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Smartgas: a smart platform for cooking gas monitoring

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***Abstract*— With the increasing demand for equipment connected to the Internet, a new area of computing has emerged, the Internet of Things (IoT). This paper shows an IoT solution to everyday problems faced by domestic users of bottled gas, which consists of two parts. The implementation of a mobile application capable of providing the user with the amount of LPG gas remaining in their bottle, attached with the development of intelligent support that provides real-time information to the app, such as the weight of the cylinder; and whether there is the occurrence of a gas leak. This solution strengthens the concept of smart cities and ensures ease, convenience and more economy for those who use bottled gas in their homes.**

Keywords— Internet of Things; LPG; bottled gas; Android Application; Arduino.

I. Introduction

The growing demand for equipment connected to the Internet, including everyday objects, has led to the exploration and emergence of a new area of computing called Internet of Things (IoT). This area studies the connection between the everyday objects and the worldwide computer network [1]. With the internet of things, it is possible that diverse information is collected and processed, providing comfort, security, practicality and economy, especially for domestic environments, where residential spaces are transformed into intelligent environments.

A big part of Brazilian families use Liquefied Petroleum Gas (LPG) in food cooking, due to several facts such as its great efficiency in cooking food, its clean flame and its ease of storage and transportation. Although there are households where LP Gas is piped, the 13 kg package is the most used, surpassing 75% of the total sales of the product in Brazil [2].

However, great problems are encountered for those who use this product, for example: knowing how much gas is left in the bottle during the period of use, since the packages are opaque; and be aware of when the gas is leaking, which can compromise the safety of users. In this way, unexpected termination of the contents of the bottle can disrupt the preparation of a meal and lead to an unplanned expenditure in the family budget, as a leak can cause serious damage to those who use the bottle.

In this context, through the application of the IoT concept as a way to enable greater interconnection of domestic activities and to enable the information exchange through technologies, this paper describes the development and validation of a smart platform integrated with a mobile application to assist, record and manage the consumption of LPG gas in domestic environments.

This paper is divided as follow. In section 2, is discussed the theoretical foundations of this research. Section 3 presents the proposed solution. Topic 4 shows the results obtained during the development of the research. Finally, final considerations and future work.

II. Background

This section discusses the main theoretical concepts needed to understand the content discussed on the paper. It is divided in three subsections: first, it is discussed some topics related to Internet of Things; then it is presented general concepts about Liquefied Petroleum Gas; and finally it is discussed the Bottled Gas.

A. Internet of Things (IoT)

Nowadays, we can find a variety of applications that make use of the new technologies available to make our daily activities easier. A huge part of these applications is developed in the actual context of the Internet revolution. These applications can be designed to collect a very large amount of data. These data can be stored in cloud, and the large datasets processing through Big Data. The information extracted can be used to a make our daily activities easier. The combination of this context and the new technologies make possible the Internet of Things (IoT) [3].

IoT is a recent area of computing that studies the connection of everyday objects to the World Wide Web [1]. Every new day, more devices that make use of internet connection or that can facilitate the accomplishment of tasks previously done only by hand are created, most of them are able to run programs, which use the devices' sensors, or to do other tasks like creating alarms or notifications, turning on or turning off the device. These objects are known as Smart Objects [4], and the idea of connect all these objects is the big core of IoT technology.

B. Liquefied Petroleum Gas (LPG)

Petrochemicals can be defined as chemicals products, derived from petroleum, that were produced from natural gas,

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natural gas liquids, or refinery products. The demand for such petrochemicals has grown rapidly and dominated the global chemicals market over the last 10 years [5].

LPG is one of the byproducts resulting from the refining of petroleum, being predominantly composed of the mixture of two hydrocarbons, Propane (C_3H_8) and Butane (C_4H_{10}). When held under pressure, it is in the liquid state, and is relatively stable. This facilitates their storage and their use in domestic sectors for cooking food [5].

Liquefied petroleum gas - LPG - is the most widely used fuel in households across the world. In the international market, the consumption of LPG is approximately 200 million tons per year. In Brazil, it reaches 95% of the residences and 100% of the national territory [6]. Along with electricity bills, the money spent with cooking gas represents around 20% of the minimum salary of Brazilian families.

