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Knowledge Sharing within Extended Enterprises: Case of Product Lifecycle Management systems

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Abstract: When it is made explicit by someone, knowledge becomes information source of knowledge for someone else. Thus knowledge sharing cannot be reduced to information sharing. The aim of this paper is promote knowledge sharing, whether tacit or "explicited" by individuals within extended enterprises. Product Lifecycle Management (PLM) systems aim at an integrated management of all product-related information and processes within extended enterprises throughout the entire lifecycle of a product. In this paper, we propose (1) to outline a semantic interoperability between a collaborative platform and a Product Lifecycle Management (PLM) system, and (2) to highlight the conditions under which a piece of information shared through a PLM system may lead to one and only one interpretation. Step (1) allows individuals to construct a shared understanding, supporting tacit knowledge sharing, whereas step (2) leads to ensure explicited knowledge sharing, i.e. knowledge that has been made explicit by someone within a certain context. PLM systems are strongly integrated within extended enterprises and their use will illustrate in this paper how our approach supports knowledge sharing. The conditions and limits of our approach, as well as its study within industrial fields, are discussed at the end of this paper.

Keywords: Knowledge Sharing, Extended Enterprise, Tacit Knowledge, Semantic Interoperability, Product Lifecycle Management.

1. Introduction

Working together within an extended enterprise is not as natural for people as working alone to pursue their own objectives. Within an extended enterprise, i.e. a network of firms collaborating in a project to achieve a common goal (Ross el al., 2006), systems interact in order to share information throughout a product lifecycle. Sharing knowledge cannot be reduced to sharing information: according to Tsuchiya (1993) knowledge can be regarded as the result of the interpretation by someone of information. So that authors as Walsham (2001) highlighted that the limit of computer systems is reached within extended enterprises when there is no awareness that the same information shared within the same extended enterprise through the same system may lead to different interpretations.

The aim of this paper is (1) to outline a semantic interoperability between a collaborative platform and a Product Lifecycle Management (PLM) system, and (2) to highlight the conditions under which a piece of information shared through a PLM system may lead to one and only one interpretation. Step (1) allows individuals to construct a shared understanding, supporting tacit knowledge sharing, i.e. knowledge that cannot be made explicit according to Polanyi (1958), whereas step (2) leads to ensure explicited knowledge sharing, i.e. knowledge that has been made explicit by someone within a certain context.

After remembering the vision of knowledge in the organization and the PLM model adopted in this work, the research proposition is introduced and tacit and explicited knowledge sharing will be explained. The perspectives of this work as well as its added value will finally be discussed at the end of this paper.

2. Background literature

Relying on the assumption that within extended enterprises individuals may interpret differently the same information, this work focuses on knowledge as being the result of the interpretation of information by someone according to Tsuchiya (1993).

The vision of knowledge in the organization adopted in this paper is introduced in the first parts of this section. Different models of PLM are then presented in the second part of this section.

2.1 A vision of knowledge in the organization

As the authors of this paper, we have got tacit knowledge, i.e. an individual cognitive construction, that we have structured into information during a process of sense-giving. As the readers of this paper, you have interpreted this information perceiving forms and colors, absorbed words, data, during a process of sense-reading, possibly creating new tacit knowledge for you (see Fig. 1). Sense-giving and sense-reading processes are defined by Polanyi (1967) as follows: "Both the way we endow our own utterance with meaning and our attribution of meaning to the utterances of others are acts of tacit knowing. They represent sense-giving and sense-reading within the structure of tacit knowing" (Polanyi, 1967, p. 301).

