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Framework for the Semantic Alignment of Enterprise's Domain Knowledge

Dissertação para obtenção do Grau de Mestre em Engenharia Electrotécnica e de Computadores

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To my family and friends…

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Abstract

Nowadays, the consumption of goods and services on the Internet are increasing in a constant motion. Small and Medium Enterprises (SMEs) mostly from the traditional industry sectors are usually make business in weak and fragile market sectors, where customized products and services prevail. To survive and compete in the actual markets they have to readjust their business strategies by creating new manufacturing processes and establishing new business networks through new technological approaches. In order to compete with big enterprises, these partnerships aim the sharing of resources, knowledge and strategies to boost the sector's business consolidation through the creation of dynamic manufacturing networks.
To facilitate such demand, it is proposed the development of a centralized information system, which allows enterprises to select and create dynamic manufacturing networks that would have the capability to monitor all the manufacturing process, including the assembly, packaging and distribution phases. Even the networking partners that come from the same area have multi and heterogeneous representations of the same knowledge, denoting their own view of the domain. Thus, different conceptual, semantic, and consequently, diverse lexically knowledge representations may occur in the network, causing non-transparent sharing of information and interoperability inconsistencies. The creation of a framework supported by a tool that in a flexible way would enable the identification, classification and resolution of such semantic heterogeneities is required. This tool will support the network in the semantic mapping establishments, to facilitate the various enterprises information systems integration.

Keywords: End-to-End, Factories of the Future, Dynamic Manufacturing Networks, Semantic Alignment

Resumo

Hoje em dia tem-se verificado uma tendência para consumo de bens e serviços disponíveis através da Internet. Os pequenos produtores ou as pequenas e médias empresas, sobretudo dos sectores tradicionais da indústria, normalmente atuam em sectores de mercado frágeis, onde imperam produtos ou serviços personalizados. Para sobreviverem e poderem competir no mercado atual têm que adaptar a sua estratégia empresarial, criando novos processos de fabrico e parcerias através de novas abordagens ao mercado voltado para as novas tecnologias. Estas parcerias visam a criação de redes dinâmicas de negócios através da partilha de recursos, conhecimentos e estratégias de forma a conseguirem consolidar-se no seu sector ou domínio empresarial para fazer face às grandes empresas.

Respondendo a esta necessidade, propõe-se desenvolver um sistema centralizado de informação, que permita às empresas, escolher e criar parceiros para o estabelecimento de redes dinâmicas de manufactura, que possam responder às suas necessidades de produção e que ao mesmo tempo, de uma forma fácil tenham capacidade de monitorização todo o processo de fabrico, incluindo as fases de montagem, embalagem e de distribuição. Os parceiros resultantes da rede criada, mesmo que provenientes da mesma área de negócio, têm uma visão própria do seu domínio acomodando caracterizações múltiplas e heterogéneas de uma área comum de conhecimento. Esta corresponde a representações particulares de conhecimento ao nível conceptual, semântico e de léxico, pelo que é espectável que a informação partilhada não seja transparente ou interoperável em toda a rede, havendo portanto a necessidade de projetar uma plataforma suportada por uma ferramenta que de uma forma flexível, possibilite a identificação, classificação e resolução de tais heterogeneidades semânticas. Esta ferramenta suportará a rede no estabelecimento de mapeamentos semânticos, cujos permitam a integração dos sistemas de informação das empresas..

Palavras-chave: Fabricação ponta-a-ponta, Fábricas do Futuro, Redes de Manufactura Dinâmicas, Alinhamento Semântico

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Acronyms

API	Application Programming Interface
ASMOV	Automated Semantic Matching of Ontologies with Verification
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CN	Collaborative Networks
COMA	COmbination of schema Matching Approaches
CSS	Cascading Style Sheets
DKM	Distributed Knowledge Management
DMNs	Dynamic Manufacturing Networks
FoF	Factories of the Future
HTML	HyperText Markup Language
HTTP	Hypertext Transfer Protocol
IF-MAP	Information-Flow-based method of ontology MAPping
IMAGINE	Innovative end-to-end Management of Dynamic Manufacturing Networks
IT	Information Technologies
JSP	JavaSever Pages
JSR	Java Specification Request
KB	KnowledgeBase
NOKMS	Negotiation process which uses Ontology-based Knowledge Management System
KPI	Key Performance Indicators
MENTOR	Methodology of Enterprise Reference Ontology development
MES	Manufacturing Execution Systems
MG	Multiple Globalizations
MO	Mediator Ontology
MoMo	Model Morphism

MRDs	Machine-Readable Dictionaries
OASIS	Organization for the Advance of Structural Information Standards
OEM	Original Equipment Manufacturers
OWL	Web Ontology Language
PLM	Product Lifecycle Management
SMART	Semi-autoMatic Approach to ontology meRging and alignmenT
RDF	Resource Description Framework
RDFS	Resource Description Framework Schema
RPC	Remote Procedure Call
SAMPOL	Semantic AlignMent of enterPrise's dOmain knowLedge
SMEs	Small and Medium Enterprises
SOA	Service-Oriented Architecture
SOAP	Simple Object Acess Protocol
SOCOM	Semantic-Oriented Croos-Lingual Ontology Mapping
SQL	Structured Query Language
SWS	Semantic Web Services
UML	Unified Modelling Language
URL	Uniform Resource Locator
VE	Virtual Enterprise
VO	Virtual Organization
WAR	Web Application ARchive
WSMO	Web Service Modelling Ontology
Xmap	eXtensible Mapping
XML	eXtensible Markup Language

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Introduction

The recent development of new technologies has improved the quality of life of the general population, but also lead to an increase of consumption of customised goods and services acquired through the Internet. Due to such kind of requests, small manufacturers or Small and Medium Enterprises (SME) have to embrace the end-to-end philosophy, which intend to reduce as many middle steps as possible to reach the final customer, enhancing the performance and productivity in their business supply chain or manufacturing process.

Thus, to maintain the sustainability of their business, SME should have the capability of answering all their clients' product requests. To reach such goal, all the SME even from industry's traditional sectors need to adopt new business strategies through new assembly processes and new market approaches with reference to state-of-the-art innovations [1].

Despite having small structure, a SME employs more people in European Union comparatively to other type of enterprises [2].

Consequently to this and to the economical status of the countries in 2008, the European Union committed to increase production performance by starting an initiative to promote effectiveness collaboration of SME designed Factories of the Future (FoF)s [3]. As a result, FoF has been promoting the development of a set of centralized systems, to enable companies to choose and create in an easy way, partner alliances. These alliances will have the capability to monitor not only the assembly process, but also the packaging and shipment phases.

Even if all the enterprises of a business network alliance come from the same business area, each one has its own view or perspective of its domain knowledge. Thus different conceptual, semantic and lexical knowledge representations may occur and therefore it is expected to happen non-transparent and interoperability inconsistencies of the shared information.

This research work proposes a framework supported by a web user interface component (tool) to facilitate the identification of possible semantic heterogeneities between two information systems in a flexible way, which would end up in the development or definition of applications able of heterogeneous information systems integration in architectures able of business networks establishment.

1.1 Motivations and Context

The assembly methods used today in SME do not meet the necessary requirements to answer the client's product specifications. Enterprises have been aware about a lack of productivity and competitiveness conducted by persisting and maintaining a traditional manufacturing process ideology. To overcome this, each single enterprise exchange data raising potential semantic interoperability inconsistencies, due to the different knowledge representations exchanged through out the process. For this reason, one of the motivations for this dissertation work has to do with an adequate maintenance on conceptual alignment between various ERP's (Enterprise Resource Planning) from different legacy systems.

The Semantic alignment research focuses on designing an ontology-based tool that aims to classify resource concepts used by such ERP systems in a fast, flexible and effective manner, in relation to reference concepts existing in a reference ontology of the domain.

Therefore this work aims to provide a possible solution in the field of semantic interoperability, with focus on the semantic alignment of information. Its main focus is to propose a framework to serve as a backbone and guideline to then develop a proper tool, flexible and portable enough to be deployed in a central and collaborative platform enabling seamless interoperability communication to support the development of business networks establishment solutions.

1.2 Research Method

The research method used in this dissertation is inspired on the classical method proposed by Camarinha-Matos [4]. The traditional seven steps of the classical method plus the "industrial application" step composes the followed research method (Figure 1.1).

Figure 1.1 – Phases of the Classical Research Method (Source: [4])

1. **Research Question/ Problem:** This is the most important step in research. It is a period of study that intends to define the area of interest of the research. The research question must be optimized according to the field of study in such a way that it could be validated or refuted. The main question may be supplemented with secondary questions to support the main idea of the research study.

2. **Background / Observation:** This step contemplates the study of the work already done by other researchers about the same research area. In other words, this is where the state of the art research takes place. This accomplishes the reviewing of general scientific literature and specific research project results reports. Furthermore it is important to have a big variety of documents for searching information on the area of interest, because some of the literature even being recent and having ground-breaking ideas, can be out-dated or of low reliability. Finally, it is also in this step that the researcher defines what from his work would differ from existent one.

3. **Formulate Hypothesis:** As its name indicates, in this step the researcher formulates the hypothesis in order to make the research simpler to understand, stating the ambitions to accomplish at the end of the project. The hypothesis states the plausible arrangements to answer the research question.

4. **Designed Experiment:** The designed experiment step aims to design a prototype architecture capable of supporting the previous denied hypothesis. The section 4 and 5 present the design of a prototype and the proof-of-concept, respectively.

5. **Teste Hypothesis:** This step comprehends the implementation of the designed prototype and the evaluation of the obtained results. A large amount of tests (especially in different scenarios) should be done in order to test effusively the outcomes given by the system. These outcomes are supposed to be collected for later analyses.

6. **Interpret/ Analyses Results:** After the batteries of tests have been made to the system it is the time to evaluate and analyse the achieved results. At this point the veracity and confidence in the hypothesis are put to the test. A number of outcomes are possible, the results can be satisfactory, providing the author right, or they can be missing the initial idea. If the initial point straights to the hypothesis, then it is reasonable to say that a good prevision was made and it is possible to consider what comes after, making some recommendations for further research. But even if the results are not what was expected it should not be taken as a failure, but as an opportunity to improve the original approach and go back again to the first steps of the search method. The researcher can then try a different approach from the one taken before.

7. **Publish Findings:** The final results, if consistent, must end up in valuable contribution to the scientific community as scientific papers. These papers can be then presented in conferences, where the author has the chance to show in person his ideas for research, presenting the results and answer questions of others researchers to prove the efficiency of the results.

8. **Transition to Industry:** Upon the validation from the scientific community, the conducted work should be analysed for a possible industrial application in order to capitalize from it and contribute to the entrepreneurial world. This can be accomplished by passing the developed work from a prototype stage to a fully functional industry application, which can be applied to various enterprises and businesses.

1.3 Research Questions and Problems

Can a technological solution capable of formal semantic mapping representations supports the establishment of interoperable communications in a manufacturing network?

1.4 Hypothesis

If a framework to establish the semantic alignment of enterprise's domain knowledge is defined supported by an organized knowledge management approach capable of semantic mappings definition and representation, then the establishment of dynamic manufacturing network is facilitated.

1.5 Dissertation Outline

The first section of this work is the Introduction, which addresses the purpose of this research work, as well as the main ideas that led to the creation of this dissertation. It also presents the thesis context and motivations. Finally, it identifies the research questions and problems that this dissertation addresses and the hypothesis followed for attempting to solve them.

Section 2 is named Knowledge Based Solutions and addresses the background research that was conducted. It covers the main tools for managing, maintain and the knowledge representation tools with a special focus on ontology tree visualization tools.

Section 3 is named Dynamic Manufacturing Networks starts with an overview of the end-to-end and Future of Factories concepts. Furthermore this section introduces and explores the properties beyond an innovative enterprise collaborative environment, which will be the building block for the proposed framework.

The next section 4, Semantic Alignment for Seamless Knowledge Interoperability, presents the Heterogeneities raised from the result ontology mapping operations, a description of the knowledge mapping type operations. Furthermore, this chapter also presents the proposed framework as a solution to the semantic alignment between different enterprises for a specific knowledge domain within a detail description of the involved modules in the system, namely the MO (Mediator Ontology), the Support Database and the Furniture Reference Ontology.

Section 5 is called Proof-of-Concept Implementation featuring the architecture of the developed prototype. The technologies used to develop it and reason why they were chosen. Furthermore, it presents the implementation steps flow of the prototype to serve as a complement to the architecture in the sense that it shows in detail the flow of the system.

The following section is the Mapping Tool Demonstration chapter which shows the results of the implemented prototype by featuring some execution examples of the developed prototype. This section also has the hypothesis validation, regarding the Research Questions and Problems present in section 1.3.

The last Section contains the Conclusions and Future Work chapter where the concluding remarks and future work topics are presented.

1. Introduction

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Knowledge Based Solutions

Section 2 starts with an introduction of the knowledge management between different enterprises and the potential benefits and risks addressed. Further, it will present a description of most common knowledge representations used on a knowledgebase system, with a special focus on ontologies. Finally, there were presented a set of visualization tools, which could be adequate for the development of the proposed tool.

2.1 Knowledge Management

Thanks to technological development, traditional key sector companies adopted to the new demands of the market by changing how a product is produced and manufactured. The diversity of a product inside a company comes not only with creativity, but also with a new re-thinking on assembly process itself.

The effective management of an organization's knowledge assets is recognized to be a critical success factor in business performance [5]. Even in the same business area, different enterprises have different perspectives regarding their own business sector. Studies inferred that the integration of knowledge management (KM) into business process is one of the keys on the future core of the knowledge management [6].

A centralized management perspective could be an indicator for the inability to recognize the mission critical knowledge resources and the ways in which knowledge collect, analyse and evaluated information [5]. A Proposed solution [7], tries to deal exactly with this problems.

Today, more than ever enterprises and organizations should reinforce assets in order to be able to get new company strategies and adapt to continuously evolving environment in a prompt and economical acceptable manner [8]. Furthermore, the way how enterprises exchange information varies according to the adopted protocol establishment. Traditional solutions typically relied on a more centralized schemes in terms of knowledge sharing, however recently approaches seems to follow a more dispersed solution. In an effort to achieve knowledge sharing sustainability, Bonifacio et.al. [9] introduced the concept of Distributed Knowledge Management (DKM) that relates to, a self-sustainable knowledge node organization cluster. Schmücker & Müller [10] highlight some advantages by using a DKM system comparatively to the centralized solutions:

- The partner's information is constantly accessible and updated
- It is cheapest to maintain since its information is available in a single place

The assembly methods practiced today on a small enterprise do not meet all the necessary requirements to answer the client's product specifications. Enterprises have been conscious about a lack of productivity and competitiveness conducted by persisting and maintaining a traditional manufacturing process ideology. Alternatively the enterprises exchange knowledge with a network of partners to acquire knowledge that is not available in their own organization. Thus, the knowledge sharing could present risk if it is not properly managed [11].

2.2 **Knowledge Representation**

Section 2.1 presented the reasons why enterprises need to share its knowledge and the adopt strategies to management of the exchanged data. It is pointless to achieve such organizational form if it is any way to sustain, organize, represent and share the knowledge without an adequate repository. A knowledge base enables the specification of such conceptualization, even if it's original from explicit or implicit knowledge [12].

Similar to tacit knowledge, implicit knowledge it is a knowledge that contains often, a non-clear and straightforward definition by its own but it is the knowledge type that people understand and have in their mind. On the other hand, the explicit knowledge is the formal knowledge that is in some way represented in any representation code as an ontology, system, book, etc.

The universe of discourse it is the set of concepts or elements that enables knowledge to be represented in a declarative formalism. Knowledge software solutions enable knowledge representation formalism among such concepts or elements and their inerrant relations [13]. The next sub-sections describe the fundamentals behind ontologies, taxonomies, thesaurus and dictionaries.

2.2.1 Ontology

Traditionally speaking, ontology have been used in distinct educational areas, from philosophy to engineering which, consists of a logical model entity, containing concepts, properties and relations [14]. Such characteristics, help the acquisition and consolidation of domain knowledge and enables the semantic integration of heterogeneous and disturbed knowledge [7].

Ontology is “an explicit specification of a shared conceptualization” [15]. This remains today as the best acceptable definition of an ontology. Heijst et. al. [16], identified two ontology dimensions (structure of the conceptualization and the subject of the conceptualization) with the correspondent seven ontology categories showed in table 2.1. According to its needs and applications, usually an ontology shares a common understanding of the structure of information among people or software agents, enabling the reuse of domain knowledge, making domain assumptions explicit [17].

The traditional database solution has exploited the ability to store and maintain a considerable number of data [18] nonetheless it absences from the fact that concepts has special semantic hierarchical relations, like disjoint, less-General or more-General associations , which are not covered by this kind of systems [19]. Instead, more suitable semantic engines are used, for instance, mediators and ontologies that have the capability to share common understanding of the structure of information among people or software agents, enables the splitting of domain knowledge from the operational knowledge to analyse contextual situations [17].

Table 2.1 - Ontology categories and their descriptions

Ontology type	Category	Description
Structure	**Terminological Ontologies**	*Such as lexicons, specify the terms that are used to represent knowledge in domain of discourse. (…)*
	Information Ontologies	*Which specify the record structure of databases. (…)*
	Knowledge Modeling Ontologies	*Specifies conceptualizations of the structure of the knowledge. (…) These ontologies tuned to a particular use of the knowledge that they describe. (…)*
Subject	**Domain Ontologies**	*(…) constraints on the structure of the domain knowledge expressions. (…)*
	Generic Ontologies	*(…) specifications of concepts in generic ontologies. (…)*
	Representation Ontologies	*(…) conceptualization that is underly knowledge edge representation formalisms. (…)*
	Application Ontologies	*(…) contain all the definitions that are needed to model the knowledge that is required for a specific application.*

2.2.1.1 Operations

The Oxford English Dictionary defines mathematical operation as a process in which a number, quantity or even an expression, is changed or manipulated according to a set of formal rules, such as addition, multiplication and differentiation [20].

Analogously, an ontology operation can be seen as a relational manipulation of concepts, properties or even attributes, origination the same or even a number of independent ontologies. The ontologies have three different operations and can be divided as follows:

- **Ontology Mapping** – This operation establish a one-to-one or a one-to-many relation with a number of concepts under two or more ontologies which create new concepts and relationships that match semantically with each other, present in several dissimilar ontologies. It does not change the meaning and the structure of the ontology [21]. The concepts must have a semantic connection or same connotation that enables to form the paired matches.

- **Ontology Alignment –** This operation is similar to ontology mapping, except that the involving ontologies (in the same domain) must agree conceptually with each other, affecting the outcome result of the final(s) ontology(ies).

- **Ontology Merging -** This process bring two or more mapped ontologies and to procedure new original ontology.

