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Tasks optimization and knowledge reuse during product design process

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Abstract

The work presented in this paper provides an approach for minimizing the time during the design project of mechanical products. This approach focuses on a process of knowledge capitalization and knowledge reuse, which encourages to take advantage of knowledge stored in the project memory to minimize design time and exploit knowledge commensurate with project design that travels the shortest minimum.

This work is based on two aspects. The first aspect is developing an ontology devoted to define and specify the knowledge domain of users; the second is the integration of an organizational model in the ontology in order to specify the collaboration between the actors and the knowledge sharing process. Through this paper, we focus on providing assistance to businesses involved in design projects.

Keywords_ Project memory, organizational model, ontology, knowledge reuse, knowledge capitalization, minimizing the time.

INTRODUCTION

During the last two decades, the competitiveness and competitive between companies has been altered. Competitive companies are those that have the ability to quickly transform new ideas precisely new knowledge into new products or develop their products through their control of the design process.

Therefore, industrial companies are facing competition from increasingly strict. In this regard, we note that the major advantage for any business is concentrated on the design activity; the latter consists in the elaboration of the definition (technical, functional and geometric) of a product based on specifications. In fact, design is a process that does not stop when we arrive at a product, but it takes every look how we can offer the market quickly and cheaply. This is why the design is becoming increasingly complex. On the one hand, the requirements of clients experienced a remarkable transformation, and on the other hand, knowledge related to the design process are constantly increasing, while improving the techniques and available solutions in order to achieve quality products that conform to our needs.

Knowledge scattered encourages companies to seek a way to store, analyze, share, and apply where the discipline of knowledge management (KM) which is interested in improving the use of the knowledge portfolio.

Knowledge management is a strategic multidisciplinary to achieve the aimed objective to exploit optimally the knowledge of the company.

Owing to this perspective, knowledge management is considered such as a major economic challenge for any organization that seeks the performance.

This work will be designed to minimize the duration of a design project. We are also interested in the knowledge reuse process in order to offer to business actors the most relevant knowledge of the process minimum duration, and also the knowledge capitalization process that is used to store and preserve knowledge from each new design project.

This paper is organized as follows: section 2 introduces the background used in this work. Section 3 describes our minimizing duration of design process approach. In section 4, we give an overview of related work and we conclude by stating the main research ideas.

BACKGROUND

a. The design process

The design process used by the company is based on the retroactive and cooperative model [Ben Miled, 2020].

This design process is mainly composed of four phases, each one containing a set of activities, which can themselves be divided into sub-activities. Each activity ends with the completion of a deliverable. Indeed, an activity involves several actors or trades. A business actor may play one or more roles. Activity takes place in a very specific time, described with a start date and an end date.

Phases of the design process are the same for all projects in product development. The first phase called phase of "feasibility study", a second phase called "preliminary", a third phase represented by "detailed study" and finally the phase of "industrialization". These four phases are responsible for the birth of a mechanical product.

The following figure shows the first phase of the design process used by the company

