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KNOWLEDGE SHARING IN HETEROGENEOUS DATA CONTEXT: APPLICATION IN PLM

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Abstract

PLM systems have emerged as effective solutions to handle the complexity, heterogeneity and quickly increasing of data. However, the complex dependencies among heterogeneous data is still a big issue to overcome. Querying this type of database is difficult for non-technician users of system. Based on some knowledge sharing techniques, the ontology-based query interface presented in this paper is expected as a good solution to simplify the database interrogation and to enhance the knowledge sharing among users. A query example in PLM domain will be used to illustrate capacities of this interface.

Keywords: Knowledge Management, Product lifecycle management (PLM), Design engineering

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1 INTRODUCTION

Nowadays, data plays an important role in the success of any organization, providing an efficient data management system is therefore an essential requirement. Recently, IS (Information Systems) have emerged as an effective solution, such as PLM (Product Lifecycle Management) for industrial companies. However, IS lead to the growth of heterogeneous data and then the dependencies between them. Thus, the links and dependencies among heterogeneous and distributed data are more and more complex during quotidian activities of users (engineers, etc.). The data exploitation (interrogation and sharing) have to be adapted to the context of large data and complex dependencies.

To overcome this current inconvenience, more and more research works have investigated and studied the Semantic Web (SW) concepts and techniques, as well as their applications to improve the capabilities of PLM solutions in order to efficiently manage lifecycle data. Ontology is a key component of SW in which concepts and the relationships between concepts can be expressed in natural language and understandable by both of human and machine. Ontology is therefore used to enhance the knowledge sharing and the data integration in many actual information systems.

Our contribution is to propose a methodology to facilitate the exploitation (interrogation and sharing) of data in an organization. Thus, the PLM domain is considered for industrial companies where the users are engineers. A global approach to construct an ontological model facilitating data exploitation is therefore illustrated from PLM context. The paper is organized as follows: in *section 2*, we present some related work in PLM systems and knowledge sharing techniques. Ontology methodologies are ever tested and used for PLM in industrial companies. Next, in *section 3*, we propose the approach for ontological model construction which be based on an existing solution of Assouroko et al. (2014). *Section 4* describes an application in PLM domain. The demonstrator is used as a smart query system. To end, *section 5* is reserved for the conclusion.

2 RELATED WORK

To ensure that the solution proposed is appropriate, we did a study on PLM solutions and Knowledge sharing techniques. Firstly, this section provides a brief summary of advantages and existing issues in PLM systems. Then, an analysis on Knowledge sharing techniques will be presented in the second part to illustrate their potential abilities in facing with the PLM systems problems.

2.1 Product Lifecycle Management

"Product Lifecycle Management (PLM) is an acronym widely adopted and defined by different communities, such as data management software vendors, academic community, end users… with slightly different interpretations" (Terzi et al., 2010). The Product Lifecycle Management systems integrate constantly all the information produced throughout all phases of a product's lifecycle to everyone in an organization at every level (managerial, technical…) (Sudarsan et al., 2005).

We can figure some key advantages of PLM systems (Eynard et al., 2004; Demoly et al., 2013):

- Establishing an effective PLM system reduces the enormous data resources to a coherent data flow, avoids redundancies and heterogeneities.
- PLM enables the collaboration through distributed and virtual/extended enterprises (workflow and process management, communication and notifications, secure data exchange...)
- PLM permits the product structure and its evolution management during different steps and track performed modifications tracking.
- PLM is a mature solution to tackle the heterogeneity, growth and complexity of the data and its processing methods as well as some of the traceability and confidentiality issues.

Take in account, PLM system brings together: Products, service, activities, processes, people, skills, data, knowledge, procedures… It aims to provide the right information for the right people at the right time. It provides an efficient solution to handle the complex and heterogeneous data resources and a mature method to track the evolution and modification of these data (Belkadi et al., 2012)

However, along with these advantages, it also exists some issues:

- Lack of strong stakeholders, ICT tools as well as a common standard between PLM systems causes data integrity problems and limits the access to and sharing of product information and knowledge distributed.

- Another issue of PLM community is the increasing of need for product lifecycle knowledge capitalization and reuse in order to reduce time and cost.
- Database exploitation requires a good understanding of database structure as well as data model especially in the context where the data is heterogeneous and the links and dependencies among data are complex.

Knowledge Engineering (KE) offers a rational framework which allows a representation of knowledge obtained though experiments and lifecycle activities. In the second part of this section, we are going to talk about Knowledge Sharing (a major process of KE) techniques that provide potential abilities to overcome PLM issues, especially in heterogeneous and complex data exploitation.