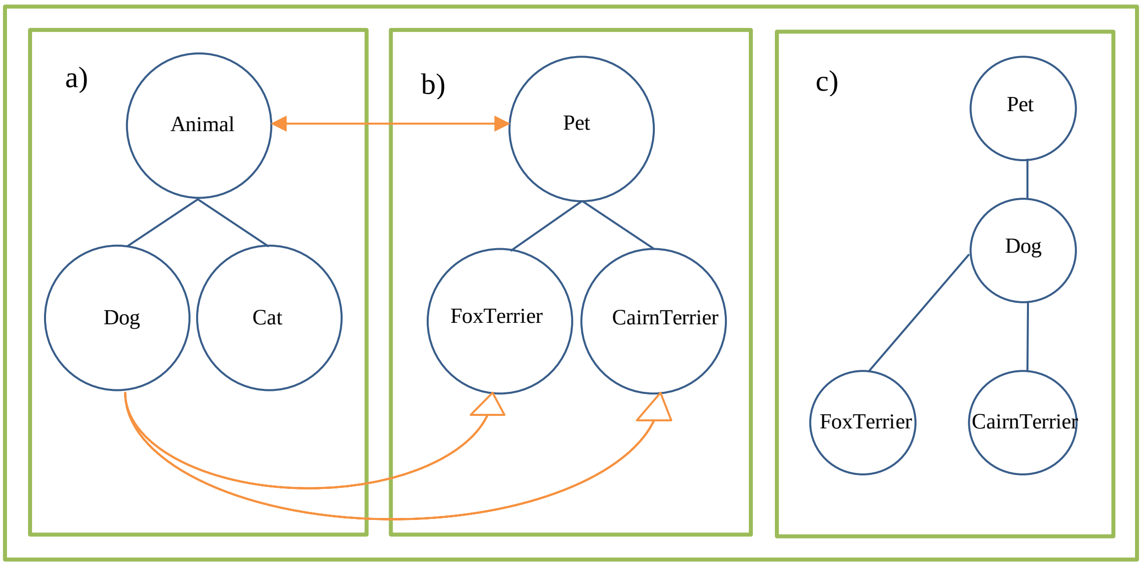


Figure 2.1 - The mapping ontology operation (a, b); the result merged ontology (c)

Figure 2.1 illustrates an ontology mapping between two ontologies. The first ontology O_1 (the leftmost ontology in the figure) shows a possible chunk of the "Animal" tree of life domain and O_2 (the central ontology in the figure) within a possible domain description of the "Pet" concept. The orange line which links the concepts "Animal" and "Pet" represents a direct ontology mapping establishment. Further, the orange line curves represents the possible "is-a" alignment operation of the two illustrated ontologies, where the O_1 concept "Dog" has a direct relation with its species "Fox Terrier" and "Cairn Terrier" on the O_2 ontology. Finally on the rightmost of the figure, identifies a possible merging of the resulted ontology alignment.

2.2.2 Taxonomy

Taxonomies have a parent-child and siblings relations. They represent any structure in tree that relates concepts. These structures can be, as an example, of "is-a" kind characteristic's relation. Thus, the concepts are organized in a tree relation kind, where all their domain characterization is centralized in a single main root concept. Any of its central nodes, contains a generalization description of its concept's domain, where its children must have a lower level of abstraction.

2.2.3 Thesaurus

Thesaurus is a particular case of a taxonomy. It represents a "is-a" kind relation in tree that relates concepts about a domain. It is like a glossary, which concepts were structured in a tree, still containing their descriptions. A thesaurus in a domain, works as a basis (starting point) for the building of an ontology on that domain..

2.2.4 Dictionary

Dictionary contains an alphabetic list of concepts, with definitions, synonyms and antonyms for each single listed word. It can use only one language (monolingual) or it could relate the concepts and the meanings (descriptions) between two different languages (bilingual).

2.3 Visualization tools

A proper visualization mechanism is essential to work and extract information from a knowledge-based system point-of-view. The visualization's tool varies according to the user perspective's application needs and can come in different shapes and sizes. Some make a focus on the class relationship, showing the siblings and parent relations, others may include property descriptions and individual's links, making the knowledge description more explicit. In the opposite side, a large amount of detail in a visualization tool could lose its primarily objective, which is for the user perspective, to clearly transmit and identify the conceptual knowledge on a representational form. For instance, the information contained in an ontology model needs to be organized in such a way, that researchers actually could read and extract information besides the present raw data. This could be accomplished by using graphs, maps, for instance tree maps or other techniques.

The Web Ontology Language (OWL) is a specific ontology language designed for Semantic Web recommended by the W3C[1] that enables representation of concepts and concept's relations. Regarding with the motivations of this thesis, this section will focus primarily on tree visualization mechanisms which looks after simplicity and flexibility, in particularly those read OWL files.

2.3.1 Webprotégé

Webprotégé[2] is a "free, open source, lightweight ontology editor and knowledge acquisition tool for the Web" [22], initially designed to better support the collaborative development in web. It allows client-to-client communication without compromise individual user changes that is working in same ontology model either directly inside the platform or in a collaborative desktop client in a real time communication environment [23]. This behavior could also be found in collaborative web tools, like *Google Docs*[3].

In order to work properly, the client side affords one user friendly and familiar interface provided by *Google Web Toolkit*[4] (GWT), the ontology model and a *Remote Procedure Call*[56] (RPC) module to interact with the server [22].

1 http://www.w3.org/
2 http://webprotege.stanford.edu
3 https://docs.google.com
4 http://www.gwtproject.org/
5 http://tools.ietf.org/html/rfc1057
6 http://tools.ietf.org/html/rfc5531

The interface layout arrangement builds on top of tab concept, enabling user customization appearance by drag-n-drop tabs from the toolbar, as illustrated in Figure 3.1.

In Section 5 will present the portlet concept, but for now let's assume that the portlet resembles a window interface which enables the display of personalized content. The class portlet is a tree-based visualization module [24] that allows user to create, delete and also control the class relations.

The application offers the possibility to choose working directly online or deploys it in a servlet container.

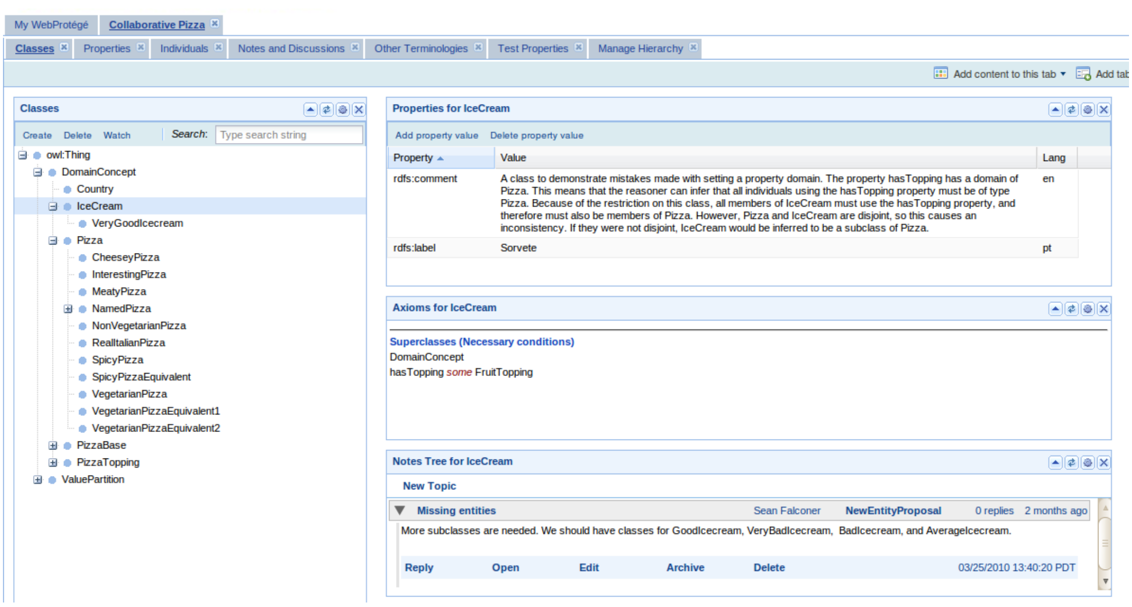


Figure 2.2 - Webprotégé layout page (Source: [25])

2.3.2 OntoStudio

OntoStudio is of the most popular ontology visualization management and ontology visualization tools in service. It stands out due to its comprehensive functions in intuitive ontology modeling. Some of OntoStudio's most important functions are the mapping tool, which can be used to match heterogeneous structures. It also has a graphic editor which allows users to edit and create rules for each single ontology model [26]. The relations are indicated by an orange line and the classes by a blue square, as it illustrated in Figure 2.3.

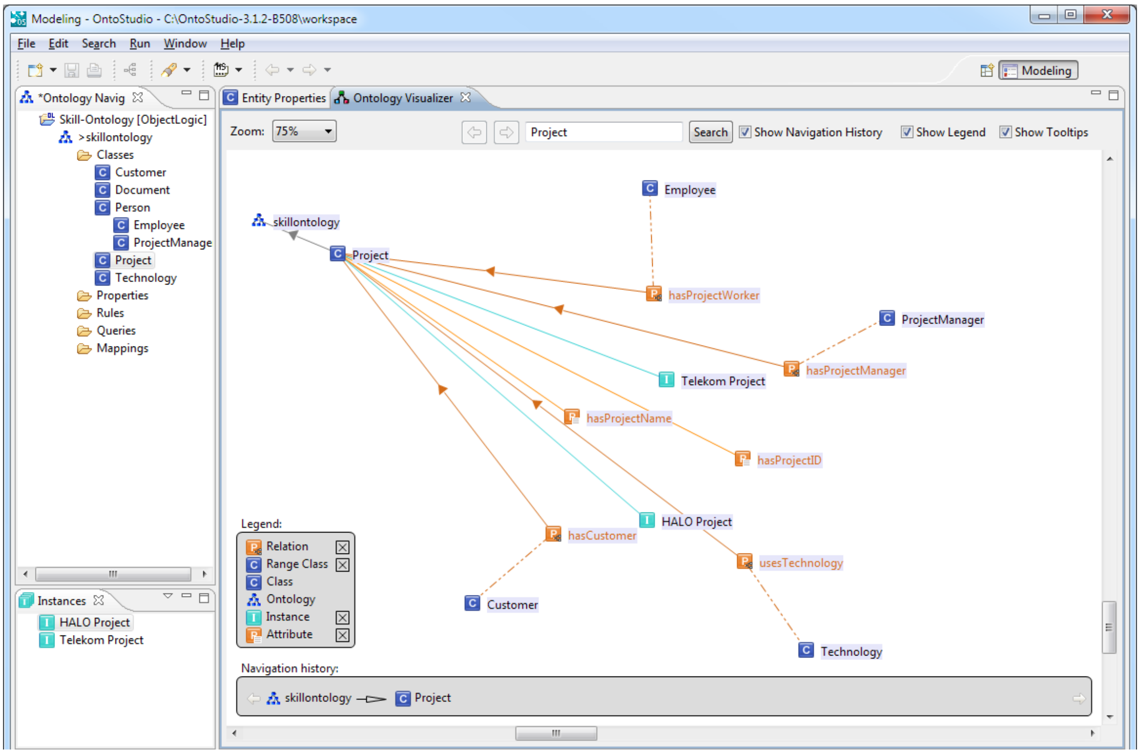


Figure 2.3 - OntoStudio ontology visualizer (Source: [26])

2.3.3 oBrowse

The oBrowse it is an open-project ontology visualization tool for the web located in Sourceforge[7] that displays an OWL in tree form of any browser, as illustrated in Figure 2.4. It explorers the OWL-API built on top of Java allowing the class manipulations and extraction of the class model relations.

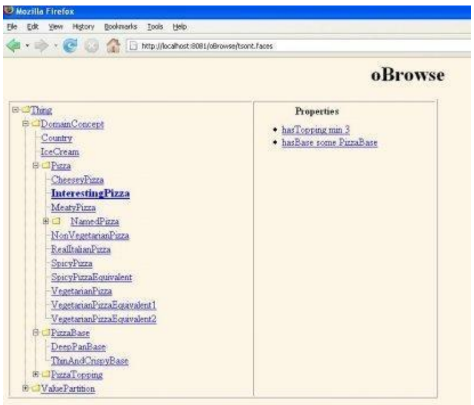


Figure 2.4 - oBrowse visualization tool illustration

[7] http://sourceforge.net/

2.3.4 jOWL

In an effort to migrate to the web 3.0, David Decraene designed the OntologyOnline [27]. The project aims to get a visualization tool on web semantic applications. The jOWL it is a tree visualization plugin tool built on top of jQuery[8] that read OWL-RDFS files which is cable of showing one navigation bar, a direct individuals and a Tree view containers and a search bar (bellow the navigation bar), as illustrated in Figure 2.5.

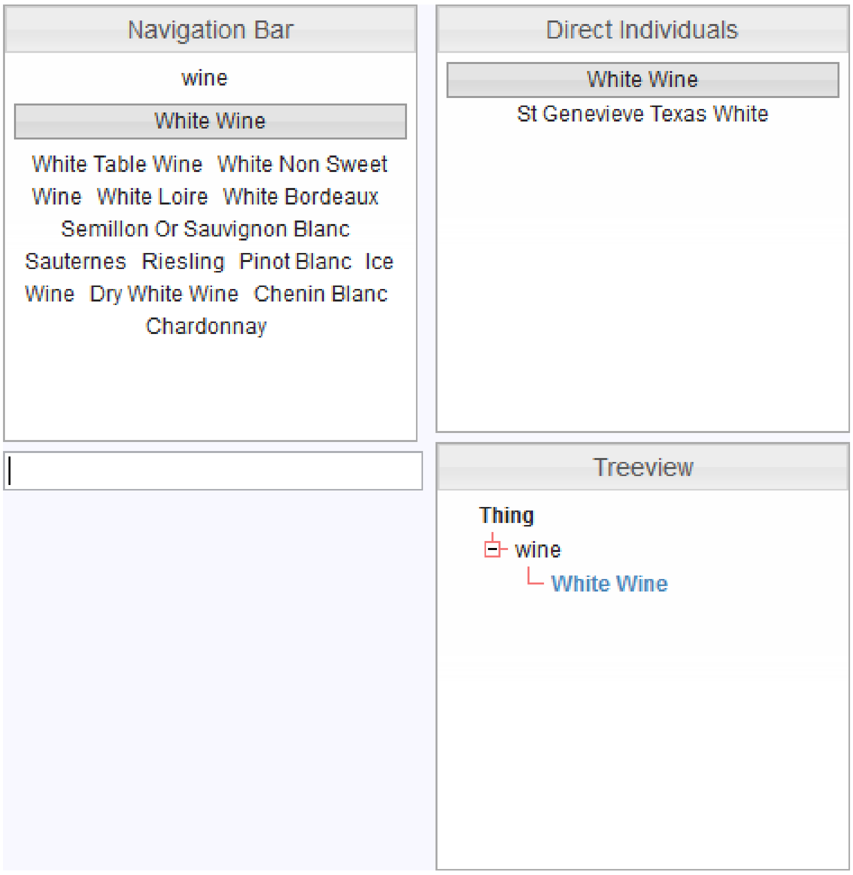


Figure 2.5 - An ilustration of the jOWL visualization tool (Source: [27])

The project also contains a 3D sphere peripheral visualization perspective view of the ontology model, called Hyperbolic Tree.[9]

2.3.5 AlloyUI

AlloyUI (known as AUI) is a framework built on top of JavaScript and CSS (Cascading Style Sheets) libraries providing a consistent and simple API for building web applications across all three levels of the browser: structure, style and behaviour [28]. The project contains one dedicated API for tree manipulation. This particular tree component was not initially design to

[8] http://jquery.com/
[9] http://jowl.ontologyonline.org/HyperBolicTree.html

ontology visualization, thus it is has the ability to represent the information regardless its origins. Besides its independency, in a semantic web point-of-view; it helps who wants a better taxonomy management of its concepts thanks to its collapsible and expandable features. The API also contains a function which, allows semi-automatic children attachment of its root node, saying the last selected node; search a node by name, telling the node relations (parents, children and siblings). Regarding the node tree, it can be also define as a radio, task and check type.

Among the other visualization tools the AUI stands out for its versatility and compatibility with the Liferay[10] portal.

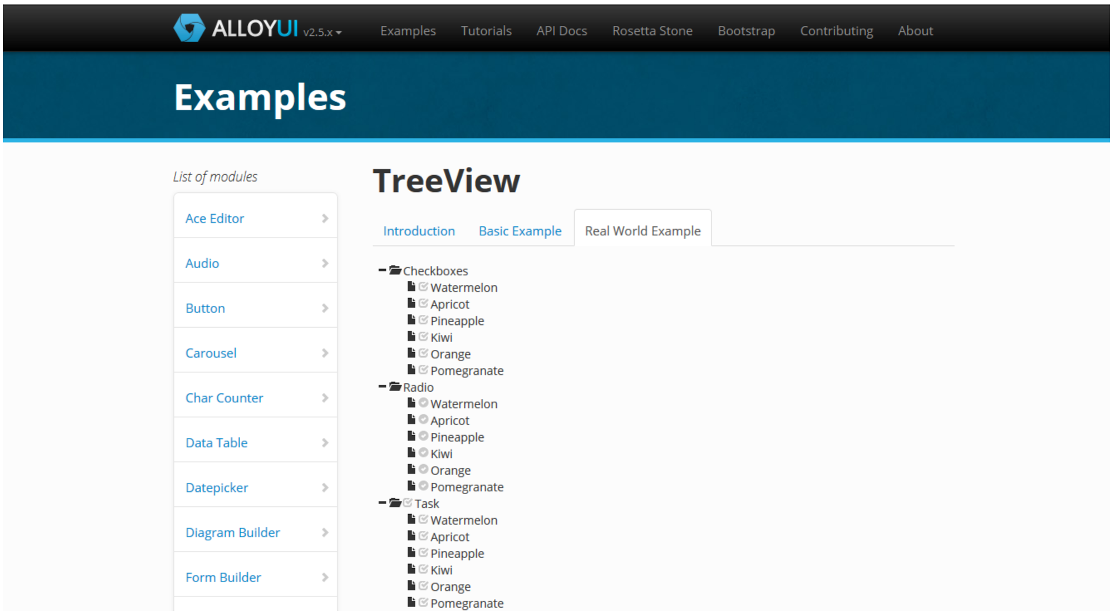


Figure 2.6 - AUI TreeView example screenshot (Source: [29])

2.3.6 OWLGrEd

OWLFrEd is a visualization tool recommended by W3C, project of Institute of Mathematics and Computer Science, University of Latvia. The tool contains an online version that allows users to view and interact directly with ontologies. It also has a more complete desktop version, which allows users to create their own ontology from scratch and customize the background and line colours and node shapes. A particular interesting feature of this tool is the ability to export the ontology diagram with the other users through an export mechanic, which creates a SVG (Scalable Vector Graphics) to be placed in any web browser. The resulting view perspective offers a tree that resembles a UML (Unified Modeling Language) diagram. Figure 2.6 shows the koala[11] OWL. The classes represented with yellow colour, the class hierarchical relations in

[10] http://www.liferay.com/

[11] http://protege.stanford.edu/plugins/owl/owl-library/koala.owl

purple, the constraints in red and the properties marked in black lines. Besides those characteristics the OWLGrEd also provides a plugin for Protégé platform.

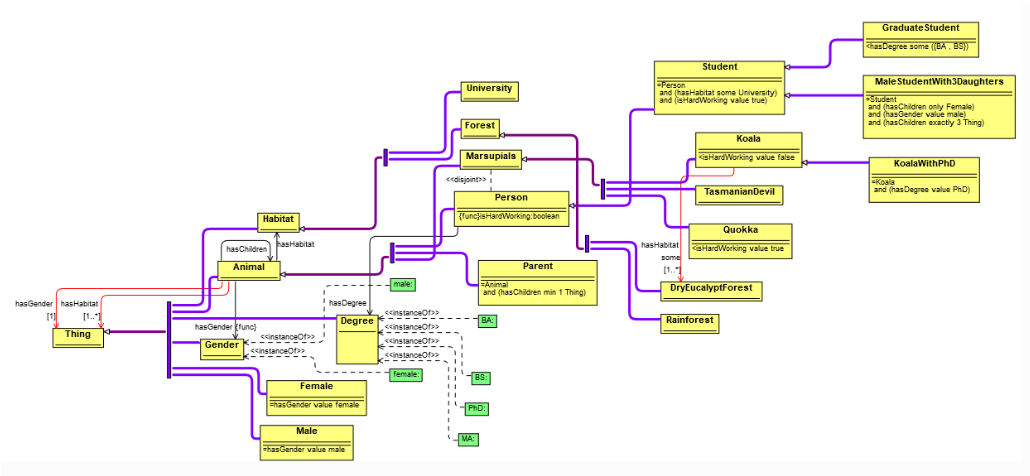


Figure 2.7 - OWLGrEd visualization tool screenshot (Souce: [30])

2.4 Visualization tools comparatives

The Section 2.3 the tree visualization tools were presented. It is time to now take a close look of all tools and make some cooperation between them and take some conclusions.

