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Ontologies for Temporal Estimation of Interoperability in Enterprise

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Abstract: The concept of interoperability has become a major challenge that must be taken into account when attempting inter-enterprise collaboration or even within an enterprise. Indeed, a lack of interoperability can lead to the appearance of problems, dysfunctions, slowdowns or more generally, losses of performance which generate a decrease in confidence between the partners. Among the existing approaches to ensure interoperability, ontologies are the most used. Ontologies are formal systems whose objective are to represent the knowledge of a domain by means of concepts, defined and structured in relation to each other. The ontological representation of knowledge ensures the maintenance of the coherence and integrity of the system as well as the evolution of the representation without changing the structure. On the other hand in order to face increasing competition, industrial enterprises must improve their organizations and operations in order to meet the requirements of quality, cost and time which are major support for industrial performance. This study presents ontologies for temporal estimation of interoperability in enterprise. Our approach consists in extracting the semantic relations from a created ontology and then in estimating the interoperability time in order to compare it with the real time within a system. The approach is applied to a local enterprise for the marketing of petroleum products and derivatives. The obtained results illustrate the losses that this enterprise undergoes in different periods by estimating the interoperability time.

Key words: Ontology, relationship, interoperability, time, evolution

INTRODUCTION

Interoperability has become a major challenge for enterprises because of the problems of heterogeneity. This problematic can be supported by ontologies. Ontologies are formal systems whose objective are to represent the knowledge of a domain by means of concepts, defined and structured in relation to each other. The ontological representation of knowledge ensures the maintenance of the coherence and integrity of the system as well as the evolution of the representation without changing the structure. On the other hand, the impact of globalization is forcing enterprises to be competitive. This competitiveness needs a performance improvement and more production in a shorter time.

The impact of globalization is forcing enterprises to be competitive and this competitiveness needs a performance improvement and more production in a shorter time. Interoperability has become a major challenge for enterprises because of the problems of information heterogeneity and also since of the inter enterprise collaboration or even within an enterprise. Indeed, an interoperability, lack can lead to the dysfunctions, slow downs and performance losses. This problematic can be supported by ontologies.

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Need for interoperability in enterprise: An enterprise is composed of several departments and services, each department can contain one or more services we group in the concept 'entity' these different notions. The interactions between the different entities can be intra or inter-enterprise. An intra-firm interaction is a relationship linking to internal entities to the system. Inter-enterprise interaction is a relationship that an entity in the system can have with another entity external to the system.

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The interoperability concept: Enterprises of assets or services must continuously improve their performance, requiring inter and intra enterprise cooperation which makes it necessary to consider interoperability.

One of the first definitions clarifying the concept of interoperabilityemerged in 1990 by the IEEE (Cypher, 1999) as “the ability for two or more systems to exchange information and to mutually use the information that has been exchanged”. This first definition concerned only areas related to computing but since then interoperability has spread across several domains and several European projects such as IDEAS (Interoperable Design of Extreme-scale Application Software) INTEROP (Doumeingts, 2006), AIF (Athena Interoperability Framework).

These projects have been initiated to respond to this need which explains the interest and enthusiasm surrounding the interoperability paradigm. Interoperability has also been the subject of several standardization work both in the technical fields with ISO 17933 in 2000 and in fields related to industrial systems with ISO 14258 in 1998.

We are interested in this work to interoperability in enterprises. We retain the definition of ISO11354-1 of 2011 which defines interoperability in enterprises as “the ability of enterprises and entities within these enterprises to communicate and interact effectively”. Interoperability is ultimately an essential ability to master for the improvement of interactions between enterprises in a collaborative situation or within an enterprise.

Interoperability representation

Ontology: Historically, ontology is a philosophical concept designating the science of being. Over the years, ontology has developed in the field of artificial intelligence in order to solve the problems of modeling knowledge and more specifically, knowledge engineering, The reference definition of ontology is given by Gruber (1993). “An ontology is a formal and explicit specification of a conceptualization”.

Each ontology includes concepts characterized by slot properties that describe them these concepts are associated via relationships. The subsumption relation is a defines a generalization link called hyperonymy and formally permits the inheritance of concepts. The is a relation must be supplemented by semantic relations to express the semantics of the domain. A semantic relation R_{sem} is defined by the concepts (c_i, c_j) that it connects with c_i the domain of the relation and c_j its range (Cimiano, 2006; Gruber, 1993).

