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Towards an Intelligent Livestock Farm Management using OWL-based Ontology Model

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Abstract

In this paper, we have designed the ontology model to achieve a cost effective livestock farm environment by maintaining safety and quality. The proposed model is built with the situational context aware data by making use of the wireless sensor network (WSN). The concepts of the proposed model are identified after considering all the possibilities with respect to the control services that help to increase the productivity and automation in the livestock farm environment. The health and diet management along with the environmental services are considered as a main service, which is a deniable fact. In addition to these services, uprising and downsizing of stock prices can affect the management behavior in regard to the production services. In order to solve the issue, both the health and diet management plans are monitored and modified automatically with respect to the changes in the stock market. With the proposed ontology model, the information from Internet of Things (IoT) is recomposed as context information, which helps in the understanding of the relationship between the livestock environmental factors.

Keywords: *Ontology, Livestock, WSN, Context-aware, IoT*

1. Introduction

Human demand for animal product is increasing year by year. Global Livestock production has increased more than double the amount in beef production compared to 1960's. According to IAASTD, with the increase in population, continuous economic growth and the shifts in human diets towards the meat consumption, the rise of animal stock is more evident. On average, every person on Earth currently consumes 42.9 kilograms of meat per year, thus increasing the global demand for meat every year. Demand projections point to increases of global meat consumption of 68% and of global milk consumption of 57% over the 2000 base period by 2030.

It shows that the consumer demands and reliability of Livestock products has increased with the speedy development of technologies [1]. The rivalry is fierce compared to the past, which leads the farmers to strive to master the production process and come up with more strategies in order to increase profit [2]. It is evident that the success falls towards smart decisions, which considers the probability in changes that happen on a regular basis. To be a successful farmer, one needs to keep track of the livestock's behavior and health to ensure the constant rise in the production system [3]. It is not easy to maintain the farm as well as keep track of many such daily duties and calculate your sale without any fault.

Major threats in the animal agriculture are disease control, environmental changes and the energy cost to maintain the livestock farm. All the threats can be disintegrated by applying the appropriated decision making system. For such decision making system, the accuracy and quality of data and information can be a

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backbone for the objective measurement [4]. Obviously, the elements required to implement the automation depends on the type of data and the value of the data to improve the decision in production management. Large amounts of data are collected and countless decisions are made regularly. In order to make a proper decision making system, all the data obtained from the sensors and the supplementary systems are converted into proper context information, which are used in decision-making. The value of the information is valued due to the significance in the production, health and environmental management.

Increasing productivity is currently constrained by the lack of skills, knowledge and appropriated technology. As a result, both the production and productivity are decreasing, which may result in an increase of wastage. Together with improved and adapted technology, we can substantially improve the productivity and a major contribution in the reduction of human labor. In other words, for holding a constant profit while taking care of the farm, automation of services is required. Even with the proper decision making system, to execute a complete automation, the relationship among the entities needs to be defined in more detail.

In this paper, we propose an ontology model for the livestock environment, which helps in the benefits of production services through a better understanding among the context entities. The model was specifically planned for a farm enterprise that promotes cattle livestock. Mainly monitoring and controlling services are focused with the light of production in mind. Both the environment and livestock parameters are collected by the corresponding sensors and these raw data are converted into high-level context information through the ontology model. As the relationship between the entities become clearer, the richness and quality of the information increase benefitting in the decision support system. The primary concepts of the livestock farm are identified after a deliberate examination of the needs and they are related as per the relationship through the ontology model.

The following section describes the related works on livestock context aware services. Section 3 explains the Livestock ontology model with the overview of the service model of the livestock environment. Section 4 illustrates an experimental scenario of the services using the Livestock ontology model. Finally the conclusion and future studies are discussed in the Section 5.

2. Related Works

Livestock are considered to be one of the major sources of employment in many developing countries as it includes various processing of livestock products, meat, manure and skin [5 6]. With the awareness and advancement in the ubiquitous computing, the research on the automation based context awareness has been growing steadily. Thus many researchers have performed much research in the ubiquitous computing field, which resulted in the progression of the computer anxiety [7] and development of numerous context aware systems, which are widely known as smart applications. There are many applications that are being profited from the context aware system, which included various fields such as bio-medical, smart home, Elderly care, *etc.*, [8 - 10]. Wireless sensor network has already blended together by benefitting our day-to-day life with diverse services and has been recently infiltrating the Livestock services.