A proper visualization mechanism (with a tree kind of representation feature) is essential to work and extract information from a knowledge-based system point-of-view. The visualization's tool varies according to the user perspective's application needs and can come in different shapes and sizes. Some make a focus on the class relationship, showing the siblings and parent relations, others may include property descriptions and individual's links, making the knowledge description more explicit. Table 2.2 resumes the characteristics and the assigned classification of a set analysed visualization tools. It addressed the following characteristics: personalization (the ability to customize and adapt the information according the desired needs); a developer's friendly (the ability for who intends to use the tool and deploy in a web environment); the collaborative environment (ability to work remotely); the online interaction (the possibility to view an ontology without a desktop environment); and finally the mapping tool (the ability to matches heterogeneities).

Table 2.2 - Tree knowledge visualization comapratives

Visualization tool	Personal content	Developer's friendly	Collaborative Environment	Online Interaction	Mapping Tool
Webprotégé	⊘	☑	☑	☑	⊘
OntoStudio	N.D.	⊘	N.D	⊘	☑
oBrowse	⊘	☑	⊘	⊘	⊘
jOWL	⊘	☑	⊘	Demo	⊘
AlloyUI	⊘	☑	⊘	Demo	⊘
OWLGrEd	☑	⊘	⊘	☑	⊘

From the defined characteristics is possible to state different statements. If the goal is to get a tool that has flexibility in how it shows the content, having a clearer view, the best option is OWLGrEd. On the other hand, only OntoStudio and OWLGrEd should not be considered for the purpose of developing a web kind application. The Webprotégé will be the ideal choice if what is required is a tool to access a remote knowledge-base (server). Additionally, there are other visualization tools without integrated specific knowledge base handlers or engines (e.g. OWL API), which requires a specific handling of the managed information as in specifc HTML or flash graphic elements. In this case, it will be possible to resort to WebProtégé or jOWL or even to OWLGrEd.

If is required a tool able to maximize user and developer interaction easiness, the AlloyUI stands out for its versatility and compatibility with as an example a Liferay portal, which would facilitate the integration to other existent components of a specific platform.

2.5 **Concluding Remarks**

The visualization tools should describe effectively its domain knowledge. Thus, a set of tools are available to help maintain, edit and share the information among different entities.

The ontology offers the most complete mechanism available that reaches maximum description of a knowledge base system. However, other representation forms could be more suitable, depending on the type of system application in use. Furthermore, taxonomy will be perfectly suitable for instance, if the intended information system only has to deal with a set of concepts linked to each other. On the other hand, if a definition of terms is needed the best option passes through the use of a dictionary.

Nevertheless, the information presented on such manage tools must be accompanied with a proper visualization to allow data extraction and manipulation. Under the different possibilities the choice should approximate a set of features to maximize user interaction.

Enterprises that exchange information must have an adequate management system to work collaboratively not fearing a leak of its market strategies to potential alliance partners. Besides the attempts to turn the network more independent and trusted, the adopted distributed mechanism do not cover yet the necessary requirements to overcome the potential risks of its collaborative architecture. The next chapter will introduce the notion of new collaborative approaches, which indeed seems to be the next tendency schemes.

3

Dynamic Manufacturing Networks

This chapter has the following structure: firstly, an introduction and overview of the Dynamic Manufacturing Networks (DNMs) is presented, which briefly explores the traditional manufacturing model concepts and reasons are given for the newest approaches; followed by the benefits and risks adopted; the lifecycle and blueprints modification. Furthermore, it is also presented the state-of-the art Dynamic Manufacturing Network platform. Finally, the identified conclusions of this chapter will be addressed in the concluding remarks section.

3.1 Overview concept

The *end-to-end* concept introduced by Saltzer et.al. [31] can be seen as two processes communicating with each other aiming consistency if they are less dependent of their intermediate's nodes. In other perspective, the probability of error in a message being transported in a communication channel raises with the number of intermediate nodes on the network configuration. Following the same idea, an end-to-end manufacture could be seen as a constant change to reach reliability on partner coalition in an enterprise network environment.

Multiple Globalizations (MG) concept has been recently emerging. Manufacturing industries no longer stay a local clustering nest. Recently economic crisis lead manufactures to adapt effectiveness to the changing of the new global economy [32], specially for those who have to constantly change their products and processes to survive in this new market paradigm. To overcome this problem, companies and organizations joined forces, working together reusing resources and capabilities in a sustainable economic collaborative environment, organized in a Collaborative Network (CN) schema [8].

Launched in 2008, concerned with the economical state of its countries and committed to increase production performance, the European Union started an initiative to promote effectiveness collaboration of Small and Medium Enterprises named Factories of the Future (FoF) [3].

Collaborative forms, with similar properties, such as virtual organization (VO), virtual Enterprise (VE), dynamic supply chain do not have straight well-defined definitions. Nevertheless some acceptable definitions could be found by Jeong et. al [33] for example, a VO as comprising a set of (legally) independent organizations that share resources and skills to achieve its mission/goal, which is not limited to an alliance to profit enterprises. A Virtual Enterprise is a particular case of virtual organizations, where a temporary alliance is made to share skills or core competencies and resources in order to better respond to business opportunities, whose cooperation is supported by computer networks. A Virtual Manufacturing Networks (VMN) is a manufacturing network usually built with the use of Information and Communications Technology bringing together different suppliers and alliance partners to create a virtual a collaborative network which is able to operate, as a solely owned supply network [34].

A different set of attribute criteria, like quantity, price, raw material, could compromise the establishment of a new network alliance, so in order to be competitive, innovative and more complex products must pass through a state-of-the-art hybrid materials and assembly processes implementation with a high degree of automation and quality control [35].

The adaptation of a centralized scheme increases the exchanged resources between different organizations, thus raising the total maintenance costs of the established network. Additionally, traditional collaborative schemes do not have monitor mechanisms, which enables an adequate and fast response to a non-predicted network configuration changes, such as unexpected production, packing and shipment delays.

Nowadays, some of the identified configurations are obsolete, thus it is time to get and design a new approach. The Dynamic Manufacturing Networks is defined as “coalition, either permanent or temporal, comprising production systems of geographically dispersed SME and/or Original Equipment Manufacturers (OEMs) that collaborate in a shared value-chain to conduct joint manufacturing” [36]. This concept although not being new is now emerging as a norm solution.

Moreover, the beyond idea of a DMN is to enable specialized people or agents to collaborate and integrate, spread goods and services globally from a set of independent sources. Additionally, as the name suggests, a DNM must be cable of change its own defined configurations, thus modifying its supplies in case of a non-predicted situation, such as, supplier disruption or travel delays [34].

3.2 **Benefits and Risks**

Partnership collations between manufacturing networks face a variety of heterogeneous systems to manage their processes and their data. A majority of benefits must be previously obtained to justify the effort. However, adopting new innovations always come with risks that must not be neglected [37]. This is the particular case of the acquisition VE models, like Dynamic Manufacturing Networks opposed to the traditional ones [36]. Some of the benefits and risks are identified as follows [34]:

Firstly, to succeed, a DMN should reach a consensus configuration to optimize the design and the development of new products and components, thus at the same time avoiding unexpected flaws and minimizing time waste consumption during the design phase of a product lifecycle. This reduces inventory costs (each selected product has a specific price according to the desired configuration), optimizing the selection of new partners and helps to maintain a healthy competitive sector. Regarding knowledge acquisition and security threats, a DMN will have to implement a confidential system that differentiates access rights and contractual agreements of the exchanged information and therefore avoiding malicious attacks that could compromise the trust of the engaged enterprises.

Moreover, the partner data has to be constantly available, therefore allowing organizations to define product specifications in prompted and efficient manner, independently of the enterprise localization. It is also important to have a system that rapidly adapts to production delays, by identifying alternative partners for instance, in case of an eventual production line failure. Nevertheless, it is expected some resistance by employees during the transition phase of the recent implemented collaborative manufacturing model system. This risk can be resolved by introducing a set of adapters that interconnects the data of all DMN members to the DMN platform, ensuring thereby smooth transition for all involved entities. The platform will be further explained in Section 3.5.

Additionally, a DMN promotes the opportunity for partners to work with more intelligent and experienced organizations by exchanging and offering an opening for the birth of new technological innovations. Consequently, out-dated information during the formation of a new alliance configuration of a dynamic network could represent a serious risk for the network maintenance; weaken quality standards and thereby jeopardizing its own life expectancy. To avoid such undesirable setup, it is crucial to have accurate information on the actual manufacturing and delivery capability of each DMN across the whole assigned partners.

To sum up, there were identified three main benefits: time savings, cost reduction, operations' enhancement and five risks: information security, poor configuration, DMN dissolution, competitive threats and loss partner's reputation, as it can be seen in Table 3.1.

Table 3.1 - Dynamic Manufacturing Network benefits and risks (Adapted: Source [34])

	Feature	Description
Benefits	**Time Savings**	Regarding DMN visibility, each configuration will have an efficient and suggestible partner selection during its creation. Further, the products and components are optimized individually for each case. It is also important to consider the planning and scheduling costs, possible reconfigurations, the exchange time between client and partners are saved.
	Cost Reduction	DMN enables customized costs during partner selection and production. This helps to reducing the market expenses of the managed resources.
	Operations' Enhancement	The gains that come from the relation between a single enterprise and the rest of the partners in the network.
Risks	**Information Security and trust**	Deliverable or indirect knowledge leaks between enterprises.
	Poor configuration	Outdated information that could jeopardize the lifetime of the DMN system.
	DMN dissolution	Unexpected partners that give up to collaborate with the rest of the network.
	Competitive threats	Competitive threats after the exiting of a partner or the dissolution of the DMN
	Loss of partner's reputation	Partners that do not achieve its own expectations, damaging the reputation of the rest of the other DMN members.

3.3 The DMN Life-Cycle

The DMN Lifecycle is an innovative method, including all supporting tools, such as Service-oriented and Business Process Management technologies, which allows the management of the entire lifespan of a manufacturing network, from planning and sourcing, to manufacturing and delivery [36]. The Manufacture Network Lifecycle encompasses the following three main phases, as illustrated in Figure 3.1:

- Phase 0: Administration & On Boarding. Info orchestration; load blueprint information, the registration of new partners and preparation and submission of the required Dynamic Manufacturing Network information.

- Phase 1: Network analyses and configuration. It's when Partner selection and DNM construction occurs. It is "one of the most critical phases in the lifecycle of a supply network" [8]. The DMN shows the available configurations, identifies knowledge breakings, thus allowing the partners to select the best resources for the requested alliance [34].

- Phase 2: Network design. The definition of the end-to-end process of the DMN.

- Phase 3: Network execution Management and Monitoring. The phase where DMN tracks its resources by producing constant reports of material consumption, production, packaging and shipment progress.

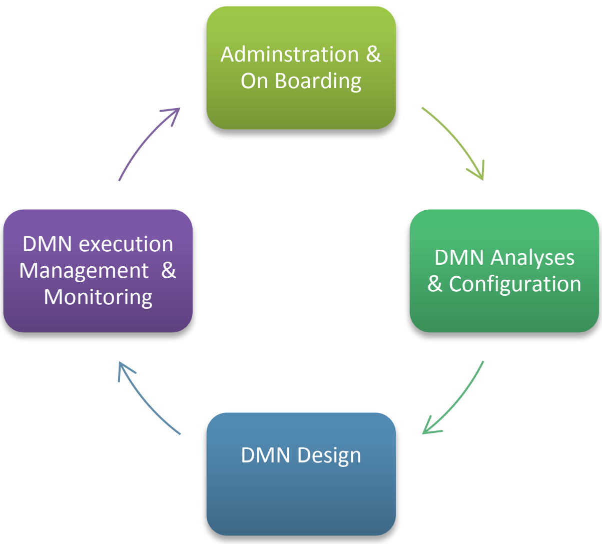


Figure 3.1 - Dynamic Manufacture Lifecyle phases (Adapted: Source [36])

3.4 Blueprints

The objective target of the Blueprint Model is to aggregate the necessary knowledge for managing enterprise resources, product life cycles, supply chains, partner relationships, operational planning, manufacturing process execution, compliance regulations and safety issues for the DMN Lifecycle [36], thus it helps to reduce the time of a product production process, avoids shipment delays and maintain an accurate production [34].

The DMN Blueprint Model was designed in several blueprint branches and extensions, thus optimizing the manufacture process, as it can be seen in the Figure 3.2.

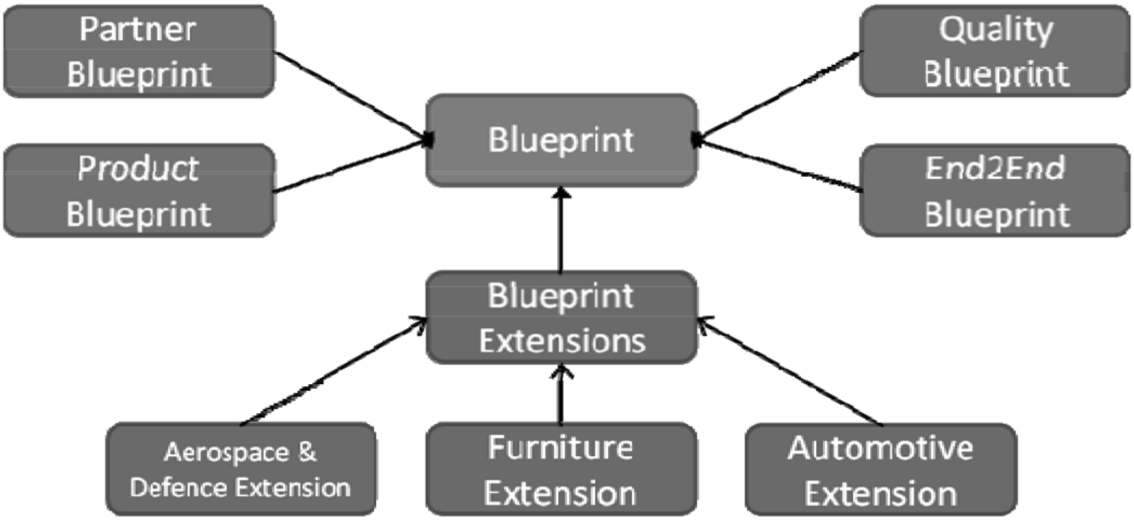


Figure 3.2 - IMAGINE blueprint model (Source: [38])

- **Partner Blueprint:** It helps to set a new network configuration and makes the captured skills and capabilities available in DMN to potential partners.
- **Product Blueprint:** It enables companies to create, maintain, re-use and share the product information of the entire manufacturing network.
- **End-to-End Blueprint:** It ties together the unobtrusive processes associated with all aspects of manufacturing and product development while providing the ability to adapt to changing environments.
- **Quality Assurance Blueprint:** It is intended to collect and maintain the resulted production information and monitor the defined DMN configuration.

The blueprint was designed to be a cross sector independent which means that several branches' extensions could be adjustable and to fit and fulfil to the desired needs. In the Figure 3.2 it is illustrated three possible extension combinations, each one representing its own sector of activity.

3.5 Information Technology (IT) platform

The constant market floatation and product competition force manufactures to have a promptly response mechanisms. The DMN platform illustrated in Figure 3.3 is a crucial component that helps manufactures to re-adjust their production when, for instance a supplier has a delay shipment or a non-mismatch requirement to the initial products specifications.

In literature [39], an attempt to fulfil not only the evaluation performance DMN nodes but also the overall current status of the DMN network partners and their rules. The overall approach and the steps followed from the order arrival to the order dispatch are illustrated in Figure 3.4.

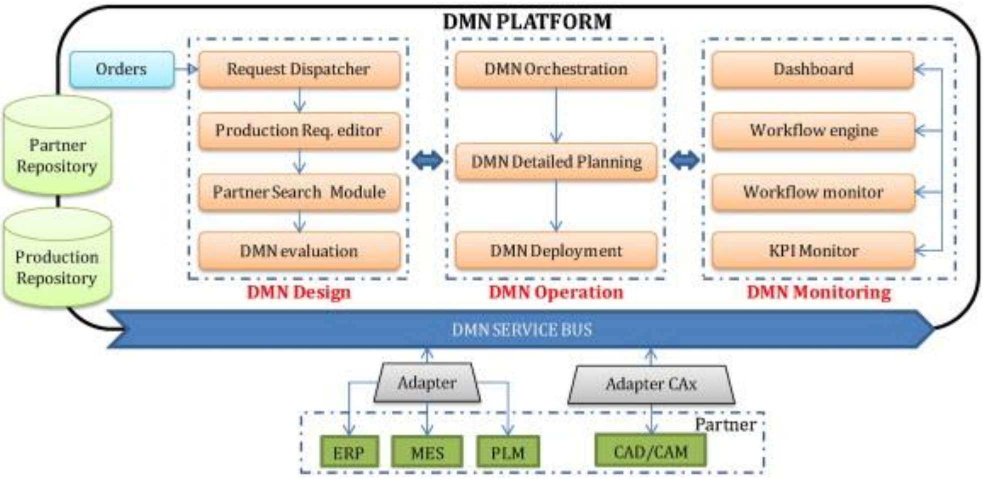


Figure 3.3 - Schematic of DMN platform modules (Source: [39])

The process starts within an arrival of a new order. The requested product is analysed by the system, which has to find among those available partners which one matches to the required product' specification.

The DMN process begins with the simulation of all network configurations and analyses which one will maximize a set of performance indicators. Consequently, constant information[12] through the portal is necessary and the best node with all the profile requirements is granted as the chosen competitor among the network.

However, an inconsistency may occur if one of the criteria fails, leading the network to re-adjust, look for new potential partners and select once again a new desired configuration.

In the end, if the platform does not detect any more inconsistencies, then it will end the DMN lifecycle and dispatch the product to its client.

[12] Information related with costs (assembly, transport, raw-material) and delays (packing, shipment)

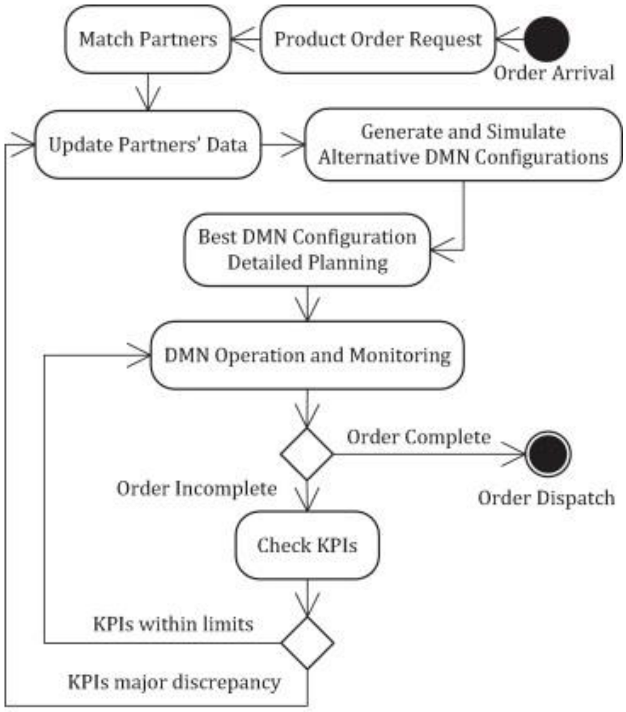


Figure 3.4 - Proposed UML diagram of the DMN methodology (Source:[39])

Special adapters are used for interfacing the platform with existing data sources and Information Technologies (IT) systems, such as Enterprise Resource Planning (ERP) systems, Manufacturing Execution Systems (MES), Product Lifecycle Management (PLM) systems and Computer Aided Design (CAD) and Manufacturing (CAM) tools.

3.6 **Conclusion Remarks**

The twenty-first century has been characterized by the rapidly growth of new technologies that inevitably triggered an increase consumption of new personalized products, which lead enterprises to change its market strategies.

