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Thesis

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Smart cow feeding management system

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In the name of Allah, the Most Gracious, the Most Merciful.

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Dedications

Praise be to Allah, first and foremost, for He is the beginning and the end, and my success is only by His grace.

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I dedicate this work to the one who gave me life, my parents. to my sisters, my dear brothers, and all my family. We would like to thank everyone who contributed to this work and helped us in its completion. Special thanks go to *Mr. Mohammed Qattel*, also known as *Abi*, who had a significant role in accomplishing this work. We would also like to express our gratitude to *Mr. AbdelKarim Mestaoui*, *Djamel Harket*, *Zakaria Mokrani*, and the esteemed teacher, *Mr. Boujamline*. Lastly, we extend our appreciation to all our colleagues.

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DINA AND ZINEB

Abstract

The agriculture sector in Algeria, specifically cow breeding, is in need to integrate digital technologies to enhance efficiency and overcome challenges associated with traditional methods. This work addresses the problem of using traditional methods in feeding cows, which often results in an inadequate feed supply or overfeeding, imprecise feeding techniques, compromised productivity, and requires effort and labor. The objective of this work is to develop a machine that enables precise and automated feeding of cows, along with a data collection system for gathering information for future analysis and improvements. The proposed solution comprises a feeding system that ensures precise and automated feeding for each cow based on their individual characteristics (Weight, milk production, type dairy cow or beef....), to provide the appropriate amount of feed, and a website to monitor feed consumption in Real-time and the configuration of the feeding system.

As a result, a website has been developed to monitor the feed consumption of each cow and configure the feeding system. Additionally, a smart cow feeder prototype utilizing RFID technology has been created and connected to the website. This prototype accurately determines the appropriate amount of feed for each cow based on its characteristics and automatically distributes it.

Keywords- *Agriculture, Automatic cow feeding, RFID, Precision feeding.*

الملخص

قطاع الزراعة في الجزائر، وتحديدا تربية الأبقار، بحاجة ملحة لدمج التكنولوجيا و الرقمنة لتعزيز الكفاءة والتغلب على التحديات المرتبطة بالأساليب التقليدية. يتناول هذا العمل مشكلة استخدام الأساليب التقليدية في تغذية الأبقار، مما يؤدي في كثير من الأحيان إلى امداد غير كافٍ من الأعلاف للأبقار أو الإفراط في التغذية، تغذية غير دقيقة، تضرر الإنتاجية، و تتطلب العمالة والجهد.

يهدف هذا العمل الى تطوير جهاز يمكّن من تغذية الأبقار بدقة وتلقائية، بالإضافة إلى نظام جمع البيانات بهدف التحسين في المستقبل. الحل المقترح يشمل نظام التغذية الذي يسمح بالتغذية الدقيقة والتلقائية وتحديد الكمية المناسبة من االعلف بناءً على خصائص كل بقرة (الوزن ، كمية الحليب المنتجة ، نوعها حلوب او تسمين.......)، وموقع إلكتروني لمراقبة استهلاك الأعلاف في الوقت الحقيقي.

ونتيجة لذلك، تم تطوير موقع إلكتروني لمراقبة استهلاك الأعلاف لكل بقرة وضبط نظام التغذية عند الحاجة لتحسين تغذية الابقار وتعزيز الانتاجية . بالإضافة ، تم إنشاء نموذج أولي لآلة تغذية الأبقار تستعمل تقنية RFID . يسمح هذا النموذج بتحديد الكمية المناسبة من الأعلاف لكل بقرة بناءً على خصائصها ويوزعها تلقائياً و بدقة.

الكلمات المفتاحية: الزراعة ، تغذية الأبقار الأوتوماتيكية ، RFID ، التغذية الدقيقة.

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List of Abbreviations

ACFS Automatic Cow Feeding Systems. 16

EID Electronic identification. 10

ICT Information and Communication Technologies. 5

IoT Internet of Things. 5

IR Infrared Technology. 22

MCU Microcontroller Unit. 17

PF Precision Feeding. 3

PLF Precision Livestock Farming. 3

RFID Radio Frequency Identification. 3

WSN Wireless Sensor Networks. 13

WT Wireless Transmission technology. 17

List of Algorithms

General introduction

1. **Context**

Livestock farming plays a crucial role in our economy and food supply. It provides us with essential sources of meat and milk, which are vital for meeting our protein needs. Proper feeding of cows is of utmost importance as it directly impacts their productivity and well-being. While traditional feeding methods have been commonly used, adopting customized and precise feeding techniques can significantly improve the productivity of the entire herd. By offering individual cows feed that caters to their specific requirements, we can optimize nutrient utilization, reduce waste, and enhance the overall health of the cows. Transitioning away from traditional methods enables us to achieve higher efficiency and effectiveness in cow-feeding practices.

2. **Problem statement**

Unfortunately, many cow farms in Algeria still use traditional feeding methods, which come with several challenges:

- The inadequate supply of appropriate amounts of feed leads to low quality and quantity of milk and meat production.
- Feed wastage and increase in feeding costs.
- Significant efforts and labor are required.
- Overfeeding and underfeeding can have detrimental effects on the health of cows.

3. **Objectives**

   Has two objectives :

   (a) **Direct objective:** Developing a machine for precise and automated feeding of cows The solution is composed of:

      - **Feeding system:** Ensuring precise and automated feeding for each cow based on their individual characteristics.
      - **Siteweb:** Monitoring real-time feed consumption and configuration of the feeding system.

   (b) **Indirect objective:** Development of a data collection system.

4. **Thesis Structure**

   The current report is structured into four chapters:

   - **The 1st Chapter:** We presented the concepts of Agriculture 4.0, one of its domains, Precision livestock farming, and radio frequency identification technologies (RFID).
   - **The 2nd Chapter:** We introduced the drawbacks of traditional feeding methods and their impact on cow production. Also, we discussed the relevant studies and companies that are working on automated feeding systems.
   - **The 3rd Chapter:** Provides a comprehensive outline of our system and demonstrates its functionality through various approaches.
   - **The 4th Chapter:** Describes the implementation of our proposed solution.

Chapter 1

Generalities

1.1 Introduction

Agriculture 4.0 is a new era of agriculture that harnesses digitalization, automation, and artificial intelligence to address agricultural and environmental challenges. Precision Livestock Farming (Precision Livestock Farming (PLF)), including Precision Feeding (Precision Feeding (PF)), is a crucial application of Agriculture 4.0. PLF utilizes process engineering principles to enhance livestock management. PF, supported by automatic data collection, data processing, and control actions, enables the use of feeding techniques that provide the proper amount of feed according to animal needs.

In this chapter, we aim to explain the concept of Agriculture 4.0, provide an overview of precision livestock farming with a focus on precision feeding, and then introduce radio frequency identification (Radio Frequency Identification (RFID)) technologies.

1.2 Agriculture 4.0

As the global population is expected to approach 10 billion by 2050, the demand for various human needs, especially food, is set to significantly increase in both quantity and quality. To meet this demand, global food production must increase by around 60-70 percent. To achieve this objective, digital technologies are emerging as a strategic solution to improve the scale, efficiency, and effectiveness of agricultural production. The Food and Agriculture Organization (FAO) of the United Nations denominates this role as the "Digital Agricultural Revolution" while other sources label it as "Agriculture 4.0" [3].

1.2.1 Evolution of Agriculture

The evolution of agriculture, from the primitive level to the advanced level of today, took place gradually over time. Technological developments in agriculture are divided into 4 long-term and named the transformation from Agriculture 1.0 to Agriculture 4.0 [10].

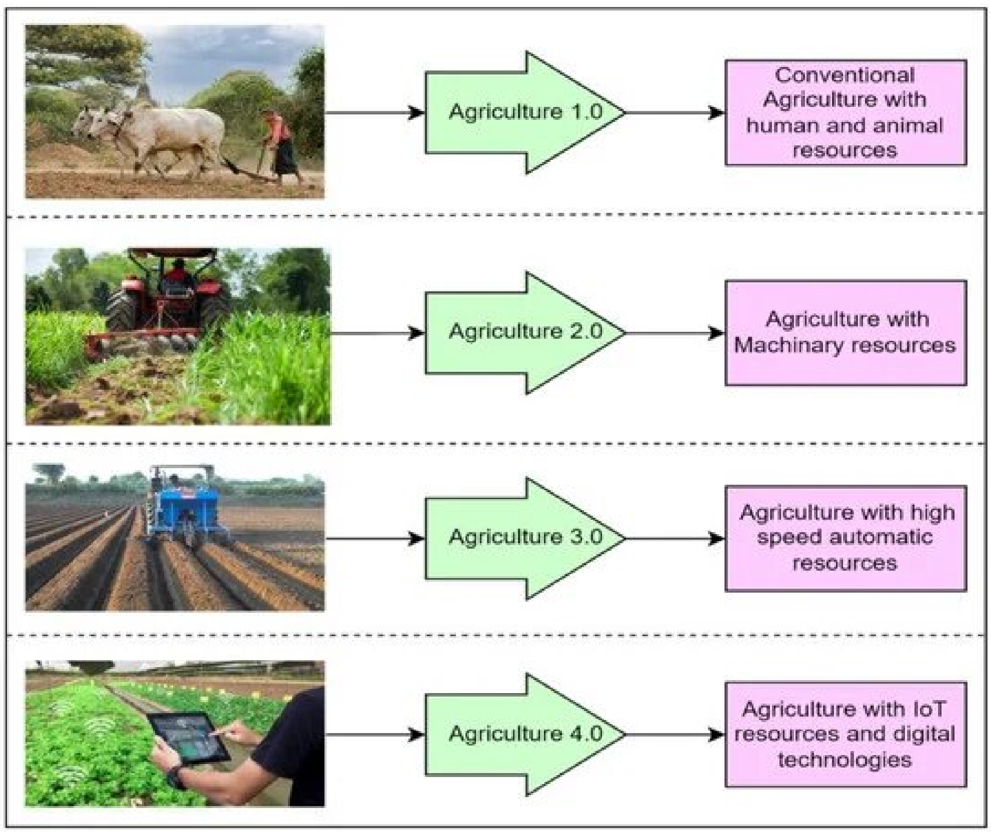


Figure 1.1: The uprising of Agriculture 1.0 to agriculture 4.0 [37].

Agriculture 1.0 relied mainly on manpower and animal forces, with simple tools used for farming. As a result, productivity remained at a low level. Agriculture 2.0 emerged in the 19th century with the introduction of agricultural machinery and chemicals [16], resulting in increased efficiency in both crop and livestock production. In the 20th century, agriculture 3.0 emerged thanks to the introduction of information and communication technologies (Information and Communication Technologies (ICT)). This involved the use of advanced technologies such as process automation and robotic techniques to perform farming operations more efficiently [16], the key problem was the lack of intelligence [37].

Presently, the evolution of agriculture has moved to Agriculture 4.0. In this respect, Agriculture 4.0 applications are responsible for providing significant improvements to the sector, with a strong economic, environmental, and social impact.

The main aims of this revolution are related to the introduction of automation and digital technologies in the agriculture sector, allowing for a transition toward smart and sustainable farming [16].

1.2.2 Agriculture 4.0 Core Technologies

The agriculture 4.0 revolution comprises five essential technologies: sensors and robotics, the Internet of Things (Internet of Things (IoT)), cloud computing, data analytics, and decision support systems [10].

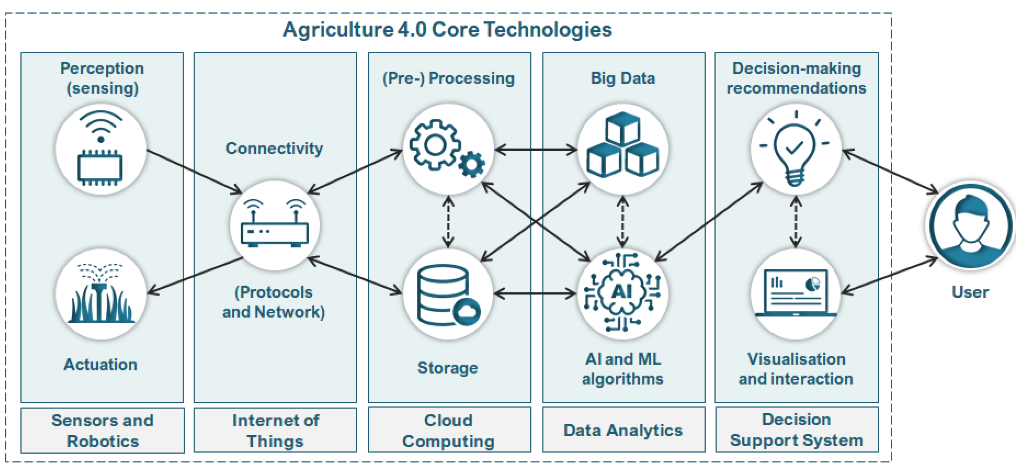


Figure 1.2: Agriculture 4.0 core technologies and connections [3].

Advances in sensor technology have allowed farmers to monitor specific parameters in real-time, while robotics have supported better automation of the processes. Additionally, computing power has become more accessible and affordable, which has also helped the creation of new decision-support tools for better agricultural management. For instance, big data support a high volume of real-time and historical data and artificial intelligence-based methods transform these data into added value and actionable knowledge [3].

1.2.3 Agriculture 4.0 applications

The application of Agriculture 4.0 can be categorized into four main groups, namely monitoring, control, prediction, and logistics [10].

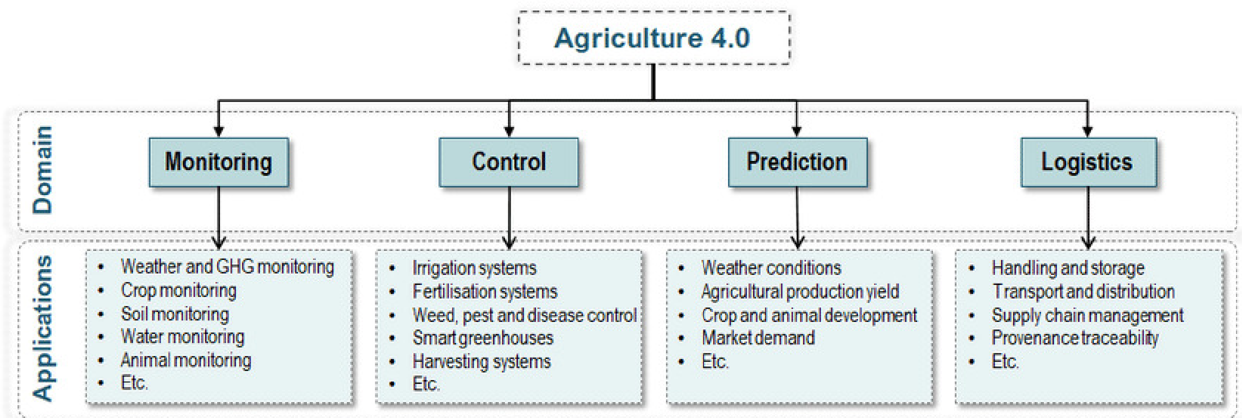


Figure 1.3: Domains and applications in Agriculture 4.0 [3].

- **Monitoring:** The first step in adopting Agriculture 4.0 is implementing automatic monitoring systems. These systems collect data from the field in real time and use advanced analytic tools to provide farmers with valuable insights. By using this technology, farmers can make informed decisions and take timely action to improve their agricultural productivity, save time and money, and protect the environment. Typically, monitoring involves various applications, such as: Weather and Greenhouse Gases Monitoring, animal Monitoring, Crop Monitoring, and Water Monitoring.

- **Control:** While information is managed in one way in the monitoring applications, the control applications use a bidirectional information line. Commonly, an IoT control system works together automatic monitoring system, which employs IoT sensors to collect necessary data and to transfer them for storage and then processing.

- **Prediction:** The predictive function in Agriculture 4.0 is used in decision-making support for optimization in the management process. Monitoring and documentation are vital processes since they use real-time and historical data to improve exact analytical methods for predicting actual events.

- **Logistics:** It is known that, in recent years, consumers have been more concerned about how the agri-food products bought are produced, handled, packaged, stored, and distributed. Agriculture 4.0 provides more efficient management and transparency by increasing efficiency in logistics, addressing food safety and security, traceability and food authentication, decreasing intrinsic risks, and complying with certifications and regulations [10].

1.3 Precision livestock farming (PLF)

An important application example in Agriculture 4.0 is Precision Livestock farming. PLF emerged in the early 21st century as an innovative approach that could revolutionize livestock management.

In this section, we illustrate the definition of precision livestock farming, explore the reasons behind its emergence, explain its systems and technologies, and finally address the most important part of our study, which is precision feeding.

1.3.1 Definition

PLF is the application of precision agriculture techniques in the livestock industry [48].

It is the use of technology to automatically monitor livestock, their products, and the farming environment in real time in order to aid farm management, either by supplying the farmer with relevant information on which to base management decisions or by activating automated control systems [45].

The main purpose of PLF is to enhance overall farm profitability and animal welfare, as well as production efficiency and sustainability. Precision livestock farming incorporates all the necessary components (e.g., automatic scales, animal identification, tracking systems, sound analysis, etc.) to accomplish the expected PLF control outcome [40].

1.3.2 The reason for the emergence of Precision livestock farming

The emergence of precision livestock farming stems from the challenges faced by agricultural production as it scales up, where farmers encounter difficulties in closely monitoring their farms, especially in relation to livestock, and making necessary adjustments. This poses practical problems that conflict with farmers' sustainability goals and raises ethical concerns regarding animal welfare and the well-being of farm laborers. Moreover, there is a symbolic cost as the traditional image of a farmer who personally knows their farm and animals recedes, impacting a farmer's identity and potentially altering public perception of farming. The loss of attentive stewardship at scale has significant effects on livestock production, where animals transition from being individually known to becoming undifferentiated units. Precision livestock farming emerges as a response to address these challenges and mitigate the associated harms [49].

1.3.3 Precision livestock farming system

The following three main steps are the crucial components of any successfully developed PLF system, namely the identification of :

- Measurement.
- Data analysis.
- Appropriate control systems.

Firstly, the measurements have to be identified that facilitate the most important decision-making processes on farms. These measurements will focus primarily on the nutritional input and environmental conditions that are required to maximize economic and biological efficiency and therefore enhance profitability and productivity.

This follows the identification of appropriate data analysis and interpretation systems that allow decisions to be made from the collected data. At this stage, nutritional or biological models need to be developed.

Finally, electronic or other appropriate control systems have to be identified that activate control actions based on the analysis of the recorded data.

These three components are then merged into an integrated system with appropriate communications links to pass information smoothly among the main components [4].