Most of the researches are based on the services related to the health of the livestock. Kim *et al.*, explains early estrus detection in the livestock to enhance the optimum fertilization [12] and the context model to increase the productivity of the livestock environment [13]. Jeong *et al.*, [14] proposes an ontology model for preventing disease in the livestock by an early detection method using the Biosensors. When we discuss about the production management, the key factor is the strategies. In other words, the decision-making is the proactive aspect of managerial behavior. Therefore, in this paper, we propose the ontology model for the livestock production management, which includes the situation-based decision support system.

3. Service Model of Livestock Farm Management

Management issues are the most common problem, due to the changes of the sales as well as commodities and due to the varying climate changes. As it is quite difficult to deal with such issues by establishing a pre-established set of actions, and for this reason, a situation-based decision making system is required. In this paper, the proposed ontology model incorporates the situational based decision support to create a smart livestock production management.

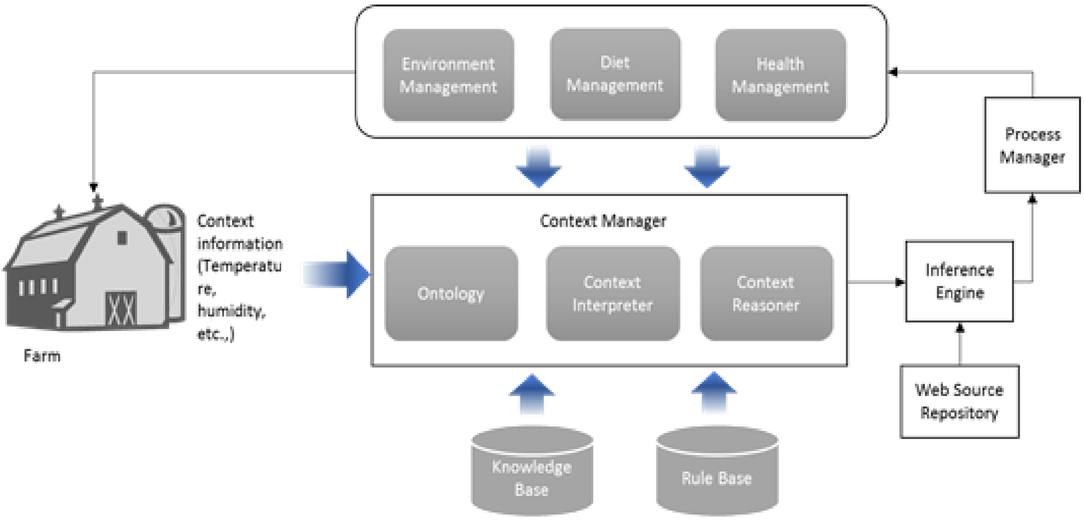

Figure 1. Service Model of the Livestock Farm Management System

The basic structure of the service model of the livestock environment is shown in Figure 1. As discussed in the above section, the production services are dependent on the services such as environment, diet and health services. Therefore, all the reports and analysis are passed onto the context manager to make an accurate decision making system. The context information such as temperature, humidity and luminance are passed on to the livestock ontology from the livestock farm, where the context interpretation and context reasoning takes place.

The received low-level raw data are interpreted to high –level data during the context interpretation. The context reasoner, such as Pellet or Hermit++, are used in the reasoning of context information by interpreting the defined rules. All the rules are stored in the rule base, which helps to reduce ambiguity and increase the richness and quality of the context information. The process manager processes the final decision made by the Inference engine. For the environmental services, the actuator performs the automation and for the production services, the related diet schedule is changed for individual herds accordingly.

As shown in Figure 2, when the monitoring and control service of environment, diet and health management are handled decisively, production services take place which help to sustain the profit in the livestock farm. Herd management service takes care of the cattle feed in the grazing field and also in many ways combines the grassland cultivation for the livestock. The health management services include the medical history of the particular cattle, and the period check-up of the cattle. Similarly, the diet schedule with respect to the food stock is managed in the diet services. On the other hand, the environmental service deals with the environmental parameter of the farm. Each service is wide enough to be created into separate ontology, but to reduce the complexity, the services are not expanded further