Consequently, each small and medium enterprise stopped to work against its direct competitors and started to collaborate with each other by addressing new manufacturing networks to promote a more dynamic knowledge exchanged to fill the technological gaps characterized by traditional approaches.

This chapter introduced the notion of a new collaborative scheme: Dynamic Manufacturing Network which invites enterprises and manufactures to work and share knowledge in an end-end fashion.

The adoption of a new approach always comes up with some benefits and risks that should not be disregarded. The design phase should consider saving time during the trade-off negotiations, to select and choose products that maximize quality/price relation and, at the same time, capable of managing partners dissolutions threats regarding security leaks and trustless configurations.

4

Semantic Alignment for Seamless Knowledge Interoperability

This chapter provides a context description of the proposed semantic alignment framework and its components. It will also be presented the related work regarding mapping concepts and knowledge alignment.

4.1 Introduction

Electronic commerce (e-commerce) strongly influences the way how enterprises exchange information, trade products and services with other organizations. The Dynamic Manufacturing Networks addresses the opportunity for manufactures to communicate with its partners and exchange information in a transparent and efficient manner.

In terms of Dynamic Manufacturing Networks interoperability concerns on the specifications that support seamless connectivity between allied partners by monitoring a set of defined performance indicators. Connections along different partners bring forth a considerable amount of data that has to be properly maintained in future integration for those who need to share their acquired knowledge [40]. The mechanism for exchanging information on the Web may contain a diversity of knowledge, each one with its enterprise resource planning (ERP) and enterprises' legacy systems for the same-shared collaborative network configuration. Thus, it is expected to find semantic heterogeneity inconsistencies during the establishment of a new DMN.

The Semantic Web is a vision for the future of the Web in which information is given explicit meaning, making it easier for machines to automatically process and integrate information available on the Web [41]. Semantic web services (SWS) technology aims to add sufficient semantics to the specifications and implementations of web services to make possible the automatic integration of distributed autonomous systems, with independent designed data and behaviour models [42].The web service modelling ontology (WSMO) [43] initiative defines the inter-related semantic support modules of the web services. Figure 4.1, illustrates three branch point-actions of the project:

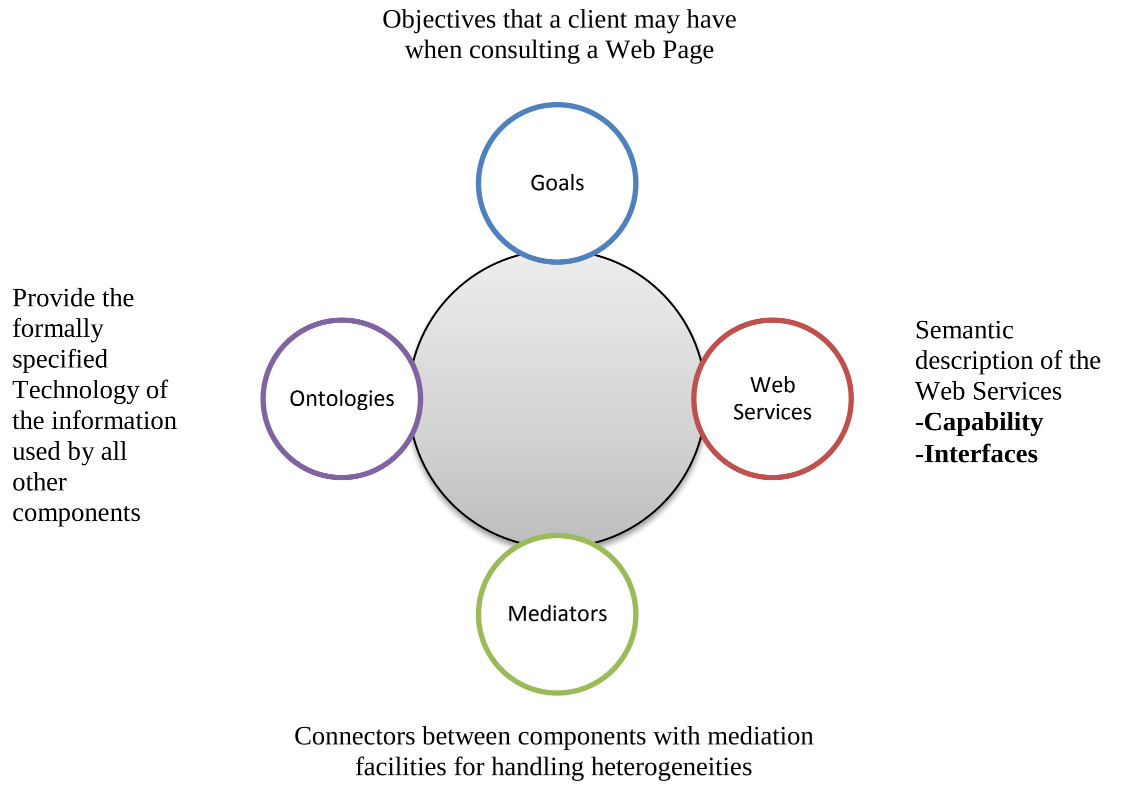


Figure 4.1 - WSMO conceptual schema (Adapted: Source [43])

Concerning about heterogeneity problems and following the WSMO initiative, this dissertation proposes the SAMPOL (Semantic AlignMent of EnterPrise's dOmain knowleLge) framework to map every company resource concept according with a reference ontology and further fill the result matches on an information ontology. SAMPOL selects each company's information and divides its resources, allowing user categorization of the in-game information, thus helping the harmonization of the synchronized shared information. The SAMPOL has a support database that stores the partner data. Every time a new company joins the network manufacture, the SAMPOL will check the income information and will classify it as data to be aligned with the reference concepts.

4.2 Heterogeneity

a) Semantic Heterogeneity

Chapter 3 (Dynamic Manufacturing Networks) identified the reason why it is important to have a system able to maintain its repository constantly updated whereas enterprises and organizations exchange data in a collaborative environment.

The resulted alliance was defined according to a set of criteria which, maximized the network performance. Since each enterprise has its own legacy system repository, a single concept may have different meanings or interpretations among the exchanged information. This phenomenon it's known as semantic heterogeneity. These types of heterogeneities can occur in form of naming conflicts, generalization conflicts, language, as shown on table 4.1.

Table 4.1 - Semantic heterogeneity conflicts

Conflicts	Description
Naming conflicts	Semantic correlations with equivalent meaning between two concepts are located in different ontologies. That's the case of the synonyms and homonym. A Synonym or equal relations occur when two or more distinct concepts presented have the same or comparable denotation. On the other hand, an antonym refers to opposite or disjoints meanings.
Generalization conflict	Two different concepts (C_1, C_2) that are semantic correlated on distinct system (S_1, S_2) where, $C_1 \supseteq C_2,\ C_1 \in S_1, C_2 \in S_2$ That's the case of the hypernym. A word A is a hypernym of B when it describes a more comprehensive description than B. In an opposite, a less general or comprehensive relation of those words are known as hyponym.
Language conflict	Two identical concepts (C_1, C_2) that are semantic correlated on distinct language systems (S_1, S_2) where, $C_1 \equiv C_2,\ C_1 \in S_1, C_2 \in S_2$ That's the case of the word "travel" and the word "viagem". Both meant the same but they are written in different native languages. The word "travel" is an English word and "viagem" is a Portuguese word.

b) Structural Heterogeneity

Further, a structural heterogeneity could appear, if the information from the DMN creation has two identical concepts or properties. In most cases, no direct concept-to-concept or property-to-property mapping are possible. In literature, like those conducted by Madnick & Zhu [44] and Ram & Park [45], it is possible to find studies that classify structural heterogeneity in several types of conflicts. The table 4.2 has a detailed description of isomorphism, aggregation conflicts; schematic and concept discrepancies.

Table 4.2 - Structural heterogeneity conflicts (Adapted: Source [46])

Conflicts	Description
Isomorphism conflict	Semantic correlated concepts (C_1, C_2) classified by different set of properties. Example: the concept Square and Circle. Square could have the property Length and the circle the property Radius
Aggregation conflict	A property or a concept in one system maps to a group of properties in other system. Example: the property Name of the concept Teacher is to a group of properties FirstName and LastName of the concept Person
Schematic discrepancies	The logical structure of a set of properties and their values belonging to a concept in one ontology are organized to form a different structure in another ontology. This kind of conflict can also be classified several types of conflicts, such as *DataValueProperty conflict*, *PropertyConceptConflict and DataValueConcept conflict.* For example, the *DataValueProperty conflict* occurs when a value of a property in one ontology corresponds to a property name in another ontology. The *PropertyConcept conflict* occurs when a property in one ontology is being modeled as a concept in another ontology and the *DataValueConcept conflict* occurs when the value of a property in one ontology corresponds to a concept name in another ontology.
Concept discrepancies	A property or a concept in one system maps to a group of properties in other system. Example: the property Name of the concept Teacher is to a group of properties FirstName and LastName of the concept Person

4.3 SAMPOL Framework

The Institute of Electrical and Electronics Engineers (IEEE) [47] describes interoperability as the ability of a system or a product to work with other systems or products without special effort on the part of the customer, either defined by Wegner [48] as the ability in which two or more software components collaborate despite differences in language, interface and execution platform.

The interoperability concept is constantly changing and adapting as large and more complex systems emerge to rise above of the overall current faced challenges. Thus, interoperability can be further classified, among others: technical or syntactical, semantic and organizational and so on. Technical interoperability helps to reduce and maintain two or more information systems regardless the established communication protocols or computer languages and access control of the exchanged information. Semantic interoperability shares, synchronizes and aggregates different collaborative knowledge sources, where each involved entity understands the common information in a consistent way. Organizational interoperability deals with the capability of organizations to organize its own business wherein dissimilar internal structures and processes are exchanged [49].

The proposed framework here presented tries to answer the semantic interoperability heterogeneities raised during the DMN configuration. The proposed framework is a two ring structure, where the internal ring supports its external neighbour in terms of semantic alignment and data harmonization during a DMN establishment. The framework topology and the quadrant relations between rings will be explained further in detail. Figure 4.2, illustrates, the Semantic AlignMent of enterPrise's dOmain knowLedge (SAMPOL) proposed framework and the respective connection modules.

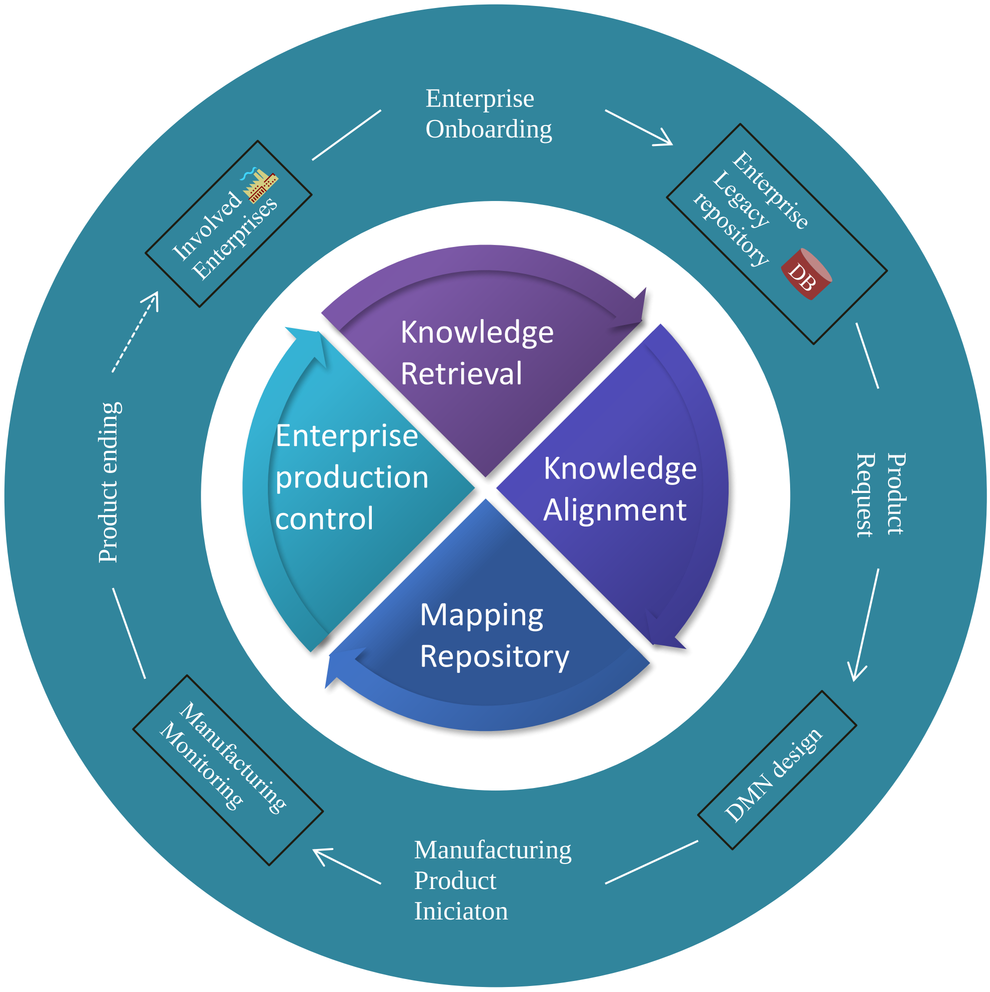


Figure 4.2 - The SAMPOL framework

The external ring is composed by eight elements which together briefly summarize a Dynamic Manufacturing Network lifecycle.

The production productivity or the innovative technologies are some appointed reasons whereon lead enterprises to support themselves and not working against each other. Thus, initially enterprises are invited to join a collaborative manufacturing network, not forgetting that each one has its own view perspective and knowledge of the domain they represent.

Before a manufacturing production begins, first it is necessary to design some of the specifications, taking into account features like: time consumptions, raw material prices or the distance between factories, when a new product request arrives to be manufactured. Moreover, it is important to define an adequate monitoring mechanism during the production phase that ensures a rapid response to non-expected events, already discussed in the last chapter.

The designed internal ring aims to support semantic consistency and therefore avoiding heterogeneities in communication during a Dynamic Manicuring Network design, by implementing previously semantic knowledge alignment mechanism, capable of resource mapping of the overall invited enterprises. Moreover, following the same line of reasoning that's the reason, why the knowledge alignment module is in the same quadrant of Product Request of the external ring. Also the knowledge retrieval module deals with the knowledge extraction of the invited enterprises and it tries to understand its own domain, divides its information in a set of categories in order to be further aligned within known reference source knowledge. Having done with the alignment, it is necessary to support and save the resulted mapping in repository. This information can be used for knowledge control and tries to understand, for instance if a mapped resource suffers modifications over time. Finally, it's also important to define a control mechanism that could find and avoid already mapped conceptual knowledge duplicates. Such module is identified in the internal ring as enterprise production control.

4.3.1 Repository Ontology for Mapping Establishment

As described in Section 2.2.1, information ontology is used to store the data in a database independent fashion. Some applications have the potential to store and maintain a record for all the data exchanged during its lifecycle. The DNM contains a self-pragmatic configurations since all information is in a continuously motion and has to adapt according to the network needs. In response, the system does not have the capability to store and maintain an entire record of exchanged data.

In order to be successful, a knowledge-alignment within two (or more) entities must happen, when they communicate and collaborate with each other. The ontology mapping operation helps to reduce, both semantic and structural heterogeneity wherein occurs resources exchange information in collaborative system environments [46].

The MENTOR (Methodology of Enterprise Reference Ontology development) [50] acts as a mediator between entities, containing a reference for mapping establishment and allows to record the result data to further use, making partner communication transparent and data exchanged weightless. The project is also able to represent ontology semantic operations, for instance: ontology mapping and semantic mismatches. Agostinho et.al. [51] proposed a tuple-based semantic architecture to encompass such mediator behaviour. The output information deriving from ontology mapping should be recorded in such Knowledge Base which will allow future data manipulations. The mapping tuple is defined by an identifier (ID), the mapped elements (MElems), the couple mismatches mapped classes (MathClass), a mapping expression (Exp) and a Knowledge mapping type (KMType) which can be Conceptual, Structural or Instantiable Data, as illustrated in Figure 4.5.

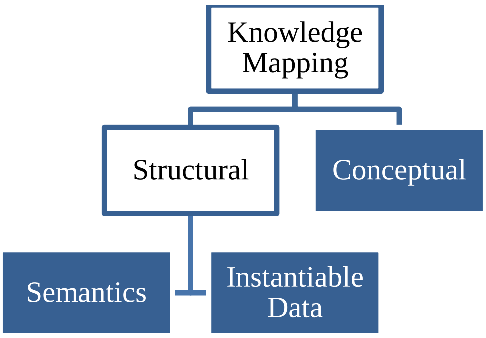


Figure 4.3 - Knowledge Mapping Chart (Adapted: Source:[51])

Figure 4.6, illustrates a modified and updated version of the proposed Mediator Ontology (MO). In structural point-of-view the mapping repository represented bellow contains two main phases: the model construction and the *Morphism* association. On the left-side of the diagram the *Object* class is a representative class that wraps the content of *ModelElement* and *InformationMode* classes. Together, the *Object* and the *InformationModel* construct the model to be represented and the *Object*_and the *ModelElement* constructs one component of the previously represented model. The model also contains relational elements that glue the classes of the desired represented model. According to the application needs, it is also necessary to state the type of element which belongs to the model. The assigned type can be a class, instance, property or concept. After the model is set, it is now possible to establish relations between two *Objects*. The *Morphism* is responsible of such relational process. The *MorphismType can* be mapping, merging or versioning. If a mapping occurs it is necessary to define the mapping type (attribute, structural, conceptual or instance). The *MatchMismatch* class classifies the result heterogeneities of the mapping process.

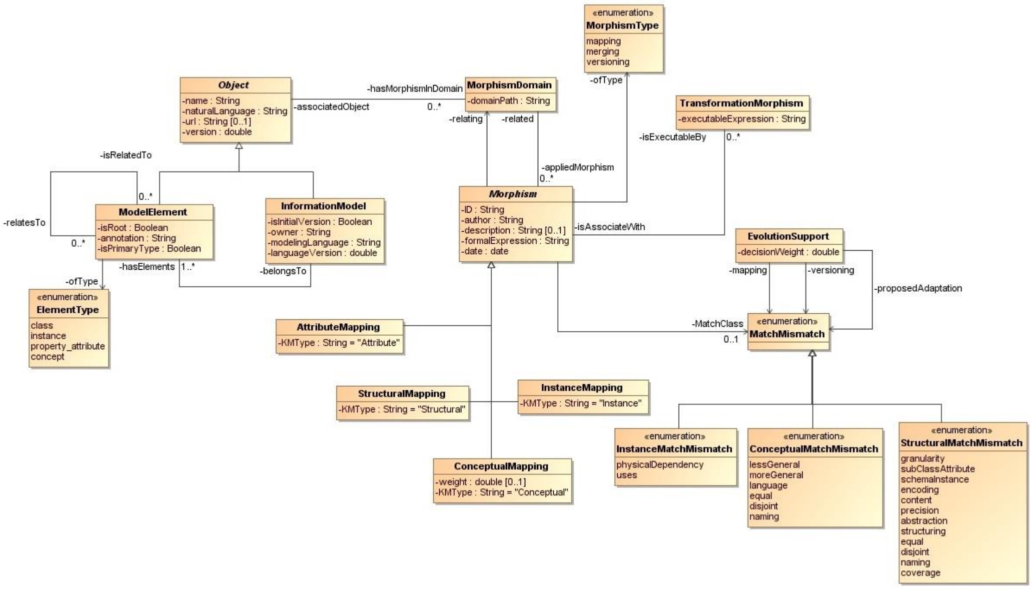


Figure 4.4 - Structure of knowledge base for mapping repository (Source: [51])

4.4 Semantic Alignment related work

Semantic alignment proposed solutions diverge according to the mapping establishment approach. Some solutions rely on ontology to extract relations just by looking for their size and hierarchical conceptual structure neglecting the proper concept meaning in the first place.