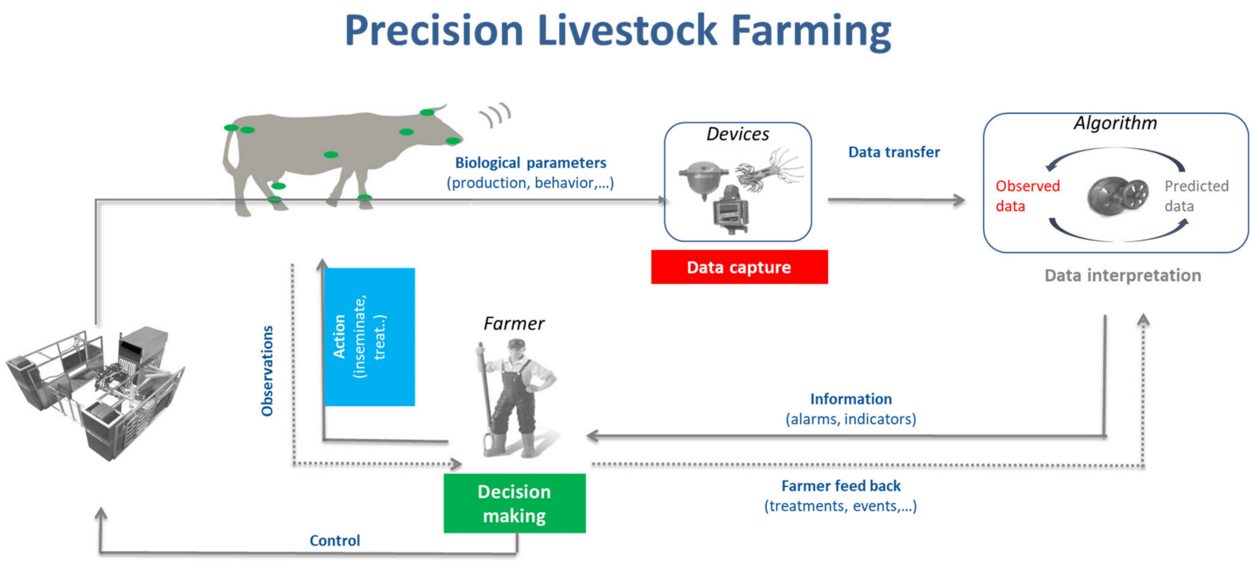


Figure 1.4: Overview of a PLF system of various components on a dairy farm [29].

1.3.4 Precision Livestock Farming technologies

A few of the PLF technologies which are in application today are:

- **Automated weighing systems:** These systems precisely measure animal weights using step-on scales or cameras with machine learning algorithms. They give critical information for monitoring cattle health and predicting management interventions.

- **Low-cost feed and water intake recording:** Sensors such as water meters and feed intake sensors track animals' feeding and drinking behaviors. These sensors, by tracking historical trends and identifying deviations, can alert early warning systems if the animals' feeding and drinking habits alter. Such alterations could be caused by factors such as disease or unfavorable environment.

- **Imaging solutions:** Imaging technology, such as 3D cameras and thermal imaging, enable the collection of data on animal weights, behavior, physiological states, growth trends, and environmental elements such as carcass quality. They are commonly used in PLF monitoring.
- **Animal sensing systems:** Sensors such as accelerometers, pressure sensors, and temperature sensors attached to animals or their environments form an IoT network. These sensors detect behavioral patterns, environment conditions, and animal health indicators, enhancing disease detection and early warning systems.
- **Electronic identification (Electronic identification (EID)) solutions:** For non-intrusive livestock identification, electronic alternatives such as RFID and advanced ear tags are utilized. In precision farming, EID enables automatic record-keeping and effective management of data.
- **GPS tracking for extensive systems:** GPS tracking technologies are beneficial in grazing systems because they allow farmers to follow the movement and location of animals across wide areas. This method increases livestock herding efficiency while also reducing losses due to theft or predator attacks.
- **Application of advanced data analytics to big data:** As PLF technologies become more widely used, a huge amount of data is generated on a regular basis. Advanced data analytics and machine learning capabilities are required for successfully processing and exploiting this data, allowing for the resolution of important animal health and farming challenges.[17]

1.3.5 Precision feeding

Precision feeding is a fundamental element of PLF. It is the practice of meeting the nutrient requirements of animals as accurately as possible in the interest of safe, high-quality, and efficient production while ensuring the lowest possible load on the environment. Nutrient requirements are not a parameter of a population but an independent statistic of an individual animal. PF is proposed as an essential approach to improving nutrient utilization and thus reducing feeding costs and nutrient waste.

PF is based on the fact that animals within a herd differ from each other in terms of age, weight, and production potential, and therefore, each animal has different nutrient requirements.

PF involves the use of feeding techniques that allow the right amount of feed with the right composition to be provided at the right time to each animal in the herd [7].

In details, PF requires: (1) a real-time determination of nutrient requirements for each individual within the group (often done using models based on the factorial approach). (2) the use of automated technology (i.e., an automatic feeding station) to distribute a tailored diet for the animal and to monitor the animal's real-time performance (e.g., body weight, feed intake, and feeding behavior). The latter will be used as feedback for the estimation of individual nutrient requirements.

Therefore, precision feeding is promising for maximizing the performance potential of individuals and minimizing environmental impacts [38].

Figure 1.5: Example of precision feeding in farms [9].

1.4 Radio Frequency Identification technology

In our work the fundamental one being Radio Frequency Identification (RFID) technology. In this section, we will provide the fundamentals of this technology.

1.4.1 Definition

RFID is the acronym for Radio Frequency Identification. More precisely, it is a technology of identification by radio frequencies that uses RFID tags to identify objects when they pass near a reader. Different from the barcode, we can follow their path but also memorize and retrieve their data. This technology allows communication between objects and readers without a direct line of sight [18].

RFID usage is quite old and dates back to the Second World War. Firstly, at the beginning of the 1940s, it was used in the identification of friendly and enemy aircraft in the UK. This was followed by nuclear material tracking applications in the 1970s, and commercial applications began in the 1990s.

RFID technology has gained prominence in recent years due to its ease of use, accurate product tracking, and reliable performance in production and storage environments [12].

1.4.2 RFID System Components

An RFID system is mainly composed of three elements (Figure **??**): RFID tags, reader, and host system.

1. **RFID Tags**

   This component is used to store the information. Each RFID tag contains an electronic integrated circuit chip and an antenna encapsulated together in a suitable package. A tag is attached to an object with a unique identification number and memory that stores additional data about its manufacturer, product type, and other related environmental information.

Commercially, the tags are available in a wide variety of sizes, shapes, and protective housings.

2. **RFID Reader**

   A reader, also known as an interrogator, is used to collect all the information stored in a tag. An RFID reader consists of a decoder to decode the information from a tag. An antenna is used for transmitting and receiving the RF waves carrying information from the tag to the reader and vice versa.

   RFID readers are able to read or write data to tags by reading nearby tag IDs and mapping this ID to an object via an external database or service; the reader can therefore sense and monitor the existence of a corresponding object.

   Readers typically have two interfaces. An RF interface that communicates with the tags in their read range in order to retrieve the tags' identities. A communication interface for communicating with the servers, generally IEEE 802.11 or 802.3. There currently exist systems that combine RFID and wireless sensor networks (Wireless Sensor Networks (WSN)) and are applied directly to healthcare environments.

3. **RFID software**

   It is used to manage the received data and the operations of the reader and tag. Indeed, software manages the information in a database; it can also contain the details of tags and readers. All the information is sent to a host computer or RFID middleware to ensure communication between the RFID infrastructure and the different intra and inter-organizational systems [6].

1.4.3 Functioning of RFID Technology

Each RFID tag is assigned a unique identification number. The RFID reader emits electromagnetic (EM) wave signals to identify the RFID objects. This communication and power transfer between the reader and tags occur wirelessly. When an RFID tag enters the radio frequency field of the reader, it receives the necessary energy from the EM waves for communication. Once the tag

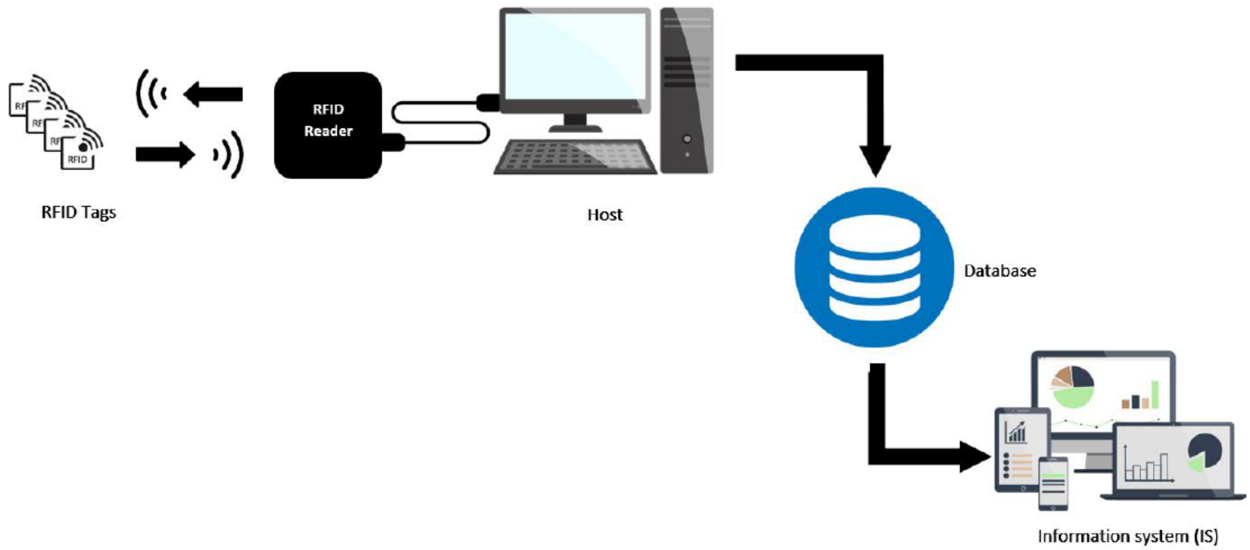


Figure 1.6: RFID System Components [19].

receives the required energy, it modulates the carrier signal based on the stored information. The modulated signal is then transmitted from the tag to the reader. The reader detects and decrypts the modulated signal using its password, allowing it to read the information. Finally, the received information is transmitted to a computer database for further processing [13].

1.4.4 RFID application domains

Passive RFID technology offers immense flexibility and finds applications in various fields. It enables easy identification and detection of different objects. Figure 1.7 below shows the various applications of RFID systems in our daily life.

For example, in manufacturing, RFID systems that can resist extreme environmental conditions can be practical for controlling and monitoring operations and thus increase the efficiency of the manufacturing process. RFID also serves as a useful tool for tracking the movement and monitoring the health of animals. In agriculture, RFID systems enable cost-effective and automated health tracking of identified animals, ensuring that each animal on the farm receives the appropriate nutrition [15].

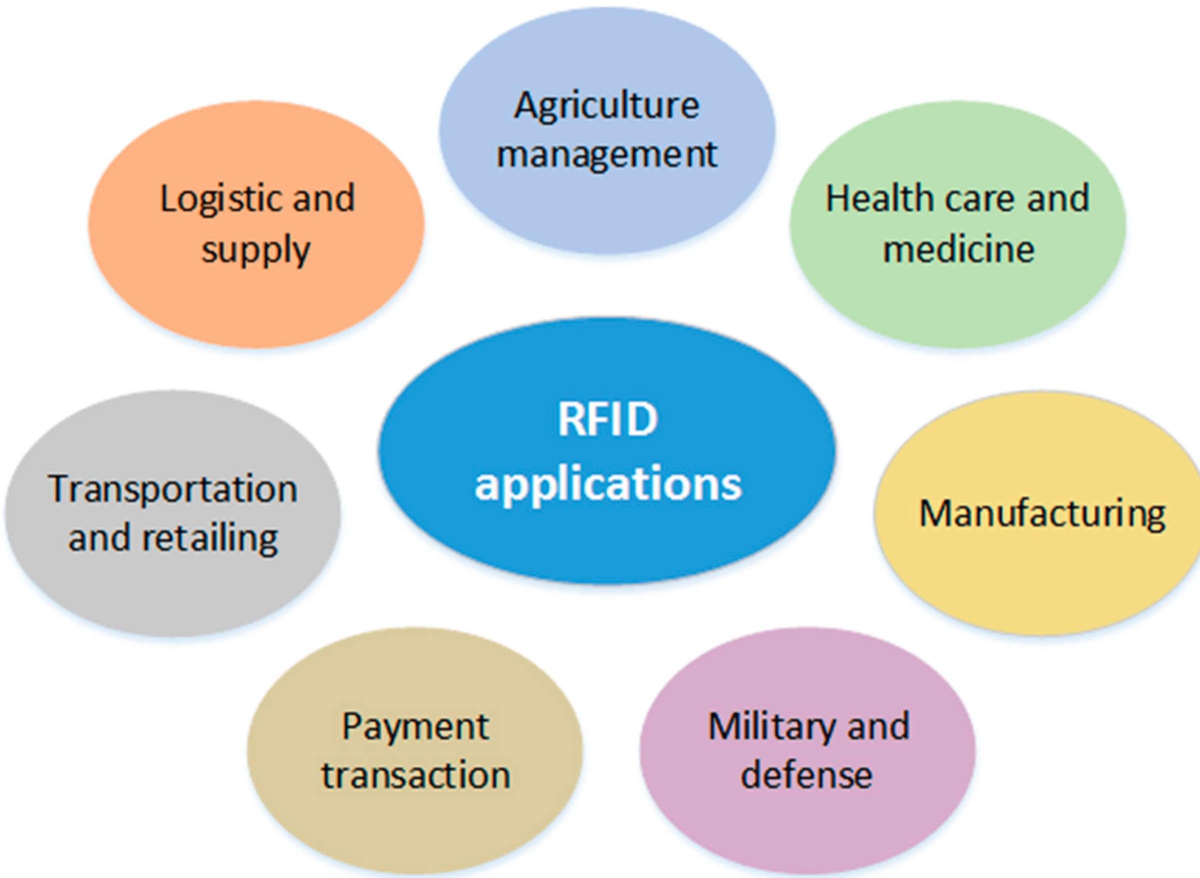


Figure 1.7: RFID application domains [15].

1.5 Conclusion

In this chapter, we covered Agriculture 4.0 and PLF and provided the fundamentals of RFID technology.

In the next chapter, we will discuss the automatic feeding system, a key tool in precision feeding. Our emphasis will be on its application in cow farming.

Chapter 2

State of arts

2.1 Introduction

Automatic feeding systems are vital for precision feeding in livestock production, particularly in dairy farming, and for transitioning away from traditional methods. They simplify feeding, improve animal management, and enhance production outcomes compared to manual feeding. In this chapter, we will focus on Automatic Cow Feeding System (Automatic Cow Feeding Systems (ACFS)), highlighting the limitations of traditional methods and their impact on cow production. We will also discuss relevant studies and companies interested in developing these systems.

2.2 The limitations of classic cow breeding techniques

Traditional cow breeding techniques have limitations due to over-reliance on manual methods, which leads to challenges in accurately determining the appropriate amount of feed for each cow. This imprecision in feeding can result in inadequate nutrition, health problems, and reduced milk production. These limitations stem from the absence of a scientific food strategy that considers specific nutrient requirements, with feeding practices influenced by forage availability and food prices. This often results in imbalanced diets and excessive use of concentrated feed, further impacting cow health and productivity. Additionally, food wastage is prevalent, with nutrient requirements exceeding 110% in around 50.2% of cases, leading to resource wastage and increased costs. To overcome these limitations, farmers should explore alternative approaches, such as incorporating technologies and data-driven strategies. By leveraging innovative tools, can optimize resource utilization, and enhance overall cow health, productivity, and profitability [5].

2.3 Related works

2.3.1 Articles

In this section, we demonstrate some previous studies that concerned the field of designing and developing automatic cow feeding systems.

2.3.1.1 The design and experiment of the track-type equipment for feeding dairy cows

Yaping LI et al. [31] proposed a track-type equipment design aimed at optimizing dairy cows' feeding processes. The equipment utilizes RFID, wireless transmission technology (Wireless Transmission technology (WT)), and infrared technology (IR) to achieve individual precision in feeding quantity.

The equipment consists mainly of a mechanical system an control system. The mechanical system consists of a feeding device and a traveling device. The control system incorporates an identification system that employs RFID and IR technology to identify individual cows. Additionally, there is a human-computer interface and an information management system operated by a computer. This interface allows for easy entry and batch import of cow-related data, processes the data and instructions based on the feeding model, and transmits the processed data to the microcontroller unit (MCU).

The Microcontroller Unit (MCU) is responsible for controlling the operation of the feeding equipment based on the information about the identified cow and the data received from the computer. For data transmission, the control system offers wireless or U-Disk methods. Figure 2.1 shows the equipment structure diagram.

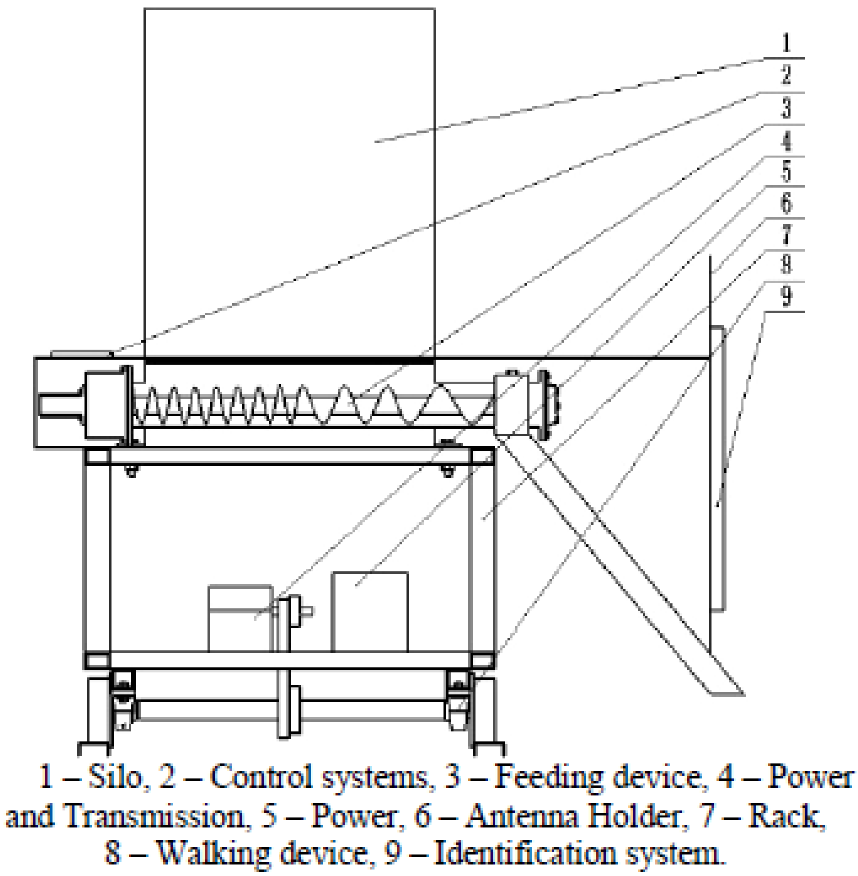


Figure 2.1: The main diagram of feeding equipment [31].

