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Functional Prototype for the Prediction of Dry Matter Intake and Nutritional Balance in Cows through an Artificial Neural Network

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Abstract
This article describes a functional prototype developed between the University of Antioquia and the Jaime Isaza Cadavid Colombian Polytechnic, which uses artificial neural networks to predict dry matter intake and nutritional balance in dairy cows, specifically Holstein breed.
The prediction of Dry Matter Intake (DMI) is important for cattle ranchers, as it directly influences the production of meat and milk in animals. The prototype applies the multilayer perceptron neural network technique, consisting of input, hidden, and output layers, to obtain accurate results and establish optimal feeding plans depending on the region.
Cutting-edge tools such as Machine Learning are used to predict DMI and nutritional balance. The goal is for animals to be well-fed, meeting their nutritional needs at a low cost, considering farm conditions and the time of year.
The article outlines the phases for the prototype development, including documentary exploration, model planning, mathematical components, neural network design requirements, and its respective navigation map describing the functionalities.
Keywords: *Artificial Neural Networks, nutricional balance, Dry matter Intake, prediction model.*

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I. INTRODUCTION

Under the Research project carried out between the University of Antioquia and the Polytechnic Colombian Jaime Isaza Cadavid with resources from the Ministry of Science and Technology, the following functional prototype was developed that allows the estimation of Dry Matter Intake - DMI and determination of the nutritional balance in dairy cows.

However, this process is an important task for the livestock producer, as it directly influences the production of meat, milk and work of their bovines of any breed of animals with respect to their production. In the particular case, it was specifically carried out for Holstein breed cows.

Currently in Colombia, bovine production [1]

bases animal feed on the consumption of forages under grazing, which is highly dependent on climate variability, since during the dry season the food supply is reduced, so it is necessary to identify, evaluate and apply alternatives such as silage, aimed at the conservation of forages during the time when plant production is concentrated, in order to ensure good quality food throughout the productive cycle.

Due to the above, the interest arises to develop this software application with students in technological training at the Jaime Isaza Cadavid Polytechnic, the subjects were part of the Research Seedbed in Artificial Intelligence with the advice and accompaniment of the co-researchers of the project and by their initiative they decided to apply the Artificial Neural Networks - ANN technique. According to Palmer, ANNs [2] "are characterized by being adaptive systems that learn from experience, that is, they learn to carry out certain tasks through training with illustrative examples" on the other hand, they are defined as "information processing systems whose structure and operation are inspired by biological neural networks" [3]. However, for this project, what was stated by [4] is taken into account, since

They consist of a large number of simple processing elements called nodes or neurons that are organized into layers. Each neuron is connected to other neurons through communication links, each of which has an associated weight. The knowledge that the ANN has about a particular problem lies in the weights.

The above is because it allows obtaining accurate results to establish a simpler and more optimal feeding plan according to the requirements of each animal.

II. RESULT AND DISCUSSION

This prototype will use cutting-edge tools and modern techniques such as Machine Learning (ML), which have increased in recent years. Currently, it is known as "machine learning or machine learning, is a branch of artificial intelligence (AI) [...] The scientific community is paying increasing attention to intelligent technology-enriched educational tools, as they have the potential to revolutionize teaching-learning processes." [5]

Based on the above, for this functional prototype, multilayer perceptron neural networks will be used, which for [4] are composed of "an input layer, an output layer and one or more hidden layers; although it has been shown that for most problems a single hidden layer will suffice." On the other hand, [6] ...mention that

Depending on the configuration, ANNs can perform recognition, identification of linear and non-linear systems, prediction, classification and automatic process control tasks. In automatic diagnosis, ANNs are used as strategies for fault classification, modeling and prediction. Among the configurations of ANNs, the multilayer connection stands out, where each functional neuronal unit is connected to the others by means of loops that are characterized by weighting the signal through a synaptic weight.