Exploitation of ontological relationships: Once created, ontology cannot be used or exploited directly by the user, it is therefore necessary to represent it by means of a formalism that will acquire all its importance once integrated. There are very few tools dedicated to the exploitation of ontologies, the most prominent are the Jade platform and the Jena API.

Jade: Java agent development framework is a multi-agent platform developed in Java. Its aim is to simplify the development of multi-agent systems by ensuring the conformity of the standards by a complete set of services and agents in conformity with the FIPA standards (foundation for intelligent physical agents). The architecture of Jade is based on the coexistence of several virtual machines and the communication between these machines is done via the method RMI (Remote Method Invocation) (Miranda *et al*., 2013; Mustafa and Aldabagh, 2014).

Jena: Is an API (Application Programming Interface) developed by researchers from the Hewlett-Packard laboratory in the United Kingdom in 2000. This API dedicated to semantic web applications allows to read, manipulate ontologies described in RDFS or in Owl and to apply certain mechanisms of inferences. Jena provides a number of Java classes dedicated to the ontology manipulation described in owl (Horridge and Bechhofer, 2011; Carroll *et al*., 2004).

The Jena API: After studying the two tools, we chose the Jena Api as it is a framework designed especially for the exploitation of ontologies. It includes a set of programming tools for reading and extracting relationships using the Java programming language. Jena has also object classes to represent graphs, these classes are named.

Resource (subject): A resource is an entity that you want to refer to. It can be a web page a link a particular user identity.

Property (predicate): A property specifies the characteristics of the resource.

Object (literal): A literal value represents a data or a resource.

MATERIALS AND METHODS

We present in this study the proposed methodology. The obtained model is based on a modular approach.

Modular approach: Our approach is split into two modules an ontology representation module and a temporal estimation module (Fig. 1).

The first module consists in creating an ontology formalizes the knowledge of a real system. This ontology includes the interactions between and within the system. In order to extract theses different existing relations we use the API Jena.

Each extracted relation has a time that will allow the second module to calculate the interoperability time. This time is compared with the real time estimate of the enterprise in order to indicate the losses and the malfunctions that may arise.

Temporal estimation of ontological relationships: To measure the operational performance of an enterprise, it is essential to evaluate time, quality and cost (Corcho *et al*., 2004) proposed in their work to evaluate the interoperability time by estimating the time required to send the request, the duration of the processing of the request, the duration of the return and the time necessary to use the request.

In the intra-enterprise, the duration of the sending and the return of the request depends on the policy established. The different possibilities for exchanging information between the different members of a system can be:

- Oral transmission
- A paper handmade
- Phone call
- Use of fax
- Sending e-mail (containing an attached file or not)

However, a bad choice of exchange can hinder a delay a slowdown or more generally of losses of performance that can lead to a decrease in trust between the partners. We propose to take the minimum of the times of exchange. The principle of the interoperability estimation is showed in the Fig. 2. So, the interoperability time will be equal:

