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Development of a Computerized Automated System for Feed, Water and Sanitation Management in Animal Farms

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Authors' contributions

This work was carried out in collaboration among all authors. Author JKT designed the study, supervised the research, wrote the protocol. Author MNWE wrote and executed the computer program likewise the first draft of the manuscript. Author JNN aided in the fabrication of the prototype and managed the analyses of the study. Author MNWE managed the literature searches during his PHD study. All authors read and approved the final manuscript.

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ABSTRACT

Frequent visits into animal farms either for cleaning, feed or water dispensation are a possible means of viral, and bacteria propagation into and out of the farms. The need for these visits compels the farmer to live in the farm and devote considerable time to these activities. A well-controlled automatic feed dispensation/water management system can considerably reduce labor and prevent frequent farm visits. This can in turn promote social distancing especially during the outbreak of epidemics. A solar energy powered automatic system for feed, water dispensation and sanitation management was developed for animal farms. It was made up of an Arduino UNO board, a water level/or feed sensor, a DS1307 Real Time Clock (RTC), two potentiometers, a buffer, an sim900 mini v3, a relay module for Arduino, a display (LCD) for visual monitoring of events. It was programmed to periodically command electric motors to release a desired quantity of feed and water into different troughs as well as open hydraulic valves to spray a jet of high pressure water to clean the enclosure. Required data was fed into the program by the farmer depending on the daily needs

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which in turn depend on the animal species, age and husbandry requirements. The system communicated with the farmer through a GSM card after each operation. Initial tests of the prototype revealed minimum of 83.33% efficiencies for all the units. The module was able to report to the farmer minutes after completing each task. It was concluded that such a system can considerably reduce labor in animal farms as well as disease propagation.

Keywords: Farm automation; feed management; farm energy management; cleaning automation; automatic animal husbandry.

1. INTRODUCTION

Livestock farming occupies an important place in the lives of the populations of the Central African sub-region in general and Cameroon in particular. In this region, beef cattle, dairy cattle, sheep, goats, pigs and poultry can be seen produced in both small scale and large scale farms as well as in domestic environment Despite the economic impact of this activity to the national economy, activities in this sector are still carried out manually using local labor and crude technology MINEPIA [1]. The consequence of this is the often poor quality of animal products, too much time allocated for animal husbandry, improper maximization of available resources, and frequent viral based epidemics. Daily visits to animal enclosures for cleaning, and feeding of animals exposes them to the communicable disease vectored by man Gianluigi et al. [2]. Because farmers are involved in other activities that take them to other locations and farms, the possibility of transporting diseases from other locations to their farm is very high. Guiliani et al. 2017, used data on veterinarian on-farm visits in a dairy farm system to build a simple simulation model to assess the role of indirect contacts on epidemic dynamics compared to cattle. Their study revealed the importance of detailed data and a deeper understanding of visit dynamics for the prevention and control of livestock diseases. Qihui et al. [3] investigated the impact of truck contamination and information sharing on foot-and-mouth disease spreading in beef cattle production systems. Their sensitivity analysis results showed that epidemic sizes are sensitive to variations in parameters of the contamination period for a truck as well as and indirect contact diseases transmission. At this time of the COVID pandemic and the importance of social distancing, the need to limit interactions with animals cannot be over emphasized. Diseases transmission in animal farms usually bring about serious losses. For example the foot and mouth outbreak in 2001 in the United Kingdom resulted in severe economic losses totaling more than £2.8 billion and required the slaughter of approximately 6.5 million animals Bernini et al. [4] while the same diseases in the United States could already cause up to USD $140 billion in damages by 2003, Bates et al. [5].

Breeding can be defined as a set of activities that ensure the multiplication of animals, for human use [6]. The various activities implemented for breeding are generally periodic, precise and routine like. The use of human labor gives room for errors in routine operations such as timing of cleaning, feeding and water supply. It also compels the farmer to live very close to the farm and to deal with the often obnoxious smells that emanate from the farm. Pet owners too are compelled to carry their pets along when going for holidays because of lack guaranteed follow up during their absence. The matter is more complicated when security dogs have to remain and guard the premises in the absence of the master. Inadequate cleaning can alter the micro environment leading to thermal stress resulting in low performance, mortality and economic losses [7-8]. The need for proper management of animal enclosures has been stressed. Daniel, N. A et al. [9], Jernej et al. [10], Landais E, Weisslinger H, [11].

Stray animals are relatively easier to manage than animals confined in an enclosure. While stray animals can move about and fend for themselves, confined animals must be attended to everyday. They have to be fed, watered and their enclosure has to be cleaned if proper sanitation is to be maintained. These activities are very time consuming and constrain the farmer to live either in the farm or very close to the farm to minimize the cost of transportation.

The main objective of this work was to improve on the efficiency of management of animal farms by automating, water and feed supply as well as cleaning of animal enclosures. Such a system was also expected to report to the farmer through short message service (SMS) after successfully carrying out each routine activity. Because of frequent power cuts in developing countries, limited access to electricity, likewise the likely event of locating animal farms far away from the electricity grid, it was necessary to develop system that can work exclusively with solar energy.

