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ONTOLOGY BASED DECISION SUPPORT KNOWLEDGE ACQUISITION MODULE

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ABSTRACT

Data integration issues have been part of the challenges faced by the oil and gas industries. This is also compounded by the fact that different kind of modeling tools has been used that are complex for decision makers thereby further making it difficult to adopt other tools. The consequence of this is sufficient previous records are not efficiently inculcated into the system for a better decision analysis during the decision making processes. Also, failures due to this insufficient analysis usually lead to huge capital costs that far surpass the equipment procurement cost. Ontology based knowledge acquisition system tool can help mitigate these issues. Expert input is used for part of data collection. Ontology knowledge model is developed which helps to build taxonomy of objects of interest in the domain to serve as a knowledge base. One of the advantage of the ontology knowledge model is its linguistic properties which is close to human semantics to help bridge the issue of technicality barrier to help decision makers understand the underlying information in the system. Web ontology language application programming interface (OWL-API) together with java codes are used to serialize between the ontology knowledge base and the graphical user interface developed in java to automatically add and update the knowledge in the database to make assessment based on the newly added data and the existing data. The tool is capable of adding new data and making appropriate inference. The tool will serve as a basis for decision makers who are usually not technical inclined to make effective decisions that will yield improved and profitable productions.

Keywords: ontology, decision making tool, knowledge acquisition, OWL-API, oil and gas.

INTRODUCTION

In the oil and gas industry where there are so many activities that needs to be performed, efficient access to information is an issue [1-3] which is also primarily due to the fact that when changes are made in some certain aspect of the operation, passing across to relevant information repository is a major issue. This is corroborated by [4], in reporting a project results research in Netherlands which revealed that the major reason for project failure cost is lack of sufficient information exchange and communication within projects. They also reported that a workshop outcome shows that project leaders and engineers are not proficient in a simple to use modelling method that is close to human semantics and suggested that proficiency in this modelling skills can improve interoperability and consequently, efficient communication among project teams. This was also corroborated by [2], that the use of decision and risk analysis tools in the oil and gas industry is still limited, they attributed this to tools complexity and suggests that selection of software tools is a critical aspect of decision making process.

The assessment and selection of equipment for use in this industry helps lower the risk of making the wrong choice of equipment, reducing failure to the barest minimum, helps reduce cost and ultimately increase the chances of optimum oil and gas recovery. This is as a result of the rate of growth in different decision scenarios at an alarming rate in the industry [5-7]. These scenarios can range from subsea processing systems to the entire subsea production systems. The subsea processing systems includes the subsea multiphase pump, subsea separation and gas compression. The subsea multiphase pump, which is currently the heart of subsea processing [8] is by no means an exception to these assessment and selection issues judging by the technical events (Subsea processing and flow assurance conference, 2015; Offshore technology conference 2015) that is yearly lined up to discuss its issues. According to [1]; semantic modelling can form the backbone of oil field applications to facilitate information integration and knowledge representation. They further reiterated that the approach in assessment and selection in the oil and gas industry is labour intensive due to its time consumption and it has scalability issues due to the large number of criteria's.

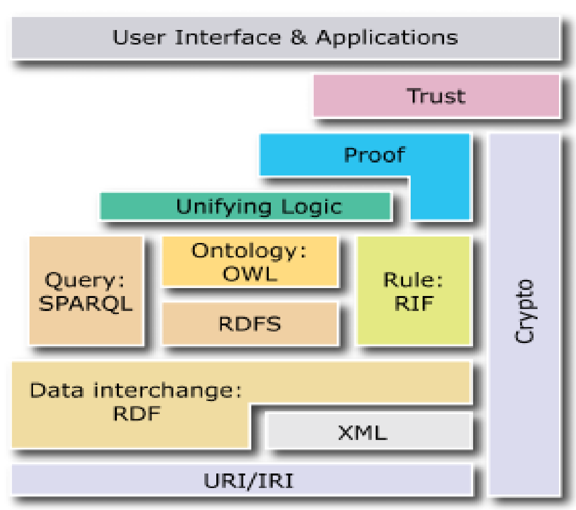

Figure-1. Semantic web architecture technologies (Source W3C).

