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A Balance Diet Management System for Livestock using an OWL-based Ontology Model

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Abstract

Background/Objectives: The main objective of the proposed model is to design an ontology model that focuses on the automation of the nutrition management in livestock. **Methods/Statistical Analysis:** In this paper, we have used Pellet reasoner which complies with the SWRL rule, for finding the accurate reasoning of the relationship between the entities. The proposed ontology model is designed and tested in the Protege 4.3. An experimental scenario is explained for the detailed understandings of the ontology model. **Findings:** Each livestock has different health and needs special care on diets according to the age, weight, health and phase of the livestock. It is not certain that all types of cow require the same amount of nutrients, as they vary in age, growth and health evidently. Therefore, the ontology model is used to define the relationship between the classes, which are built to automatically detect the accurate amount of nutrient supply for the cow, with the help of knowledge base. **Improvements:** Livestock ontology model for diet management is a reassuring model in the automation of feed management. In other words, the model is capable of deciding the nutrition requirement for the cow based on the basic information without any human intervention.

Keywords: Diet Management, Livestock, Ontology Model, Ontology Reasoner, SWRL

1. Introduction

The amount of livestock production, being the 40% percent of gross value in agriculture production, increases rapidly with the increase in the growth in population and the change of lifestyle and dietary habits[1]. The consumption of high quality foods over the livestock product such as meat, milk and dietary supplements has been increasing steadily over the past year and expected to double by 2030, which will bring a major profit in the farmer's income[2]. It is for certain that the livestock production holds an importance in the world agriculture, farmer's income and eventually the survival of many livelihoods in livestock business[3]. Most of the livestock are provided with the common roughage with some minerals and vitamins, and hence lack proper nutrition, exposing to numerous diseases especially the reproduction problem.

According to the studies, most of the reproduction problem[4] and infertility of the cow are caused due to the improper nutrition. It is common to farmers to expect more result, by increasing the amount of feed but to the hock the output is completely different. Additionally, there exist more researches which point other such problems in the cow such as heart disease, embryonic mortality and so on[5,6]. It also proven that some necessary nutrition plays important role in cow's health and digestion[7]. In regards to the nutritional and most management purposes, the annual production cycle for the cow can be divided into four phases such as Pre-calving, Postpartum, Lactating and Pregnant, and Gestation. In each phase, the required nutrition changes accordingly. With the barn full of cows, it is difficult to identify and calculate the feed intake and nutrition for each cow. As the ontology model supports the automation in many upcoming technologies like software engineering[8] and semantic development in web data[9].

To build an accurate ontology model, the appropriate reasoning needs to be applied. As there are many reasoning

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methods, there are many surveys that help to identify the required reasoner[10]. We have designed and implemented Livestock Ontology model integrating the nutrient management to avoid any reproduction problem or any other related diseases. With the technological improvement like Internet of Things in ubiquitous environment[11], the human intervention is reduced greatly with the steady go of automation in all the fields. With the help of knowledge base such as food, disease and the context information, the nutrient information is obtained for different state and status of the cow, with the help of the relationship of the entities defined in the ontology model.

The semantic information about context obtained from the livestock farm is hard to be in dealing in feed management service, and for the same reason, the ontology model is built to resolve the relationship between the classes. The amount of the feed and the appropriate nutrition information is computed for each cow, which is then loaded in the feed tray. In this paper, we focus on the ontology model that helps to derive the proper nutrition based on the phase of the cow's growth and status.

The rest of the paper is organized as follows: Section 2 explains the related works about the cause of livestock nutrient imbalance and the impacts, also the ontology benefits. Section 3 comprises the overview of the livestock farm system and the ontology model is described in the Section 4. Section 5 explains the approach and the workflow of the livestock ontology with an experimental scenario. And the last section describes the conclusion and future work.

2. Background Study

The livestock needs balanced nutrition on a daily basis, for their health and production such as pregnancy, meat, milk and growth[12]. Increasing the quantity of the food does not ensure the essential amount of energy and protein in the livestock, in contrast, less amount of supply contain right amount of energy and protein in high yielding cows. Due to the farmer's ignorance[13], the possibility of nutrient deficiency is high. Many studies[14-17] have undergone to indicate the importance of nutritional management by increasing the productivity in the livestock production process.

2.1 Need of Nutrition in Livestock

By changing the nutrition needs of the cow, the productivity is increased with the lower cost. Cows use the nutrients provided to them for bodily processes in the following order: 1) maintenance - keep alive and moving, 2) lactation - providing milk for the calf, 3) growth - including weight gain, and 4) reproduction.