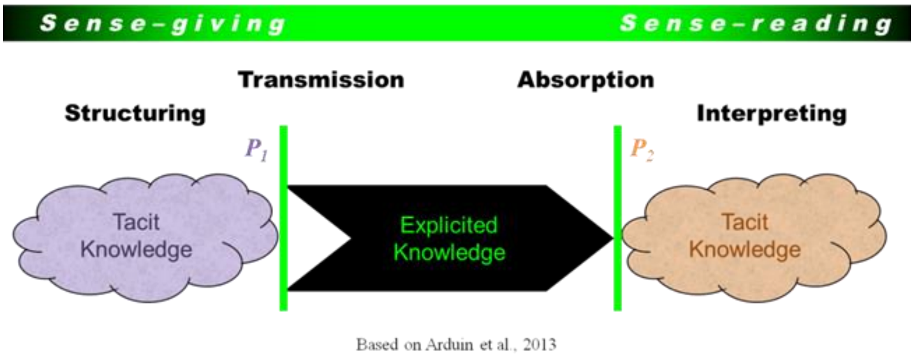

Figure 1: Knowledge sharing: explicited knowledge is transmitted and interpreted to create tacit knowledge

Information is continuously interpreted during sense-reading processes. Within extended enterprises, information can be transmitted by speaking, writing or acting, and also through information systems, such as PLM systems. Knowledge can then be:

- *explicited*, i.e. it has been made explicit by someone within a certain context, it is socially constructed and can be supported by information technologies such as information. Individuals, as well as computers are "information processing systems" as said by Hornung (2009, p. 9),
- *tacit*, it is not always articulated and cannot always be articulated, relying on Polanyi (1958) notably: "we can know more than we can tell".

So that explicited knowledge is tacit knowledge that has been made explicit by someone within a certain context. It is information source of tacit knowledge for someone else. It is "what we know and can tell" answering to Polanyi (1958) quoted above. The term "explicit knowledge" is often used (by Nonaka and Konno, 1998, or Nonaka and Takeuchi, 1995, notably), whereas it does not reflect the dynamic of the sense-giving process as well as the term of "explicited knowledge". Indeed such process is attached to a certain person acting within a certain context. That is the reason why we prefer to use the expression "explicited knowledge", which clearly shows how every piece of information can be seen as a piece of knowledge that has been made explicit by someone within a certain context.
One interprets information and creates a piece of tacit knowledge, which has a meaning for him/her. Within an extended enterprise, there may be someone who has received the same information and, interpreting it, has created a piece of tacit knowledge, which has a meaning for him/her. This meaning can differ from one person to another. Nevertheless, the use of a collaborative platform may lead to elaborate a shared understanding. We present in this paper how such platforms can be integrated in a PLM system. Now a few models of PLM are going to be presented.

2.2 Different models of Product Lifecycle Management

Product Lifecycle Management (PLM) aims at an integrated management of all product-related information and processes throughout the entire lifecycle for Saaksvuori and Immonen (2006) and Terzi et al. (2010). The product data model is used to filter, to structure, to integrate and to control the voluminous information flow during the whole product lifecycle (Eynard et al. 2004). Such model aims to structure product related information and to facilitate their reuse or their exchange. Nowadays, different types of product data models have been proposed depending on the industrial context or the lifecycle stage. The main objective of product data model is to support Product Data Model (PDM) functions of Product Lifecycle Management (PLM) throughout the product lifecycle (Demoly et al, 2013).
Le Duigou et al. (2012) proposed a PLM structure supported by the French Technical Institute of Mechanical Industries (CETIM). The aim of this proposal was to provide a PLM solution. With this PLM system, they can get into an extended enterprise structure with measured investments and time. Based on a Product – Activity – Resource – Organization meta-data structure (Fig. 2), this proposal has to be aligned with the previous value-based proposal, in order to be used to assess the product lifecycle model.
Such PLM models should interoperate with others collaborative systems in order to elaborate a shared understanding. Indeed knowledge cannot always be made explicit and directly shared through PLM systems.

