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Original Article

Design of an Embedded System Applying IoT to Reduce the Mortality of Pigs Due to Stress Syndrome Before Being Benefited

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***Abstract** - Today, per capita consumption of pork has increased considerably in the Peruvian territory, with an average increase of 5%, which has caused some farms to accelerate the processing of pigs. For this, it is very important that the pig, before being processed in the slaughterhouse, is physically and mentally healthy to obtain a good quality product. Some studies indicate that 10% of pigs die before being benefited due to various factors such as stress syndrome, infectious diseases, poor transfer of pigs in transport, among others. Therefore, this article proposes a prototype to monitor pigs at the time of their transfer to the slaughterhouse to reduce the aforementioned mortality. For this, an embedded system is used that applies IoT to monitor in real time through smart sensors that will read the temperature, humidity, acceleration and movement speed of each pig. For this, an air conditioning system is used to control the temperature automatically through the ESP32 platform, sensors such as MPU6050, MQ135 and DHT11, INFLUX DB database and a GRAFANA panel to observe the statistical graphs of the system. Finally, this prototype aims to avoid economic losses on farms, reduce mortality through IoT technology, and ensure that the pigs arrive in the best conditions to obtain fresh, good-quality meat since the latter determines the cost of each pig.*

***Keywords** - IoT, ESP32, Database, Sensors, Embedded System, Pig.*

1. Introduction

Currently, in Peru, according to the Peruvian Association of Pork Farmers (ASOPORCI), they indicated that despite the various events that have occurred in Peruvian territory with the shortage of soybeans, which is a fundamental food not only for pigs but for animals in general. In 2023, the annual per capita consumption of pork reached 10.5 Kg, in which it is projected that by 2024 it would increase in a range of 4% to 6%, reaching an annual per capita consumption of 11 to 11.2Kg, which despite increasing that percentage still remains below the average of meat consumed in South America, which is 14.5Kg [1, 2]. If we compare the meats consumed in Peru, we can see the great demand for poultry or chicken meat with an annual per capita consumption of 51kg, followed by pork, which is estimated at 10kg, beef 8kg, among others [3]. That is why, currently, ASOPORCI, with the purpose of promoting pork consumption, generates various events and conferences to seek to break the gap and improve the percentage of 5% annual per capita pork consumption that continues to be maintained since 2022 [4]. Thus, despite the great competition that exists in the consumption of pork compared to other meats, the annual per capita increase in Peru has caused various farms to optimize the pig processing process, streamlining and seeking the optimal way to satisfy the demand of the farms [5]. For this purpose, it has been observed that some slaughterhouses that process pigs in the city of Lima and various parts of Peru have a very crucial deficiency before processing a pig, which is the mortality of pigs during transport to the slaughterhouse due to stress, among other diseases. For example, out of 600 pigs processed weekly from a conventional farm, 2 to 3 pigs die before being processed due to the various factors already mentioned [6]. These accidental cases of pig mortality generate a great economic loss for the company or farm, since normally a pig that dies before being processed produces Pale, Soft and Exudative meat (PSE), since the pH of the meat decreases rapidly. Therefore, sometimes farms choose not to sell it to the public and rather seek to market it at a lower cost, selling it as industrial meat to sausage processing companies [7]. That is why, seeing this problem, in this research work a prototype is proposed to reduce mortality due to stress in pigs, which is a case that combined occurs with an average of 90%, a difference from another case of mortality that is 10% that occurs due to blows, heart attack, etc. [8]. The proposed system is a prototype that uses IoT technology for correct monitoring in real time together with a web database, which will serve to verify the physical magnitudes of the pigs when being transferred before being beneficiaries from the farm to the slaughterhouse, the purpose of the prototype is to make a daily record and verify the anomalous values of the magnitudes that are desired to be monitored in the pigs so that the specialists of this industry take preventive actions and thus reduce stress mortality, as well as reduce the economic losses that can be generated in companies and improve the efficiency of the transfer of the pig in which this article will focus as an area of study. The prototype is made up of an ESP32 module as the main component, which is responsible for processing the data from the sensors and sending them to the cloud. Likewise, this device will oversee controlling the air conditioning to maintain the ideal temperature for the pigs in the truck. The educational sensors used for the first tests of the system are the MPU6050, MQ135, and DHT11, which will read the temperature, humidity, acceleration, and speed of movement of the pig and anomalous gases. These physical magnitudes already mentioned can be displayed on a computer, phone or devices that have internet because the use of the GRAFANA platform is applied, which is an IoT technology environment, in which, together with an Influx DB database, the truck that transports the pigs can be monitored in real time, as well as recording the daily, weekly and monthly history of the activities that are desired to be monitored in transport. It is important to mention that this prototype.

However, it is true that as a first installation, it encourages the application of low-cost and educational devices, seeks to be developed in a scalable way to not only be installed in transport but in other areas or stages where it is also crucial to perform analysis or monitoring of pigs, cattle and even birds by applying technologies that will provide us with greater reach and monitoring without the need to be present in the area due to the use of the Internet of Things and the application of embedded systems [9]. For greater detail, this article is structured in several sections that are defined to understand the operation of the proposed system better and obtain favorable results with the aforementioned objectives. In section 2 of the article, a literature review of technological advances in recent years of projects related to the application of the IoT is carried out, as well as articles related to the prototype presented in this research work. Likewise, section 3 indicates the methodology that is being applied, where topics of device characteristics, design and operation of the proposed prototype are addressed. Likewise, section 4 determines the results obtained from the prototype, as well as the discussions generated through the various works carried out in the literature review. Finally, section 5 determines the conclusions, recommendations and future work expected in this article.

2. Literature Review

Currently, there are not many research works related to the monitoring of pigs in the transfer stage before being slaughtered; however, it was possible to view some research articles that are related to the monitoring of animals but in other areas that will also be of interest to strengthen and seek improvements in the present research work. In the article [10], the author indicates or proposes a pig monitoring system using IoT technology for large herds, whose objective is to observe the behavior of the pigs on their farm in order to generate alerts for the immediate attention of alterations that the pigs on their farm may have. The system he proposes seeks to be installed basically in the ear of each pig so that it can collect temperature, vocalization and noise readings in order to develop machine learning models to analyze the behavior of pigs in a certain period, and this is with the help of artificial intelligence. The system is composed of an MLX90614 infrared temperature sensor, an ADXL345 accelerometer, an ADXRS300 gyroscope and a MAX9814 sound sensor to identify aggressive behaviors and alterations of pigs. Finally, an NRF51822 Bluetooth module will be used for wireless transmission of data that will be transmitted at a frequency of 2.4 GHz. Subsequently, with regard to the tests with animals, the author first installed two growing pigs of 18 kg. As a first point after installing the sensor in the ear, it was observed that there were no alterations or physical discomfort in the pigs. The test time was approximately 1 hour and 30 minutes, during which the temperature of the pig oscillated between 36 and 39°C and, with respect to acceleration, did not exceed +-20 m/s2.