The nutrient requirements of cows can be divided into four stages[18], Maintenance, Lactation, Growth, and Reproduction. In each stage, requirements for energy, protein, minerals, and vitamins can vary. By understanding the requirements, necessary alteration in the nutrition needs to be altered and calculated.

The *maintenance* stage requires all the nutrients necessary to breath, move, eat and maintain body weight, as they are the primary variables affecting the maintenance requirements. Energy and protein increases with the increase in the maintenance requirement. Pregnancy, lactation and the growth stage also needs the maintenance for the proper growth of the cow. In *Lactation* stage, nutrient requirements for lactation are based on the amount composition of the milk, where the nutrition requirement increases with the more production of milk with high fat and protein. Requirements for *growth* are based on the weight, growth rate, and composition of fat or muscle. Adjustments to requirements for reproduction are based on expected calf birth weight and stage of gestation. Usually, pregnancy does not significantly affect requirements until the last three months of pregnancy when the fetus is growing rapidly.

Based on the calving period, the production cycle can be divided into Pre-calving, Postpartum, Lactating and Pregnant and Gestation, as the nutritional requirements varies at each stage as shown in the figure 1. In the Postpartum

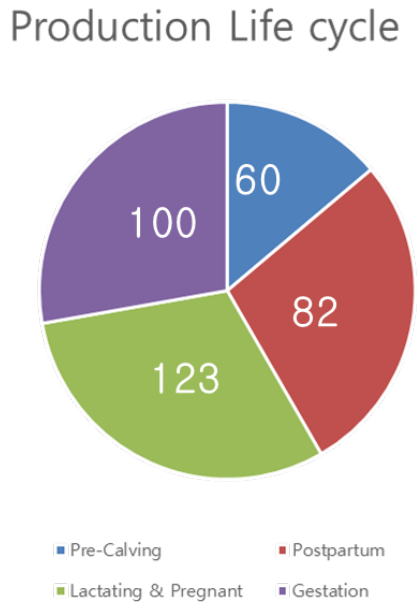

Figure 1. Production life cycle of Cow.

phase, the nutritional demands are high, as the period ranges between 80 to 90 days at calving. The cow needs more nutrition to lactate, grow and heal the reproductive traits. Therefore, the energy and the protein intake are high during this period of phase[19]. The duration of lactating and pregnant is 120 to 130 days, which also need more nutrition. Compared to the postpartum period, energy and protein are decreased by 13% and 8% respectively. Cow may lose weight during this period due to high activity. Gestation period lasts for 100-110 day after the calves are weaned. As the lactation is stopped, the energy and protein requirement also drops eventually. It can also be a good time to gain weight on cows. But the cow's voluntary feed intake is lowest during this period. Pre-calving is the period of 50 to 60 days immediately before calving, which is the most critical period of the year. Energy and protein needs increase by 20% for the fetal growth, and the calf may gain more weight during pre-calving, as the placenta is also growing and the cow is preparing for lactation. All the activities are coupled in this phase, and so it is considered to be critical phase in the production cycle of lactating cows[20].

3. Overview of the Livestock Farm Management

The Figure 2 shows the overall flow of the livestock feed management, which gives a basic structure of the ontology that helps to convert the raw data into high level data. The sensor data are usually unreliable due to many reason such as difference in threshold values, manufacturer and fault in system. Therefore, the low level data received from the sensors are converted into high level reliable data with the ontology and its entities. Many sensory devices such as temperature sensor, weight gauge, light sensor, pressure and motion sensor are used in the livestock farm to receive information related to the cattle. Wireless sensor network is used as a communication network in delivering the data to the server through the ontology model.

Using RFID reader, the Unique Id is a cow is obtained. With the RFID, the basic information of the cow is retrieved from the Database. The retrieved data are sent to the Data Extractor, which helps to analyze and find the exact state and status of the cow. The nutrition supply is calculated accordingly, by influencing the rules/Knowledge base. The history of data is obtained from the Bigdata, to calculate the feed rate of the cow. If the difference between the calculated feed and feed rate is huge, a notification is sent to the farmer.

