Design of Software and Hardware for Feed Dosing in Swine

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ABSTRACT: This research project proposes the development of a semi-automatic computerized system to control the supply of concentrated feed in pig farms. The system consists of software with an accessible interface and hardware that will distribute the appropriate amount of food to pigs through logical instructions.

The research is aimed at pig farmers and small to medium-sized businesses in the sector that need to implement a low-cost semi-automatic system for food distribution. This system adapts to the different developmental stages of pigs, adjusting the amount of food per pen as necessary.

Unlike existing devices in the international market, which have high costs, this system is designed as a more economical and efficient alternative. Its main objective is to reduce the waste of concentrated feed, which translates into savings for the pig farmer and promotes farm growth.

The system will automate pig feeding processes, dispensing concentrated feed in appropriate quantities. Additionally, it will generate detailed reports on food consumption per animal or pen, the number of sacks used in specific periods, and allow the farm manager to calculate expenses per fed pig and evaluate whether the expected production goals have been achieved.

This project seeks to offer an innovative and accessible solution to optimize feeding in pig farms, improving efficiency and profitability in the sector.

KEY WARDS: semi-automatic computerized system, pig feeding, Software and Hardware

I. INTRODUCTION

Through this research project, we aim to control the supply of concentrated feed using a semi-automatic computerized system. Software with an affordable interface and hardware will be developed. A machine will be built that communicates with the software so that, through logical instructions, it can distribute the appropriate amount of food to a group of pigs.

This research is aimed at pig farmers and small to medium-sized pig farming businesses that need to implement a low-cost semi-automatic system for distributing food to each pen depending on the developmental stage of a herd of pigs.

Existing devices manufactured in Canada, Argentina, and the United States have a very high cost. Therefore, the system to be designed will be more economical and will provide better services. The purpose of this system is to avoid wasting concentrated feed and thus save money for the pig farmer and promote farm growth.

The software and hardware will automate processes related to pig feeding. The system will dispense concentrated feed in appropriate quantities, generate reports that will allow the user to know the amount of feed consumed per animal or per pen, as well as the number of sacks consumed over a specific period. The pig farmer or farm manager will obtain reports and calculate their expenditure per fed pig, verifying if the animals achieved the expected results.

The article is structured in several sections: first, a contextualization of the problem and its justification; second, the theoretical foundations including topics such as pig feeding, developmental stages, semi-automatic systems, electronics, and a literature review on pig production; third, the methodological approach; fourth, the development of the research project; and finally, the conclusions.

II. LITERATURE REVIEW

Pigs grow in more intensive farming conditions than cattle and sheep; and they are the animals that produce the most meat per square meter. In Colombia, according to Siza et al., "pig farming at the national level is in an evolutionary process that requires advice, resources, technology, and publicity to stimulate productive activity and promote consumption". [1]

On the other hand, in Colombia, according to the 2020 National Livestock Census developed by the Colombian Agricultural Institute (ICA), there are 6,710,666 pigs, of which 61% are animals from technified farms and the remaining 39% are backyard animals. 68.7% of the total pig population in the country is concentrated in six departments: Antioquia (29.8%), Valle del Cauca (13.9%), Cundinamarca (9.2%), Córdoba (6.3%), Meta (5.0%), and Bolívar (4.5%) [2]

Based on the above, many farms in Colombia are dedicated to raising and producing meat pigs for sale and slaughter. In their pig units, they classify their animals depending on their stage of development. In some of them, especially in non-technified productions, the feeding of their animals is done manually, where disorder is observed, which implies food waste, animal diseases, and likewise, loss of money.

This means that the official in charge of carrying out the feeding task does not calculate the exact proportion, as they use a very rudimentary method for this task, placing the food in a plastic container without any exact measurement. They distribute the concentrated feed by pouring it into the feeder at their discretion, without considering the number of animals, the appropriate quantity, etc. This results in diseases and stress for the animals, and consequently, when this procedure is carried out, the expected purposes such as weight gain and pig development are not met.