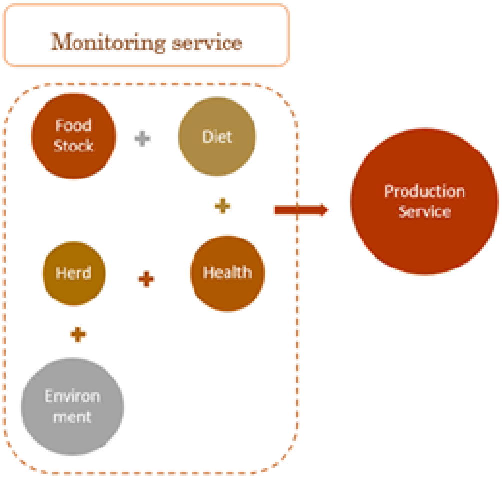

Figure 2. Relationship of Service Management

4. Livestock Ontology

Livestock ontology is designed to focus on the service based Livestock Farm, to acquire commendable profit without any human intervention. The OWL based ontology model is designed and implemented in the Protégé 4.2. After a thorough study of the farm services, the main concept of the Livestock Farm management process is identified. The classified concepts are context, Parameter, Device, Service, Animal, Location, Parameter and Context.

4.1. Context Concept

The term "context" refers to information that can be used to characterize the situation of an entity, which is a location, person or object [15]. In our model, context refers to the set of parameter, time and location. Also, an instance of the context class can be associated with a user in a time. The environmental parameters such as temperature, humidity, and light as a context element, associated with appropriate control equipment, can range from specific sectors of the farm. Thus, the location is interrelated with the context related concepts.

4.2. Service Concept

The automation of services without any human intervention is well received among the ubiquitous computing, such as smart home, smart transport, u-agriculture and smart medicine. Situational awareness of the livestock stock sale is necessary to modify the habitat of the livestock, which can lead to the profit. Considering this situation, the services are divided into three parts; control service, monitoring services and trading service. All the above services need to be maintained efficiently to increase the productivity of the livestock farm.

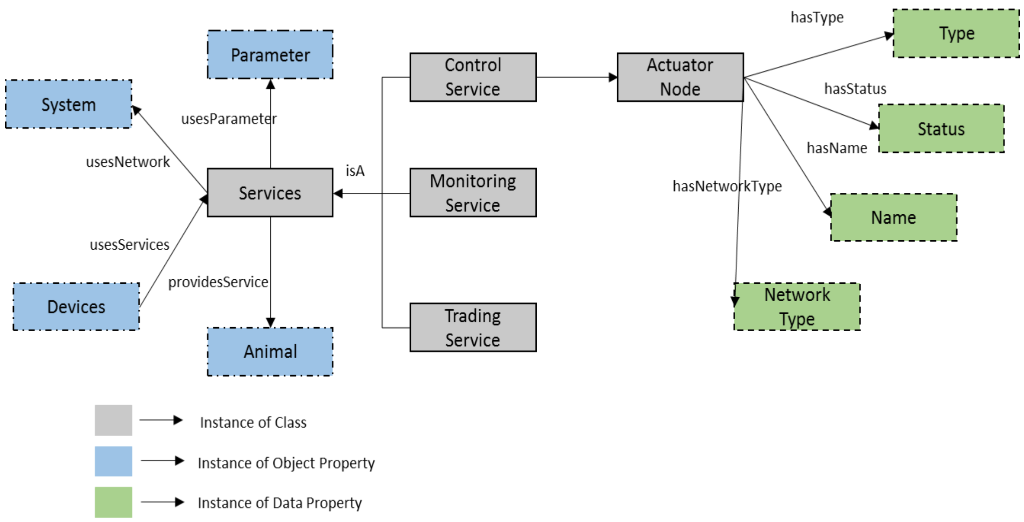

Figure 3. Service Class Concept

For a better production result, precise monitoring services are indispensable. In other words, as both the monitoring and control service are linked together, the complication in monitoring service will affect the control services, resulting in the decrease of productivity. As long as both the services are intact, the trading service moves forward smoothly with the respect to the stock price. In livestock auction, stock market price is considered to be a key factor in deciding the profit of the livestock farm. Therefore, the diet schedule is managed with the stock price in track. According to the trade and the stock sale, each individual livestock's diet schedule is managed automatically after undergoing a decision support system. Figure 3 shows the service concept in the livestock ontology.

