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Communication architecture based on IoT technology to control and monitor pets feeding

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Abstract: Technology is currently a significant benchmark in any application area; science and technology have permitted the invention of tools and devices that simplify daily activities by developing software engineering applications that provide automated solutions. In this sense, this work proposes two architectures that allow communication between the electronic device and the mobile application remotely, using the GSM/GPRS communication services and the Twitter social network. This development aims to control dogs' feeding adequately and healthily, providing the ration of food a dog needs according to the daily energy requirements. A nutritional assessment has also been performed considering different factors such as the size, breed, and weight of the dog to calculate the daily ration of healthy and balanced food according to daily energy requirements. Essentially, the electronic device consists of two parts: on the one hand, the electronic design is formed with an Arduino board, a Sim900 module to send and receive text messages, and the ESP8266 Wi-Fi serial transceiver module, which allows establishing the internet connection to receive the tweet that users post, both modules permit remote communication with the device using the Arduino board. On the other hand, the mobile application developed on Android uses a standard design according to the Google material design guidelines, allowing the owner to feed, schedule the feeding, review the dog's food history, and receive alerts when the food is going to be finished.

Keywords: IoT technology, software engineering applications, GSM/GPRS communication service, Twitter social network, mobile application, electronic device, low-cost platforms
Categories: B.7.1, D.2, K.6.3
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1 Introduction

The Internet of Things (IoT) is a current trend of technological development that has had numerous advances since the term was first coined in 1999 by Kevin Ashton [Gubbi, 13]. Several scientific progress and automation of many processes have solved complex industrial and social problems and created new and innovative products and solutions. In the last decade, improving daily activities and developing new products and services have caught society's attention in general, industry, academia, and research. IoT is a current trend of technological development. It is possible to create new applications that generate new opportunities, such as in the economy and society. With IoT technology, a scenario is presented where any physical object can be turned into a terminal connected to the Internet in a home environment, controlling and monitoring different things remotely from anywhere and anytime through an Internet connection (Vashi, 17). The interconnection of different devices mainly characterizes by being controlled remotely from available anywhere, anytime, by anything and anyone [Chin, 19], in order to be able to collect, analyze, and process data on computer platforms [McCann, 18].

In the fourth industrial revolution, technologies can transform the traditional scheduling approach to a smarter scheduling system. In this sense, there are many IoT applications in different fields, such as e-commerce [Yu, 17, Liu, 19], smart home [Malche, 17, Li, 19], smart city [Brincat, 19, Kazmi, 18], intelligent transportation [Luo, 19, Sodhro, 19], agriculture [Brewster, 17, Ruan, 19, Togneri, 19], wearable device [Cirani, 15, Sharma, 19], healthcare [Zhu, 19, Alabdulatif, 19], and many other domains [Balliu, 19, Prathik, 18, Gupta, 19, Griffiths, 18].

Nowadays, technology is a significant benchmark in any application area, science in coexistence with technology has allowed the creation of tools and devices that simplify daily activities [Quiñonez, 21]. About ten years ago, a means of communication emerged [Zeng, 10]. Since then, changes in communication methods have been experienced. The use of social networks has increased significantly. Consequently, a new scenario of communication between people has been created. In this context, the Twitter social network developers have created a platform available to everyone to share information, thoughts, and feelings from daily life.

In this sense, this work proposes the design of an automatic dog feeder controlled by a mobile application and a Twitter profile; this device uses the Arduino board, the GSM/GPRS communication services through the Sim900 module, the ESP8266 Wi-Fi serial transceiver module, and the Twitter social network. The technologies mentioned above aim to control the dogs' feeding satisfactorily and healthily and provide the ration of food that a dog needs according to the daily energy requirements.

Dogs are domestic mammals of the Canidae family, the scientific name is Canis Lupus Familiaris [GISD, 19], and currently, there are approximately 800 different breeds, with different sizes of physiognomies. Dogs' health depends mainly on a diet, regardless of breed or size; dogs require a healthy and balanced diet to enjoy a good health condition. In this sense, it is essential to perform a nutritional needs assessment to provide the food ration considering different factors such as size, breed, and life stage. Nutritional needs assessment of dogs allows establishing the Recommendation for Daily Intake (RDI). The RDI refers to the level of adequate intake of a nutrient or food component to satisfy the optimal nutritional needs [Freeman, 11], according to the levels of essential nutrients that should be consumed continuously in a healthy way to ensure adequate nutrition and health [IM, 94, Uauy-Dagach, 01]. Dogs require a balanced diet that provides an adequate supply of different nutrients such as amino acids from protein, fatty acids and carbohydrates, vitamins, minerals, and water [NRC, 06].

