A Thesis
For the Degree of Master of Science

Customised Semantic Sensor Web Based on Ontology for Pig Farms

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August 2010

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A thesis submitted in partial fulfillment of the requirement for the degree of Master of Computer Engineering

2010.08.

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2010.07.

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ABSTRACT

Sensor networks are used in various applications in several domains for measuring and determining the physical phenomena and natural events. Sensor enablement machine is used to capture and observe the characteristics of physical objects and features of natural incidents. In a computing environment, it is important that all applications must be executed on a system. This research proposes a semantic information model for heterogeneous sensor data representations in pig farms. In real world applications, sensor data is an integration of various data such as temperature, humidity, gas and wind speed in pig farms. We think that pig health management conditions and the environmental cause influences on pig care. For example, the extreme climatic conditions such as high air temperature together with high air humidity lead to reduction of pig growth. In order to support the pig care service for an increasingly intelligence society, an ontology based pig care research is certainly needed. To provide intelligent pig care services to users anywhere and anytime by converting the sensing data to context and implication information.

In this thesis, I propose a hierarchical data model by converting the sensing data to context and implication information, which is collected by using a sensor networks based on temperature, humidity, wind speed and gas sensors in pig farms environment. In proposed model, a physical layer is represented a real sensing data of pig farms environment, and an event layer is extracted the feature of physical sensing data. The semantic layer is discovered the implication information from semantic data in order to recognize the situation, and context awareness layer provide a customized monitoring services in pig farm environment. In additional, we represent these information and the relations in a hierarchical data model by using Protégé tool and relational SPARQL based on ontology. Protégé tool includes querying and interface the objects information based on ontology, and relational SPARQL queries are used to derive the relations and returning the information about the objects on their relative positions. Finally, we implement and test the semantic sensor web based on ontology using proposed hierarchical data model and information for each layers in the pig farm. Therefore, the implementation of semantic sensor web based on ontology may provide pig situation monitoring services.

Keywords: Data modeling, Ontology, Protégé, Sensors, Semantic Sensor Web.

국문초록

센서 네트워크(Sensor networks)는 몇몇 분야들에서 물리적 현상들과 자연 현상들을 측정하고 알아내기 위해서 다양한 응용프로그램에 사용된다. 센서들은 물리적 대상의 특성과 자연적 사건의 특성을 정확히 포착하고 관측하는 것을 가능케 한다. 컴퓨팅 환경(computing environment)에서 모든 응용프로그램들이 시스템에서 실행되는 것은 중요하다. 이 연구는 여러 다른 종류들로 이루어진 센서데이터 표현을 위한 계층적인 데이터 모델을 제안한다. 현실 세계의 센서 데이터응용프로그램들은 양돈 환경에서의 온도, 습도, 가스, 풍속과 같은 다양한 데이터 통합일 것이다. 동물 건강관리 조건과 환경적인 원인이 동물관리에 영향을 미친다. 예를 들어, 높은 대기 습도를 포함하여 높은 대기온도와 같은 극심한 기후 환경은 동물 성장을 저해하는 문제를 야기한다. 점점 더 지능적인 사회를 위한 동물 관리 서비스를 지지하기 위해 온톨로지(ontology) 기반의 동물 관리 연구는 필요하다. 언제 어디서든지 사용자들에게 지능적인 동물 관리 서비스를 제공하기 위해 센싱 데이터를 상황 정보나 의미있는 정보로 변환하여 사용자에게 전달해야 한다.

본 논문에는 양돈 환경에서 온도, 풍속, 가스, 습도 센서들과 같은 센서 시스템을 사용하여 수집된 센싱 데이터를 상황 정보나 의미있는 정보로 변환하는 계층적 데이터 모델을 제안한다. 시멘틱과 상황 인식 계층은 위한 시스템은 또한 상황을 인식하고, 맞춤형 모니터링 서비스를 제공한다. 더불어 양돈 환경 데이터는 다양한 센서에서 수집되고 임시 저장 서비스에 저장된다. 이러한 데이터는 protégé 를 사용하여 내부개체들을 포함하는 관계를 컴퓨팅을 하기 위해 사용되었다. 센서로부터 온톨로지 개체 정보와 처리를 위한 protege

사용은 개체정보 이상의 인터페이스와 질의를 포함하고 있습니다. 상관관계에 있는 SPARQL queries 는 그들의 상대적인 위치에 있는 개체에 대한 정보를 반환하는 관계를 파생하기 위하여 사용된다. 마지막으로 양돈 환경에서 제안한 계층적 모델과 관련 각 계층별 정보를 이용하여 온톨로지 기반의 시멘틱 센서 웹을 구현하고 실험한다. 그리고 온톨로지 기반의 시멘틱 센서 웹은 돼지 상황 모니터링 서비스를 제공할 것으로 사료된다.

키워드 : 데이터 모델링 , 온톨로지 , 프로테지 , 센서, 시멘틱 센서 웹

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I. INTRODUCTION

1.1 Background

A sensor network is a computer accessible network of many, spatially distributed devices using sensors to monitor conditions at different locations such as temperature, sound, vibration, pressure, pollutants etc. A sensor web refers to web accessible sensor networks and archived sensor data can be discovered and accessed using standard protocols and application program interfaces (APIs). The sensor web is a special type of web-centric information system for collecting, modeling, storing, retrieving, sharing, manipulating, analyzing, and visualizing information of sensors, sensor observations, and associated phenomena. Lack of standardization is the primary barrier to the realization of a progressive sensor web (Simonis 2008).

The semantic sensor web is a frame work for providing enhanced meaning for sensor observations so as to enable situation awareness. It enhances meaning by adding semantic annotations to existing standard sensor languages of the SWE. These annotations provide more meaningful descriptions and enhanced access to sensor data, and they act as a linking mechanism to bridge the gap between the primarily syntactic XML based metadata standards of the SWE and the RDF/ OWL based metadata standards of the semantic sensor web. In association with semantic annotations, ontologies and rules play an important role in the semantic sensor web for interoperability, analysis and reasoning over heterogeneous sensor data.

Ontology is a widely accepted tool for the modeling of information. The term ontology comes from the field of philosophy, and is concerned with the study of being or existence. Although there are a lot of definitions of ontology in the context of computer and information sciences, Ontology is generally regarded a formal representation of a set of concepts within a domain and the relationships between those concepts. It is used as the reasoning behind the properties of the domain, and may be used to define the domain. The foundations that represent ontology are typically classes, attributes and relationships. The definitions of these foundations include information about their meaning and constraints on their logically consistent application.

Different data bases will typically have very different metadata schemes. This will severally limit once ability to search and retrieve objects stored in distributed data bases. Ontology based semantic sensor web interoperability can overcome this problem, as it enables the relationships between the various metadata schemes to be formally represented with in a common machine processable representation i.e, and OWL ontology. The ontology acts as a mediator that facilities federated searches across heterogeneous and data repositories. The initial studies of monitoring Pigs in stressful environments are essential for welfare and commercial purpose. A sensor networks have the potential to significantly enhance the research into Pig Farms, environmental and natural resource problems. The principle features of these networks as research tools are that they can provide a dense, multivariate, high frequency, real time analysis of natural phenomena. These and other features provide an opportunity to detect previously unrecognized relationships and behaviors in Pig Farm situation monitoring system.

1.2 Objective

The objective of present research is primarily placing on the studies of semantic sensor web based on ontology for pig farms. There are three specific goals in this research:

The first goal is to propose architecture of hierarchical data modeling for pig farms and creation of semantic sensor data description. Most of the previous studies regarding this subject have been performed with different simulation models to predict the indoor climatic conditions influencing in the pig farms such as temperature, humidity and wind speed, so that the data modeling was not considered. Even though those approaches can provide scientifically meaningful information, it is essential that the customization of semantic web should be considered together, because semantic web based on ontology provides the relations between objects and entities. In order to investigate the effects of pig health condition depend on the inside environmental changes in pig farms, data modeling were proposed with various sensors. The variation of environmental changes around the pig farm was received through the sensors.

The second goal is to establish ontology based data modeling for each sensor and applying rules between layers. Up to now, the majority of the previous studies have been used the context-aware computing and ontology-based model in several environments. Indeed, those systems are suitable to study integrate high-level features that characterize the sensor networks for customizing rout behavior but their required a lot of time for development. In order to simplify the existing model ontology based data modeling study is modified to each layer, Ontology objects information from sensors and use the protégé for processing which includes querying and interface of the objects information. The usefulness of this ontology based data modeling for each layer is verifying by using protégé tool. We can ensure the feasibility of this ontology based data modeling for characterization of environmental conditions in a pig farm.

Finally, try to implement the semantic sensor web based on ontology of various sensor data and objects information in pig farm. Those semantic web technologies can provide high level information extraction and interface of sensor data and objects information. Therefore, the extensive study for implementation of semantic sensor web based on ontology may provide pig health information.

1.3 Thesis Outline

The outline of this thesis is organized as follows: Chapter I describes the Background of semantic sensor web, objectives and related works. Chapter II provides the previous researches related to ontology and semantic sensor web, sensor ML, Ontology and protégé, Pig farms in sensor networks. Chapter III Proposed hierarchical data modeling for Pig Farms, which includes the layers architecture for pig farms data modeling and semantic sensor data description for pig farms, context-awareness based architecture in pig farms inside environment and ontology based context modeling. Chapter IV covers the ontology structure of data modeling for pig farms and implementation on ontology structure with protégé was described in detail, the implementation and analysis of semantic sensor web for pig farm. It is mainly based on sensor web architecture, semantic sensor web ontology in pig farms and SNS structure. Chapter V presents at last conclusions of the findings in this research.

1.4 Related works

Many research works of academic and industrial communities has been done by several pig health conditions and inside pig farms environment using several sensors. Schauberger et al. (2000) applied the three balances to predict the indoor climate in a finishing pig unit. Tao and Xin et al. (2003) were found different models to evaluate the different influencing factors such as temperature, humidity, and velocity of the speed (Thermal Comfort index equation). Hinz and Linke (1998), Pedersen et al. (1998), which required calculation of heat loss by conduction through the building envelop, heat lost by total ventilation airflow, and sensible heat produced by the pigs . Ishak & Siraj (2002) worked on how to help pig farmers to diagnose, treat and prevent pig disease timely and effectively a serious challenge for Chinese agriculture department and pig farmers.

Pedersen et al. (1998) investigated the agreement between the ventilation flow calculated from the CO_2, moisture and heat balances in houses for pigs. Dioguardi (2008) worked in uncomfortable thermal conditions for milkers were found in dairy cattle farms in winter as all milking premises were not heated. In pig farms, the microclimate hazard concerned operators working in a very hot environment and having to withstand strong thermal shock in winter. The environment in which pigs are expected to live and grow is really the composite of many environmental factors. These factors interact with each other. This makes difficult to identify exactly which external condition is causing pigs to perform poorly (Holis, 1996). Dirty, less hygienic environments increase the level of immunological stress and depress growth and performance of pigs (Johnson, 1996). The effects of high temperature or constant temperatures on feeding behavior and components of energy balance were studied in group-housed young pigs (Anne Collin, 2001). Hwang et al. (2010) offer an integrated management; constructed a u-swinery (ubiquitous swinery) system which is consisted with USN environmental sensors to collect information from physical phenomenon such as luminance, relative humidity, and temperature and ammonia gas. Numbers of CCTV were also installed to monitor inside and outside of the swinery. Ian McCauley et al. (2005) were studied the effects of immediate environmental on the body temperature of the pigs using various sensors measuring the predominantly temperature and humidity around the pigs. Amit Sheth et al. (2008) discussed a semantic sensor Web (SSW) in which sensor data is annotated with semantic metadata to increase interoperability as well as provide contextual information essential for situational knowledge.

II. Previous researches Ontology and Semantic Sensor Web

Context awareness is one of the key features for pervasive middleware. In regions of intensive pig farming and other risks of pollution (losses of air and accumulation of nutrients in soils) are also sources of concern. Context is defined as information used for identifying the status of an entity. An entity may become a place, pigs, physical or computing objects (Pedersen et al.1998).

This context includes a user and application, and reflects the relationship of interactions between a user and an application. Based on this, entity in ubiquitous learning environments means users, position, activity, and computing device of the environments. Schilit et al. (1994) defines that context-aware computing is not only adaptable according to a place, person, and a group of objects, but also it is software which can accept changes of objects as time goes. In the context of the knowledge management, ontology is referred as the shared understanding of some domains, which is often conceived as a set of entities, relations, functions, axioms and instances (Holis et al. 1996). Through this ontology, the vocabularies of a specific domain can be defined in a common way, and thus knowledge can be shared (Johnson 1996). After context mediator gathers and judge's simple context information, as each device gains, delivers the message which is appropriate for objects.

Research on ontology-based context models are able to share context information and reason context by defining contexts using these ontology languages, have been conducted. Ranganathan et al. (2003) suggested the infrastructure that supports collection of context information from other sensors and supports delivery of appropriate context information through ubiquitous computing application. GU et al. (2004) suggested an ontology-based model in intelligent environments as well as service-oriented context aware, middleware and architectures through OWL.

2.1 Sensor Web

A sensor network is a computer accessible network of many, spatially distributed devices using sensors to monitor conditions at different locations, such as temperature, sound, vibration, pressure, pollutants. A sensor web refers to web accessible sensor networks and archived sensor data can be discovered and accessed using standard protocols and application program interfaces (APIs). The sensor web is a special type of web-centric information system for collecting, modeling, storing, retrieving, sharing, manipulating, analyzing, and visualizing information of sensors, sensor observations, and associated phenomena. Lack of standardization is the primary barrier to the realization of a progressive sensor web.

2.1.1 OGC Sensor Web Enablement

OGC is developing an open standard based on web for various sensors and sensor systems. The standard will provide a great opportunity for adding real-time sensor dimensions to the internet and the web. This is greatly important for science, environmental monitoring, public safety, facility security, disaster management, industrial controls, facilities management and many other domains of activity.

OGC sets a target for the functionalities of the sensor web as follows:

- Discovery of sensor systems, observations, and observation processes that meet an application or users immediate needs.
- Determination of a sensor's capabilities and quality of measurements.

- Access to sensor parameters that automatically allow software to process and geo-locate observations, Retrieval of real-time or time-series observations and overages in standard encodings.
- Tasking of sensors to acquire observations of interest.
- Subscription to and publishing of alerts to be issued by sensors or sensor services based upon certain criteria.

The OGC enablement of such sensor webs and networks is being pursued through the establishment of several encodings for describing sensors and sensor observations, and through several standard interface definitions for web services. Sensor web enablement standards that have been built and prototyped by members of the OGC include the following pending OpenGIS® Specifications:

Observations & Measurements Schema (O&M) – Standard models and XML Schema for encoding observations and measurements from a sensor, both archived in real-time.

Sensor Observations Service (SOS) - Standard web service interface for requesting, filtering, and retrieving observations and sensor system information. This is the intermediary between a client and an observation repository or near real-time sensor channel.

Sensor Planning Service (SPS) – Standard web service interface for requesting user-driven acquisitions and observations. This is the intermediary between a client and a sensor collection management environment.

Sensor Alert Service (SAS) – Standard web service interface for publishing and subscribing to alerts from sensors.

Web Notification Services (WNS) – Standard web service interface for asynchronous delivery of messages or alerts from SAS and SPS web services and other elements of service workflows.

2.1.2 SensorML

SensorML provides a functional model supporting the processing and geolocation of sensor observations, rather than a detailed description of sensor hardware. SensorML provides support for insitu and remote sensors, on both static and dynamic platforms shown in above Figure 2.1.

Web-enabled sensors provide the technology to achieve rapid access to various kinds of information from the environment. Presenting sensor information in standard formats enables integration, analysis and creation various data views that are more meaningful to the end user and to the computing system which process these information. Moreover, a uniform encoding benefits the integration of heterogeneous sensors and sensor platforms to form a uniform, integrated and standard view to the client. The details of encoding of SensorML are described (Studer 2004), which is basically defined over several XML schemas and extends and reuses a lot of elements. SensorML is a key component for enabling autonomous and intelligent sensor webs. It provides the information needed for discovery of sensors, including sensor's capabilities, geo-location and task ability.

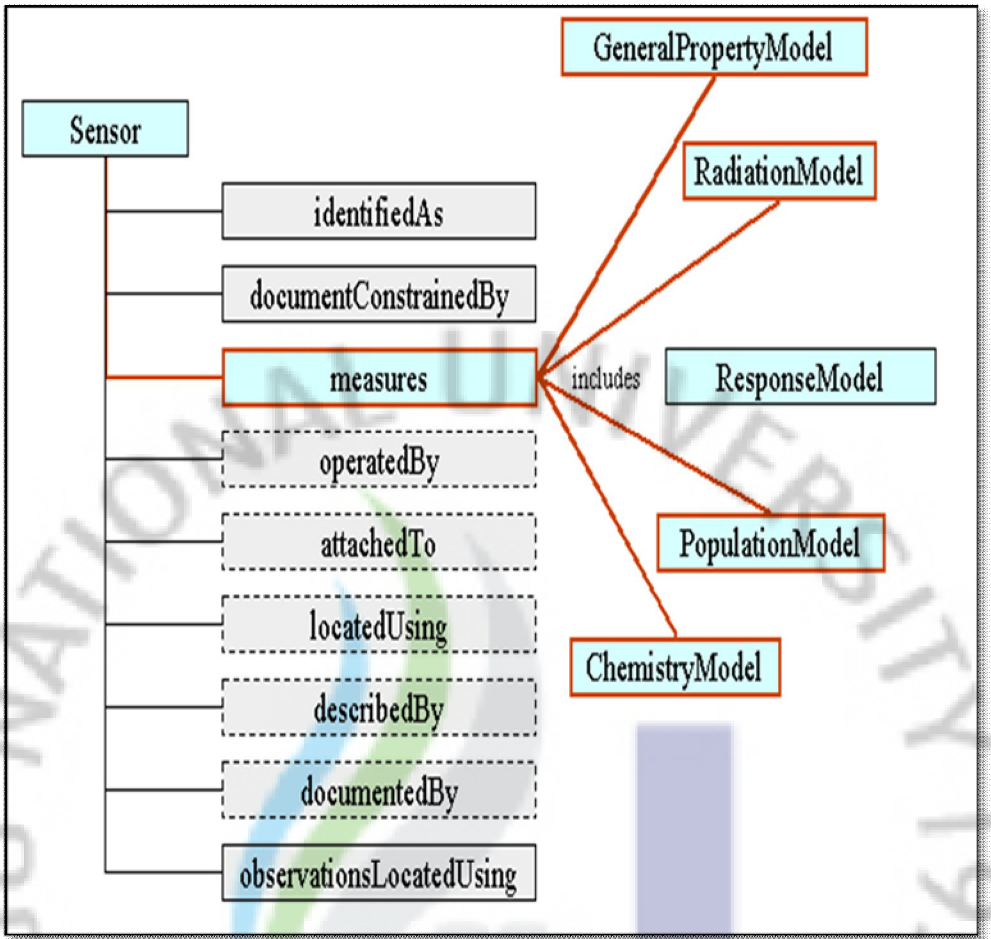

Figure 2.1: SensorML descriptions of instruments capabilities and the measured data

Currently, the framework defines catalog services for discovering sensors and sensor data, collection services for accessing real-time or achieved observation data, planning services for tasking sensors, and notification services for providing users the results of task requests or for alerting users of other services of observed phenomena of interest. Example of sensor ML was shown in Figure 2.2