Likewise, in the thesis [11] the author talks about the problems that exist in pig farming in Campo de Cartagena, in which he indicates that the correct acclimatization of pigs helps the animals not to suffer from stress due to body temperature, or due to various environmental alterations. The author seeks to propose a system to improve the quality of life of animals that are in an extensive livestock exploitation regime, as well as to improve production based on air conditioning. The system applies IoT technology, which is basically the communication of a hardware device through the internet to a virtual platform, for this it uses the ESP32 module that together with the DHT 22 sensor that measures temperature and relative humidity, the environment or pig farm will be monitored; additionally, it uses a 360 ° servomotor to open windows together with a magnetic sensor. In addition, it uses a Raspberry Pi platform together with the Telegram bot to report the pig anomalies. In the results, the author configures the system to work in a temperature range of 15 to 25 °C and a humidity of 55 to 75% RH, in which if it is outside these ranges, it will determine whether the window opens or closes.

On the other hand, in the thesis [12], the author indicates that currently, in livestock activities in Ecuador, some parameters are monitored very little, and some processes of cattle care are neglected. In this way, the author proposes an embedded system that allows for the counteracting of the problem. To do this, the temperature is monitored with the HDC1080 sensor that has a precision of 0.2 ° C and positioning through a GPS model NEO-6M-001, which will be used to control the perimeter where the animal is located. These sensors will be controlled by an ESP32, like the thesis

[11], in which a database created in MySQL on the XAMP platform will be used to store the data with the ID of each animal. In the respective tests, the author uses 2 devices on 8 animals of different breeds such as Norman, Holstein, Jersey, in which he defines that the GPS has an efficiency of 98% since the standard error according to the manufacturer with respect to the latitude is 0.211 and with respect to the temperature sensor that worked in ranges of 26 to 30 ° C for 5 hours, makes a comparison with a thermocouple obtaining an error of 7 °C. The author thus concludes that the great variation that occurred in the temperature sensor with the thermocouple is due to various factors such as the body temperature of the animal, location of the sensor, and heat dissipation of the card, among others.

Likewise, the article [13] indicates that today, attention is being paid to research on different environmental impacts on the health of pigs. That is why, in their article, a pig breeding chamber was designed under the control of environmental magnitudes, which divided it into 4 stages such as the main chamber, the air mixing section, the regulation implementation components, and the environmental control platform. As for the air mixing section, the author used it to regulate environmental quantities, such as carbon dioxide (C02), ammonia (NH3), temperature and relative humidity.

On the other hand, in the execution stage of environmental regulation, the ventilation devices, air valves, the air conditioning compressor, the air heating tube and the NH3 electromagnetic valve intervene, in which all these devices are controlled by an S7-200 PLC and a computer. Finally, for this work, they performed 3 tests, including the smoke test for the airflow field and a full and empty chamber test. In which the author concludes that the temperature precision was limited to +- 1°C, the humidity operated in a range of 50 to 80%, the NH3 concentration was limited to +-3x10-6, when the value of NH3 concentration was established at 10x10-6, practically during the 3 weeks of testing the variables and actuators of the device were precisely controlled.

In the thesis [14], the author indicates that when raising pigs, they must go through critical changes in feeding and housing, causing this change to increase mortality. For this reason, the author proposes a design of a mechatronic system for monitoring pigs in the company Alimentos CIA.LTDA in Ecuador, the system uses an SHT10 sensor that when measuring humidity has a precision of +-4.5% and temperature of +-0.5 ° C, an NRF24L01 data transmitter, Arduino ATMEGA 328P, MQ-137 ammonia sensor that works in ranges of 5 to 500 ppm and will serve to determine the gases generated naturally by the decomposition of the plant or animals or waste and to control infrared lamps and industrial curtains, a PLC is applied. In the verification stage of the system, the author determined that the sensors worked with two 1.5V batteries, recommending that the change be made every 100 days so as not to affect the data collected. On the other hand, as regards temperature, it was handled within ranges of 24 to 30 °C and regarding ammonia from 21 to 23 ppm, likewise with humidity from 45 to 80% RH. Finally, the author pointed out that the NRF24L01 wireless transducer works at no more than 60 m, which complies with the characteristics that, according to the manufacturer, mentions. The author of the article [15] indicates that in Serbia, the health of cattle is one of the controversies generated because most of the farmers are engaged in the growth of these animals, and the health of the cattle is closely related to productivity. That is why the author proposes a design to monitor the health of cattle using the technology of the Internet of Things and microservices. The system monitors the heart latitude with the SON1205 model, relative humidity, and temperature with the DHT 22, the position of the cattle by means of an MPU 6050 gyroscope and a Raspberry is used as the main component. Regarding the final tests, the author put some conditionals to generate the conformity of the state of the cattle, which should be 37.7 to 39.2 ° C with respect to temperature.

At the same time, the heart latitude should be in ranges of 100 to 140 beats per minute and respiratory rate of 30 to 60 per minute. In addition, it generates another line where the data is shown as a percentage from 0 to 100% where it is determined that 100% of the cattle have or comply with all the ranges of the parameters already mentioned, in which in the monitoring with 17 cattle the author obtained an average health status of 90%, which is within the allowed range according to the range already mentioned.

In summary, various research works were seen related to the monitoring of pigs cattle, among other species. However, there is not much information related to monitoring the transfer of pigs to the slaughterhouse, which is a very important stage where pig mortality is due to many factors, such as stress and transportation methods, among others. That is why in this article, a prototype is designed that aims to influence the reduction of pig mortality before being benefited; for this, IoT technology and sensors will be applied to control pigs in transport, with the aim of jointly contributing to existing projects that monitor pigs in various areas.

3. Methodology

In this section, each part of the segmentation of the design of the proposed prototype is developed, which through the application of Internet of Things technology seeks to reduce the mortality of pigs before being benefited, for this in this section we will talk about the characteristics of the devices, operation of the hardware and software of the project.

3.1. General System Diagram and Component Description

This section details 2 important points of the proposed system, such as the identification of variables and the operation of the prototype through embedded systems.