2 Previous Related Researches

Currently, there are few works related to automatic feeders. In the last two decades, two investigations on wireless control systems for dogs were found using wireless sensor networks to control and monitor pets through a desktop application [Jung, 07, Kim, 07]. Other works have recently addressed programmable pet feeders, smart dog feeders, and smart pet care systems. According to work proposed by [Berhan, 15], the authors presented the design of a programmable system to provide food to pets at automatically scheduled times, using microchip PIC18F4520 microcontroller, LCD, buzzer, and motors.

In work presented by [Kim, 16], have proposed a smart pet care system that provides food remotely and remote-controlled automatic defecation using a smartphone application, uses different sensors and wireless communications that work under the Arduino platform. In other research [Vania, 16], authors proposed a smart dog feeder using an Android smartphone, which uses the Arduino microcontroller to control the main program, the sensors, and actuators. It uses RFID technology to perform authentication; therefore, with the RFID tag on the neck, the dog is the only one that can make the smart dog feeder work. Through the developed mobile app, owners can monitor the feeding process and view history using food inventory reports, feeding times, and waiting times.

3 Problem Description and Proposed Approach

3.1 Analysis of the Problem

As already mentioned above, few studies are related to automatic dog feeder. However, the existing studies are based on providing feeding automatically, without analyzing the daily food ration according to the RDI and the maximum nutritional values. Therefore, for the dog to enjoy good health, a healthy and balanced diet is necessary according to the daily energy requirements. In this sense, a nutritional assessment has been performed in this work, considering different factors such as the size, breed, and weight of the dog to define the daily ration of healthy and balanced food according to daily energy requirements. Next, Figure 1 describes the factors involved in a complete nutritional assessment.

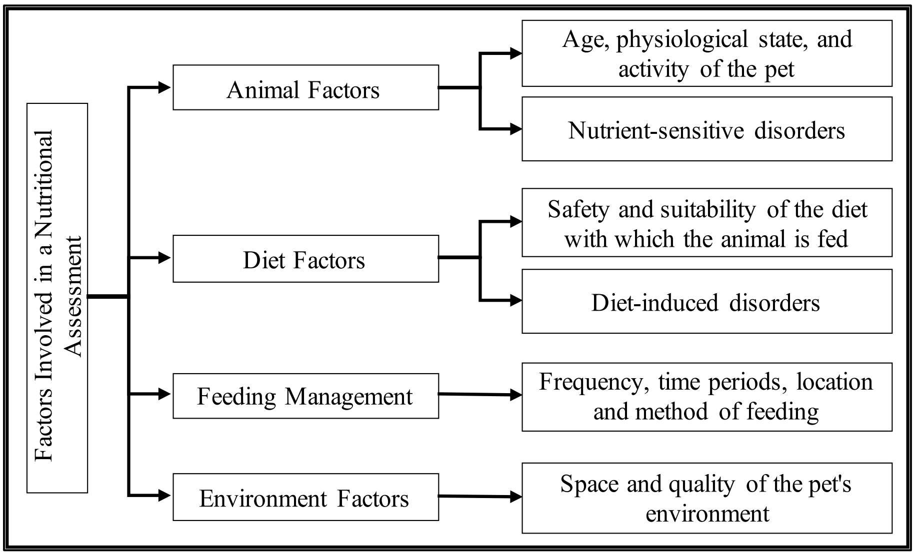


Figure 1: Factors considered to perform a nutritional assessment according to the Journal of the American Animal Hospital Association [Baldwin, 10]

According to the previous information, feeding management and environmental factors are related to disorders such as excessive or deficient feeding, deficient raising, the competencies to eat food in dogs, and the lack of an adequate environment stimulus [Freeman, 11]. Considering that each dog is different, it is crucial to determine if the amount of food is adequate based on its characteristics. Table 1 describes the essential characteristics considered to determine the amount of food according to the dog's weight and size.