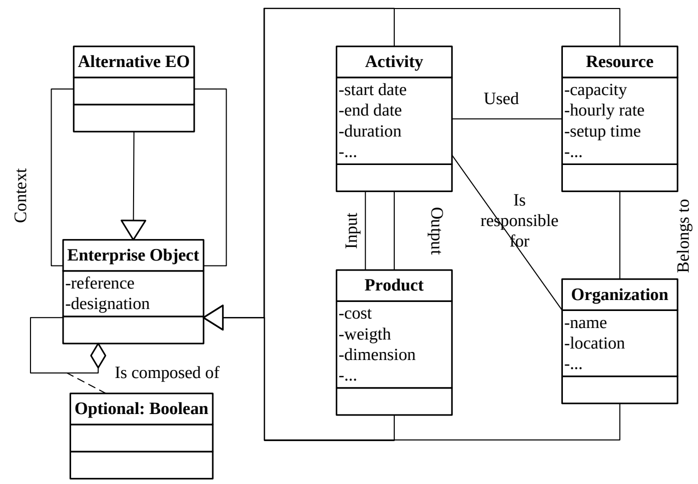

Figure 2: Product-Activity-Resource-Organization meta-model (Le Duigou et al., 2012)

In this paper, semantic interoperability of a PLM model with the model of the MEMORAe approach is outlined. Such approach relies on ontologies in order to support the construction of a shared understanding notably through social interaction. It can be considered as good a way to ensure tacit and explicited knowledge sharing within extended enterprises.

3. Research proposition

PLM systems allow information sharing throughout a product lifecycle. Through semantic interoperability, we propose in this paper a way to share knowledge with such systems within extended enterprises.

The first part of this section presents the MEMORAe approach, which allows the elaboration of a shared understanding through the use of ontologies. We consider that such shared understanding ensures tacit knowledge sharing. The second part of this section explains how the semantic interoperability of an approach like MEMORAe with a PLM system may be realized in order to support tacit and explicited knowledge sharing through such PLM system.

3.1 The MEMORAe approach

In Abel (2008) the MEMORAe approach is presented as aiming to offer an alternative to the loss of competencies and knowledge in an organization. A competency is considered as a way to put into practice some knowledge within a specific context (Abel, 2008). The MEMORAe approach offers an ontology-based learning organizational memory.

As explained by Davenport and Prusak (1998), transmitting information is not sufficient to share knowledge, due to the existence of individual interpretation in sense-giving and sense-reading processes (Polanyi, 1967). So that sharing information is not sufficient to share knowledge. Moreover even if authors as Ball et al. (1999) say that “more information is better”, others as Berners-Lee et al. (2001) consider that a web of information with well-defined meaning facilitates collaborative work between computers and individuals. Ontologies could then clarify the structure of information source of knowledge. They are a way for sharing and for re-using knowledge, whether tacit or made explicit by someone within a certain context.

Ontologies reflect a shared world view and for Domingue et al. (2001). They can support communication and knowledge sharing through a community of practice. Wenger (1998) presented what kind of practices is involved within a community of practice: “Such a concept of practice includes both the explicit and the tacit. It includes what is said and what is left unsaid; what is represented and what is assumed. It includes language, tools, documents, images, symbols, well-defined roles, specified criteria, codified procedures, regulations, and contracts that various practices make explicit for a variety of purposes” (Wenger, 1998, p. 47). With Web technologies, communities become present online, and for Grundstein (2000) an online community consists of people, a shared purpose, protocols and rules that guide interaction and computer systems. The use of a collaborative approach such as MEMORAe ensures the construction of a shared understanding within a community.

The MEMORAe project (see http://www.hds.utc.fr/memorae/ and Fig. 3) is a prototype showing ways to help users to capture knowledge. Entry points at the left of the screen provide direct access to a concept, whereas a history of the navigation is shown on the right of the screen. The part of the ontology describing current resources appears in the center of the screen and is framed by a short description of the current concept and by a list of shared resources related to the current concept (text or multimedia content) at the left of the screen. Within different spaces ("Tour Equipement" and "Atelier" in Fig. 3), individuals may have access to different resources and may be authorized to interact with different stakeholders (by chatting or through a wiki for example). By discovering new concepts, users can ensure that they interpret them correctly by browsing the entire screen of the MEMORAe project.