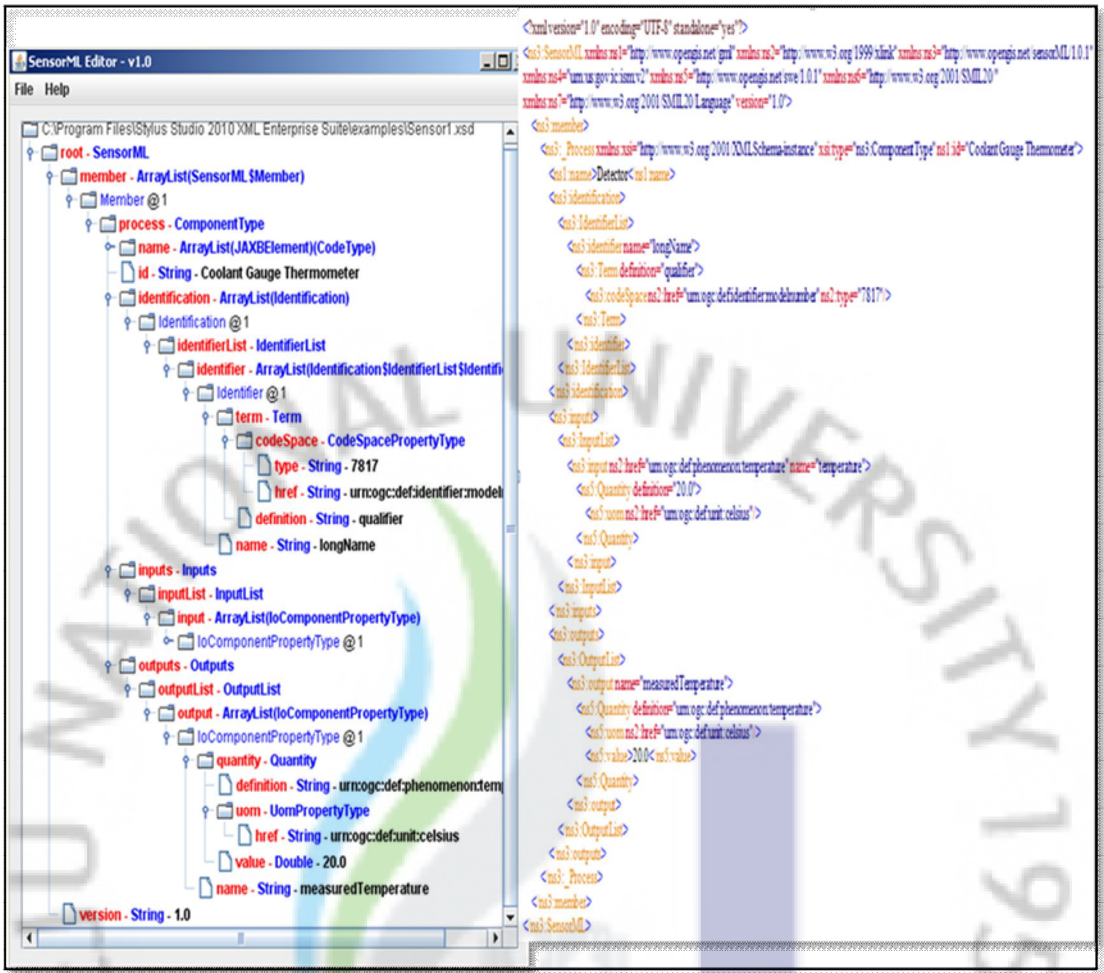

Figure 2.2: Example of SensorML

2.2 Semantic Sensor Web

The semantic sensor web initiative was taken by World Wide Web consortium. The semantic sensor web provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries. The semantic web extends the idea of web applications to an integrated web of data, which can be effectively shared by different users and can be easily processed by machines as well. The semantic sensor web is based on the Resource Description Framework (RDF). Semantic web allows people to express in a machine-processable form, the relationship between different sets of data and their properties. Thus, establishing a “Semantic Link” between data from difference sources, this allows machines to automatically understand data from many heterogeneous sources and thus be able to process and infer new information.

The semantic sensor web is a frame work for providing enhanced meaning for sensor observations so as to enable situation awareness. It enhances meaning by adding semantic annotations to existing standard sensor languages of the SWE. These annotations provide more meaningful descriptions and enhanced access to sensor data, and they act as a linking mechanism to bridge the gap between the primarily syntactic XML based metadata standards of the SWE and the RDF/ OWL based metadata standards of the semantic sensor web. In association with semantic annotations, ontologies and rules play an important role in semantic sensor web for interoperability, analysis and reasoning over heterogeneous sensor data.

The semantic web was introduced for automated programs or agents as well as humans to read and process documents on the web and produce the knowledge from the information. Agents’ understanding of a web document is quite different from that of human. Since agents such as computers have no imagination, it is impossible to teach them words expressing emotions. The ontology was developed by considering the fact that computers can recognize logical relations such as opposite (↔), equality (=), and inclusion (ε). The ontology is effective in having agents recognize the contents of documents by inputting relationships between words.

The ontology is the core in the development of technology for the next generation intelligent web, the semantic web, which enables agents to understand and process the contents of web documents automatically. In additionally, ontology reasoning is also useful in other aspects of context awareness computing.

2.3 Ontology and Protégé Tool

Ontology is a widely accepted tool for the modeling of information. The term ontology comes from the field of philosophy, and is concerned with the study of being or existence. Although, there are a lot of definitions of ontology in the context of computer and information sciences, Ontology is generally regarded a formal representation of a set of concepts within a domain and the relationships between those concepts. It is used as the reasoning behind the properties of the domain, and may be used to define the domain. The foundations that represent ontology are typically classes, attributes and relationships. The definitions of these foundations include information about their meaning and constraints on their logically consistent application. The ontology located on the RDF stratum in the semantic web defines vocabularies as the relationships between terms and inference rules. Ontology is formal theory suitable for implementing the semantic sensor web which is a new technology that attempts to achieve effective retrieval, integration, and reuse of web resources (Hendler J 2001). Ontology provides a way of sharing and reusing the knowledge among the people and the heterogeneous application systems.

The standardization method for data modeling consists of firstly proposing the sensor data-based context ontology standard using the protégé and web ontology language (OWL). As Protégé OWL has been added with a SWRL editor, it permits editing both SWRL rules and OWL ontology's (Noy et al. 2001). In some applications, rules are devoted to a specific task, which can be achieved independently by the ontology. In such cases, it is possible to use distinct languages with specific inference engines, one for the structural part and another one for the rule component. Secondly, the knowledge interface technology for pig situation monitoring services is proposed.

The Web Ontology Language (OWL) uses RDF and XML to represent information in a manner suitable for implementing in ontology. OWL ontology may include descriptions of classes, properties and their instances. With this type of ontology, the OWL formal semantics specifies how to derive its logical consequences, i.e, facts not literally present in the ontology, but determined by the semantics. OWL provides three increasingly expressive sub-languages designed for use by specific communities of implementers and users.

2.4 Pig farms in Sensor Networks

A Pig Farms in sensor networks is a group of specialized transducers with a communication infrastructure intended to monitor physical phenomena like Temperature, Wind speed, Gas and Humidity, location, motion of objects and so on. Each sensor network is deployed to serve a specific purpose and uses its own protocols. This heterogeneity in sensor networks makes it impossible to communicate with each other or to reuse and share their data with different applications. The term sensor networks is used since most sensors are connected using several sensor technologies. Sensor nodes are responsible for detecting and monitoring of certain phenomena and sending the raw measurement data to an end user. Further analysis and processing of sensor data is application dependent.

2.5 Necessity Semantic Sensor Web and Ontology

Different data bases will typically have very different metadata schemes. This will severally limit once ability to search and retrieve objects stored in distributed data bases. Ontology based semantic sensor web interoperability can overcome this problem, as it enables the relationships between the various metadata schemes to be formally represented with in a common machine processable representation i.e., and OWL ontology. The ontology acts as a mediator that facilities federated searches across heterogeneous and data repositories. Environmental temperature, gas, Wind and humidity are important sensors in the design specifications for livestock buildings because of their role in thermoregulation and hence productivity. Various sensors are also impudence the concentration harmful gases, and therefore may have an adverse impact on health. Environmental temperature is not necessarily synonymous with air temperature, except in well insulated buildings with mechanical ventilation, as in the case with many of the livestock buildings in this study. Furthermore, whether an environmental temperature is too warm or too cold depends greatly upon the physiological state of the animal which determines the upper and lower bound critical temperatures, gas, wind speed and humidity. However, the thermal environment in a livestock building can be appraised in terms of the air temperature and relative humidity alone if the buildings are mechanically ventilated and well insulated.

III. Proposed Hierarchical Data Modeling for Pig Farm

3.1 Layered Architecture of Data Modeling

The environment of the pig farms context provides sensing capabilities including light sensors, temperature sensors, humidity sensors, wind sensors, and gas sensors. The temperature sensors sensing the pig body temperature and room temperature data. If the room temperature is high or low, it depends on the pig condition such as healthy, sick, and stressed. Figure 3.1 shows the four layers hierarchical data modeling for pig farms. The data modeling architecture has been divided into physical layer, semantic layer, awareness layer and service layer. The obtained objects from the physical layer are to make the semantic layer with the context-awareness layer and transfer that information latter to the service layer. Moreover, the context awareness layer guarantees the independence of a service, device and mediates the context information provided by the sensor to a service. If the user turns on the sensing devices, the context provides suitable information from the device (Studer 2001).

The variable physical sensing devices of temperature, wind, gas and humidity sensors are used for measuring the information such as wet and dry bulb temperature, humidity and CO_2 etc. The sensing device senses the physical raw data information of a user and then transfers those raw data to the semantic layer. The context-awareness layers receives raw data from the semantic data and then generate to the context model, after that produces the context delivers to services. The semantic database manages context store and context query because the system environment is restrictive of the environments. The pig situation monitoring service is automatically stored by the context-aware framework or is selected by the user using the user interface.

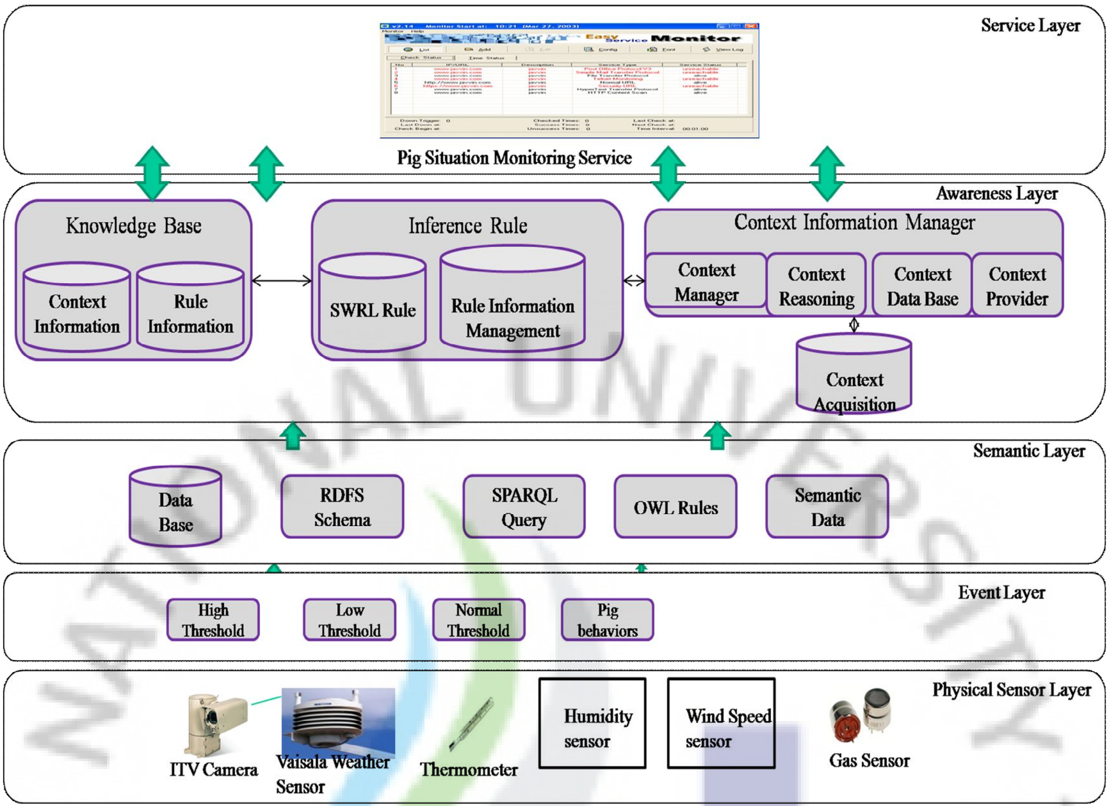

Figure 3.1: Layered architecture of data modeling for pig farms

Physical Layer: The physical layer is the data source layer which consists of heterogeneous sensing sensors. The data from sensors are collected and accessed by semantic layer. The data can have any proprietary format. For example, the physical sensor layer has various kinds of sensors such as gas sensor, humidity sensor, thermometer, temperature sensor, wind speed sensor. Those kinds of sensors collect the data and stored into the database.

Event Layer: The event layer describes the information of sensing data and perfoming the required event description. For example, the event layer access the data from each sensors through database and applying various formula's for getting the results such as upperbound threshold and lowerbound threshold. These threshold values are stored into the database.

Semantic Layer: Once the sensor data is available, it needs to describe the semantics of those data. Therefore, the third layer of this architecture consists of semantic layer. The data can be processed after defining semantics of sensor data in this layer. For example, the semantic layer getting the upperbound and lowerbound threshold values from database, which is depends on the pig health condition and pig behavior. If the room temperature is high then it depends on the pig health condition.

Context Awareness Layer: Events, rules and person ontology help to realize context awareness. The syntax diversity of context and personal profile descriptions can be solved by ontology techniques. We are involving the use of SWRL (semantic web rules language combining OWL and rules). For example, pigs are relatively sensitive to high environmental temperatures because they cannot sweat and are relatively poor at panting. Reduction in the associated thermal effect of feeding is an efficient mechanism to reduce the heat load. Generally it is recommended to raise pigs at temperature 3^0C to ambient conditions. Evaporative heat loss might occur respiratory evaporation from the wet body surface of pigs. Air temperature as critical environmental factor is influenced by relative humidity and air flow velocity. Air humidity level is very important in cooling process. Pigs with cross ventilation have been noticed higher temperatures and lower relative humidity as optimum range in summer period.

Service Layers: The service layer provides various services that require the user.

3.2 Hierarchical Data Model in Pig farms

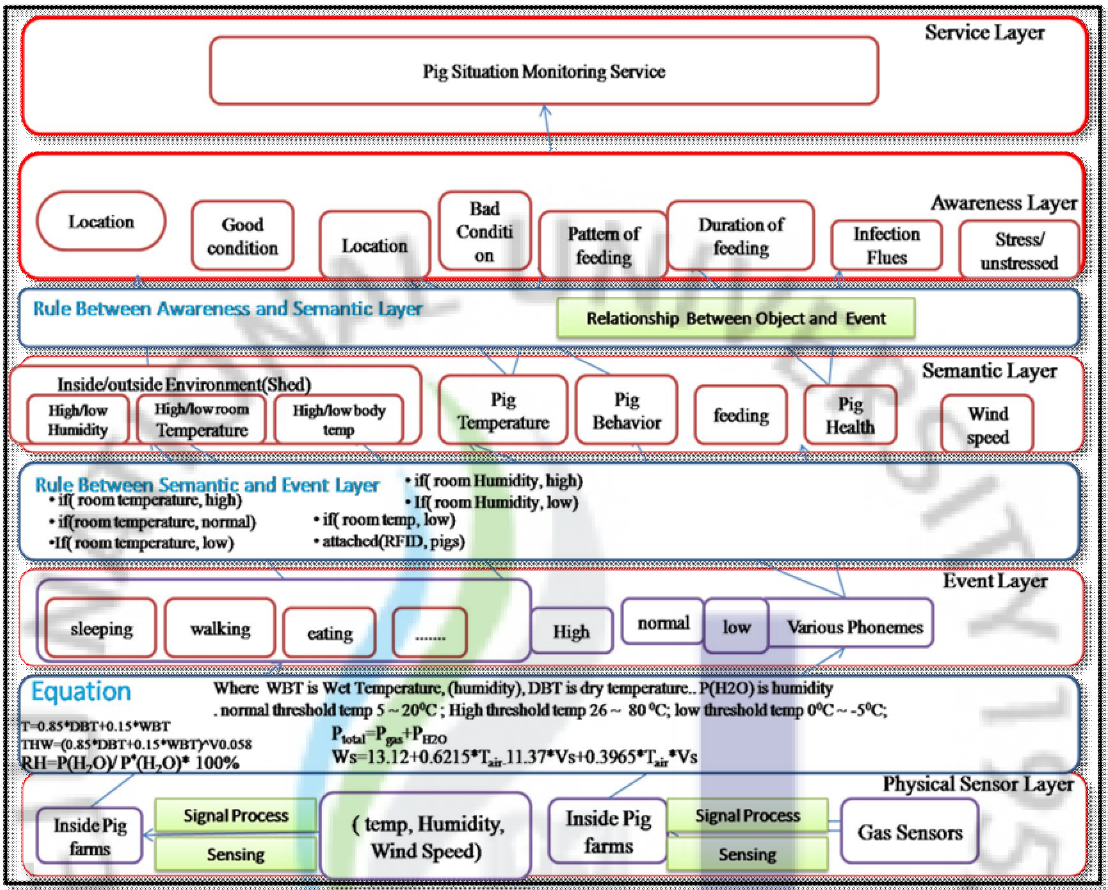

Figure 3.2: Layers data model for pig farms

Semantic information for each sensor is collected information of inside pig farm environment. I implemented the layers of ontology data modeling, which is the basis of the representation and analysis of the various objects information. It is categorize the context data into five layers, such as the physical sensor layer, event layer, semantic layer, context-awareness layer and the service layer. These layers are also including database and the inference rules. The physical sensor layer is the source of context data and also this layer serves as an abstraction between the physical world and the event data. Rules are applied in between the physical layer and event layer such as temperature, humidity, wind speed and gas equations. Once the event data is available, we need to describe the semantics of those data. Rules between the semantic and event layers was taken the analyzed values, it depends on the room temperature (high, low, normal), wind speed (high, low, normal), humidity (high, low, normal). The context awareness layer provides the description of the complex facts with the fusion of context services. Each sensor corresponds to the type of context layer. Objects and events rules are applied between the semantics and context awareness layer.

One of the examples of conditions required:

- Ventilation is needed in pig farms houses for removing harmful gases and heat in order to ensure an acceptable indoor climate.
- High air temperatures together with high air humidity increase the heat stress for the pig's health condition.
- Evaporative heat loss might occur respiratory evaporation from the wet body surface of pigs. Air temperature as critical environmental factor is influenced by relative humidity and air flow velocity as optimum range in summer period.

3.3 Context-aware based Architecture in Pig farms

In the pig farms architecture support services considering different contexts as shown in Figure 3.3, This architecture consists of a pig's information, physical sensors, computing entity and activity on a context-manager in the pig farms. Accordingly, all the components of this architecture are connected to enable both wired and unwired networking, and share sensing information as well as context information. Pig information updates and manages pig ID, pig weight, pig age, gender. Pig information also provides a context-aware manager with this information, and enables activities, physical sensors and other facilities to share context information.