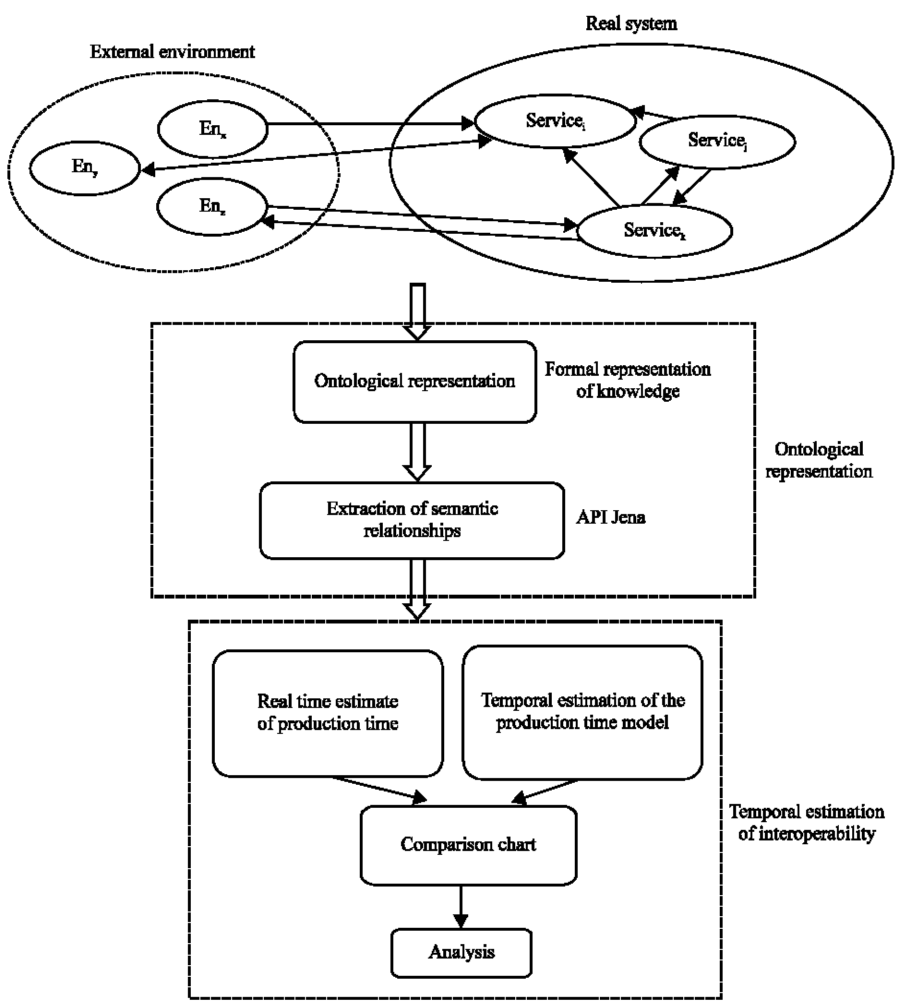


Fig. 1: Model of the proposed approach

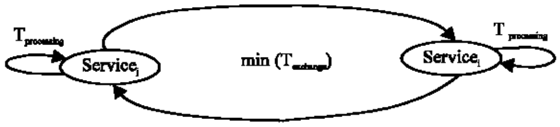


Fig. 2: Interoperability estimation

$$T_{intero} = \sum(T_{processing}) + \min(T_{exchange}) \quad (1)$$

Where:

T_{intero} = Interoperability time

$T_{processing}$ = This time groups the execution time, the time of use or validation

mins ($T_{exchange}$) = The minimum time of sending and returning the request

RESULTS AND DISCUSSION

Application to a real production enterprise: We apply the proposed approach to a real enterprise of production.

Specification of the enterprise: The application is carried out on a private enterprise specializing in the marketing of petroleum products and derivatives (fuels, lubricants, bitumens). Its main mission is to meet the needs of the market and more particularly customers by offering them a range of diversified and quality products. Its annual production of products is 45000 tons/year.

Organizational structure of the enterprise: The structural hierarchy of the lubricants production enterprise consists of five services attached to the director as shown in Fig. 3.

Functional approach: All the functions provided within this company are control, production, financial, supply chain and development function.

The control function: In order to offer its customers a superior quality product meeting all the standards required in its branch of activity, the control function managed by quality control department controls the products and the manufacturing process and this by obeying a set of procedures adapted to the system in place. The certifications acquired by the enterprise are ISO-9001 V 2008, ISO 14001 V 2004 and OHSAS 18001 V 2007. This enterprise uses the best laboratory equipment by acquiring state-of-the-art equipment including X-ray spectrometry, added to other viscosity control means and several other utilities yet. The quality control service contains the quality manager, supervisor and laboratory.

The production function: This function, managed by the production manager, ensures that the production plan is carried out in accordance with the qualitative specifications and requirements of the production department as well as the human and material resources at its disposal. The production function is split into the maintenance and process functions. The maintenance function keeps track the maintenance, the proper functioning of the equipment and the installation of the peripherals. The process function manages production.

Financial function: This function is managed by the accounting department, undertakes economic and financial studies related to investments, manages relations with banking organizations and negotiates with external partners on behalf of management (customers, suppliers, administration, accountants).

Supply chain function: This function is governed by the supply chain service which manages the availability of assets and is in close contact with customers, suppliers and carriers. It also coordinates the entire supply chain while negotiating with suppliers.

Development function: This function is managed by research development whose main mission is the search for new engine oils and hydraulic oils.

Modeling enterprise interoperability: Following the model, the first step is the creation of the ontology.

Creation of the ontology: After studying the enterprise, we identified 22 intra-enterprise relationships and 6 inter-enterprise relationships. Knowing that the main mission of this enterprise is the manufacture of petroleum products and derivatives we are particularly interested in the interactions in products which are 11 in number.