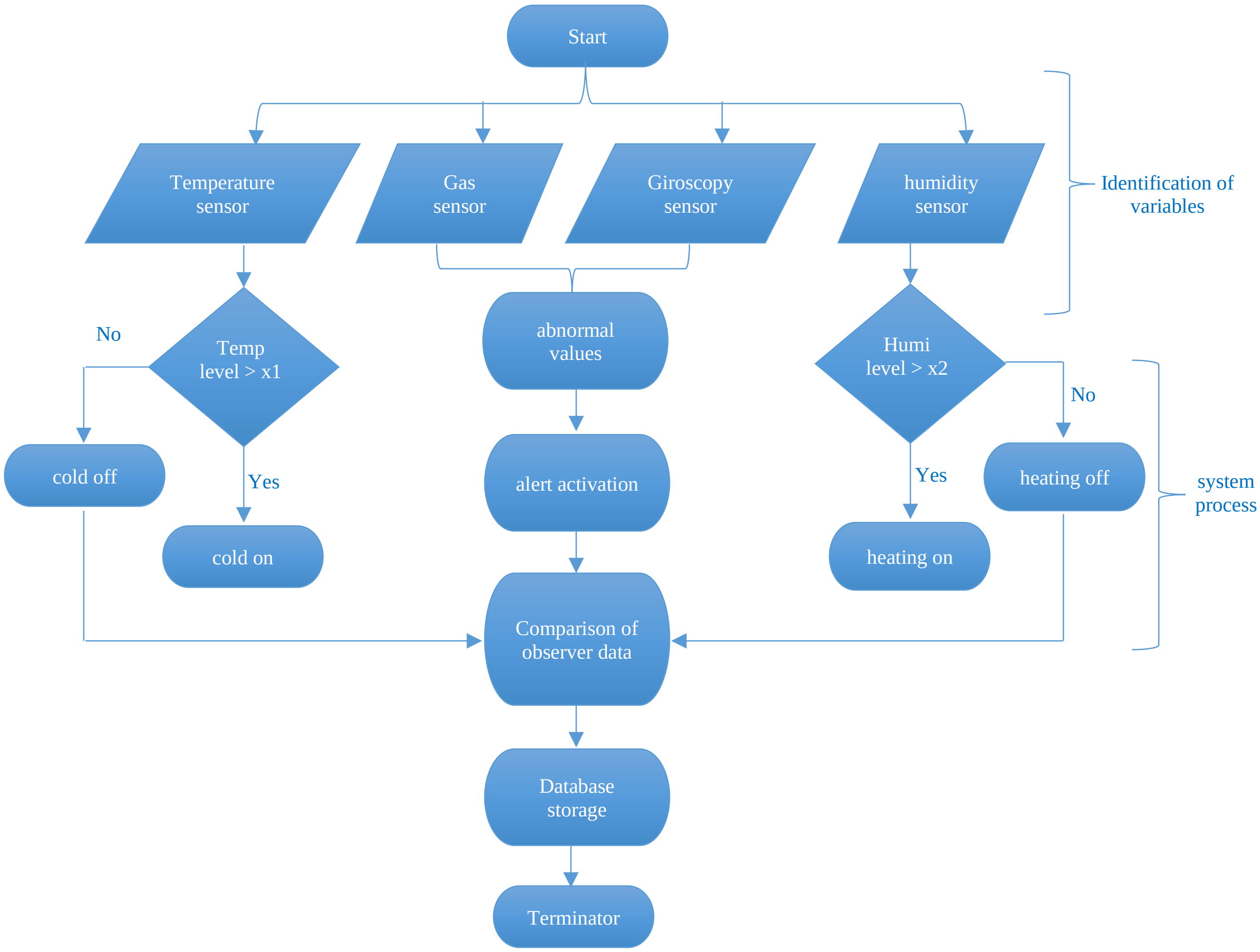


Fig. 1 Flowchart of the embedded system applying IoT for pig tracking

Figure 1 shows the diagram of the proposed system, where the declaration of variables is established as the first point, which is determined by 3 sensors that will read 4 magnitudes such as temperature, humidity, gas and rotation speed. On the other hand, the second part shows the system process, which has 2 conditionals that are related to temperature (X1) and relative humidity (X2) that represent M values that will be programmed according to the age classification of the pig. For example, for a fattening pig, its ideal temperature is in the range of 16 to 20°C, while weaned piglets should remain at 22 to 28°C and suckling piglets in the range of 28 to 31°C [16]. ,[17].

On the other hand, the sensor that will directly monitor the pig with respect to the gas reading and rotation speed will serve to determine the discomfort that the pig may have, for this the data will be processed by a microcontroller that will be sent to the cloud to through an IoT platform where the monitoring of the magnitudes already indicated will be shown in real time. Below, we will proceed to describe in greater detail the 2 relevant points of the flow chart in Figure 1.

3.1.1. Identification of Variables

At this point, the technical data of the electronics of the system that was selected for pig monitoring is detailed, such as the MPU6050, DHT11 and MQ135 sensors.

3.1.2. Accelerometer and Gyroscope Sensors

This sensor is applied to various educational platforms, such as the Arduino ESP32, among other microcontrollers. It is characterized by its inertial measurement unit with 6 degrees of freedom, 3 of them for accelerometers and the remaining 3 axes for the gyroscope. The technical characteristics of this device will be detailed below [18].

Table 1. Characteristic of the MPU6050

Model	**MPU6050**
Power supply	3.3 -5 VDC
Communication protocol	I2C
Accelerometer	+/-2, +/-4, +/-8 y +/-16g
Gyroscope	+/-250, 500, 1000°/s(dps)
Gyro sensitivity	131 LSBs/dps
A/D converter	16 BIT

3.1.3. Temperature and Humidity Sensor

The DHT 11 sensor is an ideal sensor for environmental detection and data recording in various areas of the industry. This device works through a digital signal, one of its characteristics being the accuracy of the sensor with respect to humidity, which is +-4% RH. At the same time, the temperature has an error of +- 2 ° C [19, 20]. It is important to mention that although there is an improved version such as the DHT22 that has an accuracy of +-0.5 ° C and humidity of 2 to 5%, it is not considered a great difference with the application carried out in the present research work, in addition to the fact that being an initial prototype what is sought is the fidelity and effectiveness of the resources of economic and educational devices. Table 2 below shows the characteristics of the DHT11 sensor.