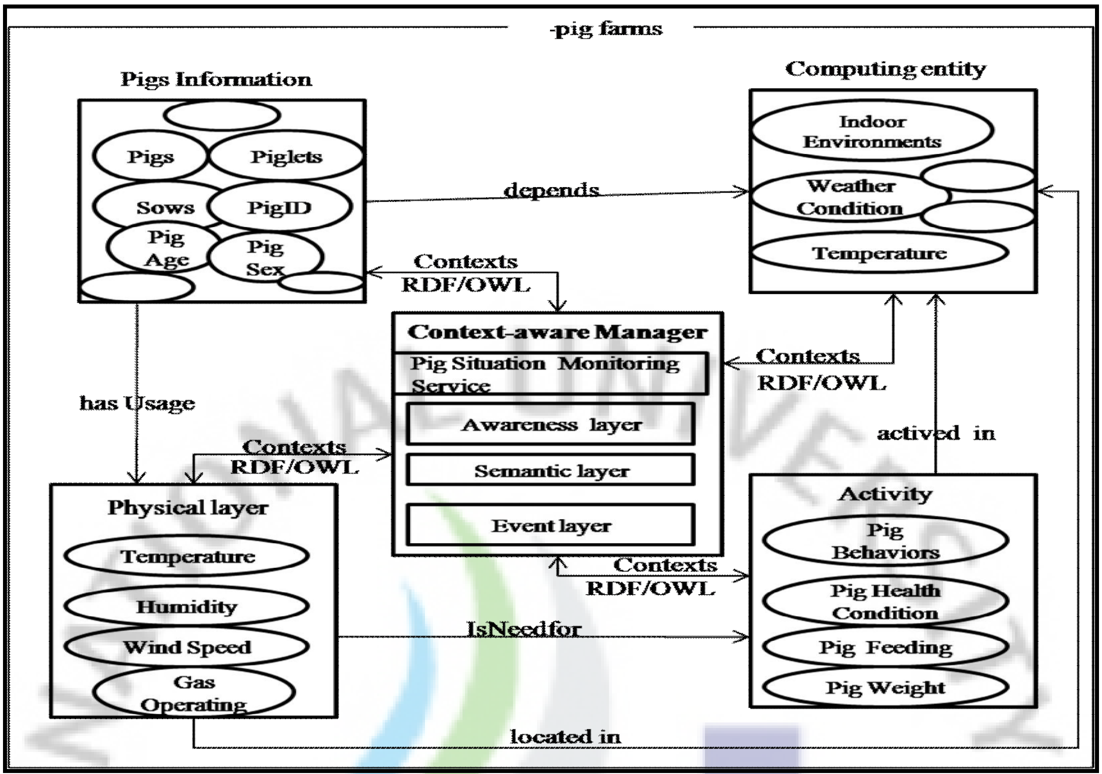

Figure 3.3: Context-aware pig farms service

A physical sensor includes sensor devices such as temperature sensor, humidity sensor, wind sensor, gas sensor and light sensor etc. as well as contents providing users with services. In addition, a computing entity provides a context-aware manager with not only the fixed information of specifications, functions, formats and spaces but also with the changed information related to an individual. An activity manages the information such as pig's behaviors, pig health condition and daily activities of feeding, sleeping and also providing that information to context manager. A physical sensor is one arranged in the pig farms such as outside weather condition, temperature, wind speed, place, time, a related content as well as transmitting it to a context-aware manager.

A context-aware manager consists of a context providing module, a context knowledge base, a context reasoning engine and a pig farms service coordination module. A context-aware manager controls a context module based on ontological reasoning, transforming a new context into semantic place and updating a context module. In addition, it makes context information shared and provides a proper context-aware pig situation monitoring service by in advance applying a changing context into a rule set.

3.4 Ontology Context Modeling

Context is any information that can be used to characterize the situation of an entity. Context-aware computing is the use of context to provide relevant information and services to the pig recognition. A context-aware system should automatically recognize the situation which is based on various sensors. Context modeling is very important in context-aware systems to provide context for intelligent service. Therefore, context modeling is a key feature in the context-aware system.

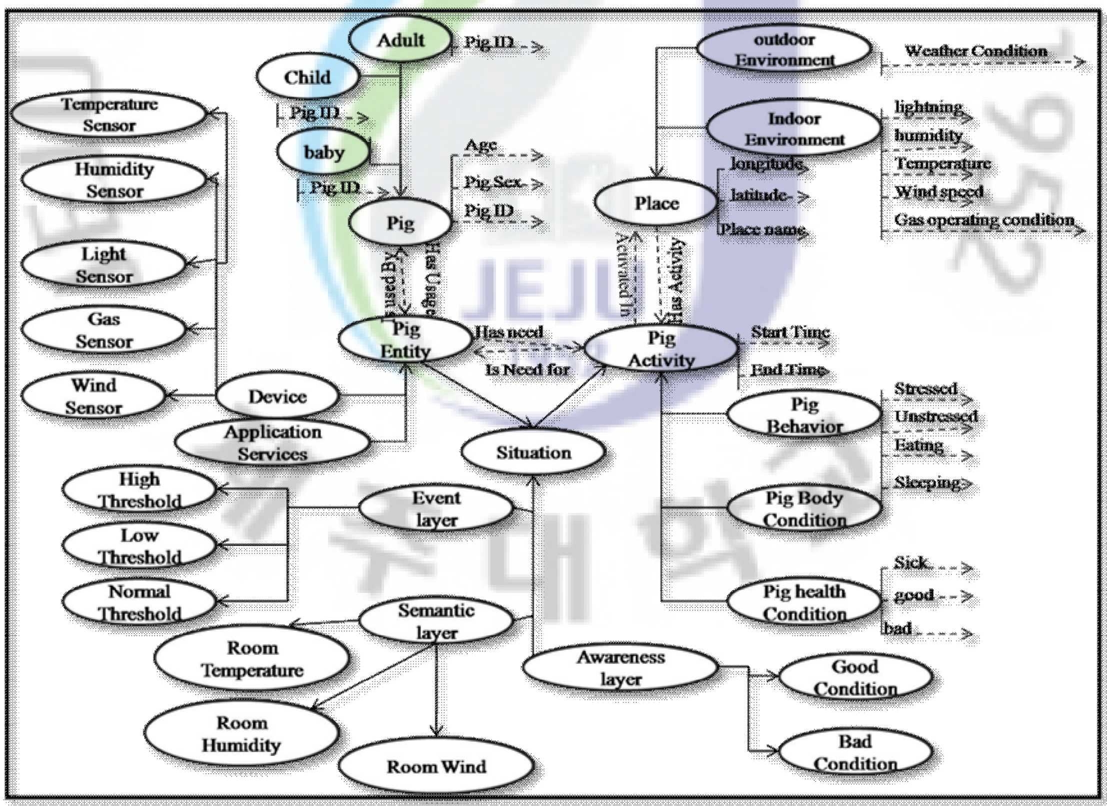

Figure 3.4: Context ontology modeling for pig farms

Ontology is used in order to make explicit assumptions and to separate domain knowledge from operational knowledge. Ontology has the advantage of sharing of knowledge, logic inference and the reuse of knowledge. If any system uses ontology, the system can provide a general expressive concept and offer syntactic and semantic interoperability and mapping concepts in different ontologies, structured information can be shared. Ontology is a good candidate for expressing context and domain knowledge. In Figure 3.4 shows the relation between the classification of the pig farms ontology model and major properties through the graph.

3.5 Semantic Sensor data Description

Most of the current work on providing semantic data for sensor networks is focused by using semantic description for sensor nodes and data elements. This supports advance analytics, pig situation and context awareness in sensor networks. As shown in Figures 3.5, 3.6 and 3.7 are separated different layers of data ontology for thermal comfort. Creating a semantic sensor data model for sensor data related to measurements and observations in another important aspect in designing highly scalable and advanced heterogeneous sensor network applications. I propose a framework for a semantic data description model which provides interoperability and facilities deriving additional knowledge from real-time and/or stored sensor data.

The semantic data model in collaboration with a semantic sensor network will support designing applications using sensor networks. Protégé is used as an open source ontology editor and knowledge acquisition system developed at the University of Stanford (Smith et al. 2004). The protégé editor is used to design the class and property structure of the proposed semantic data model and also to define the constraint rules for the associations and attributes.

To describe the semantics of sensor data, it needs to create ontology, for that used the Noy and Mc Guniness ontology development guide (Noy et al. 2001).

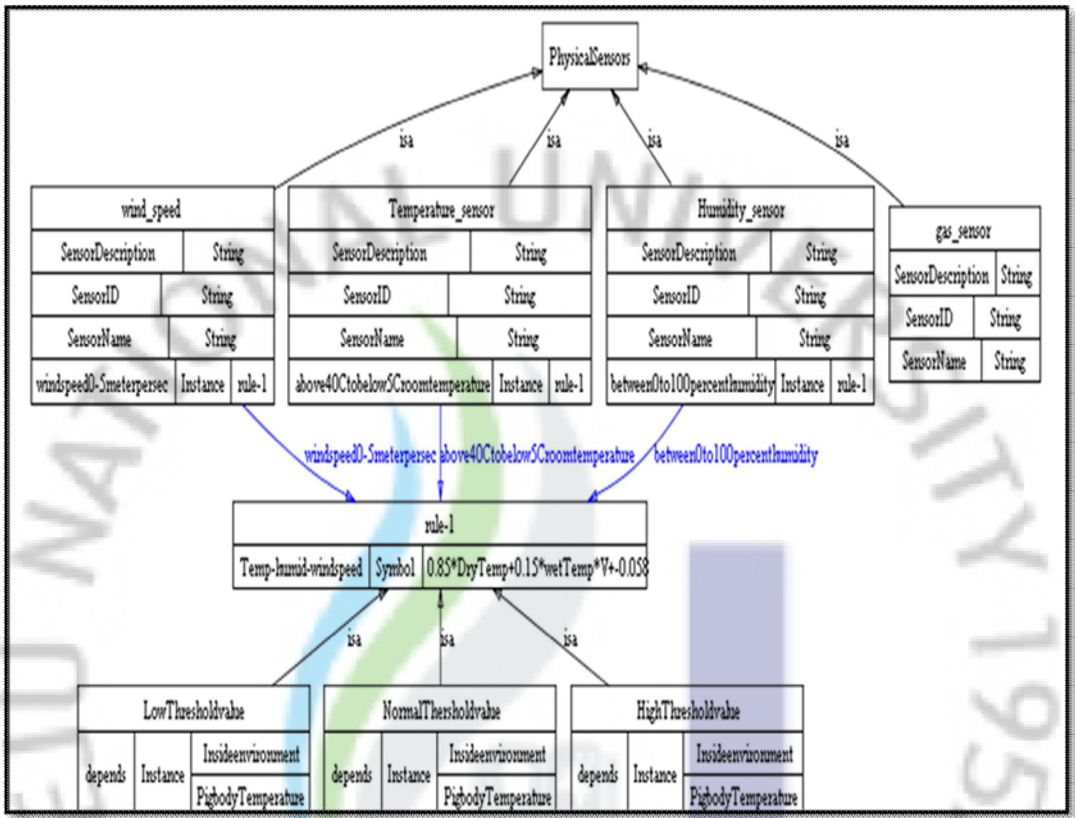

Figure 3.5: Data ontology of physical sensor and event layer for thermal comfort

Figure 3.5 shows, the data ontology of physical sensors and event layer, which describes the physical sensors of wind, temperature, humidity and gas sensors and applying the rule such as thermal comfort index (Temperature-wind speed-humidity) and conditions. If satisfies the rule then it provides lower, upper or normal threshold values depends on the pig body temperature, Inside environment.

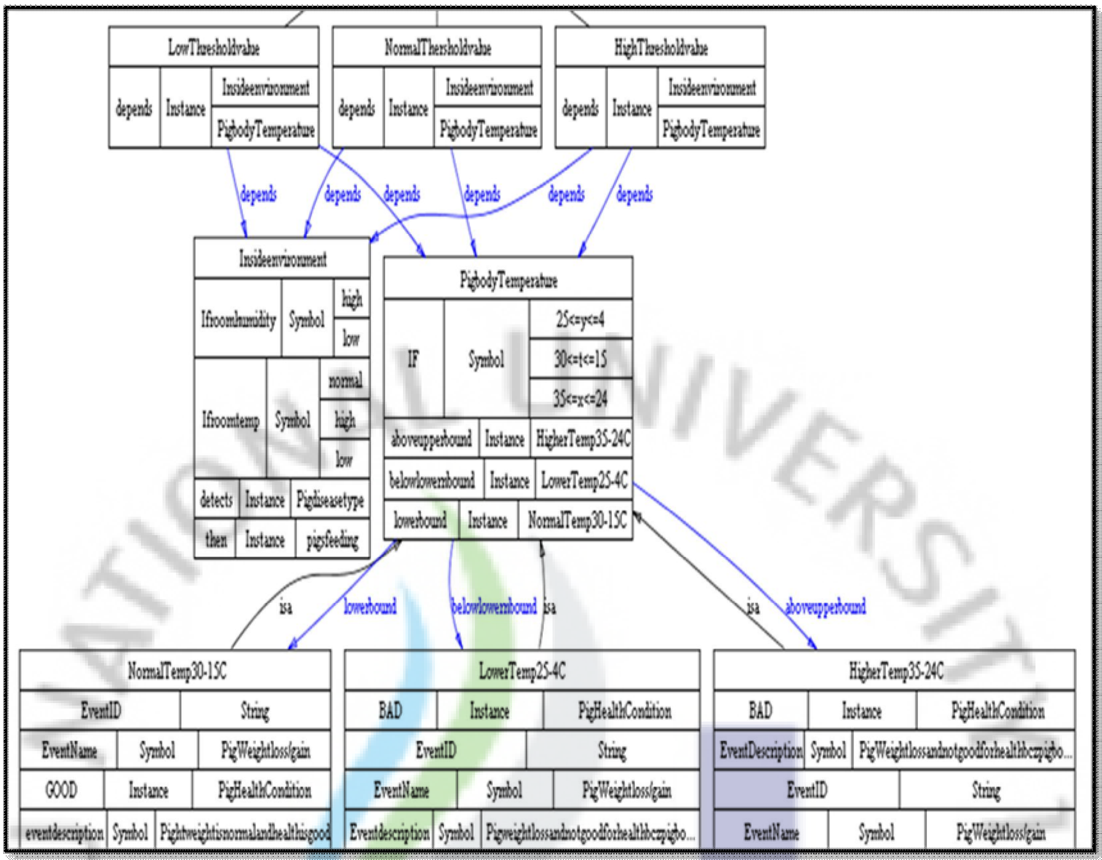

Figure 3.6: Data ontology of event and semantic layer for thermal comfort

In the event to semantic layer data description was shown in Figure 3.6. If the room temperature is lower than the specified normal temperature (15^0C-30^0C), the pig body temperature shows lower. Similarly, if the room temperature higher than the specified normal temperature (15^0C-30^0C), the pig body temperature shows higher.

In the semantic, awareness and service layer describes the each context information as shown in Figure 3.7. Such as pig health condition (Good/Bad) and pig behavior, which is supported by the pig situation monitoring service. The data analysis and using ontology-based reasoning to extract additional knowledge from the data will only occur in processing nodes, which has more processing capabilities. The major cost will only occur in processing nodes. The major cost of using the proposed method will be some extension of the transmitted data from the sensor data.

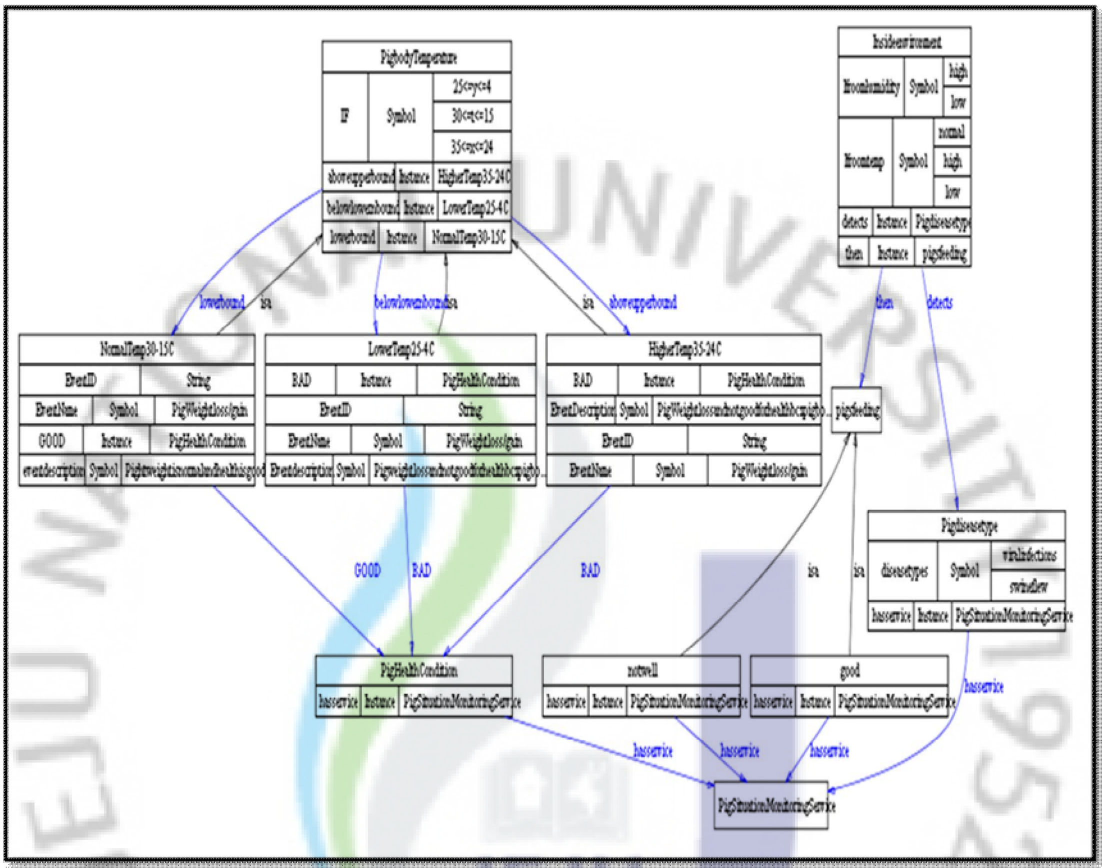

Figure 3.7: Data ontology of semantic, awareness and service layer for thermal comfort

Ontology is used in order to make explicit assumptions and to separate domain knowledge from operational knowledge. Ontology has the advantage of sharing of knowledge, logic inference and the reuse of knowledge. If any system uses ontology, the system can provide a general expressive concept and offer syntactic and semantic interoperability and mapping concepts in different ontology’s, information can be shared. Ontology is a good candidate for expressing context and domain knowledge (Dey et al. 2000).

Many ontology languages exist including Resource Description Framework Schema (RDFS), DAML+OIL, and OWL. OWL is a key to the semantic web and was proposed by the web ontology working group of W3C (Henricksen et al. 2002). OWL is a language for defining the web and is more expressive than other ontology languages such as RDFS. OWL is based on the Resource Description Framework (RDF) (Hwang et al. 2010). RDF embodies the idea of identifying objects using web identifiers and describing resources in terms of simple properties and property values formed by triple. This approach could make produce a new meta-data generating procedure using semantic relationships.

3.6 Examples of Layers Data Model for Pig farms

Ventilation is needed in pig farms houses for removing harmful gases and heat in order to ensure an acceptable indoor climate. Indoor climate parameters such as the concentration of gases, temperature, humidity, and wind speed affects the welfare of pigs. The ventilation rate need not be continuously measured for a good climate. The growing interest of the population in animal welfare and environmental protection is clearly evident. Hot weather periods are one problem in the pig farms. High air temperatures together with high air humidity increase the heat stress for the pig's health condition.