The expansive consumption of this type of gas is mainly due to its high calorific value, especially when compared to other fuels in the market. 1kg of cooking gas has the calorific value of 11,500 kcal, while the yield of 1 kg of coal is equivalent to 5,000kcal [7]. In addition, LPG is a low-polluting fuel, like most gases, because it's burning generates carbon-free gas essential for photosynthesis, unlike fossil fuels such as coal.

C. Bottled Gas

The most used form of LPG distribution is the 13 kg cylinder [8], which represents more than 75% of total sales of the product in Brazil. These containers are produced in carbon steel, opaque and it is not possible to visualize their contents. This fact generates uncertainty for the users of this product, often causing the end of gas in bad times, or even if the bottle is, sent back to the distribution companies without all the content has been consumed. In addition, since it has high combustion power, safety measures are necessary to minimize the occurrence of accidents.

It is necessary for LPG to be odorized by security measures to facilitate the detection of leaks, according to Article 6º of ANP Resolution 18/2004 [9]. Although not poisonous, LPG is suffocating. Because it is heavier than the air, when there is a leak in an enclosed space, it accumulates at ground level and gradually expels the oxygen from the environment, causing suffocation in those who remain in the place [10]. Therefore, it is important to seek strategies that assist in monitoring in order to minimize these problems regarding the consumption and safety of cooking gas.

III. RELATED WORK

More and more houses and apartments around the world are becoming more advanced and technological, in that sense, works related to smart home and residential automation are very noted. In [11] is described a smart elderly alert system for families who may wish to monitor elderly relatives to keep them safe. This system is composed by a mobile application and a large amount of sensors present in the home rooms with the objective of monitoring the elderly behavior around the house. The communication between the sensors and the application occurs through wifi. Still in [11] is described an energy conservation system in smart homes, through a wifi system integrated to a computer. The user can know the amount of energy that each household appliance is wasting daily. In addition, [12] addresses ways to reduce energy consumption in homes through the introduction of new more efficient technologies. Specifically, in [13] and [14] is presented a smart system that provide more security to the user in preparation food moment. In [14], the stove was equipped with some sensors responsible to get important information, like pans temperature, the flame temperature and duration, gas concentration in the air and others risk factors. In [13], was developed a smart platform that can detect leaks through a gas sensor, and then canceling gas supply and send a SMS alert to the user's smartphone. This system can also inform the bottle weight, but can't provide more helpful information to the user.

This paper is also inserted in the context of smart kitchens. Similar to [13], our system can also measure the bottle weight but in addition we can store this this information over time and provide helpful information to the user that can help in domestic planning and contribute to domestic economy. We can also detect gas leaking and send this information to the user contributing to prevent accidents in the kitchen environment.

IV. PROPOSED SOLUTION

In order to provide a facility to domestic users that uses bottled gas, this work presents a solution based in IoT that consists of three basic parts, presented in Fig. 1: (i) an intelligent platform (hardware) attached to the bottled gas so that periodic measurements can be made of the cylinder weight, detection of gas leaks and sending of data through the cloud; (ii) a web server where the data processed by the support are stored and from where the application will retrieve information through the database; and (iii) a mobile application (software) responsible for displaying consumption information. An initial version of this work was already presented in [15].

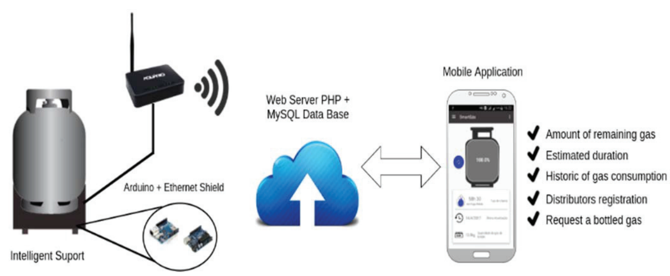

Fig. 1. Functioning of the platform from data collection through the support, web server processing and data visualization in the mobile application.