2.3.1.2 Automatic cattle feeding system

Pratiksha Karn et al.[27] introduce a robotic feeding system that aims to ensure optimal feeding for each cow by maintaining a timely and consistent quantity of feed for every group of cattle. The system is a battery-operated robotic vehicle that follows a predetermined path and dispenses feed to the cattle along the feed fence.

The robotic vehicle is divided into two sections: a lower section that includes a line-following robot guided by IR and ultrasonic sensors to ensure precise line following and exact determination of the feed point.

The upper section is the feed distributor, which utilizes a sliding door driven by a DC motor to dispense feed at the feeding point. The entire system is controlled by an ATmega328 microcontroller and an Android application, which communicates with the system via Bluetooth technology. This application enables control and system shutdown in the event of hardware issues.

The figure 2.2 shows the ACFS that has been developed in the work field.

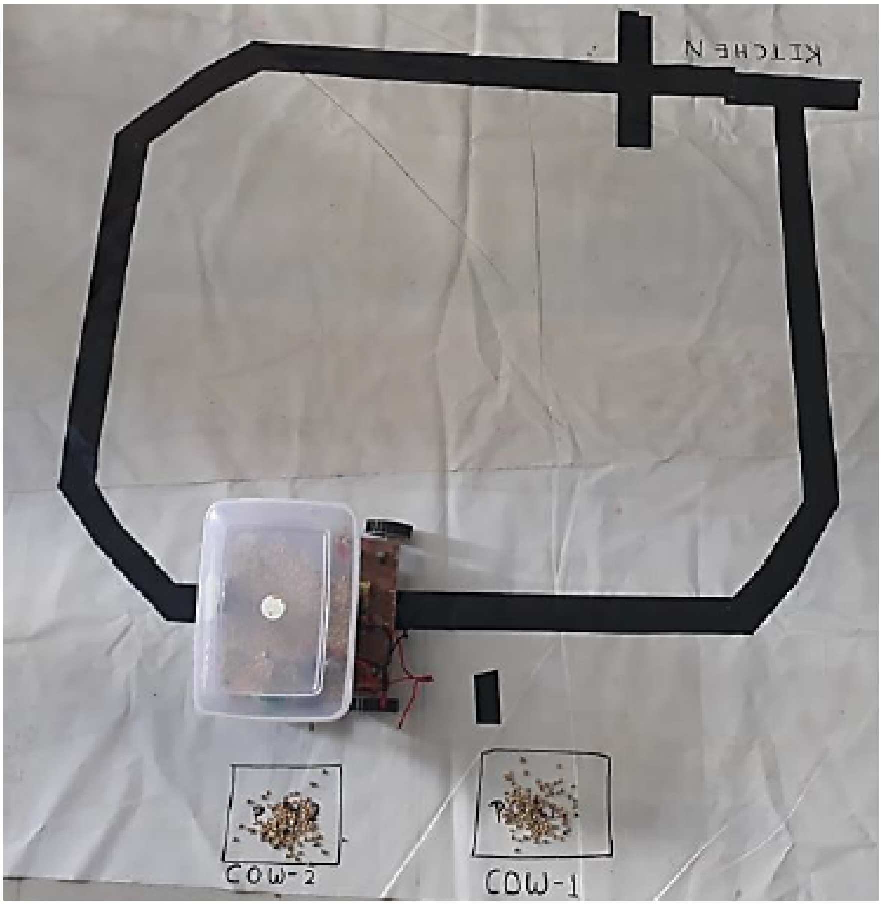


Figure 2.2: The system in Work Field [27].

2.3.1.3 Control and Monitoring System for Livestock Feeding Time via Smartphone

The main objective of J. S. Eik1 et al. [14] is to develop an Internet of Things (IoT)-based ACFS that enables farmers to manage and monitor cow feeding schedules through a smartphone application.

The proposed system is designed with hopper storage for the feeding system and a container for the weighing system. The tools employed in the system include two ultrasonic sensors, a load cell, and a servo motor.

The system is monitored and controlled by the Arduino WeMos D1R2 microcontroller and the Blynk application. The Blynk app enables users to effectively manage livestock feeding schedules, monitor food levels in the hopper storage, detect livestock presence near the food container, and track the remaining food weight in order to monitor whether the livestock have eaten. Figure 2.3 shows the final result of this project.

Figure 2.3: The prototype design [14] .

2.3.1.4 Design of cow cattle weighing system technology and automatic giving feed

The weight of cows is a key factor for farmers in determining the feed quantity precisely. Dodon Yendri et al.[54] have introduced a solution aimed at assisting farmers in cattle weighing and implementing automated feeding schedules for morning, day, and night meals.

The technology is designed using a keypad as an input medium to activate the system, a load cell sensor of 500kg for cow weighing, a load cell sensor of 100 kg to measure the weight of the feed in the feed box, the HX711 module as an ADC, the RTC DS3231 for scheduling time readings, the servo motor to rotate and push the weighed feed, the Arduino as a control center, and an LCD as an information viewer tool.The figure2.4 depicts the tool's design.

The automatic cattle system software architecture is a pipeline of programs that will run on the Arduino Mega microcontroller. The system began to weigh cows at the time the weigh function was activated, and the system will schedule meals three times a day in the morning (at 08.00), noontime (13.00), and afternoon time (17.00).

The results showed that the system could work properly. All components used can function as expected.

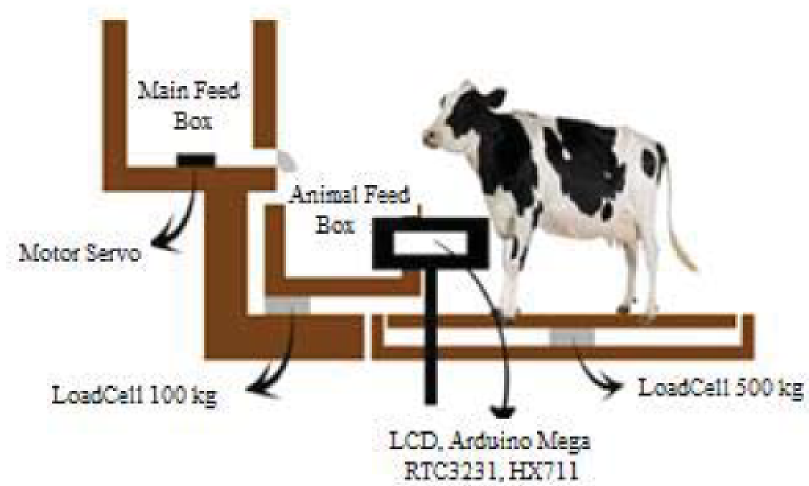


Figure 2.4: Tools design [54].

2.3.1.5 Automatic animal food feeding system

In this work, Aditya R. Rajput et al.[42] present a laboratory model for automating the animal food feeding process, a Programmable Logic Controller (PLC)-based ACFS that aims to reduce the manpower and time required to complete the feeding process.

The model comprises a hopper, container, and feeder platform on wheels that move on a rail track.

The feeder platform is equipped with four wheels driven by DC motors, allowing it to move within left and right boundaries defined by limit switches. The feeder container is equipped with Infrared Technology (IR) sensors that detect the presence of cattle near the gate. These sensors control a distribution fan, which is operated by a DC motor. The fan adjusts the feed rate based on the cattle's needs.

The entire system is controlled by a PLC system connected to an Arduino, which manages data acquisition and control strategies.

Figure 2.5: The system setup [42].

Table 2.1 summarizes the main characteristics of reviewed studies considering detection and identification systems (types), user-machine interaction, decision support, feed ration delivery method, data collection, and control unit used.

Work	Cow detection system	Cow identification system	User-machine interaction	Decision support	Data collecting	Control unit
Yaping LI et al. [31]	Infrared sensor	RFID	Desktop app	Information of cows, TMR feeding model	-	MCU
Pratiksha Karn et al. [27]	Infrared sensor	-	Android App	-	-	ATmega328
J. S. Eik1 et al. [14]	Ultrasonic sensor	-	Android App	-	-	Arduino WeMos D1R2
Dodon Yendri et al. [54]	-	-	Keypad LCD	Cow weight	-	Arduino mega
Aditya R. Rajput et al. [42]	Infrared sensors	-	PLC	-	-	PLC Arduino

Table 2.1: Summary of related works highlighting their characteristics.

2.3.2 Companies

Automatic cow Feeding Systems have numerous examples and companies worldwide working on it. In this section, we will present three renowned global leader companies in the field.

2.3.2.1 Hanen Automatic Livestock Feeder

Service Line's Hanen Automatic Livestock Feeder is a highly advanced feeding system designed for various types of livestock, including horses and cattle. The feeder is both manufactured and sold in the United States of America, specifically in Wisconsin.

It enables accurate and customizable feeding schedules of up to six times per day, ensuring optimal nutrition levels for the livestock. The feeder uses audio signals to call the livestock for feeding, making the process more efficient and streamlined.

The Hanen Automatic Programmable Cattle Feeders come in two models that are AC-powered for indoor use: the LSF-2 Two-Head Feeder and the LSF-4 Four-Head Feeder. There are also two solar-powered models available: the LSF-12 Twelve Head Feeder and the LSF-20 Twenty Head Feeder. All models are constructed using heavy-gauge steel and powder-coated for extreme weather conditions, ensuring durability and longevity [20].

Figure 2.6: The hanen automatic programmable cattle feeders [20].

2.3.2.2 Nedap

Nedap is a technology company based in the Netherlands, founded in 1929, that specializes in developing intelligent solutions for various industries, including livestock management.

Nedap livestock management is a global leader in farming automation that provides solutions for both dairy farming and pig farming challenges.

One of its solutions is the dairy's electronic concentrate feeding with the Nedap Cow Feeding Station using individual electronic animal identification (RFID). This cattle feeding equipment gives every cow the right feed at the right time in the right portion size, following a tailor-made feed curve you can easily set up based on factors such as milk production, lactation days, and individual dietary requirements.

The feeding station is designed to be robust and durable, capable of withstanding challenging barn environments and various animal behaviors. It prioritizes the safety and comfort of each animal, ensuring that feeding is conducted in a secure and comfortable manner. The station optimally spreads concentrate portions throughout the day, ensuring that cows receive the right amount of feed at the right times. Additionally, it provides the flexibility to dispense multiple feed types as required. Nedap also provides a health monitoring system that continuously (24/7) registers the behavior of cows, enabling precise monitoring of their health, well-being, and nutritional status. It identifies potential issues and bottlenecks, allowing for early detection of health problems, intensive monitoring of transition cows and post-treatment recovery. This information enables better individual cow treatment, saving time and costs for farmers [36].

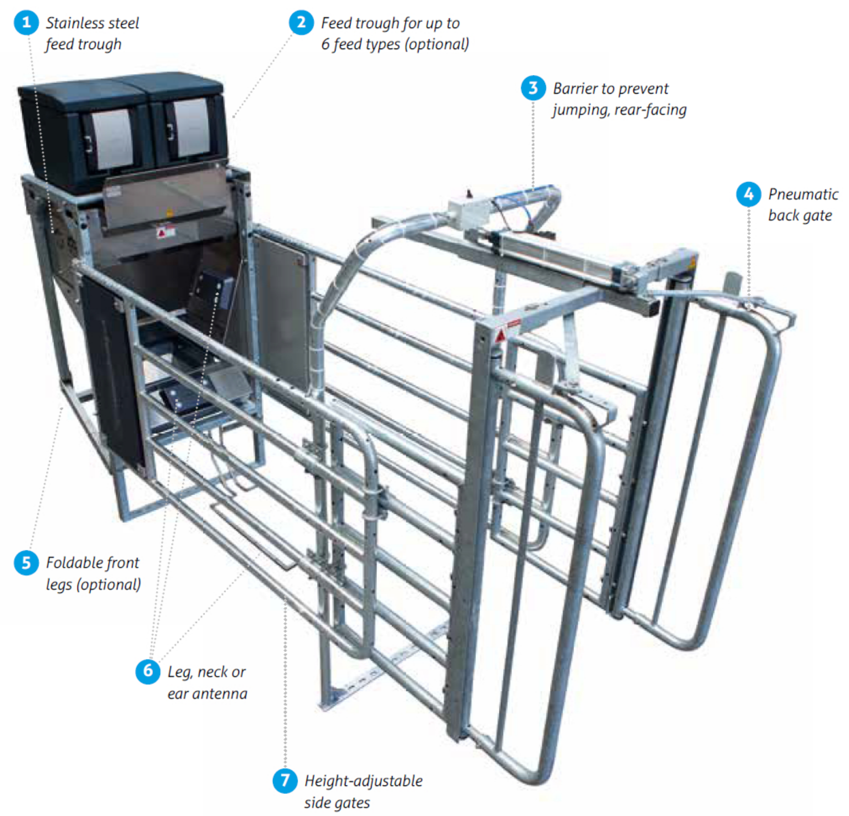


Figure 2.7: The Nedap cow feeding station [36].

2.3.2.3 Hokofarm Group

Hokofarm Group B.V. is a company based in the Netherlands that was founded in 1979. The company specializes in the production of automatic feeding systems for both cows and sows. Their systems are designed based on individual electronic animal identification specifically RFID.

One of their notable products is the RIC2Discover, a system specifically created to measure the individual feed intake of dairy and beef cattle. The RIC system can be installed in existing as well as new barns, and it features a modular construction that is robust, durable, and low maintenance.

The system consists of a feed-weigh trough and an intelligent feeding gate that gather individual cow data related to feed intake. Additional components such as water-weigh troughs and animal-weigh scales can be added to collect more individual cow data.

When a cow approaches one of the feed-weigh troughs, the system identifies the animal and starts recording data. It measures the eating period, continuous feed intake, and registers individual cow data regarding feed and water intake as well as eating time.

The management software provided by Hokofarm Group allows easy access to the recorded data. It can be accessed via a computer or mobile device, providing users with the ability to organize and analyze the collected information [22, 21].

Figure 2.8: The RIC2Discover system [22].

	Hanen Automatic Livestock	**Nedap Cow Feeding Station**	**Hokofarm RIC2Discover**
Company Origin	United States	Netherlands	Netherlands
Company website	http://www.automatic cattlefeeder.com/	https://www.nedap-livestockmanagement .com/dairy-farming/	https://hokofarmgroup .com/
Livestock Supported	Horses, Cattle, Various Livestock	Cows	Cows, Sows
Cow identification System	No	RFID	RFID
Control system	No	computer or mobile device	computer or mobile device
Real-time monitoring	No	Nutritional status, well-being	Nutritional status

Table 2.2: Comparison of the companies feeding systems.

2.3.2.4 Discussion

Based on previous work, we observed a diversity in the techniques and materials used in the studied systems. This diversity arises from the various problems they address and the goals they aim to achieve.

Furthermore, we found that certain research articles and commercial systems incorporate automatic identification systems and detection systems that utilize RFID technology along with ultrasonic or infrared sensors. These combinations ensure accurate and effective identification and detection processes.

In terms of feed determination, different approaches were identified. Some systems rely on decision-making algorithms that take into account individual cow information, while others utilize weight-based measurements and scheduled feeding.

Regarding control systems, their characteristics and objectives vary. Monitoring-oriented systems are often connected to smartphone or desktop applications or websites.

Based on these findings, we designed our system to leverage individual cow information, integrating RFID and ultrasonic sensors for accurate and effective identification and detection. Load cells are employed to precisely determine the feed amount. Additionally, a website is developed to enable real-time and efficient monitoring of the feed process.

2.4 Conclusion

In this chapter, we discussed the limitations of traditional cow breeding techniques and explored automatic feeders as solutions to them by presenting the solutions proposed in related works and by companies to improve the feeding process. In the next chapter, we will present the design of our proposed system, which aims to incorporate the suitable techniques and materials from the discussed systems to design and develop a prototype capable of automatically distributing precise amounts of feed based on the individual needs of cows.

Chapter 3

Design of smart cow feeder

3.1 Introduction

In the previous chapter, we explored articles that focused on the development of automated cow feeding systems. We also highlighted renowned companies specializing in the production of these systems. By conducting a comparison of these solutions, we were able to identify their individual advantages and incorporate them into our solution.

Our proposed solution represents an efficient approach to precision feeding, aiming to optimize cow health and enhance production by implementing automation and smart feeding techniques.

This chapter aims to provide a comprehensive and detailed description of the system architecture. This will be accomplished by providing a detailed description of each component, accompanied by relevant diagrams.

3.2 General Architecture

We present the general architecture of our project in this section. As illustrated in Figure 3.1, our proposed solution consists of a smart cow feeder, which accurately determines the appropriate amount of feed and distributes it automatically. Additionally, it has a site web that enables farmers to monitor the feed consumption of individual cows in real time and configure the feeding system.

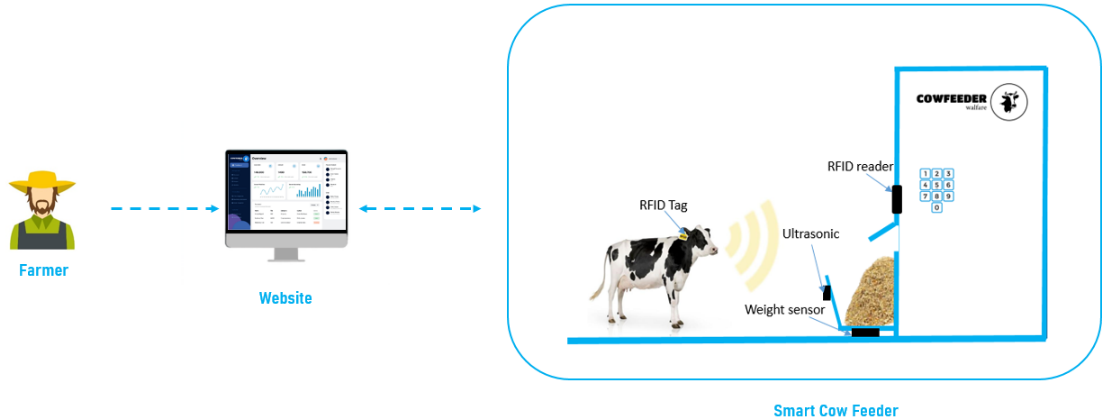


Figure 3.1: Smart cow feeder global architecture.