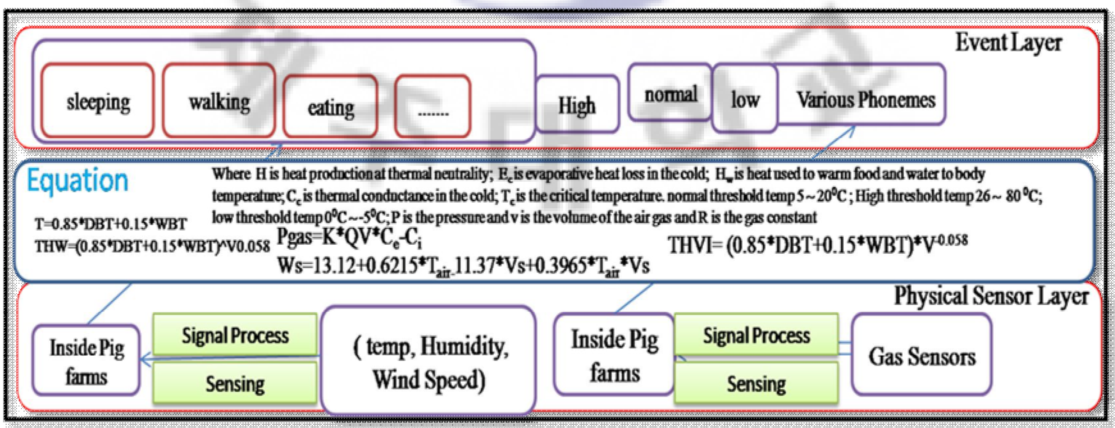

Figure 3.8: Examples of Physical Sensor and Event Layers

In Figure 3.8 shows, the first layer is the data source layer which consists of sensor networks consisting of different sensors such as temperature, humidity, gas and wind. The data from various sensors are gathered, it can be accessed through a standard sensor. For a legacy sensor system, the data can have any proprietary format. For example, the rule-1 between physical sensor layer and event layer applied equations is as follows

$$Temperature=0.85\times DBT+0.15\times WBT \quad (1)$$

Where DBT is Dry bulb temperature, WBT is Wet bulb temperature.

$$Ws=13.12+0.6215\times T_{air}-11.37\times Vs+0.3965\times T_{air}\times V_s \quad (2)$$

Where V_s is wind speed, T_{air} is temperature.

$$THW= (0.85\times DBT+0.15\times WBT)\times V^{\wedge}-0.058 \quad (3)$$

Where THW is Temperature-Humidity-Wind speed, DBT is Dry bulb temperature, WBT is Wet bulb temperature, V is Wind speed.

$$R_H=P(H_2O)/P\times(H_2O) \times 100\% \quad (4)$$

Where R_H is relative humidity, $P(H_2O)$ is partial pressure of water vapour, $P\times(H_2O)$ is the saturation vapour pressure of water at the temperature.

$$Gas=P_{gas}+P(H_2O) \quad (5)$$

Where P_{gas} is the pressure of the gas mixture in the atmosphere, $P (H_2O)$ is the partial pressure of water vapour.

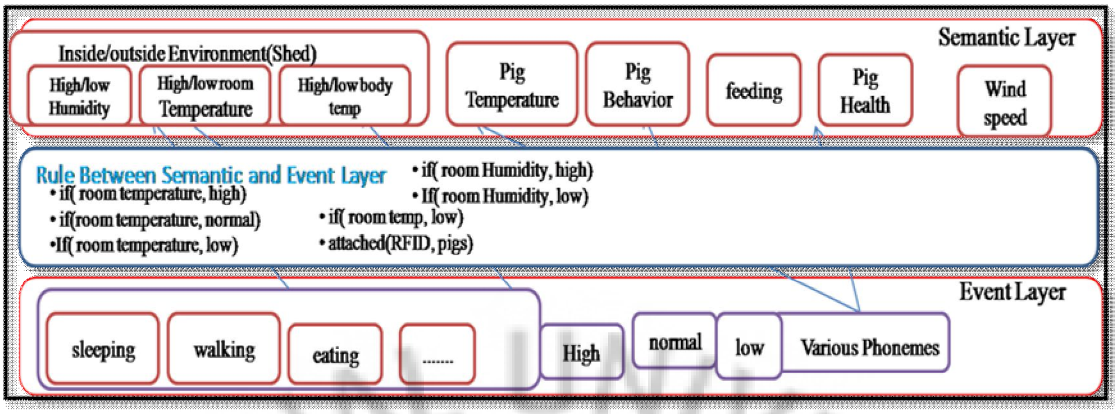

Figure 3.9: Examples of Event and Semantic Layer

In Figure 3.9 shows the rule between the event and semantic layer, once the sensor data is available through the various sensors, it needs to apply the equation and to get the threshold values in the event layer then to describe the semantics of those data. For example the rule between the layers of environmental variation such as if (room temperature, high/ low/normal), if (room Humidity, high/low/normal), which depends on pig health condition, pig behavior, pig body temperature.

In Figure 3.10 shows the data processing after defining the semantics of sensor data by the awareness layer. The pig houses mostly are forced ventilated. For this kind of animals need cooling systems-like evaporative systems, geothermal heat exchanger using heat store capacity of the ground and technical cooling are applied to reduce the heat stress. For example, Pigs are relatively sensitive to high environmental temperatures because they cannot sweat and are relatively poor at panting. Reduction in the associated thermal effect of feeding is an efficient mechanism to reduce the heat load. Generally it is recommended to raise pigs at temperature 3^{0}C to ambient conditions.

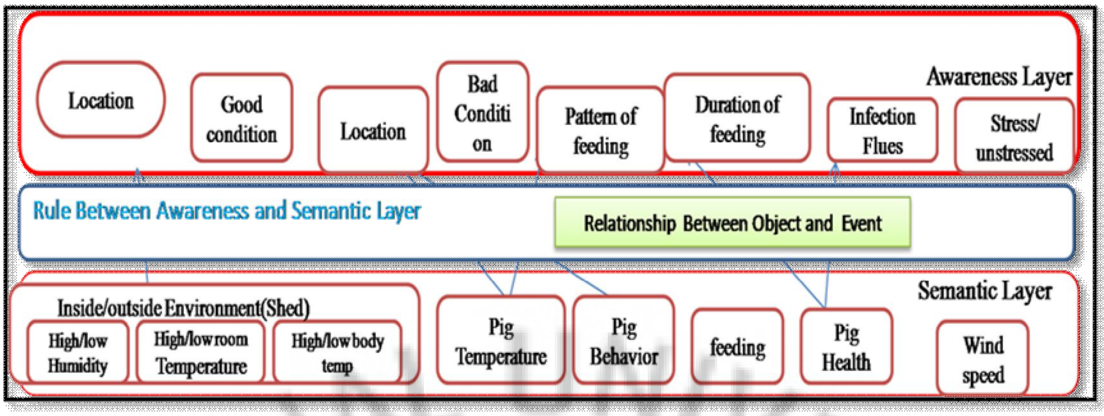

Figure 3.10: Example of Semantic and Awareness Layer

Evaporative heat loss might occur respiratory evaporation from the wet body surface of pigs. Air temperature as critical environmental factor is influenced by relative humidity and air flow velocity. Air humidity level is very important in cooling process. Pig with cross ventilation has been noticed higher temperatures and lower relative humidity as optimum range in summer period.

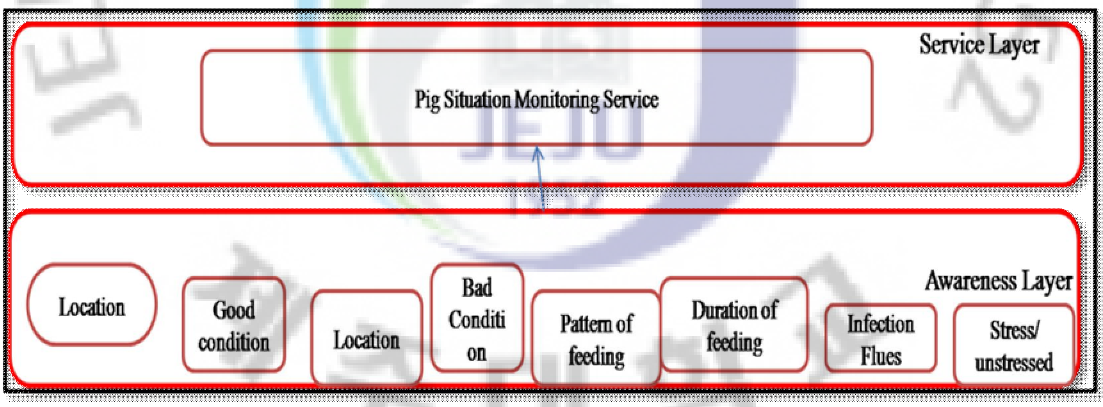

Figure 3.11 Examples of Awareness and Service Layer

In Figure 3.11 shows the awareness layer is informed the entities to the service layer. An entity can become locations, good or bad condition of pig, duration of feeding, pattern of feeding. The service layer consists of different user applications that require the sensor data. The processed sensor data can be available to pig situation monitoring applications.

3.7 Ontology Structure of Data Modeling

I implemented the layers of context data modeling ontology, which is the basis of the representation and analysis of the pig behaviors and condition. It is categorize the context data into five layers, such as the physical sensor layer, the event layer, the semantic layer, the context-awareness layer and the service layer. These layers are also including database and the inference rules. The physical sensor layer is the source of context data, this layer serves as an abstraction between the physical world and the semantic data, and the context awareness layer provides the description of the complex facts with the fusion of context services. Each sensor corresponds to the type of context layer.

In Figure 3.12 shows, the ontology structure of the data modeling for temperature, wind speed, gas and humidity in the inside pig farm. If the room temperature threshold is high or low depends on the pig body temperature. The lower critical temperature to the point where metabolic rate is actively reduced to heat stressed. The physical contexts of the ontology includes the description of the pig information, causes of the pig feeding or diseases, pig weight loss, heat stress etc. Below the lower critical temperature either by metabolizing body fat or by increasing feed intake. Above the temperature zone the pigs reduces its activity, increases breathing rate and reduces feed intake.

In pigs accommodations the temperature sensor is an integral part of the ventilation system, which determines the ventilation rate and whether additional heat should be added. Modern ventilation systems might both have inside and outside sensors. The latter one measures the temperature of the incoming air and it aids in fine adjustment of the ventilation rate, e.g., if the outside temperature suddenly drops dramatically the outside sensor measures the change much faster than the inside one.

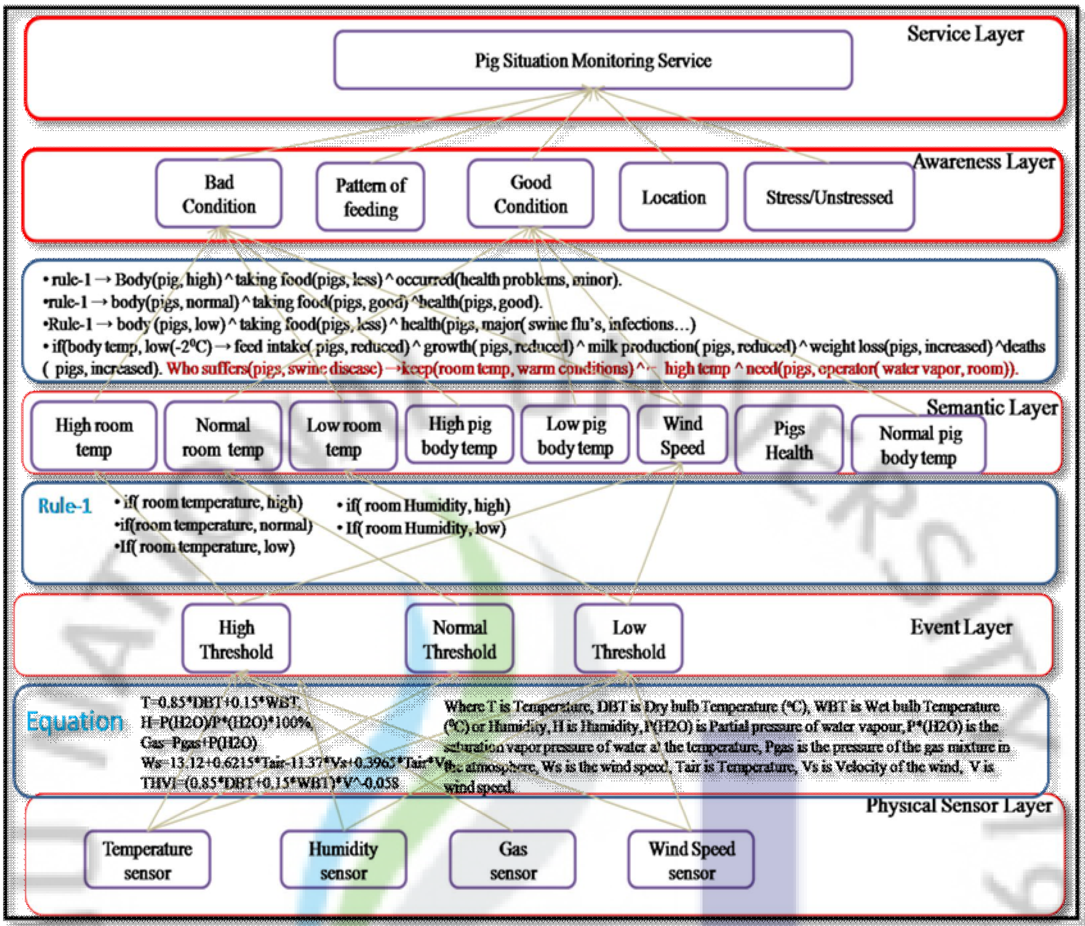

Figure 3.12 Ontology structures of data modeling for pig farms

In Figure 3.12 shows the content of water vapour of the air is generally expressed by the relative humidity (R_H). Pigs readily accept a wide range of humidity. The relative humidity is an indicator of the air quality since it depends on the heat and moisture balance of the accommodation. A dry environment affects the nasal mucosa of the pig negatively and increases the risk of air born infection. In a wet environment pathogens might be transferred via water droplet.

In Figure 3.12 shows the gas and wind speed sensors in the environment may lead to a change in emission. Drying humidity may lead to volatilization of solved and adsorbed compounds during the drying phase, and further to decreased volatilization after drying.

Reducing the moisture content reduces the pigs growing in manure. Increased emissions of most volatiles were correlated to increased temperature and increased humidity. For dust from air filters, temporary emission peaks were found when the moisture rapidly increased. Wetting of a pig's body temperature may release gases produced earlier.

In Figure 3.12 shows many ventilation systems have a moisture sensor as an integral part of the control system. It should be noted that moisture sensors are not as robust as temperature sensors. Therefore, malfunction of the ventilation system might be due to a defect moisture sensor, which usually results in excessive energy. Data modeling is any information that can be used to characterize the situation of an entity and context-aware computing is the use of context to provide relevant information and services to the user, where relevancy depends on the particular task of the user (Ian et al. 2005).

A context-aware system should automatically recognize the situation which is based on various sensors. Data modeling is very important in context aware systems to provide context for intelligent services (Amit Sheth et al. 2008). Therefore, Data modeling is a key feature in the context-aware system. A data modeling should provide rules, databases and context-aware interfaces. Data modeling should describe the relationship between the domain vocabulary and the concept of the domain knowledge.

Reasoning:

The reasoning is responsible for checking ontology inconsistency and the implied relationship, along with testing and checking the rules for understanding the context. There are two kinds of approach, Ontology reasoning and user-defined Rule-based reasoning. Ontology reasoning used to check the ontology itself, such as looking for inconsistency between classes and relations. User-defined Rule-based reasoning is based on first order logic and computes the inferred reason using user-defined roles. Both approaches were used in this research. For ontology reasoning, I used the functionality of the protégé tool. Protégé can easily check class inconsistencies by selecting an appropriate reasoner. User-defined roles using SWRL were used to take advantage of inferencing.

Ontology Reasoning:

Ontology reasoning uses transive, inverse, symmetric, subclassof, subPropertyOf, disjointwith, and other properties are axioms to reason about the consistency of the ontology (see Table-2).

Table 1: OWL ontology Reasoning Rules

Transitive	(?P rdf:type owl:TransitiveProperty) ^ (?A ?P ?B) ^ (?B ?P ?C) => (?A ?P ?C)
subClassOf	(?A rdfs:subClassOf ?B) ^ (?B rdfs:subClassOf ?C)=> (?A rdfs:subClassOf ?C)
subPropertyOf	(?A rdfs:subPropertyOf ?B) ^ (?B rdfs:subPropertyOf ?C)=> (?A rdfs:subPropertyOf ?C)
disjointWith	(?C owl:disjointWith ?D) ^ (?X rdf:type ?C) ^ (?Y rdf:type ?D)=> (?X owl:differentFrom ?Y)
inverseOf	(?P owl:inverseOf ?Q) ^ (?X ?P ?Y) => (?Y ?Q ?X)
Symmetric	(?P rdf:type owl:SymmetricProperty) ^ (?A ?P ?B) => (?B ?P ?A)

Example of OWL Ontology Reasoning Rules defined shown in Table 2:

Table 2: Example for pig farm OWL ontology reasoning rules

Situation	Reasoning Rules
Normal Health rule	(?m rdf:type owl:Temperature Measurement)^(?m ns:hasHealthIndex?h)greater than(?h,5)^(?m ns:haspig ?p)-> (?P ns:hasHealthCondition ns:Normal)
Critical Health rule	(?m rdf:type owl:Temperature Measurement)^(?m ns:hasHealthIndex ?h)less than(?h,2)^(?m ns:haspig ?p)->(?P ns:hasHealthCondition ns:critical)
Critical Health rule	(?m rdf:type owl:Temperature Measurement)^(?m ns:hasHealthIndex ?h)greater than(?h, 30)^(?m ns:haspig ?p)-> (?P ns:hasHealthCondition ns:critical)

Table 2 shows the example of illustrates that by applying first-order-logic rules a more flexible way of reasoning can be performed in order to calculate high-level context, such as on the information of the activity of the pig behavior. This allows including the facts received from the ontology reasoning.

User-defined Role-based Reasoning:

User-defined role-based reasoning, which is defined using first order logic, means user-defined roles are used to infer reasons. To do reasoning using this method, the pellet reasoner was chosen and a rule set was established using the Semantic Web Rule Language (SWRL), which is proposal for a semantic web rule-language, combining sub-languages of the OWL Web Ontology Language (OWL-DL and Lite) with those of the Rule Markup Language. SWRL uses logic operators to define rules, and SWRL rules are stored in the ontology as concepts are shown below in Table 3.

The primitive context information of pig farm is as follows. We assume the rules in Table 3, the pig situation monitoring service checks in correct answers. The pig situation monitoring service provides items that are similar with incorrect items.

Table 3: User-defined Rules for pig farm

Rules	User-defined rules	Description
Rule-1	pigs(?x) ∧ sensors(?y) ∧ attached(?y, insidefarm)∧ Measuredby(?y, environmentalconditions)	If various sensors attached in inside farms and measured various environmental conditions then identified the status of the pigs.
Rule-2	pigs(?x) ∧ attached(?x, Temperature_Sensor) ∧ Measuredby(?x, temperature) → haspigstatus(?x,	If attached the temperature sensors for pigs and measured body temperature then identifies the pig status.

	temperature) ∧ sqwrl:limit(High, low)	
Rule-3	pigs(?x) ∧ Temperature_Sensor(?y) ∧ Measuredby(?y, insidefarm) → hasvalue(?y, High) ∧ depends(?x, bodycondition)	If measured the inside farm temperature then define the value of temperature it depends on the pig health condition.
Rule-4	pigs(?x) ∧ Measuredby(?x, temperature) ∧ hasvalue(temperature, High) → feedintakes(?x, reduced) ∧	If a pig body temperature is high then pigs reduces feed intakes and weight loss and also increased deaths.

	weightloss(?x, reduced) ∧ deaths(?x, increased)	
Rule-5	pigs(?x) ∧ whosuffers(?x, Swine_Disease)→ keeps (Room_temperature, Warm_Conditions) ∧ needs(?x, ventilations)	If the temperature keeps in warm conditions, suffers the swine disease and also pigs need ventilation air.

For example, Rule-1 describes for temperature sensor as "pigs(?x) ∧ sensors(?y) ∧ attached(?y, insidefarm)∧ Measuredby(?y, environmentalconditions) → isidentifiedstatus(?x, health)", if various sensors attached in inside farms and measured various environmental conditions then identified the status of the pigs.

Rule-2 described the "pigs(?x) ∧ attached(?x, Temperature_Sensor) ∧ Measuredby(?x, temperature) → haspigstatus(?x, temperature) ∧ sqwrl:limit(High, low)", if attached the temperature sensors for pigs and measured body temperature then identifies the pig status. Rule-3 describes the "pigs(?x) ∧ Temperature_Sensor(?y) ∧ Measuredby(?y, insidefarm) → hasvalue(?y, High) ∧ depends(?x, bodycondition)", if measured the inside farm temperature then define the value of temperature it depends on the pig health condition.