The aim, in the MEMORAe approach, is to put into practice organizational learning through organizational memory, i.e. the explicit and persistent representation of knowledge and information in an organization, in order to facilitate access and re-use by members of the organization for their tasks for Dieng et al. (1998), based on the synergy of three fundamental layers:

- knowledge management to support capitalization,
- Semantic Web to support sharing and interoperability,
- Web 2.0 to support social processes.

This approach is implemented in the MEMORAe project (Fig. 3) with the following functionalities:

- explicited knowledge capitalization as a resource in a learning organization: classical resources (documents, videos, images, etc.), Web 2.0 resources, annotations, etc.,
- management of communities: users and groups management, etc.,
- work artifacts organization at an individual and a group level,
- common-ontology sharing,
- semantic-indexing of resources with concepts of the ontology,
- resources and concepts annotation to support tacit knowledge explicitation,
- customized user-access based on a selection of concepts relevant for a user profile (entry-points allowing to access to the resources indexed with user-interest concepts),
- Web 2.0 tools enabling collaboration in diverse collaborative settings: semantic wiki, forum, chat etc.,
- social networks to support information sharing within communities.

The ontology is an essential element of this approach as it serves at the same time the purpose of semantic indexing, common-reference enhancing collaboration trough a common vocabulary and interoperability-enabler. Such ontology gives a context to capitalize explicited knowledge and provides advanced search mechanisms, when the ontology is expressed in a logic-based formalism.

In a design context for example, communities are formed and have to closely work together. This fact generates particular collaboration needs, which have to be reflected in the ontology content and use: teams are created ad hoc, collaborators need to be aware of the human and geographical organization as well as the actual product development process and the reference solution. The context in which knowledge has been explicited, through a process of sense-giving in the sense of Polanyi (1967), can be reconstructed based on the ontology and on the resources affected.

Fig. 4 highlights a part of the domain ontology in the MEMORAe approach describing the organization: persons, groups, hierarchy and relationship between employees (managers or peers), the roles they play depending on the activity and on assigned responsibilities, division of the organization into departments and sites.