- Relation ordre_melange between the supervisor (superviseur) and the process (process)
- Relation op_melange made by process engineer (ingenieur process)
- Relation controle_echantillon between the process engineer and the laboratory (laboratoire)
- Relation echantillon_conforme between the laboratory and process engineer
- Relation decharge_cuves made by process engineer
- Relation ordre_cond between process engineer and packaging manager (responsable conditionnement)

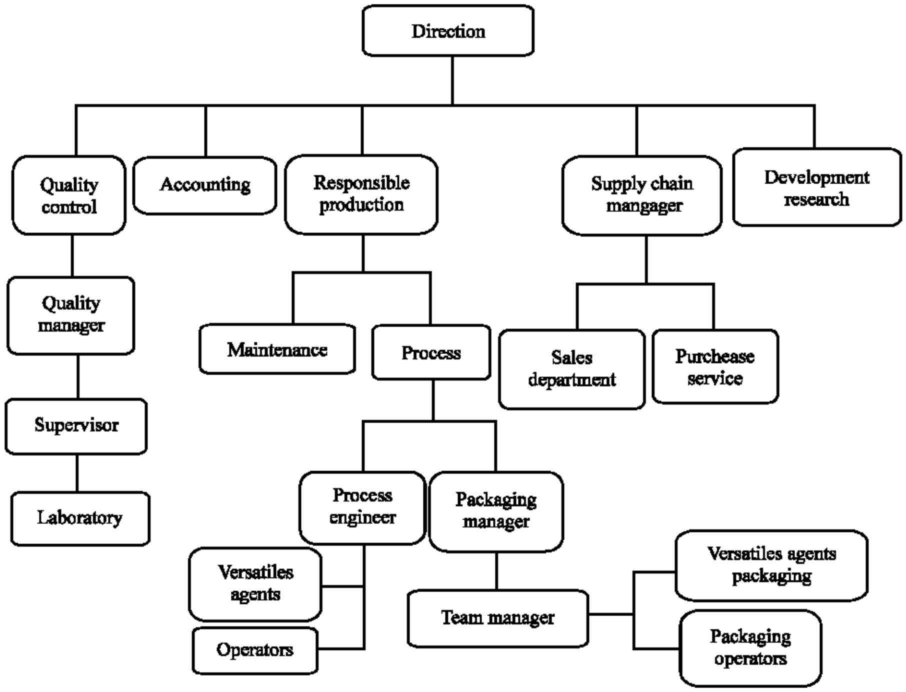


Fig. 3: Organizational structure

- Relation cond_fut between the packaging manager and the team manager (chef equipe)
- Relation controle_fut between the laboratory and quality manager (responsable qualite)
- Relation order_package between the laboratory and responsible packaging
- Relation emblallage made by the respnsable packaging
- relation transfert between the packaging manager and the sales department (S commercial)

The creation of the ontology is done by the Protege tool. Protege (Malviya *et al*., 2011; Sivakumar and Arivoli, 2011) is a graphical ontology development environment based on the Methondology methodology (Corcho *et al*., 2003). Its architecture allows users to insert plugins (Dudas *et al*., 2014; Knublauch *et al*., 2004; Lohmann *et al*., 2014) that can bring new functionalities while benefiting from the latest advances in ontological research (knowledge base management, ontology visualization, alignment and merge, etc). Figure 4 shows the set of productive interactions. With the green color green illustrates hierarchical relationships. The blue color shows semantic relations.

Extraction of semantic relations: After integrating the Jena API into the Eclipse programming environment (Ameen *et al*., 2014) we read the file.owl in order to extract relationships.

Jena provides the ability to generate all existing relationships from the owl file or to program filters based on the three criteria: subject/property/object. We obtain as a result a set of relations R with R = $\{R_1, R_2, ..., R_n\}$ where each relation R_i is in the form of a triple {S, P, O} with S: Subject refers to a class or relationship. P: Property with the type of the subject. The criterion P can take three choices. P = [t, d, r] with t: type (relation or class); D: domain (an incoming entity of the relation); R: range (the outgoing entity of the relation). O: Object that is a class.

The different results of the executions are recorded in a text file and Fig. 5 and 6, respectively list for each relation the domains and the ranges. For example, for the relationship Order_Package (Ordre_Emballage) we have; Order_Package|Domain|Laboratory; Order_Package|Range|Packaging Manager.

Temporal estimation of interoperability in production: In this study, the second step of the model is described to measure interoperability by taking an example of production.