Rule-4 describes the "pigs(?x) ∧ Measuredby(?x, temperature) ∧ hasvalue(temperature, High) → feedintakes(?x, reduced) ∧ weightloss(?x, reduced) ∧ deaths(?x, increased)", if a pig body temperature is high then pigs reduces feed intakes and weight loss and also increased deaths.

Rule-5 describes the "pigs(?x) ∧ whosuffers(?x, Swine_Disease)→ keeps (Room_temperature, Warm_Conditions) ∧ needs(?x, ventilations) ", if the temperature keeps in warm conditions, suffers the swine disease and also pigs need ventilation air.

3.8 Representation using Protégé and Pellet

To implement and constructed taxonomy an ontology development tool, called protégé is used to build and edit the ontology. The knowledge representation language for modeling the various data types of physical sensor, Event data is OWL-DL. I manually add classes to the ontology by creating event data and physical sensor classes and all their sub-classes. The constructed class hierarchy is called manually created classification hierarchy and is shown in Figure 3.13.

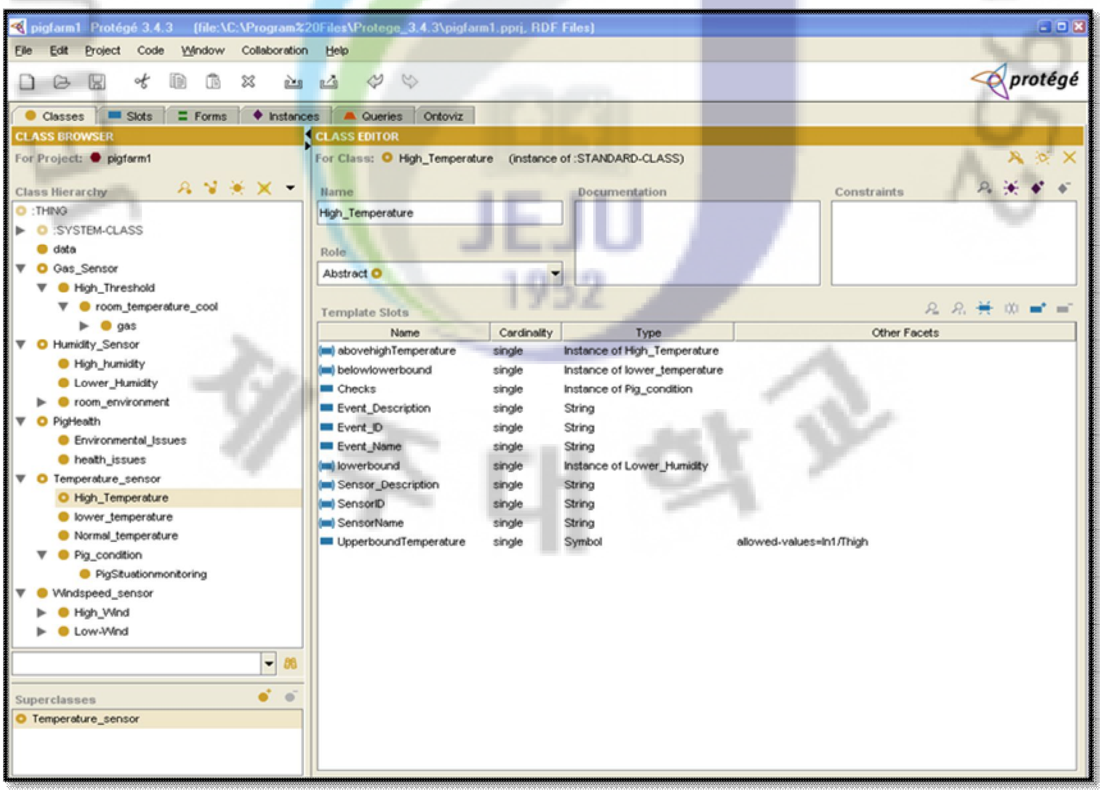

Figure 3.13: Proposed hierarchy relationship and classes based on ontology using protégé for pig farms

As a validation tool, I used Pellet 1.5.2 because of its strong reasoning capabilities and interoperability with protégé. The manually created class hierarchy is fed to Pellet 1.5.2 whose main responsibility is to automatically compute the inferred class hierarchy (called asserted ontology) based on the description of classes and relationships. To perform the subsumption test, both protégé and Pellet 1.5.2 should be up and running. For example, the class Hierarchy was defined as event data > pig health > physical sensors > Humidity_sensor > Temperature_sensor > Wind_sensor > Gas_sensor. The class editor for class was edit as Diseases_Type single symbol and other facets allowed-values = (swine_flues, viral_infection). Similarly, pig_condition single symbol and allowed-values= (good, bad), windpressure single symbol allowed-values.

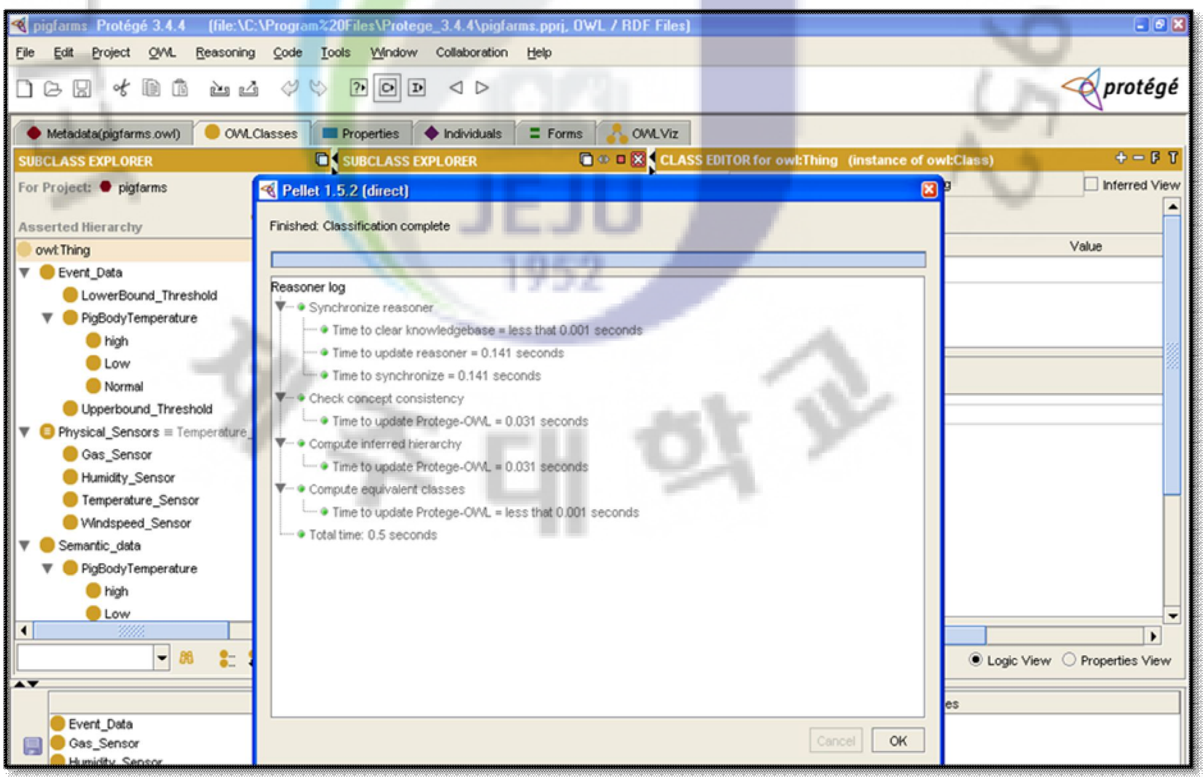

Figure 3.14: Protégé provides access to description logic classifier and can display both the asserted and the inferred hierarchy of pig farms

In Figure 3.14 shows, having started Pellet 1.5.2, the ontology now can be sent to the reasoner to automatically compute the classification hierarchy (called taxonomy classification) and also to check the logical consistency of the ontology. We should distinguish two ontologies: the manually constructed class hierarchy and the automatically computed one, both must be identical if the subsumption classification is error free. On the other hand, if the ontology has inconsistency, the logical consistency check test must be able to detect them. For example the class hierarchy defines the event data, physical sensors, semantic data and pig situation monitoring service. One of the roles is to test whether or not one class is a subclass of another class. The other roles of pellet 1.5.2 is consistency checking. The pellet can check whether or not it is possible for the class to have any instances. The pellet reasoner checks such as synchronize reasoner, check concept consistency, compute inferred hierarchy and compute equivalent classes.

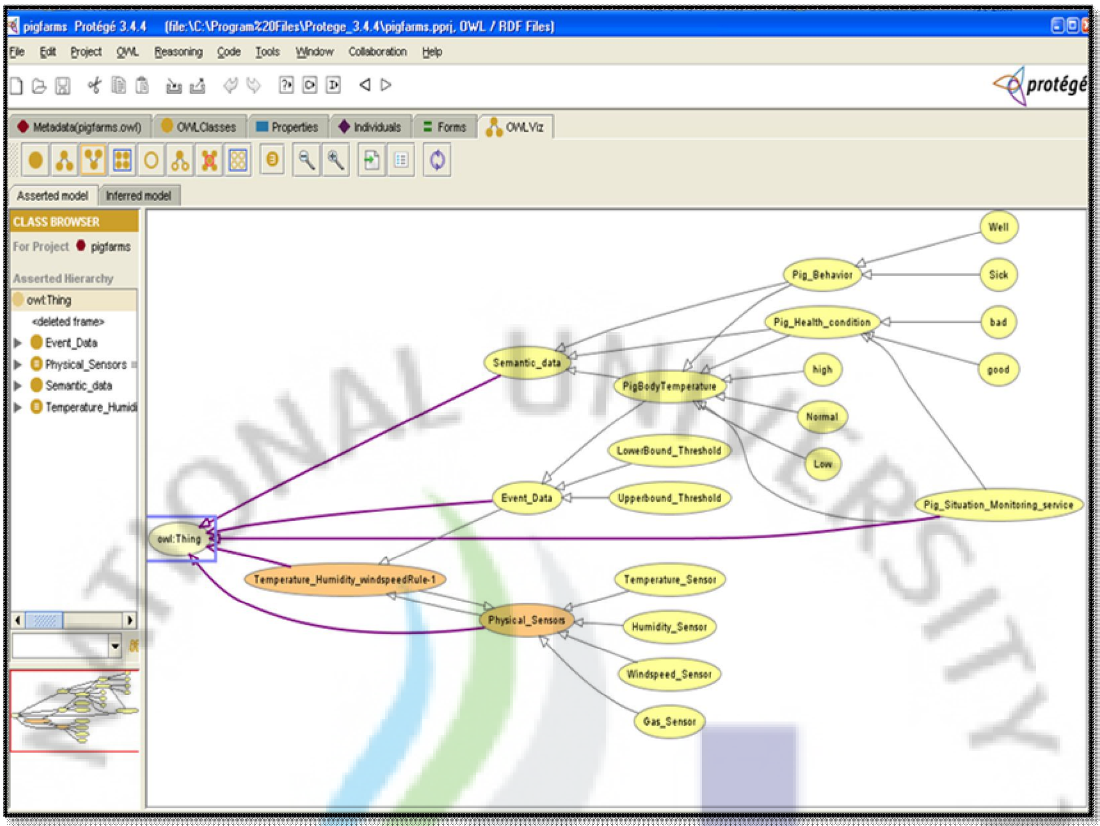

Figure 3.15: Pig health data ontology structure for OWL graphical representation

Figure 3.15 describes the pig health data contexts hierarchy and sameAs relation. Pig farm ontology was built by Protégé that shows the relationships super classes and subclasses. I designed pig health data as pig situation, pig behavior, pig body temperature etc. As we use a sameAs relation, we can interpret any context providers which generate pig body temperature or temperature. The pig health context has the raw data context, because the physiological signal should be displayed in raw data format in the pig situation monitoring service. If an application requests pig health raw data, the file size and the time information using the raw data context of the pig health context.

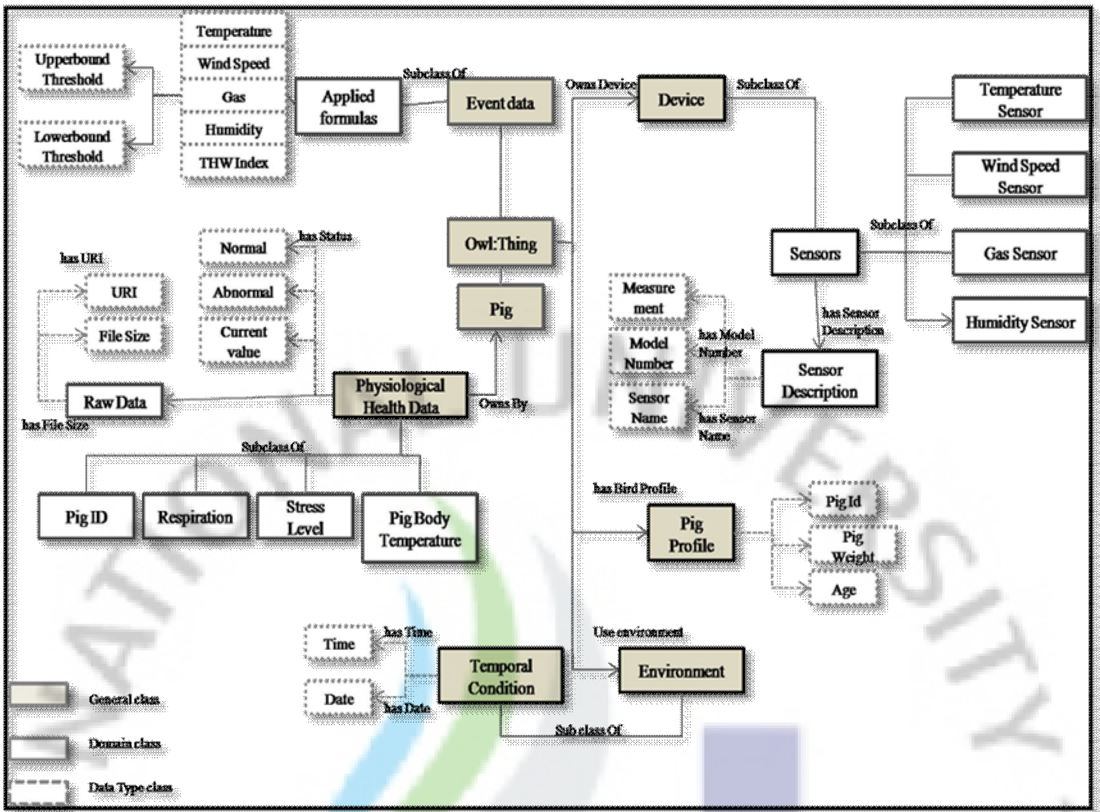

Figure 3.16: Hierarchal data representing owl graph for pig farms

The class hierarchy should now resemble the hierarchy shown in Figure 3.16 Physical sensors, event data, semantic data, temperature-humidity-wind rule and pig situation monitoring service classes are subclass of all: Thing. temperature_sensor, humidity_sensor, gas_sensor, wind_sensor classes are subclass of physical sensor. The lower bound_thershold and upper bound_threshold classes are subclass of event data. The pig body temperature, pigbehaviour, pighealthcondition classes are subclass of semantic data.

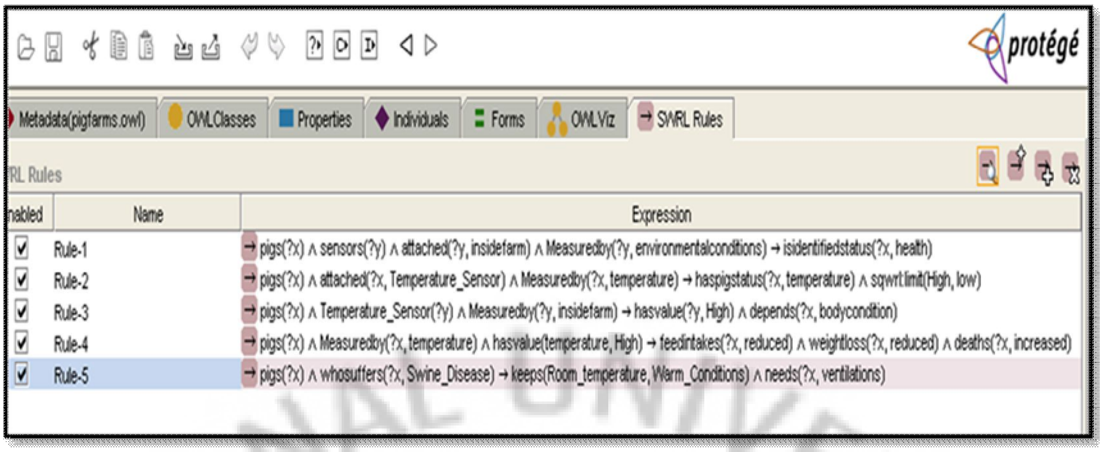

Figure 3.17: SWRL Rules

The high-level context generating rule converts low-level context into high-level context. An example of generating a high-level context rules are required to capture the relationships between the metrological and topological properties. Rules are required to capture relationships not only between ontology properties, but also relationships to other domain properties. Some of these rules can be represented in SWRL and visualized with the SWRL Editor. For example, SWRL Rules are defined as

Rule1→pigs(?x)^sensors(?y)^attached(?y,insidefarm)^Measuredby(?y,environmemntalconditions)→inidentifiedstatus(?x,health). Similarly, the other Rules are defined and as shown in Figure 3.17.

For semantic data processing used protégé. The two main aspects of processing that we have covered are semantic data querying. It needs to define a method for querying the data. SPARQL is the candidate recommendation of W3C for querying RDF/OWL data graphs and designed specifically to support semantic web applications. Once the raw semantic data is transformed in to RDF/OWL format, we can use SPARQL to run queries. For instance, Figure 3.18 shows the SPARQL code to find the user's information.

The protégé OWL API can be used issue queries at run time. The implementation is based on mechanism to wrap a Jena model inside the protégé API. The queries are executed by the Jena SPARQL engine. The query consists of two parts: the SELECT clause identifies the variables to appear in the query results, and the WHERE clause provides the basic graph pattern to match against the data graph. Once it defined in the ontology for sensor data mapping, it needs to define a method for querying the data. SPARQL is the candidate recommendation of W3C for querying RDF/OWL data graphs and designed specifically to support semantic web applications. Once the raw sensor data is transformed into RDF/OWL format, we can use SPARQL to run queries.

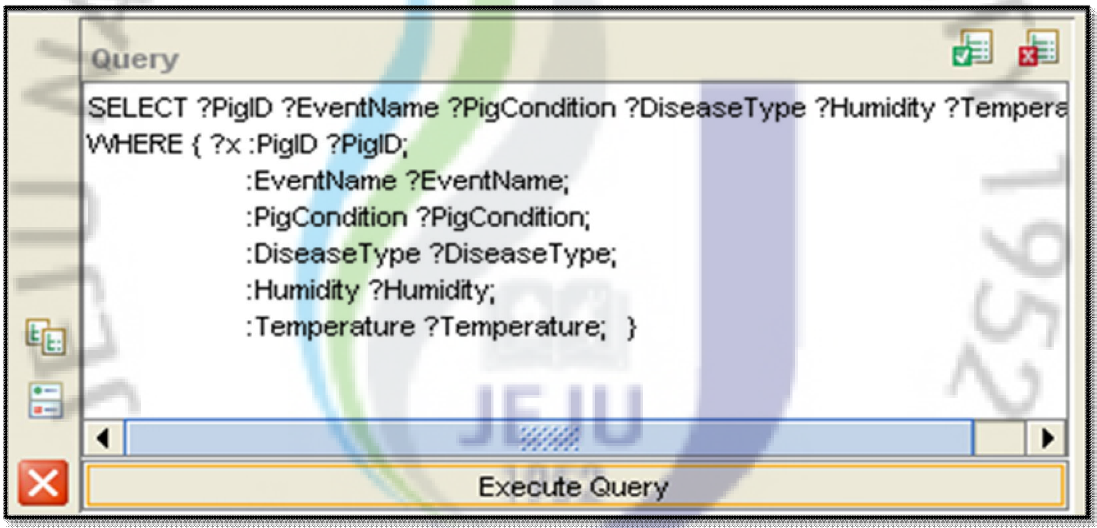

Figure 3.18: SPARQL Query

For instance, Figure 3.18 shows the SPARQL code to find the health index measurements of each pig. The SPARQL query results are returned as an XML document in a format known as “SPARQL variable Binding Results XML format.” Thus, we can easily display and access the SPARQL query results over internet.