A. System Architecture

The system architecture, Fig. 2, is divided into three layers, the first one, the application layer, represents the software solution, and it is organized in the Model-View-Controller (MVC) pattern, that is the application of this three-way factoring whereby objects of different classes take over the operations related to the application domain (the model) the display of the application's state (the view) and the user interaction with the model and the view (the controller) [16].

In addition, the application layer has a local database for data storage without the need of communication with the service layer, in situations where the app is not connected to the Wi-Fi. The communication with this database was implemented using the SQLite language. All the application programming was developed using the Java language and XML markup language in a native Android implementation using Android Studio development software.

The middle layer, called service, is located on a server and has been programmed in the PHP language. It is responsible for the communication between the hardware and application layers, providing and receiving data from both.

The lower layer, of hardware, was developed using the Arduino API and its drivers and it was programmed directly in Arduino IDE, using C++ language for the circuit operation.

Because each of these layers were developed in a different language, it has been used HTTP protocols to enable communication between them, so changes in one layer do not mean big changes in the others, since their communication is done through protocols of network.

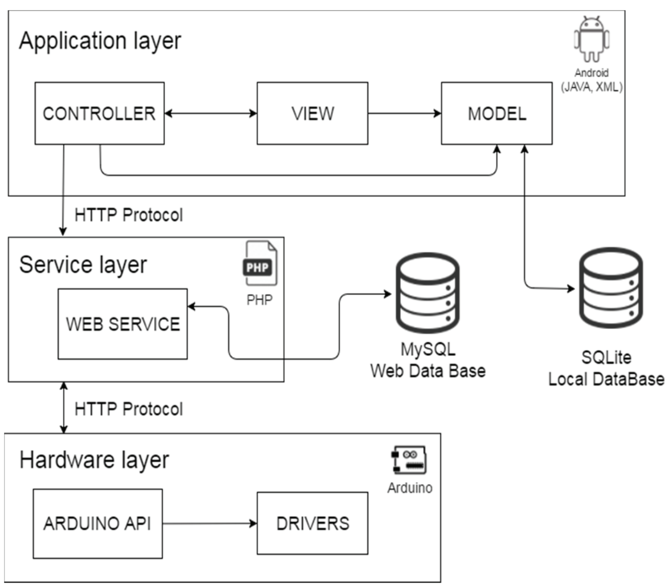

Fig. 2. System architecture overview

B. Hardware

For the implementation of the hardware part, it's proposed to build a support for the bottle with a built-in force sensing resistor and connected to an electronic prototyping board, which will bring benefits due to its low cost. In addition, a liquefied petroleum gas (LPG) detector will be attached to the electronic prototyping board for leak detection, especially in the immediate moments of changing the bottle. This detector is sensitive to the concentration of LPG gas present in the environment, which will be constantly analyzed and an alert will be sent to the user through the mobile application if the gas concentration exceeds a percentage that compromises its safety. The data will be sent to a web server through a Wi-Fi module.

1) Components.

For the implementation of the hardware part, a support prototype for the bottle was built on an electronic prototype board. TABLE I lists all the electronic components used, its description and the purpose.

TABLE I. COMPONENTS USED TO THE CONSTRUCTION OF THE SMART PLATFORM.

Components	Description	Purpose
Arduino UNO R3	A microcontroller board with digital and analog inputs and outputs.	Connect and control the sensors and platform components.
Ethernet Shield	A microcontroller board connectable to the network.	Receive information from arduino and send it to the server through an ethernet cable.
MQ-2 Sensor	A flammable gas and smoke sensor, capable of detecting concentrations of combustible gases and smoke in the air.	Detect gas in the air when its concentration is above the safe level.
LCD Display	It has 16 columns by 2 lines, blue backlight and white writing. It has the HD44780 controller for interaction with the Arduino.	Show simple and quick information to the user.
Buzzer	Extremely compact 4mm SMT buzzer	Emit beep alert when the sensor MQ-2 detects gas leak.
Force Sensing Resistor	Can measure between 100g and 10kg, depending on the force applied to the detection area. The higher the pressure in the sensor, the lower the measured resistance.	Detect the weight variation in the bottle.