Weight (kg)	Puppy	Adult	Old	Size
1 to 5	0 to 12 months	1 to 8 years	8 + years	Miniature
6 to 10	8 to 12 months	1 to 8 years	8 + years	Small
11 to 20	8 to 12 months	1 to 7 years	7 + years	Medium
21 to 35	16 to 24 months	1 to 6/7 years	6/7 + years	Big
35 to 50	16 to 24 months	1 to 6/7 years	5/6 + years	Giant

Table 1: Factors considered establishing the amount of food according to the dog's weight and size

It is essential to know the amount of Metabolizable Energy (ME) of the food to determine the exact amount that a dog should ingest according to daily energy needs; in this sense, equation 1 is a good estimator for the daily energy requirements of a dog [NRC, 06]:

$$EM = k * p^{0.75} \tag{1}$$

where *EM* is the metabolizable energy, *k* is a constant established at 99 if the dog is not active, and 132 if it is an active dog, *p* corresponds to its body weight. Hence, to determine the exact amount that a dog should ingest, it is necessary to consider the information provided in Table 1, according to weight and age (active/non-active), to perform the necessary calculations using equation 1.

3.2 Analysis of the Problem

The automatic dog feeder has the purpose of controlling the dogs' feeding adequately and healthily (see Fig. 2) and provide the ration of food that a dog needs according to the daily energy requirements. In this sense, two architectures are proposed to allow communication between the electronic device and the mobile application remotely: first, using GSM/GPRS communication services, and second, using the Twitter social network. Figure 3 shows the proposed architectures' main parts to communicate between the electronic device and the mobile application.

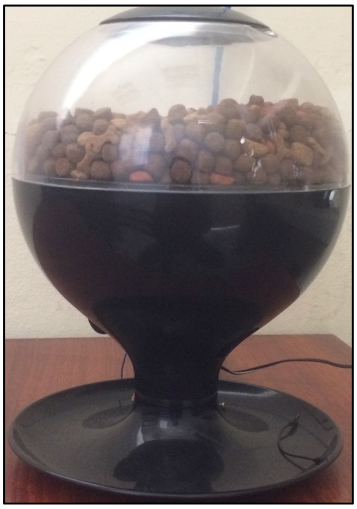
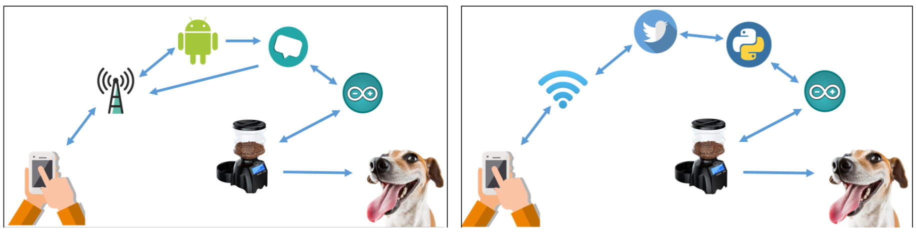


Figure 2: Automatic Dog Feeder



(a) (b)

Figure 3: (a) Communication architecture using GSM/GPRS services and (b) Communication architecture using the Twitter social network

3.3 Development phases

Firstly, the project's need was identified, where the parameters and objectives were specified; later, a preliminary investigation and a feasibility study were performed to know the technological alternatives and existing designs. Then, in the conceptual design stage, the economic costs and implementation times were estimated. Once the prototype was obtained, the first tests were performed to verify the device's correct operation.

4 Implementation Tools

Currently, different low-cost platforms allow the development of technological devices; some of these platforms are Arduino [Arduino, 20], Raspberry Pi [Raspberry, 20], OpenPicus [OpenPicus, 20], Cubieboard [Cubieboard, 20], Udoo [Udoo, 20], amongst other. An exhaustive analysis of each of the platforms' characteristics has been performed; the most widely used and known are Arduino, OpenPicus, and Raspberry Pi. This work focuses on the Arduino platform, concerning communications services the GSM/GPRS technology and the Twitter social network have been used. Finally, the Android operating system is used to develop the mobile application.

The Arduino board is based on the 8-bit ATMEGA328 microcontroller, it has 13 input/output ports, and six of them can be configured as outputs to handle Pulse Width Modulation (PWM) signals. It has 1 UART port and a six-channel analog/digital converter module. It has a 32KB program flash memory and a 2KB EEPROM memory unit [Pathak, 17]. It offers some advantages concerning other platforms; for example, it is multi-platform, the programming language is simple and straightforward, the boards are low cost, both the hardware and the software are open-source [Arduino, 20].