The SPARQL query is selecting the item of Pig ID? EventName? PigCondition? DiseasesType? Humidity? Temperature? The query is finding and defines the item which has Pig ID of pig condition.

Results

PigID	EventName	PigCondition	DiseaseType	Humidity	Temperature
fe336	pighealthcondition	bad	Swine flues	56.07	27.88
ed6t378	pighealthcondition	good	healthy	54.85	28.1
ret5362	pighealthcondition	bad	viral infections	55.66	27.98
y3567	pighealthcondition	bad	viralinfections	55.41	27.69
gd732	pighealthcondition	bad	Swineflue	55.58	27.92

Figure 3.19: SPARQL Query Result for Pig Farms

The results of SPARQL query are shown in Figure 3.19. For example, PigCondition has “bad” of 56.07 % humidity and 27.88^{0}C of temperature with swine flues. PigCondition has “good” of 54.07 % humidity at 28^{0}C of temperature with healthy. So it is satisfied in condition which has Pig ID ed6t378 and fe336 for pig farm.

IV. Implementation and Analysis of Semantic sensor web in Pig farms

4.1 Proposed Semantic Sensor Web Architecture

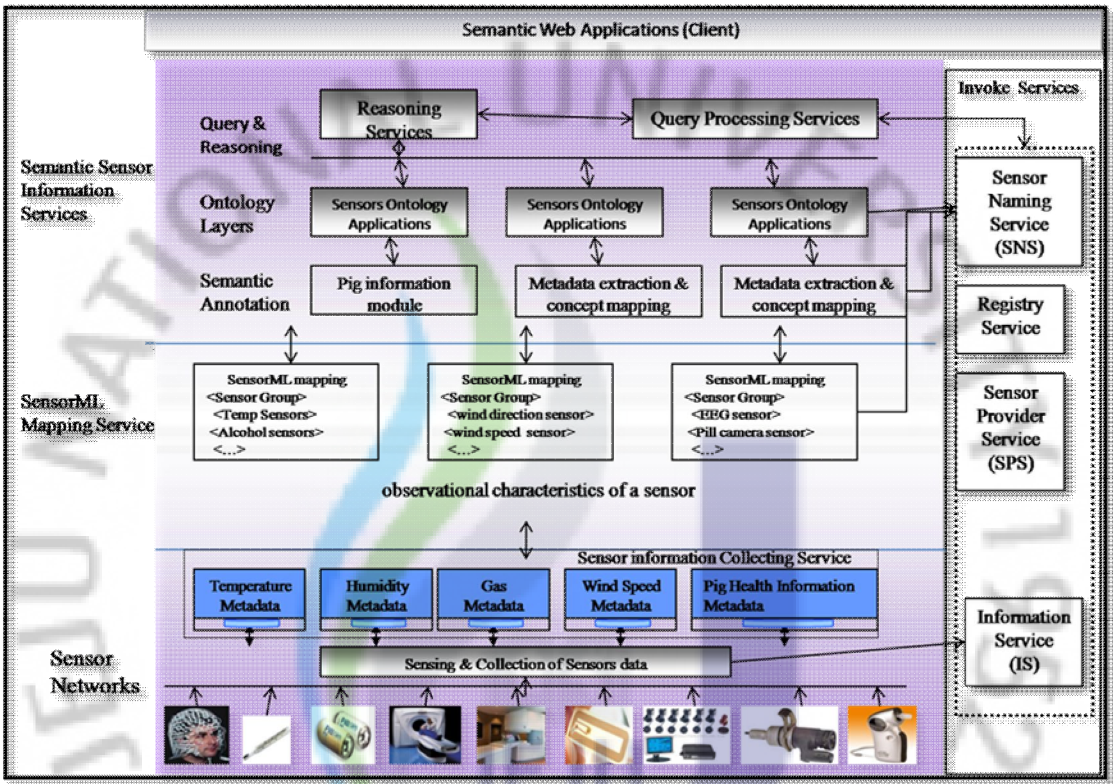

Figure 4.1: Semantic Sensor Web Architecture

Figure 4.1 shows the sensor web is a special type of web-centric information infrastructure for collecting, modeling, storing, retrieving, sharing, manipulating, analyzing, and visualizing information about various sensors and sensor observations of phenomena. It is divided into the three components such as sensor networks, SensorML mapping service, and semantic sensor information services. Sensor networks can collect the information data through various sensors and stored into the metadata such as temperature, humidity, gas, wind speed and pig health information metadata. Metadata describe an interpretation of real-world information from various sensor observations, such as objects or events. SensorML mapping service created the sensor model language to provide a programming interface for any sensor web. SensorML provides an XML schema for describing sensors, systems and processes provides information needed for discovery of sensors, location of sensor observations, processing of low-level sensor observations, and listing of task able properties. SensorML focuses on a subset of sensors used for in-situ observation of the environment. SensorML is also designed to ease development of the multiple software components required for sensor webs. XML schema is encoding observations and measurements from a sensor, both archived and real time. XML based metadata standards of the sensorML mapping service and the RDF/OWL-based metadata standards of the semantic sensor information services. SensorML provides semantic annotations for simple concepts such as spatial region, temporal coordinate and timestamp any domain-specific entity from the expressiveness of an ontological representation. Ontology layer would be needed to provide semantic descriptions of entities such as objects/ events and their relations.

The ontology layer supports for each layers applications such as physical to event, event to semantic, semantic to context. The physical layer is the data source layer which consists of heterogeneous sensing sensors. The data from sensors are collected and accessed by semantic layer. The data can have any proprietary format. For example, the physical sensor layer has various kinds of sensors such as gas sensor, humidity sensor, thermometer, temperature sensor, wind sensor. Those kinds of sensors collect the data and stored into the database. The event layer describes the information of sensing data and perfoming the required event description. For example, the event layer access the data from each sensors through database and applying various formula's for getting the results such as upperbound threshold and lowerbound threshold. These threshold values are stored into the database. Once the sensor data is available, it needs to describe the semantics of those data. Therefore, the third layer of this architecture consists of semantic layer. The data can be processed after defining semantics of sensor data in this layer. For example, the semantic layer getting the upperbound and lowerbound threshold values from database, which is depends on the pig health condition and pig behavior. If the room temperature is high then it depends on the pig health condition. Events, rules and person ontology help to realize context awareness. The syntax diversity of context and personal profile descriptions can be solved by ontology techniques. We are involving the use of SWRL s web rules language combining OWL and rules). For example, pigs are relatively sensitive to high environmental temperatures because they cannot sweat and are relatively poor at panting. Reduction in the associated thermal effect of feeding is an efficient mechanism to reduce the heat load.

Generally it is recommended to raise pigs at temperature 3^0C to ambient conditions. Evaporative heat loss might occur respiratory evaporation from the wet body surface of pigs. Air temperature as critical environmental factor is influenced by relative humidity and air flow velocity. Air humidity level is very important in cooling process. Pigs with cross ventilation have been noticed higher temperatures and lower relative humidity as optimum range in summer period. The service layer provides various services that require the user. The query & reasoning services is used to analyses of user's request based on concepts and descriptions available in ontology software and return the results to the sensor naming service. Sensor naming service is the web standard service interface for asynchronous delivery of messages or objects information from IS (Information Service) and SPS (Sensor Provider Service). Information service is the standard web service interface for requesting sensor collection management environment. Sensor provider service for requesting, filtering and retrieving the observations and sensor system information's through the client and sensor naming service. These services are shown in Figure 4.2 in detailed.

4.2 Semantic Sensor Web Ontology in Pig farms

Figure 4.2 shows, First of all information service requests registered each sensor through sensor networks. If registered confirmed then information service getting the sensing data through sensor networks and stored into the database. Sensor naming service manages both information service and ontology.

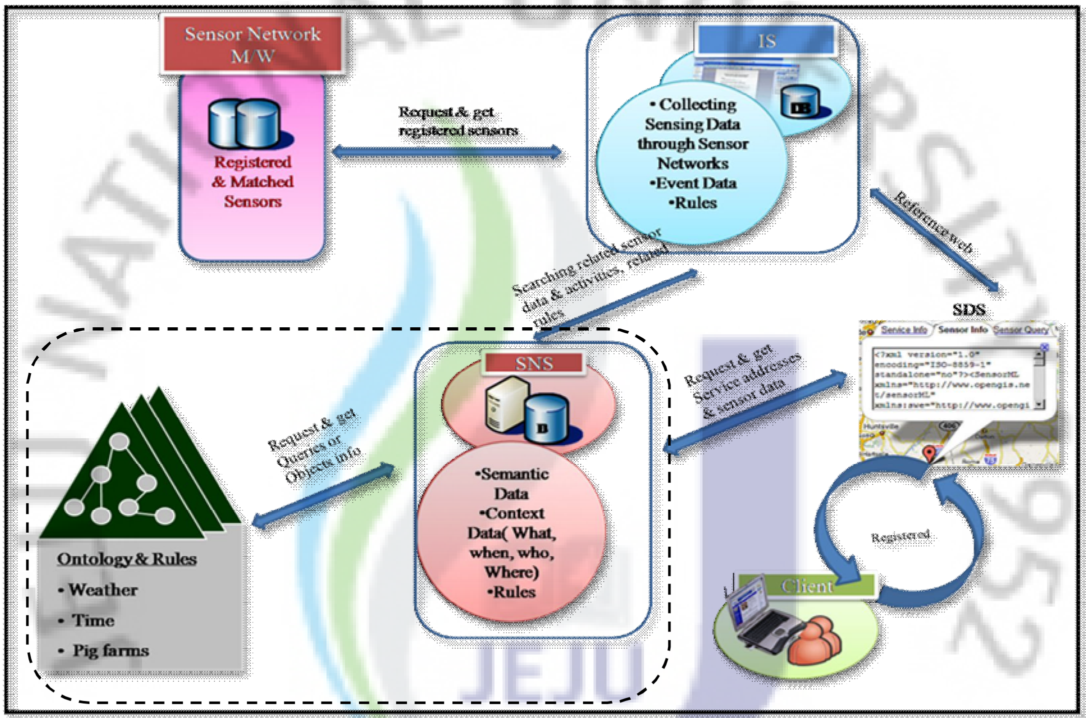

Figure 4.2: Proposed Semantic Sensor Web Configuration Based on Ontology

Information service sends only sensor data and sensor information. Ontology sends the objects information and rules/ queries. Next, client request registered in pig farm web page to SPS (Sensor Provider service). SPS provides registered confirmed successfully to client. Again client sends request sensor information, sensor data to SNS. Sensor provider/Directory service request the sensor address or sensor data to sensor naming service. Sensor naming services search the entire data and send back to sensor directory service. If the sensor directory service needs the relations of objects information then send request to SNS. SNS sends request to ontology. Ontology sends objects information to SNS. SNS receives the related objects information and send it back to SDS. We proposed SNS related to ontology in this architecture as dotted line indicate in the Fig. 4.2 and the outside the dotted line is already existed system.

4.3 Semantic Sensor Naming Service Structure

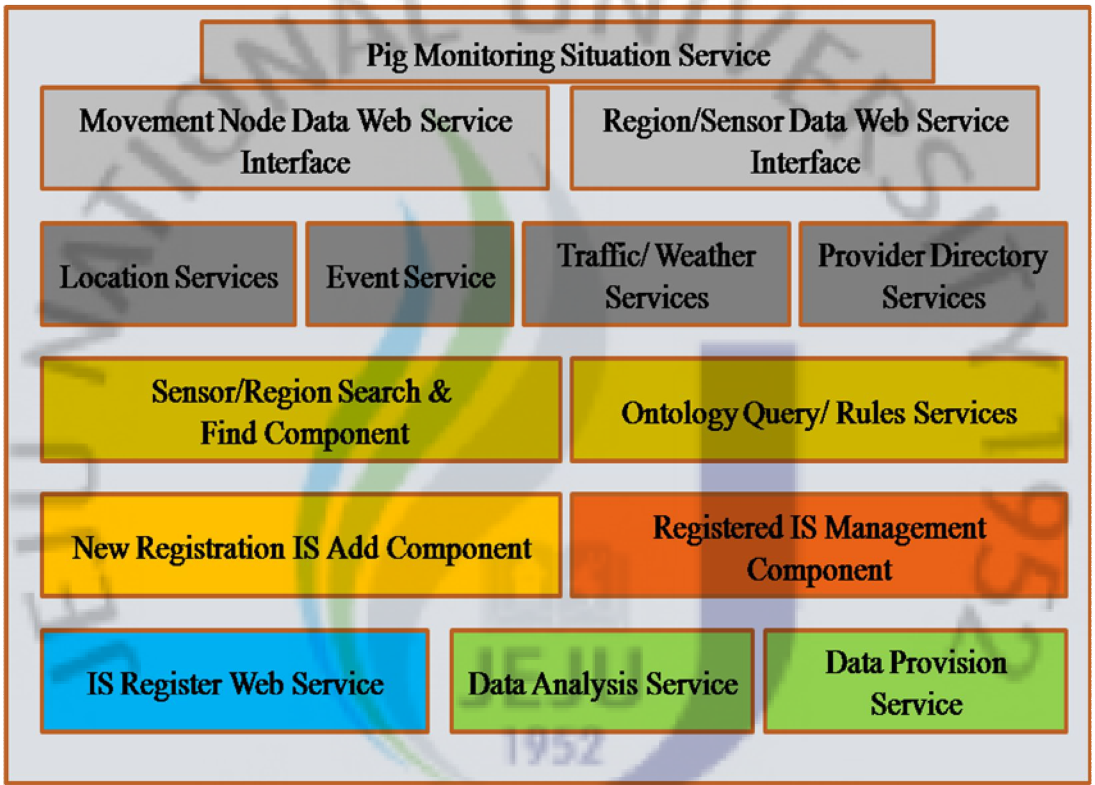

Figure 4.3: Semantic sensor naming service structure

In the above Figure 4.3, IS registers the web browser interface module, which can registered various sensors and sensing data for each sensors such as temperature, humidity, gas and wind sensors. If each sensors not registered in the IS (Information service) component then farmers must registered in IS. IS management component, it manages the IS register web service and new registration IS add component. Data Analysis and Data Provision Service can get the sensing data through database and analyze the data. The region of sensor module which provides the data and the case sensor nodes where the sensor node will escape IS areas from SPS continuously. Ontology query or rules services the objects information through SNS. Services can get the sensing data through each sensor and perform their related services. These are all components supported the pig monitoring situation service.

4.4 Sequence Diagram of Semantic sensor web for Pig farms (getting pig information from ontology)

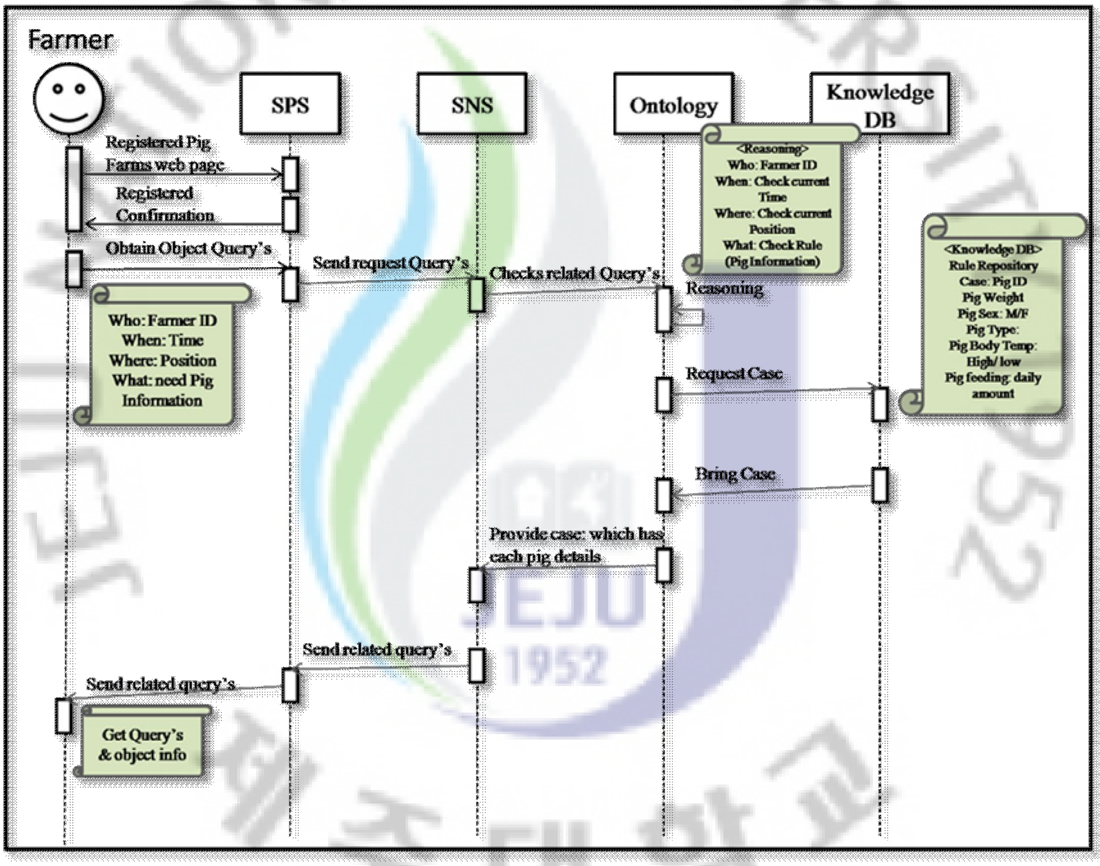

Figure 4.4: Sequence diagram for pig farms

The sequence diagram for the proposed SNS and ontology service is shown in Figure 4.4, first of all farmer must registered in pig farms web page. Farmer request registered pig farms web page to sensor provider service. After conformation of registration, request obtains object queries through sensor provider service to sensor naming service. Once, sensor naming service checks his ontology and runs the ontology reasoning. Once the data is available then brings the queries through knowledge data base. Ontology provides the related queries through sensor naming service (SNS). SNS transfer the related queries through sensor directory service to farmer.