2. MATERIALS AND METHODS

2.1 Design of the Water Management Module

The protocol designed for the computerized water dispensation manager had the responsibility of measuring the quantity of water from an overhead tank, delivering it into the drinking troughs, sounding of a buzzer to signal any water shortage, and sending an SMS message to the cell phone of the farmer to report that the task had been executed. These SMSs were designed to be sent after water dispensation, possibly at 6:00 am, at 12:00 noon at 18:00 hours and 24:00 hours. However, there is a possibility for the farmer to program different times depending on the animals, their ages, species and the water requirements of the enclosure. The quantity of water was measured by operating an actuated valve for a specific interval and allowing the water to be delivered through gravity flow. An LCD display provided visual communication with the outside environment. The schematic layout of the water dispenser is as shown in Fig 1.

The control center was responsible for treating information and operating the electronic valve to allow the programmed amount of water into the drinkers. Water had to be stored in an overhead tank as shown on Fig 1. The computerized module in the control center sent signals to the electronic valve according to the programmed data. The interval the valve was opened depended on the quantity of water required. The dispensed water was further divided equally into the different troughs.

2.2 Design of the Feed Management Module

Animal feed was removed from a storage silo with the use of motorized screw conveyors. The amount of feed was measured by timing the operation period of the screw conveyor knowing the flow rate. A buzzer sound was emitted every time there was lack of feed in the silo and the farmer received the message in his cell phone. The quantity of feed to be dumped was therefore a function of the flow and the duration of flow in the feeder using a screw conveyor. The approach used in the deisgn of the screw was similar to that described by Sreenivasula [12] and Olarenwaju et al. [13]. The feed screw conveyor is powered by an electric motor that receives signals from the control center. The feed rate is determined by the time interval the electric motor operates the screw. The schematic layout of the module is as shown in Fig 2. The system was also designed to send an SMS to the cell phone of the farmer after the operation has been completed. The time intervals inserted into the program were 6 AM, 12 AM, 6 PM and 12 PM but the farmer has the possibility of inserting different times depending on the animal feeding protocol. After proper measurement of the feed, it is further distributed to the various feeders depending on the weight desired.

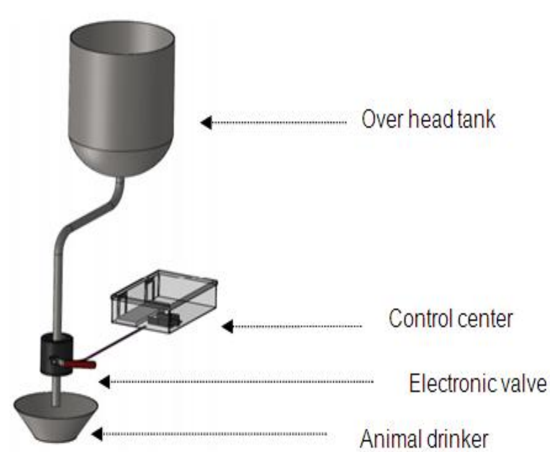

Fig. 1. Schematic diagram of the water dispenser

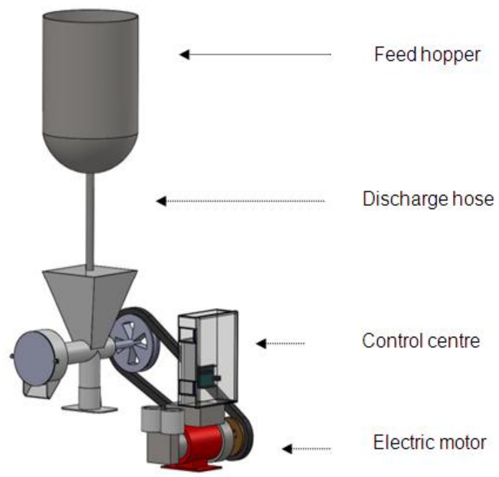

Fig. 2. Schematic diagram of the operation of the feed dispenser

2.3 Design of the Cleaning Management Module

For the module to function, the animal enclosure needed a proper inclined floor for water, urine and droppings to flow. The floor slope angle proposed in this research work, was a gentle slope of 10%. The microcontroller checked the amount of water in the cleaning water tank using sensors placed in the tank. If there was shortage of water in the tank, a buzzer was created to signal the lack of water. Messages (SMS) were sent to communicate with the farmer and report on the execution of any process. An actuated valve allowed flow for a specified time to define the amount of water to be sprayed for cleaning. This quantity of water discharged was a function of the duration and flow rate by gravity. An LCD display provided visual communication with the outside environment.

Fig. 3 illustrates the cleaning management device layout. The water storage reservoir was connected to the electro valve which in turn was connected to the intelligent management control system. A jet of water was released from, the valve at intervals defined in the computer program. The high pressure jet cleaned the enclosure and a message was equally sent to the cell phone of the farmer reporting a successful hitch free operation.

2.4 Power Supply

The power supply was developed to run exclusively on solar energy. The main electric loads used in the design were electric motor, the lighting units and the intelligent control module. The standard PV GIS sizing techniques and solar data at geographic coordinates of Dschang in Cameroon (from the NASA data Center [14], 5° 27’ 0” North, 10° 4’ 0” East were used to determine the solar installation needed to run the appropriate inverters and charge controllers.