4.3. Device Concept

Sensor and Actuator are basic sensory devices used in the livestock farm. Apart from the environmental sensor, there are a few more sensors that help in the analysis of healthiest livestock. Some of the sensory equipment is the RumiWatch [16], which helps in the identification of rumination using the pressure and motion of the mouth, the pedometer to get the burnt calories and the movement of the livestock, and lastly, CCTV and RFID are used to track the livestock activity. While the sensor collects the data, the actuator performs action accordingly. The actuator has control over the control equipment, which involves the Humidifier, Heater and Light. In accordance with the context parameter, the control equipment are selected. Figure 4 depicts the Device Concepts and its instances in the livestock environment.

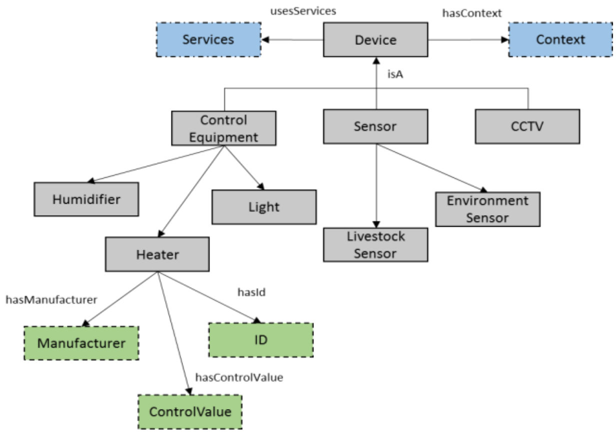

Figure 4. Device Class Concept

4.4. Parameter Concept

Apart from the context information about Livestock Farm, we also need other supplementary information to our services. Hence, the parameter concepts are divided into Context Parameter and Supplementary Parameter. The Context Parameter consists of environmental and livestock information from the respective sensors such as temperature, humidity, illuminance, pressure and motion, whereas the supplementary parameter contains stock and weather information. The selection of the services is mainly dependent on the parameter values, which are accompanied by the SWRL rules. The result in the variation of environmental parameter affects the actuator to maintain the optimal condition through controlling the equipment. As we mention environmental parameters, it includes both the indoor and outdoor environmental conditions. Although the indoor factor plays a major role, the outdoor factors are not to be omitted. According to the daily weather condition, the environment parameter can be manipulated for the indoor purpose and also, the cattle grazing in the outdoor field is adjusted. Figure 5 represents the overview of the parameter concept and the instances of the livestock ontology.

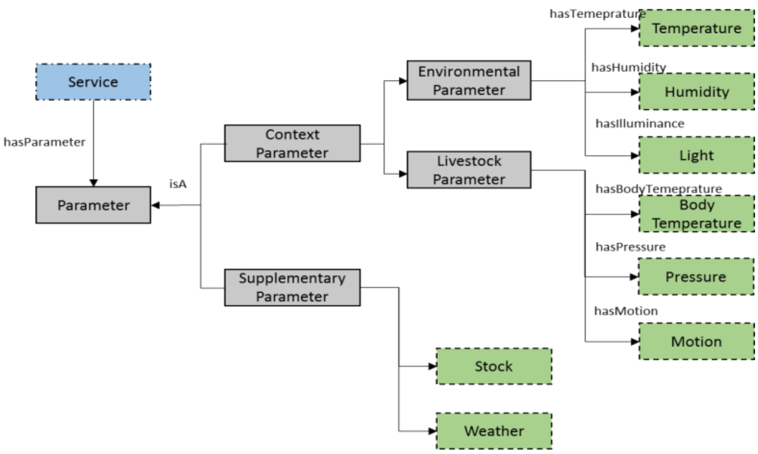

Figure 5. Parameter Class Concept

4.5. Location Concept

As there are many sensory devices around the farm, the location of the sensor and actuator are significantly necessary to maintain the automation process. Usually on the farm, the herds move back and forth for the indoor and outdoor field grazing, so the location concept is divided into indoor and outdoor location. The location of the cattle can be determined or controlled using the RFID reader, as each cattle is given a unique RFID tag. On a large-scale livestock production, the number of buildings and sectors are plentiful. Therefore, it is necessary to be appropriate to the farm's location. In livestock ontology, considering the above situations, the location is divided into farm and livestock location as shown in the Figure 6.