Table 2. Characteristic of the DHT11

Model	DHT11
Humidity	20 - 90 % RH
Temperature	0 - 50ºC
Resolution	0.1°C y 1 % RH
Precision	+/- 2°C y 5%RH
Voltage and Current	5VDC - 2.5mA

3.1.4. Air Quality Sensor

There are several models of the MQ family that are sensors that work under the principle of variation in the contact resistance of the gas to be monitored; however, in the present work, the MQ135 sensor is selected because it reads various toxic gases, unlike other models, its unit in which it works is parts per million (ppm). It can work with analog and digital signals [21]. This device is very commercial and low cost and is also completed with well-known educational platforms such as ESP32, Arduino, and Raspberry Pi, among others. Its characteristics are indicated in greater detail below in Table 3. Finally, these 3 sensors, DHT11, MQ135 and MPU6050, were selected according to the characteristics of the design intended in this research. As mentioned in previous lines, various devices are more precise than those proposed; however, their cost is higher, while these sensors are very economical and, for a first prototype, very reliable. It is worth mentioning that one of the disadvantages of these inexpensive sensors is that they must be kept on for 24 hours before starting to operate to obtain stable and reliable results according to the manufacturer's recommendation. In the same way, with respect to the MPU6050, calibration of the angular velocity and acceleration is also recommended [22].

Table 3. Characteristic of the MQ135

Model	MQ135
Operating voltage and current	5 V DC – 150mA
Reading range	10 a 1000ppm
Operating temperature	-20 a 70°C
Operating humidity	<95%RH
Preheating time	20s
Detect	NH3, CO, CO2, ETC.

3.1.5. System Process

Below in Figure 2 is the block diagram of the prototype proposed in this article, in which the sensors that will monitor the pigs need a device that processes them and then sends the information wirelessly via WIFI to a database to store and record the monitoring of the status of the pigs that will be displayed by a computer or cell phone through an IoT platform in real time.

Figure 2 shows the operation of the established system through block diagrams, in which a closed loop system was created for the process. As a first point, what is sought to be monitored are pigs through sensors, as seen in point (a) where 2 sensors are used that will read the temperature, humidity, acceleration and rotation speed, in which the Sensors will send the data to the ESP32 platform that belongs to point (b), who will be in charge of collecting the data and automating the area where the pigs will be. For this, 2 conditional conditions, as shown in Figure 1, were considered, one of which is temperature (X1). and humidity (X2). Next, Table 4 shows the temperature and humidity conditions established to turn on the air conditioning system (e), according to the stage of pig development [23, 24].

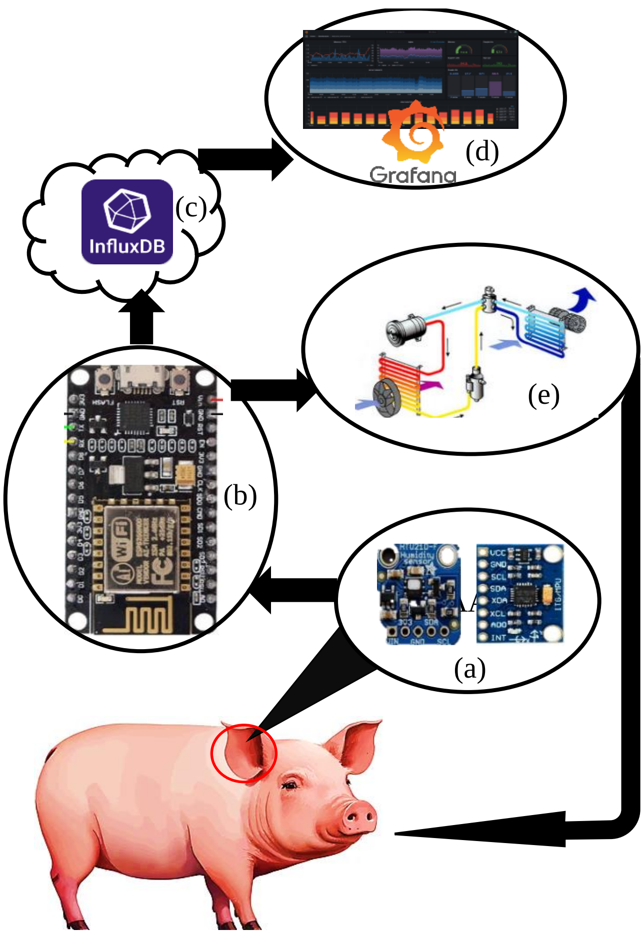


Fig. 2 Block diagram of the integrated system

Table 4. Conditions for turning on and off the air conditioning system according to the classification of pigs

List	Temperature	humidity	heating	cooler
Suckling piglet	< 28 °C	> 60 %	ON	OFF
	> 31 °C	< 60 %	OFF	ON
Weaned piglet	<22 °C	> 70 %	ON	OFF
	>28 °C	< 70 %	OFF	ON
Fattening pig	<16 °C	> 80 %	ON	OFF
	>20 °C	< 80 %	OFF	ON

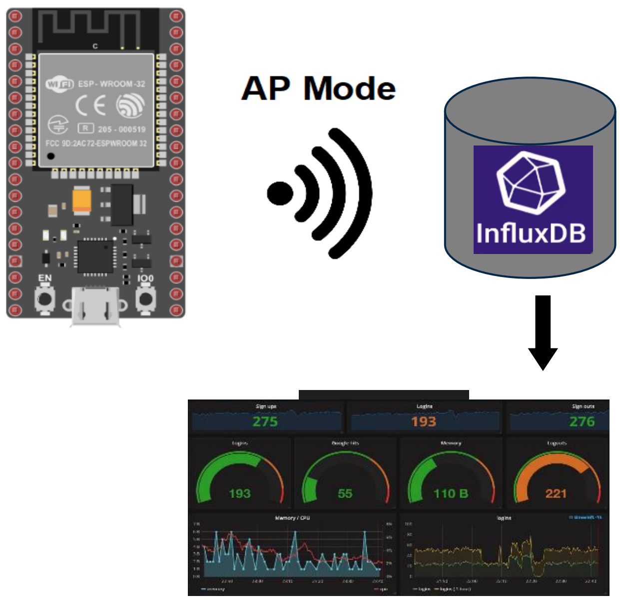


Fig. 3 Communication of the ESP32 in the cloud

After the ESP32 collects the data from the sensors, it will automatically send the information wirelessly to the Influx DB database shown in point (c), which unlike other databases in its free version allows storing and retrieving records in real time and can also be linked to various platforms such as Python, Arduino IDE, GO, Java. In the present design to collect data from the sensors, the ARDUINO IDE and INFLUXDB platforms are used to share the monitored data on the GRAFANA platform, which is an Internet of Things environment as shown in point (d), in which it will provide the statistical tables and timeline of each magnitude to be monitored by the pig, it is worth mentioning that GRAFANA has several additional functions that differentiate it from other environments such as Cayenne and Think speak, which are also limited free environments, which is why later we will talk in detail about the functions provided by GRAFANA [25]. Below, in Figure 3, the communication of the ESP32 with the database is shown more clearly, applying what is the Internet of Things [26].