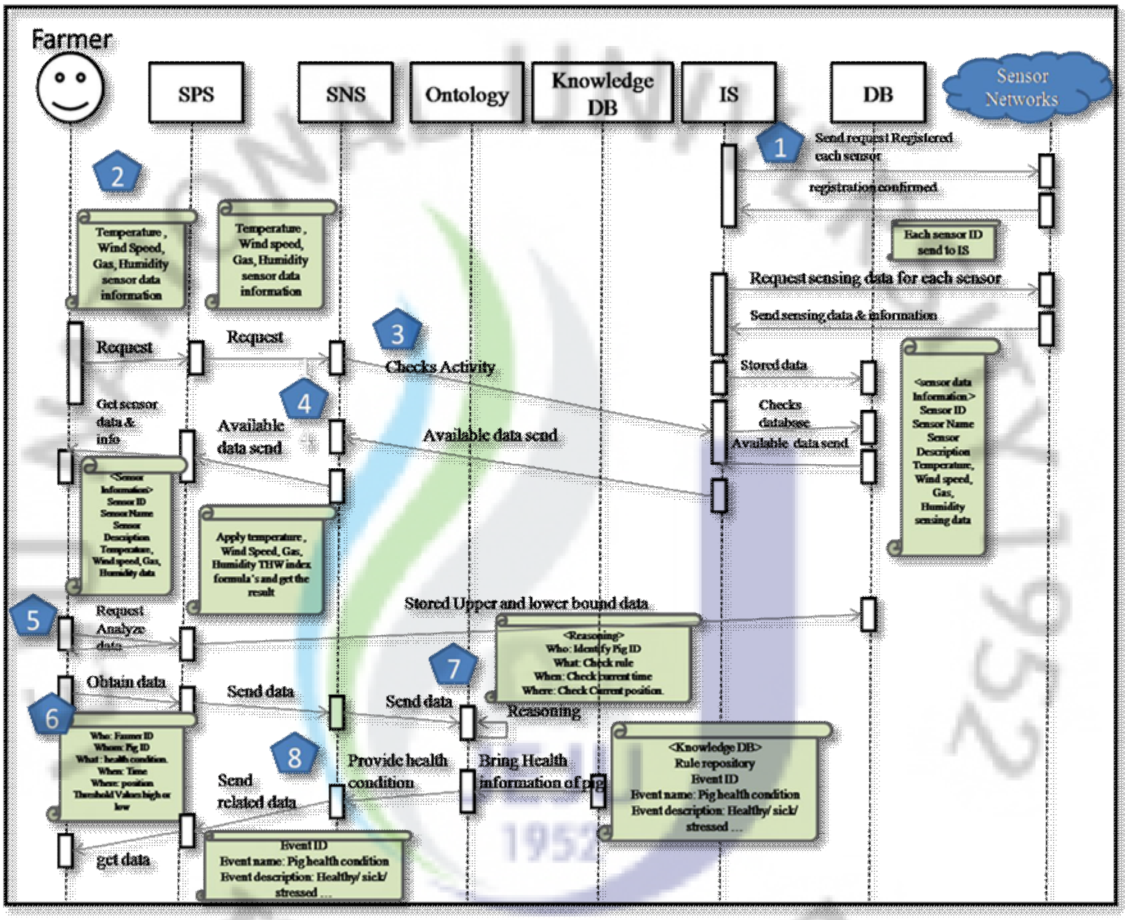

Figure 4.4.1: Sequence diagram for pig farms using various sensors

The sequence diagram for the proposed SNS and ontology service using various sensors is shown in Figure 4.4.1. The description of various labeled steps for pig farms using temperature, wind, gas and humidity sensors are as follows.

1. Information service registered each sensor through sensor networks. Information service send request registered each sensor through sensor networks. Once the registration confirmed and then easily receiving the sensors data through sensor networks. After receiving the sensor data in each sensor and send sensing data into the data base.

2. The farmer submits a request through sensor providing service (SPS) to sensor naming service (SNS), indicating the type of various sensors such as temperature, wind, gas and humidity sensors information.

3. SNS starts checking activity to information service. If the information service data such as temperature, wind speed, gas and humidity is available, then provide the sensor data and sensor information to sensor naming service, otherwise firstly information service registered related sensors in the sensor networks. After conformation of registration then access the data of temperature, wind speed, gas and humidity. Sensors provide the sensor information and data through sensor naming service.

4. Sensor naming service transfer related sensor information and data through sensor providing service to farmer. Farmer receives the collected temperature, wind speed, gas and humidity information (sensor ID, sensor name, sensor description, sensing temperature data).

5. Next, request and analyzes sensing data through sensor providing service. Sensor providing service applying the temperature formula and obtained the upper bound and lower bound results transfer to farmer and at the same time stored into the data base.

6. Farmer receives the temperature upperbound and lowerbound results, request the objects information through SPS (sensor provider service) to SNS (sensor naming service).

7. Sensor naming service checks the objects information in ontology. SNS (Sensor Naming Service) checks the objects information in ontology reasoner, once the reasoner matches the farmer objects with each of the pig information. If the object information is available then ontology provides the related objects information to SNS (sensor naming service).

8. Sensor naming service transfer to the objects information through sensor provider service to farmer.

4.5 Database Design for Semantic Sensor Web

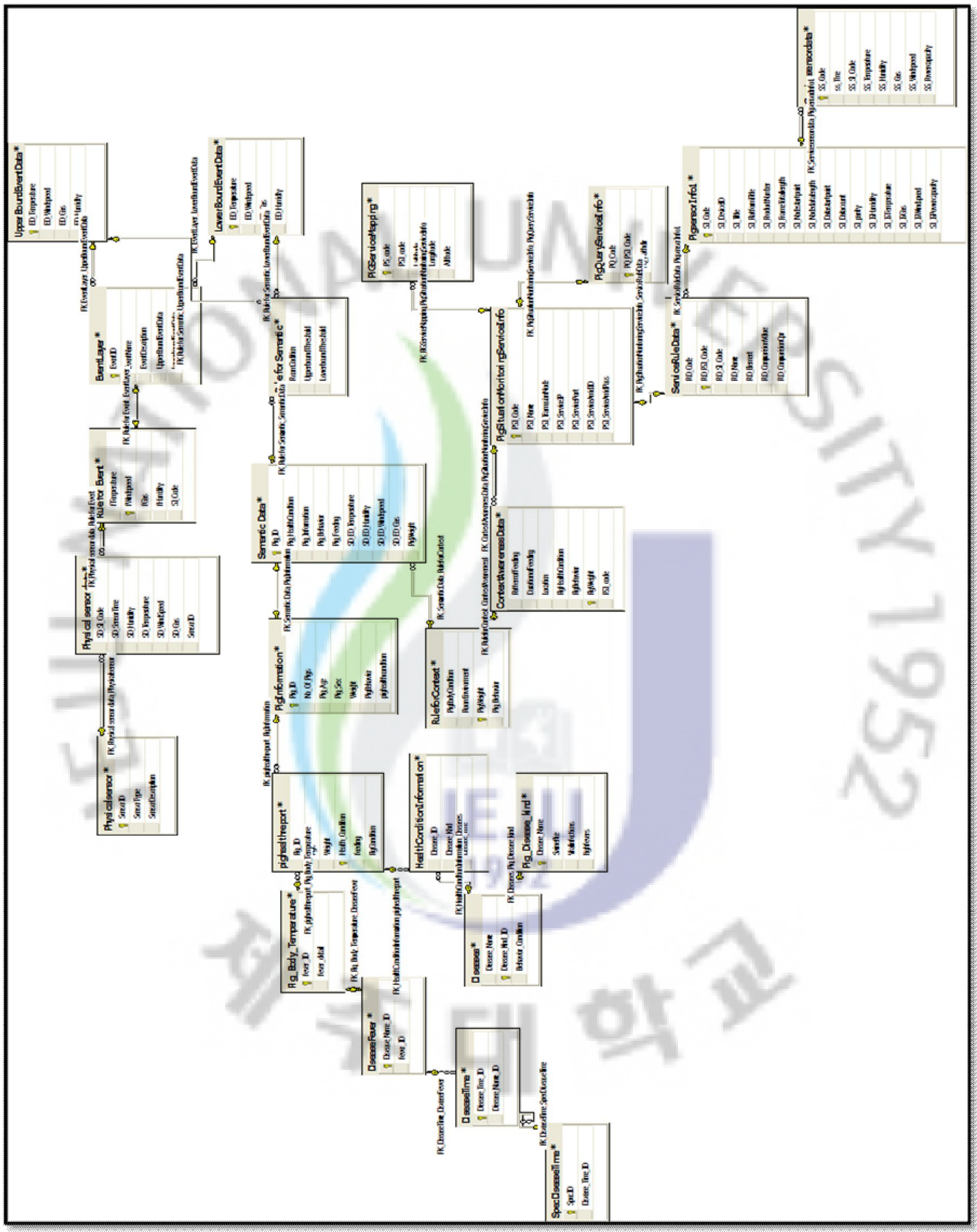

Figure 4.5: Data base diagram for sensor naming service

The database diagram of real-time pig farms information system was shows in Figure 4.5. Layers information was displayed as table format, due to that it can be easily understandable.

The physical to event layer, collected the physical sensor data such as sensor type, SD_Temperature, SD_Humidity, SD_Wind speed, SD_Gas, and applied the rule for event of temperature, humidity, gas, wind speed and thermal comfort (TWH) in the physical to event layer. Event layer displays the results using the rules as upper and lower bound of temperature, wind speed, gas and humidity data.

Those event data of upper and lower bound was used by the semantic rules and it displays the semantic data. According to the semantic rule data, Pig health condition changes such as pig body temperature, disease fever, and disease time as shown in Figure 4.5. This semantic data supports the context data and rule for context pig condition; pig behavior, pig health, and feeding are applied between the semantic data and context awareness data in this layer. According to the rule of context, semantic data describes the pig information such as pig weight, pig body temperature and pig health condition.

Once the semantic to context rules are displayed, the data was transfer to context to service layer. In this layer the context awareness data linked to pig situation monitoring system which can exist several pig services such as pig service mapping, pig query service information, service rule data as shown in Figure 4.5. The pig sensor information provides the various sensors information to physical layer.

4.6 Result of Semantic sensor naming service

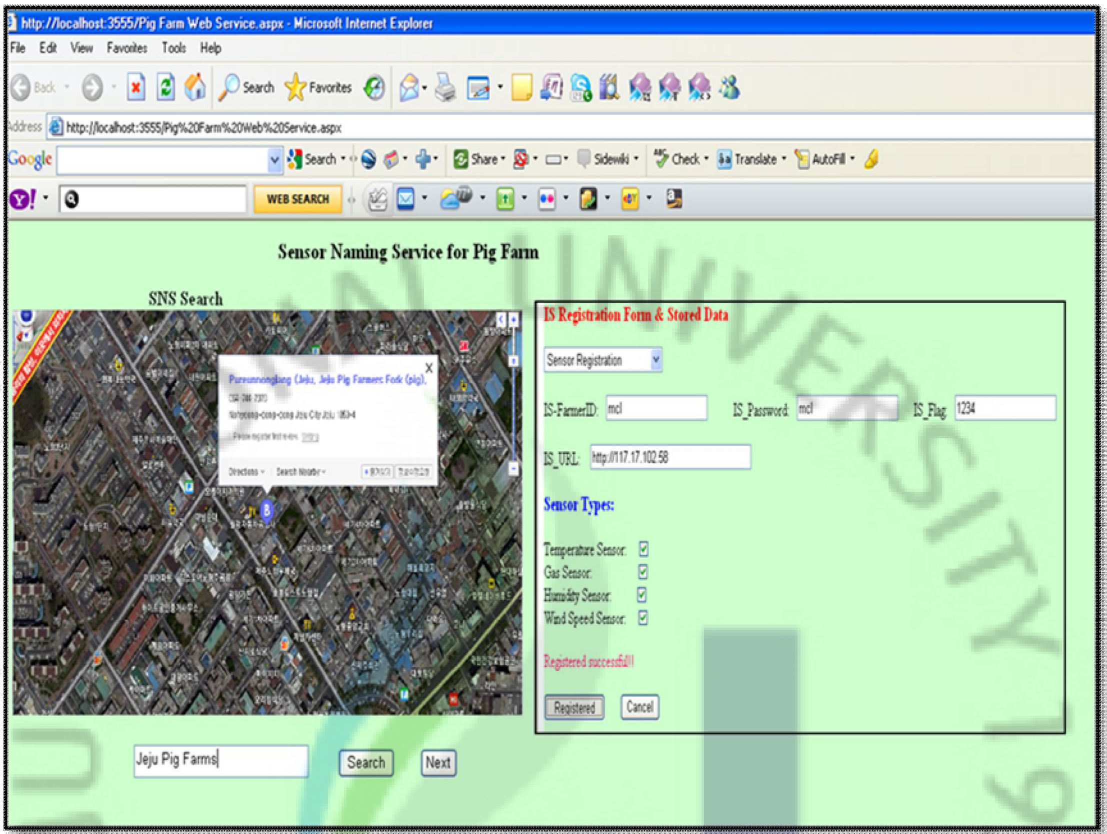

Figure 4.6: Semantic IS registration for sensors

First, the sensor naming service searches the location of pig farm from "Daum maps", which can find the location of required pig farm. After locating the pig farm, it connected to the web page. Figure 4.6 is a part of a screen capture of Jeju pig farm. As show in the picture, the small blue circular indicator with label indicates the position of the pig farm. The sensors in the pig farm generate observation. Information service registers for each sensor such as temperature, wind speed, humidity and gas sensors. Once it registers all the sensors and then goes to the getting sensor data web page. Figure 4.6 is the example of sensors registration request and register. The drop down list box identifies the sensor registration by selecting the corresponding sensors. For example, first of all IS must registered each sensor and get those kind of information's are sensor information, sensor data. "IS_FarmerID: mcl, IS_Password:

mcl, IS_Flag: , IS_URL: http://117.17.102.58” and select the each sensor in the figure 4.6 such as temperature sensor, humidity sensor, wind speed sensor, gas sensor and press the registered button, its automatically registered those kind of each sensor.

4.6.1 Semantic sensor naming service Registration for each sensor, Receiving and Stored data temperature, wind speed, gas and humidity

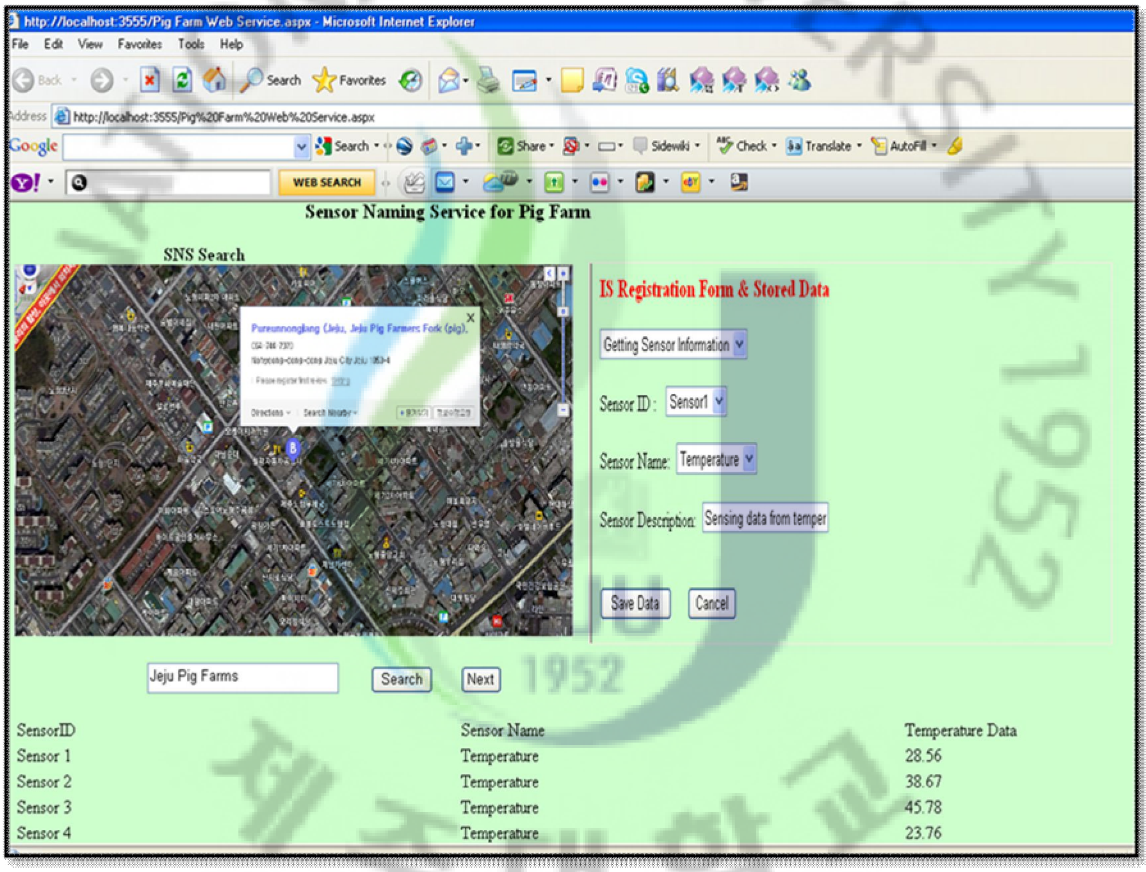

Figure 4.6.1: Semantic IS receiving data and stored into the database of temperature, wind speed, gas and humidity

Once the registration of sensors in the sensor naming service was over, it receives the sensor data through each sensor’s. Here, the clicking button for selection of the sensor ID, sensor name and sensor description. The sensor name parameter specifies the required sensor and once we select the particular sensor, sensor data and information was stored in to the data base by clicking the save data button. Figure 4.6.1 shows the example of receiving the temperature sensor data and stored in to the data base. Similar procedure has followed for other sensors such as wind speed, gas and humidity for getting the data and stored in to the data base. For example, getting sensor information are sensor id is sensor 1, sensor name is temperature, sensor description is "sensing data from temperature sensor", temperature data 28.56 ^{0}C and save these data into the data base.

4.6.2 Semantic sensor naming service for Event data information for temperature, wind speed, gas, humidity and thermal comfort

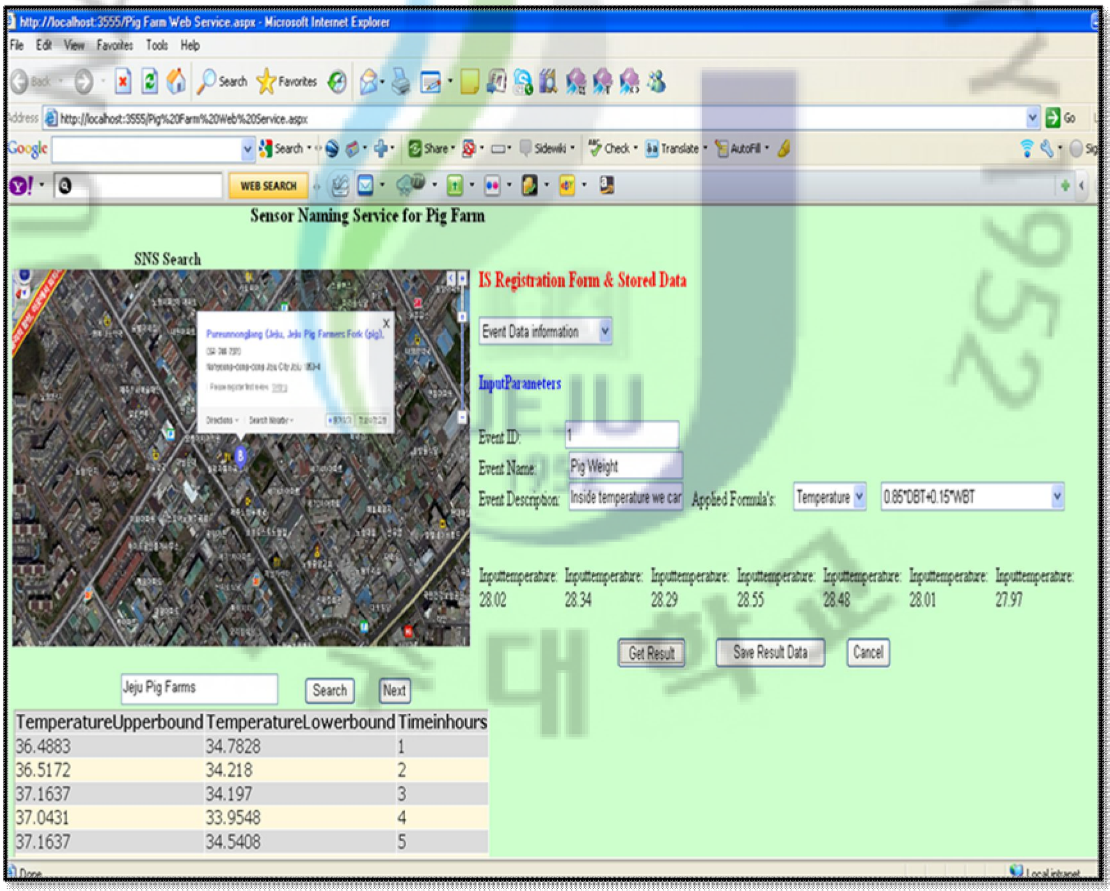

Figure 4.6.2: Semantic sensor naming service for event data information for temperature sensor

The input event parameters specifies the Even ID, Event name, Event description and sensing temperature data, which applies the temperature estimation rule for obtaining the temperature upper and lower bound for each hour in a day. Fig. 4.6.2 shows the SNS event data information for example, temperature data, here the event name was specified as "pig weight" and event description was specified as "inside room temperature" and applied formula "Temperature = 0.85*DBT+0.15*WBT" and get the results are temperature upper bound is 36.4^{0}C, temperature lower bound is 34.78^{0}C and Time in hours is 1. Similar procedure was followed for the event data information for other sensors such as wind speed, Gas, Humidity and Thermal comfort (TWH) and applied the corresponding formulas for obtaining upper and lower bound results.