2.5 Intelligent Control Program

A logical flow chart was developed for the programing as shown on Fig 4. The various inputs were then coded and fitted into the program. The program was then inscribed on the electronic components and built in using the ISIS PROTEUS software electronic diagram, as described in Cathleen and Gordon [15], Christian [16] and GO TRONIC [17].

Fig. 4 illustrates the layout of electronic components of the water supply automation unit; It was made up of an Arduino UNO board, a water level sensor, a DS1307 Real Time Clock (RTC), two potentiometers, a buffer, an sim900 mini v3, a relay module for Arduino, a display (LCD) for visual monitoring of events. The mounting of the elements was as described in Thomas et al. [18] and Arduino [19]. The LCD could be connected directly to a desktop computer monitor.

2.6 Device for the Automation of Feed Supply

Feed supply was done using a screw conveyor controlled by a microcontroller. This microcontroller sent signals to the starting unit activating the electric motor at the appropriate time and for a given duration which depended on the quantity of feed to be supplied. The farmer can alter and adjust the quantity by modifying the time of operation of the feed auger.

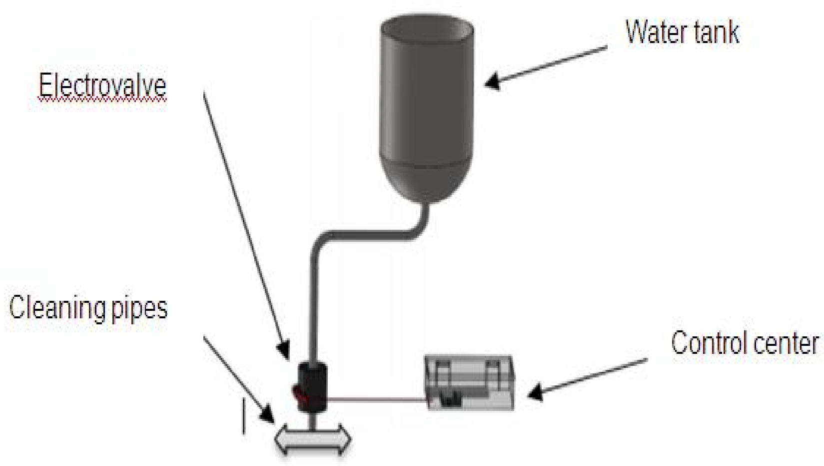

Fig. 3. Schematic layout of the cleaning management module

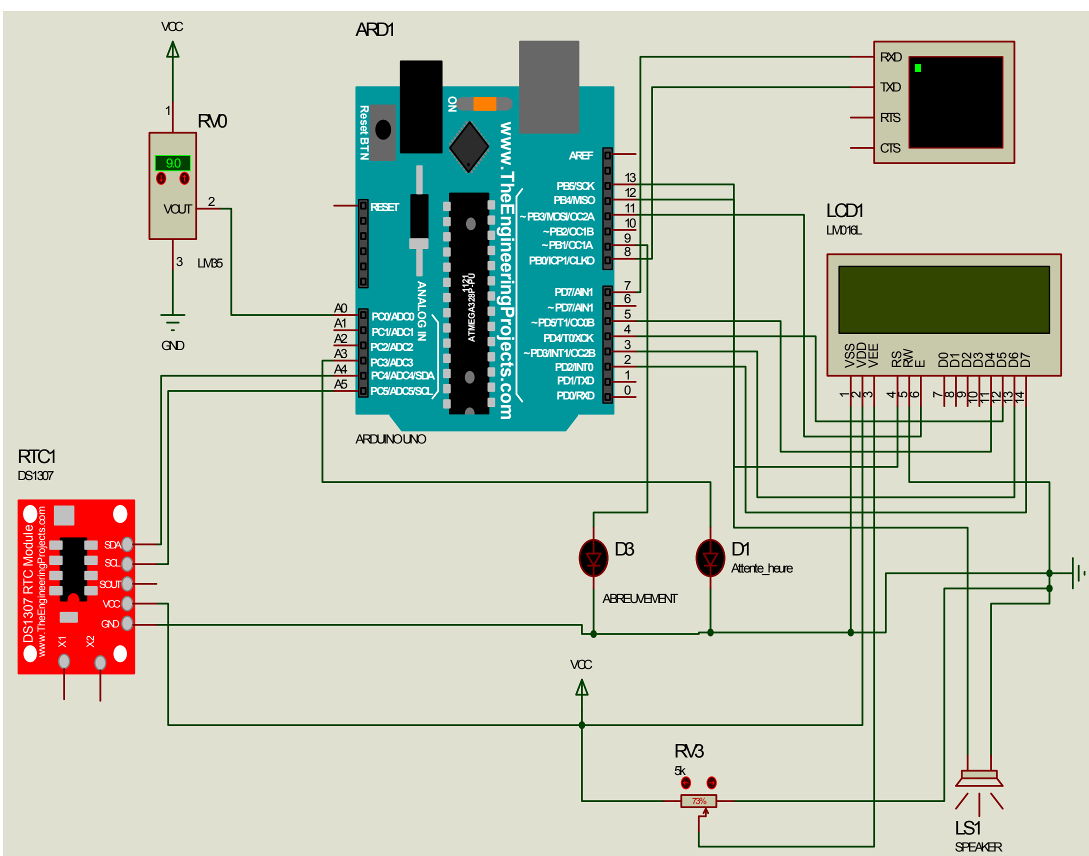

Fig. 4. Diagram of the automation of the watering automation

The diagram of the feed of automation device designed and developed consists of electronic components such as, the Arduino UNO card, a position sensor, a real time clock (RTC) DS1307, two potentiometers, a buffer, a sim900 mini v3, a relay module for Arduino, a display (LCD) as shown in Fig 5.

