooking Gas) and Natural Gas MQ-5 is a safety device used mainly in the development of electronic projects, having high sensitivity for detecting LPG Gas (Cooking Gas) and Natural Gas, this, as long as it works in conjunction with prototyping platforms, such as, for example, Arduino or ESP32.

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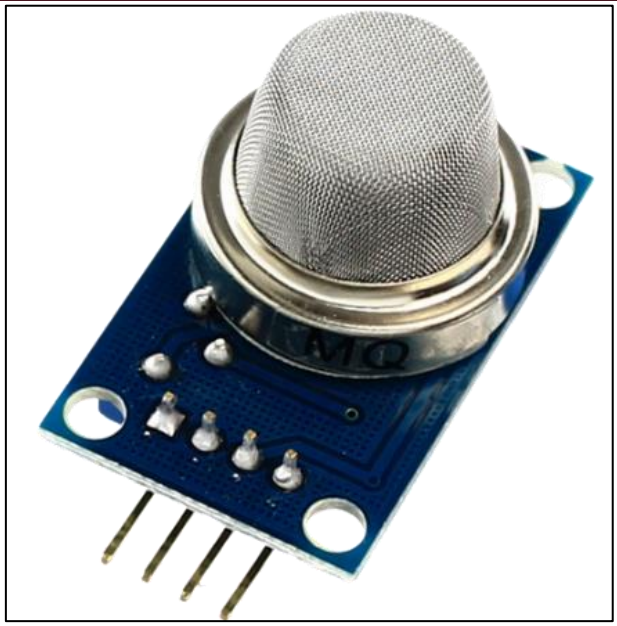

Figure 10 – MQ-5 Gas Sensor
Source: (Robocore, 2023)

3.1.8.DHT11 HUMIDITY AND TEMPERATURE SENSOR

The MQ-5 Gas Sensor LPG (Cooking Gas) and Natural Gas is a safety device used in the development of electronic projects, having high sensitivity for detecting LPG Gas (Cooking Gas) and Natural Gas.

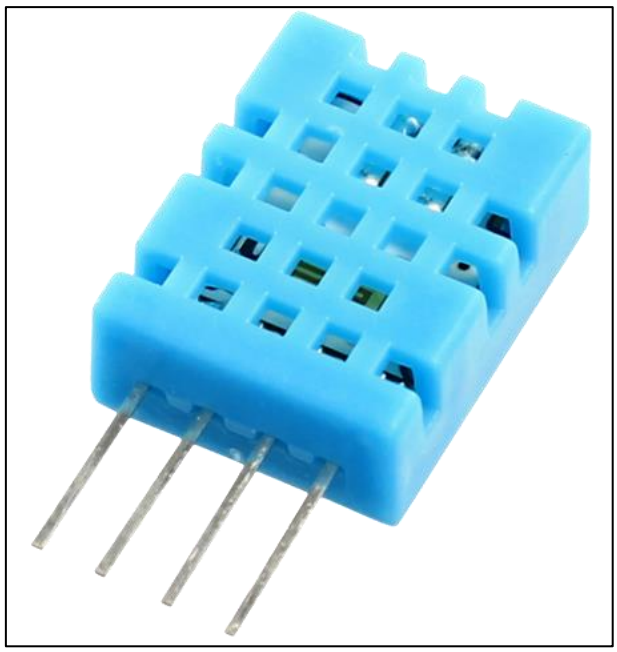

Figure 11 – DHT11 Sensor
Source: (Robocore, 2023)

3.1.9.INFRARED FLAME SENSOR

The infrared flame sensor is an electronic device developed to alert the microcontroller system about the fire presence in each environment, so that it can take the necessary actions.