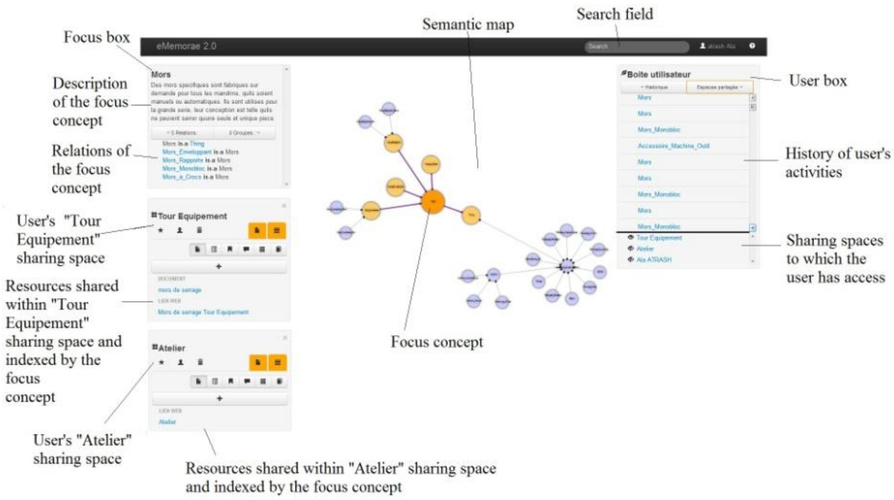

Figure 3: The main communication interface of the MEMORAe project web platform

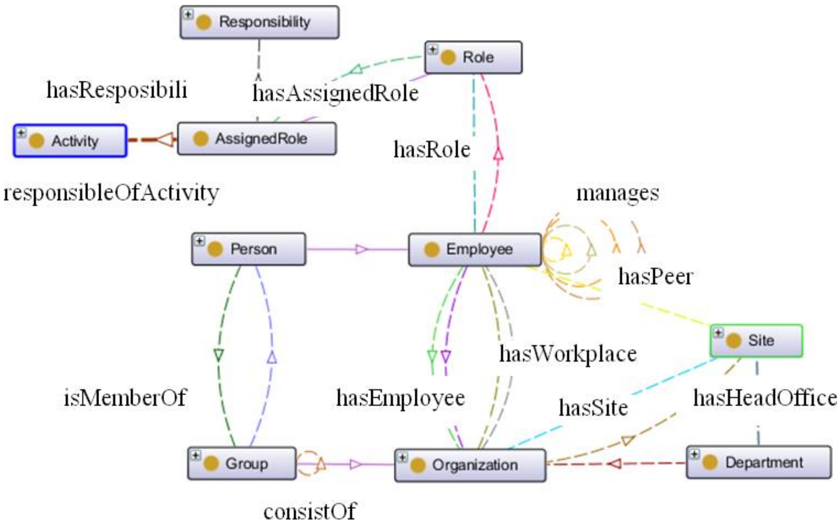

Figure 4: Part of the domain ontology defining the organization

3.2 Towards tacit and explicited knowledge sharing

Collaborative working systems such as Computer-Supported Cooperative Work (CSCW) result of information technology whose implementation has been polarized around the individual user for Schmidt and Bannon (1992). Individuals are users and they are individually using a system. Stockdale and Standing (2006) notice that neglecting social activity leads to "meaningless conclusions", and Jordan (1996) insists when she reminds that knowledge is not only based on the group but is also tacit, embodied in individual interpretation: "We believe that there is yet another dimension that needs to be explored and that is the knowledge that is not only group-based but also tacit, implicit, embodied, and not articulated." (Jordan, 1996, p. 18).

3.2.1 Tacit and explicited knowledge sharing in PLM systems

The use of an approach as MEMORAe leads to collaboratively elaborate a shared understanding, so that tacit knowledge sharing is supported. Indeed tacit knowledge cannot always be made explicit according to Polanyi (1958). Collaboratively elaborate a shared understanding is a way to share tacit knowledge even if it cannot be made explicit. Additionally, within extended enterprises, PLM systems share information in every corner of the globe. Under certain conditions, a piece of information shared within a PLM system leads to one and only one interpretation. So that under certain conditions, sharing information within PLM systems is sufficient to share explicited knowledge. We are now going to explain these two major strengths of our proposal: (1) ensuring tacit knowledge sharing within a PLM system through the use of the MEMORAe approach, and (2) identifying the conditions allowing explicited knowledge to be shared through a PLM system.

Within extended enterprises, knowledge is created and used by several actors, within several information systems and in every corner of the globe. The MEMORAe project (Fig. 3) is a platform relying on Web Semantic standards. It allows the creation of institutional or dynamic groups, which refer to:

- institutional groups, which are created and leaded by a manager and include two or more collaborators,
- dynamic groups, which are created by any member of the organization without requiring a validation from the hierarchy. It can be a community of interest around a specific topic, person or both. The opening of such a group to other members of the organization may be restricted within private groups.

So, a shared environment is proposed and allows people, regardless where they are and regardless who they are, to elaborate a shared understanding through the use of ontologies. They can additionally actively participate in communities by creating them, by managing them, or by inviting relevant persons in them. This shared environment ensures tacit knowledge sharing and its integration by stakeholders: within such communities they all give the same meaning to the same information shared through the system.