2.7 Automatic Cleaning Module

This device provided automatic cleaning with a slightly inclined plane ensuring the flow of water by gravity and pumped into the farm for the evacuation of urine, feces as well as other wastes available in the area. The flow of this water was done at fixed and controlled hours.

Fig 6. shows the electronic diagram of the cleaning device. It consisted of the electronic components such as the Arduino UNO card, a water level sensor, a real time clock (RTC) DS1307, two potentiometers, a buffer, a sim900 mini v3, a relay module for Arduino, a display (LCD).

The software test was performed just like in the feed supply section using an Arduino UNO board connected to a computer's CPU, Proteus software and Arduino IDE. Fig. 6 shows the image of the result obtained in real time.

2.8 Software Test

The software test was performed using the Arduino UNO board connected to a computer's CPU having a Proteus software and Arduino IDE. Fig. 7 shows the image of the results obtained in real time. Thus, the feed is supplied at specific times and the remaining amount of feed determined as inscribed in the functional program introduced into the microcontroller. The theoretical time 120 s. As shown on Fig. 8, the LCD screen is showing the date, the time and the action taken ie the quantity of feed released into the feeding toughs.

3. RESULTS ANALYSIS AND DISCUSSION

3.1 Results of Software Testing of the Automatic Drinking Water Dispenser

The software test was performed using the Arduino UNO board connected to the computer's CPU, Proteus software and Arduino IDE. Indeed, watering was done at specific times and after control of the water level using the written and functional program introduced into the microcontroller. Fig. 9 illustrates the test image software of the device of automation of the water delivery. For drinking while Fig. 10 shows results for water delivery for cleaning.