Ontology is a data model of a set of concepts in a domain and the relationships between the concepts that can be shared. It has widely help in knowledge management and information integration [3]. Definitions and concepts of the domain help identify the instance (individual) in the domain of interest while the knowledge base (data store) holds data that are instance of the ontology. Ontology language represents ontology which must be able to have sufficient features for concept definition, expressiveness, proper instance representation and query. According to the World Wide Web consortium (W3C) "The Semantic Web, is based on the Resource Description Framework (RDF)and it provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries. It is a collaborative effort chaired by Tim Berners-Lee and Jeffrey Jaffe of the W3C with participation from a large number of partners which includes researchers and industry." Figure-1 depicts the semantic web architecture technologies.

The demand for assessment and selection tool is high [9]. This is usually achieved by using analytical models that evaluate criteria's. Based on comparison of these criteria's and proposing the best option. Ontologies has been viewed as a language that can be used to build semantically rich knowledge base in systems that requires information management [10]. The widespread use of ontology in different applications has been widely reported in the literature [1, 11-13]. Emphasis has been laid to the fact that in order for the ontology to be useful to make meaningful inference, the key issues are making consideration for all the processes that affects the domain [13]. According to [12]; language for expressing ontologies are closer in expressibility to descriptive logic (first order logic), than other database model languages. Ontology gives extensible vocabularies of terms; the terms have a well-defined meaning and relationship with other terms in the ontology. This makes ontology important components in a lot of knowledge intensive applications [12]. Ontologies has also been designed for query based search [14].

Decision support tool has been widely used [15] as they are part of the information processing systems that aid decision makers in decision making. Areas of applications include: the information technology [15], medicine [16], Aerospace [17], financial institutions[18], Describing a concept using abstract terms eases complex reality domain information which in turn eases construction of reasoning engine that facilitate getting the right knowledge from the knowledge encoded [19].

The application of semantic technologies is beginning to gain some acceptance in the oil and gas industry as a viable means of assessment and selection as it gives a unified view of a domain [1] due to its expressive representation of different data source which is a way to deal with information management issues. Web ontology language (OWL), the most matured of the technologies (W3C) is discussed. A number of researchers [1, 3, 11, 20], have enumerated the important role ontology as a tool can play in the information retrieval of information in the oil and gas industry. Ontologies has been applied in decision making as a tool to give a structured and formal representation of knowledge [9].

OWL, has been used to define asset integrity concepts for assets integrity management with their relationships as a framework to describe external corrosion of oil and gas facility by integrating and analyzing data sources to build an asset integrity system [1]. [20] used ontology in the information retrieval of subsea Christmas tree structural information to assist in the monitoring of the production efficiency of a well in the oil and gas exploration and production. In their ontology, they computed a feature vector for each of the domain concept so as to adapt the ontology concept to the domain terminology. However, their ontology is based on high level language that only the knowledgeable in the semantic web technology can use. [3], applied ontology to solve the information integration issues in reservoir management (such as simulation models and production forecasts) together with real time oil field operations settings and the knowledge management issues in the oil and gas industry. [11] utilized an ontology framework for oil and gas production process monitoring and maintenance decision support system. Petroleum production plant components were modelled using ontology and business rules for the decision support system. [21] used ontology as a knowledge base to build a system that can diagnose faults in the oil and gas sucker rod pumps. OWL 2 ontologies, an improved version of OWL provide classes, properties, individuals, and data values and are stored as Semantic Web documents which has become a standard for lot of applications making efficient inferences to be achieved [14, 22].

This paper main focus is on how to use semantic web technology such as ontology to design a knowledge base for use in decision analysis.

METHODOLOGY

The knowledge acquisition system is depicted in Figure-2.