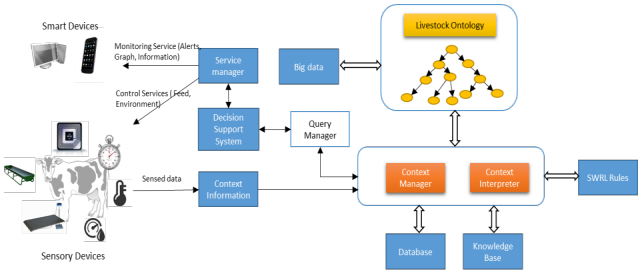

Figure 2. Overview of the Livestock Nutrient management process.

If the calculated feed is more or less similar to feed rate, then the feed bunk will be loaded with the food supply.

In the feeding system, there are two important factors that is considered for the nutrition management, one is related to the health and other is related to the age and state of the livestock. According to the age and phase of the cow, the calculated amount of nutrition is acquired, but, if the cow is unhealthy or needs special assistance, the plan for nutrition should be changed, in favor to the cow's cure. For this purpose, the entities are defined and the properties are assigned in the ontology model, where the properties are inferred to determine the balance diet for the livestock.

4. Ontology Model for the Livestock Feed Management System

To build a smart livestock farm, the first step is to construct an ontology model which can interlink the relationship between the domains with the beneficial rules. Therefore, by using an ontology, the relationship of the domain can be used to process automation easily. First, the scope of the ontology needs to be decided, and for this purpose, we make use of competency questions such as "Is the cow heifer or calve?", "Does the nutrient X can be fed to lactating heifer?" and so on. With this type of questions, the type and the domain of the ontology are identified and the concepts are Animal, Device, Location, Nutrient, Parameter, Phase, Service, System and User as shown in figure 3.

Animal Concept: As our point of interest for this project is Cow, the concept contains the information on the Cow. It also contains the genre of the cow such as heifer, calf, mature cow and bull. As the different genre of cow needs different care and observation, the class cow is further extended.

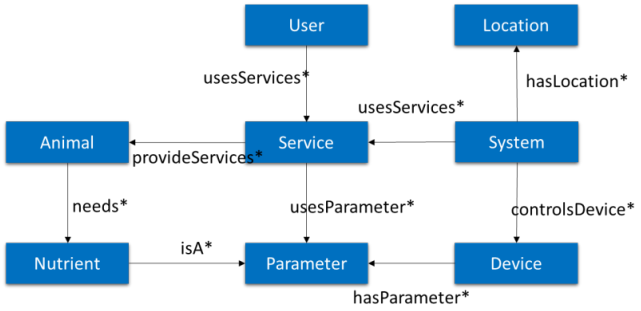

Figure 3. Livestock Ontology Entity Relationship.

Device Concept: For a successful automation process, sensory devices such as Sensors and Actuator take a major role. The concept is classified into Sensor, which generates the sensed data, Control Equipment that indicates the Air Conditioner, Humidifier, Food Mixer and Light, RFID for identifying the cow's unique ID and CCTV, to monitor the livestock movements.

Service Concept: The service concept is subdivided into control and monitoring services. Control services includes services such as Feed control, Nutrition control, Environmental Management and Production Management and monitoring services are Herd Management, Information and Data Management.

Location Concept: Location of the animal, sensors and the control equipment are required to access and manage the respective data and the services. The concept is classified into Farm and Livestock location which is further divided into indoor and outdoor location. All the sensory location is also obtained to reduce the trouble.

Nutrient Concept: The essential nutrient for the cow of all stages are stated in this concept, which includes Hay, Grass, Corn, Pasture and Soymeal. Each food has a defined nutrition value, while combined together in specific amount, it can serve as a balanced nutrition for the livestock.

Parameter Concept: The concept keeps hold of all the parameter such as environmental parameter, which are obtained from the sensors and other devices, livestock parameter that refers to the parameter related to the cow such as body temperature, food intake, motion, weight and so on. It also consists of supplementary parameter such as weather, to make note of the climate and weather and stock rate, to keep track of stock price and manage the productivity of the livestock farm.

Phase Concept: The four phase of the cow life cycle is included in the model that consist of growth, lactation, nurture and reproduction. The Lactation phase is further divided into pre-calving, postpartum, lactating and gestation.

System Concept: The system concept consists of Platform, Database and Network. The concept takes care of the communication related process with both wired and wireless communication.

User Concept: Typically, user represent the farmer or the staffs employed in the livestock farm. The information or alerts related to the livestock health and movements are shared to the users through the smart devices.