Due to the above, the Multilayer Perceptron is used for the project since it can be represented in different aspects, but one common aspect they must have is the ordering of the neurons in their layers, which is why within the layer there are three (3) types of layers: Input Layer, Hidden Layers and Output Layers, as represented by the following figure:

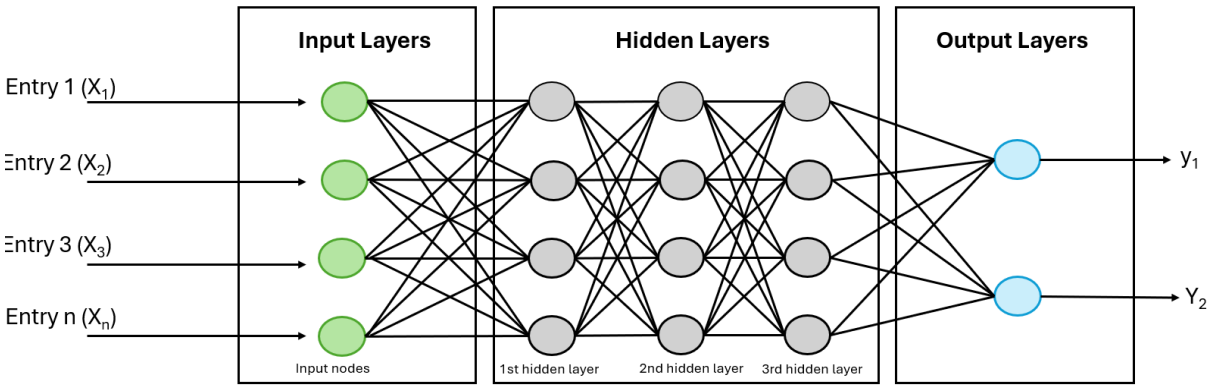

Figure 1: Multilayer Perceptron Layers (Self-made)

With one of these neural networks, it will allow calculating the total daily dry matter intake of an animal. It is important to highlight that this information provides the basis for calculating the nutritional balance through a second neural network, always taking the animal's body requirements as a reference.

On the other hand, Ramírez [7] defines Dry Matter (DM) as the nutrients or feed that animals need to consume, but which are contained in a dry portion of a feed. This means that the water is extracted from the feed. This term is normally "used in diet formulation to identify the remainder after the removal of water from the raw material or diet being worked with. Dry matter = entire content minus water" [8].

Furthermore, [7] indicates that "if a sample of feed 'X' is subjected to moderate heat (typically 65°C for 48 hours) such that all the water evaporates, what remains is the dry matter portion of that feed."

The ultimate purpose is for the animal to be well-fed, to meet its needs, but at a lower cost, taking into account the time of year and the specific conditions of the place where the animals live. Aiming to avoid excesses or deficiencies of nutrients. In general terms, for proper nutritional balance, two basic aspects must be considered: the animal's physical conditions and the farm's resources, to achieve productive potential.

To better understand, it is important to take into account the dry matter calculation proposed by [7] with the following formula:

$$\left(\frac{grams\ dry\ sample}{grams\ wet\ sample}\right) x100$$

$$\left(\frac{grams\ wet\ sample - grams\ dry\ sample}{grams\ wet\ sample}\right) x100$$

With all the information collected, we began designing a neural network model that would allow prediction of dry matter intake and nutritional balance in Holstein cows. But to do this, it was necessary to carry out the following:

- Documentary exploration to characterize the variables of dry matter intake and nutritional balance, in order to define the input variables in the Neural Network prototype.
- Plan and model a supervised system that consolidates a learning set to serve for training the neural model prototype.
- Select, understand and model the mathematical components that will allow the design of a neural network architecture that generates prediction of dry matter intake and nutritional balance with a minimum margin of error. This margin of error has not yet been delimited, as it depends greatly on the data that can be entered for learning.
- Development of the functional prototype with multilayer perceptron neural network technology.
- Execute test cases, perform functional and unit testing with experts, to facilitate the validation and verification of the multilayer perceptron neural network with test data to begin its learning, and also to identify possible improvements to the prototype design in terms of usability and functionality.