In Figure 1, the operator can be observed pouring food without measuring the amount of food that the animals should consume, taking their stage of development as a reference.

Figure 1: Operator pouring feed to animals

Any organism that is well-fed and in adequate body condition is more resistant to the action of parasites and other pathogens that constantly threaten to cause disease; and therefore, an animal that does not have these conditions will be more vulnerable and prone to illness.

A healthy animal is one that maintains a balance between the functions that allow it to express optimal production within a given environment, while a sick one gradually loses or diminishes its productive potential. In relation to this, Quiles and Hevia state that "voluntary consumption or appetite in pigs is determined by nutrient needs, which significantly affects the level of production." [3, p. 15]

Following this, pigs should consume a balanced diet proportional to their stage of development. The lack of this can cause problems in the urinary system, which could lead to reproductive issues, growth and development problems, and failure to obtain a good quality animal for sale and slaughter. Therefore, the following research question arises: How can the control of concentrated feed supply to pigs on pig farms be improved?

Information technologies constitute one of the fundamental pillars that drive business competitiveness, serving as a foundation for the innovation of products, processes, and services through the application of the latest scientific and technological advances. Consequently, the agricultural sector must remain at the forefront in the development, implementation, and deployment of software implementing information and communication technologies (ICT), as Bernal-Jiménez and Rodríguez Ibarra state, "it has become an excellent tool that allows companies to generate added value to operational activities, seeking to offer business advantages to consolidate in a global market" [4]

On the other hand, regarding semi-automatic systems and process automation in the area to be investigated, it cannot be stated that companies or some universities are developing a system with the same characteristics as the one intended to be shown in the following article. However, for the development of the system, a programmable logic controller was used, which according to Cegelski et al. "is a digital device used for the control of machines and process operations. It is an electronic board with a programmable memory for storing instructions, allowing the implementation of specific functions such as: logic, sequences, timing, counting, arithmetic, etc. with the aim of controlling said machines and processes. [5]

Next, a brief description of the resources used will be made. First, the RS-232C Serial Port, which is a standard for serial communication data transmission. It is used to connect computers and peripheral devices to

allow serial data exchange. Among its main characteristics is that they perform asynchronous communication, point-to-point communication, and are typically used for low-speed and short-distance communication. [6]

A Microcontroller is also used, which for Ayala is a small computer on a single integrated circuit, containing a processor, memory, and programmable input/output peripherals; its main uses are for Embedded Systems, Automation, Control Systems; among its main characteristics are Low energy consumption, Real-time operation, and it is cost-effective for single-purpose applications. [7] For the specific case of this project, the PIC16F84 was used, whose characteristics are: 8-bit microcontroller, 1K words of program memory, 68 bytes of data memory, and it has 13 I/O pins. [8]

Additionally, a sensor was used which detects and responds to some type of input from the physical environment; its main uses are to measure physical quantities, monitor environmental conditions, and provide input for control systems. Among its characteristics are that it converts physical parameters into electrical signals, can be analog or digital, and currently there are various types, for example, temperature, pressure, proximity, among others. [9]

For their part, actuators or stepper motors are components that convert energy into motion. A stepper motor is a type of electric motor that divides a complete rotation into a series of equal steps, mainly used for precise positioning, speed control, robotics, automation, among others. Its characteristics are high torque at low speeds, precise positioning and repeatability, and possible open-loop control. [10]

On the other hand, and no less important is the animal feed dispenser that is responsible for distributing measured amounts of food to animals, with the purpose of ensuring precise portions of food and being an automated feeding system, it is intended to be programmable for timed feeding including the sensors and microcontrollers mentioned above.

Another aspect to consider is that each pig farmer must have a feeding program, for this they must use the concentrated feed of their choice, but in the appropriate proportions and quantities for each stage of life of the pigs, which is why the table 1 indicating Feed consumption and expected results in pig breeding was adapted from the Merck manual. [11]

Table I. Feed consumption and expected results in pig breeding adapted from the Merck manual.