2.2 Knowledge sharing

In this section we deal with knowledge sharing techniques and their capabilities in facing with data interrogation and data sharing in PLM systems. Before going to the main part, it is important to understand the knowledge and knowledge management notions.

2.2.1 Knowledge and knowledge management

We can find various definitions of "knowledge" notion in literature. Knowledge is defined as information processed by individuals including ideas, facts, expertise, and judgments relevant for individual, team, and organizational performance. It is also considered as information possessed in the mind of individuals: it is personalized information which may or may not be new, unique, useful, or accurate related to facts, procedures, concepts, interpretations, ideas, observations, and judgements (Small and Sage, 2006).

Knowledge management (KM) aims at capturing explicit and tacit knowledge of an organization in order to facilitate the access, sharing and reusing of that knowledge. Through KM, organization seeks to acquire creating potentially useful knowledge and to make it available to those who can use it at an appropriate time and place. They then achieve maximum effective usage of this knowledge in order to positively influence organization performance.

KM is generally consisted in four major processes:

- Process of creating knowledge,
- Process of storing and retrieving knowledge,
- Process of transferring and sharing knowledge,
- Process of applying knowledge.

Knowledge sharing is considered as one of the most important process in KM. We then present some concepts and techniques used in this process.

2.2.2 Knowledge sharing

Knowledge play an indispensable role in the long-tern sustainability and success of organization. The need for processes that facilitate the creation, sharing and leveraging of individual and collective knowledge has emerged recently for this reason.

Knowledge sharing (KS) has been introduced as one of the major activities of knowledge management and some definitions of knowledge sharing can be found in the literature (Hendriks, 1999). KS can be defined as activities of transferring or disseminating knowledge from one person, group or organization to another. The individuals initially create knowledge but it can be produced and held collectively. At the most basic level; knowledge sharing involves the process through which knowledge is transferred between a source and a recipient by using knowledge sharing techniques.

Information technology (IT) provides techniques to capture knowledge, categorize, search, extract content information and present it in more meaningful formats across multiple contexts of use. Some authors (Sato et al., 2002; Zhang et al., 2008; Yoo et al., 2014) have invested their efforts to construct platforms that enable knowledge sharing by using ITs. Sato et al. (2002) used XML Linking Language (XLink) as a method of knowledge representation describing and proposed an architecture for sharing that knowledge among users. He used the peer-to-peer technology to help users to better understand how to reuse existing knowledge on computer networks. Zhang et al. (2008) tried to re-define knowledge resources in the network by object-oriented thinking and proposed three-layer knowledge sharing model. By using technologies on Web 2.0, a knowledge-sharing system is built on the Internet, allows the knowledge acquisition, sharing, extension and retrieving.

In next part, we are going to talk about ontology as the most common method to represent knowledge, the basis that enables the knowledge of sharing and using on the Semantic Web.

2.2.3 Ontology based and knowledge sharing

Ontology is defined as an explicit formal specification of a shared conceptualization. It is the basic structure or armature around which a knowledge base can be built. Ontology is a vocabulary of entities, classes, properties, functions and relationships between them.
Ontology enables both of knowledge sharing and knowledge reuse:

- **Knowledge sharing:** Ontology is a common way to represent knowledge. It transforms knowledge form tacit form to explicit and formal form. Furthermore, the standardized format of ontology could be used to enhance the knowledge sharing.
- **Knowledge reuse:** The ontology previously developed can be reused in other systems. In other way, by reusing well-defined Web ontologies of different domains, we can compose large-scale context ontology without starting from scratch.

Ontology-based approach therefore is an efficient approach for knowledge sharing systems. Yoo et al. (2014) proposed a system based on ontology expressing economics knowledge and Semantic Web technologies. Figure 01 presents the architecture of this system that consists of five layers: registration, ontology, data storage, reasoning and economic knowledge sharing. Users can register economics knowledge pertaining to a certain economics paper. They define then the metadata and the relationships between notions discussed in the paper. According ontology model, the system transforms this knowledge into semantic data in a machine-understandable format. Two functions: basic search and knowledge navigation were implemented.