2) Circuit

The developed circuit, Fig. 3, acts on the pressure detection exerted through a resistive force sensor. The force sensor was chosen at first because it allows a faster prototyping and allows the simulation of the weight.

In order for the force exerted to be always the same, a base with the same dimensions of the total area of the resistive sensor was used, allowing a stable measurement. In addition, through Shield Ethernet the information obtained with the sensor is sent to a PHP web server to send the data to the system's MySQL database.

C. Software

The development of the mobile application was initially thought for the Android platform because a great majority of smartphone users uses this operating system, being in about 82.9% of the gadgets [17].

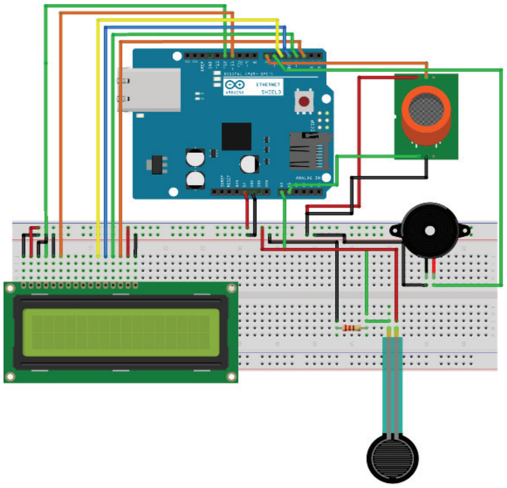

Fig. 3. Circuit Design

The application will access the information saved by the intelligent support on the server and will provide the user a variety of information such as: the current amount of gas in the bottle; the estimated duration of cooking with different flame levels (low, medium and high); the history of gas consumption; and alerts the user in case of leaks. In addition, the application will have other functionalities, such as to allow the user to operate the application manually, avoiding the need of the platform acquisition and still maintaining all the benefits that the platform brings to the user; register your favorite gas distributors; view map of the nearest distributors and even make a request for the delivery of a bottle to one of these distributors.

1) Use case diagram.

The system use-case diagram, Fig. 4, is divided into SmartGas App (Android) and SmartGas Platform (Arduino). In the first section, the user will be able, among other things, to:

- Visualize the amount of gas remaining in the bottle: the user accesses the main screen and displays by means of self-explanatory images the amount of gas remaining in the bottle.
- Access measurement history: the user has at his disposal information regarding past measurements of the current bottle and previous bottle.
- Update bottler's weight manually: the user can manually update the current weight of his canister by inserting it into the application through the image recognition function, where he can read with the camera of the smartphone the weight of the package.
- View graph: The user has access to information graphs relating, such as weight per number of measurements, consumption per week, price per bottle.
- Change flame level: the user can switch between the three flame levels (high, medium and low); the estimated duration of the gas usage is also changed according to the selected flame level.
- Thus, in the second section the Arduino is responsible to:
- Mensure weight: the force-sensing sensor detects the change in the weight of the canister and sends a measurement to the web server.
- Print weight in LCD visor: the LCD shows the actual weight of the bottle in kg.
- Check leak status: The MQ-2 sensor verifies the amount of gas or smoke present in the environment, if it is above that the allowed, arduino will be informed and will activate the communicative components.
- Emit beep alert: After leak detection, the buzzer sounds an alert, informing the situation of risk.