Food Used	Week	Weekly consumption KG	Consumption per day Kg	Initial weight Kg	Final weight Kg	Week Gain KG
Preinitiation	1	0,8	0,114	6	6,5	0,5
	2	1,8	0,257	6,5	9	2,5
	3	2,9	0,414	9	12	3
	4	4,49	0,641	12	15,6	3,6
	End	9,99	0,357	15,6	15,6	9,6
Initiation	5	5,65	0,87	15,6	19,4	3,8
	6	7,5	1,071	19,4	23,4	4
	7	8	1,143	23,4	27,6	4,2
	End	21,15	1,028	27,6	27,6	12
Levante	8	8,8	1,257	27,6	32	4,4
	9	9,5	1,357	32	36,6	4,6
	10	10,5	1,500	36,6	41,4	4,8
	11	11,4	1,629	41,4	46,4	5
	12	12,5	1,786	46,4	51,6	5,2
	End	52,7	1,506	51,6	51,6	24
Priming	13	12,60	1,800	51,6	56,8	5,2
	14	13,50	1,929	56,8	62,3	5,5
	15	14,50	2,071	62,3	68,20	5,9
	16	15,80	2,257	68,2	74,50	6,3
	17	16,90	2,414	74,5	81,20	6,7
	18	18,00	2,571	81,2	88,30	7,1
	19	19,80	2,829	88,3	96,00	7,7
	20	22,00	3,143	96	102,00	6
	End	133,1	3,8028	102,00	102	50,4

As mentioned above, this table refers to the amount of feed to be fed to the animals depending on their stage of development; however, there are several kinds of agricultural by-products and residues of human food, which can be used for pig breeding, but their content varies, and there is no data to recognize and calculate the true nutritional value and the amount of the components, so it is recommended to balance the ration, using concentrated feed.

III. METHODOLOGY

The project considers the quantity of production and the quality of the data obtained with respect to pig feeding and the semi-automatic computerized system. Due to these requirements, the research to be used will be of a quantitative-qualitative type. Therefore, "quantitative research can begin where qualitative research ends, when the latter, as a result of its application and development, proposes hypotheses more amenable to measurement in order to know the nature of the phenomenon with greater precision and thus have a comprehensive understanding of it." [12]

In this sense, the approach to be applied is the empirical-analytical one, which is based on any fact, situation, or phenomenon, whether produced by chance or casually, that represents an experience within the everyday. This approach tends to separate the study focus and the methods to be used, it has an instrumental objective, a study object is chosen, it is delimited, explained, interviews are conducted, and finally results are obtained.

This research is applied since one of the main purposes of the project is to develop a semi-automatic computerized system as a new technology of an applicative nature.

Quasi-experimental designs deliberately manipulate at least one independent variable to see its effect on one or more dependent variables. They only differ from true experiments in the degree of security or reliability that can be had on the initial equivalence of the groups. In these designs, individuals are not randomly assigned to groups, but rather these groups were already formed before the experiment; they are intact groups. The reason why it suggests how they were formed has nothing to do with the experiment. Two groups are used, of which one is the system to be designed using an electronic interface (hardware) and a data acquisition system (software), and the other is the traditional system used for food dosing on the Farm.