Finally, Figure 4 shows the different options offered by GRAFANA for monitoring pigs. To do this, point 1 indicates that the proposed system has a user ID and password for each driver or person in charge of the vehicle that transports the pig. Then, point 2 shows the option to change the resolution of the date and time of the monitoring, in which through this option you can see the previous days of system monitoring thanks to the storage options available with the Influx DB database and Grafana. On the other hand, points 3,4,5 show the process of exporting data in an Excel table, which will help to have better control of the entire litter of pigs before being slaughtered, thus determining the percentage of pigs that were affected by various anomalies, depending on the monitoring period or day [27].

Fig. 4 Steps to configure graphs and export system data in GRAFANA software

4. Results and Discussion

4.1. Results

At this stage, the results obtained in the implementation process of the prototype of the embedded system are mentioned, in which the following simulation tests were carried out both at the hardware and software levels. At the software level, Fritzing was used to simulate the entire system, as shown in Figure 5.

After the simulation in the software, the prototype devices were implemented on a breadboard and tested together with a 5V linear power supply as can be seen in Figure 6, to verify the operation of the sensors and avoid breakdowns prior to assembly.

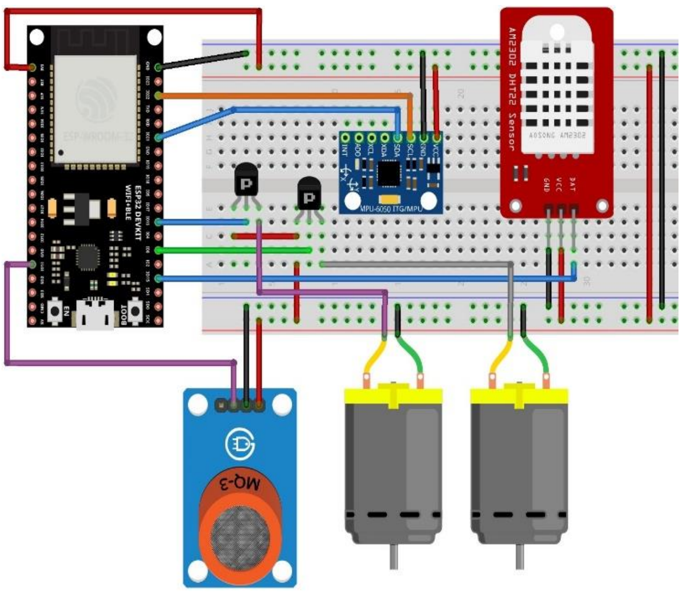


Fig. 5 System simulation in Fritzing

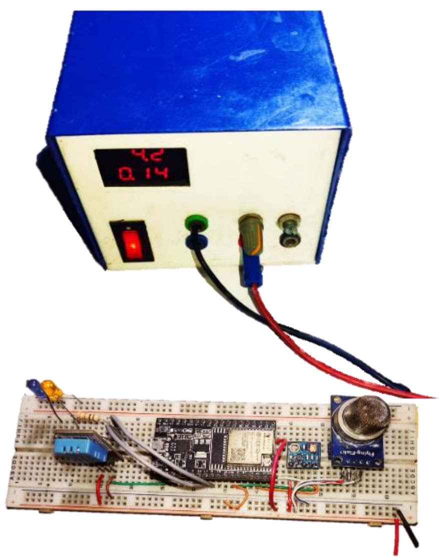


Fig. 6 Hardware simulation of the proposed system

Likewise, the communication of the ESP32 and the sensors was also verified through the ARDUINO IDE software as seen in Figure 7, where it is verified that the various sensor variables detect the magnitudes correctly, in the same way, it happens with the communication of the ESP32 to the router through WIFI wireless communication.

Figure 8 shows the design of the proposed prototype for pig monitoring, in which the system in Figure 6 will be installed in a bell-type collar to acquire data from each pig, and then send it to the cloud and be processed through a phone or tablet, with the help of GRAFANA software. It should be noted that it was considered to apply the collar as a prototype since it is a good location to generate favourable readings in terms of tracking the pig when it is transferred to the stall.

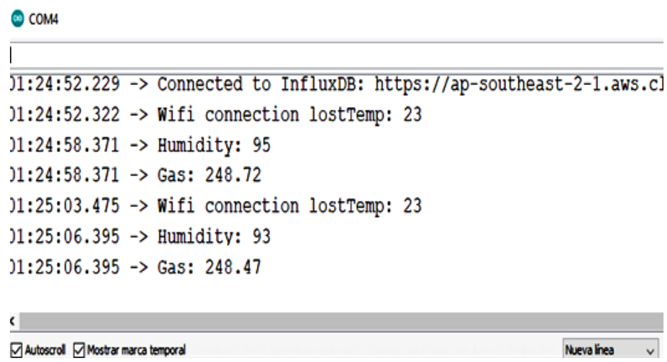


Fig. 7 Verification of sensor communication through the ARDUINO IDE platform

Fig. 8 Design of the prototype for pig monitoring

Fig. 9 C02, Temperature and humidity pattern X-CO2-1

A comparison was made of the temperature and humidity sensor data in the laboratory to perform the sensor efficiency test. For this, an X-CO2-1 device was used as a standard that detects temperature, humidity and CO2 shown in Figure 9, in which it has a precision of +- 0.5°C and with respect to humidity +-3% and with CO2, it has +-50ppm.

Table 5. The final result of the proposed integrated system for pig monitoring

Embedded system	Resulted
Hours of operation	168h
System power	5VDC - 1A
Temperature reading	25°C – 32°C
Humidity reading	75 - 85%
Carbon dioxide sensor reading	500 – 710ppm

Table 6. CO2 monitoring of the proposed prototype

CO2 (PPM)		
True value	**Middle value**	**Absolut mistake**
706	706	0
705	710	5
600	605	5
650	650	0
690	695	5
700	700	0

Subsequently, prior to the evaluation and comparison of the sensor data with the standard, the stability of the sensors of the proposed system was verified by keeping them on for 24 hours to obtain a correct reading, as indicated by the manufacturer. Table 5 below shows the general results of the monitoring during the 1-week test period in the laboratory with 2 piglets of 8 and 12 kg.

As can be seen, Table 6 indicates the monitoring of the MQ 135 sensor (10ppm- 1000ppm), which is responsible for generating readings of various gases but particularly CO2 [26], in whose comparison with the pattern in Figure 9, got a relative error no more than 5 PPM.