Global System for Mobile Communications (GSM) is a mobile communication system based on time division multiple access technologies. General Packet Radio Service (GPRS) is a technology that shares the frequency range of GSM, uses data transmission through packets, and provides services more efficiently. GSM data transmission is performed at a minimum speed of 9.6 Kbps, and GPRS data transmission is increased to a minimum of 40 Kbps and a maximum of 115 Kbps [Wenzheng, 07].

The Sim900 module for Arduino is based on GSM/GPRS technology, allows communication between the electronic device and the mobile application remotely. The module is compatible with any Arduino board. It consists of the following elements: a SIM 900 chip, an antenna with coaxial cable, a SIM card, power connector, input, and output pins, microphone and earphone connectors, a Universal Asynchronous Receiver-Transmitter (UART), and finally, the card status indicator LEDs. The SIM900 delivers GSM/GPRS 850/900/1800/1900 MHz performance for voice, SMS, data, and fax in a small form factor and low power consumption.

The ESP8266 Wi-Fi serial transceiver module is one of the most used for IoT applications due to its low cost and versatility. It is a self-contained system on a chip integrated with TCP/IP protocol stack, Wi-Fi Direct Peer-to-Peer (P2P), and Soft Access Point (AP) mode. The ESP8266 module offers a complete and autonomous Wi-Fi network solution; it can host the application or download Wi-Fi network functions. It can also serve as a Wi-Fi adapter; wireless Internet access can be added to any microcontroller-based design with simple connectivity [Rosli, 18].

Social media is an inevitable part of modern life and has become a powerful tool for sharing information, interacting with other users, search content of interest and transacting digitally. There are different social media platforms, the most used being Facebook, Twitter, Instagram, WhatsApp, among others [Bustos-López, 18, Salas-Zárate, 20]. In this work, the Twitter social network is used to provide food to the dogs remotely through tweets' emission and reception.

5 Experimental Results

Currently, in the market, there is a great variety of automatic dog feeders of different prices and quality of materials, some with LCD screens to facilitate the programming and configuration of the various feeding modes, others have a camera or voice recorder and integrated speaker. However, most of these dispensers provide a certain number of grams in the different rations but do not provide a daily ration of food that a dog should eat concerning the weight. In this sense, two communication architectures are proposed that facilitate the owner to feed through a dispenser that gives the exact amount that the dog should eat.

This section summarizes the different tests and results collected with the two proposed communication architectures using the GSM/GPRS communication services and the Twitter social network. Before conducting communication tests with the electronic device, a nutritional assessment was performed. Different factors such as the dog's size, breed, and weight were considered to calculate the daily ration of healthy and balanced food according to daily energy requirements. Then, to determine the exact amount of food (grams) that a dog should eat according to daily energy requirements, equation 1 was used to obtain the daily ration of food that a dog should eat according to its weight. Table 2 shows the daily ration of food that a dog should eat concerning the weight (from 1 to 50 kilograms).

Size	Weight (Kg)	Grams	Size	Weight (Kg)	Grams
Miniature	1	38.94	Big	26	448.27
	2	65.49		27	661.27
	3	88.77		28	474.02
	4	110.15		29	466.66
	5	130.21		30	499.20
Small	6	149.29		31	511.62
	7	167.59		32	523.95
	8	185.25		33	536.19
	9	202.35		34	548.33
	10	218.99	Giant	35	560.38
Medium	11	235.22		36	572.34
	12	251.08		37	583.23
	13	266.62		38	596.03
	14	281.86		39	607.76
	15	296.82		40	619.41
	16	311.54		41	630.98
	17	326.04		42	642.49
	18	340.32		43	653.93
	19	354.40		44	665.30
	20	368.30		45	676.61
Big	21	382.03		46	687.86
	22	395.59		47	699.04
	23	409.00		48	710.17
	24	422.27		49	721.24
	25	435.40		50	732.25

Table 2: Amount of daily intake a dog should eat based on weight

Once the nutritional assessment analysis is done, the experimental results of the project were performed. First, it was to install the Android Studio, Arduino, and Python libraries, then, the assembly of the components of the first architecture was performed using the GSM/GPRS communication services, to verify the operation of the device with the Arduino board, the SIM900 module, and the DC motor. Figure 4 shows the assembly schematic with all the architecture components that use the GSM/GPRS communication services.