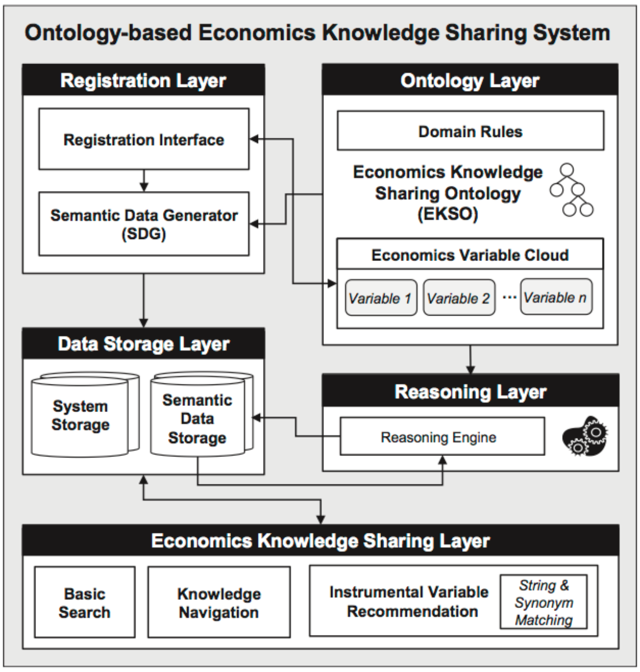

Figure 1. Ontology-based economics knowledge sharing system architecture (Yoo et al., 2014)

OntoShare (Davies et al., 2002) is another ontology-based knowledge sharing system, in which, as users contribute information to the community, a knowledge resource annotated with metadata is created by using ontologies that have been defined using Resources Description Framework Schema (RDFS) and populated using RDF.
Inspired by the capacities of ontology in expressing knowledge and in enhancing the knowledge sharing, we aim to apply it in the case of PLM. The difficulties in data exploitation and technical information in PLM systems come from the low-level of data model representation, the increasing of the complexity of links and dependencies among heterogeneous data. To exploit data from database, it requires a deep understanding of data model and the dependencies between these data. Ontology promises an efficient solution to enable the sharing this understanding. The data model and the

complex relationships could be also presented obviously, visually and easily to perceive by using ontology. In the next section, we continue with our methodology before going to present a case study in the context of PLM system (section 4).

3 METHODOLOGY

To ensure a concrete view, we started our work by interviewing some engineers, end-users from PLM domain where the complexity, variety, heterogeneity and growth of data resources have been handled. In fact, most of them have difficulties in data exploitation and they almost cannot accomplish this task without helps of database technicians. This issue comes from the complexity of dependencies and the new links added between the data existing and the new data which are generated during their quotidian activities. The understanding of these links and dependencies needs to be assimilated to all users. Thus, a common ontology is an ideal solution. We present in this section an approach for ontological model construction which enables the management of evolving character of links and dependencies.

3.1 Ontological model construction

The basic elements of ontology consist of a set of expert concepts with a clear definition of the hierarchy (taxonomy) between concepts, set of relationships (properties) between concepts, all being supported by a Logic Language (OWL-DL for example). It is important to notice that the definition of an ontological model for a given domain relies on the principle of the meta-model or meta-ontology.
For example, Figure 2 presents the conceptual model of Relationship Manager (Assouroko et al., 2014) in which, **Entity** (E) is the key object and it represents any type of product data used in BOL phases. **Entity** generalizes both *ExpertEntity (EE)* and *RelationshipEntity (RE)*. *EE* represents any metadata and/or document resource stored in existing CAx applications and/or management systems (RTM, PDM, SDM…) and is mainly described by its *URI* (Uniform Resource Identifier – a hypertext link to the corresponding data in the related CAx applications). *RE* is the core object of the model and represents any entity used to link two other Entities.