Regarding the development model or life cycle to be used, it is the Incremental Model since it is "a software development approach that combines elements of the waterfall model with the iterative philosophy of prototype creation" [13]

Figure 2 exemplifies the Incremental Model, which has an interactive nature because at the end of each increment, a fully operational product is delivered.
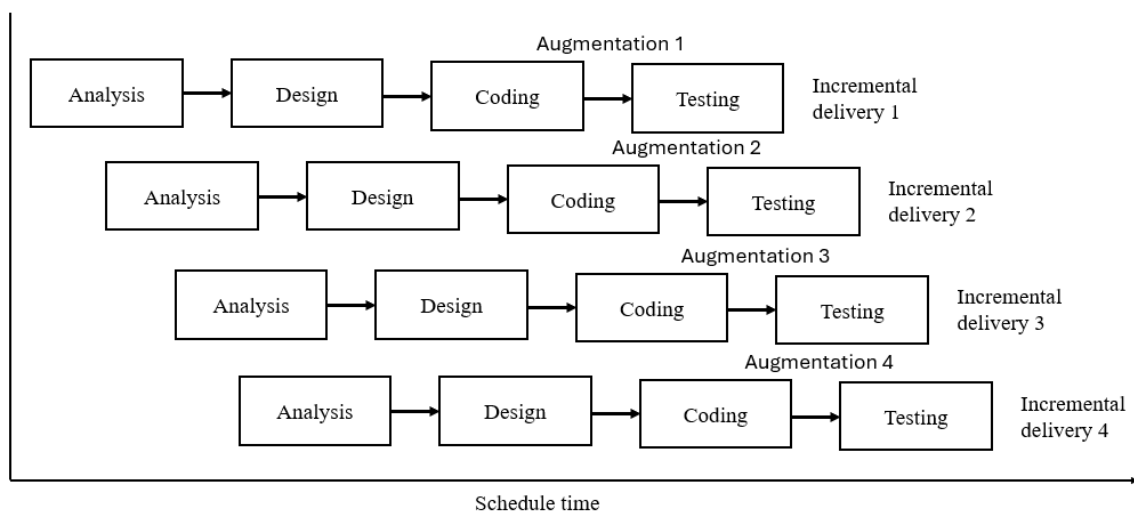

Figure 2: Incremental model adapted from Pressman [13]

In a generic view, the process is divided into 4 parts: Analysis, Design, Code, and Test. However, for Software production, the principle of pipeline work is used, utilized in many other forms of programming. This keeps the client in constant contact with the results obtained in each increment.

IV. RESULTS AND DISCUSSIONS

Functional Requirements

For the construction of the software, information was gathered based on observations, interviews with experts and farm operators. Among the most relevant functional requirements extracted were:

- Dose and pour the amount of food in real time
- Issue an alert in the absence of food
- Know the reports of changes generated in the system
- Personnel management
- Farm management
- Animal management
  o Know the stage the animals are in
  o Duration of each stage
  o Ration calculation

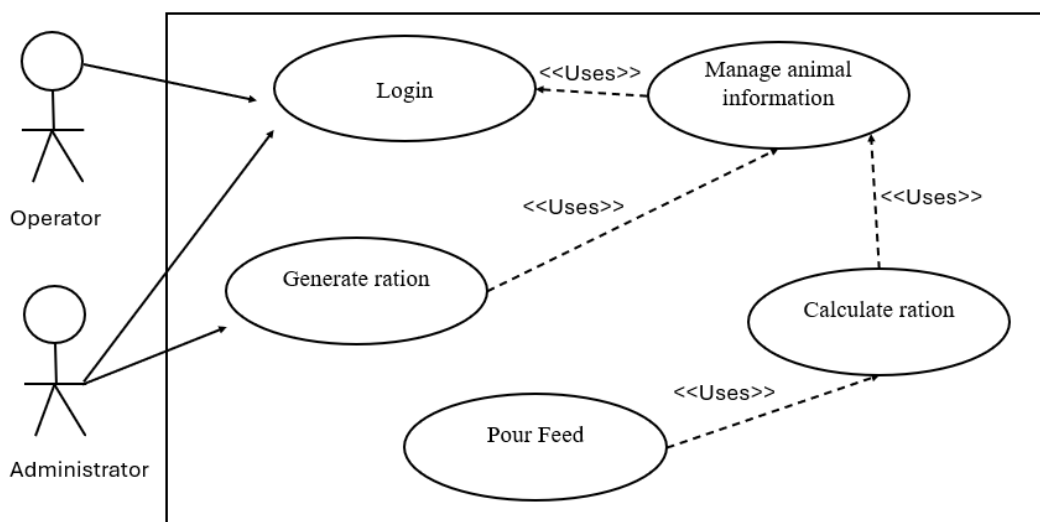Based on the above, the following use case diagram for the system resulted, which can be visualized in Figure 3.