It comprises of the web ontology language application interface (OWL-API) libraries that is used to serialize between the ontology domain knowledge and the graphical user interface. The OWL-API.gui Library serves to provide the necessary gui codes to be used in the tool. The MainProject.gui consists of a set of written java codes that was developed as a rule engine to be fired when assessment and selection requests are initiated while the Ontology Database / Database Management consists of the subsea multiphase domain information which is obtained from the survey administered to domain experts. It is an hirarchical structure to serve the purpose of database of the domain information built on the basis of linguistic terms that is close to human semantics.

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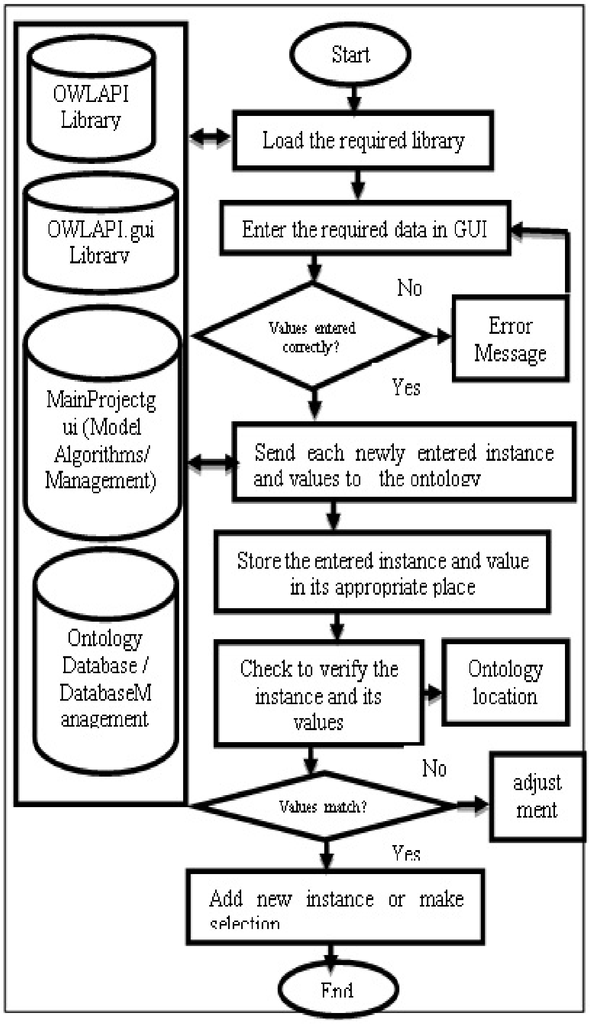

Figure-2. Knowledge acquisition system flow chart.

Knowledge acquisition module

This module accepts knowledge in and transform this knowledge into the ontology format through the graphical user interface (GUI). The knowledge that is accepted is automatically sent to the OWL as production rules to be stored in the program using the OWL knowledge representation language. The production rules are stored in two format which is the antecedent (If / else part) and the consequence (then part). For example: *If a is X, then b is Y where a,b* are linguistic variables and X,Y are values gotten from the GUI that is determined by previous experience. This module is contained in a java class named MainProjectGUI. Based on the knowledge acquisition module, the system performance is enhanced making assessment and selection decisions to be robust with more data as it becomes available thereby making the ontology knowledge model to be equipped with experienced data.

Subsea multiphase pumping and case study

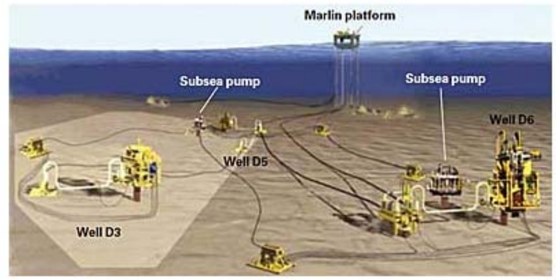

Figure-3. Multiphase pump in susbea operations (Nexans).

Two main principles govern the multiphase pump technique used in the subsea domain, which are the rotodynamic principles and the positive displacement principles. In the subsea domain, the main pumping equipments that has been deployed are[23, 24]: the helico-axial multiphase pump, the twin-screw pump and the electrical submersible pump. Helico-axial multiphase pump and the electrical submersible pump are of the rotodynamic principles while the twin-screw pump is of the positive displacement principles. Figure 3 depicts a typical multiphase pump arrangement in subsea operation.