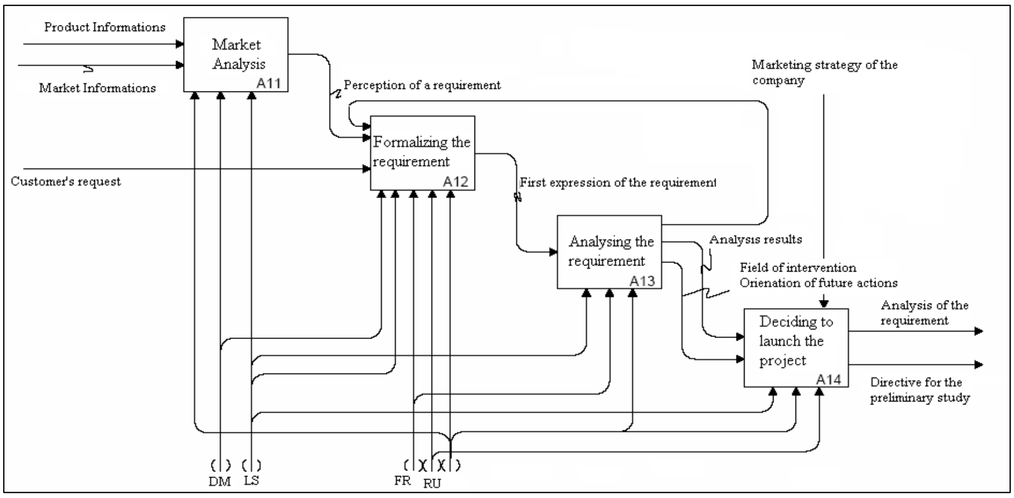

Figure 1.The first phase of the design process used by the company

b. Meta-Model RIOCK

We [Ben Miled, 2014] have resorted to the use of organizational model in engineering design projects. Indeed, the organizational model reflects the inclusion of social and cooperative aspects of the design process that encourages business actors to work together by creating, using and sharing their knowledge in order to achieve a common goal.

Organizational modeling is based on the meta-model RIO [Hilaire, 2000], which is essentially based on three main concepts namely: organization, interaction and role. This model is intended to represent an activity by an organization. Within this organization we describe the roles of business interact. With relation to this, an interaction means collaboration and exchange (sharing) of knowledge between business actors' trades.

The Meta model RIO allows us to represent a phase of an organization divided into activities, including those activities are themselves described by organizations.

Moreover, the meta-model RIOCK [Ben Miled, 2020] adds to the model RIO competences and knowledge. It highlights the knowledge and skills that actors have jobs and are necessary for the performance of a design project.

Each activity at each phase is represented by an organization (Figure 2) describing the roles and interactions on the one hand and the knowledge associated with competences on the other hand.

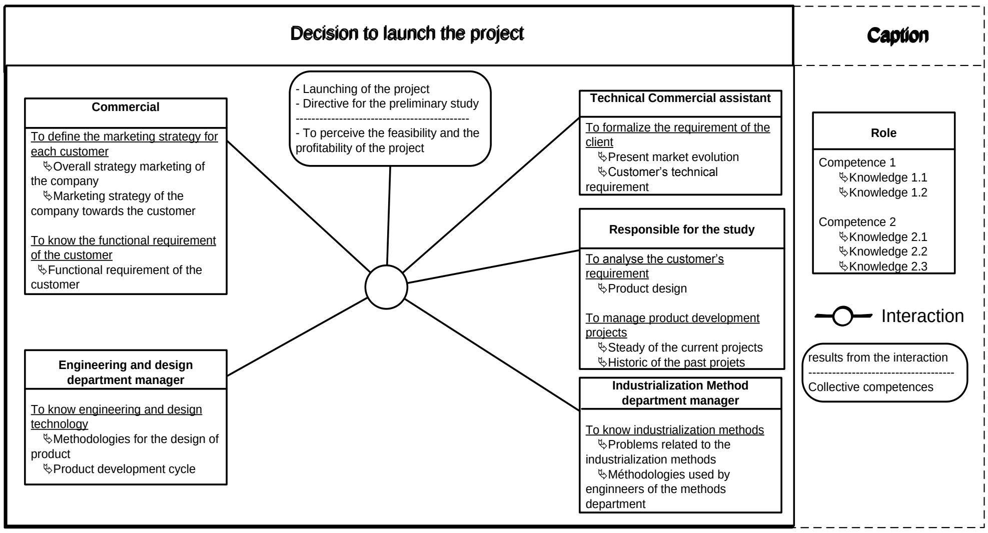

Figure2. An organization in RIOCK Model

Competence can be expressed as the ability of an individual to demonstrate his knowledge and expertise in a professional [Le Bortef, 2000].

Knowledge is defined as an interpretation of information in a specific context.

For this reason, our knowledge cartography is based on Monticolo's research work [Monticolo, 2007], so that we can properly lead the process of capitalization and reuse of knowledge in design projects.

c. Project memory model

A project memory is defined as: "*a model with the organization of information and knowledge created, shared and used in a project, for reuse by business actors*" [Matta, 2000].