Figure 3: Use case diagram

Modular Design

- User Module: In this module, the user will be able to access the system.

· User
- Login (Username)
- Password
- User Level

- Animal Module: This module will handle the main data of the animal such as: General data of the sow, births, species, mortality, animal weight, development stage, among others.

· Animal
- General data
- Births
- Species
- Causes of death
- Birth weight
- Weaning weight

- Date of entry to development stage
- End date of the development stage
- Daily consumption by development stage
- Weekly consumption by development stage

- Dispenser Module: This module will manage the food to be consumed by the animals, pouring it into a feeder.

· Dispenser
- Manage food
- Time interval to supply food
- Amount to dose
- Pour concentrated food into feeder

- Reports Module: This module is exclusive to the administrator, which will allow them to visualize the information handled in the database, in a complete and organized manner, either in paper print or on screen.

· Reports
- Inventory Report
- Cage Report
- Animal Report
- Dosing Report
  Daily concentrated feed consumption
  Weekly concentrated feed consumption
  Monthly concentrated feed consumption
- Mortality Report
- Birth Report
- Weight Report
- People Report

- Help Module: Displays on screen each of the forms and functions that allow the User support assistance about the system.

· Help
- Content
- About

Block Diagram

Figure 4 presents the block diagram which allows interpreting the handling that the dispenser will have, with its electronic components and their respective relationships.
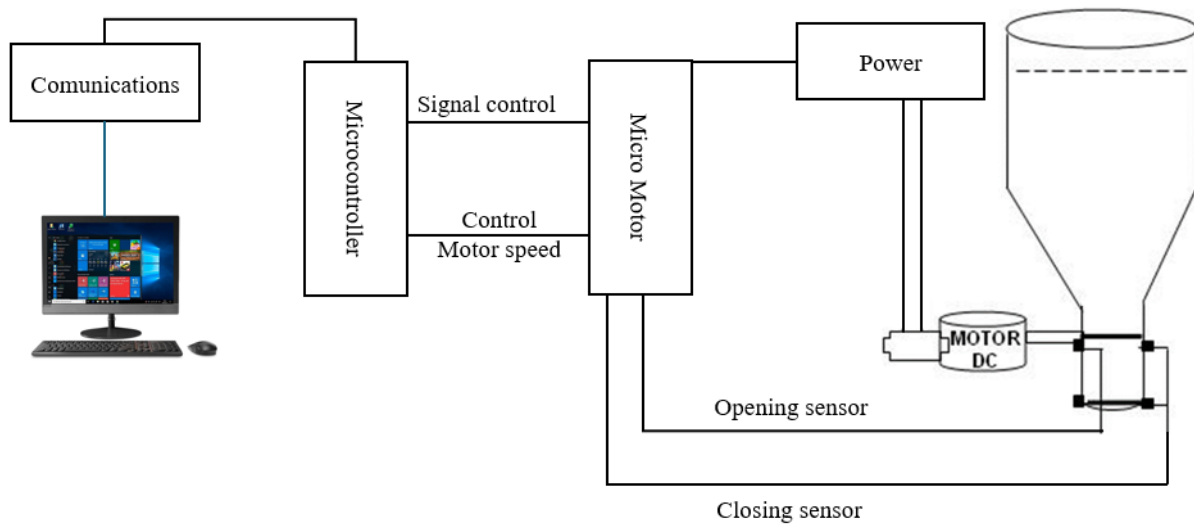
Figure 4: Block Diagram

Design Transmission Interface and Electronics

An interface is a device that allows the interaction of a computer with the external environment. In it, different electronic components are identified in which the microcontrollers stand out, performing the logic function that, combined with the power stage, control the number of turns that the motor must make to calculate the amount of concentrated feed to be dosed.