Figure 10 shows the timeline of monitoring of approximately 5h of the reading of the MQ135 sensor and the pattern mentioned in Figure 9, in which in the range of 14:30 hours it can be observed that at the lowest point, a reading of 600ppm is obtained with respect to the MQ135 and the pattern had a reading of 605ppm, in addition to the highest peak obtained at the beginning of 12:30 hours with 706 ppm, in which it is confirmed that the effectiveness of the devices in the verification is 95%.

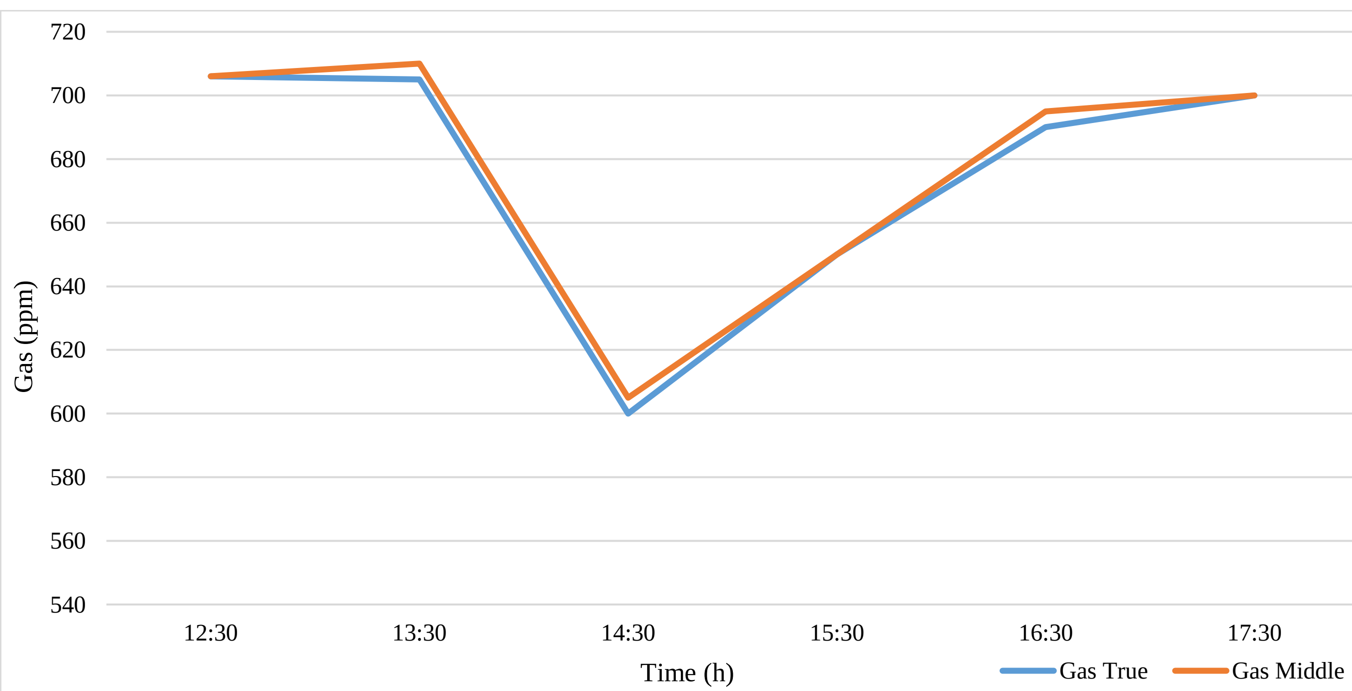


Fig. 10 Timeline of CO2 gas monitoring and X-CO2-1 pattern

Table 7. Monitoring of the temperature and humidity of the proposed prototype

Temperature (°C)			Ambient humidity (%)		
True value	**Middle value**	**Absolut mistake**	**True value**	**Middle value**	**Absolut mistake**
23	23	0	77	80	3
22	23	1	77	80	3
22	24	2	79	79	0
21	21	0	79	79	0
21	22	1	80	80	0
22	23	1	83	82	1
21	23	2	83	82	1
21	21	0	82	82	0

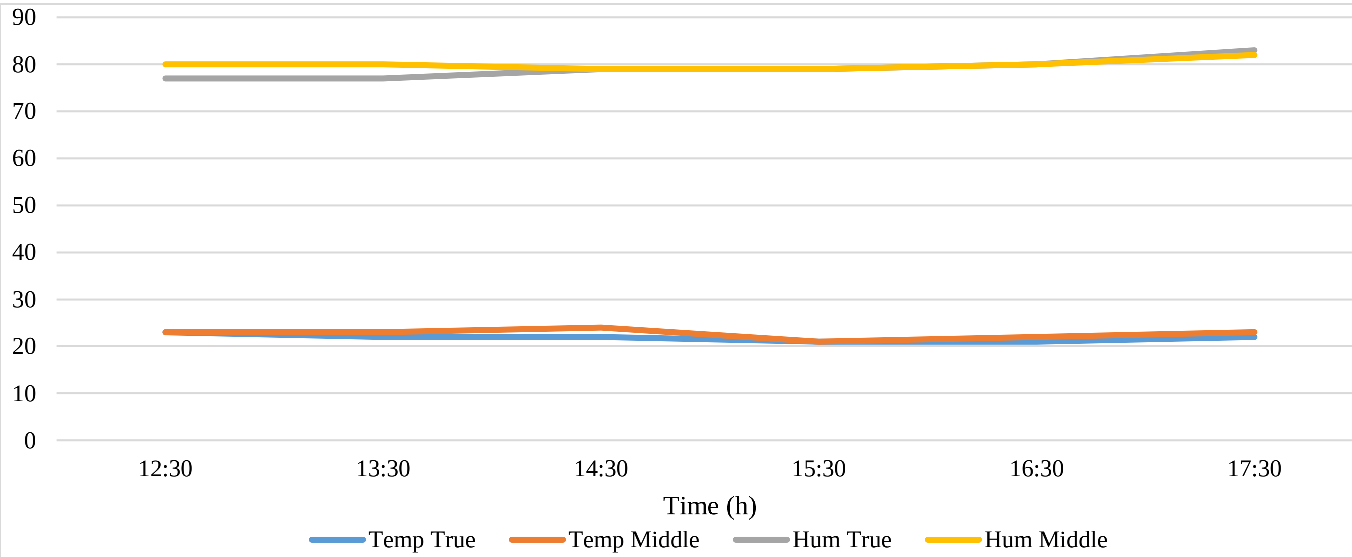
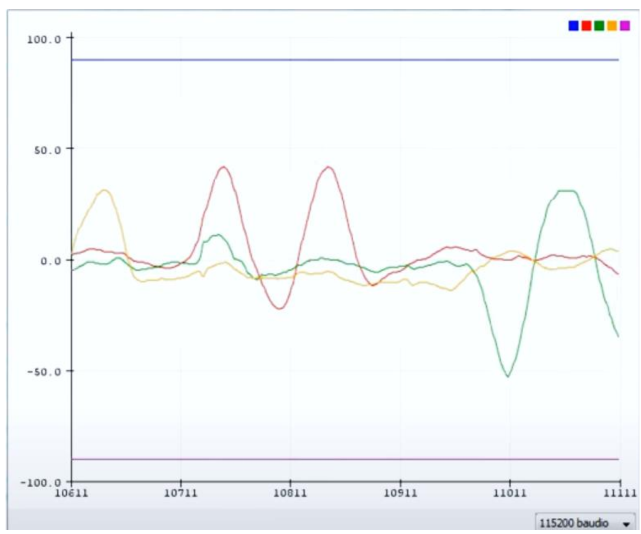