It is used to store and index the knowledge used in projects, in order to facilitate their access, their shares and their reuses by business actors. It defines the structure and the explicit representation of knowledge on organization.

Monticolo [Monticolo, 2007] proposed a memory project model called "*Memodesign*", this model describes a collection of knowledge related to the business context of the project and will be subsequently classified according to its typology and taxonomy.

This project memory is built round six groups of knowledge, namely: *Project Background, Project Evolution, Project Vocabulary, Project Experience, Project Process and Project Expertise*.

III. Minimization approach proposed

The idea of our work is to develop a knowledge management system which ensures minimization of the duration of a project design, promoting reuse and capitalization of knowledge.

Our system proposes the design process that follows the minimum duration, as well as knowledge. It can assist the business actor in the process of mechanical product design. Moreover, it contributes to the construction of the project memory, because we store the knowledge of each new design project.

a. Building the ontology

The construction of ontology is based on the model of the life cycle of an ontology proposed by [Fernandez-Lopez, 1999]. This life cycle can be summarized in three main activities that are: management, construction, and support. Whose construction involves four steps: specification, conceptualization, formalization and implementation.

Obviously, we will rely on the methodology proposed by Ben Miled [Ben Miled, 2020] to prepare the tables presenting the concepts, attributes and relationships between concepts.

Figure 3 below shows a sample of our ontology developed. This excerpt highlights the organizational structure generated in organizational modeling in the design process. We find the design process part, related to different phases via logical constraints, where each phase can also distinguish its own activities. Each organization at the organizational model represents an activity identified by a concept in the ontology.

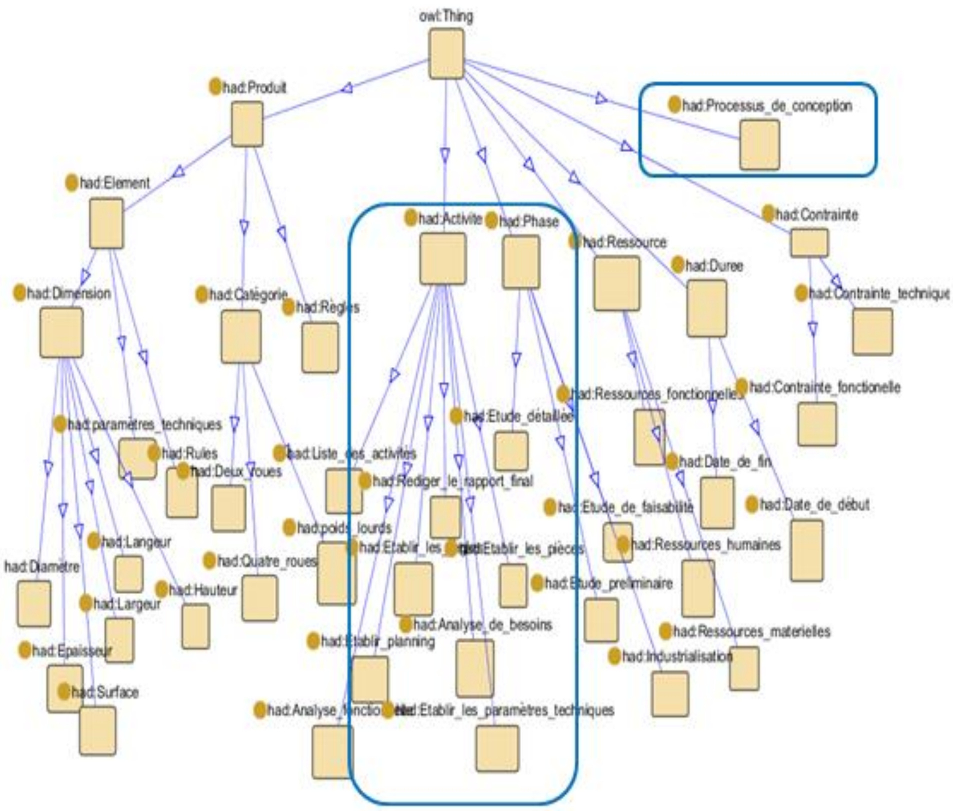

Figure 3. Excerpt of the proposed ontology.