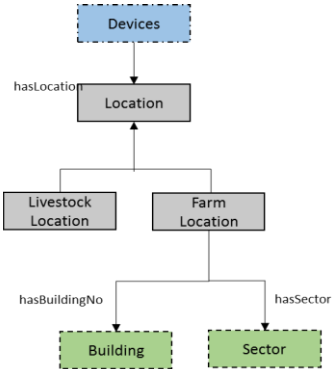

Figure 6. Location Class Concept

3.6. Animal Concept

In this concept, the details of the individual animal's information are included, which are nurtured in the livestock farm environment. Each livestock is given a unique RFID tag, which contains the history of the specific Livestock. RFID [17] is the wireless use of electromagnetic fields to transfer data, for the purposes of automatically identifying and tracking tags attached to objects. Apart from that, the RFID has become crucial in animal identification and other reasons include disease control, cost control, safety, crime prevention and improving customer service. The RFID reader is placed in the farm to collect the data of the livestock periodically. Figure 7 shows the few instances of data property for the Cattle class, which includes ID, Age and Weight. Age and Weight play the major role in the trading service of the cattle. Slaughtering age of the cattle is between 2 to 3 years with an average weight of 450 to 550 Kg. Each phase of the cattle is categorized respectively, with the age and type.

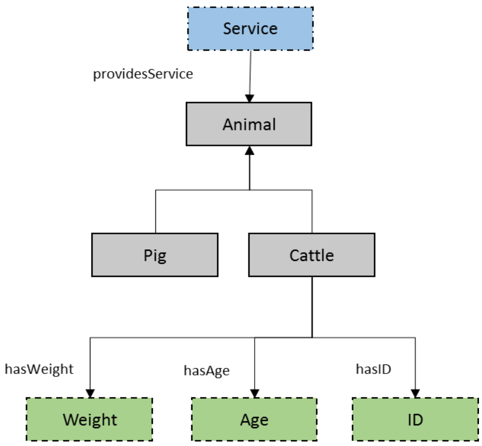

Figure 7. Animal Class Concept

3.7. System Concept

In this pervasive environment, the communication and storage is the most important factor that cannot be ignored. Not to mention, the WSN is overwhelming all over the world. The sensor uses the wireless communication protocol to deliver the parameter to the server. The wireless technology used in the vertical farm environment is Zigbee technique, which uses the frequency of 2.4GHz. The programmable logic controller (PLC), which is the wired communication protocol, helps in controlling the control equipment. Figure 6 depicts the system concept used in the livestock model. Control services use the network type to determine the controller and the system makes use of the context to store and process the information for the decision support system.

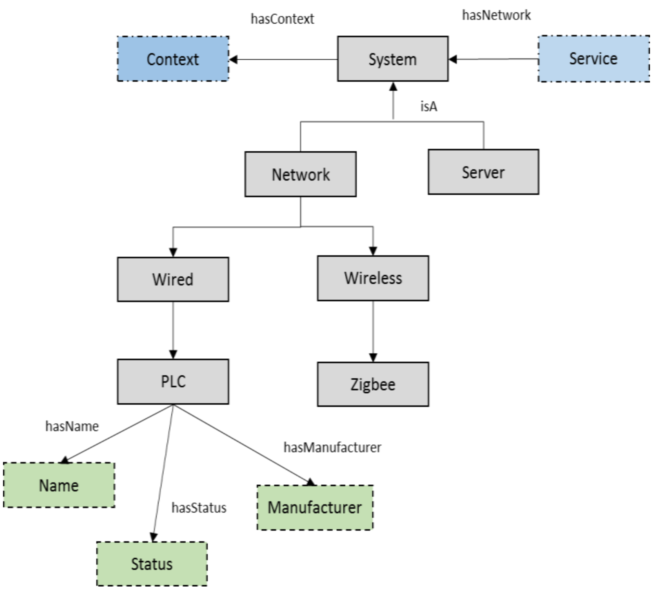

Figure 8. System Class Concept

5. Instantiation of Livestock Ontology

The Livestock Ontology is designed to increase the productivity of livestock products through smart services in a service-oriented pervasive system. The OWL Web Ontology Language that defines and instantiates the web ontologies are used. The ontology model was implemented in protégé 4.2. Protégé is a free, open source ontology editor and a knowledge acquisition system. OWL Ontology was verified by retrieving the desired information with SPARQL Query Language. The semantic interoperability to exchange and share knowledge between the systems is achieved using the ontology model.

OWL ontology consists 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 individuals are the members of the class. As shown in the Figure 9, the concepts are classified into the class, whereas the object and data properties are stated according to the triples, which helps in defining the relationship of the entities. The individual element is an instance that contains all the corresponding RDF-triplet information.