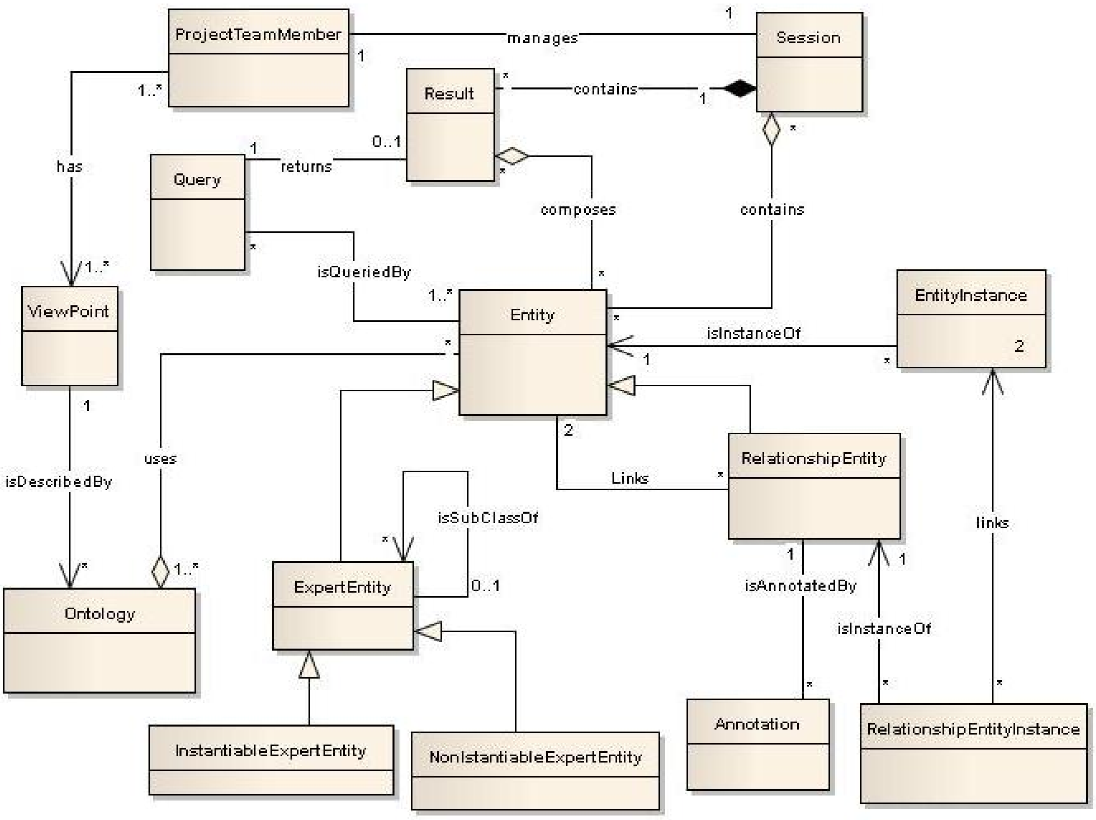

Figure 2. The extended conceptual model of Relationship Manager (Assouroko et al., 2014)

Based on this conceptual model, the main entities of ontological model have been identified and presented in an ontology graph (Figure 3). The key element of the ontology is the class **Entity** (belong to the key object Entity in conceptual model) which has three subclasses: *RequirementEngEntity*, *MechanicalDesignEntity* and *SimulationEntity*. The class Entity defines two basic semantic relationships, *hasURI* and *hasResource*, respectively to URI and Resource concepts. They state that every instance of **Entity** and subclass of **Entity** is characterizes by an URI scheme (as unique identifier) and associated with one or more document resource(s).

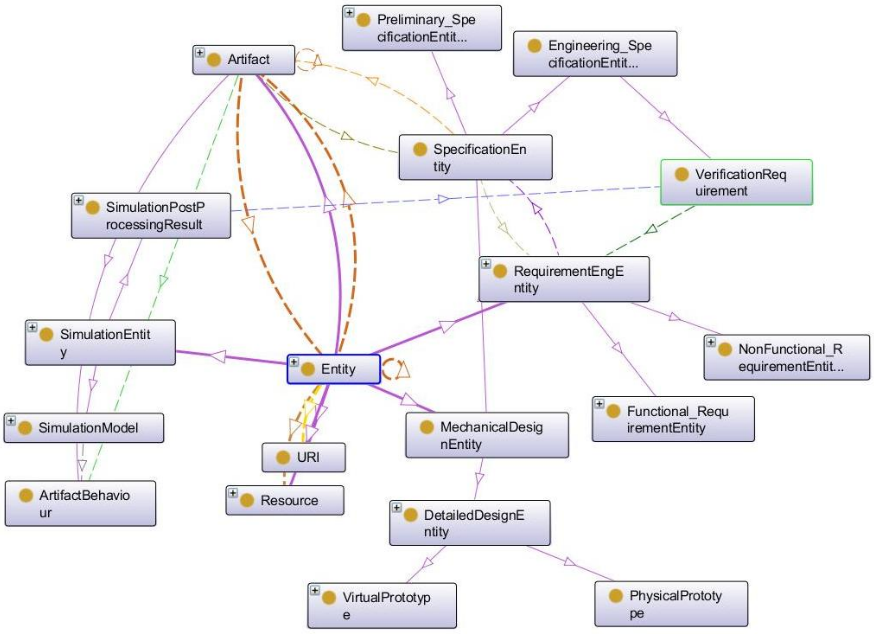

Figure 3. Main entities of the proposed product BOL ontology (Assouroko et al., 2014)