Application to recipe production "engine oil"

Recipe production procedure: This enterprise produces exclusively lubricants (engine and hydraulic oils) and bitumens. We take for example the lubricants and consider the production of the SAE 40CDX1 engine oil recipe with

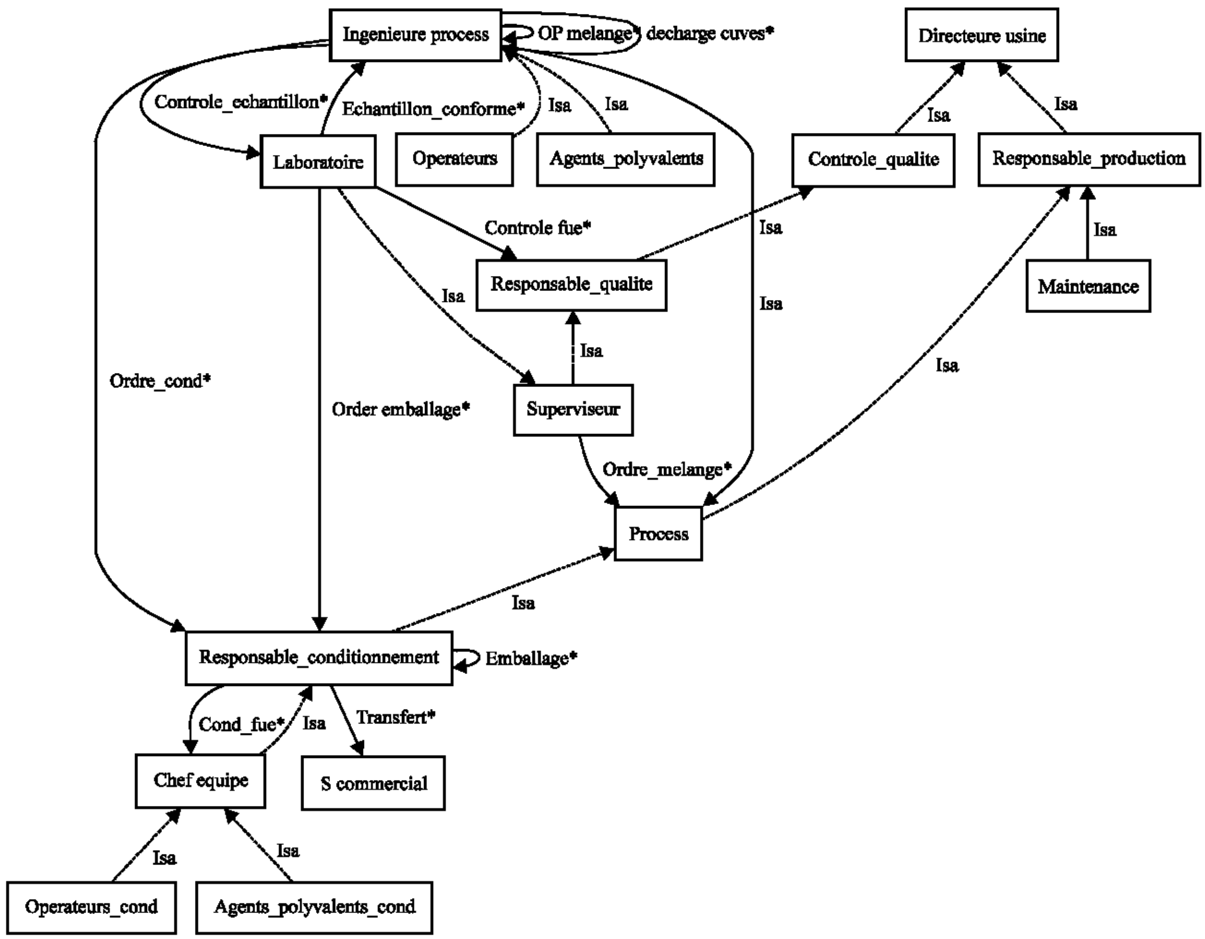


Fig. 4: Interactions of production department

a quantity of one Batch (1 Batch = 10 tons). After the supervisor attached to the quality control specifies the dosage of the base oil and the additive necessary for the production of the recipe a production order is given to the process attached to the production manager. The tasks of recipe process are:

- The process service performs the mixing operation in an estimated time of 60 min
- The manufacture is controlled by the laboratory to test its conformity, this treatment lasted 15 min
- The packaging manager unloads the recipe in the tanks in 30 min (there are 8 storage tanks, each tank has a capacity of 20 tonnes)
- The drum conditioning phase is established by the Team leader, this phase lasted 1 h 20 min and the control of trums is done by quality manager in 30 min
- The packaging manager carries out the packaging of the barrels in an estimated time of 30 min

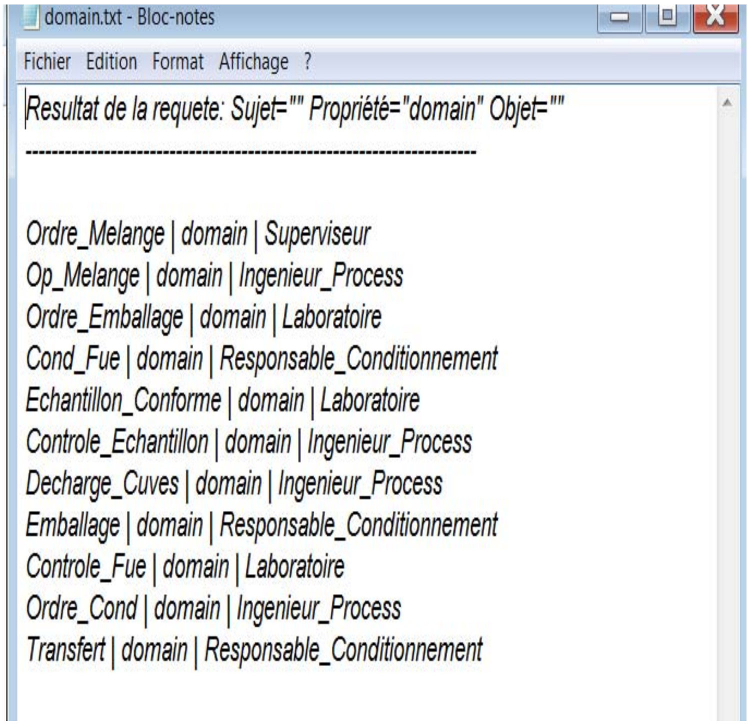
Thus, the production of the recipe is split in to:

- The manufacturing process established by the process engineers includes mixing operation, laboratory agreement and unloading in the storage tanks
- Packaging drums and control
- Packaging

Workforce of the enterprise: The enterprise owns an ABB mixer with a manufacturing capacity of 45,000 T/year, 2 blowing units, 1 canister packaging unit, pumpers with a unit capacity of 3 tons of 1 L/day and 11 tons of 5 L/day for a total of 14 tons/day.

Intra enterprise exchanges: The intra-enterprise exchange is either by phone calls or by sending mail with respective estimates of one minute and 15 min.

Process diagram: All the activities of the production process of the recipe are given in a process flow chart

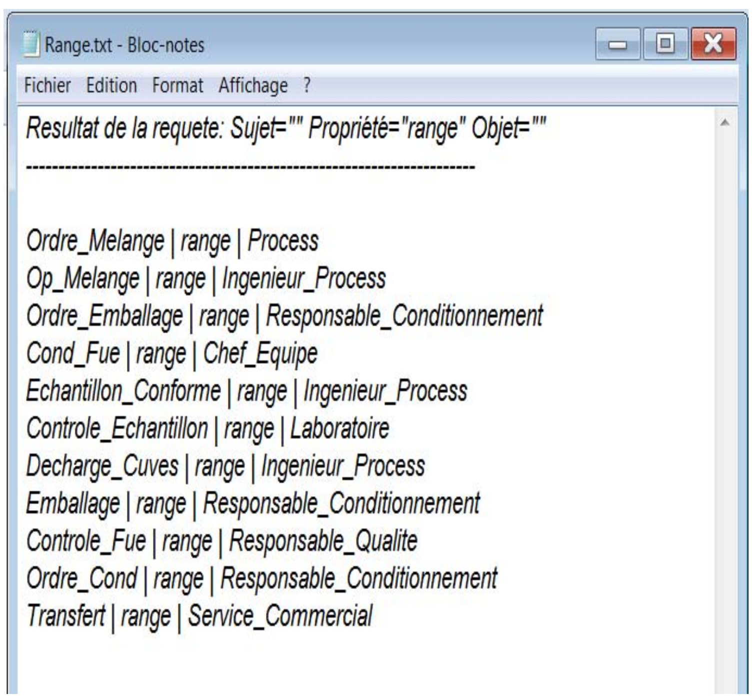


domain.txt - Bloc-notes
Fichier Edition Format Affichage ?