Table 1below shows some concepts of our ontology.

Term	Concept ID	Parent ID	Definition in natural language
Design process	Design_process	__________	The process in question.
Phases	Phases	__________	All phases forming a design process
Preliminary study	Preliminary_study	Phase	The preliminary study is a phase that fits in the concept phase.
Activities	Activities	________	The activities forming each phase.
Needs analysis	Needs_analysis	Activities	*Analyse de besoins* is a type of activity.

Tab 1. Some concepts from our proposed ontology.

The ontology concepts are formalized through OWL and RDF. The following example (fig.4) reflects the concepts (Needs_Analysis, Activities).

```
<owl:Class rdf:ID="Needs_Analysis">
<rdfs:subClassOf>
<owl:Class rdf:ID="Activities"/>
</rdfs:subClassOf>
</owl:Class>
```

Figure 4. Definition of class « **Needs_Analysis** »

Table.2 below shows some attributes of our ontology.

Attribute	Id relation	concept associated	Attribute type	Description
Start date	Startdate		Date time	The start date for determining on each type of activity: This is to say when the actor began his task.
End date	Enddate		Date time	The end date of an activity, that is to say, when we finished this task.
Human resources	Human_resources		String	Roles available to complete each activity.

Tab 2. Some attributes from our proposed ontology.

The figure (fig. 5) below shows the definition of an example of an attribute on the concept of "activity". The example "Startdate" is a property DataProperty, which is of type "& xsd; dateTime".

```
<owl:DatatypeProperty rdf:ID="Startdate">
<rdfs:domain rdf:resource="#Activities"/>
<rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#dateTime"/>
</owl:DatatypeProperty>
```

Figure 5. Attribute Defintion « **Startdate** »

Table 3 below shows some relations of our ontology.

Relation	ID relation	Original concept	Target concept	Definition in natural language
Has activities	Has_activities	Phase	Activity	Activities that make up each phase.
Has phases	Has_phases	Processus_de_conception	Phase	Phases that determine each design process.
Has date	Has_date	Activities	Date de début Date de fin	An activity consists of two dates: a start date and an end date.

Tab 3. Some relations from our proposed ontology.

b. Exploitation of project memory

Knowledge conceptualized in our ontology can be used in different ways. Therefore, we note SPARQL [Seaborne, 2008] which is considered both as a language and as a query protocol. SPARQL allows querying RDF descriptions using clauses.

We want to especially address the following question: Determine the start date of all activities (fig. 6). And in the same way we also determine all end dates of activities.

```
SELECT ?x
WHERE {
?activite had : numero “Numero 1“.} UNION
?activite had : numero “Numero 2“.} UNION
?activite had : numero “Numero 3“.} UNION
?activite had : numero “Numero 4“.} UNION
?activite had : numero “Numero 5“.} UNION
?activite had : numero “Numero 6“.} UNION
?activite had : numero “Numero 7“.} UNION
?activite had : numero “Numero 8“.} UNION
?activite had : Startdate ?x.}
```

Figure 6. Sparql Query

The figure (fig. 7) f below shows the result.

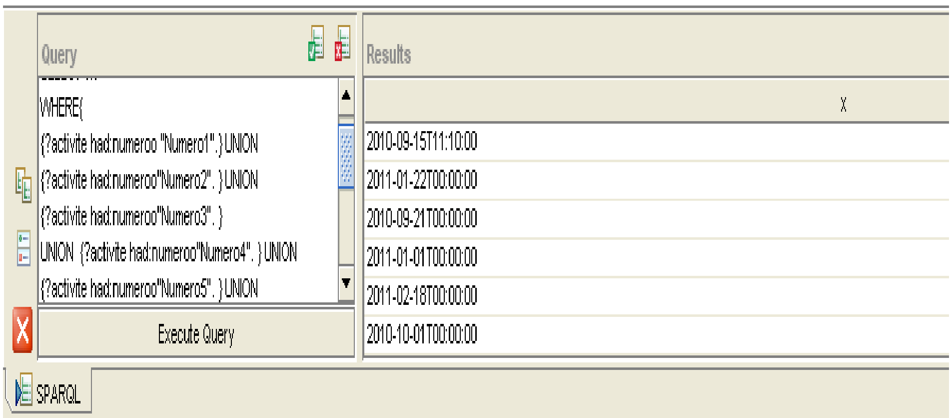

Figure 7. The result of the query

The results given by the queries: determine start date and end date, will help us to highlight our devoted approach to minimizing the duration of a project design.