A sequence diagram was designed where the communication process between the user and the electronic device is established. It is specified how the process is performed using the GSM/GPRS communication services. Next, Figure 5 shows the sequence diagram "feed through the mobile application using the GSM/GPRS communication services." First, the dog owner uses the mobile application to feed it; second, it chooses the size and weight. And then, once the information is selected, the parameters are sent through an SMS message. This way, it is linked to the Arduino board installed in the automatic dog feeder using a GPRS signal with the feed instruction. According to the received parameters, the algorithm verifies the amount of food it will provide and the time the DC motor must be activated to feed the dog.

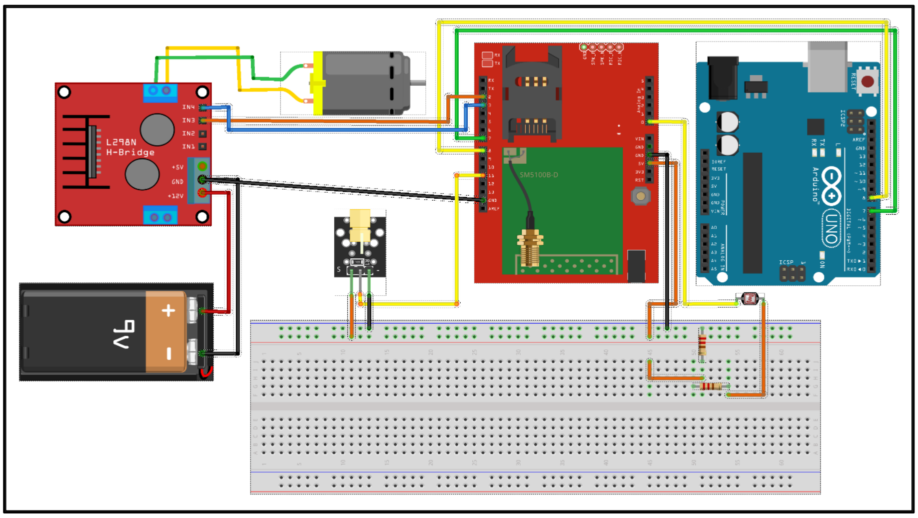


Figure 4: Assembly schematic using all components: the Arduino board, the SIM900 module, and the DC motor

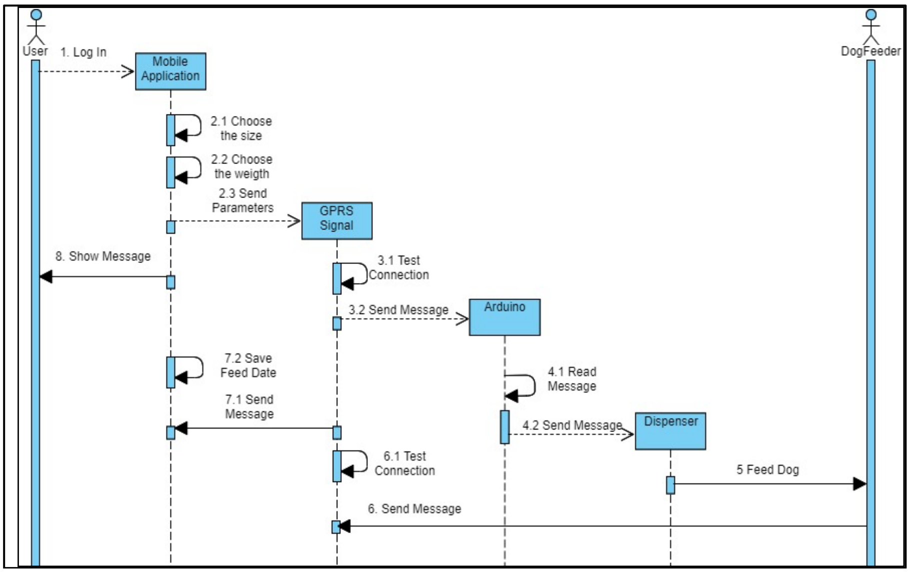


Figure 5: Sequence diagrams: feed through the mobile application using the GSM/GPRS communication services

According to the received parameters, the algorithm verifies the amount of food it will provide and the time that the DC motor must be activated to feed the dog. It was necessary to perform physical tests on the electronic device to define the DC motor's activation time. A digital scale with a capacity of up to 1 kilogram was used to measure how long the DC motor must be activated to provide the exact amount of food for different dogs' weights from 1 to 50 kilograms (see Table 2). This process was repeated ten times, with each of the weights from 1 to 50 kilograms. Finally, the average time was calculated, and the DC motor's activation time was defined for each of the weights. For example, for a dog weighing 25 kilograms, the electronic device must provide 435.40 grams, and according to the tests carried out, the device takes 25.69 seconds. Figure 6 clearly shows the time (seconds) that the DC motor has to be activated to provide food as a function of the dog's weight.