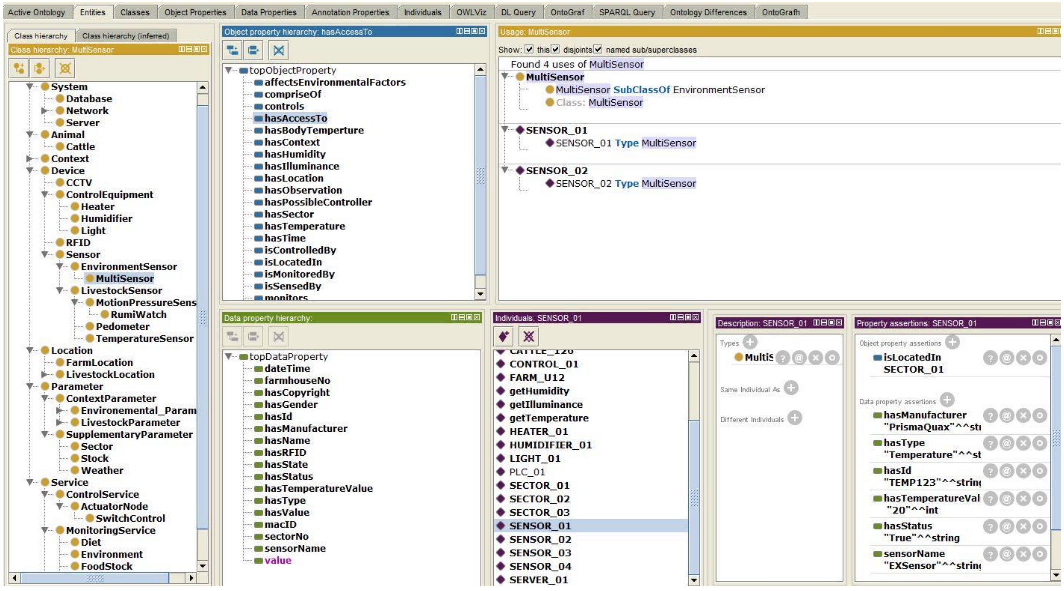

Figure 9. Entities of Livestock Ontology

To ensure the flawless decision support system, the relationship between the entities and the level of formality needs to be precise. It is made possible with the OWL reasoner like Pellet or Hermit++. The reasoner creates the inferred instances after analyzing the entities and the SWRL rules. SWRL is a proposed language for the semantic web used to express rules as well as the logic combining the OWL DL. In OWL, the SWRL is semantically layered at the top, mainly used in the statement that OWL cannot express. SWRL rule has its own syntax, but it can also be expressed as regular defined rules. In protégé, rule is provided where all the rules can be expressed. Inferred results are obtained after starting the reasoner in the protégé. Among the reasoners, the only Pellet supports the SWRL rules with and without the SWRL syntax. Therefore, the Pellet reasoner is used to infer the result in the livestock ontology.

For example, when the environmental temperature falls below the optimal temperature, the heater is switched on. This particular example can be expressed in rule with and without the SWRL syntax; Rule 1 follows the direct way of providing the value of the optimal temperature, whereas in the rule 2, the logical approach is followed expressing through the SWRL syntax.

Rule 1:

MultiSensor(?x), hasTemperatureValue(?x, ?tvalue), greaterThan(?tvalue, 25) -> hasController(?x, CONTROL_01)

Rule 2:

Multisensor(?x1) ∧ isLocatedIn(?s1) ∧ hasCurrentTemperature(?x1, ?x2) ∧ hasOptimumTemperature(?x1, ?x3) ∧ swrlb: lessThan(?x2, ?x3) -> hasPossibleOfController(?s1, CONTROL_01)

> **Rule 3:**
>
> System(?s), hasNetworkType(?s, ?n), equal(?n, "Wired") -> isControlledBy(?s, PLC)