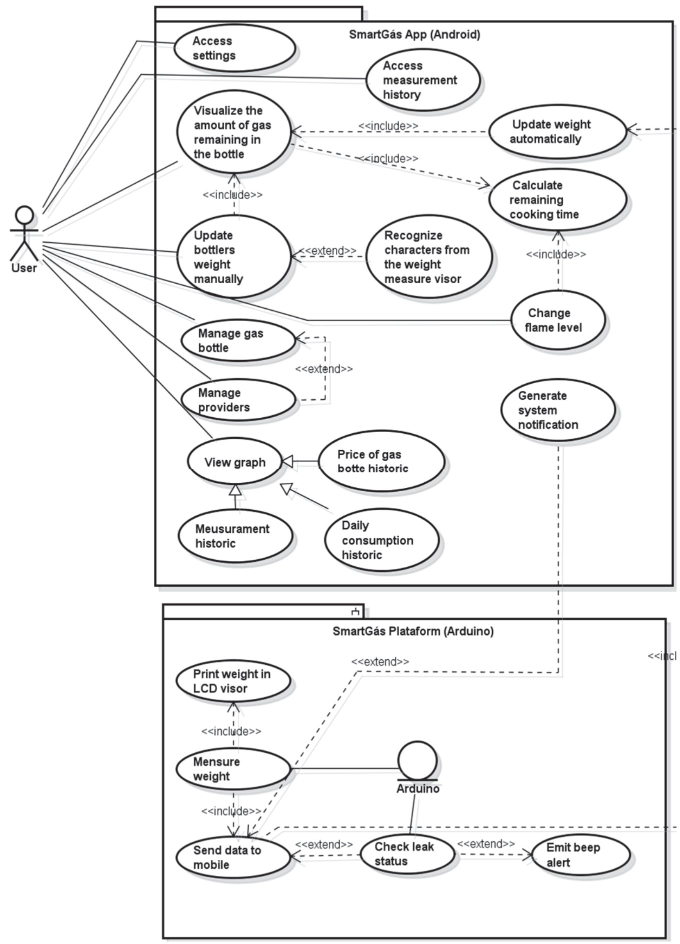

Fig. 4. System use case diagram

V. Results

The results obtained during this research are divided into two topics, 4.1 Hardware and 4.2 Software, in which the developed prototypes and their usability characteristics will be exposed.

A. Hardware

In the intelligent platform, a support prototype for the resistive pressure sensor was developed, as well as an acrylic box for better visualization of the circuit in operation, as shown in Fig. 4. It was used a small plastic object to represent, in reduced scale, the use of the platform with a gas bottled. The Fig. 4 shows a prototype, developed with low cost equipment, which confirms the communication between two technologies used in the system, Arduino and Android Application.

Its use consists of two simple steps: (1°) position the cylinder on the pressure sensor; (2°) connect the arduino cable to the socket and the Ethernet shield cable on the router. Simple as that and your platform is ready to be used.

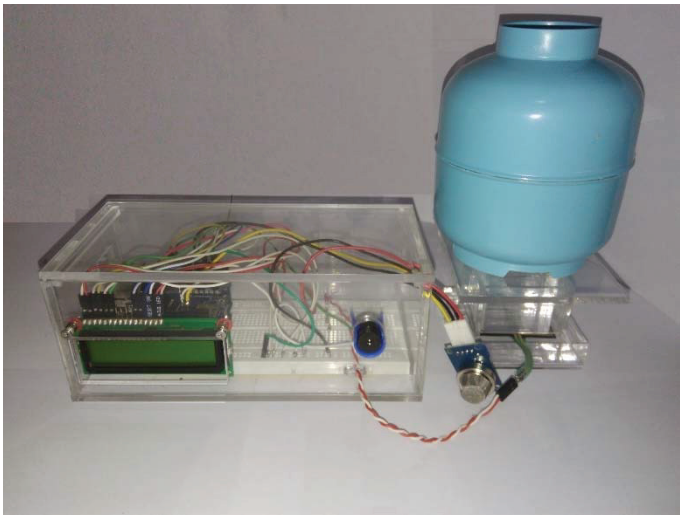

Fig. 5. Functional prototype built

B. Software

The mobile application was developed on the standard Google development platform for Android called Android Studio, using Java programming and XML markup languages. Registration screens have been created, where the user will inform physical characteristics (model, tare, weight, and manufacturer) and buy characteristics of his bottle (date, price, and distributor).

Fig. 6 represents three important screens of the mobile application. The Fig. 6(A) is the main application screen, which contains information of simple and fast interpretation, such as the estimated cooking duration on the three different types of flame; the amount of gas remaining in the bottle in kilogramme and percentage; and the date of the last bottle weighing. Fig. 6(B) represents the functionality of passing the weight of the bottle to the app manually, through image recognition; case the user has a weight measurement in his residence.