PROMPT (formerly SMART) [52], an user-interaction semi-automatic tool that continuously suggest the concept matches until the desired alignment is reached. As a result a merged ontology with the results of such mapping process appears from the mapping process.

COMA++ [53] was one of the first proposed solutions containing a repository support to store the mapping information present on a tree ontology visualization interface.

Hierarchical speaking, ontologies resembles an object-oriented programmer computer language. Manner fact, not only those conceptual classes presented in an ontology and their relations could be used to extract the semantic alignments on a mapping tool, but also properties or individuals are in the manner fact well-accept. Jason Jung [54], proposed a mapping alignment between two VE taxonomies by capturing the instance similarities of the respective paired concepts. However, the solution may be meaningless if some instance concepts or relations are missing despite the automated process.

Traditional approaches relied on the structure between the concepts presented in the ontologies in order to establish a possible concept alignment. The process computes how far each character is alphabetical apart from each order between two distinct concepts. A more recent based on information distance theory approach proposed by Jiang et.al. [55], tries to find similarities on the involving concepts by using the Google page.

IF-MAP [56], identifies mappings automatically based on the theory of information flow. It exploits both schema and instance information to match two ontologies. It first examines their instances to determine whether they can be assigned to concepts in reference ontology and then uses formal concept analysis to derive an alignment.

XMAP [57], explores a combined weighted sum with a sigmoid function, not only for the linguist similarities in the ontologies but also, it tries to find correspondences on the class that has identical property cardinality constraints in semantic heterogeneities. This approach, reaches a better performance methodology, making the possible mismatches much easier to find, plus the advantage to have free human agent interaction on the overall process.

ASMOV [58], solution computes semantic alignment inconsistencies. It uses two distinct faces, one that tries to find similarities on a two input ontologies within a third pre-aligned ontology and a second process which tries to validate the possible matches established in the first phases. The drawback of this approach is the computational time needed to find the mappings in the first place.

The mapping tools so far presented lack from the fact that the shared concepts must be written in the same natural language. A heterogeneity problem could raise, if the source and the target ontologies came from different native languages. Concepts written in different languages offer a linguist barrier for those who try an establishment agreement.

SOCOM++ [59], solution translates the two ontologies in the same language before the mapping takes place and the resulted morphism is managed by a MoMo (Model Morphism) system.

4.5 Concluding remarks

In this chapter the proposed semantic alignment of enterprise’s domain knowledge framework was presented. Its goal is to provide technological solution capable of formal semantic mapping representations supports the establishment of interoperable communications in a manufacturing network. Therefore, the chapter also included a breathily script description of its components to support future collaborative networking integration to any semantic alignment system that needs to exchange data from different knowledge sources.

5

Proof-of-Concept Implementation

Proof-of-Concept Implementation chapter will explain the proposed mapping tool according to the scenario presented in section 5.2. The proposed solution designed a mapping tool which will map each ERP's registered company concepts according to the knowledge of the reference ontology in order to avoid interoperability inconsistencies in the *i-platform.*

In this chapter will be possible to find a briefly reference of the used technologies that supports the construction of the mapping alignment process. To understand how such semantic alignment is made, the proposed architecture of the mapping tool followed by an enlightening explanation of its components is also presented.

5.1 Used Technologies

5.1.1 Liferay Portal

Liferay Portal is a free and open source enterprise portal written in Java and distributed under the GNU Lesser General Public License and proprietary licenses.
According to Oracle [60] a portal is "web based application that commonly provides personalization, authentication, [and] content aggregation from different sources and hosts the presentation layer of information systems".
Liferay portal allows the user to create custom web content in independent window container so called portlets [28]. The JSR-168 [61] specification defines portlet as:

> *Portlets are web components – like servlets – specifically designed to be aggregated in the context of a composite page. Usually, many portlets are invoked to in the single request of a portal page. Each portlet produces a fragment of*

> *markup that is combined with the markup of other portlets, all within the portal page markup.*

Portlets provide the user interface of the portal by accessing distinct applications, systems, or data sources and generating markup fragments to present their content to portal users [62].

5.1.2 Java

Java is an object-oriented high-level programming language.
On the technical side, the portlet is a Java class that implements the javax.portlet.Portlet interface and is a packaged and deployed as a WAR file inside of a Portlet Server container. The Protégé API it is in Java language which encompasses the support for ontology manipulation.

5.1.3 Java Server Pages (JSP)

JavaServer Pages (JSP) technology enables Web developers and designers to rapidly develop and easily maintain, information-rich, dynamic Web pages that leverage existing business systems. As part of the Java technology family, JSP technology enables rapid development of Web-based applications that are platform independent. JSP technology separates the user interface from content generation, enabling designers to change the overall page layout without altering the underlying dynamic content [63].

5.1.4 JavaScript

JavaScript is a dynamic computer programing language. It is commonly used as part of web browsers, whose implementations allow client-side scripts to interact with the user, capture events that occur on the page, provide the website of dynamic manipulation of the HTML content displayed without needing to reload the page. This is the reason why the propose solution utilizes the AlloyUI amongst all visualization tools discussed previously in Section 2.3.

5.1.5 MySQL

MySQL [64] is a multiplatform open source relational database system that allows current access through multiple kernels. It is the worldest popular database for the web and it is the number two choice of the web brands today, due to its flexibility and security concerns. It stores its information exclusively in tables, supporting a diversity of data types, ordering functions being an efficient auxiliary support to OWL management [18].

5.1.6 Protégé-OWL API

Designed by Stanford University, Protégé is one of the most popular free ontology modelling tool editors. The management tool offers an OWL-API which allows developers to use and edit its Java source code, thus implementing class, property or even attribute manipulation of its OWL or RDF files.

5.1.7 Service Oriented Architectures

The Organization for the Advance of Structural Information Standards[13] (OASIS) defines the Service Oriented Architecture (SOA) as a "paradigm that has gained significant attention within the IT and business communities" [65].

5.1.7.1 Web Services

A Web service is a "software system designed to support interoperable machine-to-machine interaction over a network"[66]. It exposes its features programmatically over the Internet (e.g., XML[14] message send through HTTP[15]), and can be implemented via a self-describing interface based on open Internet standards [67].
In particular, SOAP (Simple Object Access Protocol) offers the tools and the mechanisms to implement Web services that perform Remote Procedure Calls between programs in a language and system-independent way. The requested message is contracted in XML format and is sent to the server, using the HTTP protocol. The reply message come also in XML format. In this way, applications on heterogeneous platforms can communicate [68].

5.2 Network Agents

Even before an ontology mapping begins, it is necessary to state a reference for the specific domain establishment. To be successful, agents need to exchange messages in a protocol fashion. NOKMS [69] proposed solution relies on ontologies to negotiate an agreement between agents. Recently efforts [70], [71] rely on more robust free-agent strategies which overcome the possible mismatches trends during the protocol establishment.

In an attempt to avoid such inconsistency exposed in Section 4.2, the author identifies six agent entities that communicate and work collaboratively. Each user has a special capability and well-defined tasks which all together working in collaborative way helps define and maintain the DMN configuration.

Agents talk to each other in order to achieve a consent understanding through all shared concepts under the DMN. Table 5.1, define the platform agents and their rules to form the domain knowledge ontology system establishment as base line for further mapping establishment.

[13] https://www.oasis-open.org/
[14] http://www.w3.org/XML/
[15] http://www.ietf.org/rfc/rfc2068.txt

Table 5.1 – The adopted semantic aligment

Platform Users	Description
DMN Manager	It has the responsibility of creating a DNM, which represents the manufacture process of a product
Company ERP Manager	The company production manager which has the role of deciding a participation in DMN and update their own ERP
Knowledge Engineer	An agent that has the role to update the knowledge of the systems (e.g. ontology concepts that represent categories)
Domain Expert	Domain expert agents. It knows the terminologies for a specific industrial activity sector.
LL Administrative	Officers with an administrative cargo that make the subscriptions in the platform of the enterprises. Example: Office department
Informatics Engineer	Known as a computer science or a computer engineer that manages and supports the subscriptions in the platform of the enterprise.

The Domain Expert is the most suitable person to say what entities and relations concepts needed to acquire the representation of the knowledge for each specific case. Then the Informatics Engineer store such information on an ontology database which will be the guided reference for classify the information present in each company.

5.3 Adapter for Enterprise's Legacy System Integration

The adapter acts like an intermediate module to grant that each enterprise contains the necessary requirements specified in their blueprints. A correct and success registration should has their knowledge concepts mapped according to the legacy ERP's before the company information is sent to the *i-platfom*. This facilitates the process of searching for new suppliers, adding a simulation process taking account different scenarios, while enterprises autonomously exchange information. This gives companies the ability to provide order tracking and monitoring transparently to the user in real time.

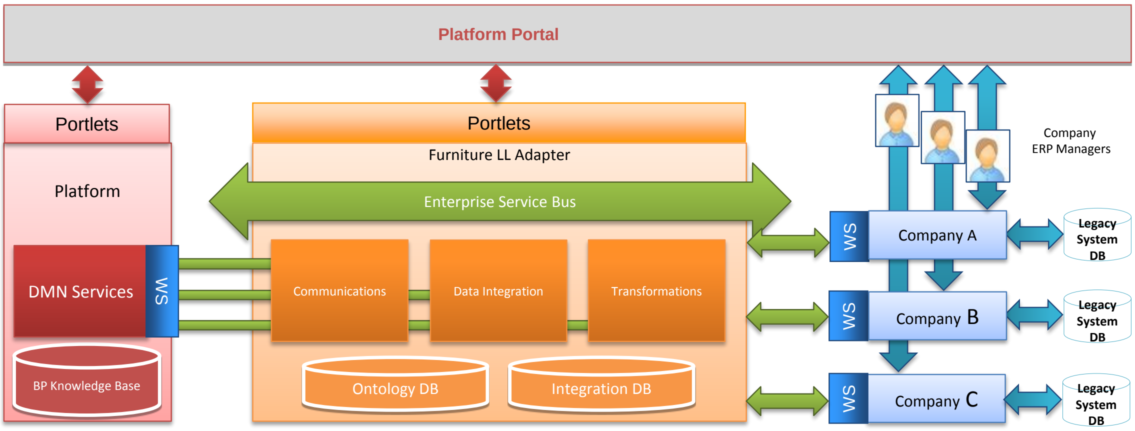


Figure 5.1 - IMAGINE Adapter screenshot (Adapted: Source: [38])

The workflow information in the adapter and the architecture models are explained as follows:

1. The process starts every time a new company is invited and joins the platform system. If it is successful, the registered company needs to transfer its resources and legacy systems through a web service connection linking the adapter.

2. The transformation module is responsible and test if the domain information is well characterized according to the blueprint specifications. This is an important phase since an absence of such structure it may compromise the further knowledge alignments on de the Data Integration Module. Figure 5.2, illustrates the two transformations taken by the Knowledge Engineer. The orange arrow symbolizes the transformation among Organization (AP236) and the Company blueprint. The orange arrow symbolizes the address transformation under the Organization (AP263) and the ContactDetails on the blueprint side.

3. The Ontology DataBase contains knowledge reference, which will be used as a competitive guideline for mapping establishment. This ontology will be explained in Section 5.4.1.

4. The Data Integration Module has the capability to align the knowledge between the ERP's and the defined reference ontology. The mapping tool proposed in Section 5.3 manages and supports the functionality of this module.

5. A parallel communication channel Communication module which allows the final prepared information being send to the *i-platform*.

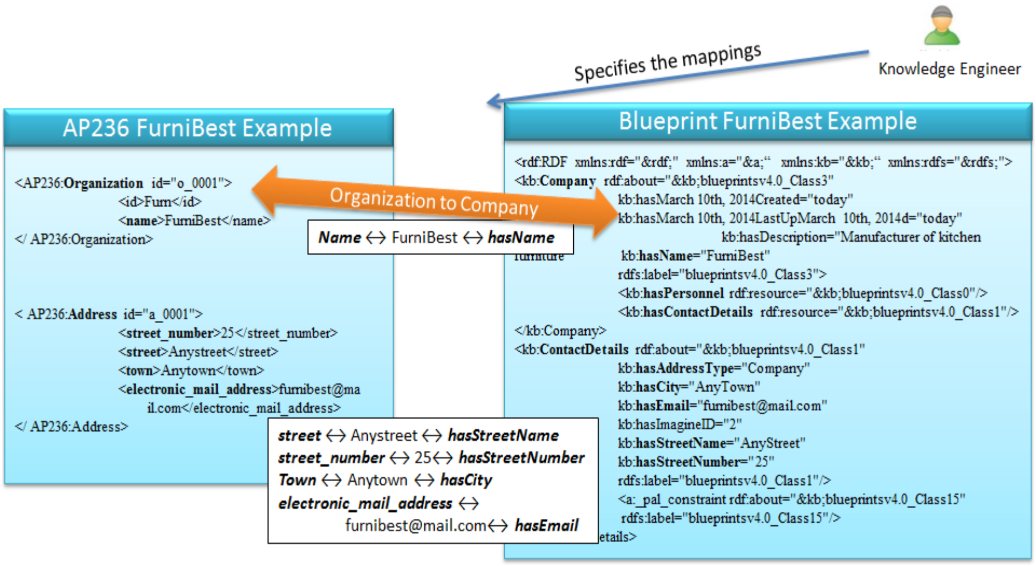


Figure 5.2 - Mappings establisment between enterprises legacy and the BP data models (Source: [72])

5.4 Mapping Tool Architecture

In Section 4.4 some mapping tools were presented regarding some strategy approaches. The mapping tools architecture are inspired in some characteristics and advantages of each one those works.

The mapping process tends to be a demand task for user interaction, that's the reason why more recent approaches look to get automatic. Besides the possibilities of having such mapping process, the tool still maintains manual control to be more computer-light and maximize the final map quality.

Concerning about a better sustainability, the mapping architecture presented also cares about the scientific progress. The user involvement, the explanation of matching and the structure and support are identified by Shvaiko et.al. [73] as future challenges that were taken in consideration during the design phase of the proposed tool.

Due to its flexibility, the proposed mapping tool allows an user to determine the most accurate matches in an effortless way. Figure 5.3 shows an overview of the proposed mapping tool which will enable harmonization between ERP's and a domain reference.

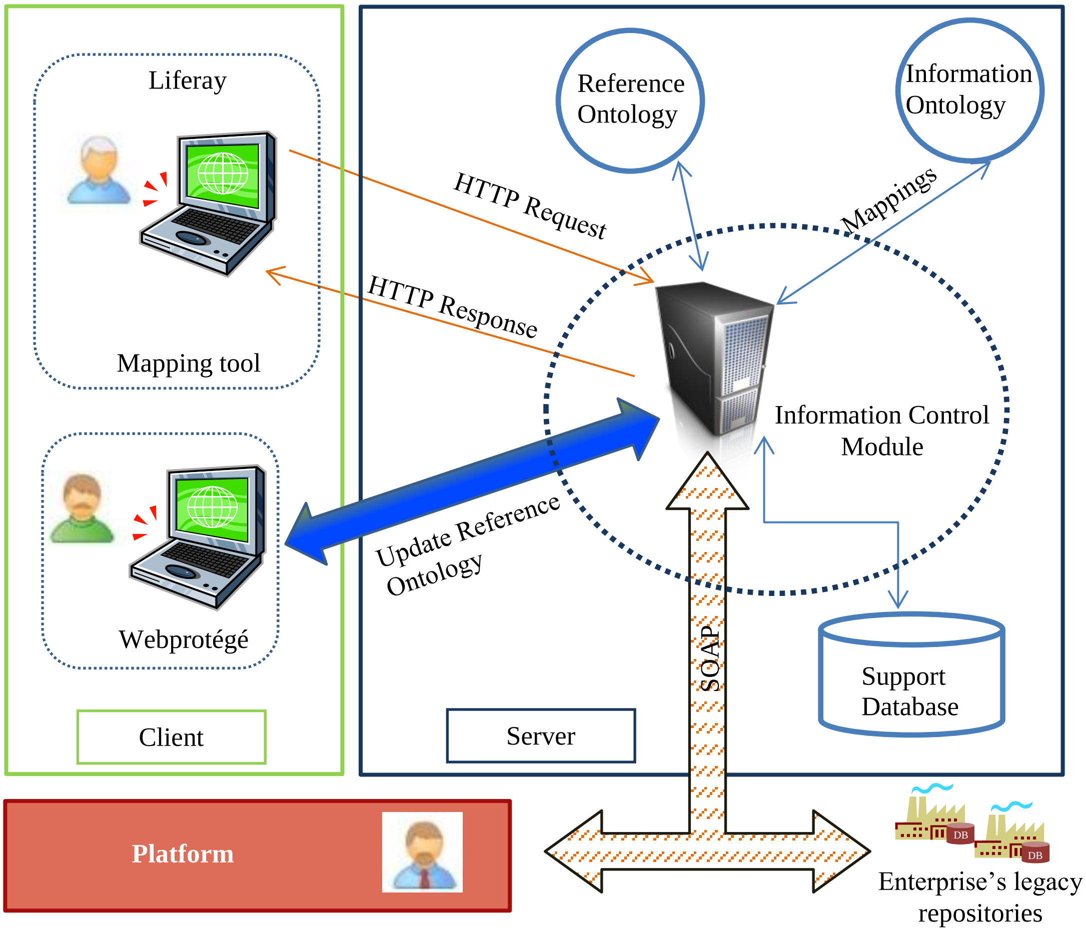


Figure 5.3 - Client-Server mapping tool architecture model

The mapping tool is divided in the following components and actors:

- The Reference Ontology, which contains the reference knowledge for future alignments.
- The Support Database that acts as a manager of income and outcome information and temporary mapping repository.
- The Information ontology which, stores the final aligned concepts.
- The domain expert that maps the partner data concepts according to the knowledge defined in Reference Ontology.
- A platform which receives the aligned information.
- The DMN manager defines, publishes and starts a new manufacturing network configuration.
- The partner data present in each of the enterprise's legacy repository.
- The Information Control, which transforms and controls the income and outcome information from the other modules.

- The mapping tool portlet interface, which enables the semantic alignments of the exchanged resources.
- The Webprotégé enables reference domain knowledge re-adjustments.
- The Informatic Engineer to control the Webprotégé environment.

The architecture is based on client-server communication model with a third external connection to the IMAGINE platform. The client side is composed by one domain expert and an imformatics engineer. Each one controls the designed mapping tool interface and the Webprotégé environment respectively. When the expert domain agent finishes the mappings for a single enterprise, the aligned information is sent to the platform to be further managed by the DMN manager. Furthermore, the informatics engineer has the capability and the permission to change and modify the reference ontology, thus providing accuracy and reliability of the postulated domain knowledge. The server side has one integration repository that contains the temporary information of income and outcome mappings and enterprise's legacy resources; a reference ontology that contains the in vogue domain knowledge; a mediator ontology to store the resulted mapping establishments.

5.4.1 Reference Ontology

The reference ontology was designed in order to guarantee the most accuracy as possible. Figure 5.4 shows the knowledge modelling ontology that states as a reference model for the categories and concepts for each industrial domain. The class names and associated description of the information ontology model are explained as follows:

- **Category –** The main root class of the entire model. Contemplates a descriptive text and manages the relationship with the *platform* blueprint knowledge base;

- **Company –** A direct child class of Category class to identify the type of activity of each company (e.g. manufacture, retailer);

- **Domain –** A direct child class of Category class to identify the working domain (e.g. automobile, furniture);

- **Market –** A direct of class of Category class to describe the type of market that the company can reach (e.g. European, Asian);

- **Product - –** A direct class of Category class to represent the name of a company's product order (e.g. leather, glass);

- **Material –** A direct class of Category class to represent the material of each company process (e.g. leather, glass);

- **Equipment -** A direct class of Category class to represent the equipment that each company has in their facilities to execute processes (e.g. 3D printer);

- **KPI -** A direct class of Category class to maintain a list of standardized key performance indicators (KPI). These can have metrics to enable subsequent evaluations;

- **Standard -** A direct class of Category class to indicate the standards in use;

- **Unit –** Class to represent measuring units (e.g. meters). As the Category class, it also enables to define a relationship to the *iplatform* blueprint knowledge base.