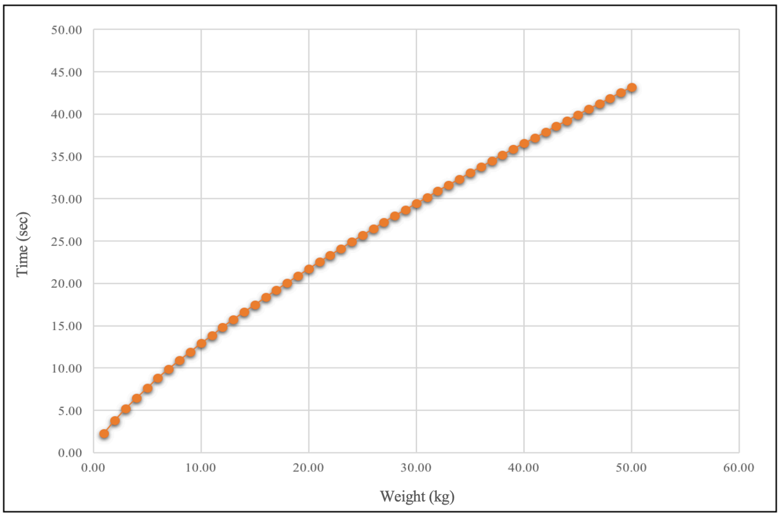


Figure 6: Time in which the DC motor must be activated as a function of the dog's weight

The first tests performed on the device were simple tests such as turning on a led or the DC motor to test the operation of communication with each of the proposed architectures. Then, the mobile application design in Android Studio for end-users was made. The application is straightforward; first, it selects the dog's size and weight; after that, the feed button is pressed. Once the option feed is selected, it sends the instruction to the electronic device using the GSM/GPRS communication service to activate the DC motor at a specific time that is directly related to the grammage calculated for the selected dog's weight. Finally, the operation of the mobile application and the electronic device was verified jointly. Figure 7 presents a series of images showing the operation of the project.

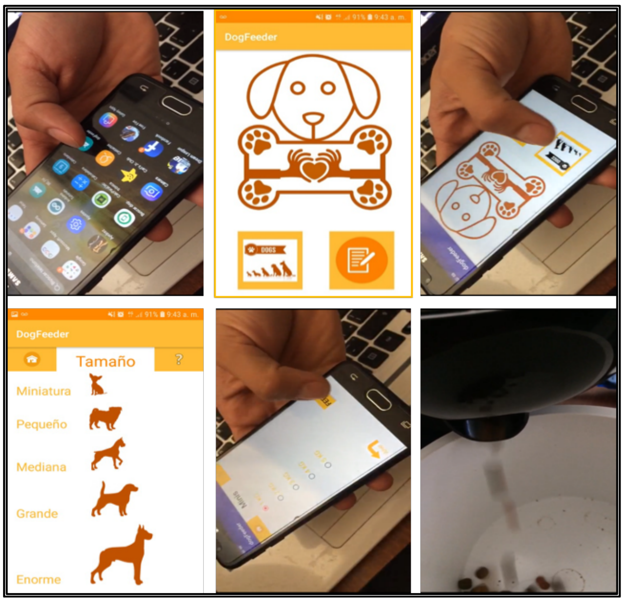


Figure 7: Operation of the mobile application and the electronic device.

The second architecture was performed using the Twitter social networks; it is mainly based on traditional tweet posting; it is only necessary to make a tweet with the dog weight. Then, the electronic device automatically provides the food ration. The posted tweet is extracted using three Python libraries: Tweepy [Tweepy, 20], Nltk [Nltk, 20], and pySerial [pySerial, 20]. Subsequently, the tweet is sent to the Arduino board through the ESP8266 Wi-Fi serial transceiver module. The algorithm receives this information and determines the food ration according to Table 2.