To organize the project and understand the step-by-step execution, the phases presented in the following figure were proposed:

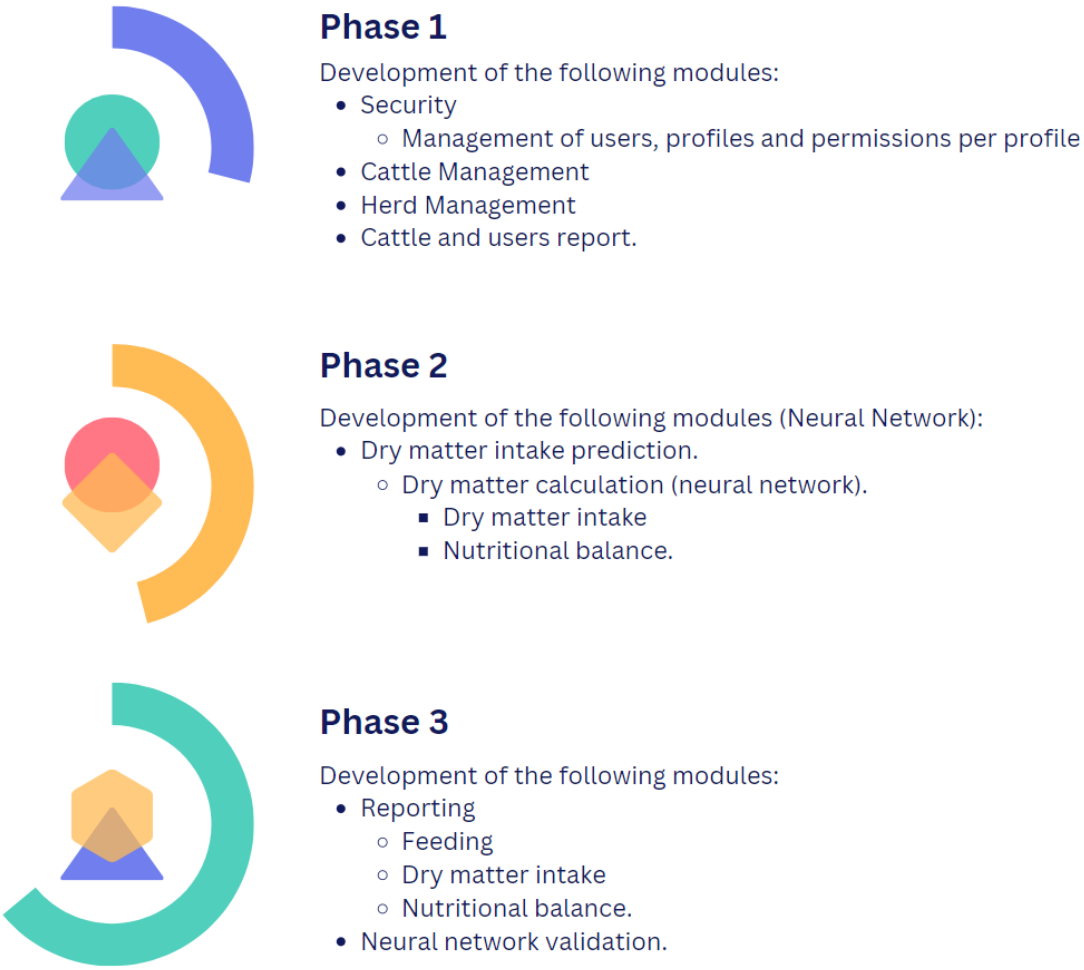

Figure 2: Modular development of the prototype organized by phases (Self-made)

It is important to clarify that there are currently mathematical models that allow calculating Dry Matter Intake and Nutritional Balance in cattle, which were taken into account for the development of the prototype. However, for the prediction model, neural networks trained with data according to the Colombian territory were implemented.

For the development of the described modules, information gathering was carried out and the following functional requirements were elicited:

Table 1: Functional Requirements.