3.3 Detailed Architecture

As we covered in the previous section, the main components of our project. In this section, we are going over them in more detail. Figure 3.2 illustrates the detailed system of the smart cow feeder.

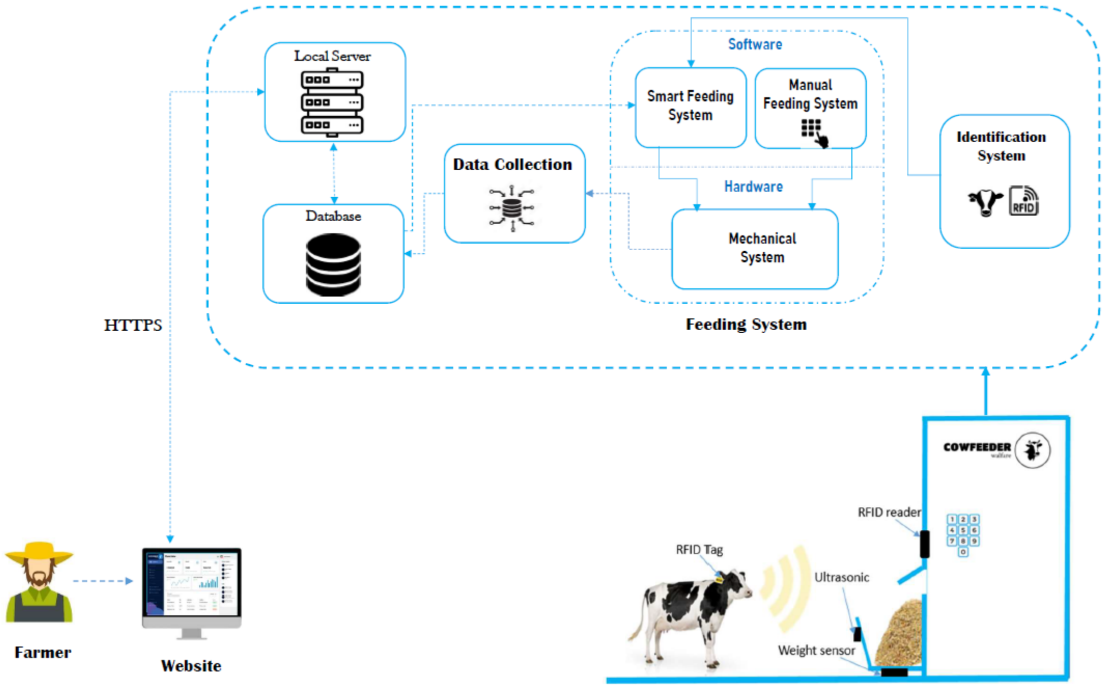


Figure 3.2: Smart cow feeder detailed architecture.

3.3.1 Website

Is hosted on a local server. It has various functionalities that the farmer can utilize. These functionalities are as follows:

1. **Cow information view:** Providing a comprehensive view of cow information such as their ID, breed, weight, age, milk production, consumed feed by each cow, and other relevant data.
2. **Real-Time data display:** Includes feed consumption by individual cows and the tank level. This real-time monitoring capability enables the farmer to monitor feed consumption patterns.
3. **Notifications and Alerts:** Alerts the farmer about important statuses, such as anomalies related to cow health, based on feed consumption. Additionally, the system generates alerts when the tank level is almost empty, indicating the need for refilling.

   - **Check abnormal cow function**

This function evaluates the cow's feed consumption to determine the abnormal cows.

Algorithm 1 Checking abnormal cow.

```
Function checkAbnormalCow (feedConsumptionDataWithinWeek,feedNeededPerDay-WithinWeek, Threshold,idCow)
    feedNeededPerWeek ← ∑(feedNeededPerDayWithinWeek)
    feedConsumedPerWeek ← ∑(feedConsumptionWithinWeek)
    deviation ← (expectedFeedPerWeek − FeedConsumedPerWeek) / expectedFeedPerWeek × 100

    if deviation < Threshold then
        send_alert(idCow)

    end
```

- **Check tank level function**

  This function allows notifying the farmer when the tank level is almost empty, indicating the need for refilling

Algorithm 2 Checking the tank level

```
Function checkTankLevel (tank_level,current_tank_level)
    threshold ← predefined threshold value;
    deviation ← (current_tank_level × 100) / level_tank ;
    if deviation < threshold then
        send_alert("Tank level is almost empty. Please refill.");
    end
```

4. **Configurations:**

   Enables the farmer to configure:

   - **Managing cows:** Enables adding new cows, modifying information about cows as needed, and removing cows when necessary.
   - **Setting feeding time:** Enables setting the feeding schedule for the cows.
   - **Managing rules of rule-based system:** Enables to add new rules, modify rules, and delete rules.

3.3.2 Identification system

The system uses RFID technology to identify cows accurately. By associating the ID of the RFID tag with specific cow characteristics stored in a database, such as weight, type (dairy, beef), and status (e.g., production, pregnancy, etc.), the smart feeding system can effectively determine the appropriate amount of feed for each cow. This approach allows for individual feeding based on each cow's characteristics, improving the feeding process's overall efficiency.

- **Identify cow function**

  This function allows identifying individual cows.

Algorithm 3 Identification of Cow using RFID

```
Function identifyCow(RFID_tag)
    cowID ← ReadID(RFID_tag);

    if cowID is not empty then
        cowCharacteristics ← getDataFromDatabase(cowID);
        return CowCharacteristics;
    end
    return null;
```

3.3.3 Feeding system

Used to determine the appropriate amount of feed and distribute it automatically and precisely for each cow. This system has two parts:

1. **Software:** This part is responsible for conducting analyses to determine the appropriate amount of feed. It offers two potential systems for this purpose:

   - **Manual feeding system:** Uses a control panel interface to enter the appropriate amount of feed. Also, it has a security measure requiring a password for authorization before the farmer can enter the amount of feed. However, this system relies only on the entered quantity by the farmer.

- **Enter feed amount manually function**

Algorithm 4 Manual feeding

```
Function enterFeedAmountManually ()
    initialize verified ← false;
    while verified = false do
        print "Enter password: " ;
        read inputPassword ;
        if inputPassword Is correct then
            verified ← true;
        end
        else
            print "Invalid password. Please try again." ;
        end
    end
    amount_feed ← enterAmountFeed ();
    return amount_feed;
```

- **Smart feeding system:** Uses a rule-based system to determine the appropriate amount of feed for each cow based on its characteristics. Here's a description of the rule-based system:
  - **Interface:** A friendly interface to communicate with the rule base to add new rules, edit rules, or delete rules.
  - **Making decision:** Involves evaluating the rules based on data acquisition and executing the rule to determine the appropriate amount of feed.
  - **Rule acquisition:** Enables gathering rules added from an interface to build a rule base.
  - **Data acquisition:** Once the cow is identified, the smart feeding system gathers important information about the cow, such as weight, production milk, type (dairy, beef), and status (e.g., production, pregnancy),... This data is crucial in determining the appropriate amount of feed.
  - **Rule base:** Contains the knowledge represented as a set of rules for feeding cows

helpful in determining the appropriate amount of feed.

* **Rules as a knowledge representation technique**

  The rule consists of two parts:

  The IF part is called the antecedent (premise or condition)

  And,

  The THEN part is called the consequent (conclusion or action).

  The basic syntax of a rule is:

  IF <antecedent>

  THEN <consequent>

  The rule can have multiple antecedents joined by the keywords AND (conjunction), OR (disjunction), or a combination of both.[2]

  The rule incorporates the notion of priority, which allows certain tests or evaluations to take precedence over others due to their greater importance. It also integrates the handling of real numbers and symbolic evaluations (<, >, =, !=) [30].

  Rule: IF X_1 and X_2 and ... and X_n THEN Y

  where,

  X_1, X_2, ...,X_n are characteristics of the cow (weight, production milk, status, type,...)

  Y is the amount feed

  Example :

  IF type == 'dairy' AND status == "production" AND production milk == "20"

  THEN amount feed = 20

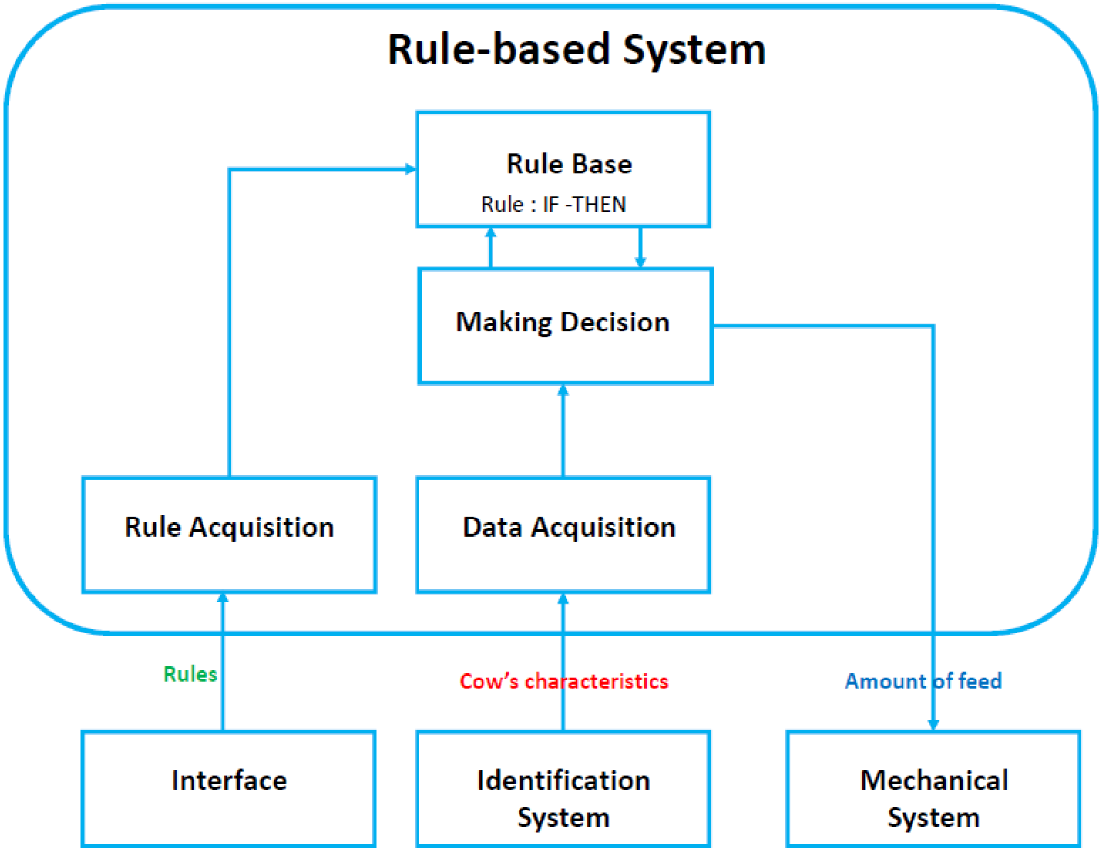


Figure 3.3: Smart Feeding System.

Smart Feeding function:

Algorithm 5 Smart Feeding

Function *RFID_tag*

characteristics ← identifyCow(RFID_tag);

rules ← retrieveRules();

appropriateFeedAmount ← determineFeedAmount(characteristics , rules);

return appropriateFeedAmount;

2. **Hardware :**

- **Mechanical system:** Mainly consists of three servo motors, two weight sensors, and two ultrasonics. Once the system determines the appropriate amount of feed for each cow, depending on the chosen method (manual feeding or smart feeding), it will distribute the feed with precision and automation. To distribute the feed automatically, the feed is first emptied into the weighing box to measure the appropriate amount. Then, it is transferred to the feeding box where the cow can consume the feed. Finally, unconsumed feed is emptied into the weighing unconsumed feed box to record the amount consumed by the cow in the database(We will explain these steps of distribution feed in more detail in The prototype implementation section chapter 4).

3.3.4 Data collection

Allows collecting and recording information as follows:

- **Data collection of consumed feed:** This process involves collecting data on the amount of feed consumed by each cow. It includes recording details such as the cow ID, the amount of feed consumed, the appropriate amount of feed, and the feeding duration. This data is used for monitoring individual cow feeding patterns and making decisions regarding the state of the cow's health.

3.4 The working principle of feeder equipment

In this section, we are going to prepare a simplified flow chart that outlines how the feeder equipment functions to feed cows effectively. The figure 3.4 offers a visual representation of the process:

The working principle of the feeder equipment can be summarized as follows:

1. **Choosing the system to determine the amount of feed:**
    - In the case, The smart feeding system is chosen:
        - Test if the time is the feeding time.

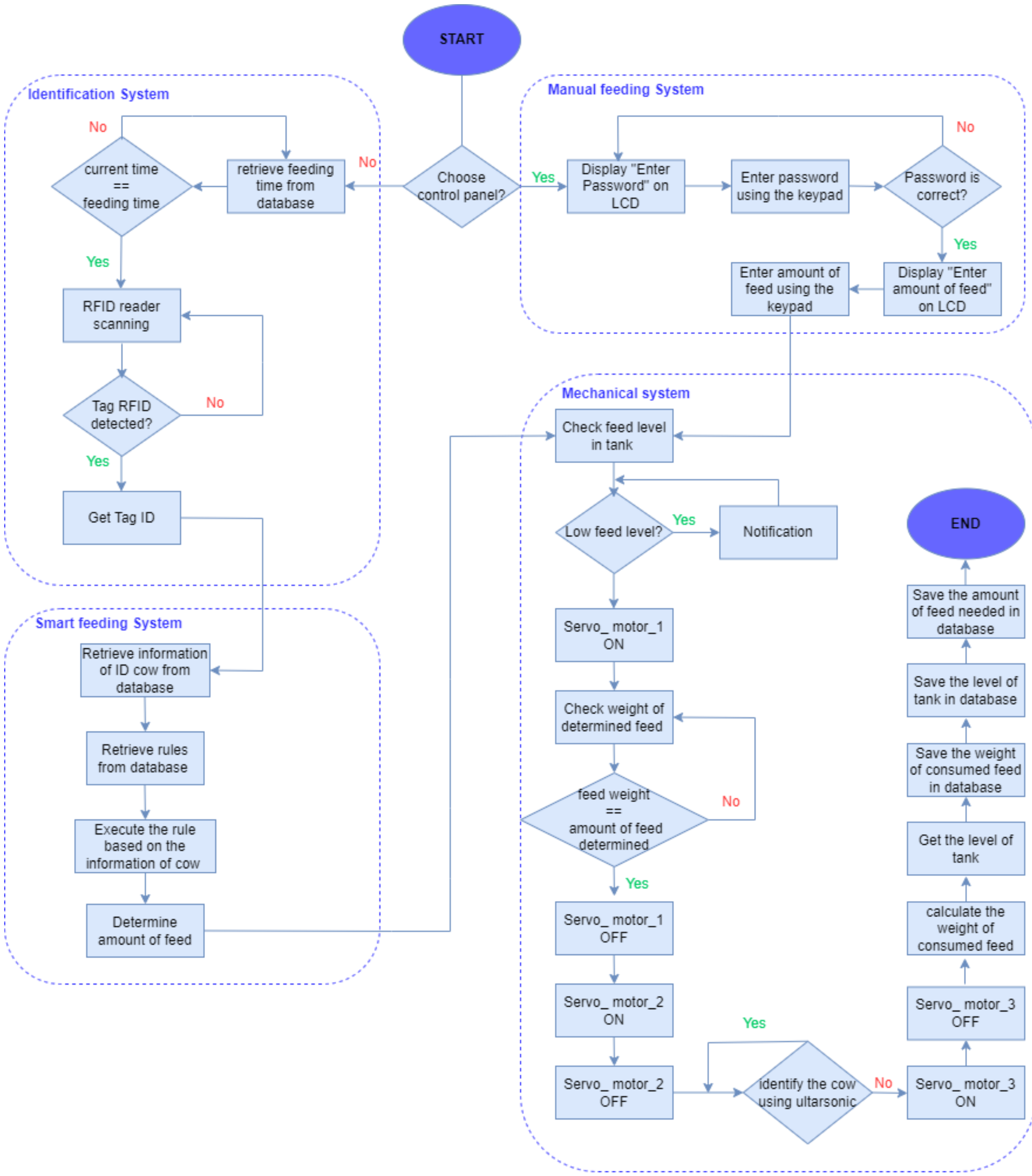


Figure 3.4: The working principle of feeder equipment flow chart .

- Identify the cow by obtaining the RFID tag ID and retrieving its characteristics from the database.
- retrieve the rules from the database.
- Execute a rule-based system to determine the appropriate amount of feed.

- In the case, The manual feeding system is chosen:

    - Enter the password.
    - Enter the appropriate amount of feed.

2. **Distributing the amount of feed using a mechanical system:**

    - Check the tank level.
        - If the tank does not have enough feed, send a notification to fill the tank.
    - Automatically distribute the predetermined amount of feed.
    - If the cow is not identified by ultrasonic.
    - Calculate the amount of the consumed feed.
    - Store the following data in the database:
        - Amount of the consumed feed.
        - Tank level.
        - Appropriate amount of feed.

3.5 Functionality of the system

In this section, we aim to provide a comprehensive representation of our system by utilizing use cases, sequence diagrams, and class diagrams. These visual depictions will illustrate the various functionalities and interactions within the system, thereby enhancing our understanding of its operation. Through these diagrams, we can gain a clearer picture of how the system functions and how different components interact with each other.