RESULTS AND DISCUSSION

The interface of the knowledge acquisition system tool is shown in Figure-4. It can be accessed by double clicking on the "Decision.jar" an executable file. This opens up the interface window. This is the graphical user interface (GUI) window in Java that is enclosed in a main panel that contains "add equipment" tab for the knowledge acquisition module where new data can be added and the "equipment selection" tab.

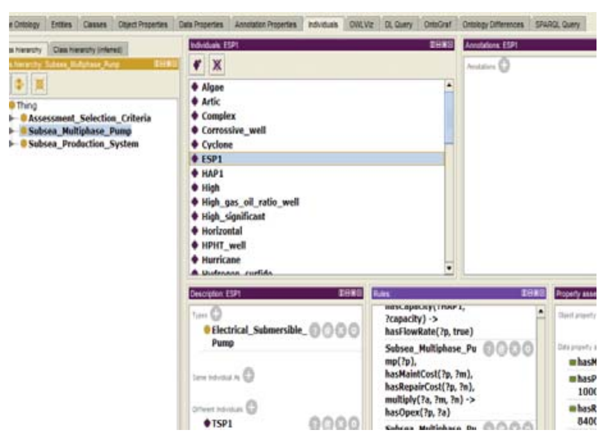

Figure-4. Knowledge acquisition interface.

Different individuals (instance) can be added through this interface as the backend axioms has been modeled in the ontology. It also shows how data is added to the knowledge acquisition module through the add

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equipment interface. This data is automatically transferred to the ontology knowledge base through the OWL-API libraries that is loaded as the application is launched. This added equipment can be ESP1, ESP2, ESP3 and so on (different variants of the subclass Electrical_Submersible_Pump), HAP1, HAP2, HAP3 and so on (different variants of thesubclass Helico_Axial_ Pump) and TSP1, TSP2, TSP3 and so on (different variants of the subclass Twin_Screw_Pump). These individual can also be manually entered through the ontology.

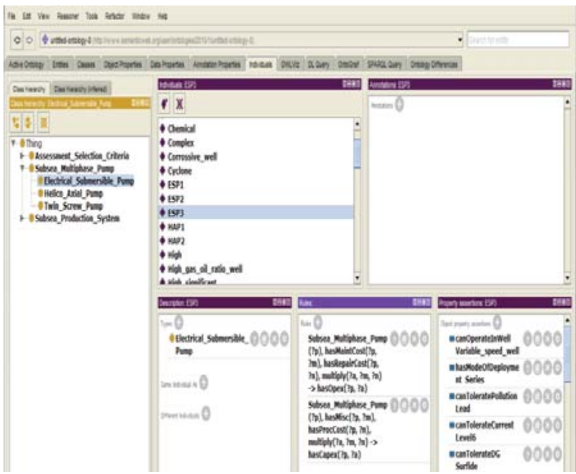

Figure-5. Ontology individual (instance) interface.

To demonstrate the capability of the system to add individuals and their properties through the GUI, the individual HAP3 is automatically added to the ontology knowledge base through the GUI thus saving the user the time and effort to learn the use of the ontology, Figures-5 - 8 depicts the process. Figure-5 shows the ontology before adding the individual through the GUI. This is the present state of the ontology knowledge base and decisions can be made based on information that exists in the ontology knowledge base. Figure-6 show some of the data and object properties for instance ESP3. These data and objects properties has been modelled in the ontology as a platform for each equipment data and object parameters that are critical for making informed decisions, such as canOperateInWell which is an object property denotes the types of well the multiphase equipment can survive in and the data property hasReliabilty denotes the reliability of each equipment. After clicking on save in Figure-4, Figure-7 prompts up in the ontology and after clicking yes, the individual is automatically added through the OWL-API library that serialize to and fro the GUI and the ontology knowledge base. Figure-8 shows all the newly added objects and data properties of the new equipment in their appropriate places. Inferences can be made on this newly added individual together with the existing ones in the ontology knowledge base. The addition of new data as they become available increases the robustness of the system to make informed decisions.