Requirement ID	Requirement Name	Requirement Description
RF-01	Manage Users	The system must allow: create, save, modify or delete users with the following fields: User ID Document Full Name Email Phone
RF-02	Manage Profiles	The system must allow: create, save, modify or delete profiles. The identified profiles are: Administrator, Farm Owner, Operator, Guest
RF-03	Manage Permissions by Profile	The system must allow management of permissions according to the profile described in RF-02
RF-04	Federated Authentication	The system must allow login via Google accounts
RF-05	Manage Owner	The system must allow: create, save, modify or delete users with the following fields: User ID Document Full Name Email Phone Farm Name Number of Lots Number of Animals
RF-06	Manage Farm or Ranch	The system must allow: create, save, modify or delete farms or ranches with the following fields: Farm or Ranch ID Farm or Ranch Name Farm or Ranch Owner Farm or Ranch Area (hectares) Lots (for cattle production) Climate Type Pasture Type Address or Location GPS Coordinates
RF-07	Manage Animal	The system must allow: create, save, modify or delete animals with the following fields: Animal ID Animal Name Breed Production Type (Milk or Meat) Farm it belongs to Lot it is located in Feed Type Weight Date of Birth Place of Origin Observations
RF-08	Calculate Dry Matter Intake	The system must allow the user to generate an estimate of the dry matter intake (kg) of each of their cattle
RF-09	Calculate Nutritional Balance	The system must generate a report indicating the current state of nutritional balance of a particular bovine and show recommendations to improve or keep it stable
RF-10	Generate Reports	The system must allow the user to generate reports by date of dry matter intake and nutritional balance of all cattle associated with their farm.

Table 2: Functional No Requirements.

Requirement ID	Requirement Name	Requirement Description
RNF-01	Security	The system must limit access to information and resources according to the farm associated with the user.
RNF-02	Usability	The system must have a user-friendly and accessible interface.
RNF-03	Portability	The system must be able to run on devices with Android OS.
RNF-04	Availability	The system must be available to the user 24/7.

BUSINESS RULES

● To log in to the application, a Google account must be registered.

● Every owner must be associated with a farm, therefore, to create the owner there must be at least one farm created.

● Every bovine must be associated with an owner, therefore, to create a bovine there must be at least one owner.

● One of the variables to perform the nutritional balance is the result of the dry matter calculation, therefore, a nutritional balance calculation cannot be performed without first performing the dry matter calculation.
● The nutritional balance calculation must be performed automatically after performing the dry matter calculation.
● Dry matter and nutritional balance calculations cannot be performed on bovines with a "dead" status.
● The fields name, weight, number of births and owner cannot be modified if a bovine has a dead status.
● The fields name, weight, number of births and owner can only be modified if the bovine has a living status.

USER NAVIGATION MAP

The navigation map is a diagram used to represent the system's functionalities. It significantly guides the end-user, as it allows them to visualize the routes to access the system's functionalities. In this case, the diagram shown in Figure 3 has been proposed, in which the operations that the functional prototype will have are outlined.

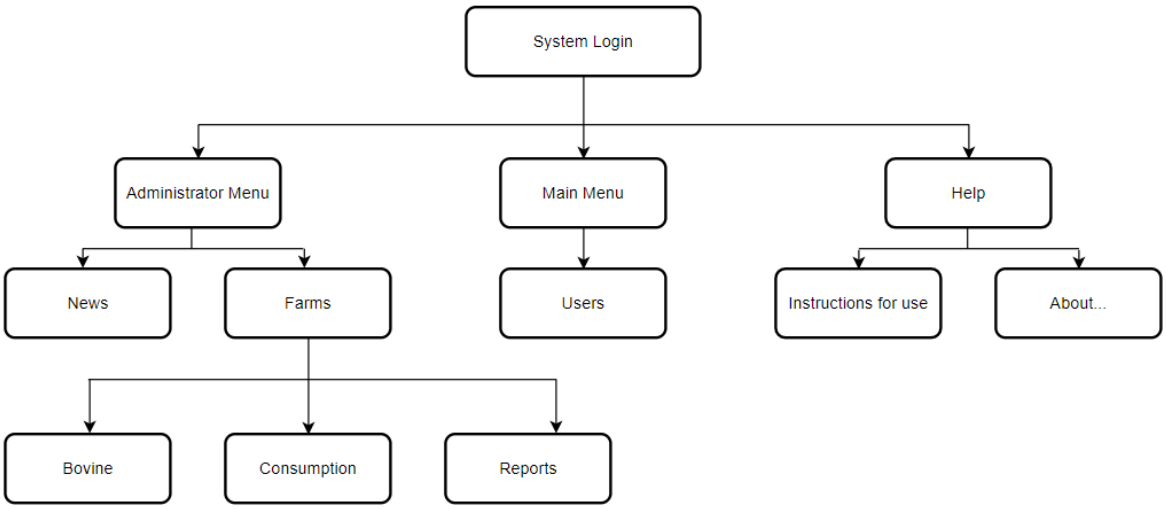

Figure 3: User Navigation Map (Self-made)

UML DIAGRAMMING

For the development of the application, the following diagrams were proposed with the purpose of refining requirements, organizing information and applying good software development practices.