Resultat de la requete: Sujet="" Propriété="domain" Objet=""

Ordre_Melange | domain | Superviseur
Op_Melange | domain | Ingenieur_Process
Ordre_Emballage | domain | Laboratoire
Cond_Fue | domain | Responsable_Conditionnement
Echantillon_Conforme | domain | Laboratoire
Controle_Echantillon | domain | Ingenieur_Process
Decharge_Cuves | domain | Ingenieur_Process
Emballage | domain | Responsable_Conditionnement
Controle_Fue | domain | Laboratoire
Ordre_Cond | domain | Ingenieur_Process
Transfert | domain | Responsable_Conditionnement

Fig. 5: Relationships domains



Range.txt - Bloc-notes
Fichier Edition Format Affichage ?

Resultat de la requete: Sujet="" Propriété="range" Objet=""

Ordre_Melange | range | Process
Op_Melange | range | Ingenieur_Process
Ordre_Emballage | range | Responsable_Conditionnement
Cond_Fue | range | Chef_Equipe
Echantillon_Conforme | range | Ingenieur_Process
Controle_Echantillon | range | Laboratoire
Decharge_Cuves | range | Ingenieur_Process
Emballage | range | Responsable_Conditionnement
Controle_Fue | range | Responsable_Qualite
Ordre_Cond | range | Responsable_Conditionnement
Transfert | range | Service_Commercial

Fig. 6: Relationshipe ranges

(Pahl and Beitz, 2013). This formalism is widely used in industry to describe and improve a production process. It analyzes the sequence of actions that make up a process. These actions are decomposed in to: operations, intended

	Flow chart							
	Lubricants and bitumen production company					Day 13/04/2014		
	Studied process: Production of SAE 40CDX1 engine oil recipe		Operation	Transfer	Storage Destocking	Control	Waiting	Time (min)
		Description of activities						
Final production	Manufacturing process	Additive mixture with base oil	60					60
		Telephone call between the process engineer and the laboratory					1	1
		Conformity test	15					15
		Sending mail of the conformity sheet to the process engineer					1	15
		Unloading and storage in storage tanks		25	5			30
	Outside manufacturing	Telephone call between the process engineer and the package manager					1	1
		Packaging drum and control			8	3	1	111
		Order for packaging to the package manager					1	1
		Packaging of drums	30					30
Total			105	25	85	30	19	264

Fig. 7: Process diagram

to modify the characteristics of the material for example machining, forming, assembly. The operations of an industrial production process almost always involve machines that can be automated or not. Transfers intended to modify the location of the material. Storage, intended to allow the passage of time without influencing the characteristics or the location of the material. Controls, intended to control the quality of the product, generally by comparison or by measurement. Waiting represented the waiting time. Figure 7 presents the process diagram where the durations of the various operations involved in manufacturing and final production process are mentioned.

Temporal estimation of interoperability: To calculate the interoperability time we take into account the steps of production of the recipe.

Real estimation: The real estimation is evaluated from the above times on two levels, the final production and the manufacturing process.

In final production: The real estimation of the final production is evaluated through the following Eq. 2:

$$\text{Time production of a Batch} = \text{Time processing} + \text{Time exchange} \quad (2)$$

Where:

$$\text{Time processing} = \text{Time to make the recipe} + \text{Time packaging and control} + \text{Time packaging}$$

So, for the example, the production time of a Batch = 264 min/Batch.

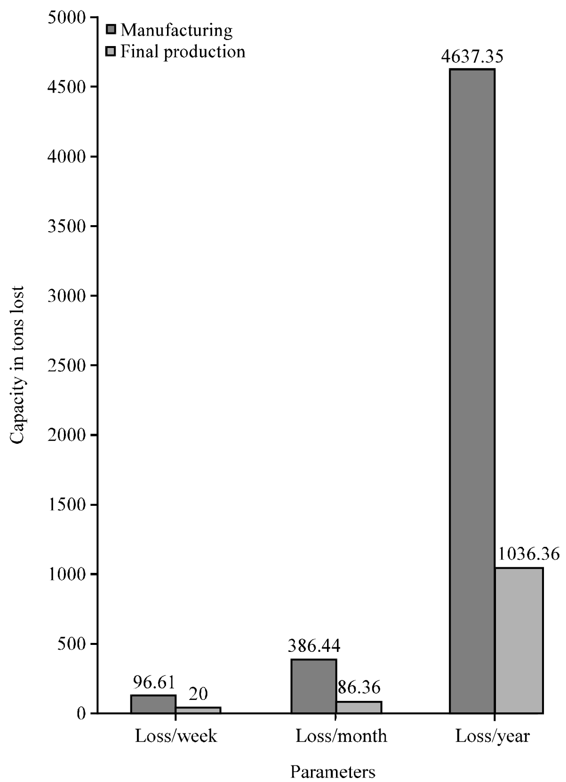


Fig. 7: Capacity in tons lost on different manufacturing and final production periods