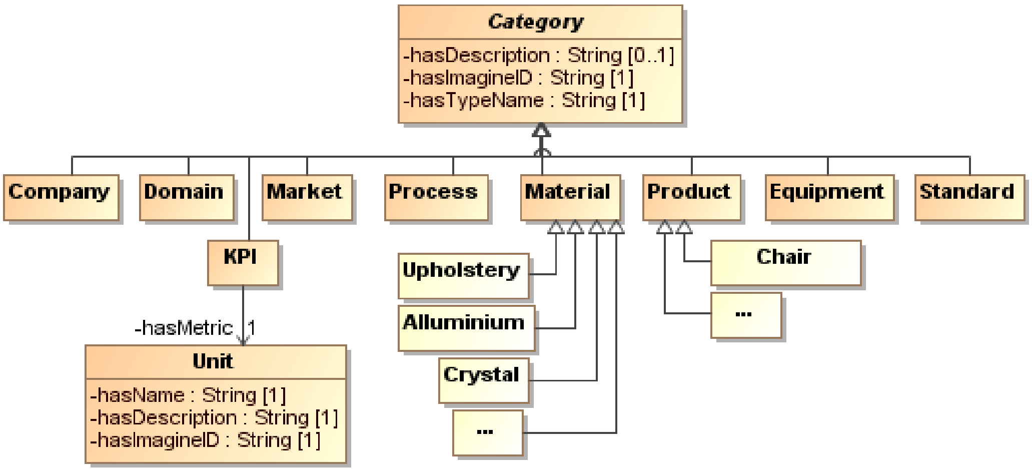


Figure 5.4 - Knowledge modelling ontology for enterprise's resource categorization (Source: [38])

The Domain Expert is the most suitable agent to say what entities and relation concepts are needed to acquire the representation of the knowledge for each specific case. The result information is stored by an Informatics Engineer on an ontology database which will be the guided reference to classify the information of each company.

For technological reasons, the project utilizes an adaptation of a catalogue whose acquired knowledge is present in ontology partner[16] with a property that indicates which categories, i.e. the concepts that will be eligible for subsequent mappings. Among the conceptualized knowledge, only those tagged concepts should be elected and presented in the proposed tool for further knowledge alignment. The idea behind all of this is to have a reference ontology, which

[16] www.aidima.es

concepts could be known and used by all, without forcing semantic changes in enterprises legacy system.

It is important to have an extended set of concepts to help describe and categorize the intended domain and then as the repository gets larger it is expected to find more close information, wherein it is crucial to have a way how to differentiate each resource among the remaining categories.

The reference ontology has an *IsReference* boolean data type property whether the requested resource is identified as a potential concept for mapping establishment with the received partner concept of the external channel. It also has in its rdfs:comment property an optional description of the selected class, thus turning the mapping process more feasible by helping the knowledge expert to choose a category as future reference resourse. Figure 5.3, illustrates both, *IsReference* and the rdfs:comment properties for the concept *DomesticChair* present in the Reference Ontology.

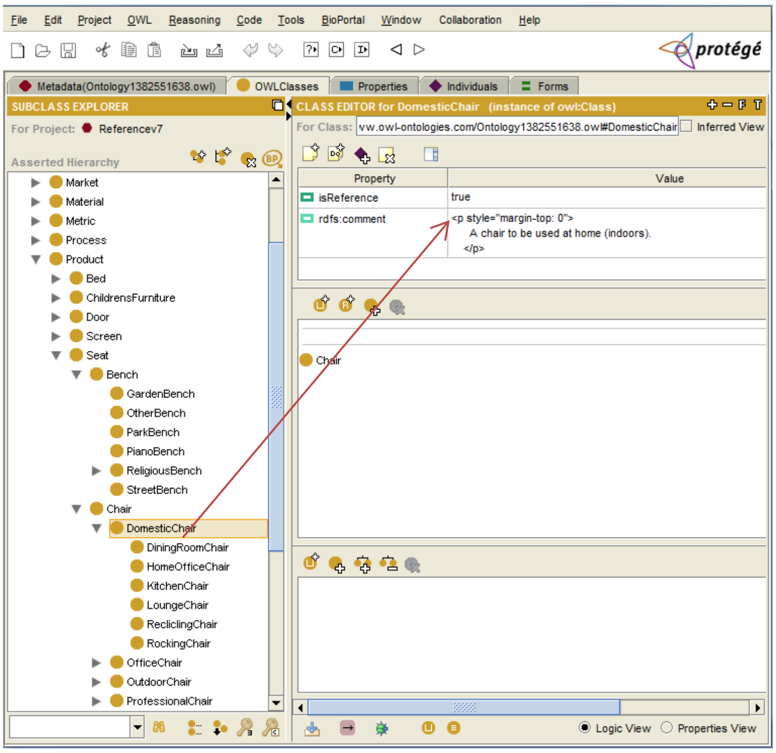


Figure 5.5 – Reference ontology screenshot

Among the three hundred and thirty seven classes present in the reference ontology, were initially considered only four classes (categories) as classifiers to the type of resource to be mapped: Material, Product, Process and Equipment. A given material is for the purpose of manufacture directly associated with a particular product. Therefore, the category Product is merged with Material category a possible resource type to be mapped. The proposed tool is not necessarily limited to these three possible resources, which can alternatively consider other resources, depending on the intended application.

Once recorded, each company will have its knowledge classified according to their types of resources, such as specified in the categories present in the reference ontology. The information for each company is recorded and saved in database integration.

5.4.2 Support Database

The database integration is the fundamental base of support for maintenance and management of the registered enterprises and its category resources, the unfinished and the remaining mapping establishments. The tables used in the mapping tool architecture are integrated in the integration database of the IMAGINE adapter illustrated in Figure 5.1. Besides its size and complexity, only five of the initial twelve tables are used to manage, implement and support the proposed mapping tool architecture. Figure 5.6 shows the enhanced entity-relationship model and therefore the names, data types and relations used in the integration DB.
The five used tables and its descriptions are presented below:

- **Company**: Table responsible for storing the information from the registered companies. It contains the name of the registered company, imagineCompanyID generated by the platform and the vatNumber (unique identifier of the company).
- **Legacyerpresource:** Table responsible for storing the remaining information of each enterprise resource to be further mapped. It contains information regarding the type, name and description of each successfully registered enterprise in company table. Thus, the resource table contains the information resources of all companies registered in the adapter, so there is a connection "one-to-many" with the company table.
- **Mappingcategories**: This table was originally designed to indicate which resources have been mapped from the registered companies. As it will be explained later, this table will play an important role in the management and optimization of the content shown in the portlet mappings.
- **Resourcecategories:** Table responsible to identify the matched pairs to be further submitted into the platform.

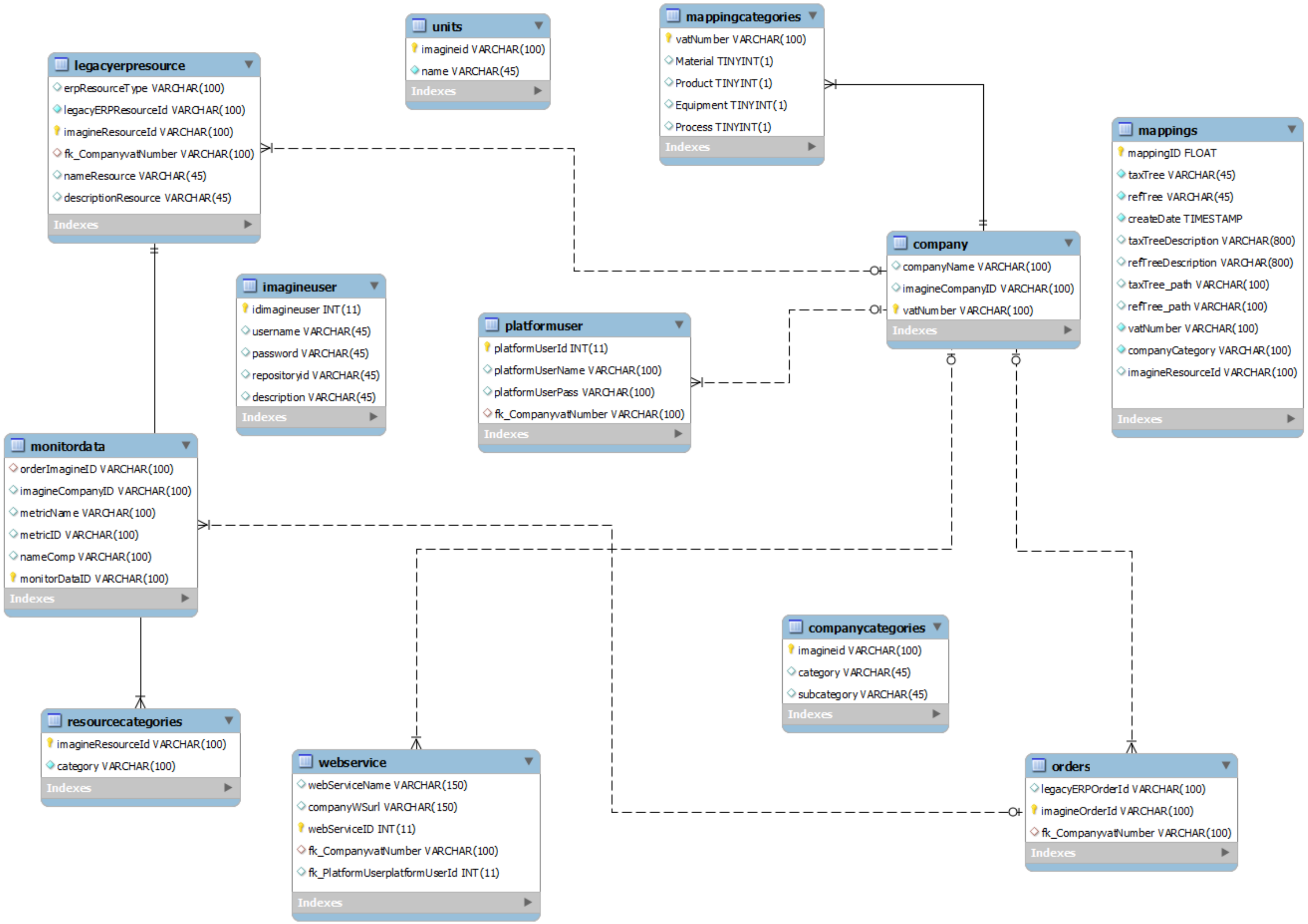


Figure 5.6 - The integration database enhanced entity-relationship model

- **Mappings:** The mappings table is responsible for storing the mappings established in portlet. It contains the mapped pair concepts (the resources received by the external channel with the reference concepts), the mapping date, the descriptions of each map establishment (when available), the taxonomy path, the company vatNumber, the platform number and the resource type (imagineResourceId). This number will serve to identify the concept sent by the service side of the platform after the mapping has been established.

5.4.3 Information Ontology

This module already was described and widely clarified previously in Section 4.3.1 and therefore it will not be once again explained. However it is important to remember that this module concerns mainly on keeping a record of the semantic alignments and its resulted morphism took in the mapping tool.

5.4.4 Information Control Module

The proposed tool tends to respond the ability to semantically align the received resources among the registered partners with a specified reference.

The information control module is the most important component of the entire framework and acts as a central base communication among the remaining modules. The Figure 5.7 shows the proposed management module and its three modular components: 1) data preparation of the reference ontology and information for enterprise resource registered in database integration, 2) the conceptual mapping of a given business use stage 3) save mapping and forwarding information to the platform.

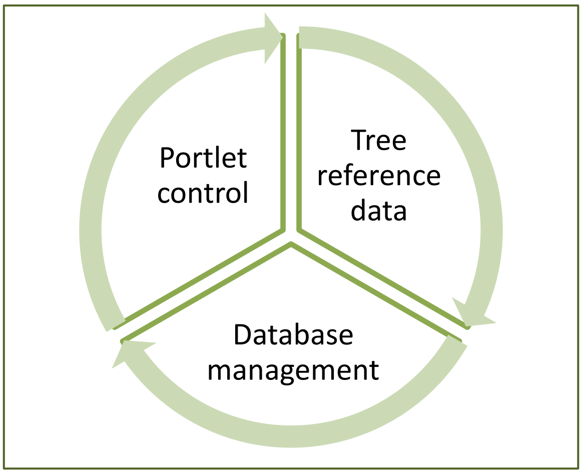


Figure 5.7 - Information control module phases workflow

a) *Tree Reference Data*

The Tree reference data module is responsible to retrieve, organize and the reference ontology classes and its hierarchical relations in a tree java object. This allows to easily searching for a specific class by name, analyses the hierarchical relations between relative nodes and at the same time maintain its own representational structure. The module is composed by *edu.ontology.tree* java package with three classes.

The class *Node.java* defines a node of the requested tree in a java object and can be set as class, property or attribute type. It also has one Boolean and one String data type to record the description and the reference value present in the reference ontology. The remaining two classes *Tree.java* and *ModeltoTree.java* together with the Protégé-OLW API read each create node object and fill it into a tree java object.

b) *Database management*

The Tree reference data module is responsible for income and outcome information coming from the support database. The information flow is controlled by the *accessSQL.java* class which implements the ordering, searching and writing methods.

c) *Portlet control*

The portlet control module manages all the information regarding server side flow control, including portlet Uniform Resource Locater (URL) phases. The functionality is located in *com.tree* java package, which contains the *TreMapConstants.java* interface and *TreeMap.java* class. The interface has the implemented constants and the class implements the portlet functionality.

5.5 Application Scenario

The following scenario presents the interactions for a specific chair order between a retailer and client of the IMAGINE project to support the applicability of the proposed thesis work.

Nagasawa [74] shows on his study that only around 38% of the inquired population sample would buy a long term piece of furniture. These could be an indicator of the sector's fragility and thus it has to constantly adapt in a non-predict way to be competitive in their business niche. Products with short lifecycles characterize the sector. As a result, time-to-market is essential to keep up with customer demand and ensure customer satisfaction. Moreover, The Furniture sector relies mostly on human intervention and manual processes in order to deal with most of the tasks related to Product Lifecycle Management [75].

The DMN configuration is no exception. Each enterprise has a specific knowledge of their domain and a description of their products, processes and even equipment. An inconsistency may occur, when two or more entities try to start a dialog. To avoid such scenario, all parties must have an intermediate domain knowledge entity that acts like a mediator through the rest of the network. Let's take the following example.

A client C_1 contacts chair manufacture M_1 to order a 1000 customized chair model, by modifying one of the chairs of M_1 catalogue (model 145), for C_1 conference's room . The manufacture contacts his production department to design a blueprint with the C_1 product specifications. The chair model contains different parts, each with a specific raw material with a wooden back, textile seat, an aluminium structure and a crystal piece, as is illustrated in Figure 5.8.

The manufacture has to look for partners that manufacture all parts of this chair model "145" since he is not able to manufacture: textile aluminium legs. He only has the ability and the known how to produce the wooden back. The manufacture must contact his associates and requires a blueprint with the detailed specification for each chair component. The final result blueprint, eventually could present some errors or incompatibilities that do not match with C_1 needs. The wrong blueprint has to turn back to produce a new modified version, originating undesirable delays. To respond accordingly, a conceptual mapping between the associates is needed. Each associate contains his knowledge represented in a Knowledge solution, like those presented in Section 2.

A conceptual mapping between two ontologies from distinct companies is taking place by an agent. Section 5.2 will describe the network of furniture agents involved in the process. Let's assume that the agent is a person who has the sufficient knowledge and skills to work with an ontology and with an ontology editor. Each company has their own ontological concepts and their legacy database systems respectively. The agent finds the concept "145" on one of the present ontologies. On a first glance and without any further information, it is almost impossible even for a domain expert in the field to tell what kind of relation this concept could have within the correspondent concept in the second ontology. The analogy is identical when a traveller in transit does not speak the same language as the locals. In this case, verbal expression has to be done by a translator.

To avoid such interoperability break, the author has constructed an ontological model representation that helps the categorization of the income enterprise information.

Eventually, M_1 receives a satisfactory blueprint and start the production phase. At this stage, M_1 has to contact his manufacture suppliers S_1 to produce each single chair component. This could be worse if a single supplier contacts its own network of suppliers, raising the network complexity exponentially.

At the end of the production phase, M_1 needs to evaluate the best option according to quantity, quality and costs. In a final phase, M_1 remotely monitors the production progress for each component. The final delay can raise fair behind the deadline if the assembly line stops operating due to a line error leading one of the $M_{1's}$ supplier productions to temporally stay stationary.

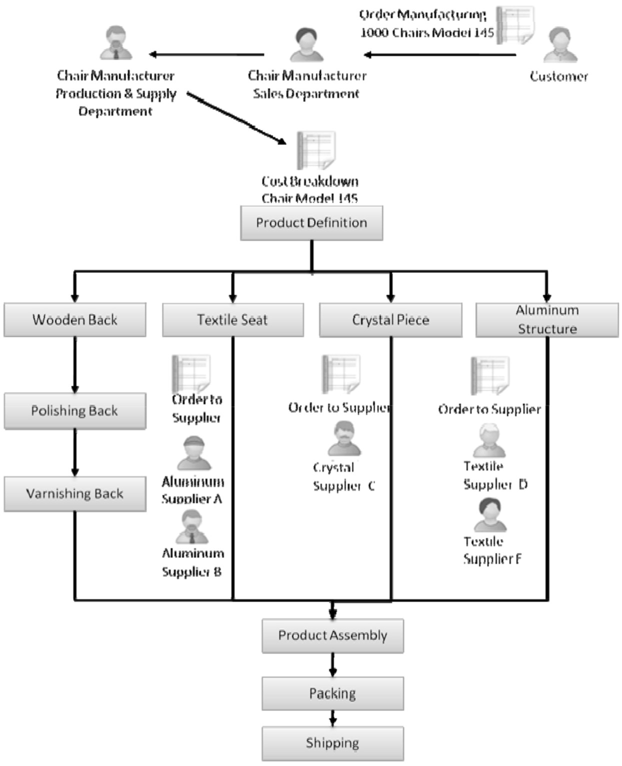


Figure 5.8 - Furniture production operations diagram (Source: [38])

5.6 Implemented steps

Chapter 5 started with the description of the involved technologies and the proposed semantic mapping tool that intends to facilitate the establishment of new dynamic manufacturing network configuration. The present Section aims to describe the implementation steps of the proposed framework architecture illustrated in Figure 5.3.

In response to a client HTTP request, the first step the preparations of the reference and legacy resources to be sent into the mapping tool. The tool also checks in this phase, for possible remaining enterprise's resources that have not been yet mapped and aligned with at least, one of the reference categories. The second phase refers to the control, management and layout of the received information in the mapping portlet.

Lastly, phase three implements the knowledge reception of the mapped resources to be stored in the support database and it waits for the completion of all categories resources alignment. The mapping lifecycle is endless, which means that the process re-starts every time the last phase comes to an end and originating the beginning of a new cycle, as shown in Figure 5.9.

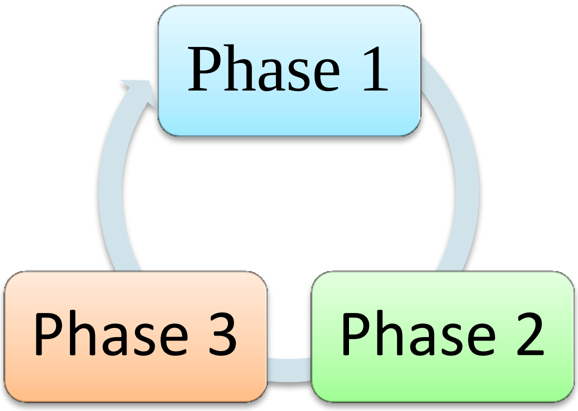


Figure 5.9 - Mapping tool architecture lifecycle

5.6.1 Step 1 – Management and Monitoring of Mappings & Resources

To accomplish total control of the received data, the server should prepare itself its own information before the resources are sent back to the client in a HTTP (Hypertext Transfer Protocol) message. Therefore the following sub processes are presented.