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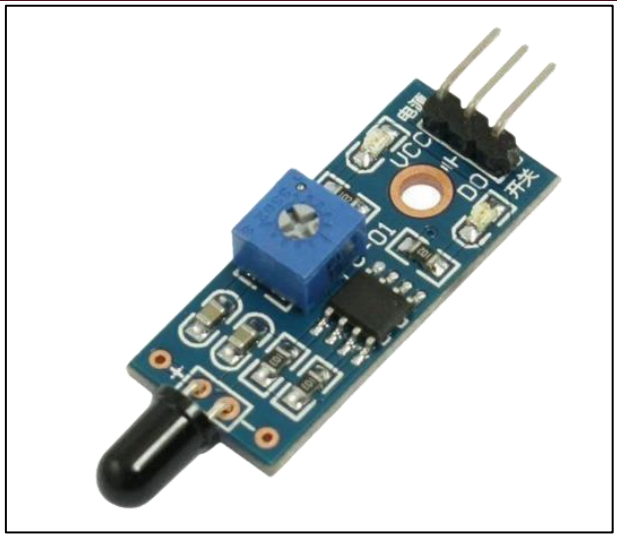

Figure 12 – Infrared Flame Sensor
Source: (Robocore, 2023)

3.1.10. MQ-2 Sensor

The MQ-2 Flammable Gas and Smoke Sensor is capable of detecting concentrations of combustible gases and smoke in the air. This versatile sensor provides early warning for potential fire hazards by detecting a wide range of gases, including methane, propane, hydrogen, and smoke particles. Its high sensitivity and rapid response time make it a valuable component in fire detection and safety systems.

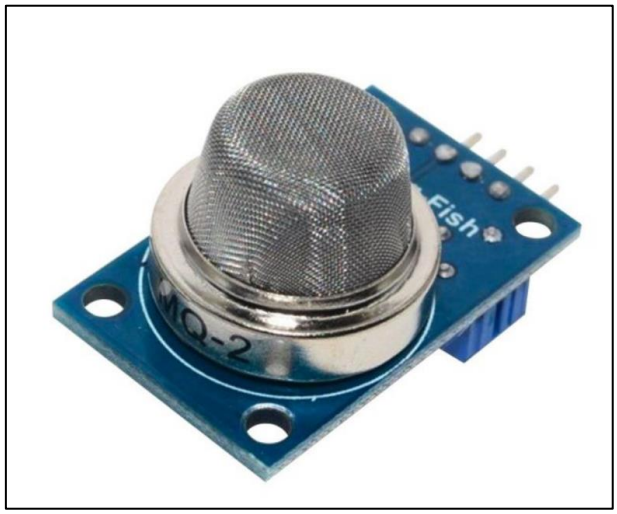

Figure 13 – MQ – 2 Sensor
Source: (Saravati, 2023)

3.1.11. I2C SERIAL MODULE

Frequently, the number of available pins on a microcontroller is limited, especially when connecting displays and sensors, leaving only a few pins for other functionalities. With this I2C Serial Module, you can control your LCD using just 2 (two) pins. This module enables you to efficiently manage an LCD display with only two microcontroller pins: analog pin 4 (SDA) and analog pin 5 (SCL). The I2C (Inter-Integrated Circuit) communication protocol simplifies the interface between your microcontroller and the display, making it an ideal solution for optimizing pin usage and reducing complexity in your projects.

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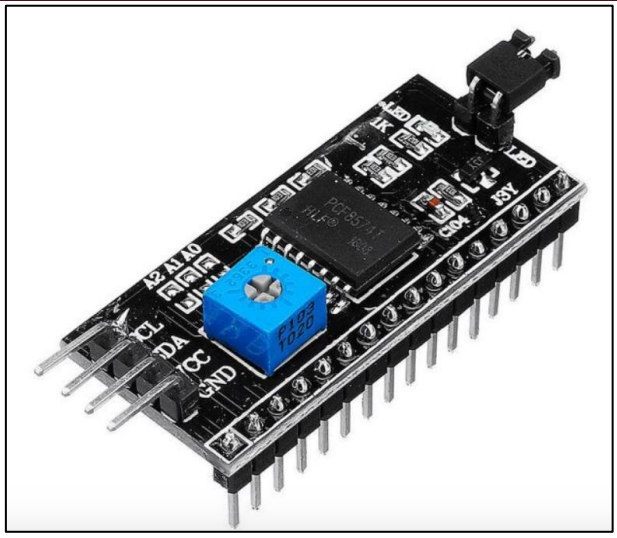

Figure 14 – I2C SERIAL MODULE
Source: (Saravati, 2023)

3.1.12. ESP32 ESP-WROOM-32 Micro USB / USB-C

This expansion shield is a purpose-built expansion board designed to enhance and simplify the connectivity options for IoT development boards like the ESP32-DevKitC-32 ESP-WROOM-32 with 30 pins. This shield features a P4 connector for external power sources, supporting DC voltages in the range of 6.5V to 16V. In addition, it is equipped with both: a USB Type-C 5V connector and a Micro USB port, offering more options for power input and data connectivity.