The mechanical device obeys to a harmonic movement with horizontal displacement, where the perforated tray coincides with the fixed tray, allowing the displacement of the concentrate to the collecting vessel.

In this case, the Semiautomatic System requires the use of electronic interfaces to manage the amount of concentrate feed to be dosed to each pig; where the interface will send periodic information to the computer, the data obtained from the consumed feed will be processed by the computer so that the user can issue reports and queries.

Pin-to-Pin Block Diagram

A Pin-to-Pin Block Diagram is a detailed graphical representation that shows the specific connections between the components of an electronic system, focusing on the connections at the individual pin level. This type of diagram is especially useful in the design and analysis of complex electronic circuits. [14]

Additionally, this Pin-to-Pin Block Diagrams shows the specific connections between components, allowing to identify possible compatibility problems and facilitates the debugging of complex systems and finally it is a guide in detail of the physical construction of the circuit. Figure 4 shows the Pin-to-Pin block diagram of the system.
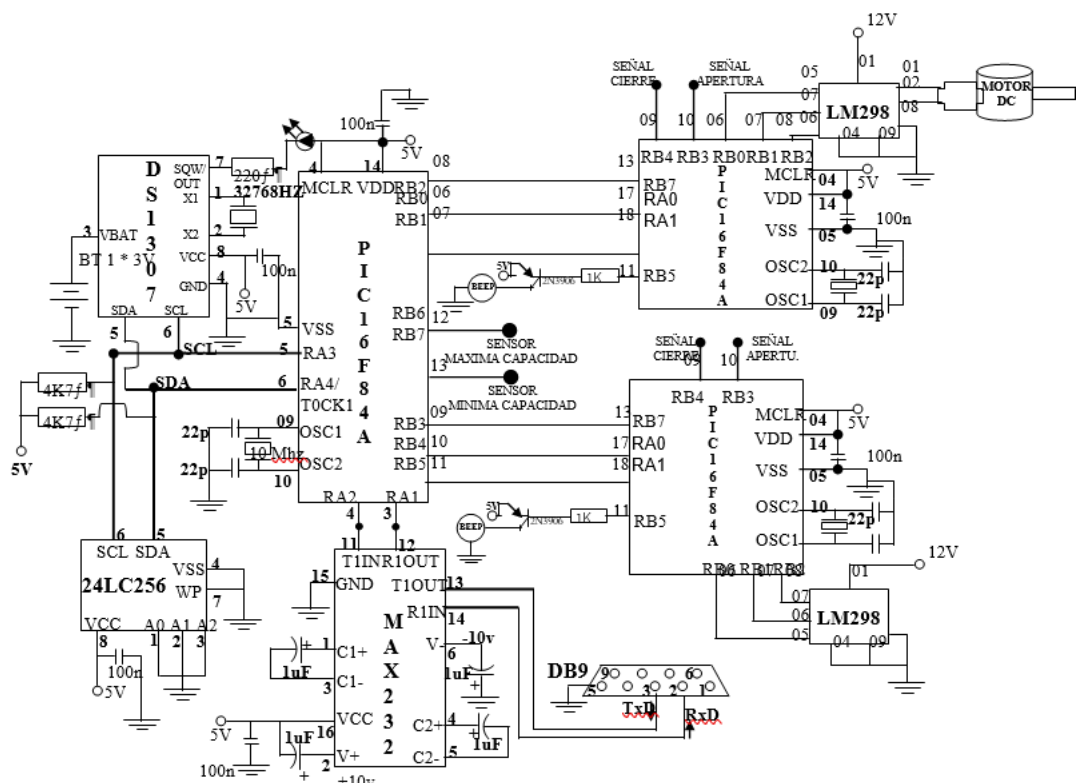
Figure 5: Pin-to-Pin block diagram

It is important to clarify that although these are detailed diagrams some aspects of the physical design such as the length of the tracks or impedance considerations, which can be crucial in high frequency or high-speed systems, may be omitted. [15]

V. CONCLUSIONS AND RECOMMENDATIONS

Identifying the different processes carried out by the operators in charge of feeding pigs in different farms resulted in this innovative project that combines software and hardware, which can improve the current system of this activity, highlighting that it is a viable alternative to improve the management of this process, minimizing costs and increasing efficiency.