4.6.3 Sensor naming service semantic and Context ontology data for temperature, wind speed, gas, humidity and thermal comfort

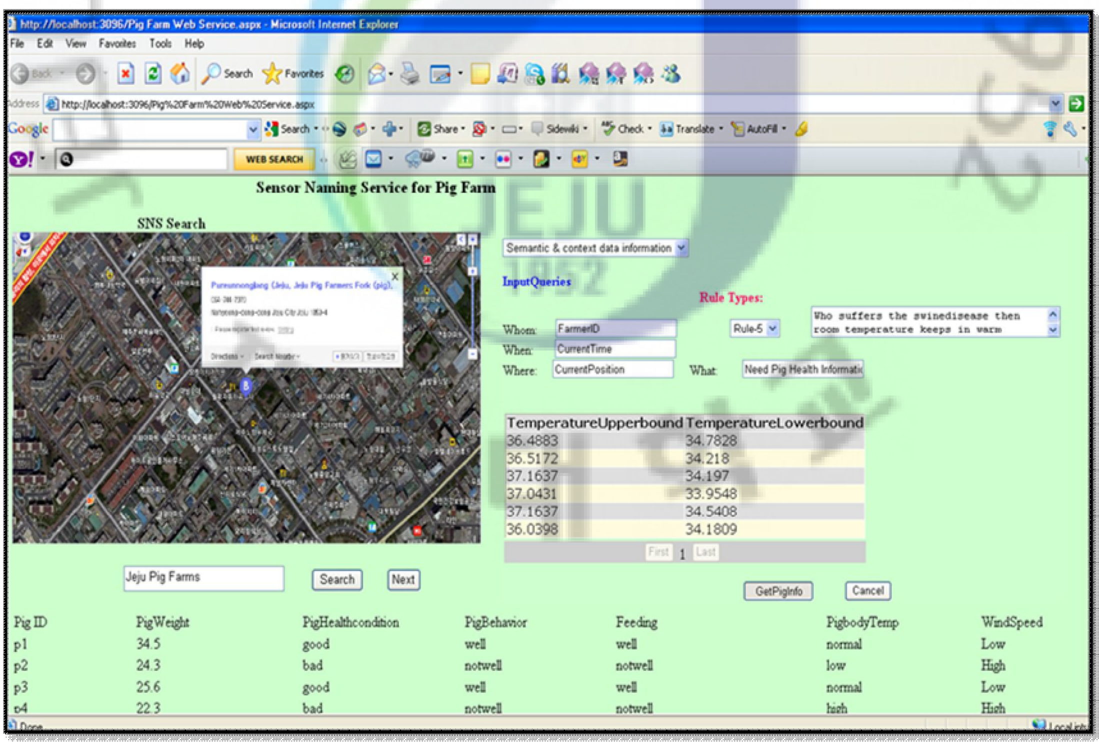

Figure 4.6.3: Sensor naming service for semantic and context ontology data for temperature sensor

The input parameters of the semantic, context ontology specifies the whom, when, where, what kind of information and sensing temperature data such as temperature upper bound and temperature lower bound are required. Once the simulated temperature data was input into the semantic web page and clicking the "GetPiginfo". Which is automatically provides the pigbehaviour, pighealthcondition, and feeding as shown in Fig.4.6.3.Similar procedure was followed for the semantic, contest ontology data information for other sensors such as wind speed, gas, humidity and thermal comfort (TWH). SNS for semantic and context ontology data information for wind speed, gas, humidity and thermal comfort (THW) input into the semantic web page and clicking the "GetPiginfo". This automatically provides the pigbehaviour, pighealthcondition, and feeding. For example, input queries are whom: farmerID, when: current time, where: current position, what: need some pig information health and apply the rules described "who suffers the swine disease then room temperature keeps in warm conditions and also pigs needs ventilation air", and get the pig information are pigID is p1, pig weight is 34.5, pig health condition is good, pig behavior is well, pig body temperature is normal, feeding is well and wind speed is low. For example, if the semantic information of the room temperature is higher than the normal temperature then the context information of the pig behavior and pig health condition is changes such as pig behavior is "not well", pig health condition is" bad" and feeding is "not well" . If room temperature is lower than the normal temperature then the pig health conditions is "bad", pig behaviors is "not well", and feeding is "not well". If the room temperature is normal then the context information of the pig health condition is "good", pig behaviors is "well" and feeding is "well".

4.7 Test and Analysis

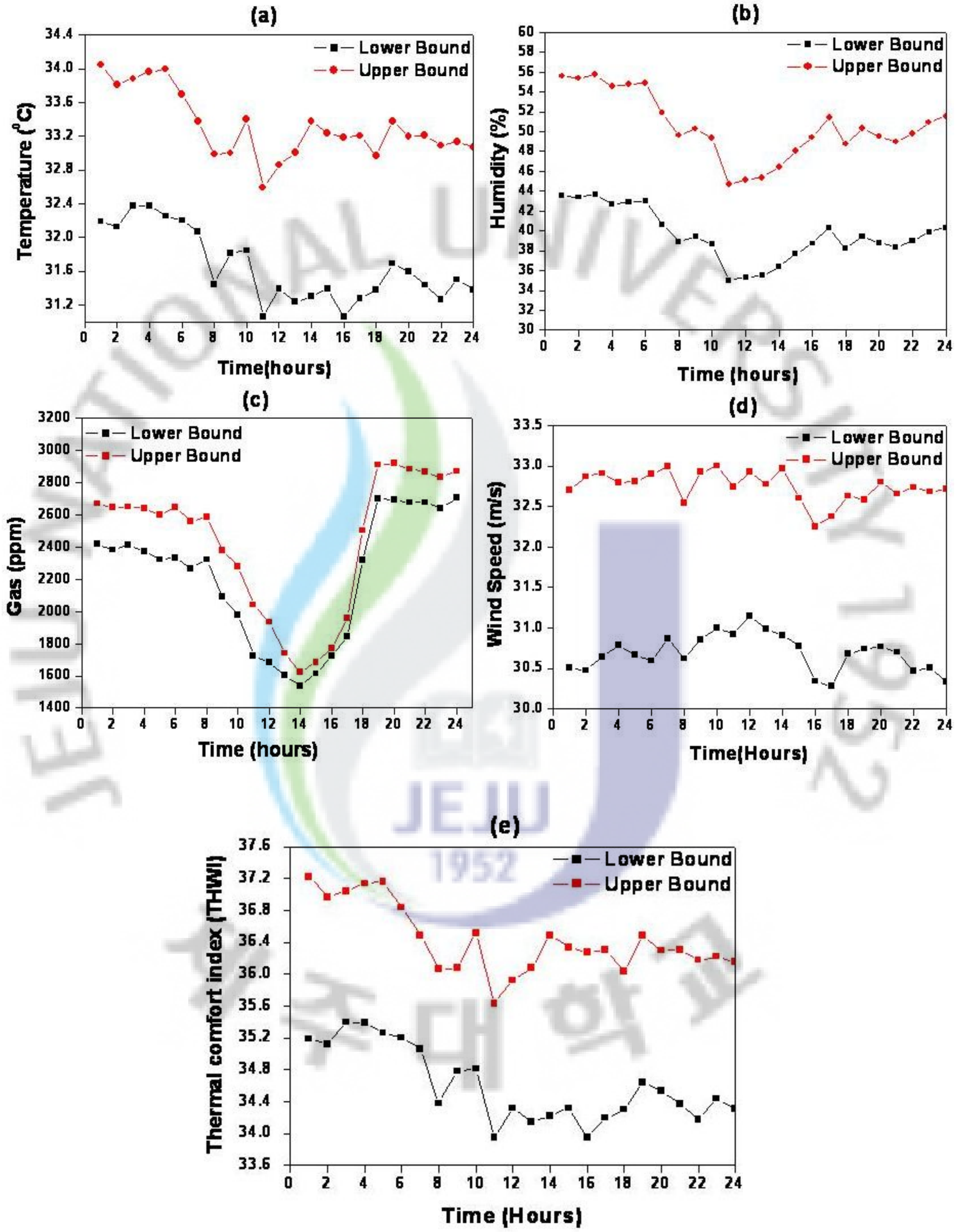

Figure 4.7: Indoor climate variations of (a) temperature, (b) humidity, (c) gas, (d) wind Speed and (e) thermal comfort (THW) in pig farm at various times

Figure 4.7 shows the inside climatic variations of the temperature, humidity, gas and wind speed of each hour in a day. The sensor data was collected for an interval of one minute and those data was averaged for obtained in each hour. Based on those temperature-humidity-wind speed variations, thermal comfort (THW) was estimated. The variations of the environment condition above or below the normal defined values gives the lower/upper bound. The temperature of the inside pig farm was decreased as the time goes from each hour during a day for both lower and upper bond values as shown in Figure 4.7(a).

Similarly, the humidity and gas was much lower at the middle of the day for both lower and upper bound as shown in Figure 4.7(b) and (c), respectively. The variation of wind speed was not fluctuated for both the lower and upper bound as shown in Figure 4.7(d). The obtained environmental changes of temperature-humidity- wind speed of inside the pig farm was used to estimate the thermal comfort (THW) index for lower and upper bound, which was shown in Figure 4.7(e). The thermal comfort index describes the comfortable condition of the pig farms. The variation of the environment was damped behind the heat exchanger and the temperature this kind of animals cooling systems – like evaporative systems, geothermal heat exchanger using heat store capacity of the ground and technical cooling – are applied to reduce heat stress. Beside the cooling effect in the summer the fresh air in the winter period will be pre-heated. The variation of environment to upper and lower bound influence the pig situation, pig health condition and the feeding rate as obtained by using semantic sensor web. To find better observation of the environmental condition, thermal comfort (Temperature-Humidity-Wind speed) index was used. Semantic web based ontology has esteemed benefit for understand the situation anywhere, anytime for controlling the pig farm environment or by knowing the extreme conditions such as low gas and humidity at the middle of the day as shown in Figure 4.7(b) and (c). Those objects information may useful to immediate indication of situation in the pig farm for animal care and production rate.

VI. Conclusions

In this research work, I described my approach of data modeling and managing context information in a semantic service framework for intelligence environments. The main purpose of this system was to detect the pig health condition and pig situation monitoring depends on the inside environmental conditions of pig farms to providing semantically related concepts to improve by searching and offering better pig situation monitoring services. First, I defined ontology for describing the concepts and relationships of the sensor objects information for the pig farm. An ontology data modeling was used as a tool in this research. I presented some preliminary results on the pig farm ontology system that is concerned with the collection, presentation and use of knowledge in the form of ontology. It is related to pig behavior, pig situation and the relationship between all of them. It presents an ontological representation of environmental sensor observations and objects information that could add much value to sensor data on the semantic sensor web.

General framework using ontology based semantic web suggested here to provide a basis for research and development of complete systems and solutions specifically targeted for pig farms applications. The environmental contexts are related to physical environments and the ontology includes the description of objects information, inside the pig farm. The proposed architecture and data modeling of customizing pig farms was able to build sample of ontology through the protégé and verified the proposal system through the SPAQRL Query. The semantic sensor web integrates semantic web technologies with sensing system in order to provide more expressive representation, enhanced analysis and improved access and discovery of sensor data on the semantic web for pig farms. Finally, I successfully implemented and tested the semantic sensor web based on ontology using proposed hierarchical data model and information for each layers in the pig farm.

However, in this future research will be extended to apply with more sensors and research estimation in the real-time situations. Second, an accurate and objects estimation for the proposed method by the criteria of verified was not yet completely performed, but the estimation was done by using available resources. Lastly, for the establishment of proposed method may mobilized diverse external technologies of semantic sensor web for the proposed system of its own, has not been concentrative developed, which may be the most critical of this study.

As for the future research task to extension in order to support the semantic web services planned to investigate to health care monitoring services and acoustic vehicle by building a functional ontology that describes operations on sensor data and sensor information. The development of a real semantic sensor web services system in which ontology based search method proposed in this study, is applied, is necessary prior to anything else. These efforts will be a future step in the direction towards enabling semantic sensor web services to access and process sensor data and sensor information.

BIBLIOGRAPHY

Beigl M, Zimmer T, Decker C "A Location Model for Communicating and Processing of Context" , Personal and Ubiquitous Computing, vol.6, pp. 341-357, 2002.

Brickley D, Guha R.V, "RDF Vocabulary Description Language 1.0: RDF Schema", World Wide Web Consortium, January 2003.

Dey A and bowd A G, "Towards a Better Understanding of Context and Context-Awareness", Workshop on the what, who, where, when and how of context-awareness at CHI, April 2000.

Dey A, bowd G.A and Salber D, "A Context-Based Infrastructure for Smart Environments", Proceedings of the 1st International Workshop on Managing Interactions in Smart Environments (MANSE '99), pp.14-128,1999.

Dioguardi L, Sangiorgi F, Ariano E, "Identifying Physical hazard for intensive pig and cattle breeding operators and defining prevention measures", University of Milan. Institute of Agricultural Engineering. Via Celoria, 2-20133 Milan, Italy, 2008.

Collin A, Milgen J, Dubois S and Noblet J, "Effect of high temperature on feeding behavior and heat production in group-housed young pigs", Institut National de la Recherche Agronomique, 34490 Saint-Gilles.

Gu T, H. Pung, and D. Zhang, "An ontology-based context model in intelligent environments", Proceedings of Communication Networks and Distributed Systems Modeling and Simulation Conference, San Diego, CA, USA, 2004.

Henricksen K, Indulska J, Rakotonirainy A, "Modeling Context Information in Pervasive Computing Systems", In Proceedings Pervasive Computing, Zurich, August 2002.

Hinz T, and S. Linke, “A comprehensive experimental study of aerial pollutants in and emissions from livestock buildings”, Part 1: Methods. J. Agric. Eng. Res. 70:111–118, 1998.

Holis G, Environmental stress. In. Porknet “The Online Resource for the Pork Industry”, University of Illinois, IPIC papers. 2 p, 1996.

Horrocks, P. F. Patel-Schneider, H. Boley, “SWRL: A Semantic Web Rule Language Combining OWL and RuleML”, http://www.w3.org/Submission/SWRL/ , 2004.

Huang C, C. Sun, F. Shih, and J. Hsieh, “Mining Domain Ontological Information from Online Publications”, Proceedings of the 6th WSEAS International Conference on E-ACTIVITIES, Tenerife, Spain, December 14-16, pp.155-160, 2007.

Hwang J, Hui-dong Ju, Kang H, “Implementation of Swinery Integrated Management System in Ubiquitous Agricultural Environments “, 한국통신학회논문지, Vol. 35 No. 2, pp 252-262, 2010.

Ian McCauley, Matthews B, Nugent L, Mather A and Simons J, “Wired Pigs: Ad-Hoc Wireless Sensor Networks in Studies of Animal Welfare”, IEEE, EmNetS-II, pp 29- 36, 2005.

Ingo Simonis Geoss and the sensor web. Technical report, GEOSS DA07-04 Workshop, Geneva, Switzerland, May 15-16, 2008.

Ishak W. H. W, & Siraj F, “Artificial intelligence in medical application: an exploration http://www.hi-europe.co.uk/files/2002/Artificial Intelligence In Medical Application an Exploration”, pdf. 2002

Johnson R.W, "The energy cost of illness on Swine. In. Porknet The Online Resource for the Pork Industry", University of Illinois, IPIC papers. 4 p, 1996.

Noy N.F, and McGuinness D.L, "Ontology Development 101: A Guide to Creating Your First Ontology", Stanford Knowledge Systems Laboratory Technical Report KSL-01-05, 2001.

Pedersen S, Rom H B, "Diurnal variation in heat production from pigs in relation to animal activity", EurAgEng, Paper No 98-B-025, AgEng Oslo98, 1998.

Ranganathan A and Campbell R, "An infrastructure for context-awareness based on first order logic", Personal and Ubiquitous Computing 7(6), pp. 353-364, 2003.

Schilit B, N. Adams, and R. Want, "Context-aware computing applications" , Proceedings of the workshop on Mobile Computing Systems and Applications (Santa Cruz, CA, USA, December 1994), IEEE Computer Society, pp. 85-90, 1994.

Schauberger G, Piringer M, Petz E, "Steady-state balance model to calculate the indoor climate of livestock buildings, demonstrated for finishing pigs", International Journal of Biometeorology, 43, 154–162, 2000.

Seta K, T. Okazawa, M. Umano, and M. Ikeda, "Ontology Based Organizational Risk Knowledge Creation Support Based on Incident Reports", Proceedings of the 11th WSEAS International Conference on SYSTEMS, Agios Nikolaos, Crete Island, Greece, July 23-25, pp. 337-342,2007.

Sheth S, Henson C, and Sahoo S, "Semantic Sensor Web", IEEE, pp 78-83, 2008.

Smith M, Welty C, McGuinness D, "OWL Web Ontology Language Guide", http://www.w3.org/TR/owl-guide/, 2004.

Staab S, Stude R., “Handbook on Ontologies”, Springer-Verlag Berlin Heidelberg New York, 2004.

Stanford University School of Medicine: “Protégé Knowledge acquisition system, “At address: http://protege.stanford.edu/, 2003.

Tao X and Xin H,“Temperature-Humidity-Velocity Index for market-size broilers”, Proceedings of the ASAE Annual International Meeting. Paper n. 034037, Nevada-USA, 2003.

W3C Recommendation: “OWL Web Ontology Language Overview”, At Address: http://www.w3.org/TR/owl-features/, 2004.

ACKNOWLEDGEMENTS

This thesis is the result of two years of work in which many had their helping hand. It's a great opportunity to express my gratitude for all of them.

First of all, I am extremely grateful to my advisor Prof. Do-Hyeun Kim for his guidance and support during my studies in Jeju National University. Without his help, thoughtful guidance, constant interaction and helpful discussion this thesis would not have been possible.

I wish to offer my humble gratitude to Prof. Khi Jung Ahn, Prof. Sang-Yong Byun for their useful suggestions and extremly important comments during the process of my thesis evalution. I would like to express my sincere thanks to Prof. Khi Jung Ahn, Prof. Sang-Yong Byun, and Prof. Jang-Hyung Kim and other professors of my department for their kind help and extended support in many ways to fulfill my course work successfully.

Finally, Special thanks are extended to my following graduate students, lab members and department secretaries for their help and cooperation. I wish to thank the Jeju National University and the Informational Technology Research Center (ITRC) for their technical and financial support.

I would like to express my deepest gratitude and love to my dear parents, brother and my husband for their support. Without their love, understanding, support and encouragement, the completion of this study would have never become possible. I thank them for all their love and help they are giving me. I am very much thankful to almighty for pondering divine blessings on me. Last but not the least I am thankful to all my friends, relatives and teachers who stood by my side in tough times to combat difficulties and gave me moral strength which paved the way for me to pursue Masters in Korea.