c. Proposed system

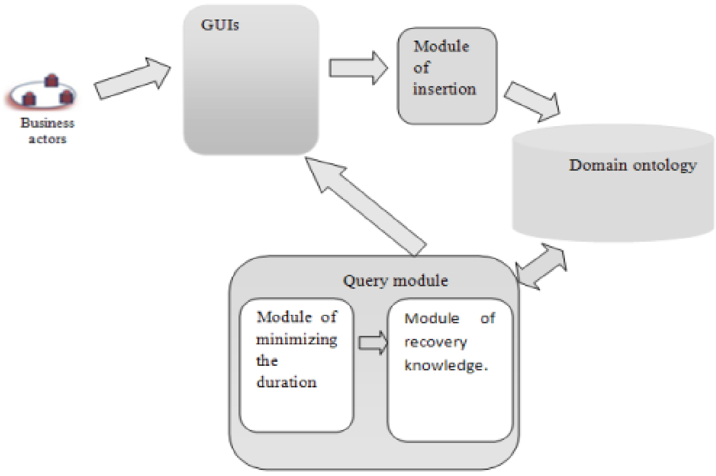

Figure 8. System components

The figure above (fig. 8) shows our system to minimize the duration of a project design. This system is divided into two modules namely the inserter and the interrogation module which, in turn, consists of two inseparable modules, which are the module of minimizing the duration and the retrieval module knowledge.

We also disclose information to two passages, one painted path capitalization saying the path through which we store our knowledge, the other draws the path of knowledge reuse by business actors.

The first path is then essential and unavoidable step in the development of the project memory can be re-usable and help to maximize the design of future products. Thus, we aim to work through this to keep track of all projects carried out within the organization.

The second path leads the organization to reuse the knowledge and the past solutions to meet the new demand proportional to our new product.

The interrogation module of ontology is used to query the ontology, based on the query language SPARQL. Indeed, it has two modules that are heavily dependent: after searching for the minimum process, we try to retrieve knowledge. This passage is important because it guarantees us to reuse again the most relevant knowledge.

Module minimizing the duration facilitates the determination of process with the shortest minimum. It also allows us to see tracking scheduling to perform all activities involved in this process.

The retrieval module knowledge provides the knowledge we need every time. It gives us a knowledge reuse of the design process that runs the minimum time.

Figure 9 shows the retrieval module interface which presents activities of process with the shortest minimum