Due to Twitter privacy, to extract the tweet, it is necessary to request permission as a Twitter Developers [Twitter, 20] to obtain the tokens and the platform's approval, to establish communication with the email account requesting the service. Once the Twitter Developers permissions have been granted, it shows the option to "create an app" and configure the application data such as application name, description, and logo.

Figure 8 shows the configuration options once the platform has granted the permissions.

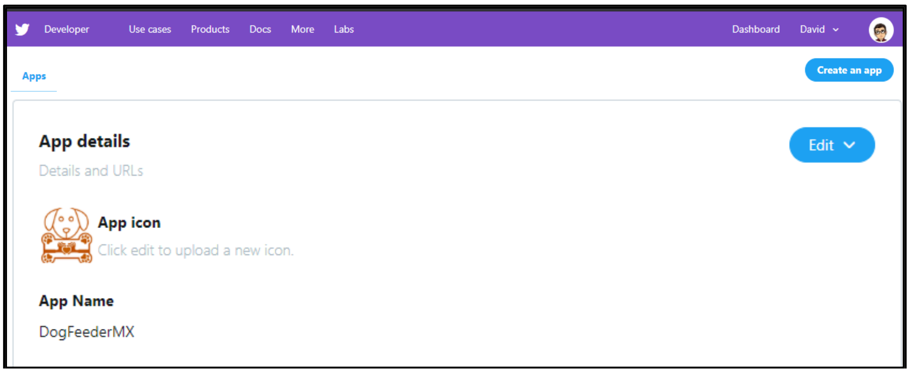


Figure 8: Configuration options to Twitter Developers [Twitter, 20]

The assembly of the second architecture components is formed by the Arduino board, the ESP8266 Wi-Fi serial transceiver module, and the DC motor. Figure 9 shows the assembly schematic with all the components for the architecture that uses Twitter social network.

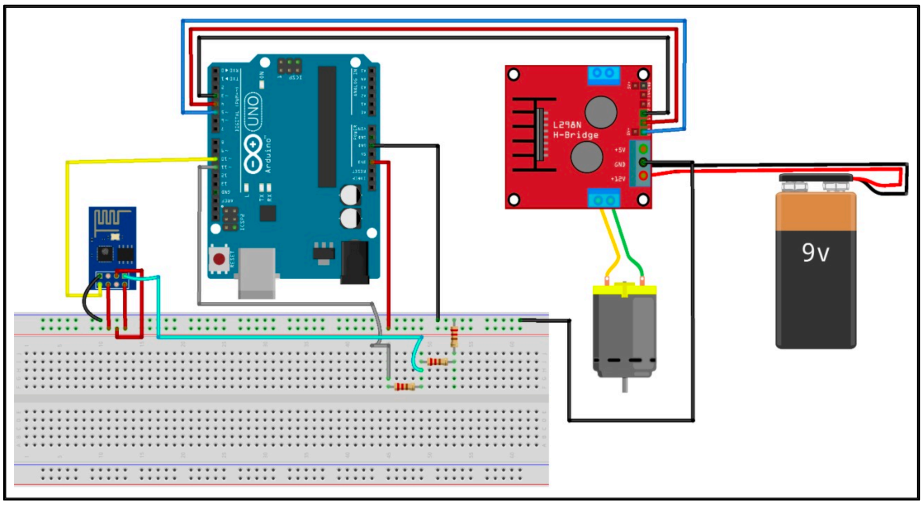


Figure 9: Assembly schematic using all components: the Arduino board, the ESP8266 Wi-Fi serial transceiver module, and the DC motor

A sequence diagram was designed that describes the way of communication between the user and the electronic device using the Twitter social network. Figure 10 shows the sequence diagram "feed through the social network Twitter." First, the user login to the Twitter account; then, it is necessary to post the dog's weight through a tweet to send the feed instruction through Python. Once the tweet information has been read, the Tweet is tokenized and sent to the Arduino board through the ESP8266 Wi-Fi serial transceiver module with the instruction to feed. According to the received parameters, the algorithm verifies the amount of food it will provide and the time that the DC motor must be activated to feed the dog. Finally, a confirmation tweet is sent to the user to indicate that the pet has been feed.