3.5.1 Use case diagram of the smart feeding system

In this subsection, we present the use case diagram for the "Smart Feeding system"

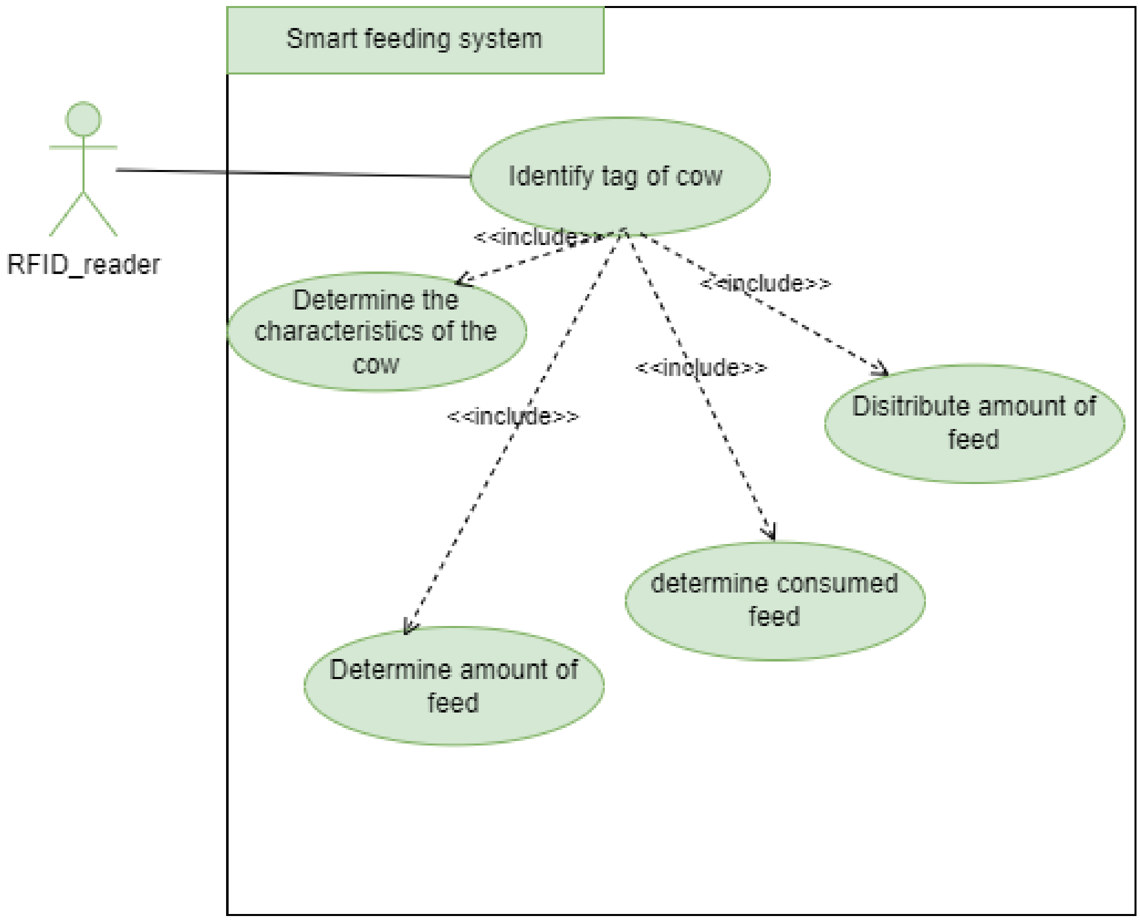


Figure 3.5: Use case diagram of the smart feeding system.

Use Case	Smart feeding System
Actor	RFID Reader
Objective	Determining the appropriate amount of feed based on characteristics of cow
Precondition	None
Scenario	Identify the tag of the cow Determine the characteristics of the cow. Determine the amount of feed. Distribute the amount of feed. Determine the consumed feed.

Table 3.1: Description of Smart feeding System system Use Case

3.5.2 Use case diagram of the manual feeding system

In this subsection, we are going to present the use case diagram for the "Manual feeding system"

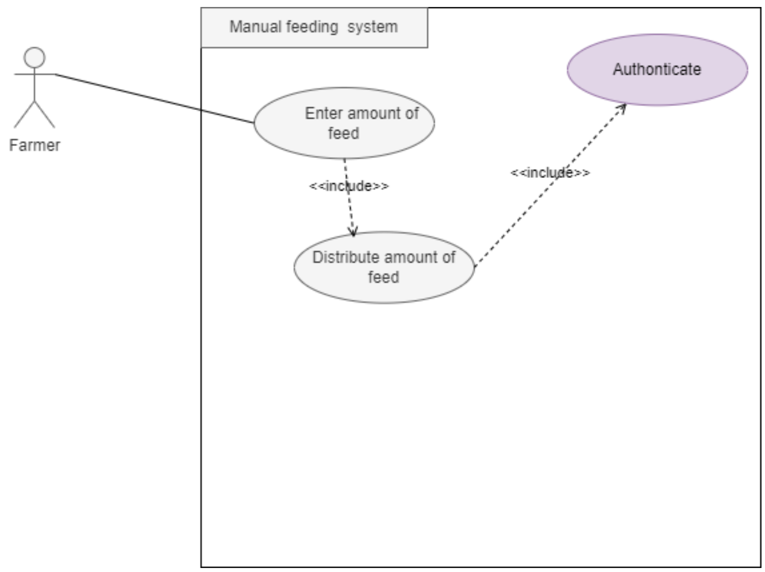


Figure 3.6: Use case diagram of the manual feeding system.

Use Case	Manual feeding System
Actor	Farmer
Objective	Determining the appropriate amount of feed using the control panel.
Precondition	Authenticate
Scenario	Enter the amount of feed. Distribute the amount of feed.

Table 3.2: Description of manual feeding system use case

3.5.3 Use case diagram of the system

In this subsection, we are going to present the use case diagram for the " Feed management system" .

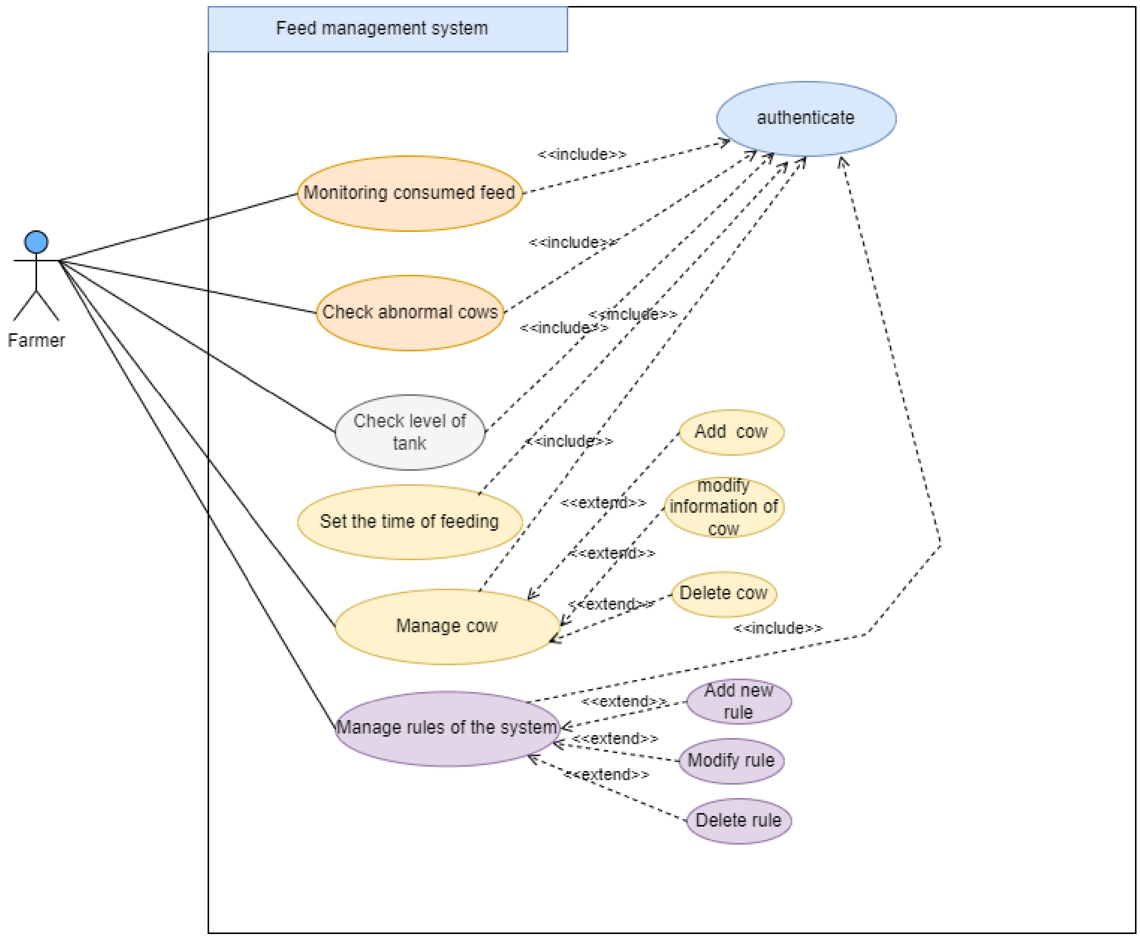


Figure 3.7: Use case diagram of the system.

Use Case	Feed Management System
Actor	Farmer
Objective	Monitoring feed consumed and configuration (setting feeding time, managing cows,and rules of the expert system).
Precondition	Authenticate
Scenario	- Monitoring consumed feed. - Check abnormal cows. - Check the level of the tank. - Set the feeding time. - Manage cows (add, modify, delete). - Manage rules (add, modify, delete).

Table 3.3: Description of the Feed Management System Use Case

3.5.4 Sequence Diagram: Smart Feeding

In this section, we present the sequence diagram for "Smart Feeding". The sequence diagram illustrates the interactions and flow of events among various components involved in the smart feeding process.

The diagram depicts the steps involved in determining the appropriate amount of feed based on the characteristics of the cow. It showcases how the RFID reader identifies the cow by scanning its tag, retrieves its characteristics from the database, and executes the rule-based expert system to determine the appropriate amount of feed. The diagram also illustrates the distribution of the amount of feed and storage of relevant values in the database (the consumed amount of feed, tank level, and amount of feed needed).

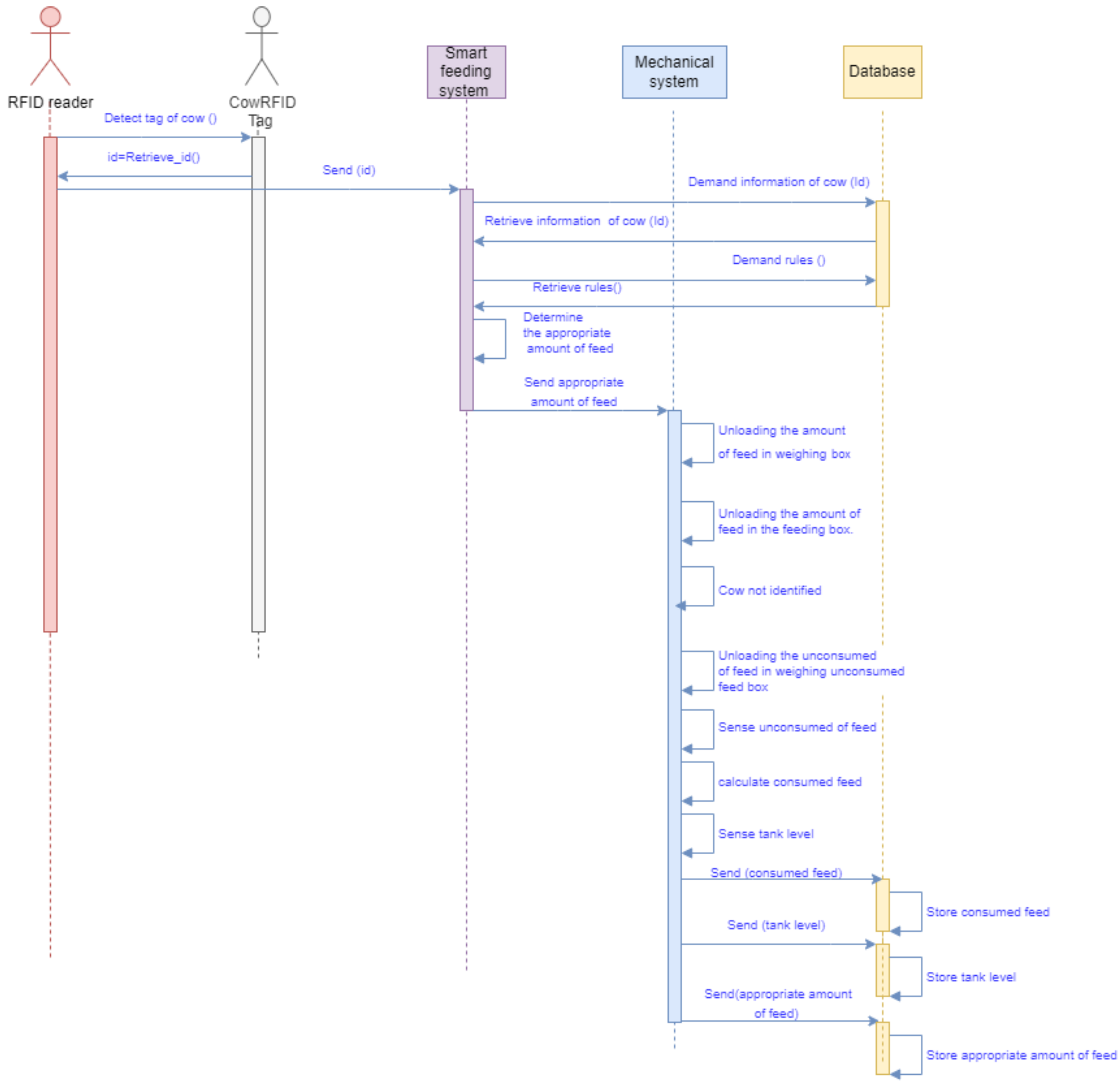


Figure 3.8: Sequence diagram of smart feeding .

3.5.5 Sequence Diagram: Configuration

In this section, we present the sequence diagram for the “Configuration” process, which includes various tasks that the farmer can perform, such as adding new cows, adding new rules, and setting the feeding time. The sequence diagram illustrates the interactions and order of actions between the farmer and the system during the configuration process. It provides a visual representation of how these tasks are executed and the flow of information within the system.

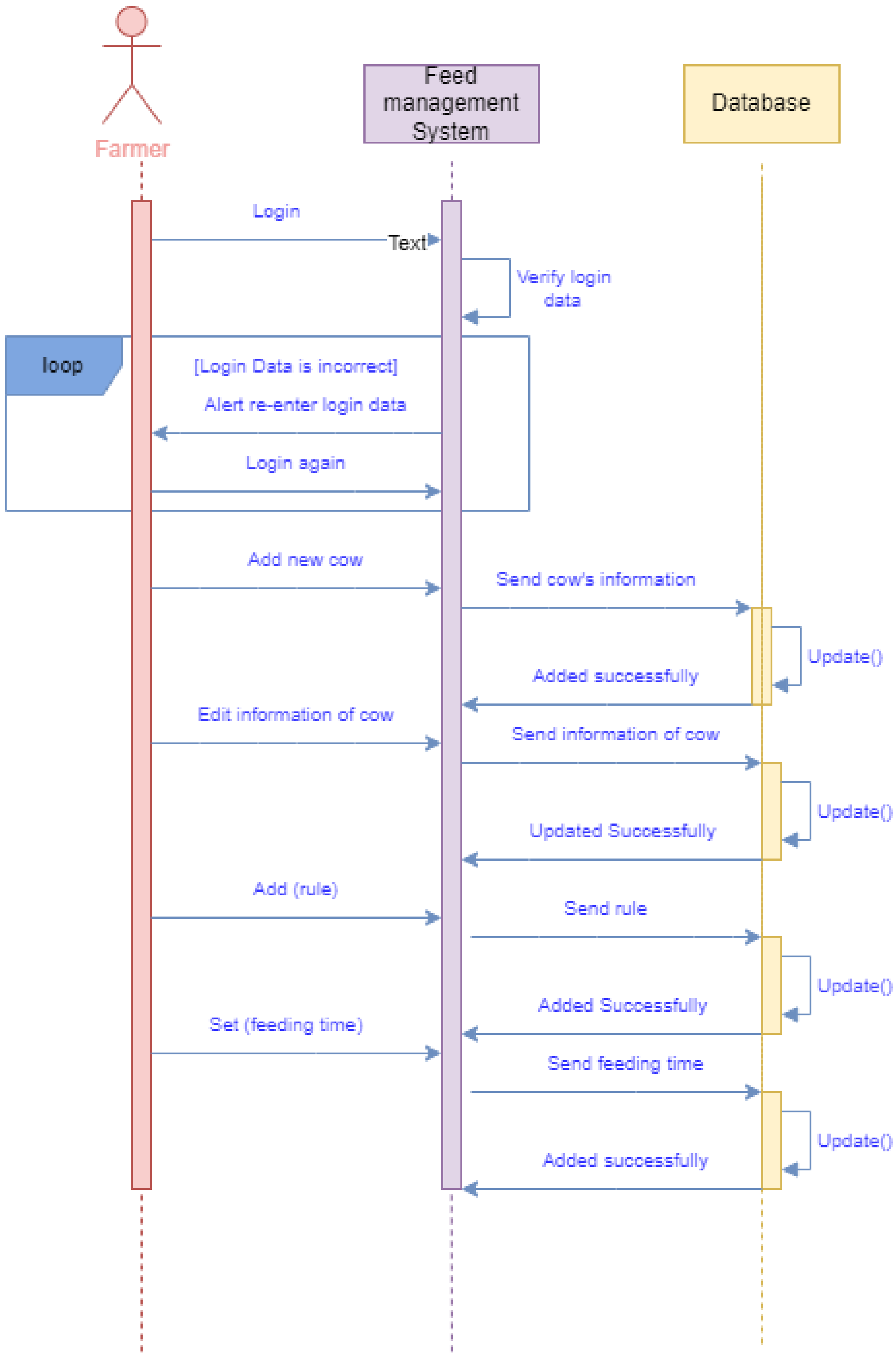


Figure 3.9: Sequence diagram of configuration .

3.5.6 Class diagram of the system

- **Farmer:**
  - The farmer class represents the farmers or owners of the cows in the system.
  - The farmer table includes attributes such as ID (an auto-incremented integer value), name, birthdate, email, phone, and address.
- **Feeder:**
  - The feeder class represents the feeding device.
  - The feeder table includes attributes such as ID (an auto-incremented integer value), tank level, and ID farmer (an attribute that establishes a reference to the Farmer table).
- **Cow:**
  - The cow class represents individual cows in the system.
  - The cow table can include attributes such as ID cow (an auto-incremented integer value), status, milk production, breed, weight, age, and ID farmer (attribute establishes a reference to the Farmer table)
- **Schedule Feed:**
  - The schedule Feed class represents the times of feeding cows.
  - The schedule Feed table includes attributes such as ID schedule feed (an auto-incremented integer value), feeding times, and num meal (first or second meal).
- **Feed consumed:**
  - The feed class represents the consumed feed for each cow.
  - The feed consumed table includes attributes such as ID feed consumed (an auto-incremented integer value), feed consumed, feed needed, date, status, ID cow (attribute establishes a reference to the cow table), ID schedule feed (attribute establishes a reference to the schedule feed table).