Fig. 6(C), the user can consult pre-registered gas distributors to request a new bottle through the app or consult and edit information about it. On this screen, you can also register new gas distributors based on geographic proximity using the Maps and Places APIs. Fig. 6(B) is the screen responsible for making available to the user, through graphs, information regarding the use of his bottle in the previous weeks, as well as making comparisons with the use and price of previously used bottles by the same user. In the third screen.

VI. Conclusions and Future Work

This paper proposes an implementation of a mobile application capable of providing the user with the amount of LPG gas remaining in their bottle, attached to the development of an intelligent medium that provides real-time information to the application, to assist with greater comfort and economy the domestic users of bottled gas.

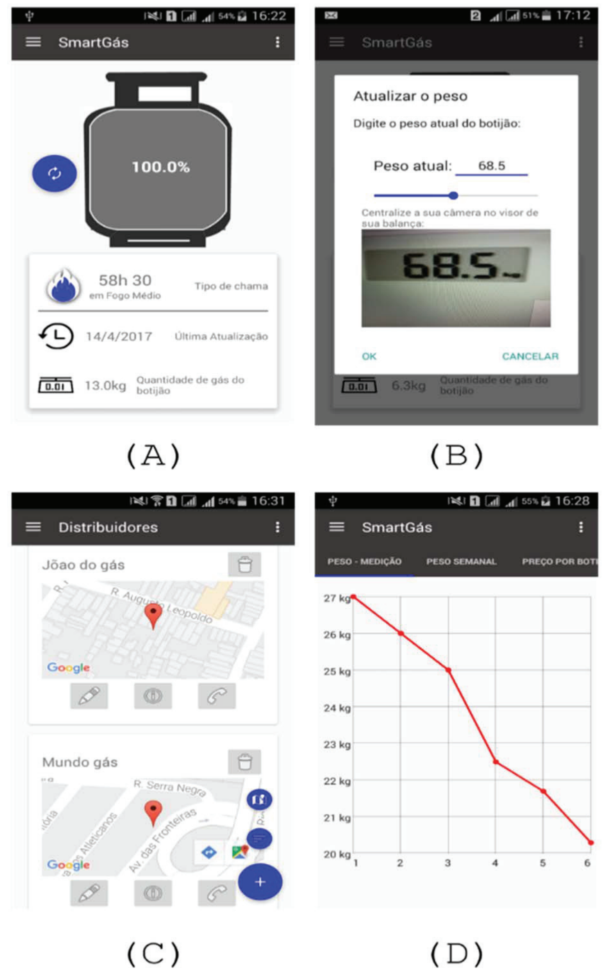

Fig. 6. Mobile application. (A) Main screen; (B) Image recognition; (C) Access to distributors; (D) Access to charts.

A. Main Contributions

- Detection of leaks through the platform: The platform sends a data to the server; the application accesses the data and notifies the user in case of gas leakage.
- Control of domestic economy: By having control of how much, you spend in a week or a month and knowing when your gas will end, getting prepared to buy another bottle.
- Possibility of manual measurement: by typing the weight in the text field, or by using the functionality of image recognition with the camera of your smartphone.

- Register distributors: where you can register the distributors closer to you, using your location with google maps.

B. Threats to validity

The feasibility study can only be fully realized when we reach a more advanced stage for the intelligent platform. Thus, this can only be achieved through the support of sponsors or gas bottle manufacturers, to fund the purchase of materials for the platform and its maintenance.

That way we intend to study the ability of this product to compete (price and quality) with other highly sophisticated products of large companies.

C. Future work

We crave to implement a space in the app where the gas suppliers can advertise promotions or even promote their business. It's also intended that the application allow the gas level monitoring by the distributor of that user, so that he can knows when his client gas is in the end. It is also hoped to implement a QR Code reading in partnership with the suppliers, being possible that with a simple point of the camera to the bottle, the application captures all its information (such as tare, model, manufacturer, and price), providing greater ease to the user.

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