Explicited knowledge is tacit knowledge that has been made explicit by someone who created information within a certain context. It can be supported by information technology such as PLM. Nevertheless, contrarily to tacit knowledge, explicited knowledge is detached from its meaning, which depends of the person who is receiving it and of the context of its use. A piece of explicited knowledge EK is a piece of information created by a person P_1 from his/her tacit knowledge TK_1 within a certain context C_1. That piece of explicited knowledge EK may be disseminated through an information system and it becomes then information source of tacit knowledge TK_2 for another person P_2 within a certain context C_2. Note that even if EK is a raw object (it is information), TK_1, C_1, TK_2, and C_2 may differ from one person to another, except when shared information is:

- *highly contextualized explicited knowledge*, which refers to explicited knowledge attached to a context avoiding interpretation variance (in the sense of Arduin, 2014). For example the sentence "the cutting speed on such material is *x*" may lead to different interpretations depending on the tool, the engine, the geometry of the piece, the lubrication, etc. Such piece of information is not highly contextualized and cannot lead to efficiently share explicited knowledge, because it may lead to different interpretations.
- *technical and unambiguous explicited knowledge*, which refers to explicited knowledge detached from natural language ambiguity. It may not lead to different interpretations. For example "15°" is detached from natural language but it is ambiguous as it may lead to different interpretations: disseminated within a PLM system, "15°" may mean "a temperature of fifteen centigrade degrees" or "an angle of fifteen radius degrees". Such piece of information is not technical *and* unambiguous and cannot lead to efficiently share explicited knowledge, because it may lead to different interpretations.

These two conditions under which explicited knowledge, i.e. information source of tacit knowledge for someone, can actually and efficiently be shared through PLM systems have been identified: there is no ambiguity, no discussion, and no need of explanations. The semantic interoperability of an approach like MEMORAe with a PLM system in order to support tacit and explicited knowledge sharing through such PLM system will now be outlined.

3.2.2 Interoperability between MEMORAe and PLM

To link a data model of PLM and MEMORAe, the proposed methodology is to use a model driven engineering approach to create a transformation from a model to the other. Model driven engineering is an approach that aims to use models all along the development cycle of a software passing from contemplative models to productive model.

The model transformation allows creating a target model from a source model. The transformation is constituted of two steps: the specification of the transformation rules and the application of these rules to generate the target model. Several languages exist to describe these transformations, like QVT (Query/View/transformation) a standard from OMG and ATL (Atlas Transformation Language) that implement QVT in Eclipse.

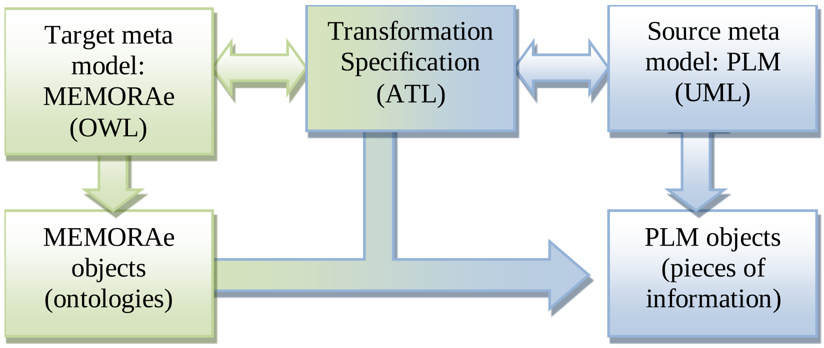

Figure 5: The aimed semantic interoperability

The closer PLM data model to MEMORAe ontology is the PLM data model from Le Duigou et al. (2012). They are both based on the same Product, Process, Resource, Organization main objects with a possible specialization at the application level (the company level). The differences allow extraction of the main objects specific to the PLM domain and to the collaborative and human interaction domain. For PLM specific domain, the main specific objects are:

- the alternative and the optional objects, to construct different product configurations,
- the versioned objects, to trace the history of an object.

For the collaborative and human interaction domain, the main specific objects are:

- cluster, to create and manage communities of practice,
- annotations, to dynamically annotate the document.

Fig. 5 illustrates the aimed semantic interoperability between MEMORAe and PLM models. At the moment of writing this article, we are focusing on the realization of such semantic interoperability through the use of ATL. Nevertheless, we already identified forthcoming results and perspectives of this work.