- **rules:**
  - The rules class represents the rules base of the system.
  - The rules table includes attributes such as ID rule (an auto-incremented integer value), condition, min value of the condition, max value of the condition, action (amount of feed), and the value of the action.
- **Abnormal cows:**
  - The abnormal cows class represents the list of cows that have not consumed the appropriate amount of feed within the week.
  - The abnormal cows table includes attributes such as ID (an auto-incremented integer value), and cow id (attribute establishes a reference to the cow table).

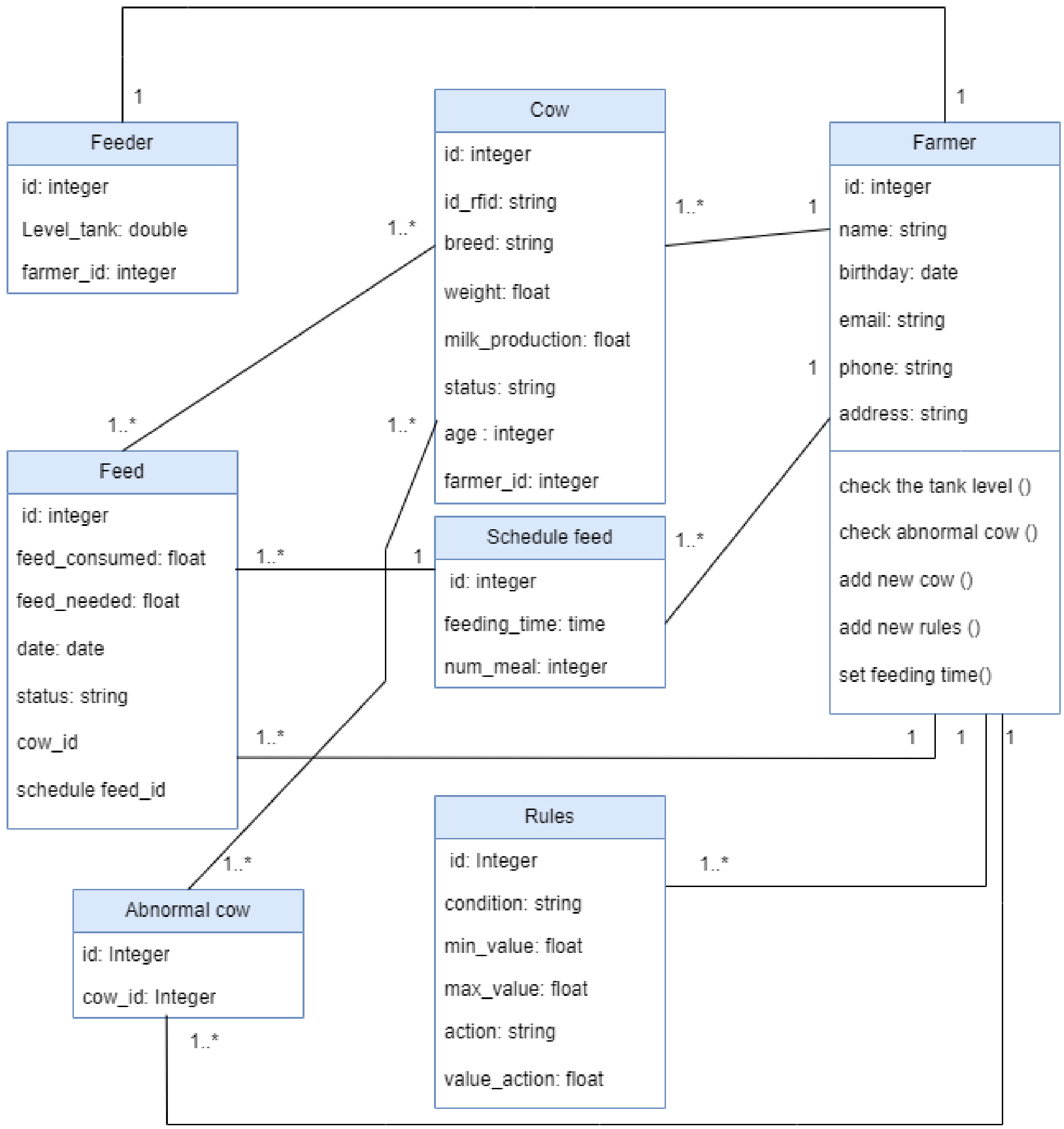


Figure 3.10: Class diagram of the system.

3.6 Conclusion

In this chapter, we have provided a comprehensive and detailed description of our solution. We began by introducing the general architecture of the system, emphasizing its main components. Then, we delved deeper into a detailed architecture, where each component was thoroughly explained, along with the relevant algorithms. To make it easier to understand, we used flowcharts and diagrams, such as use case , sequence diagrams, and class diagrams to showcase the system's functionality.

In the next chapter, we are going to represent the implementation of the smart cow feeder .

Chapter 4

Implementation

4.1 Introduction

After thoroughly explaining the architecture of the smart cow feeder system and outlining the core concept of our solution in the previous chapter, this chapter emphasizes the practical implementation of the project. We begin by introducing the hardware and software tools employed in the project. Subsequently, we showcase the results obtained through a collection of screenshots and pictures.

4.2 Hardware tools

In this section, we are going to introduce the hardware used tools in the prototype.

4.2.1 Raspberry Pi

The Raspberry Pi, created by the Raspberry Pi Foundation, is a highly popular electronics prototyping platform aimed at teaching computer science and programming to students in developing countries. It is a credit card-sized, low-cost, and low-power single-board computer that can connect to various sensors, LCD displays, servos, and motors. With 40 GPIO pins, it can serve as a control center for complex projects like robotics and autonomous vehicles. The Raspberry Pi runs on a Broadcom BCM2835 SoC, housing a 700MHz ARM processor and video core 4 GPU. It has a wide range of applications, including web servers, IoT hubs, sensor and industrial equipment control, automated systems, and data processing. The Raspberry Pi OS, based on Linux, provides a secure and stable environment. Programming options include Python, C/C++, Java, Scratch, and more. The Raspberry Pi offers an exceptional platform for learning programming and building electronics projects [24].

The Raspberry Pi 2 Model B is an upgraded version of the Raspberry Pi, featuring 1 GB of RAM, an Ethernet port, HDMI output, audio output, RCA composite video output (via the 3.5 mm jack), and four USB ports. It also includes 0.1" spaced GPIO pins, providing connectivity for general-purpose input and output functions [44].

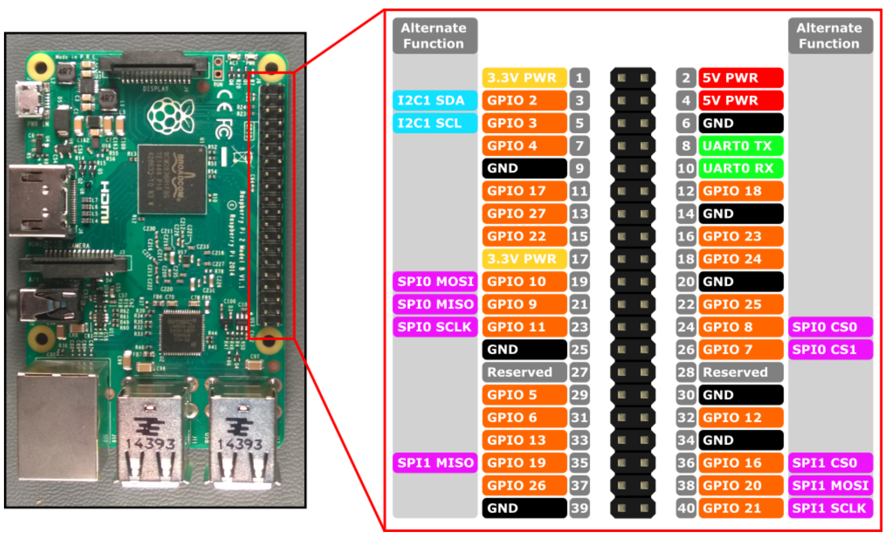


Figure 4.1: The Raspberry Pi model 2 GPIO pinout [43].

4.2.2 Ultrasonic Distance Sensor (HC-SR04)

The HC-SR04 ultrasonic sensor uses sonar to determine the distance to an object. This sensor reads from 2cm to 400cm (0.8inch to 157inch) with an accuracy of 0.3cm (0.1inches), which is good for most hobbyist projects. In addition, this particular module comes with ultrasonic transmitter and receiver modules.

The ultrasonic sensor emits a high-frequency sound wave (40 kHz) that travels through the air. When it encounters an object, the wave reflects back to the sensor module, where it is captured by the receiver as an echo. By measuring the time it takes for the sound wave to travel to the object and back, the sensor calculates the distance [8].

Figure 4.2 shows the HC-SR04 ultrasonic sensor.

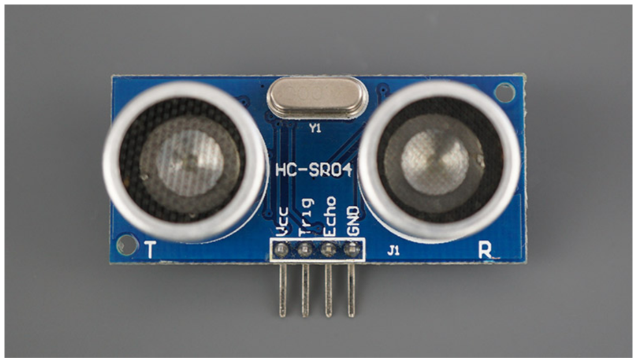


Figure 4.2: The HC-SR04 ultrasonic sensor [8].

4.2.3 Servo Motor Micro SG92R

The Servo Motor Micro SG92R is an upgraded version of the popular SG90 micro servo, featuring improved gears and torque. Its key features include very small micro size, POM with carbon fiber gears, stall torque up to 2.5 kg-cm, and 180-degree rotation. This servo motor is suitable for basic servo experimentation and applications where small size and moderate torque are required. The motor's gears are made of durable POM plastic with carbon fiber particles.

The servo motor comes with a built-in 3-pin female connector for easy connection, with the pins assigned as follows: brown for ground, red for 5V power, and orange for the PWM signal [46]. The Servo Motor Micro SG92R is shown in figure 4.3.

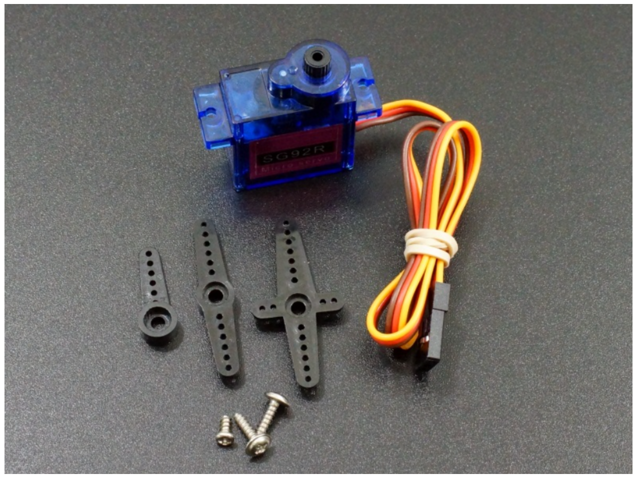


Figure 4.3: The Servo Motor Micro SG92R [46].

4.2.4 Load cell

Load cells are highly accurate transducers that are designed to sense force or weight in various conditions. They are crucial components in electronic weighing systems but can also be vulnerable. Load cells operate based on the strain gauge principle, where strain gauges are attached to force sensor elements. When force is applied, the element deflects, causing the strain gauge to stretch or compress. The ability of a load cell to accurately measure weight relies on its repeatability in deflection when load is applied or removed. Installing mechanical overload stops can be beneficial in applications to prevent excessive deflection [32].

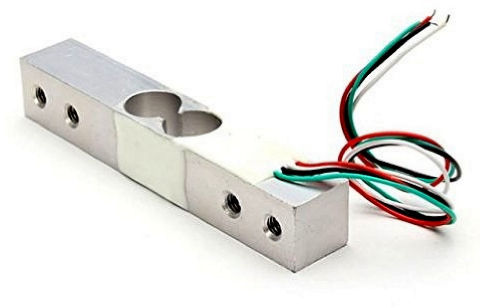


Figure 4.4: The load cell sensor [34].

4.2.5 Load Cell Amplifier - HX711

The HX711 Dual-Channel 24 Bit Precision A/D weight Pressure Sensor Load Cell Amplifier and ADC Module is a small device that helps you measure weight accurately. It works by connecting the module to your microcontroller and reading the changes in resistance from a load cell. With calibration, you can get very precise weight measurements.

This module is useful for various applications such as creating industrial scales, process control systems, or simple presence detection [33].

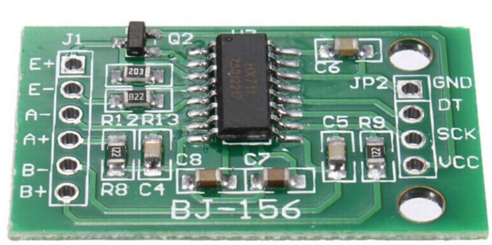


Figure 4.5: The HX711 module [33].

4.2.6 RC522 RFID Reader/Writer Module

The RC522 RFID Reader/Writer Module, also known as a transceiver, is built around an integrated circuit called MFRC522 from NXP Company. It operates at a frequency of 13.56 MHz and enables contactless communication. RFID stands for Radio Frequency Identification.

This module uses radio frequency electromagnetic waves to transfer data, both for reading and writing purposes. It supports various types of transponders, including RFID card tags and key fob tags, as long as they have a memory capacity of 1KB and operate at 13.56 MHz frequency. The module itself is small, inexpensive, and operates at low voltage. It utilizes the SPI protocol, allowing it to easily connect with a wide range of microcontrollers such as ATTiny, Arduino, ESP8266, Raspberry Pi, and other advanced development boards [51].

Figure 4.6: The RC522 RFID Reader/Writer Module [51].

4.2.7 16x2 I2C LCD

The 16x2 I2C LCD Display Module with Yellow Backlight is a display module that can show 2 lines of 16 characters each. It uses the I2C interface to communicate with the microcontroller that controls it. This LCD module is a cost-effective option for projects that require text, data, or ASCII character display.

To connect this module, you will need to provide power (Vcc and Gnd) and connect the serial data line (SDA) and serial clock line (SCL). It operates at 5VDC and is typically assigned the I2C bus address 0x27 or 0x3F, depending on the configuration [1].

Figure 4.7: The 16x2 I2C LCD Display Module with Yellow Backlight [1].

4.2.8 Keypad 3x4 Matrix - Membrane

The keypad has a Phone-style design and includes 12 numeric buttons. It is made of durable hard plastic with solid buttons that provide tactile feedback. The buttons are arranged in a matrix, requiring only 7 microcontroller pins (3-columns and 4-rows) for connection [28].

Figure 4.8: The Keypad 3x4 Matrix - Membrane [28].

4.3 Software tools

In this section, we aim to provide a comprehensive overview of the software used in the development of our system. We will introduce the development environments, programming languages, and various tools that were crucial for the system's development process.

4.3.1 XAMPP

XAMPP is a software package that provides a convenient and easy-to-use environment for testing websites and web applications.

It consists of several components, each represented by a letter in the acronym XAMPP. X stands for Cross-Platform, meaning it can be used on different operating systems like Windows, Linux, and macOS. A represents Apache, which is a popular web server. M stands for MariaDB, a database management system similar to MySQL. Finally, the two Ps stand for PHP and Perl, which are scripting languages used for web development.

Together, XAMPP allows developers to set up a local server on their own computer to test and debug their web projects before deploying them to a live server [53].

4.3.2 Bootstrap

Bootstrap is a highly popular framework for building responsive and mobile-friendly websites. It's a free tool that encompasses HTML, CSS, and JavaScript, making web development faster and easier. Bootstrap provides pre-designed templates for various elements like typography, forms, buttons, tables, navigation, modals, and image carousels. It also supports JavaScript plugins. One of its main advantages is enabling the creation of responsive designs that adapt well to different screen sizes [50].

4.3.3 MySQL

MySQL is a highly popular and widely used open-source database management system. It is known for its speed, scalability, and user-friendly nature. MySQL is often used in conjunction with PHP scripts to develop powerful and dynamic server-side or web-based applications. It allows for efficient management of relational databases, providing features like table operations, relationships, referential integrity, and automatic index updates. MySQL supports multiple operating systems and programming languages such as C, C++, and Java. Its SQL queries enable the retrieval and manipulation of data from multiple tables, facilitating effective information retrieval for end-users [35].

4.3.4 PHP

PHP (Hypertext Preprocessor) is an open-source, server-side scripting language mainly used for web development. It is interpreted and object-oriented, making it versatile and easy to learn. PHP handles dynamic content, database management, and session tracking for websites. It supports protocols like HTTP, POP3, SNMP, LDAP, and more. PHP offers features such as form handling, data encryption, validation, and user access control. Its simplicity, performance, and open-source nature contribute to its popularity among developers. PHP executes scripts quickly and efficiently, and its source code is freely available for customization and development [39].

4.3.5 SQL

SQL, which stands for Structured Query Language, is a database language used for managing and manipulating data in relational database management systems (RDBMS). It allows users to create, modify, and retrieve data from databases, as well as define structures and constraints. SQL has become the standard for working with structured data and is widely used in data science and analytics. It provides capabilities for inserting, updating, deleting, and retrieving data, as well as defining views, stored procedures, and permissions. SQL was initially developed by IBM researchers in the 1970s and has evolved into a powerful and widely adopted language for working with relational databases [47].

4.3.6 HTML 5

HTML stands for Hyper Text Markup Language, is a markup language used for designing web pages. It defines the structure and layout of web content. HTML 5, the latest version, has introduced new features and APIs, including support for multimedia elements like audio and video, vector graphics, and semantic content tags. It enables drag and drop functionality, geolocation services, and offline data storage using SQL databases. HTML 5 also allows for drawing shapes and provides simplified syntax for declaring doctype and character encoding. It is widely used for creating web pages and provides enhanced capabilities for creating dynamic and interactive web experiences [23].

4.3.7 CSS3

CSS, or Cascading Style Sheets, is a language used to style and format web pages by controlling the appearance of elements. It provides properties for colors, layouts, backgrounds, fonts, and borders, enhancing content accessibility and allowing for visual customization. CSS3, the advanced version, introduces additional features for structuring and formatting web pages, and is supported by modern browsers. It modularizes CSS standards for easier learning and usage [11].

4.3.8 Visual Studio

Visual Studio is a versatile Integrated Development Environment (IDE) developed by Microsoft. It enables the development of various applications such as GUI, console, web, mobile, cloud, and web services. It supports multiple programming languages, including C sharp, C++, VB, Python, and JavaScript, among others. Visual Studio has evolved since its initial release in 1997 as Visual Studio 97, with the latest version being Visual Studio 2017 (15.0). It is available for both Windows and macOS platforms and provides extensive support for Microsoft software development platforms [25].