In manufacturing: From the Eq. 2, the timely processing is deduced. So, the recipe making time is 121 min/Batch.

Estimation in the model: As mentioned above, the intra enterprise exchange is established either by phone call estimated at one minute or by sending an email estimated at 15 min. According to Eq. 1, we take the minimum exchange time and we calculate the interoperability time in the final production and manufacturing process based on the different temporal estimates in Fig. 8. So, the waiting time of the mail sending activity will be 1 min. In final production: the estimated interoperability time ($T_{interop}$) of the final production is 250 min/Batch.

In manufacturing: The interoperability time is evaluated to 107 min/Batch.

Interpretation of results: The obtained results can be interpreted through the waste of time on the two levels.

In final production: The difference between the real production time in the enterprise and the calculated is 14 min/Batch. This means that for the production of a 10 T, the enterprise loses 14 min:

Table 1: Production and manufacturing losses

Loss	1 Batch	24 h	Weeks	Months	Years
Manufacturing					
Minute	14	167	1169	4676	56112
Batch		1,5	9 Batch 6T	38 Batch 6 T	463 Batch 7T
Tonne		15	96,61	386,44	4637,35
Production					
Minute	14	76	532	2280	27360
Batch		Conditioning the barrels	2	8 Batch 6 T	103 Batch 6T
Tonne			20	86,36	1036,36

- In 24 h, the enterprise is losing 76 min, this time can be gained in the phase of conditioning the barrels
- In 1 week, the enterprise lost 532 mins equivalent to the production of 2 Batch (20 T)
- Within 1 month, the enterprise loses 2280 mins equivalent to production of 8 Batch and 6T (86, 36 T)
- In 1 year, the enterprise loses 27360 mins equivalent to the production of 103 Batch and 6 T (1036, 36 T)

In manufacture: In the production, the loss of 14 min is not felt in the process of packaging of the barrels. Employees attached to the packaging cannot stop their work, unlike manufacturing employees who must wait for the laboratory compliance card to be able to unload in the storage tanks.

The difference between the real manufacture time in the enterprise and the calculated is 14 min/Batch. This means that for the production of a 10 T the enterprise loses 14 min. So:

- In 24 h, the enterprise loses a total of 167 mins, equivalent of manufacturing 1.5 Batch (15 T)
- In a week, there is a loss of 1169 mins equivalent of manufacturing 9 Batch 6T (96, 61 T)
- In 1 month, 4676 minutes are lost equivalent to the manufacture of 39 Batch 6T (386, 44 T)
- In 1 year, 56112 mins are lost equivalent to the manufacture of 463 Batch 7T (4637, 35 T)

Table 1 summarizes the different results. The results obtained show that a poor exchange procedure affects the production and manufacture of the product. The most appropriate case for this enterprise is that laboratory should not penalize the manufacturing process, it should just confirm by telephone call to the process engineer the unloading in the storage tanks and after sending the compliance form by email.

CONCLUSION

We present in this study ontologies for temporal estimation of interoperability in enterprise. We discussed the notion of ontology and interoperability while detailing the proposed approach which is split into two modules. The first one describes the representation of relationships through an ontological mode and the second one evaluates the temporal interoperability in the enterprise.

Our goal was to be able to calculate the interoperability time and to compare it with the real estimate in the enterprise in order to detect the dysfunctions and the slowdowns which can hinder the good functioning of the enterprise.

The case study was done on a real example of a petroleum products and derivatives business. The obtained results show that a poor exchange procedure affects the production and manufacture of the product. The most appropriate case for this enterprise is that laboratory should not penalize the manufacturing process, it should just confirm by telephone call to the process engineer the unloading in the storage tanks and after sending the compliance form by email.

At the end of this study and by comparing the different results obtained we were able to show that a bad choice of exchange information between services has large repercussions on the quantity of production daily, monthly and yearly.

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