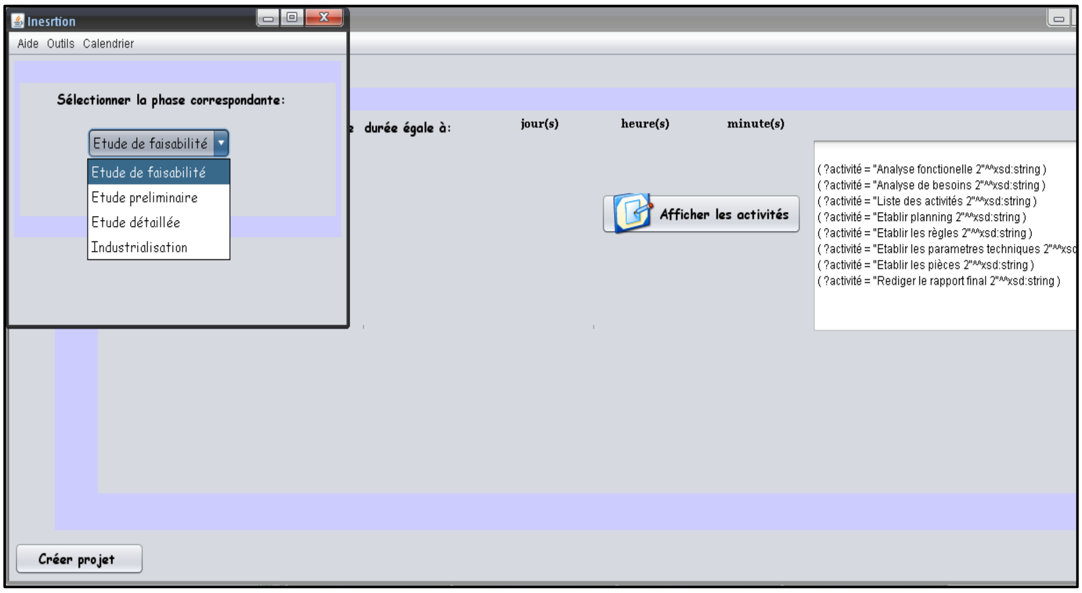

Figure 9. The retrieval module interface

d. The features of the proposed system

The first feature is summarized in minimizing the duration of a project design. Activity has a start date and an end date. We will calculate the duration of each activity and summing for the total duration of the design process. Subsequently, we determine which has the shortest minimum (Fig. 10).

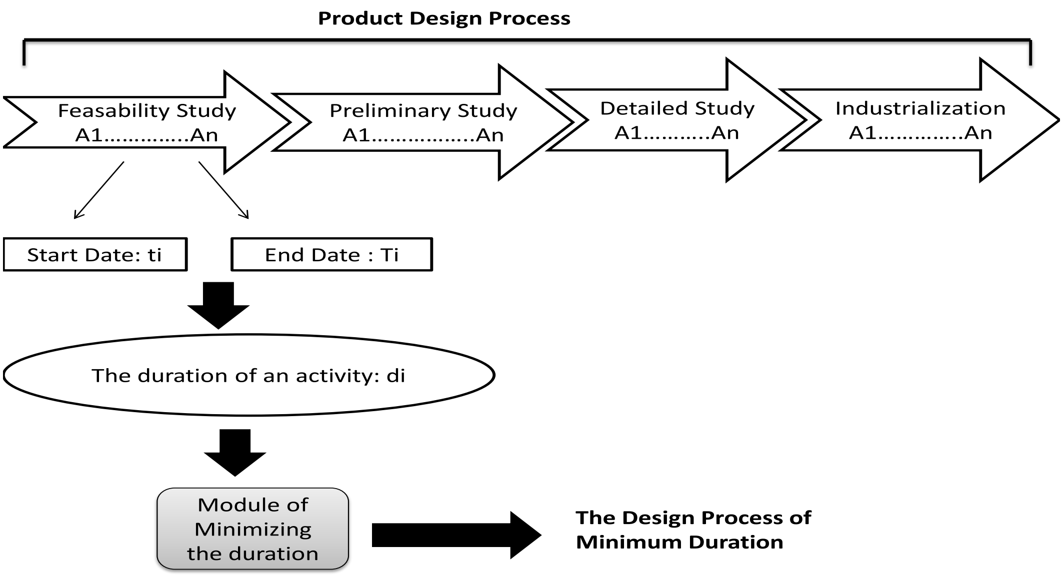

Figure 10. Minimizing the duration

With A1 An: All activities which form a phase.

A second feature is expressed through the reuse of knowledge. Reuse is defined as a major contribution in this paper, but it is represented in a different context compared to the works cited in the literature since the latter is proportional to the concept of time. It serves to make knowledge stored in memory accessible project in a timely manner.