The semantic alignment could be a demanding and fatiguing task if it is not correctly designed. The proposed mapping tool implements some mechanisms to minimize mapping establishment time consumption. To accomplish such behaviour, the knowledge preparations phase is divided in four sub process steps where which one has a specific and well-defined and distinct task during the server side runtimes. At the end of this phase, the tool "concats" all information involved in a String object class and writes it in the HTML (HyperText Markup Language) body.

a) *Load Mapping Information*

The mapping tool must have a self-checking mechanism, which determines and indicates if a determined enterprise resource was already mapped with a reference category. This was possible by viewing how much resources have already been mapped including, its names, its tree paths and IMAGINE's Ids. The mechanism will allow the tool to control and say if a specific required resource is mapped with its reference. In this way, the tool avoids at the same time, the repeated alignments and reduces the induced hand process mapping fatigue. The Figure 5.10 shows the mapping information diagram.

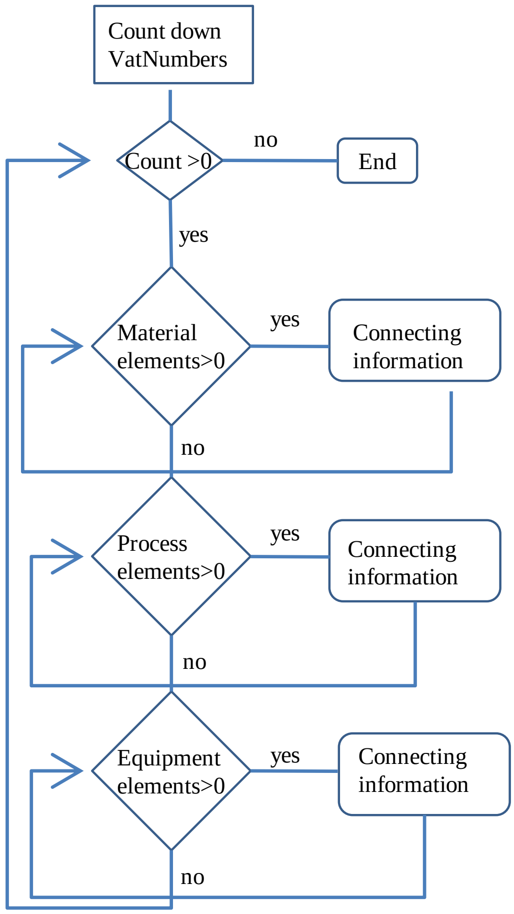


Figure 5.10 - Load mapping information diagram

b) *Last Mapping Establishment*

The server looks for the previous mapped resource and sends its information to the clients' side. This allows the tools to put the last mapped information in portlet in order to facilitate the mapping process and once again reducing the unwanted repetitive action in which leads users to select one enterprise and its correspondent category, every time the portlet process in the client web browser.

c) *Load Enterprise Resources*

The mapping tool can access and collect its own information, including the enterprise Vat Number, name and a list of resources, as were mentioned previously in Section 5.3.2.

The load enterprise resources counts the number of successful enterprise registered entries in the support database and sees one by one the following information:

- The type resource category registered (Material, Process and Equipment)
- The number of resources already mapped for a single category

- It counts the un-mapped resources
- The description of each resource
- Each IMAGINE resource identifier

Finally it puts all the collected data into a tree java object which enable an easy manipulation and extraction of the acquired information, as illustrated in Figure 5.11.

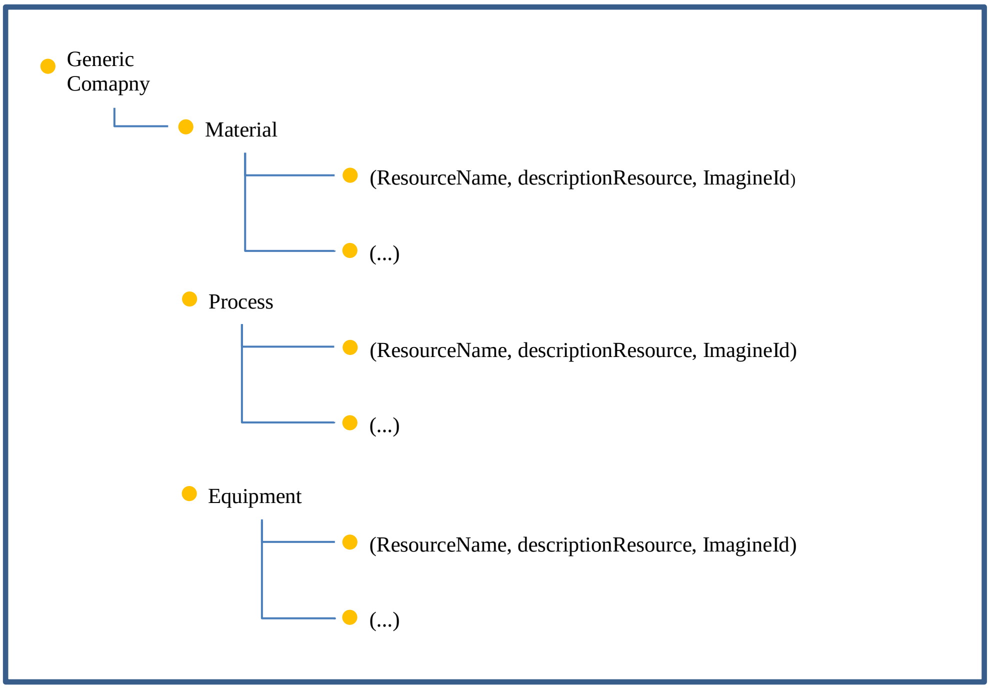


Figure 5.11 - An example of the developed tree object

d) *Reference Retrieval*

The reference retrieval is one of the most important sub phases of the Management and Monitoring of Mappings & Resources phase of the mapping tool lifecycle once it reads, extracts the ontology reference knowledge into the portlet interface. To accomplish such task, the tool uses the Protégé API to correctly get the wanted classes into a Tree Java object. As it was previously mentioned in Section 5.4.2, only three categories will be used in the alignment process. Thus, to help the acquisition of the desired data, the tool searchers a specific class by name, it reads the siblings and its own child's until a non-*isRefenrece* class is reached.

5.6.2 Step 2 - Client side Control

In a general perspective, the Client side phase manages and allows users to semantically alignment each enterprise resource with a possible correspondence within the reference ontology. To implement this, the tool reads the incoming HTTP information (sent during the last phase), constructs and publishes the information on the portlet interface. It also implements a checking functionally to block the undesired Root node to be mapped with other valid resource. The Root node only acts as a father node to support tree construction, thus it should not be considered as a future candidate for mapping establishment. Moreover, the portlet manages and testes if a specific category's enterprise has all resources mapped, thereby allowing their resources to be sent to the platform by SOAP connection. This connection will be further explained in the third implemented step.

5.6.3 Step 3 – Mapping update & submission

The Mapping update & submission phase starts when a user submits an alignment in the portlet interface, returning the information back to the server side. Depending on the type of the requested URL, the portlet will temporarily save the mapped information or it will get all semantic alignments to be sent to the platform through a SOAP message. In this case, if a successful connection is established, then the system will erase all information, since an expert manager already mapped all the data previously.

On the other hand, if the system detects a remaining category to be mapped, it triggers a Java Database Connection to store a new alignment or update an existent resource.
The phase ends by returning to portlet its first state, re-starting once again a new cycle and thereby allowing users to map more resources.

6

Mapping Tool Demonstration

This chapter shows an example of to the semantic alignment methodology of a single enterprise for the furniture domain knowledge and intents to demonstrate the framework introduced in section 4.3 and feature results of the developed mapping tool based on the implemented steps, which was implemented according to the architecture presented in Section 5.4.

6.1 Identified Challenges and Proposed Functionalities

As the name suggests, this section will describe the challenges and functionalities faced during the development phase of the proposed mapping tool. In an overall perspective point of view, each one of the topics concerns with compatibility with the adapter architecture is presented as follows:

- **Successful enterprise registration**: The portlet must have the capability to understand and test if all companies have its Vat and ImagineId numbers null or empty. This could lead to an inconsistency of the read information.
- **Category resource's management:** The tool must know which ones and how many categories have successfully been mapped for a single enterprise. Consequently, it also has to know the number of the remains resourses for both category and enterprise.
- **Last mapped resource:** This is especially important once, it enables the portlet recovery its last work state, thus minimizing the repetitive process of choosing a new enterprise and category that a user may experience every time the tool loads the portlet in the client side.

- **Reference categories:** To be able to detect and present only the identified possible reference categories tagged as *isReference* Boolean.
- **Avoid repeated data:** The tool has to be able to identify all mapped categories and subsequently enterprises by not rendering its information, thus avoiding unnecessary data in the mapping tool.
- **Temporary mapped resources identification:** To visually make known which resources were previously mapped. This helps users to remember which resources were semantically established.
- **Avoid duplicates:** The tool must be able to detect a second mapping attempt for the same resource, thus avoiding unnecessary duplicate information.

6.2 Semantic Alignment Demonstration

The identified challenges and proposed functionalities of the mapping tool were identified in the last subsection. This section will demonstrate how the semantic alignment is achieved by resorting the proposed mapping tool describe in Section 5.3.

Figure 6.3 shows the mapping tool interface of the Enterprises Data Categorization portlet. The interface was designed to be as clean and friendly as possible and it is divided into two drop-down menus, two tree sections, central control output information and two button description boxes. The first thing a user has to do is, to select a register enterprise and consequently the available category that has not yet been totally mapped. Thus, the information regarding the legacy resources and the reference ontology of the selected enterprise and the correspondent category are shown in the Taxonomy and Reference sections, respectively. To establish an alignment between those resources, the user only has to select the desire concepts and confirm its operations by clicking a submitting button. The management and monitoring; the client side control and the mapping submission will be describe in the following four subsections.

Section 5.3.4 discussed the three management lifecycle phases of the implement tool. Since the information control module has endless process, it will only be shown one example to demonstrate the overall functionalities, since it is the client starting point, the demonstrations start with the explanation of the clients' module control.

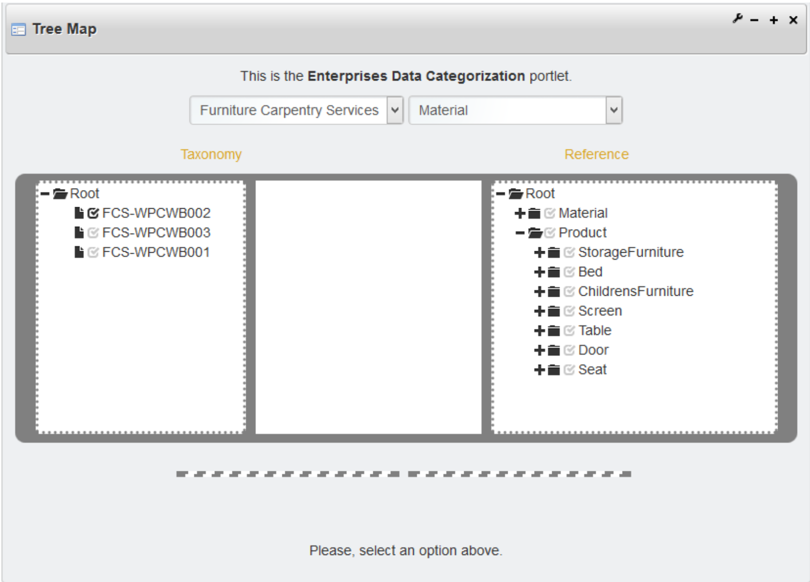


Figure 6.1 - Enterprises Data Categorization portlet

6.2.1 Client side Control Demonstration

The portlet must be able to control the enterprise and the category menus. The menu is designed to only show valid category among the registered enterprises, thus both menus are implemented in a two level selection chain. The portlet will show the referred information only if both menus have a valid and not empty option selected. Figure 6.2 (a) illustrates an empty selection menu waiting for a user to choose an available enterprise and (b) the correspondent associated category.

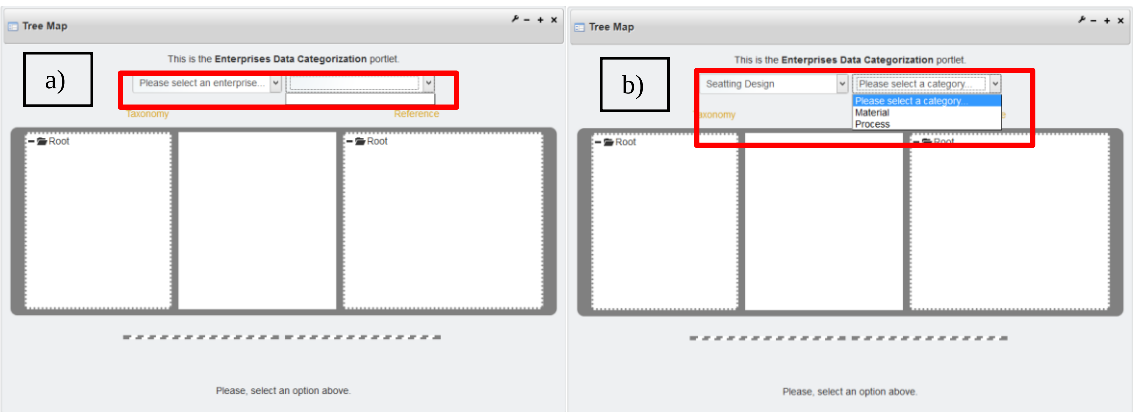


Figure 6.2 - Enterprise and category selection (a) without enterprise; (b) with enterprise selected

After the user makes its choice, the Enterprise Data categorization portlet will show the correspondent information in tree form. Since the Product category is merged with the Material, therefore the reference information regarding both concepts are attracted in the same Tree, located in Material category. Figure 6.5, shows the taxonomy of the Material resources for the Seating Design enterprise, where it is also possible to see the presence of the both, material and Product trees.

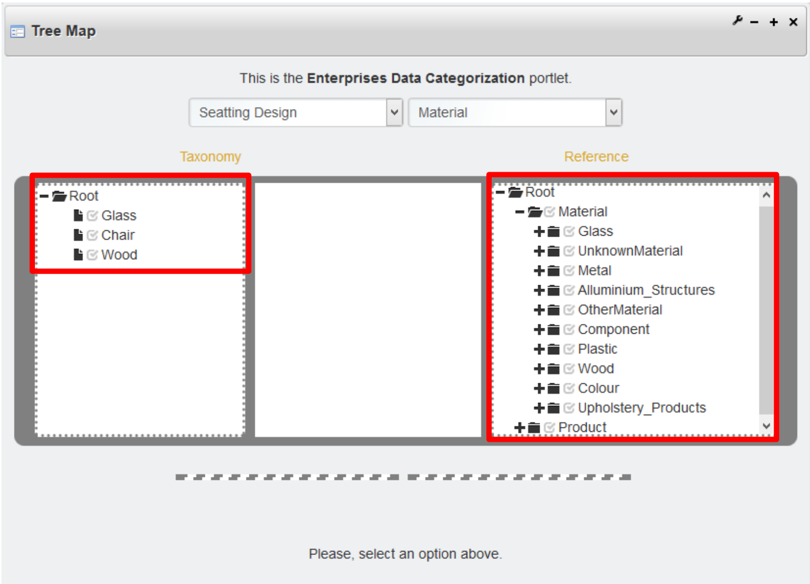


Figure 6.3 - Seating Design Material resources and the material refrence tree

The portlet implements on-click events that enable, for instance, users to select a tree node to be marketed as a future correspondence on the semantic alignment operation.

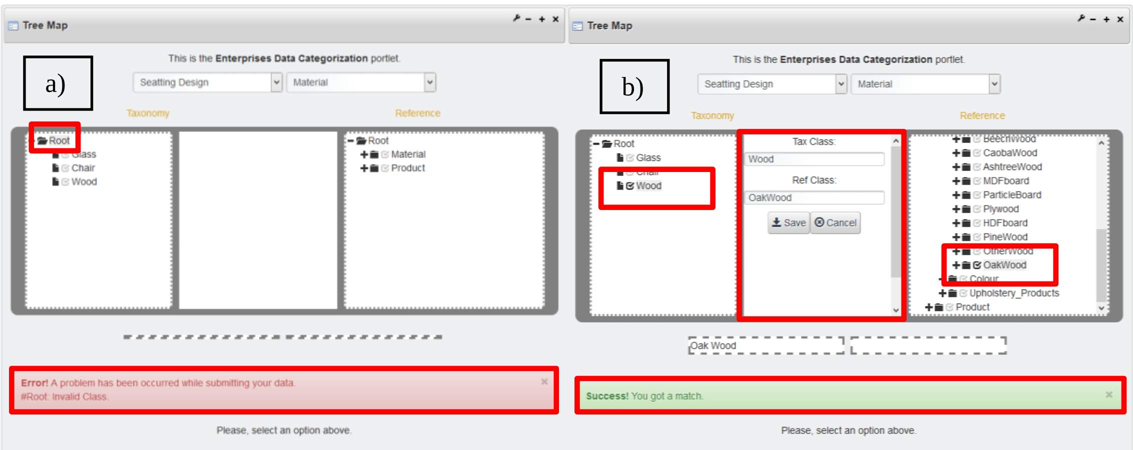
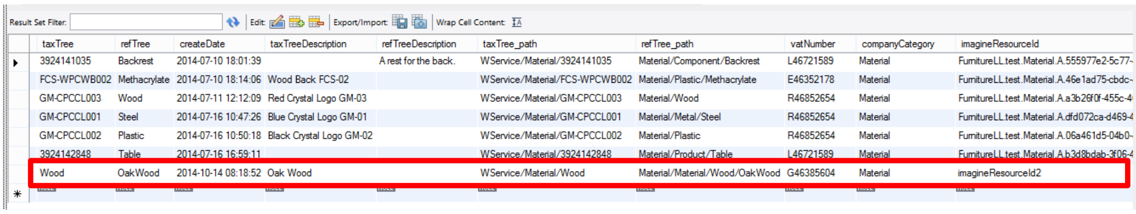


Figure 6.4 - Selection of a new mapping establishment (a) selected invalid node; (b) a valid correspondence

Therefore, the developed portlet implements messages to alert the user that it is committing an invalid or non-support operation. Figure 6.4 shows the selection process to enable new mapping establishment, where (a) shows the error message result by the selection of the *Root* node in the taxonomy tree; (b) illustrates a success message indicating that the user has established a valid correspondence. The Figure 6.4 (b) also shows the match between the concept *Wood* (which is described as Oakwood) and the reference concept Oakwood. When available, the concept's description helps the user to characterize the concept, thus help it to find the best accordant correspondence. Further, the mapping tool also indicates if the concept is pressed by checking the selected tree node. Both *taxonomy* and *Reference* Trees auto-scroll themselves to facilitate tree manipulation. Finally, the information is stored temporarily in the support database if the button *Save* is pressed, or even return the portlet state (illustrates in Figure 6.5) if the button *Cancel* is pressed.

6.2.2 Temporary Stored Mapping Demonstration

Due to the previous mapping described in the last Subsection, the resulted alignment is stored temporarily in the *mapping* table, as it can be seen in Figure 6.5.