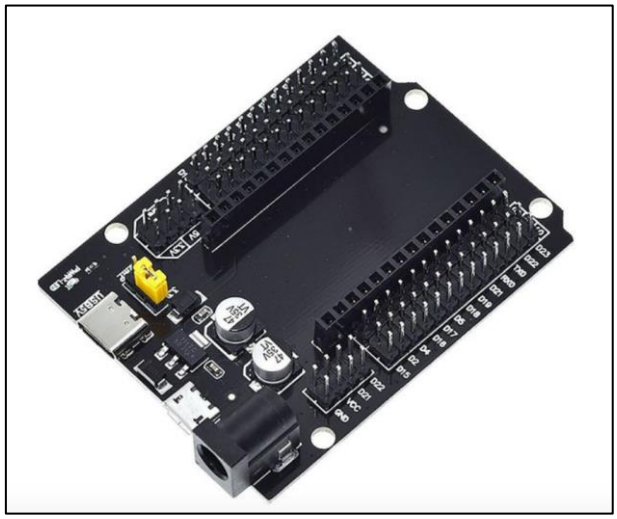

Figure 15 – ESP32 ESP-WROOM-32 MICRO USB / USB-C
Source: (Saravati, 2023)

3.2. METHODS

Examine the methodologies applied in the development of B. A. E. Guard:

3.2.1. INTERNET OF THINGS (IOT)

In recent times, the progress of computing and digital communication technologies has driven the need for more agile solutions and interactions in all sectors of society. This demand has given rise to an emerging field in technology known as the Internet of Things (IoT), also called the Internet of Things in Portuguese. According to Snataella (2013), IoT represents the current state of the Internet, where

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objects, including humans and animals, are transformed into carriers of computing devices capable of connecting and communicating.

Due to its adaptability, IoT implementations have aroused interest in both the academic community and industry (Santos, 2016). This is due to the broad applicability of IoT, as there are no restrictions regarding the objects that can be connected.

Smart devices can access a network in several ways, the most popular being low-energy radio transmitters, which use Wi-Fi or Bluetooth protocols, and communication via tags using Radio Frequency Identification technology is also highly widespread. Tags (RFID).

3.2.2.UNIFIED MODELING LANGUAGE (UML)

According to Guedes (2018), UML (Unified Modeling Language) is a visual language widely adopted in the software engineering industry to model systems based on the object-oriented paradigm. It has become the internationally recognized standard modeling language, used to define characteristics of a system, such as requirements, behavior, logical structure, process dynamics, and physical needs.

According to Booch (2006), UML is not a programming language, but rather a modeling language, a notation that assists software engineers in designing and planning systems.

3.3. TECHNOLOGIES USED

Check out the software tools used in the development of B. A. E. Guard:

3.3.1.ANDROID SYSTEM

The Android operating system is a mobile platform developed by Google that has become extremely popular on mobile devices such as smartphones and tablets. Launched in 2008, it was designed based on the Linux kernel and stands out for its flexibility, usability, and vast library of available applications.

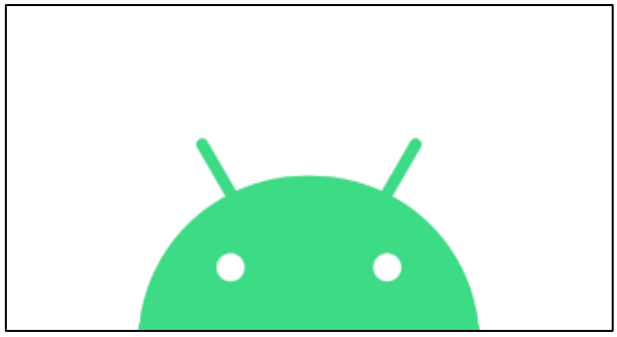

Figure 16 – Android logo
Source: (Google LLC, 2023)

3.3.2.KOTLIN

According to the official documentation (JetBrains, 2023), Kotlin is a programming language designed for the Java Virtual Machine (JVM) platform and developed by JetBrains. It was introduced to the public in 2011 and has since rapidly gained popularity due to its interoperability with Java and its ability to combine object orientation and functional programming.