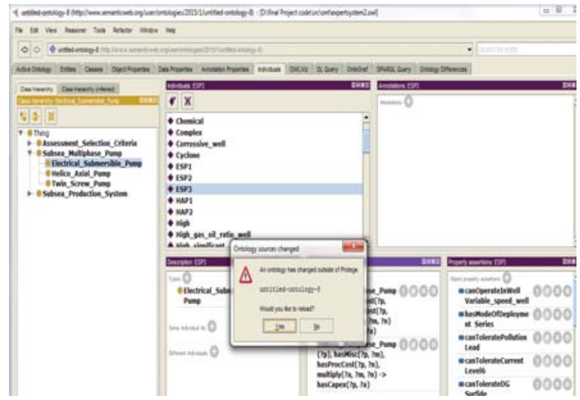

Figure-6. Data and Object properties for an instance.

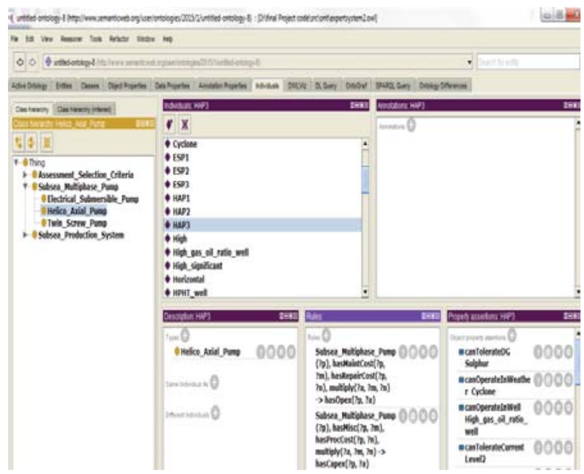

Figure-7. Prompt on the ontology after clicking safe on the knowledge acquisition interface.

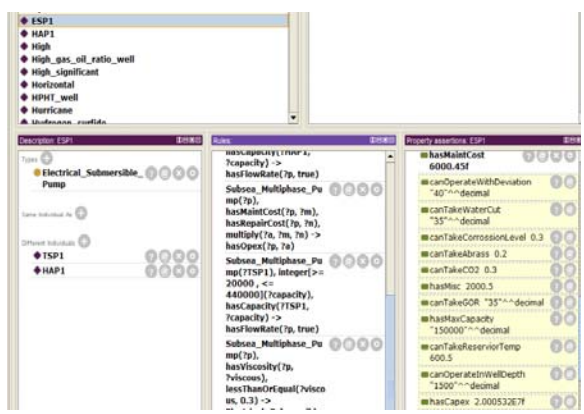

Figure-8. Inferred instance data and object properties with a reasoned.

CONCLUSIONS

This research has described the method in developing a tool using OWL, OWL-API and java in supporting complex oil and gas technology decisions. The strengths of these three software languages has been merged together to provide a robust tool that is not influenced by the scarcity of data as it becomes more robust as prior data becomes inputted through the GUI built on the java platform and automatically sent to the OWL ontology knowledge based, whose semantics is close to human language through the OWL-API and the java built in codes. It is also easier to use as it offers a click and see platform that makes it easy for persons who are not proficient in the software language to use effortlessly. The questionnaire survey / interview method was adopted as a way of getting important data from the domain experts on subsea multiphase pumps and on subsea processing systems in general. This forms part of the basis for the knowledge base built on the OWL platform.

VALIDATION

The executable file was sent to experts in the field; two field experts related the tool usability criteria as in Table-1 below. The result was further used in improving the tool.

Table-1. Usability criteria.

Criteria	Weight	Rank
Tool Organization	0.2225	2
Tool Effectiveness	0.2225	2
Learnability	0.0247	4
Time Response	0.0202	5
Automation	0.1781	3
Understandability	0.3316	1

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