3.2 Ontological model construction steps:

An ontological model is constructed with the aims of facilitating the technical information sharing during users' quotidian activities and the data exploitation from database. In this approach, it's necessary to transform the data model to meta-model and meta-ontology. We propose a general approach as below:

1. **System conceptual model construction:** In this step, the most important task is to identify principal concepts of data model and the relationships among them. The conceptual model of system is then constructed based on this identification.
2. **Ontological model construction:** We then rely on principles of the conceptual model to determine classes and subclasses of ontological model and presented them in ontology graphs.
3. **Ontology graph construction:** An ontology graph is a representation of all ontology concepts and relationships between them. Sub-graph of some ontologies can be eventually developed according to the complexity of ontological model.

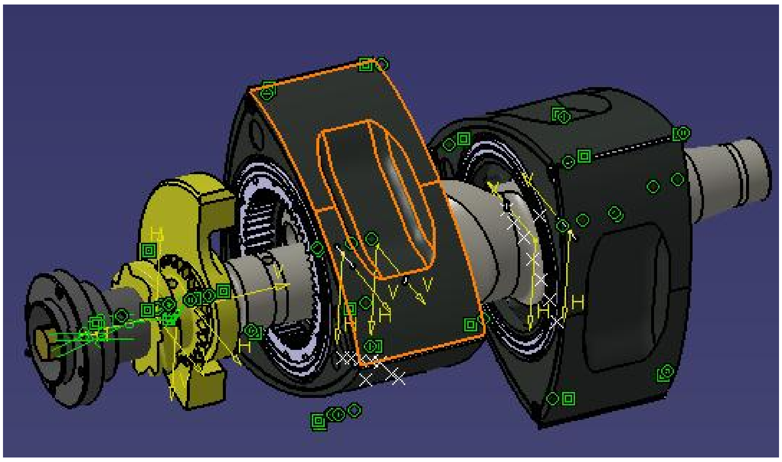

Figure 4. A Rotors-Crankshaft sub-assembly of the Wankel engine (Assouroko et al., 2014)

An engineering design case study (Product using: The rotors of the Wankel rotary-piston engine, as showed above in Figure 4) is used to test the proposed product ontology (Figure 03). Figure 5 represents a capitalization graph illustrated ontology concepts search results. From this capitalization, users can navigate (create, modify, delete) the semantic relationships among concepts.

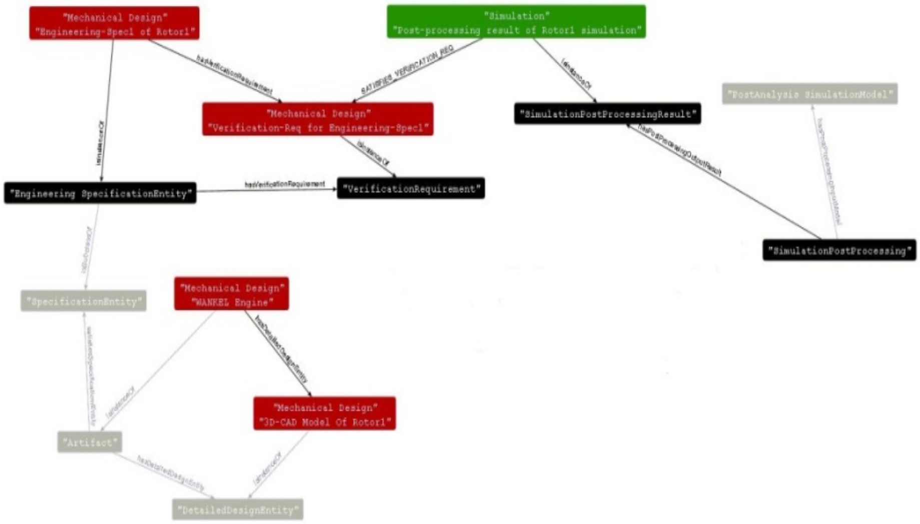

Figure 5. Illustration of a capitalization graph of the Wankel engine (Assouroko et al., 2014)

Based on this global approach, we are going to show the ontology construction in a similar case study where the data managed is complex and very dependent on each other.