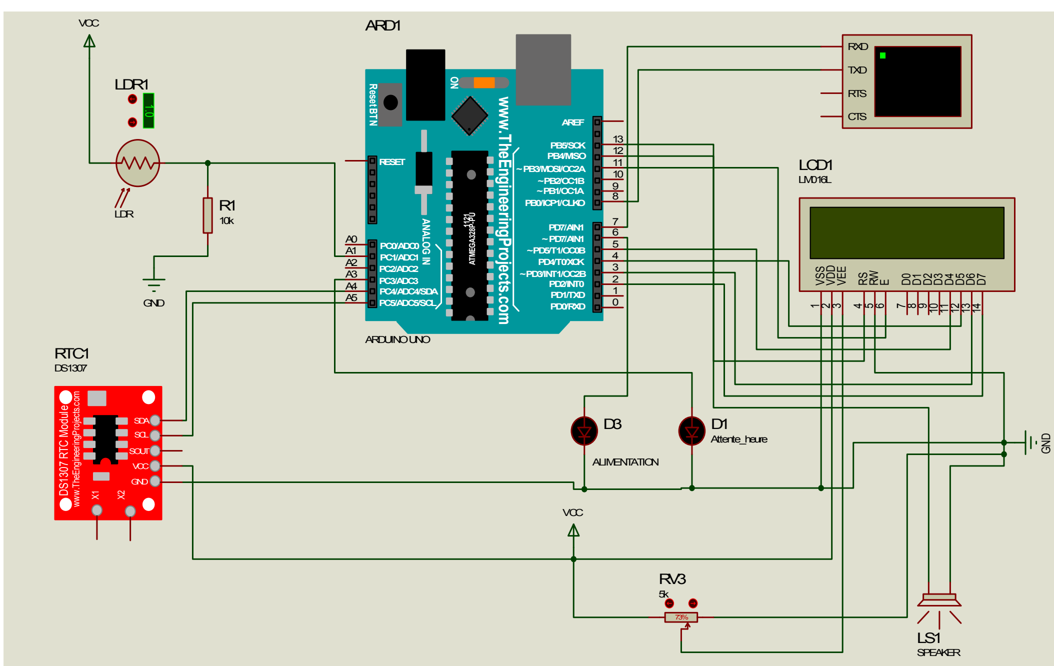

Fig. 5. Arrangement of the automatic feed dispenser

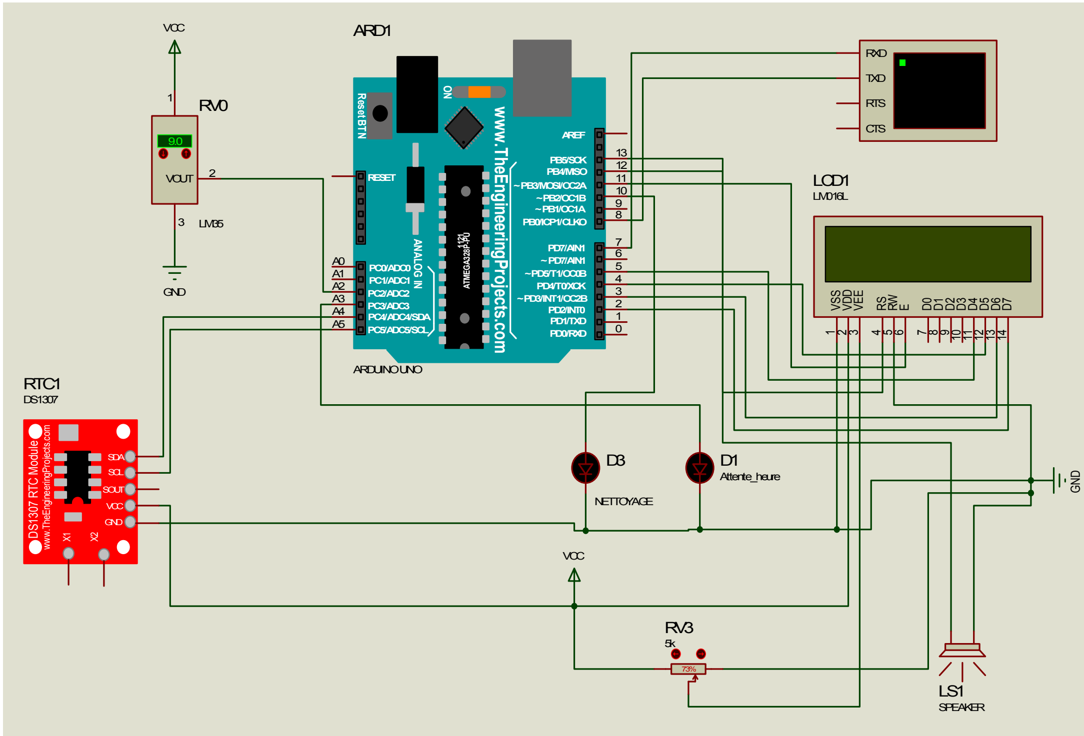

Fig. 6. Electronic diagram of the automatic cleaning module

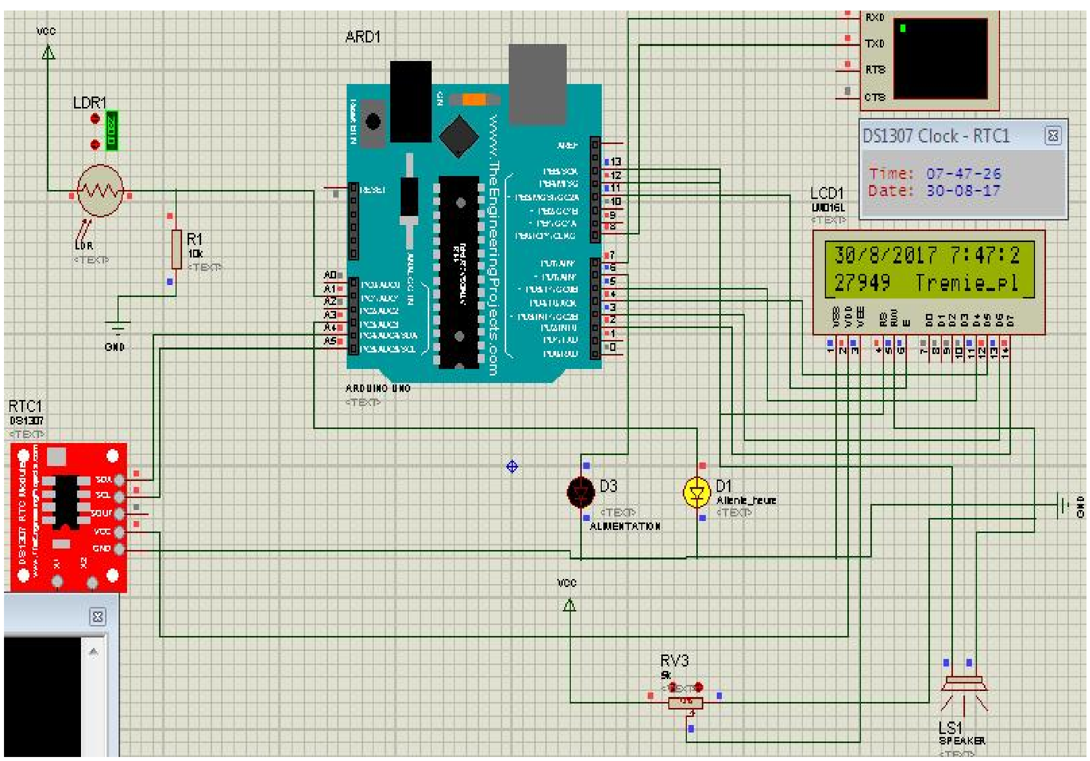

Fig. 7. Image of the test automatic feed dispenser

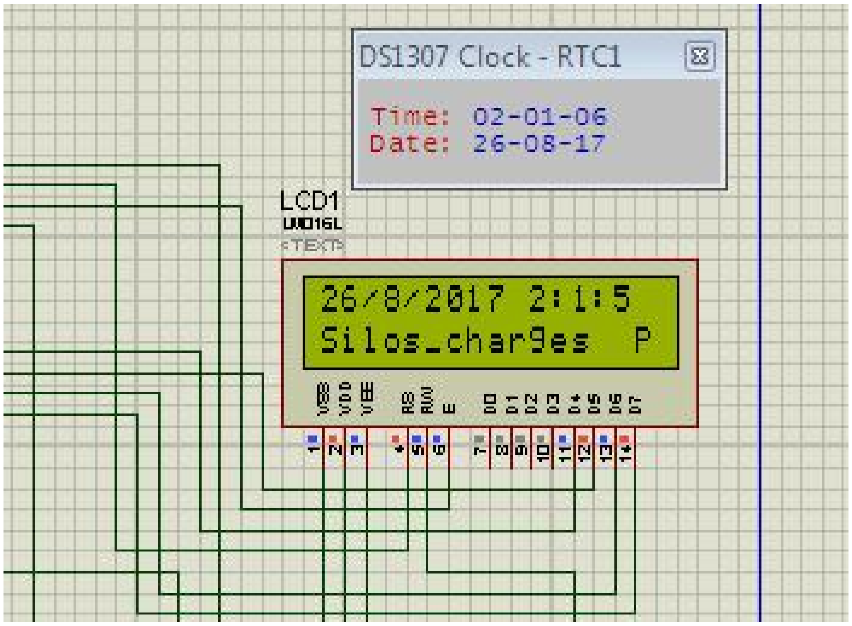

Fig. 8. Display of results of cleaning

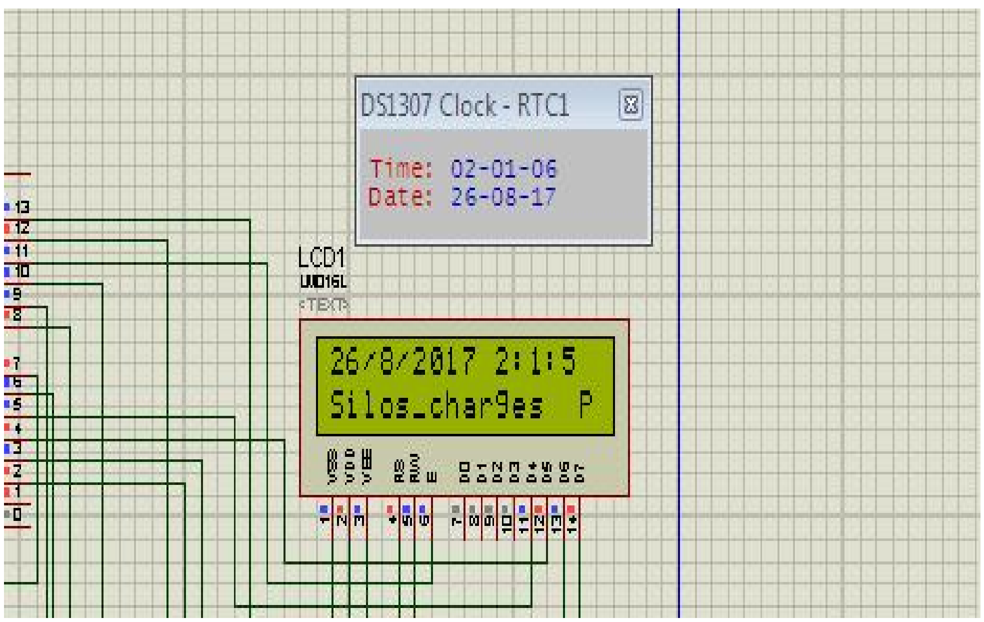

Fig. 9. Image of the test of the automation for water delivery for cleaning

3.2 Photovoltaic System Characteristics

Table 1 illustrates the characteristics of the photovoltaic system. The PV system provides an uninterrupted power supply of electrical module. The design of the solar energy consumption demand made use of the NASA 2016 data base for solar radiation at the experimentation centre.

Fig. 10 shows a picture of the photovoltaic system installed with a solar panel, a charge controller and the battery bank.

The software test was performed using the Arduino UNO board connected to the computer's CPU, Proteus software and Arduino IDE. Fig. 11 shows the software test image of the water management, feeding and cleaning module of an animal farm. Thus, the control of the presence of water in the tanks and that of the food in the hopper was carried out as well as watering, feeding and cleaning at fixed times. The theoretical time was then 210 s.

Fig. 12 shows the image of the management of the watering, feed dispensing and cleaning of the animal farm developed. Fig. 12 (a) shows the front views and the two reservoirs one for water and the other for feed while (b) shows the side view indicating the positioning of the solar module. The real time was 248 s.