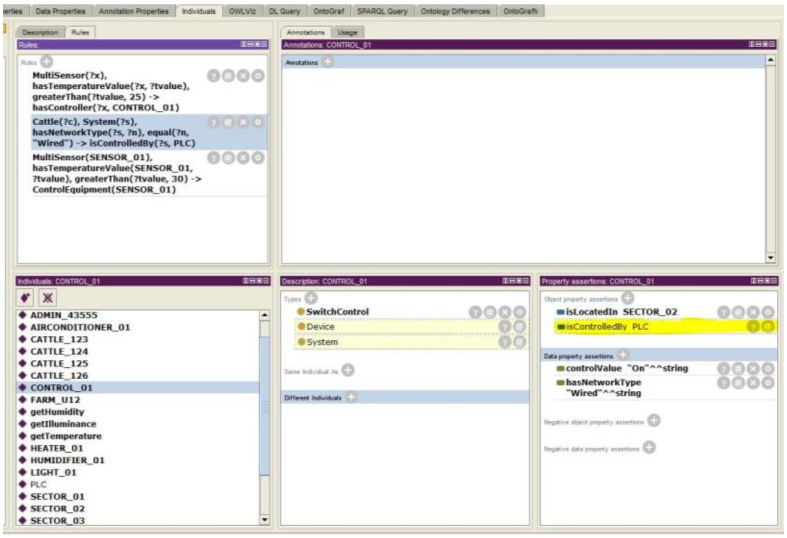

Figure 10. Inferred Result of Individual CONROL_01

The Rule 1 explains one of the possibilities of control selection with respect to Temperature and Humidity. According to the SWRL rule, when the sensor receives the temperature value greater than 25 degree Celsius, the controller is called. As the temperature is increased to 30 degree Celsius, the air-conditioner is called to reduce the temperature, which belongs to the CONTROL_01 individual. Likewise, all the relationships are defined and inferred to create a smart decision support organization for the livestock farm production service.

The inferred result is not only formed by the rules, it also depends on the relationship of entities defined along with the object and data properties. For example, the systems with the wired communication are controlled by the PLC of a particular location.

Although the rule is simple enough, the inferred result is obtained only when the location of the controller is defined in the corresponding individual. Usually, when the reasoner is started, the inferred instances are revealed in the individual tab of Protégé. As shown in the figure 10, the inferred results in the rule 3 are highlighted. The instance "isControlledBy" is generated that explains the Controller (CONTROL_01) is controlled by PLC. As discussed above, as a result of the relationship, the "isControlledBy" instance, found its way to the CONTROL_01. The explanation of the inferred result is shown in the Figure 11.

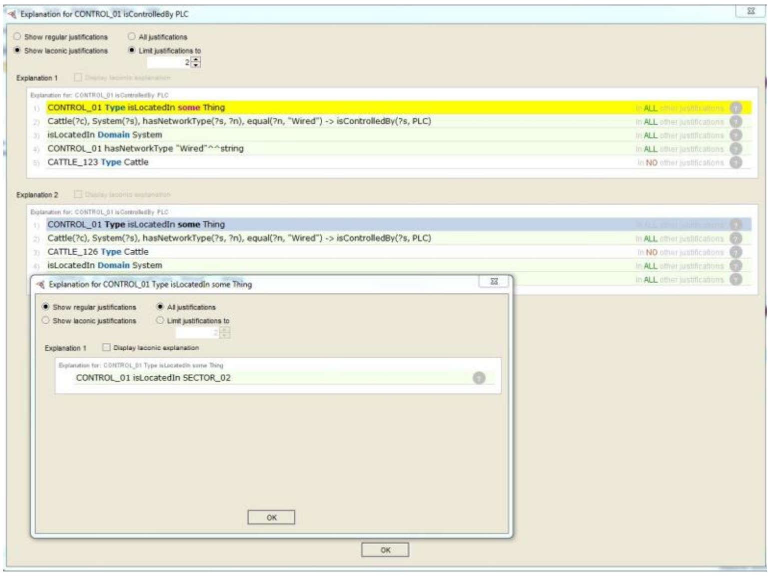

Figure 11. Explanation of Individual CONTROL_01

As it describes, the CONTROL_01 is located in SECTOR_02 and the object property "isLocatedIn" has a domain type system. Linking the rule with the above two triples, the instances are generated. Following the same logic, all the individuals earn the implicit information.

6. Experimental Scenario

To improve the perceptive view on the ontology model, we have discussed an experimental scenario. Let us assume the Cow livestock being tendered in a feedlot farm environment.

Case 1. Temperature variation is a common environmental issue in the degradation of the livestock health.

In case of the environmental condition, regardless of the outside weather, the optimal temperature needs to be maintained inside the farm. When the temperature exceeds the optimal temperature, the fan is turned on to bring down the temperature. Similarly, when the temperature drops, the heater is turned on to maintain the room condition.