4.3.9 Thonny

Thonny is a free Integrated Development Environment (IDE) specifically designed for beginners learning Python. It offers several features to support the learning process, including code autocompletion, bracket matching, error highlighting, and a simple debugger. Thonny's debugger allows users to step into function calls, providing information about local variables and displaying the code pointer. Additionally, Thonny provides an easy interface for installing packages, making it beginner-friendly and suitable for those new to programming [52].

4.3.10 JavaScript

JavaScript (JS) is a popular, lightweight, and object-oriented programming language used for scripting web pages. It enables dynamic interactivity on websites and allows for building modern web applications without reloading the page. Introduced in 1995, JS is supported by all major web browsers and has no direct connection with the Java programming language. It follows a syntax similar to C and is known for its weak typing and prototype-based inheritance. JavaScript is a versatile language that provides users with control over web browsers and is compatible with various operating systems [26].

4.3.11 Python

Python is a high-level, interpreted programming language known for its emphasis on code readability and significant indentation. It supports multiple programming paradigms, including procedural, object-oriented, and functional programming. Python's dynamic typing and garbage collection contribute to its ease of use. Guido van Rossum initiated the development of Python in the late 1980s, and it has since undergone major releases, including Python 2.0 and Python 3.0. Python 2 was discontinued in 2020. Python consistently maintains its position as one of the most popular programming languages [41].

4.4 Presentation of website interfaces

In this section, we are going to present the interfaces of the website in the form of screenshots. these interfaces are the following:

4.4.1 Login page

First, when we start our server, the first page that appears is the login page (Figure4.9) In this page, we can see :

1. The logo of the website.
2. Is an input for the email of the farmer.
3. Is an input for the password.
4. Button for logging into the system.

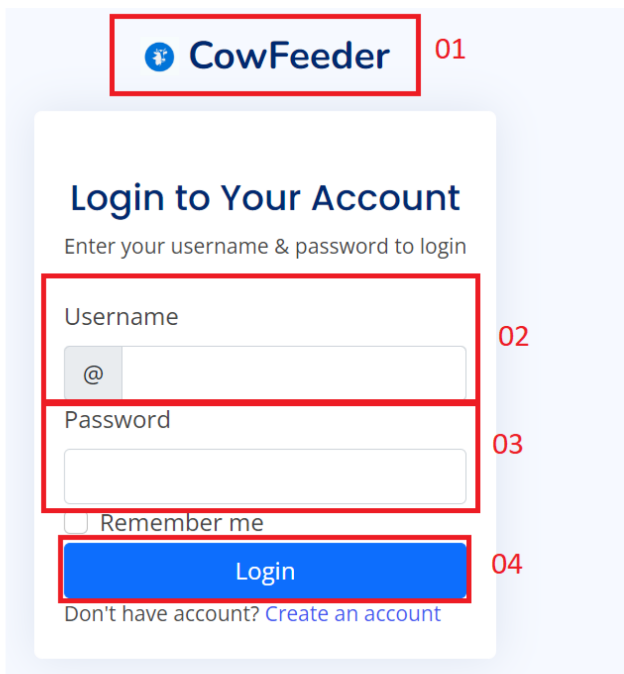


Figure 4.9: Login page.

4.4.2 Dashboard

After the login page, the dashboard page will appear, the system has only one admin. this page has two parts :

a. It shows the general information as the count of normal cows and abnormal cows that have not consumed the appropriate amount of feed within a week.

- When clicking on 'Show All', the page Figure 4.11 will display a list of abnormal cows along with relevant data about the consumed feed.
- When Clicking on the 'more details' button will provide additional information Figure4.12 about each abnormal cow.

b. Information about the current cow (cow detected). It contains:

1. It shows the ID and breed of the currently detected cow through RFID.
2. It shows the recent amount of feed consumed by the detected cow.
3. It shows factors such as the amount of production milk and the weight, and age of the cow. These factors play a crucial role in determining the appropriate amount of feed for the cow. 4.10
4. It shows the amount of feed consumption of the detected cow is represented in the form of a graph within a week Figure 4.13.
5. It shows the level of the tank Figure 4.14.

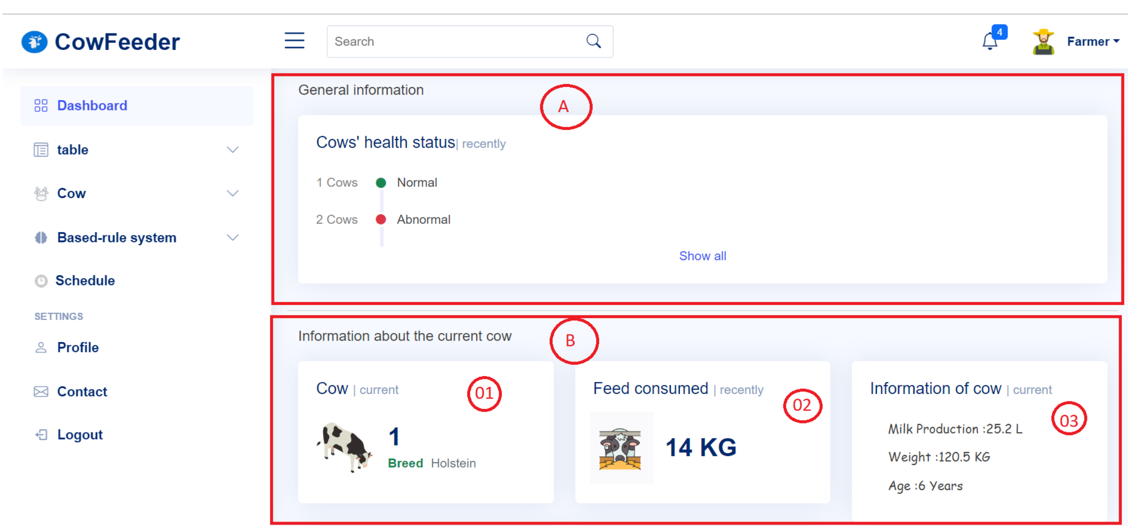


Figure 4.10: Dashboard.

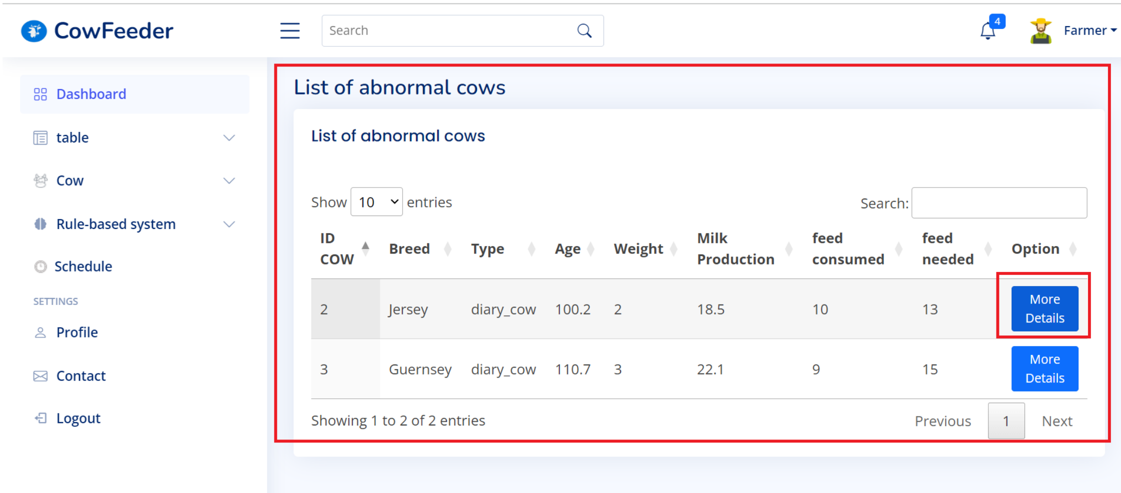
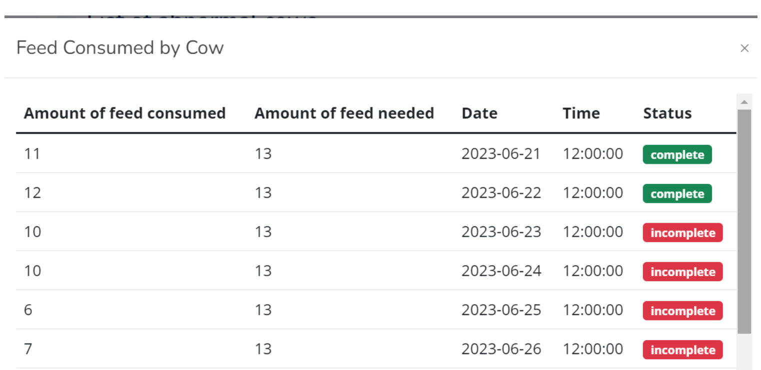


Figure 4.11: Abnormal cow page.

Figure 4.12: List of information of abnormal cow.


Feed Consumed by Cow

Amount of feed consumed	Amount of feed needed	Date	Time	Status
11	13	2023-06-21	12:00:00	complete
12	13	2023-06-22	12:00:00	complete
10	13	2023-06-23	12:00:00	incomplete
10	13	2023-06-24	12:00:00	incomplete
6	13	2023-06-25	12:00:00	incomplete
7	13	2023-06-26	12:00:00	incomplete

Figure 4.13: The amount of feed consumption in the form of a graph.

Figure 4.14: The level of the tank.

4.4.3 Table: feed consumption page

This page Figure 4.15 contains :

1. It provides options to export the consumption feed list as a PDF or CSV file, as well as the ability to print it.
2. It shows all the data related to the consumed feed from all cows.

4.4.4 Cow: list page

- This page shows the all cows with relevant information Figure 4.16.
- It has buttons :
  1. **Add button** It shows the form for adding new cow Figure 4.17
  2. **Edit button** It shows the form for editing cow information Figure 4.18
  3. **Delete button** It shows the alert message before deleting cow4.19

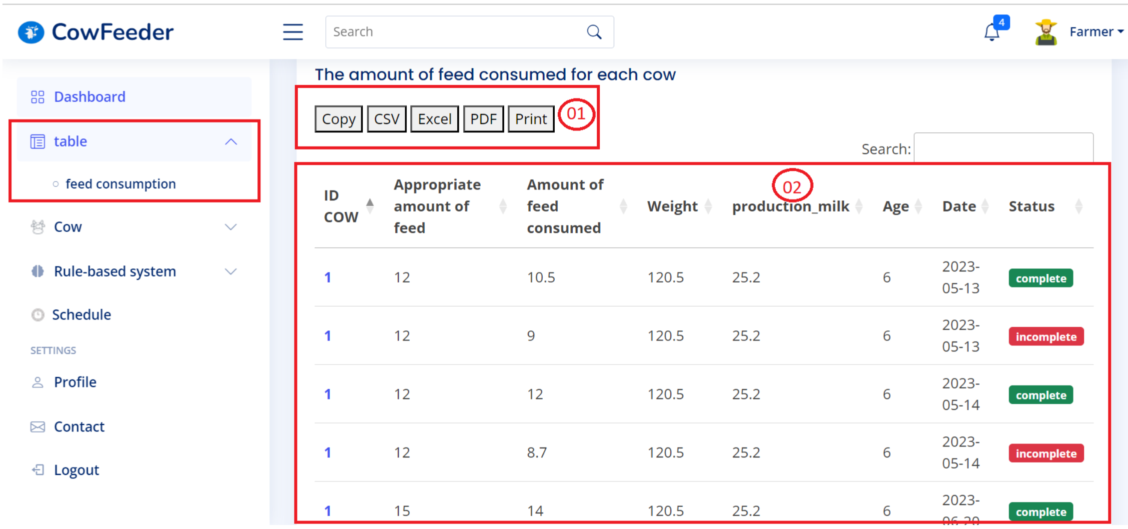


Figure 4.15: Table page: feed consumption.

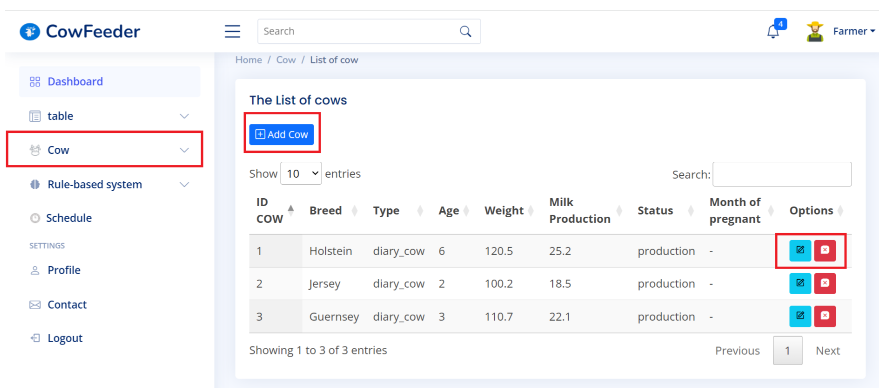


Figure 4.16: Cow page.

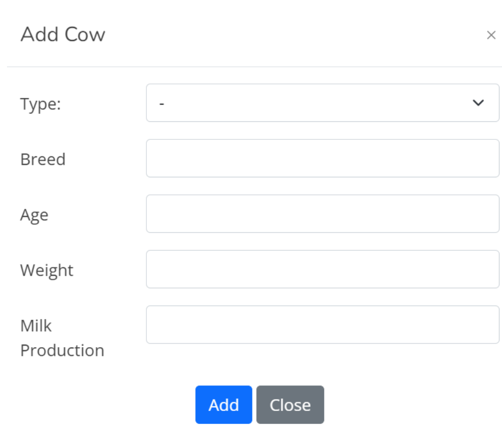


Figure 4.17: Add new cow.

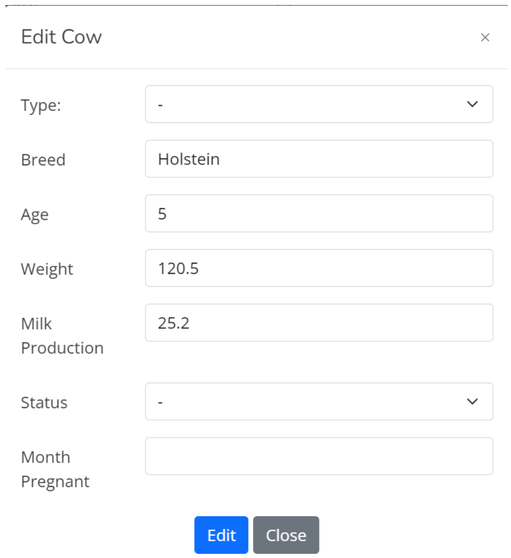


Figure 4.18: Edit information of cow.

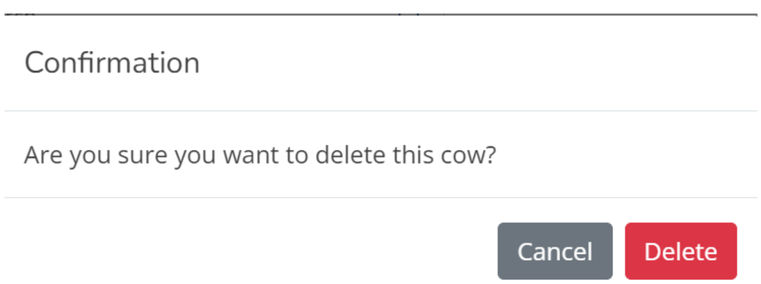


Figure 4.19: Alert message.

4.4.5 Rule-based system : rules page

- This page shows the expert system rules to determine the feed amount Figure 4.20.

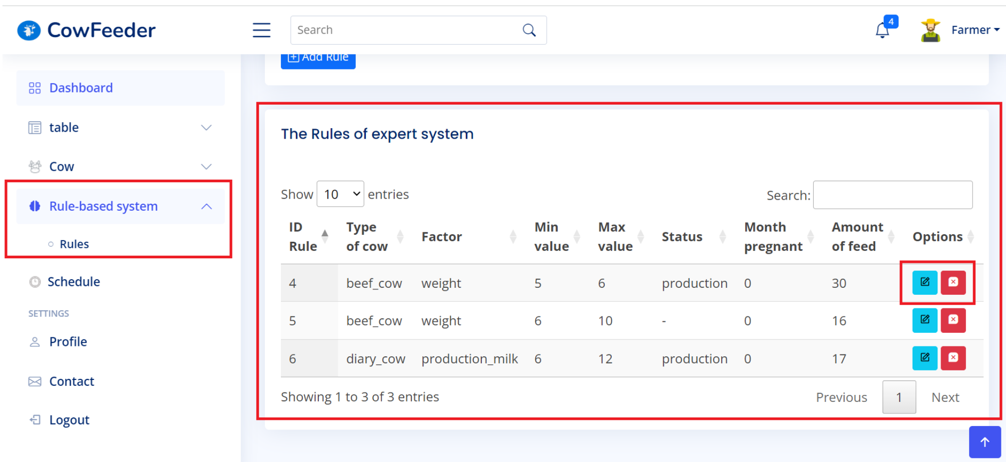


Figure 4.20: Expert system page.

- Has buttons:

1. **Add rule:** shows the form for adding a new rule Figure 4.21
   Also, when selecting the factor dairy cow, it will display a new field relevant to it for adding rules with precision, Figure 4.22.
2. **Edit rule:** Shows the form for editing a rule. Figure 4.23
3. **Delete rule:** Shows alert message before deleting a rule Figure 4.24

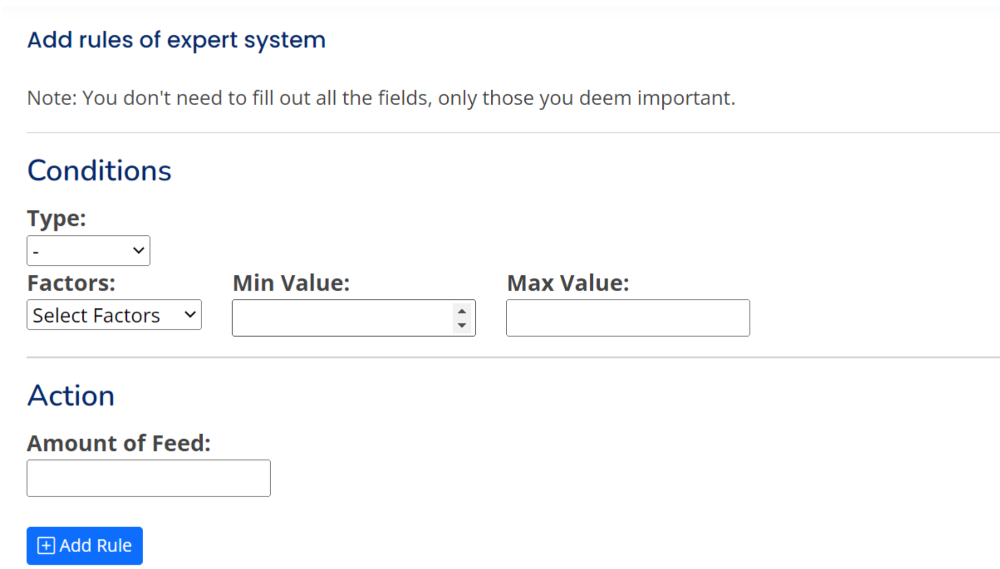


Figure 4.21: Add rule .