Fig. 10. Installed photovoltaic system

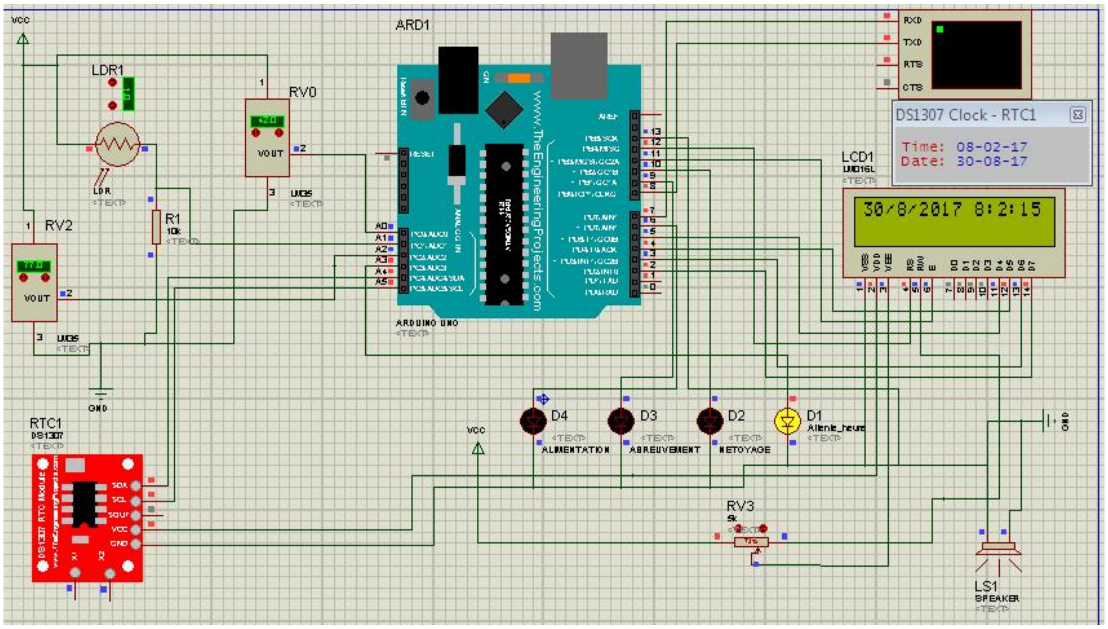

Fig. 11. Final display Image of the water management module software test, feeding and cleaning of an animal farmImage of the Realized Management Module

3.3 Electronic Module for Management of Watering, Feeding and Cleaning of the Animal Farm

Fig. 13 shows the image of the electronic module for water management, feeding and cleaning of an animal farm. The mothereboard and the relays can be clearly seen.

3.4 General Organization Chart of the Management Module

The Fig. 14 illustrates the general flow chart for the operation of the watering, feeding and cleaning module.

The flowchart designed allowed the automation of our watering, feeding and cleaning module that strictly complied with the specifications. We first initialized the inputs and outputs, audio and visual signaling subprograms. The watering and feeding programs were written followed by the real-time time control program. The automation program for water management, feeding and cleaning was designed:

- to clean the room every day at 5.45 am after checking the presence of water in the cleaning tank;
- release feed and water to the animals every day at 6:00, 12:00, 18:00 and 24:00 after checking the presence of water in the water tank and the presence of food in the hopper and finally;
- to display the operation on an LCD display, and to sound buzzer as well as send an sms to the farmer using a sim900 for audible and visual signaling to indicate complete operation.

The 3D model design with SOLID WORKS software is illustrated in Fig. 15.

Table 1. Characteristics of the photovoltaic system

No	Unit	Characteristic
1	Power consumed by the module	83 w / day
2	Energy consumed per day	258 Wh / day
3	Battery capacity	Lithium Iron Phosphate batteries 12V -200Ah DYNO EUROPE-20h-80%
4	Power of solar panels to install	Two solar panels Monocrystalline - SUN POWER CLEVERSOLAR SPR-100 - Pmax = 100W - Isc = 5,92A - Vsc = 22,7V - Vmp = 18,49V - Imp = 5,41A
4	Charge controller	PWM - 10A - 12v / 24v

(a) (b)

Fig. 12. Completed unit for automatic feed and water management animal farms (a) front view (b) side view

3.5 Efficiency of the Module

3.5.1 Efficiency execution of watering for module

The performance of the device for watering was 86.95% in normal operation. We considered the report of the theoretical time (80 seconds per day s) on the real operating time (92 seconds s) per day. The efficiency was estimated by comparing the theoretical amount of water commanded to the actual amount delivered.

3.5.2 Efficiency execution of power to the module

The performance efficiency of the device for feeding was 84.51% in normal operation. We considered the report of the theoretical time (12 s 0 seconds) on the real-time operating in one day (142 seconds).

3.6 Efficiency Execution Module for Cleaning

The performance efficiency of the device for cleaning was 83.33% in normal operation; this consideration by the time of the theoretical ratio of (1 0 seconds s) on the real-time operating in one day (12 seconds s).

3.7 Overall Efficiency of the Watering, Feeding and Cleaning Module

The efficiency of the module has been estimated at 83.33% in normal operation; This consideration by the report of the theoretical time (21 s 0 seconds) on the real-time operating in one day (252 seconds s).

3.8 General Discussion

Although it was not possible to measure the impact of this project on disease transmission from animal to man and vice versa, it was clear that limiting the number of visits to an animal farm could completely eliminate the vectoring of viruses and other communicable diseases into and out of the animal farms. This can go a long way to eliminate the serious damages caused by epidemics and pandemics as described by Daniel, N. A et al. [9], Jernej et al. [10], Landais, Weisslinger H [11]. Depending on the size of the animal farm, it is possible to fill out the hoppers and water tanks for a one month independent control without any visit especially if security cameras are installed in the farm and also made to send images directly to the farmer. The solar energy systems incorporated assures continuous energy supply without the interruption that is very common in developing countries. Generally solar systems are expected to expire in 25 years Shahariar et al. [20], although many systems still function well above this age, there is the possibility of recycling them.