4 APPLICATION

Following the global approach of ontological model construction presented above, we constructed an ontology which is used to leverage the understanding of dependencies among data in database, from that, the issues in data interrogation will be handled. In this section, we present a visual query interface based on this type of ontology.

4.1 Ontology construction

The ontology tree and ontology graph have been constructed based on the data model implemented in TeamCenter 9.1 (Figure 6). The objective of the construction of this ontology is to help non-technical users to understand the relationships among concepts and from that, to enable the capacity of data querying.

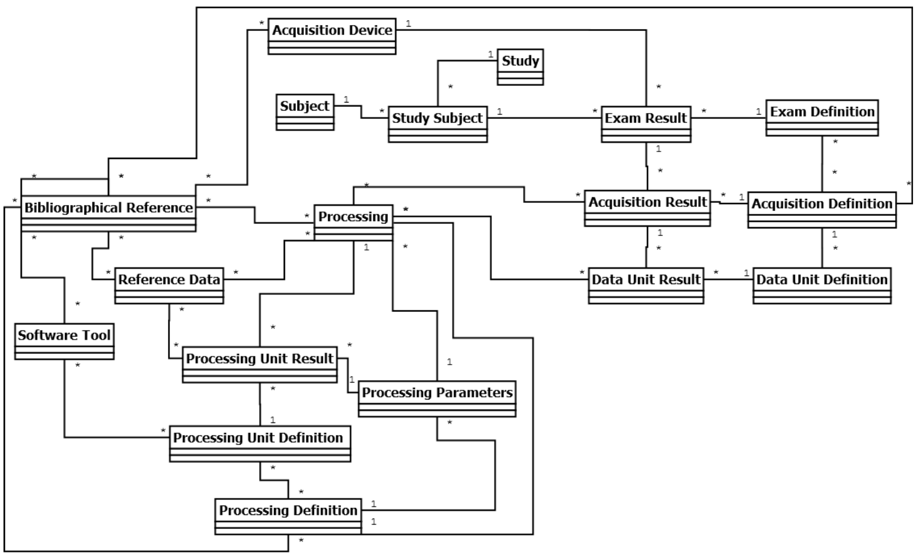

Figure 6. BMI-LM data model implemented in TeamCenter 9.1 (Allanic et al., 2014)

Ontology tree consists of most concepts, sub-concepts existing in the classification and the data model in TeamCenter. These concepts are classified into three major categories: **Tools**, **Data**, and **Process**. Relationships among these concepts are identified as in Figure 7.

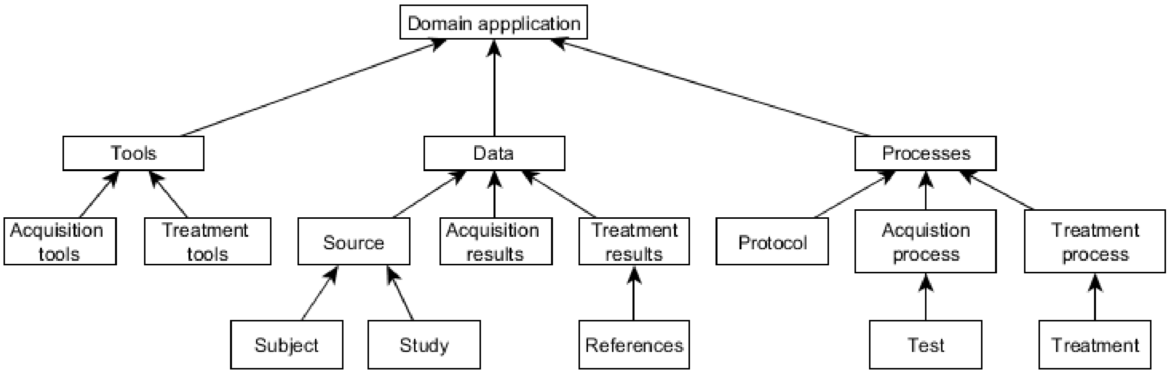

Figure 7. Conceptual tree of ontology

Nodes in conceptual ontology graph (Figure 8) correspondent with concepts in ontology tree, but we added the relationships among these concepts. This ontology can be developed in more detail by expanding each concept (node) into its sub-concepts (sub-nodes). All sub-nodes have the same relationship with their parent-node. For example, *Tools* node has two child-nodes: "*Acquisition tools*" and "*Treatment tools*" (see the ontology tree), therefore, they have also the relationship "*use*" with *Tools*.