The Livestock Ontology is modelled to optimize the nutrition balance within the livestock and avoid any reproduction problem in the Livestock through smart services in service-oriented system The OWL-based Ontology model was implemented and tested in the protege 4.3 integrating the SWRL rules and pellet reasoner. Protege is free, open source ontology editor and a knowledge acquisition system. OWL Ontology was tested by inferring the model using the pellet reasoner and querying the OWL file with SPARQL Query Language. Ontology helps to achieve the system with the excellent semantic interoperability to exchange and share knowledge between the systems, by defining the relationship between the entities.

OWL ontology consist of basic elements such as classes, properties, instance of classes and relationships between these instances. The classes are the basic concepts in the domain and the individual are the members of the class. As shown in the Figure 4, the concepts are classified into the class, whereas the object and data properties are stated according to the triples which helps in defining the

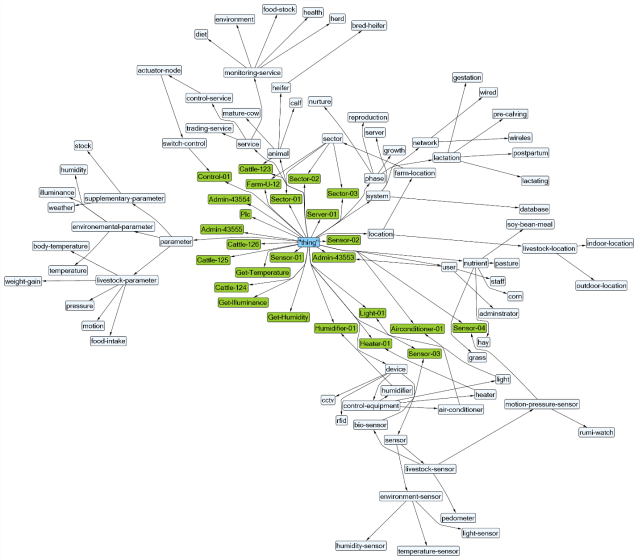

Figure 4. Basic structure of Livestock Ontology.

relationship of the entities. The individual element is an instance that contains all the corresponding RDF-triplet information.

5. Workflow of an Experimental Scenario

A farmer runs a big barn with a number of cows in his livestock farm which vary from cow, heifer, calves, and mature cows, which has various health condition. The most important factor ensures the livestock belongs to the allocated group and also calculate the appropriate amount of nutrition to every individual cow. The workflow of the process to maintain a balanced diet nutrition is shown in the figure 5 and also explained as follows,

- Using RFID reader, the Unique Id is Cow is obtained.
- With the RFID, the basic information of the Cow is retrieved.
- The retrieved data is used to analyze and find the exact state and status of the Cow.
  a. If the status of the Cow is identified as "Lactating Heifer", the phase of the lactation period is calculated from the date of the calving.
  b. If the phase of the lactation period is "Gestation", then the protein is "decreased by 36%".
- The nutrition supply is calculated accordingly (by influencing the rules/Knowledge base).
- The previous data are obtained from the bigdata, to calculate the feed rate of the cow.
- The present calculated with the feed rate of the cow.
  a. If the calculated feed is more or less similar to feed rate, the feed supply process to next step.
  b. If the difference between the calculated feed and feed rate is huge, a notification is sent to the farmer.
- The feed bunk is loaded with the food supply.
  a. The weighing machine under the feed tray is used the feed intake by identifying the difference before and after the feed.
  b. Feed rate of cow is stored under the cow's unique id for next feed calculation.

To calculate the nutrition supply for the cow, first we need the unique id of the cow to retrieve its information. Let us consider that the cow ID is "CATTLE_123". The individual "CATTLE_123" is of type "Animal" and the other data such as calves count, date of birth are retrieved from

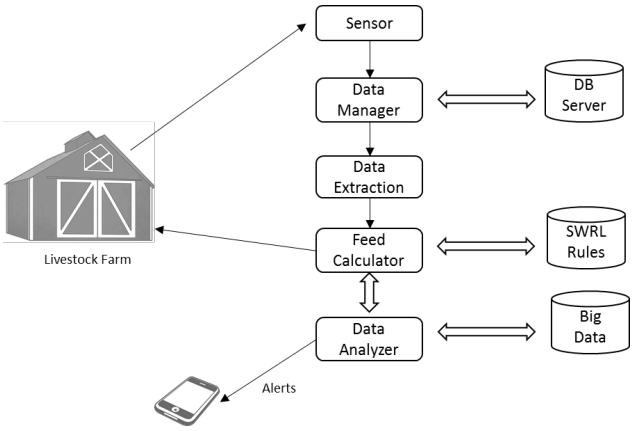

Figure 5. Workflow of Livestock feeding system.

the database into the OWL properties. With the following SWRL rule, the type of cattle is determined as "Heifer" which indicates that the cow doesn't have any calves.