Fig. 11 Temperature and humidity monitoring timeline and X-CO2-1 pattern

Table 7 shows the comparison of the DHT11 sensor (temperature and humidity) and the AX-CO2-1 pattern, where good efficiency of the proposed sensor was obtained, resulting in a relative error no greater than 2°C and 3%. humidity.

Figure 11 shows the timeline of the data shown in Table 7, where greater stability of temperature and humidity is observed. Regarding temperature, its minimum range of 21°C with the DHT11 sensor is expressed in the time slot from 2:30 p.m. to 4:30 p.m., while the AX-CO2-1 pattern generates an average reading of 22°C. Now, the minimum humidity is obtained in the time slot from 12:30 to 2:30 p.m. with a reading of 77% RH, unlike the AX-CO2-1 pattern which generates a reading of 80%, in which it is concluded that the precision is maintained according to the technical data of the DHT11 described in Table 2, which is no greater than +-2°C and 5% RH. Now regarding the gyroscope, during the calibration process the MPU6050 sensor remains in its normal operation, so when programming on the esp32 platform the offsets are read. Likewise, to program on the Arduino Ide platform, the angular velocity and acceleration values are identified through 3 variables such as X (red), Y (green), and Z (orange), which determine the movement of the pig, as we can see in Figure 12.



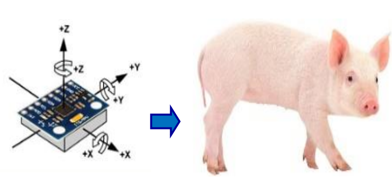


Fig. 12 Simulation of the MPU6050 Gyroscope in ARDUINO IDE

Table 8. Necessary surface area according to pig classification

Classification	Surface (m^2)
Suckling pig	0.10 -0.20
Sparrow pig	0.20 -0.40
Pig	1.50 -3.0

Finally, another aspect that must be considered for the correct monitoring of pigs, apart from the magnitudes of the sensors and the use of IoT technology, is the area in which the pigs are located at the time of being moved since the objective is to ensure that the pigs move as comfortably as possible.

To this end, Table 8 shows the area that the pig must maintain according to the classification. It is worth mentioning that these data were obtained according to a brief survey of 20 farmers to obtain their point of view on the system and the data required in Table 8.

Where Figure 13 determines the statistical graphs of the results obtained by the survey of suckling piglets with 70% reflected in 0.10 to 0.2 m2, while for the cochineal the selection was 75% in a range of 0.20 to 0.40; finally with pigs it was very controversial reaching 50% of the votes with a dimension of 1.5 to 3m.