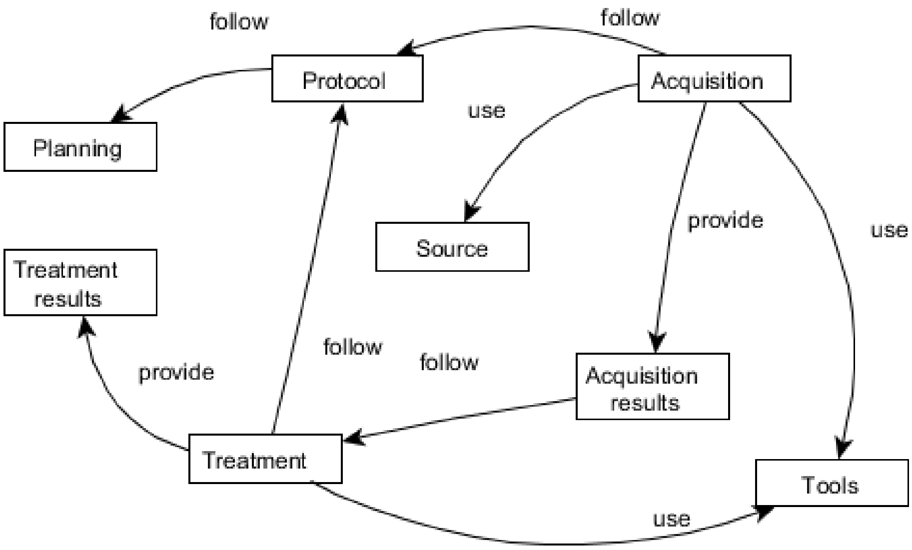

Figure 8. Conceptual graph of ontology

4.2 Ontology-based graph query interface

By using ontology tree and ontology graph, ontology-based graph query interface helps users to make a query more easily. It consists of three major parts: (1) Query history; (2) Ontology tree/graph; (3) Search criteria table. By using the ontology tree and ontology graph, users can understand the relationships among concepts and directly choose query parameters in (2) and set the value for their attributes in (3). Users also can choose a query in query history to re-execute, modify or complete it. Figure 09 illustrates the using of our proposed query interface to make this query:

> *Querying the subjects (StudySub) that have certain characteristics (*name = *"StdName";* sex = *"man",* age <= *"45") and who have passed a test (ExamRes) (*name = *"ExmName";* date <= *"01.12.2014" which suffers* ***treatment*** *(ProcessRes) (*name = *"ProcessName";* decription *contains "Description")*