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Figure 17 – Kotlin logo
Source: (Kotlin, 2023)

3.3.3.JETPACK COMPOSE

According to the official documentation (Google LLC, 2023), Jetpack Compose is a contemporary User Interface (UI) library designed by Google for crafting native Android user interfaces. It was introduced as a substitute for Android XML and conventional UI libraries like Android View, to simplify application development and offer a more fluid and productive experience for developers.

Figure 18 - Jetpack Compose logo
Source: (Google LLC, 2023)

Jetpack Compose is not a single project but instead a composite of various modules that collectively create a comprehensive stack. The primary layers of Jetpack Compose include:

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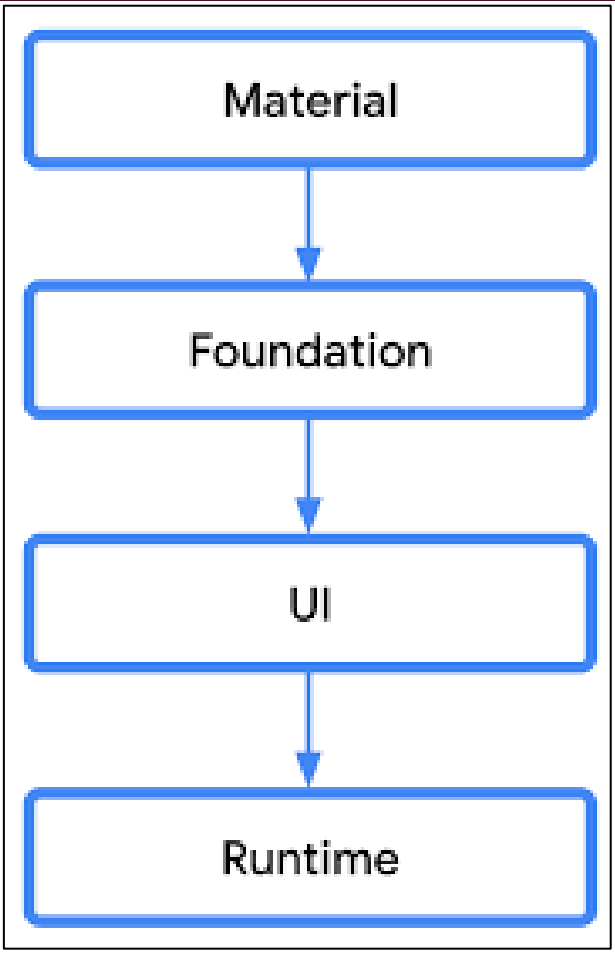

Figure 19 - Jetpack Compose architecture layers
Source: (Google LLC, 2023)

- Material Layer: The Material layer in Jetpack Compose is based on Material Design, which is a design language developed by Google. This layer provides pre-defined components such as buttons, text fields, cards, and more, following Material Design guidelines and standards. It enables you to create modern, consistent user interfaces that look and feel like Android users expect.
- Foundation Layer: The Foundation layer is responsible for providing the foundations and building blocks for developing user interfaces in Jetpack Compose. It includes essential APIs for handling themes, styles, system resources, animations, gestures, and other fundamental aspects. This layer reduces complexity, making it easier to develop rich, interactive user interfaces.
- UI Layer: The UI layer is where you build the user interface using Jetpack Compose components. In this layer, you take elements from the Material layer, customize them based on your application's needs, and combine them to create the visual hierarchy of your interface. Component interactions and behaviors are defined here.
- Runtime Layer: The Runtime layer is responsible for executing and managing the lifecycle of the user interface created with Jetpack Compose. It handles efficient component rendering, event processing, state handling, and synchronization with the Android operating system. The Runtime layer ensures that your UI updates effectively and responsively, reflecting user interactions and state changes.

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3.3.4.FIGMA

Figma is a web-based, desktop-based collaborative design tool that has gained significant popularity in recent years. It allows design teams to work together in real-time, regardless of geographic location, which makes the interface development process more efficient and effective.