Result Set Filter: Edit: Export/Import: Wrap Cell Content:

taxTree	refTree	createDate	taxTreeDescription	refTreeDescription	taxTree_path	refTree_path	vatNumber	companyCategory	imagineResourceId
3924141035	Backrest	2014-07-10 18:01:39		A rest for the back.	WService/Material/3924141035	Material/Component/Backrest	L46721589	Material	FurnitureLL.test.Material.A.555977e2-5c77-
FCS-WPCWB002	Methacrylate	2014-07-10 18:14:06	Wood Back FCS-02		WService/Material/FCS-WPCWB002	Material/Plastic/Methacrylate	E46352178	Material	FurnitureLL.test.Material.A.46e1ad75-cbdc-
GM-CPCCL003	Wood	2014-07-11 12:12:09	Red Crystal Logo GM-03		WService/Material/GM-CPCCL003	Material/Wood	R46852654	Material	FurnitureLL.test.Material.A.a3b26f0f-455c-4
GM-CPCCL001	Steel	2014-07-16 10:47:26	Blue Crystal Logo GM-01		WService/Material/GM-CPCCL001	Material/Metal/Steel	R46852654	Material	FurnitureLL.test.Material.A.dfd072ca-d469-4
GM-CPCCL002	Plastic	2014-07-16 10:50:18	Black Crystal Logo GM-02		WService/Material/GM-CPCCL002	Material/Plastic	R46852654	Material	FurnitureLL.test.Material.A.06a461d5-04b0-
3924142848	Table	2014-07-16 16:59:11			WService/Material/3924142848	Material/Product/Table	L46721589	Material	FurnitureLL.test.Material.A.b3d8bdab-3f06-4
Wood	OakWood	2014-10-14 08:18:52	Oak Wood		WService/Material/Wood	Material/Material/Wood/OakWood	G46385604	Material	imagineResourceId2

Figure 6.5 - The stored data in the mapping table (mySQL Workbench screenshot)

The table stores the enterprise resource named *taxTree*, the reference resource known as *refTree*, the submission data, the descriptions of both concepts, their tree paths, the enterprise *VatNumber*, the chosen company Category and the IMAGINE resource identifier.

6.2.3 Mapping update and Management Mappings Demonstration

It is possible to update the last resource and therefore change the content of the previously temporary mapping establishment. The user has to select the enterprise resource concept and change its correspondence with another reference concept. The Figure 6.6, show the previously mapped *Wood* concept with the reference *OtherWood* concept.

Once again the user needs to select the desired concepts and press the Update button to submit the new information into de database.

6. Mapping Tool Demonstration

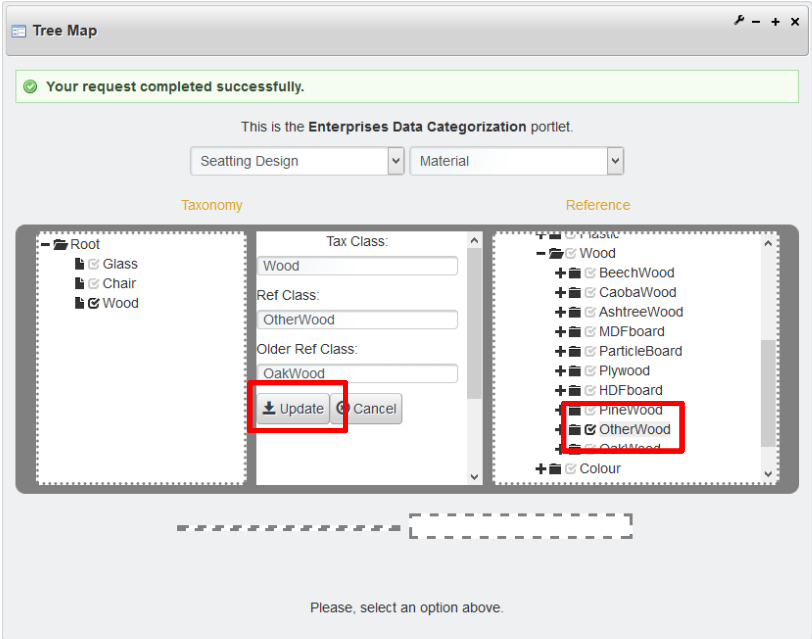
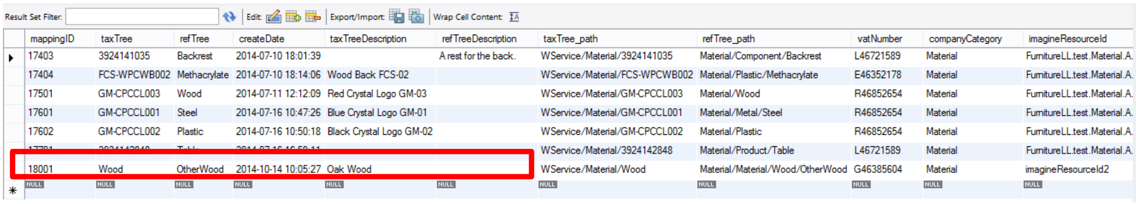


Figure 6.6 - Updating a mapped resource

At this stage the concept already has the new correspondent concept, as it can be seen in Figure 6.7.



mappingID	taxTree	refTree	createDate	taxTreeDescription	refTreeDescription	taxTree_path	refTree_path	vatNumber	companyCategory	imagineResourceId
17403	3924141035	Backrest	2014-07-10 18:01:39		A rest for the back.	WService/Material/3924141035	Material/Component/Backrest	L46721589	Material	FurnitureLL.test.Material.A.
17404	FCS-WPCWB002	Methacrylate	2014-07-10 18:14:06	Wood Back FCS-02		WService/Material/FCS-WPCWB002	Material/Plastic/Methacrylate	E46352178	Material	FurnitureLL.test.Material.A.
17501	GM-CPCCL003	Wood	2014-07-11 12:12:09	Red Crystal Logo GM-03		WService/Material/GM-CPCCL003	Material/Wood	R46852654	Material	FurnitureLL.test.Material.A.
17601	GM-CPCCL001	Steel	2014-07-16 10:47:26	Blue Crystal Logo GM-01		WService/Material/GM-CPCCL001	Material/Metal/Steel	R46852654	Material	FurnitureLL.test.Material.A.
17602	GM-CPCCL002	Plastic	2014-07-16 10:50:18	Black Crystal Logo GM-02		WService/Material/GM-CPCCL002	Material/Plastic	R46852654	Material	FurnitureLL.test.Material.A.
17701	3924142848	Table	2014-07-16 16:50:11			WService/Material/3924142848	Material/Product/Table	L46721589	Material	FurnitureLL.test.Material.A.
18001	Wood	OtherWood	2014-10-14 10:05:27	Oak Wood		WService/Material/Wood	Material/Material/Wood/OtherWood	G46385604	Material	imagineResourceId2
NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL	NULL

Figure 6.7 - The updated data in the mapping table (mySQL Workbench screenshot)

It is possible to see the control functions of the server side control since its operations are mirrored into the portlet interface. The portlet controls the number of the mapping establishments that already took place during its information control lifecycle (as previously discussed in Section 5.4.4) and consequently, its names and relations are also to be considered during this management phase.

After a successful mapping establishment, the portlet indicates the user by identifying the mapped node with a check mark. It also shows a message to tell what reference concept were previously mapped and automatically expands the reference tree to its target node by clicking on the mapped enterprises resource. The middle window also shows the present enterprise selected resource, the present selected reference resource and the old reference selected recourse. Figure 6.8, illustrates such portlet control behaviour.

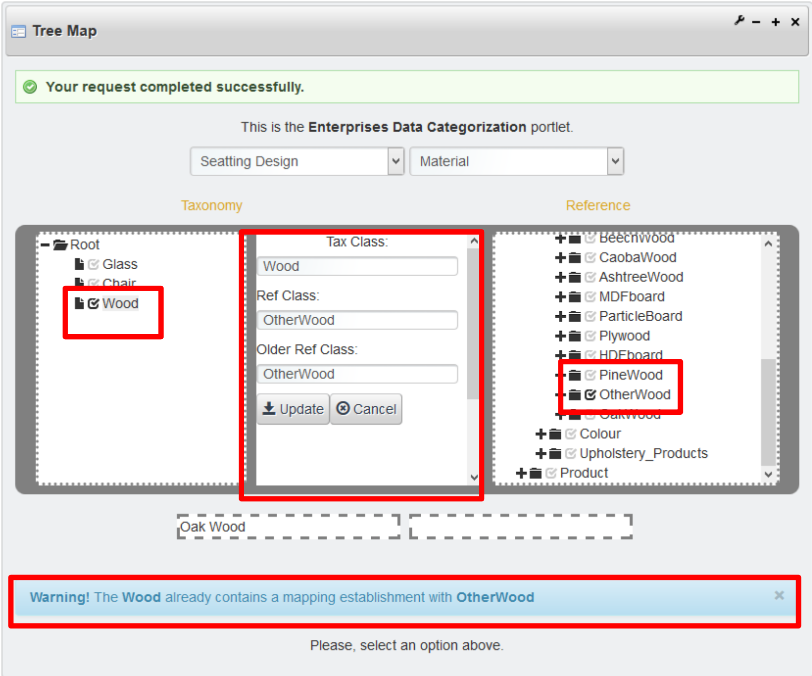


Figure 6.8 - The warning message to alert user to a mapped concept

The tool also alerts the user if only one concept it is selected, as it is illustrated in Figure 6.9, where the concept Chair "waits" for its correspondent reference pair.

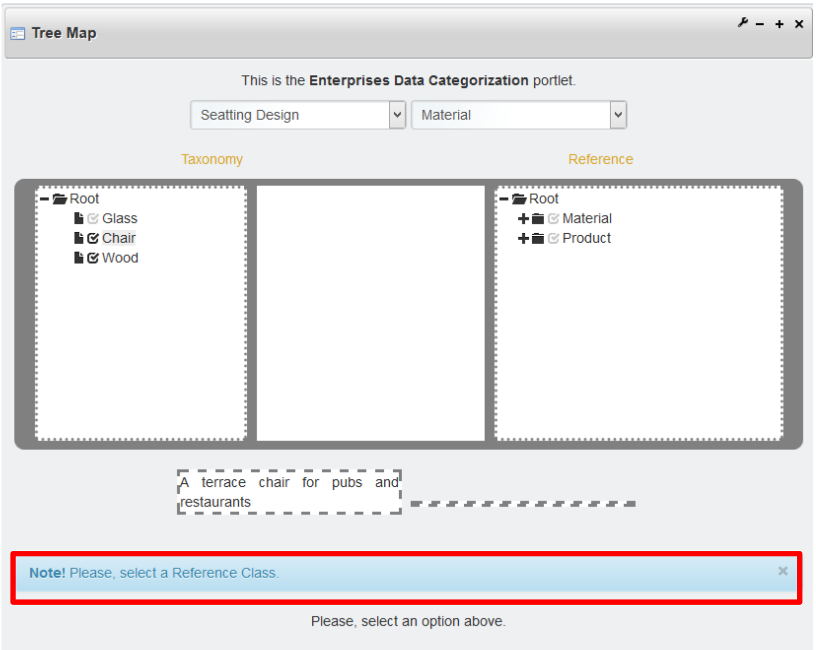


Figure 6.9 - Reference node to be selected

The portlet will show a message to notify the user that all available enterprise resources for a specific category are completely mapped and are prepared to send the aligned information to the platform, as it can be seen in Figure 6.10.

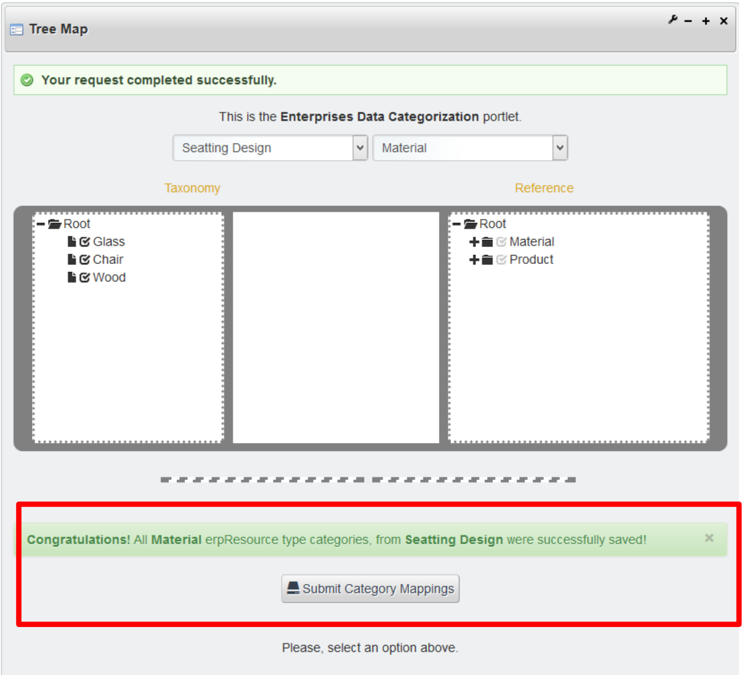


Figure 6.10 - Category resources submission message

6.2.4 Mapping Submission Demonstration

The Submission process gets all mapped resources, encapsulate the information in SOAP message and update the support database by removing the sent resources and marking the *Material* concept as for the Seating Design enterprise as fully mapped category. The portlet no longer shows the information regarding this category, since all resources were semantically aligned with a defined reference and sent to the platform. The processes are illustrated in Figures 6.11 and 6.12, respectively.

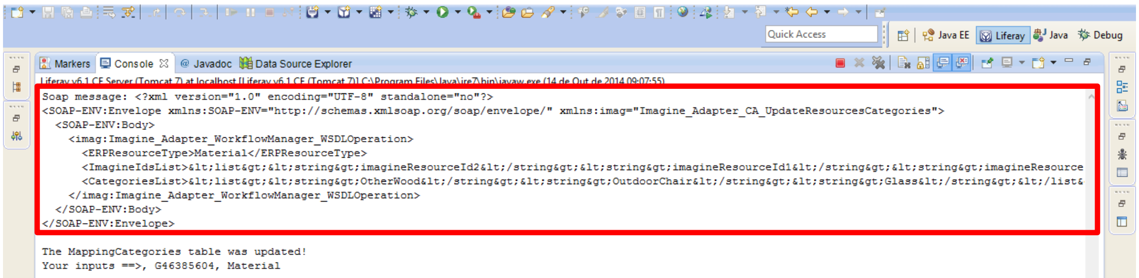


Figure 6.11 - The resulted SOAP message

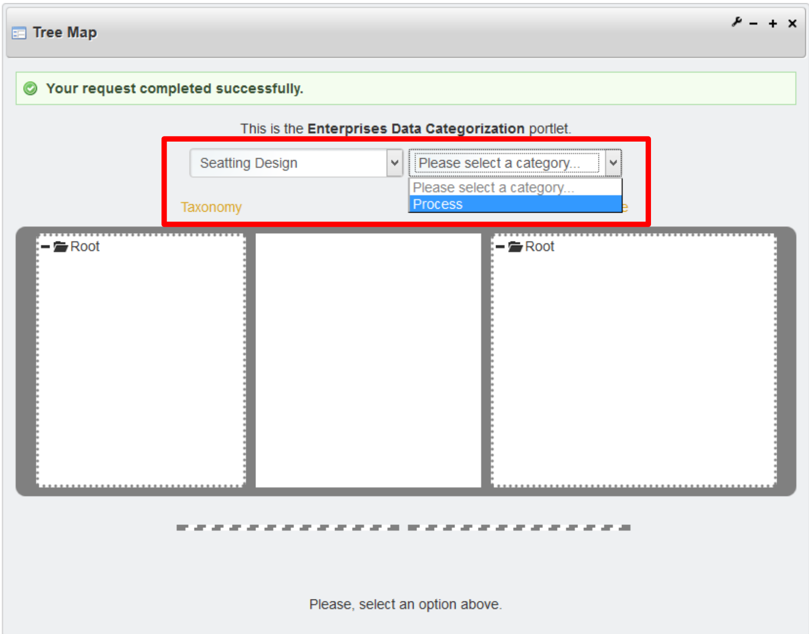


Figure 6.12 - The Seating Design categories after the Material resources submission

6.3 Hypothesis Validation

Regarding the research question presented in the beginning of this dissertation, it was verified that it is possible to semantically align the data exchanged between enterprises legacy system and systems databases by resorting to the guidelines provided by the proposed framework, thus facilitating the establishment of a dynamic manufacturing network.

6.4 Industry Contribution

The transition to industry was one of the identified steps discussed in Section 1.2: Research Methods. Thus, the chance to see the work being used in a real world scenario raises if it is well accepted by the industry sectors.

IMAGINE (Innovative end-to-end Management of Dynamic Manufacturing Networks) is a Research & Development project, funded by the European Commission under the “Virtual Factories and Enterprises” theme of the 7th Framework Programme (FoF-ICT-2011.7.3, Grant Agreement No: 285132). The project concerns with the

> *development and delivery of a novel comprehensive methodology and the respective platform for effective end-to-end management of dynamic manufacturing networks in an innovative plug and produce approach, and aims at supporting the emergence of a powerful new production model, based on community, collaboration, self-organisation and openness rather than on hierarchy and centralised control.* [76].

The initiative has a centralize system which in an autonomously way will facilitate an eventual supply or production problems, by providing a production manager the capability to monitor and track the production lifecycle of its joined manufacturing enterprises in the Furniture sector [75].

This work contributes to the IMAGINE project by semantically align each future collaborative enterprise domain knowledge (in the furniture sector) within a previously defined reference so the information can be readable without heterogeneity inconsistencies during the design phase of a new dynamic manufacturing network.

7

Conclusions and Future Work

The traditional manufacturing process practiced by enterprises fulfilled all market expectations and enabled them to achieve product competiveness. The growth of emerging technologies raised the consumer's expectations in how products are presented and produced. Consequently, this fact lead enterprises to adopt new approaches by embracing new collaborative schemes that inevitably changed the way how manufactures work and exchange knowledge under the same network architecture. Therefore, it is expected semantic interoperability issues during the establishment of a collaborative network, since each enterprise serenely have different knowledge, for instance in how the products are produced or dispatched.
The knowledge exchanged should put together a central line communication in order to offer a continuously and instant access to all available information existent in the network. Moreover, it is also important to define an adequate knowledge management and representation mechanisms to maximize knowledge sharing and acquisition.

The proposed framework was developed with the idea to provide specific information for manufacturing solutions in various contexts or situations, allowing at the same time enterprises to effectively assess if their ERP's data with in the current domain knowledge representation. Following pre-determined guidelines, defined in this work, it was possible to assess the semantic alignment of the involved resources on the application scenario that comprises clients, retailers and their suppliers. Furthermore, this framework can also be used for enterprises to establish the mapping of their own ERPs before the definition and creation of a new Dynamic Manufacturing Network. In conclusion, the proposed framework could prove to be a valuable asset in helping, as a guideline, in the semantic alignment establishment of enterprise's knowledge domain.

7.1 **Future Work**

The main purpose behind the developed solution is to have seamless knowledge interoperability between different representational systems, and in order to fulfil that goal all cases that can be identified need to be implemented. Therefore, in terms of future work, more features of the prototype tool can be implemented such as, the cases of 1-N mapping, supported with merged operation and finally an integration with a mediator ontology for advanced reasoning solutions implementation.

8

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9 Appendix

9.1 TreeMap MVCPortlet super constructor

```
@SuppressWarnings({ "null", "rawtypes" })
	public void doView(RenderRequest renderRequest, RenderResponse
renderResponse)
	throws IOException, PortletException {

	String initializations =loadPortletSettings();
	String mapping_info_tabel= loadMappingInfo();

	renderRequest.setAttribute("last_mapping_establ",getLastMappingE
stablishment());
	renderRequest.setAttribute("portlet_content",initializations);
	renderRequest.setAttribute("mapping_info",mapping_info_tabel);
	renderRequest.setAttribute("string_tree_material",getReferenceTr
eebyConcept("Material"));
	renderRequest.setAttribute("string_tree_product",getReferenceTre
ebyConcept("Product"));
	renderRequest.setAttribute("string_tree_process",getReferenceTre
ebyConcept("Process"));
	renderRequest.setAttribute("string_tree_equipment",getReferenceT
reebyConcept("Equipment"));
		super.doView(renderRequest, renderResponse);
}
```