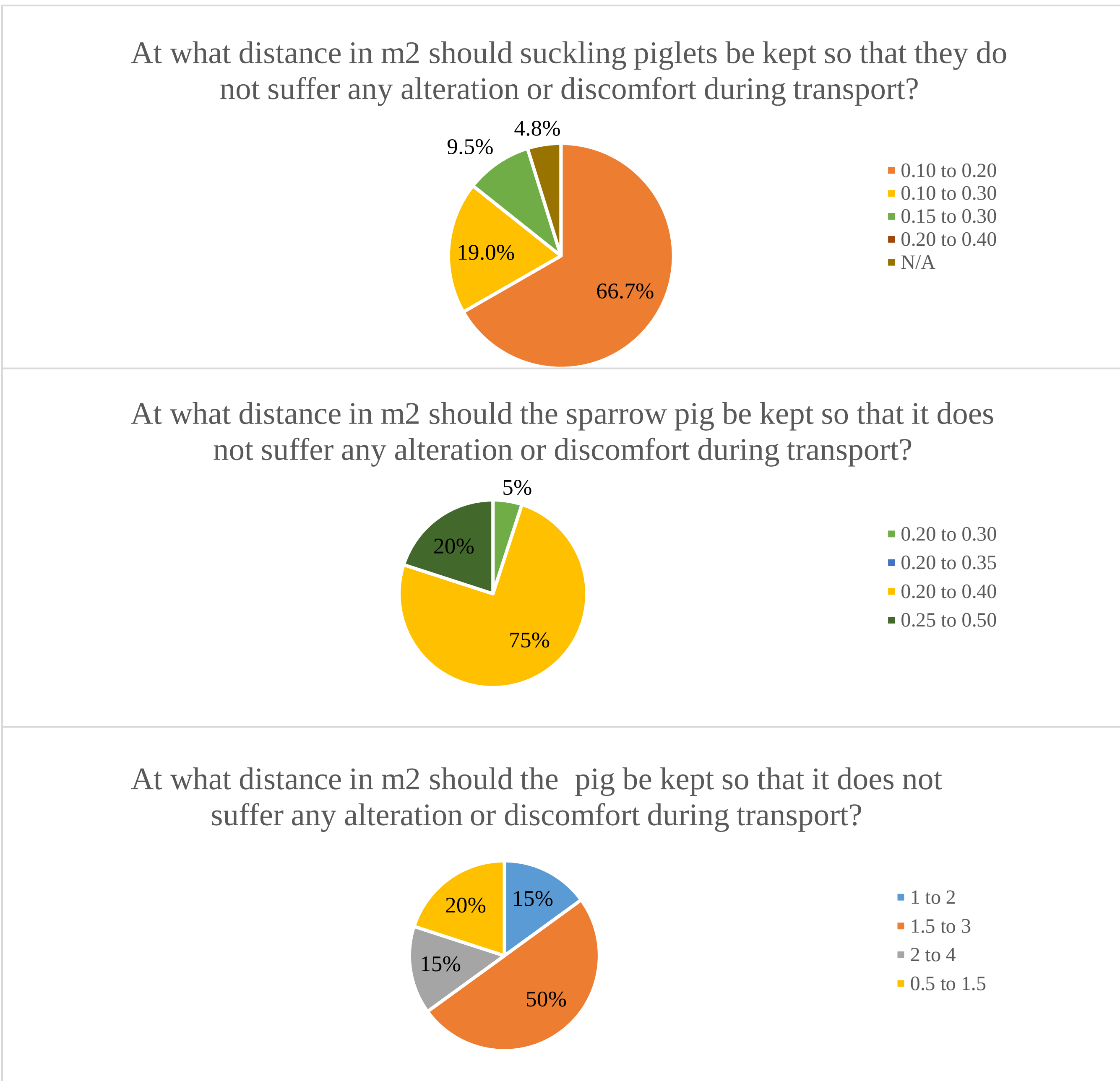


Fig. 13 Survey for final research adjustments

Fig. 14 Operational tests of the system embedded in the GRAFANA platform

After verifying the operation of the sensors and obtaining favourable results, we proceeded to verify the operation of the GRAFANA platform, in which the statistical graphs of the monitoring of the embedded system are shown in greater detail in Figure 14. Likewise, it was determined that the sending of data from the ESP32 platform to the INFLUX DB and GRAFANA database is no longer than 5 seconds, concluding that the platform responds correctly as it is free software. Likewise, the options offered by GRAFANA, as shown in Figure 4, were reviewed to export the data and daily reports when moving the pigs.

4.2. Discussion

The present work seeks to monitor pigs to reduce pig mortality through an embedded system applying IoT technologies. This project aims to reduce economic losses on farms, using educational technologies that are not as expensive compared to others as shared by the author of the article [10] and [11], which also seeks to contribute to the monitoring of pigs, cattle, among other species in its locality. However, the author of these already mentioned articles, especially [11], uses limited platforms such as Arduino and communication systems such as Bluetooth for data processing, while in this article it is proposed to use an ESP32 platform that provides wireless communication through of WIFI, which generates ease of work through a free database and a control panel applying IoT. On the other hand, it is observed that the author of the thesis [12] applies educational, technological devices such as the ESP32, Raspberry pi and a DHT22 sensor to monitor pigs in Cartagena, in which he uses the Telegram platform to monitor through messaging in the cloud; however, it is considered that there are better application options that could provide us with greater detail of the monitoring we want to perform, such as Cayenne, Thinkspeak, Grafana among others. That is why one of the options chosen in this article is Grafana, which offers us various options such as a variety of graphics, data export, regular date and time resolutions, and database linking, among others.

Furthermore, performing the respective communication tests, Grafana provided a very favorable response time, taking a maximum of 5s to process the data, while in the tests with Thinkpeak and Cayenne, there was an extension of 10 to 15 seconds, in which it demonstrated that Grafana is the best option to be able to monitor the proposed embedded prototype in real time. Likewise, it is observed that in the thesis [13] the author indicates that he did not have good results when comparing his temperature sensor and a thermocouple, obtaining an error of 7°C, in which it is considered that he did not verify the Stabilization of the sensor, According to the manufacturer, it is recommended to keep the device on for 24 hours to have a correct reading, which is why this article analyzes the reading of the DHT 11 sensor, where it is verified using the X - CO_2 - 1 pattern shown in Figure 9, obtaining a favorable result no greater than an error of 2°C, the same occurs with respect to the use of the MQ135 sensor that monitors various gases obtaining an error no greater than 5ppm with respect to CO_2 monitoring obtaining effectiveness of 95%. Although it is true that the author of the research [14], [15] uses industrial devices such as a PLC controller to control his system, I consider that it would be an alternative as future work for this article, since if we wanted to control larger areas with more precise devices, it would be a good option to use PLC, that is why on this occasion the ESP32 platform was used because it is considered prudent that to monitor and control air conditioning signals it would be the most appropriate, in addition to the study area where you want to apply There is transportation, which is a very small area. Likewise, it was also decided to use an ESP32 wireless transmitter and not NRF24L01 like the one in the work [15] because when monitoring data in a small space such as transportation, it does not merit the use of these transmitters, which would serve in open fields.

5. Conclusion

Finally, the proposed system is verified using a temperature, humidity and CO2 pattern of the AX-CO2-1 model, obtaining an absolute error of +-2 °C in temperature, +- 3%RH humidity and 5ppm in toxic gases, as observed in tables 7 and 8 where it shows the monitoring that was carried out in the laboratory. Likewise, with respect to the simulation of the air conditioning, the activation of the signal of the conditionals that was set with respect to the variables X1 and X2 that relate the temperature and humidity that must be maintained for the pig according to its classification is verified by means of LED indicators in Table 4.

It is worth mentioning that, as it is an initial work, commercial and economic sensors are applied to determine the efficiency of these sensors and, in the future, to change them for one with greater precision. Regarding the communication of the ESP32 to the INFLUX DB database, it is assumed that the response time of the sensor monitoring was within a range of 5s per reading, in the same way with respect to the GRAFANA IoT platform, it is verified that the functions that this platform offers for free are very useful because it provides independent graphics and statistical reports for each magnitude measured in the proposed prototype. In addition, with respect to the tests carried out, it is verified that sensors such as the MQ 135 toxic gas sensor and the gyroscope must be calibrated prior to the evaluation of the pig to have a correct reading of the sensors, in the same way, they must be kept on for 24 hours prior to their operation as mentioned by the manufacturer. Now, with respect to the ESP32, if you wanted to amplify the WIFI communication, it would be advisable to add a 10 dB antenna to amplify the signal and avoid interference depending on the work area to be applied. On the other hand, regarding the structure of the prototype shown in Figure 8, it is estimated that the system should be installed in a bell-type collar, and this is determined since in article [12] the author through a collar had good responses from his sensors, and that is why as a first prototype it was evaluated through that system.

As future work, we seek to massify the project by including IP cameras and thermal images to monitor pigs with greater precision, additionally adding sensors with greater precision if we want to monitor temperature and humidity in greater detail, also using the database and artificial intelligence to make predictions to prevent deaths due to stress in pigs. Regarding the application, what is sought in this article is that it can be applied in various areas of the food industry since mortality due to stress in pigs does not only occur when they are transferred to the slaughterhouse. Finally, it is concluded that the embedded system works correctly, obtaining an effectiveness of 95% compared to the AX-C02-1 pattern used in the various tests shown in Table 5, 6 and 7, in which it is observed in more detail on the GRAFANA platform in Figure 14.

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