Rule 1:
"Animal(?c), hasCalves(?c, ?a), equal(?a, 0)-> Heifer(?c)"

Rule 2:
Animal(?c), isPregnant(?c, ?flag), equal(?flag, "True") -> BredHeifer(?c)

As stated in the rule 2, if the heifer is pregnant, then the status of the heifer is "BredHeifer". By finding the type of the cattle, the nutrition plan is retrieved from the knowledge base and the feed bunk is filled accordingly. The instantiation of the example is explained in the protege tool as shown in the Figures 6 and 7.

With the first rule, the animal is interrupted as heifer and with the further rule, the heifer is again interrupted to be the BredHeifer. With this, the phase is found and the amount of feed for the type of animal is identified.

Similarly, after finding the state of the livestock, the phase of the lactation period is calculated from the date of the calving. Let us consider the lactating cow, with the phase of Pospartum.

Rule 3:
"Animal(?c), DaysAfterCalvation(?c, ?cdate), greaterThan(?cdate, 80), lessThan(?cdate, 90)-> Postpartum(?c)"

By using the rule, the phase of the lactation can be identified. If the phase of the lactation period is "Postpartum", then the protein and energy is "increased by 30%". Thus, the nutrition calculation is done with relating the class and amending to the SWRL rules as shown in the Figure 8.

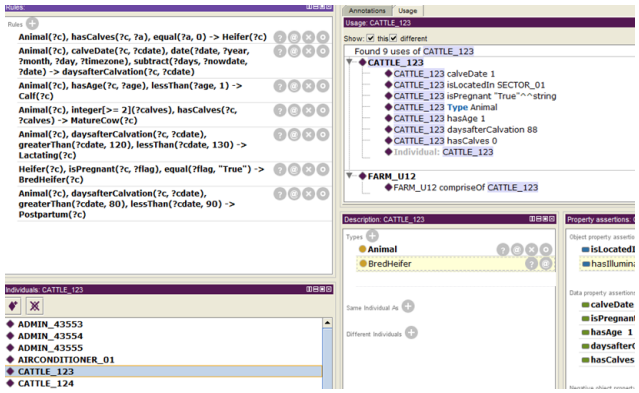

Figure 6. Instantiation of livestock ontology feeding service.

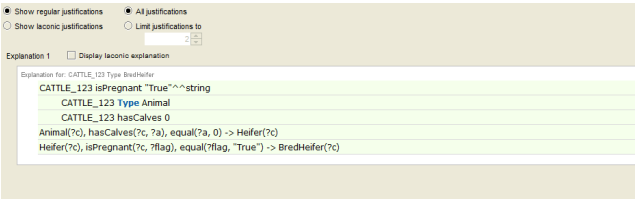

Figure 7. Reasoning for "BredHeifer" type Class.

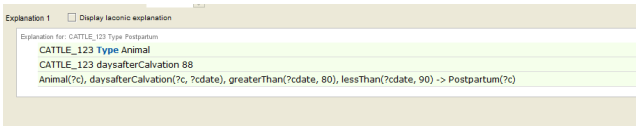

Figure 8. Reasoning for "Postpartum" type Class.

So the nutrient supply for the particular cow is identified. After the feed is mixed, the food is loaded in the feed tray. With the proper identification of stte and phase of the livestock, the balanced diet chart is pulled from the knowledge base and the feed is provided to the cow appropriately. With this, the human intervention is reduced, which decreases the human work load, as well as increase the production rate of the livestock farm.

6. Conclusions

In this paper, we have presented a context based ontology model to detect the amount of nutrition supply for the Cow, by individually identifying the state and phase of the cow. The relationship between the systems and services are handled by the ontology model which, in turn, connects with the rule database and knowledge database for the calculation. The balanced diet chart is drawn for the individual cow or the herd of cow of similar category and the feed bunk is loaded accordingly An experimental scenario is described for the better understanding of the services interlinking the SWRL rules in the OWL based ontology model. For the future work, we plan to link the ontology model with the semantic web and develop an application for monitoring and managing the nutrition management chart systematically.

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