Use Case Diagram

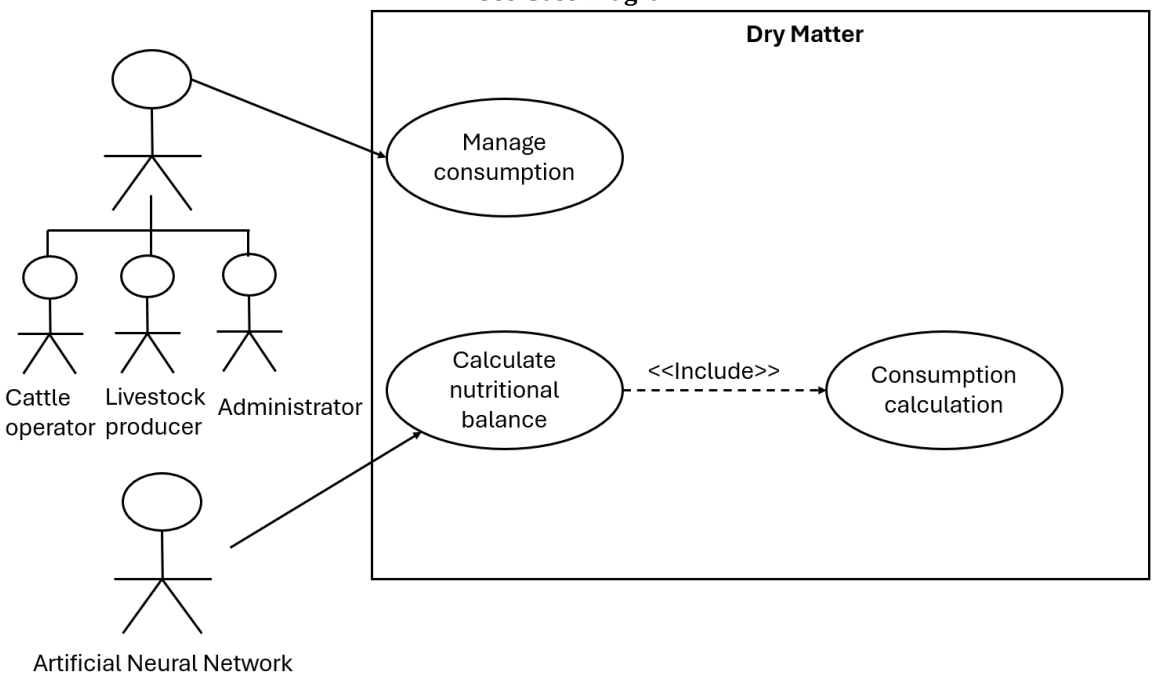

Figure 4: Diagram of general use cases of the system (Self-made)