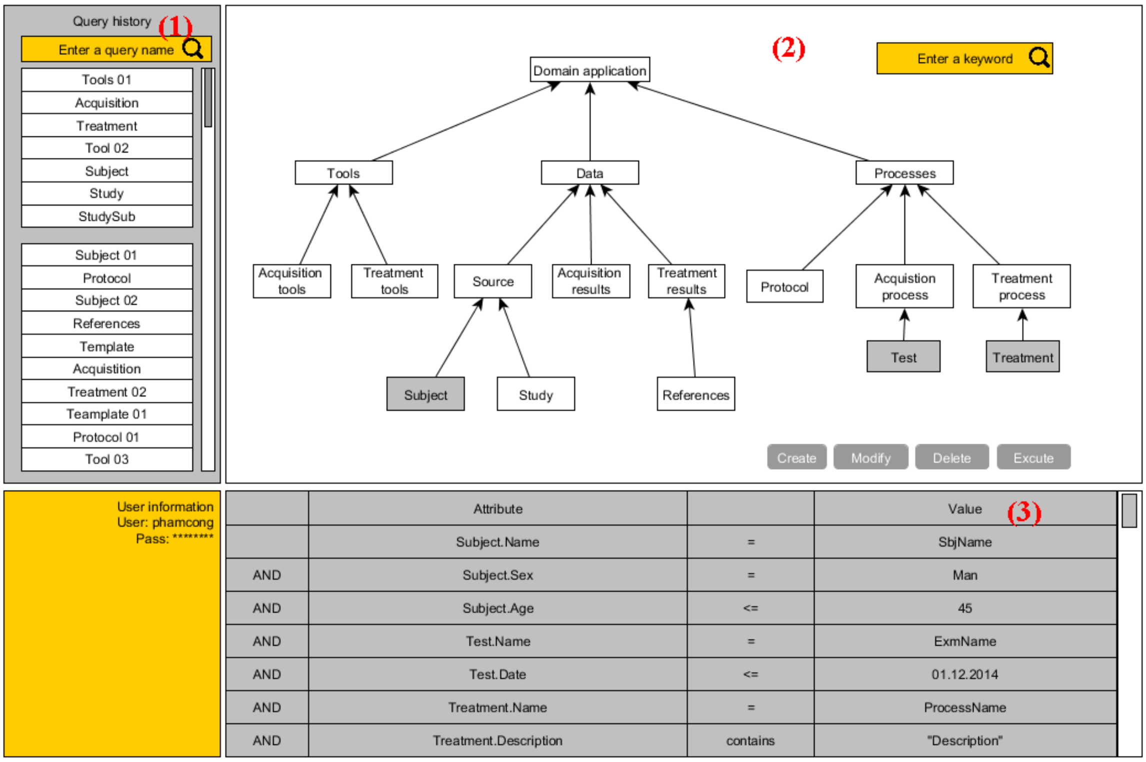

Figure 9. Ontology-base graph query Interface

When a user completes his query, our system does as follows:

1. Identifying nodes links, following relations in ontologies.
2. Generating an output query in a format understandable and executable by Query Processor, XQuery Engine for example.
3. Executing the output query on PLM database and return the results in an .xml or .json file.
4. Visualizing then the results in form of a graph in the same interface.

The return results will be represented in the form of graph as in Figure 10, in order to leverage end-users knowledge acquisition possibilities.

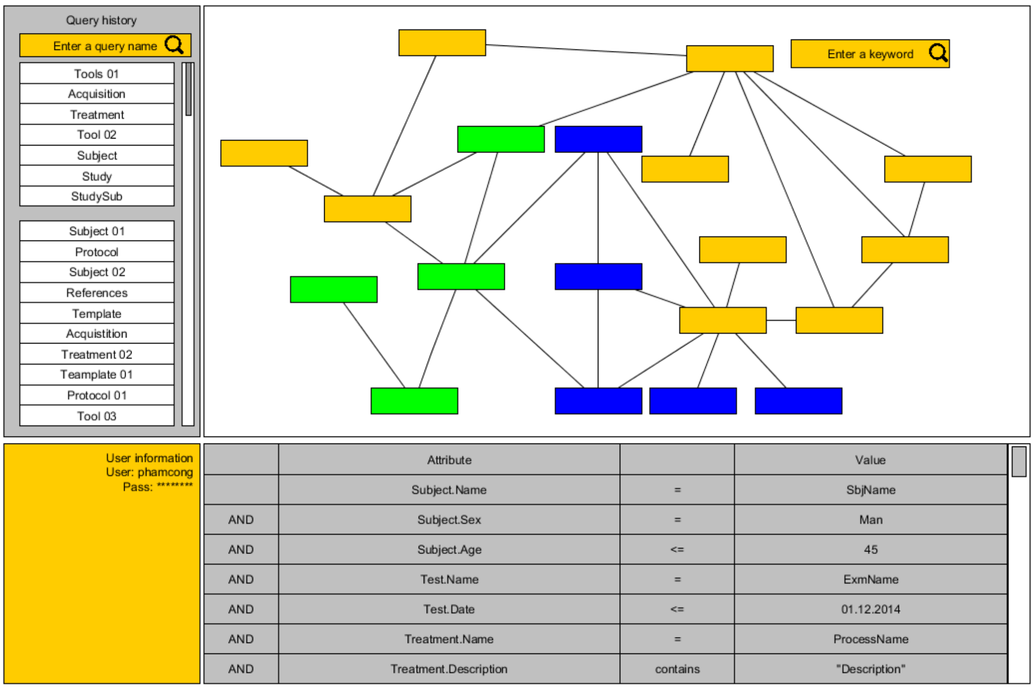

Figure 10. Result interface (each node correspondents with an object in return results)

5 CONCLUSION

In this paper, we have dealt with the knowledge sharing in heterogeneous data context and have presented an application in PLM domain. A general approach for ontological model construction and an ontology-base query interface then has been presented as a solution to tackle the difficulties in data exploitation from PLM database. A use case in PLM domain has been used to illustrate the abilites of our proposed interface.

As future work, we will focus on the test of proposed query interface with various queries sets and on the more complex case study of engineering design (in PLM). The ontology tree and ontology graph must be also developped to cover all concepts in lifecycle steps of PLM. This ontology will also be implemented in semantinc web language (RDF, SPARQL) in order to use inference engine for information search. We plan to test different inference engines for this aim.

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