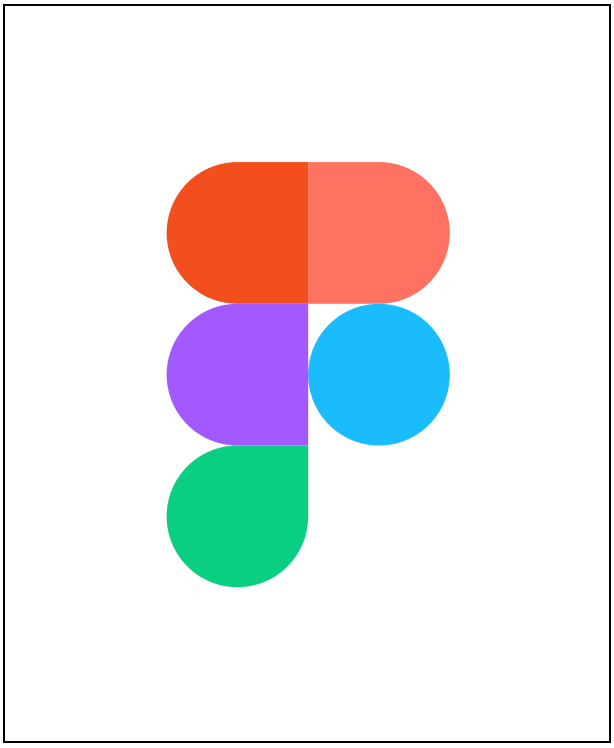

Figure 20 – Figma logo
Source: (Figma, 2023)

Figma offers a wide range of features and functionality that make collaborative design more efficient and productive.

The tool allows multiple people to edit the same file simultaneously, allowing team members to view updates in real-time. This eliminates the need to use other forms of communication to share changes. Because it is web-based, it is possible to store all files in the cloud, which allows designers to access and edit their projects from anywhere, at any time. It also offers reusable component creation capabilities, which allow users to create component libraries and share them between different projects.

Additionally, the program allows you to create interactive prototypes to test usability and user experience. This makes it easier to validate ideas and quickly iterate on design.

3.3.5.FIREBASE

According to the documentation provided by Google LLC (2022), Firebase is a platform, developed by Google, that provides a variety of services and tools to simplify and speed up the application development process. With a wide range of features, the platform has become a popular option for developers who want to build scalable, reliable, real-time applications.

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Figure 21 – Firebase logo
Source: (Google LLC, 2023)

Firebase is widely used for mobile app development on iOS and Android platforms. With features like user authentication, real-time data storage, and push notifications, developers can create highly interactive and scalable mobile apps.

Apart from mobile apps, Firebase is also an excellent option for web app development. With features like application hosting, user authentication, and real-time database, developers can create responsive and efficient web applications.

4. RESULTS E DISCUSSION

The development of this system involved the selection and integration of various hardware components and software technologies. The materials included components like ESP32 microcontrollers, gas sensors, LCDs, and infrared flame sensors, while the software utilized technologies such as Kotlin, Jetpack Compose, and Firebase. Through rigorous testing and prototyping, the system demonstrated the potential to provide an efficient and cost-effective solution for mitigating the increasing risk of residential fires. The IoT approach allows for real-time monitoring and data collection, enhancing the system's ability to provide early warnings and enabling faster and more effective responses to fire incidents. The integration of the mobile application with the sensors ensures user-friendly control and remote monitoring, while compliance with safety regulations ensures the reliability and effectiveness of the system.

The excessive cost of traditional fire detection systems and the growing incidence of residential fires, especially during the quarantine, underscore the significance of this work. The B.A.E. Guard system has the potential to significantly reduce fire-related damage and promote the adoption of safety measures and effective firefighting actions. By providing accessible and efficient fire detection and prevention capabilities, this system addresses a critical need to safeguard the safety and integrity of people while minimizing material and economic damage in homes.

5. FINAL CONSIDERATIONS

The development of the B.A.E. Guard system represents a promising step towards improving fire safety in residential settings. The combination of IoT technology and a mobile application offers a cost-effective and efficient solution for early fire detection and response. The selection of appropriate hardware components and the integration of various software technologies have resulted in a robust and reliable system. By providing real-time monitoring and data collection, the B.A.E. Guard has the potential to reduce fire-related damage, foster the adoption of safety measures, and encourage more effective firefighting actions. In a time when the incidence of residential fires is on the rise, this system addresses a critical need, contributing to the safety and well-being of residents.

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