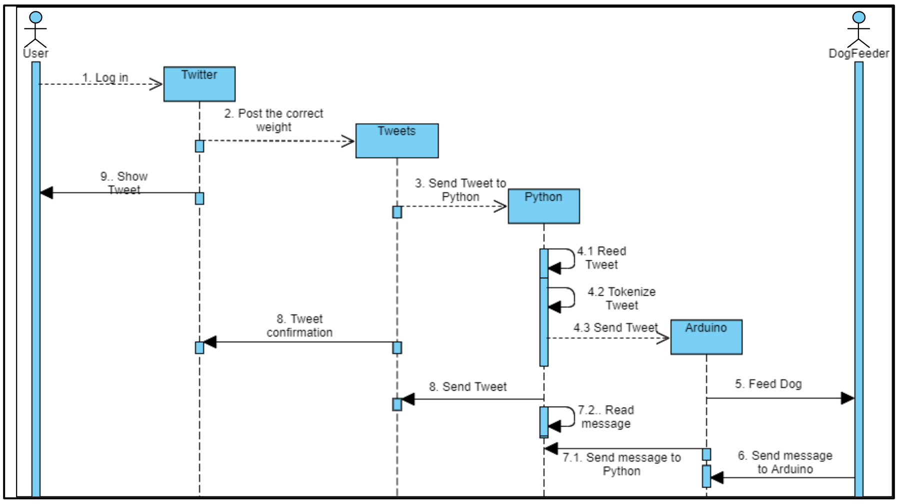


Figure 10: Sequence diagrams: feed through the Twitter social network

Figure 11 presents the application settings, profile made on the Twitter social network. in which the application name, description, logo, and profile security in public or private mode can be changed.

Figure 11: Twitter profile for Automatic Dog Feeder

According to the results obtained, it can be said that concerning the time it takes for the device to establish communication in both architectures, it varies between 5 to 10 seconds, depending on the architecture used, either the GSM/GPRS communication service or the Twitter social network. The significant advantage when using the Twitter social network is that communication with the device can be established from a mobile phone or any desktop computer. It is only necessary to have an internet connection, in case of forgetting or losing the cell phone, it would not be trouble feeding the pet. On the contrary, when using the GSM/GPRS communication service, it is necessary to use a mobile phone application where the electronic device was configured.

6 Conclusions and Future Work

Nowadays, technology is a fundamental benchmark in any application area, science in coexistence with technology has allowed the creation of tools and devices that simplify daily activities. In the last decade, improving daily activities and creating new products and services has caught society's attention in general, industry, academia, and research. There have been numerous advances and technological developments for different personal applications, at home, in education, in organizations, and the manufacturing industry is no exception since it has become a great interest topic.

In this work, two communication architectures have been presented as an alternative to feed pets, specifically for dogs. The GSM/GPRS communication services and the Twitter social network have been used, allowing owners to control and monitor feeding remotely from anywhere and anytime. It also allows to establish the timing and provide the recommended ration according to the dog weight. Moreover, it has alerts that notify the owner when the food is about to run out and send reports on feeding times. This electronic device's development tries to control the dogs' feeding according to the daily energy requirements. In this sense, an exhaustive analysis was performed related to the dogs' recommended daily intake and the systematic analysis of the amount of metabolizable energy in dog food.

According to the results obtained, both architectures are functional to establish communication remotely, anywhere, and anytime. However, when using GSM/GPRS communication services through the Short Message Service (SMS), the communication establishment depends on the mobile network's coverage. The device's SIM card must have a phone plan or recharge cards to send SMS and perform the feeding process. Otherwise, when using the Twitter social network, it is necessary to have a wireless internet connection where the electronic device is located to establish communication through the ESP8266 Wi-Fi serial transceiver module. Once communication is established, it is only necessary to post a tweet from the Twitter user account using any device connected to the Internet.

As already mentioned before, both communication architectures work correctly, since nowadays, there is wide coverage of mobile networks worldwide and Internet services have good data transmission speed. However, there is a disadvantage when using the GSM/GPRS communication architecture because the electronic device's operation is limited to the mobile phone where the application is installed; if the mobile phone is lost or forgotten, feeding will not be possible to perform. This limitation does not happen when using the Twitter social network because the owner only needs to log in from any computer or mobile phone connected to the Internet.

Currently, both architectures work for a single electronic device at the same time. It would be interesting to implement some hardware modifications to work on more than one device, using the same application or the same Twitter account. That means if the owner has more than one dog, that allows him to create profiles with each dog's characteristics and provides the food ration in different devices according to each one's weight.

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