3.2.2 Discussing the results, the added value, and the perspectives of this work

Whereas information can efficiently be shared through information systems such as PLM systems, knowledge, whether tacit or made explicit by someone within a certain context, is extremely difficult to share. Information may be useful throughout a product lifecycle, nevertheless knowledge is a crucial resource whose absence can stop ongoing processes (Grundstein, 2009).

Through semantic interoperability, we proposed in this paper a way to share tacit knowledge within extended enterprises. The use of a collaborative platform allows stakeholders to elaborate a shared understanding. So that even if it cannot be made explicit (Polanyi, 1958), tacit knowledge and its meaning are shared through information systems, when they interoperate with such collaborative platforms.

By highlighting the conditions under which a piece of information may lead to one and only one interpretation within information systems, we also proposed in this paper a way to share explicited knowledge within extended enterprises. So that when it is disseminated, explicited knowledge and its meaning are shared through information systems, when these conditions are satisfied.

Some semantic differences between MEMORAe and PLM models must now be highlighted. Indeed, they form research perspectives for this work that we need to be aware of. For example, whereas PLM models consider that a “product” is related to activities and resources, MEMORAe considers that a “product” is a resource able to produce information potentially source of knowledge for someone. On the same way, a “human” is a resource for PLM models, whereas it can also be a user for the MEMORAe model. Such semantic differences form a limitation of this work if and only if we are not aware of. So that they are now studied in order to be understood and managed.

During early experiments realized with students, it has been observed that the use of a collaborative platform, such as MEMORAe, facilitates and encourages interaction between stakeholders (Abel, 2008). Observed students learned rapidly studied concepts and they all understood the same thing, whereas some of the studied concepts usually lead to different interpretations.

This work must now rely on industrial fieldworks in order to identify whether the proposed approach will actually be useful within extended enterprises. At the time of writing this paper, it is not possible to present an industrial case study validating or invalidating the proposed approach. This constitutes also a weakness of this work, which is currently tested within several enterprises. The preliminary design phase in a product lifecycle can for example be facilitated when stakeholders share efficiently knowledge on the product to be designed.

Such phase is facilitated when stakeholders, regardless where they are and regardless who they are, share not only information on their wills about the envisaged product, but also knowledge they hold. They have the means to collaboratively elaborate a shared understanding of information disseminated through the PLM system. So that knowledge and its meaning are shared through such PLM system within extended enterprises.

4. Conclusions and perspectives

As pointed out along this paper, knowledge, whether tacit or made explicit by someone within a certain context, is a crucial resource which has to be shared within extended enterprises.

This paper proposes (1) to outline a semantic interoperability allowing the integration of a collaborative platform within a PLM system, and (2) to highlight the conditions under which a piece of information shared through a PLM system may lead to one and only one interpretation.

The proposal aims at sharing tacit and explicited knowledge within extended enterprises. To do so, it is firstly proposed to make interoperate PLM with the MEMORAe approach. Such approach allows individuals to construct a shared understanding, which supports tacit knowledge sharing. Then even if it cannot be made explicit (according to Polanyi, 1958), tacit knowledge and its meaning can be shared through a PLM system using approaches such as MEMORAe. Secondly, conditions under which a piece of information shared within a PLM system may lead to one and only one interpretation are highlighted. Then not only information has been shared, but also explicited knowledge and its meaning have been shared through such PLM system.

After remembering the vision of knowledge in the organization and the PLM model adopted in this work, the research proposition has been introduced and tacit and explicited knowledge sharing have been explained. The perspectives of this work as well as its added value have finally been discussed at the end of this paper.

PLM systems have a real strength which is that they are strongly integrated and used within extended enterprises. They give individuals the ways to collect, to process and to share huge amounts of information. This work considers that when it has no meaning, information is useless for an organization. So that within extended enterprises, where individuals may be spread throughout the world, it is crucial to ensure that the same information shared through the same information system will have the same meaning for people, regardless where they are and regardless who they are.

5. Acknowledgement

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