The combination of these modules for the animal husbandry in Cameroon can greatly improve the stakes in animal farming from what is mentioned in Bouba M [21]. It can aslo go a long way to ensure animal health and curb environmental pollution usually associated with animal farms. Jernej P, et al 2019 [22]

(a) (b)

Fig. 13. (a) and (b) Images of the developed electronic module

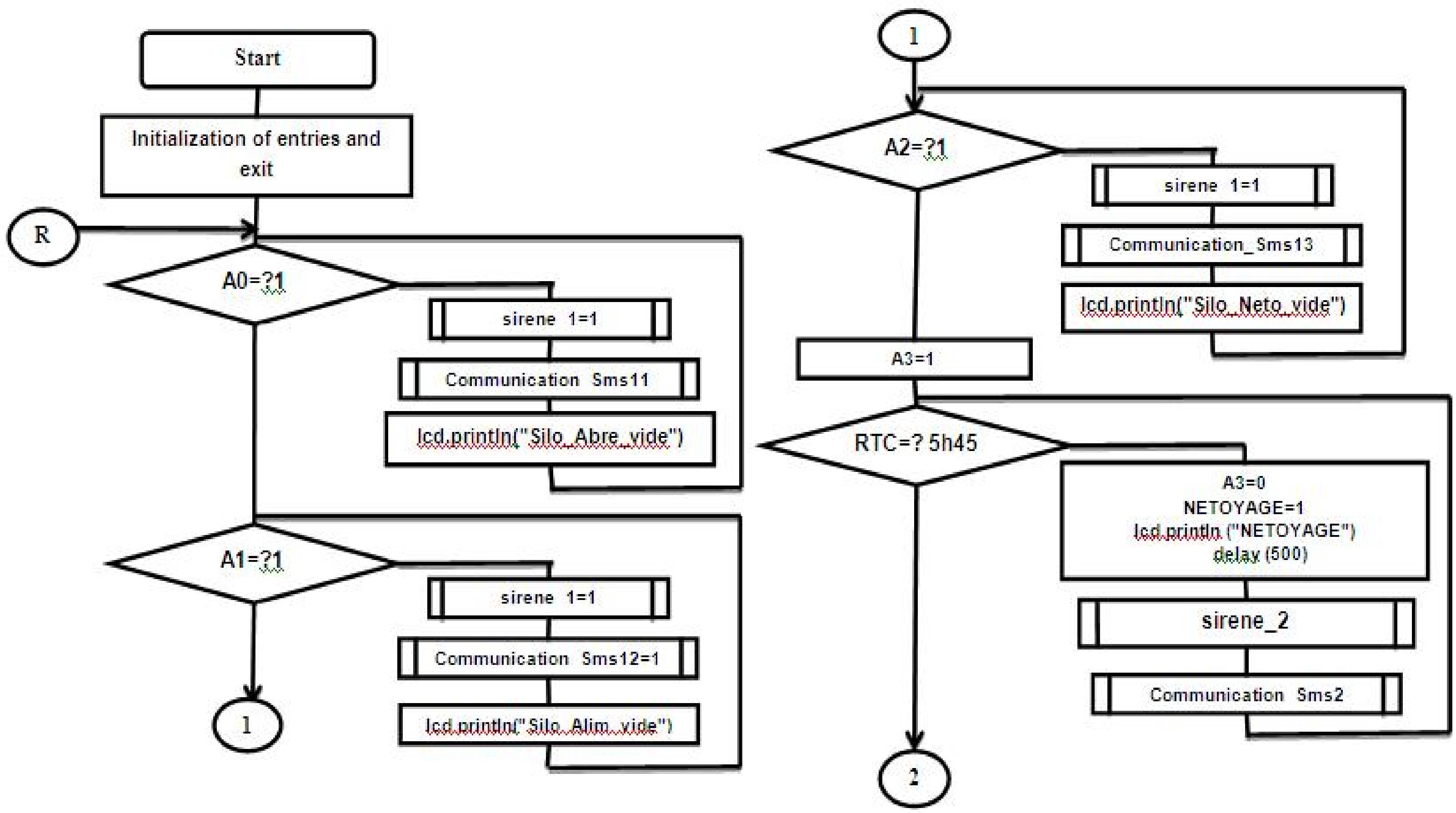

Fig. 14. Flow chart indicating the logical sequence of the computer program

Fig. 15. Image of the management module for watering, feeding and cleaning an animal farm: three-dimensional model (3D)

4. CONCLUSIONS

Given the objectives set, the methodology adopted and the results obtained, the following conclusions could be drawn:

The automation of the drinking water management prototype was designed and implemented. This prototype, had an efficiency of 86.95%. The automation of the power management prototype was successfully designed and built in the same enclosure as that of the watering. Its efficiency was 84.51%. The cleaning module had an efficiency of of 83.33%.

The uninterrupted power supply system consisted of two parallel-mounted 200 W CLEVERSOLAR solar panels, two DYNO EUROPE-20h-80% Lithium-Iron -Phosphate 12V -200Ah batteries and a charge controller. PWM - 10A - 12v / 24v - solar. It had an autonomy of about 48 hours as expected. The lowest efficiency of any unit, 83.33% was taken as the overall efficiency of the module. It was concluded that the use of this automatic control module can greatly limit the number of visit to animal farms thereby promoting social distancing especially at this time of the global COVID Pandemic.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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