- When the *Current Temperature > Optimum Temperature*, then change the Status of Temperature == "*HOT*".
- When the *Status of Temperature == HOT*, then turn on the Air Conditioner (*State of AirConditioner == "ON"*)

With the help of the biosensor, the body temperature of the livestock is periodically monitored. If the temperature exceeds the normal temperature, the values are logged and an alert message is sent for an immediate health check-up. The health report with a detailed examination is uploaded after the check-up. Even the epidemic disease can be figured out earlier which can be prevented from spreading.

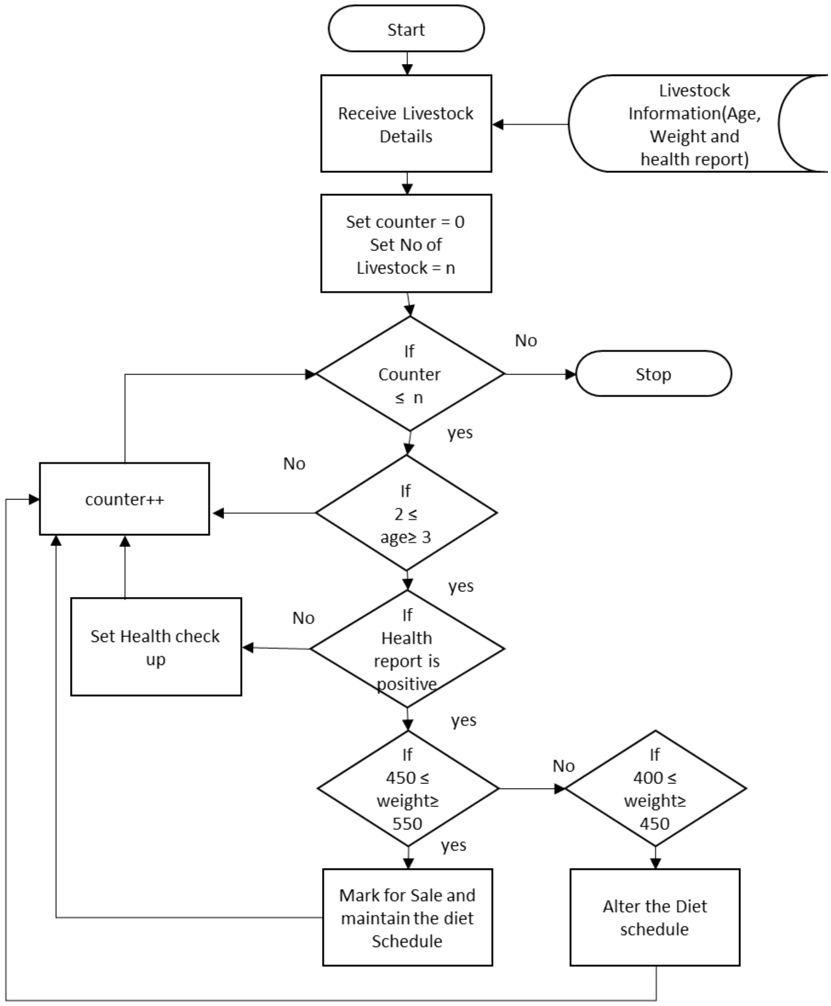

Figure 12. Basic Check Scenario for Livestock Production Management

Case 2. For an intelligent production system, the management strategies should be more active with the planned task considering the stock changes. The stock sale plays an important role in the production management of livestock environment. Figure 12 shows the livestock selection and the schedule update for diet and health checkup.

Stock sale is monitored and analyzed periodically. If the stock shows an uprising, the service to be provided includes as follows:

- *When the Stock = "UPRISING", sort the livestock according to age.*
- *If (2 > AGE < 3), Check for the "Health status == POSITIVE".*
- *else Change the State of Livestock == "NEED_HEALTH_CHECK_UP"*
- *If (450 > WEIGHT < 550), State of the Livestock == "READY_FOR_SALE"*
- *Else if (400 > WEIGHT < 450), State of the Livestock =="CHANGE_DIET"*
- *Else, State of the Livestock == "MAINTAIN_DIET"*

7. Conclusion and Future Work

In this study, a context-based ontology model was designed for the production management service to identify and control the situational uprising and downsizing of stock sale in livestock environment. With the Context information from the Sensory devices and other supplementary services, the management of the production system was improvised to reap a good profit. For our future work, we have planned to extend the scope of the production service with detailed algorithm including the fuzzy logic technique. We have also decided to extend the view of various services in the livestock to include in the ontology model.

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