Class diagram

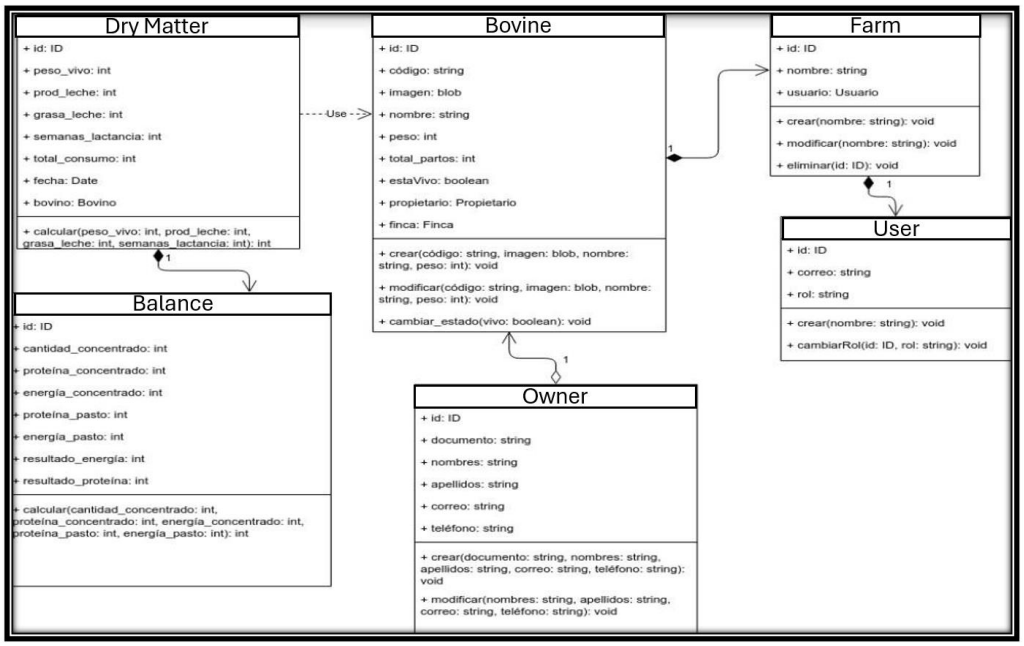

Figure 5: Diagram of general use cases of the system (Self-made)

Diagram of packages

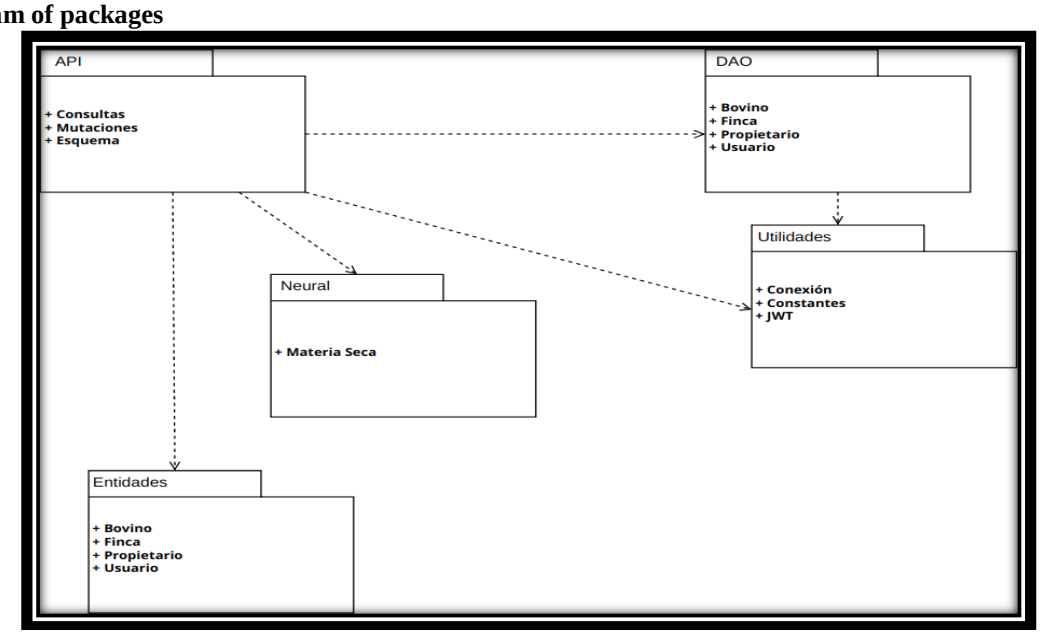

Figure 6: Diagram of packages (Self-made)

III. CONCLUSION

It was The purpose of this research is to use a predictive model from an application that implements neural networks trained with information according to the conditions of the Colombian territory, which allows the cattle producer to estimate, store and monitor the Dry Matter Consumption of the animals in real time, which will allow making the right decisions on the nutritional management of cattle, thus improving the efficiency of resource utilization and increasing the profitability margin.

The project involved students in training and this enriches the teaching and learning processes since it allows them to learn about topics different from the training area, to venture into new technology topics and this reinforces professional, training and ethical issues, among others.

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