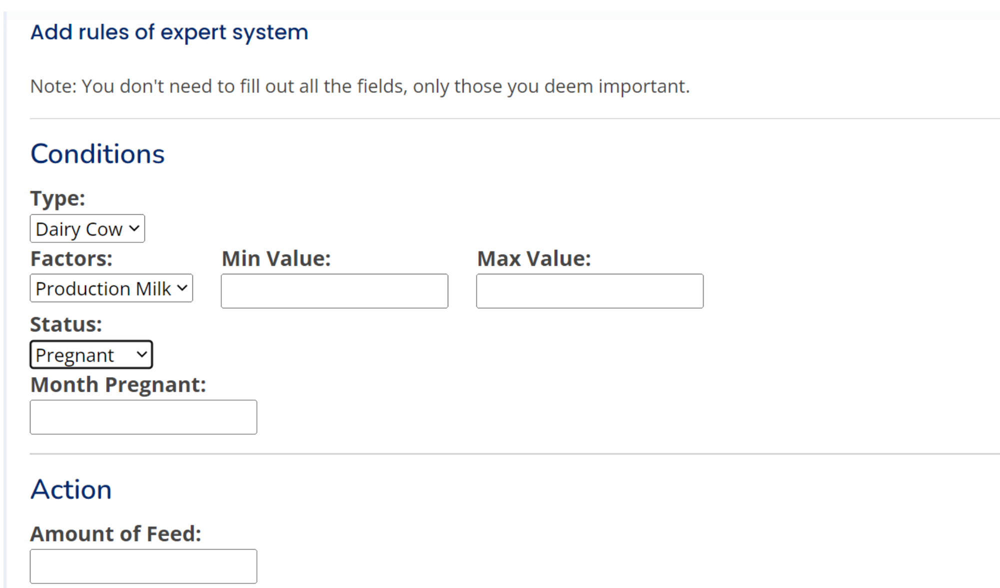


Figure 4.22: Add rule .

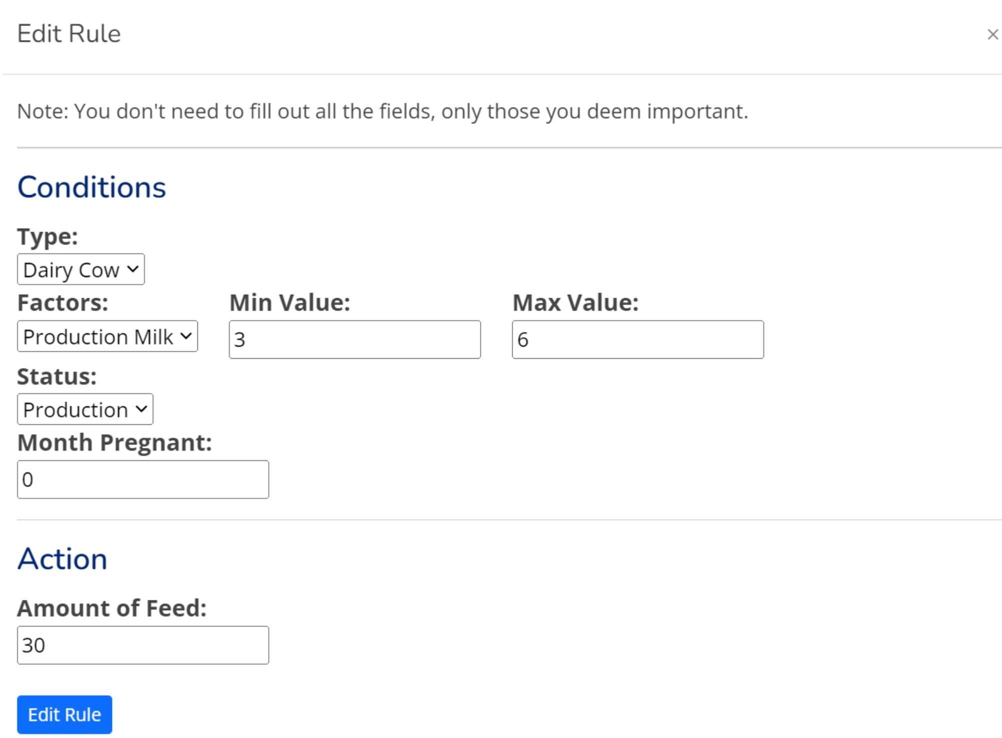


Figure 4.23: Edit rule .

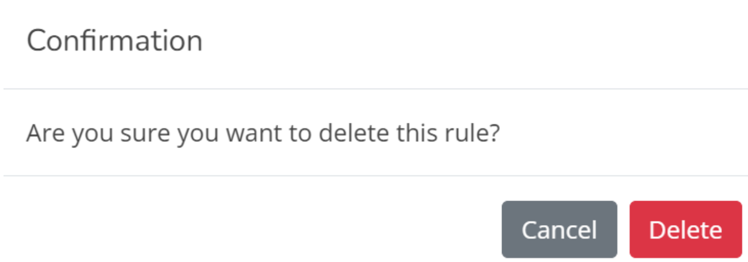


Figure 4.24: Delete rule .

4.4.6 Schedule page

This page shows the form to set time of feeding Figure 4.25.

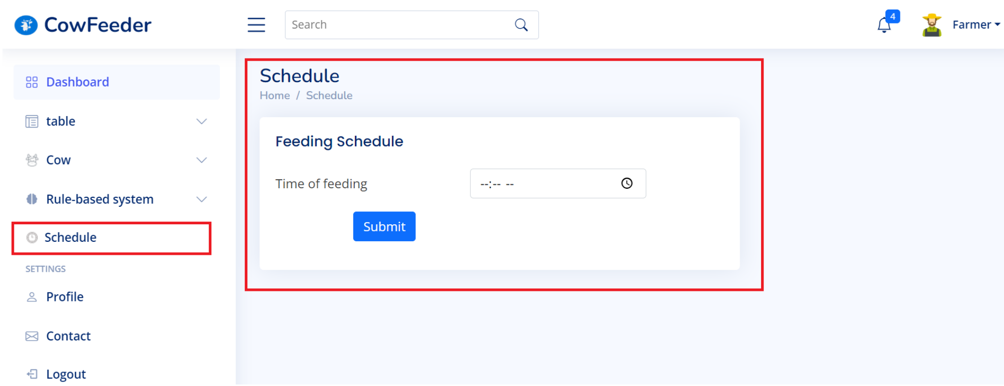


Figure 4.25: Schedule page

4.5 The smart cow feeding system prototype

4.5.1 The prototype design

The feeding system that we proposed comprises four individual feeding stations, all installed on a central structure where each station has its own set of necessary components for its operation.

To ensure the viability and assess the feasibility of our design, we utilized Solidworks, a design and testing tool. Through Solidworks, we were able to simulate and evaluate the functionality of the design, as well as its compatibility with real-world implementation. This comprehensive process ensured that our design met the required specifications and could be implemented. Figure 4.26 illustrates the design of the proposed feeding system.

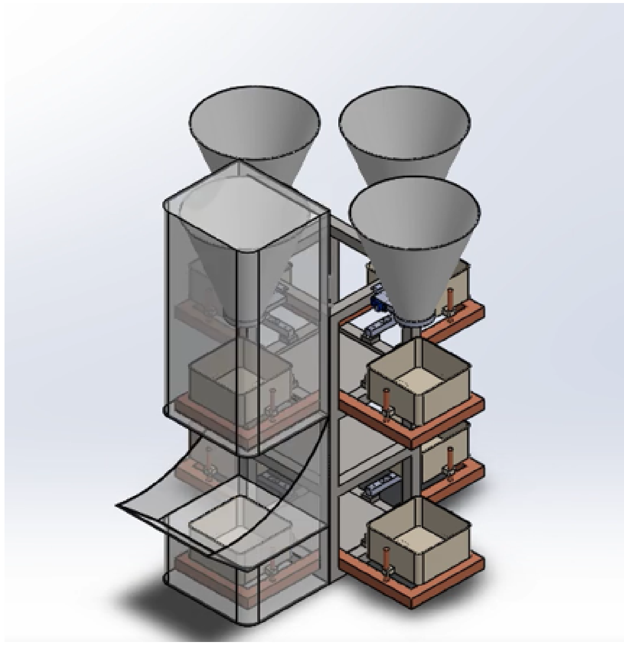


Figure 4.26: The 4 in 1 feeder design.

4.5.2 The prototype implementation

4.5.2.1 The mechanical system

As a prototype, we implement only one feeding station. The prototype comprises a main chassis designed to support and fix the various components of the feeding system (part 1 in figure 4.27). These components include the tank, cover, food box, and weighing boxes. All parts of the model were made of wood except for the cover, that made of forex. A detailed description of the model will be provided below:

1. **The feed storage and unloading**

   This section encompasses a tank, a weighing box, and an upper cover, representing parts 2, 3, and 4, respectively, as depicted in Figure 4.27.

   - The tank is equipped with an HC-SR04 sensor to monitor the food level inside it. It also has a servo motor connected to a sliding door, which enables the discharge of feed into the weighing box.

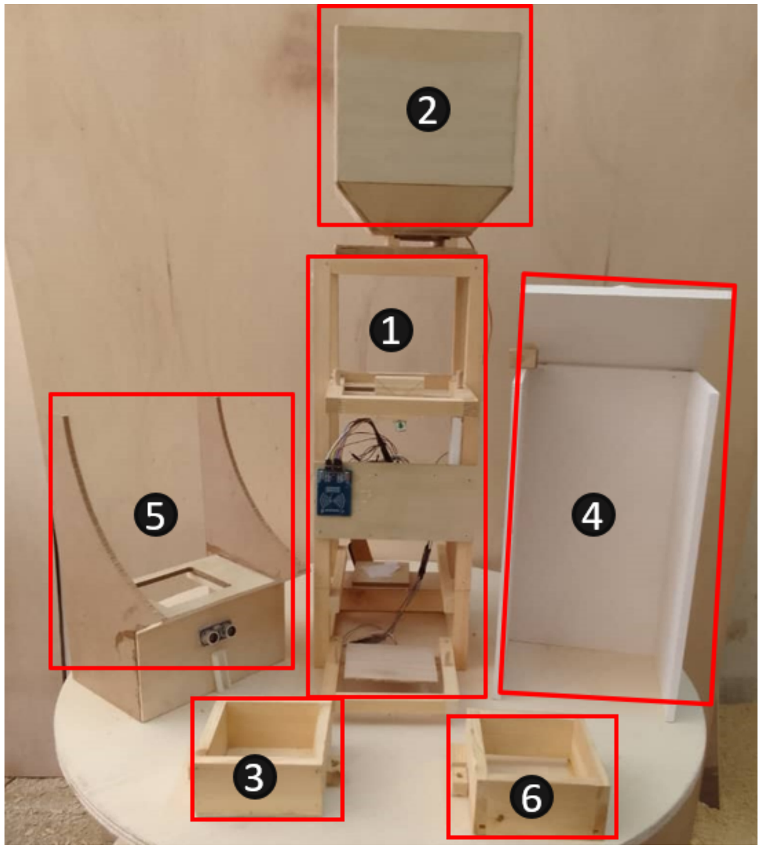


Figure 4.27: The prototype design.

- The weighing box is equipped with a load cell positioned below it to accurately measure the amount of feed dispensed from the tank. The box is designed with a sliding door base, which is operated by a servo motor, to facilitate the unloading of feed into the eating container.
- The upper cover has a dual purpose: it serves to cover and secure both the tank and weight box. Furthermore, the cover also functions as a manual control panel. Additionally, it provides a convenient means for the farmer to fill the tank.

2. **The feeding container**

   This section primarily comprises a feeding box and a weighing box for unconsumed feed , denoted as parts 5 and 6, respectively, in Figure 4.27.

   - The feeding box is designed to be comfortable, safe, and suitable for cows. It is equipped with an RC522 RFID module and the HC-SR04 sensor for cow identification and detection. the box base is a sliding door that is driven by a servo motor, allowing it to for unloading feed into the weighing box.

- The weighing unconsumed feed box is equipped with a load cell, to track the remaining food weight in order to monitor whether the cow has eaten.

3. **The manual control panel**

   The manual control panel, located in the upper cover, which is an LCD and keypad, this section allows the farmer to control the feeding system by entering the desired amounts of feed. This section is utilized in the following scenarios:

   - In the case of an RFID system malfunction.
   - For feeding cows whose RFID tag information has not been updated.
   - For feeding cows that do not have RFID tags.

Figure 4.28 shows the prototype setup.

Figure 4.28: The prototype setup.

4.5.3 Material Connection

Figure 4.29 depicts the schematic diagram of the smart feeder system, which was plutted using the Fritzing tool. The diagram includes two HC-SR04 sensors, two load cells accompanied by two HX711 amplifier modules, three servo motors, an RC522 RFID module, an LCD, and a keypad. These components are connected to the Raspberry Pi 2.

Regarding the power supply, the Raspberry Pi provides power to all the system components, while the motors are powered externally.

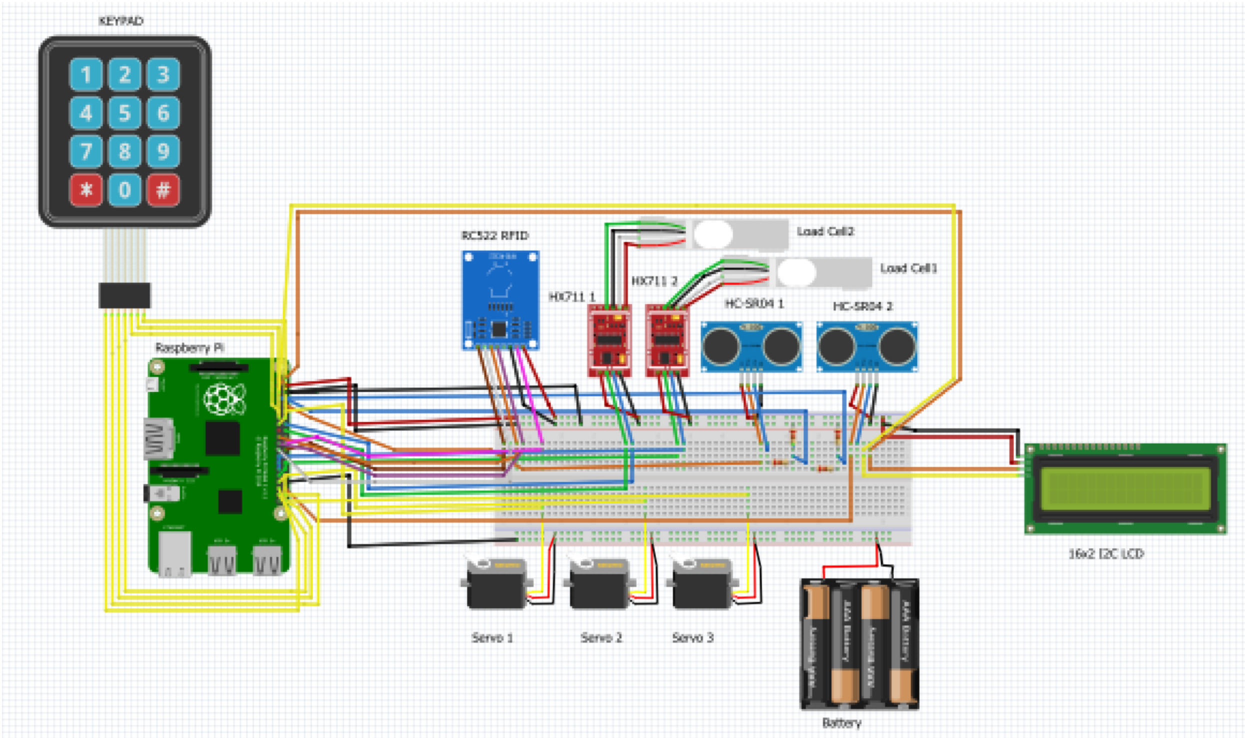


Figure 4.29: The schematic diagram.

4.6 Conclusion

In This chapter, we presented the implementation of our solution. Firstly, we introduced the software tools and materials utilized. Then, we provided a detailed presentation of the administration dashboard, describing each page individually. Lastly, we provided an explanation of the smart cow feeder prototype.

General conclusion

In Algeria, the agriculture sector faces substantial challenges when it comes to feeding cows using traditional methods. The lack of precise measurements to determine the optimal feed quantity for each cow can have negative impacts on their health and overall productivity. Therefore, it is crucial to embrace the digitization of the agriculture sector.

To tackle these challenges, we propose the implementation of the smart cow feeder. This solution aims to address the limitations of traditional feeding methods and actively contribute to the digitization of the agriculture sector in Algeria

The smart cow feeder utilizes RFID technology to identify cows and collect their individual characteristics. This valuable information is then used within a rule-based system to accurately determine the optimal amount of feed required for each cow. Through this process, the feeder automatically distributes the feed accordingly. Additionally, our solution encompasses a feed management system that enables continuous monitoring of feed consumption and allows configuration of the feeder. This approach ensures efficient and precise feeding practices for enhanced cow health and productivity

Furthermore, the data collection system integrated into the smart cow feeder plays a crucial role in storing essential information regarding cow feeding. This data not only provides valuable insights into the feeding patterns and requirements of each cow but also lays the foundation for future advancements.

Future work: We aim to leverage artificial intelligence (AI) techniques to enhance our system. By analyzing the extensive data collected from this system, we intend to develop a model that can accurately determine the optimal feed quantity based on historical consumption data and other relevant factors. This AI-driven approach will enable us to make informed decisions and optimize feed allocation for improved efficiency and productivity.

Participation in events

- This project took part in a competition during the scientific week dedicated to artificial intelligence at the service of the community. (our project won first place in this competition.)

- Our project has been presented in the presentation of the most important advanced projects in the completion process, within the framework of a university degree, start-up/patent. (our project won in the top 10 in this event.)

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