The system is integrally related to different areas of knowledge and led to research on Electronics, Zootechnics, Telecommunications and Systems Engineering, which allow optimizing processes; as in this case, supplying the right amount of concentrated feed to pigs according to their stage of development.

An important aspect of the project is that it has a social projection of great impact that benefits the livestock sector, because with it many processes can be optimized and at a low cost. In this specific case, the control of concentrated feed to avoid waste, to have an updated stock record and to achieve a better profitability in the farm.

In a future work, it is expected to validate the device in real time to validate the optimal growth of the animals to make validations and improvements to the hardware or software.

REFERENCES

[1]   L. Siza, K. Díaz, A. Dueñas and A. Gómez, "PORK MEAT PRODUCTION CHAIN IN COLOMBIA," Bucaramanga, 2021.
[2]   Agricultural Risk Management Unit-UGRA and Vice Presidency of Agricultural Guarantees and Risks, "Intelligence File: Pig Farming," Finagro, Bogotá, 2020.
[3]   A. Quiles and M. Hevia, "Factors influencing feed consumption in pigs," Murcia, 2008.
[4]   M. C. Benal-Jiménez and D. L. Rodríguez-Ibarra, "Information and communication technologies as a factor of innovation and business competitiveness," Scientia Et Technica, vol. 24, no. 1, pp. 85-96, 2019.
[5]   C. D. Cegelski, S. E. Katogui, H. A. Stoisa, L. J. Corrado and M. F. Nuñes, CONTROL SYSTEMS Automation as the engine of development, Misiones: University Editorial - National University of Misiones, 2019, pp. 1-338.
[6]   E. I. Association, "Interface Between Data Terminal Equipment and Data Communication Equipment Employing Serial Binary Data Interchange," in EIA Standard RS-232-C, 1969.
[7]   K. J. Ayala, "The 8051 Microcontroller: Architecture, Programming, and Applications," IEEE Micro, vol. 16, no. 2, pp. 78-79, 1996.
[8]   J. M. Angulo, I. Angulo and J. M. Martija, "Microcontrollers: Fundamentals and Applications with PIC," IEEE Industrial Electronics Magazine, vol. 2, no. 3, pp. 59-60, 2008.
[9]   J. Fraden, "Handbook of Modern Sensors: Physics, Designs, and Applications," IEEE Sensors Journal, vol. 11, no. 9, pp. 2220-2221, 2011.
[10]   P. P. Acarnley, "Stepping Motors: A Guide to Theory and Practice," IEEE Control Engineering Series, vol. 63, no. 4, 2002.
[11]   Merck & CO - Whitehouse Station, Merck Veterinary Manual, Sixth ed., Barcelona: Océano Editorial, 2007, pp. 1-2711.
[12]   F. A. Sánchez Florez, "Epistemic Fundamentals of Qualitative and Quantitative Research: Consensus and Dissensus," Digital Journal of University Teaching Research, vol. 13, no. 1, pp. 119-120, 2019.
[13]   R. Pressman and B. R. Maxim, Software Engineering: A Practitioner's Approach, New York: McGraw-Hill Education, 2015.
[14]   T. L. Floyd, Electronic devices: Conventional current version (10th), Pearson, 2021.
[15]   A. Malvino and D. J. Bates, Electronic principles (8th ed.), McGraw-Hill Education, 2015.