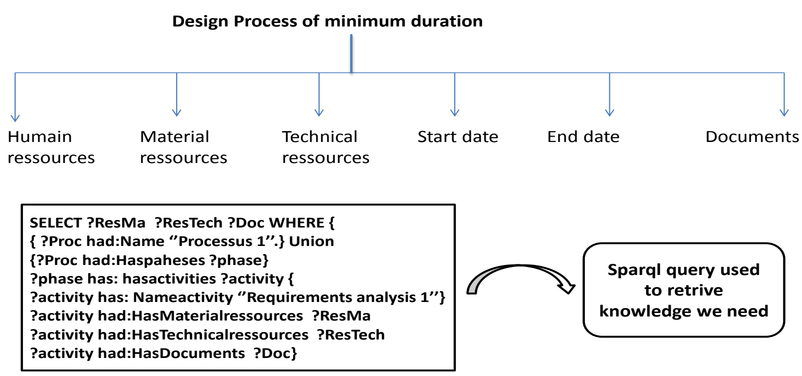

Figure 11. Knowledge reuse

As a result of the Sparql query (figure 11) the user receives a help window which provides him with knowledge in need. Figure 12 shows a portion of the push interface that presents an example of how the knowledge is proposed. The user can take into account this help and can also ignore it.

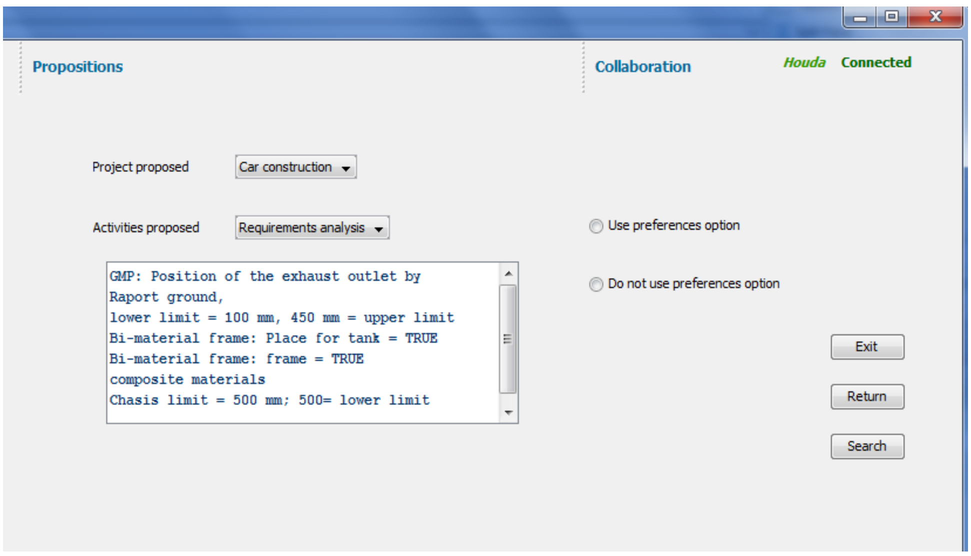

Figure 12: The push Interface

The third feature after our work focuses on the capitalization of knowledge. The aim is to retain the knowledge relating to each design process within the project memory (fig. 13).

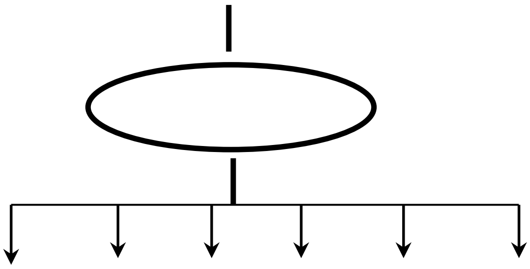

Figure 13. Knowledge capitalization process

Each project established at the organization must be registered at the memory, to ensure that we can turn back to the knowledge of past projects via module reuse. It is therefore to determine the start dates, end dates, material resources, human, technical, input and output parameters (Fig. 13).

IV Experiments

We have tested the tool by the help of groups of students collaborating on the conception of different products. We provided students with questionnaires to show in which phase knowledge proposed by the tool are relevant and have been reused. The students attributed a note between 0 and 5 for each phase (No benefit, Small benefit, Moderate benefit, large benefit, Very large benefit, extraordinary benefit). The more the note is raised, the more the proposed knowledge is relevant and was reused. The results extracted from the questionnaires are presented in Fig. 14. This figure shows that the proposed knowledge are mostly reused during the first two phases. This can be explained by the lack of information about product to be developed.

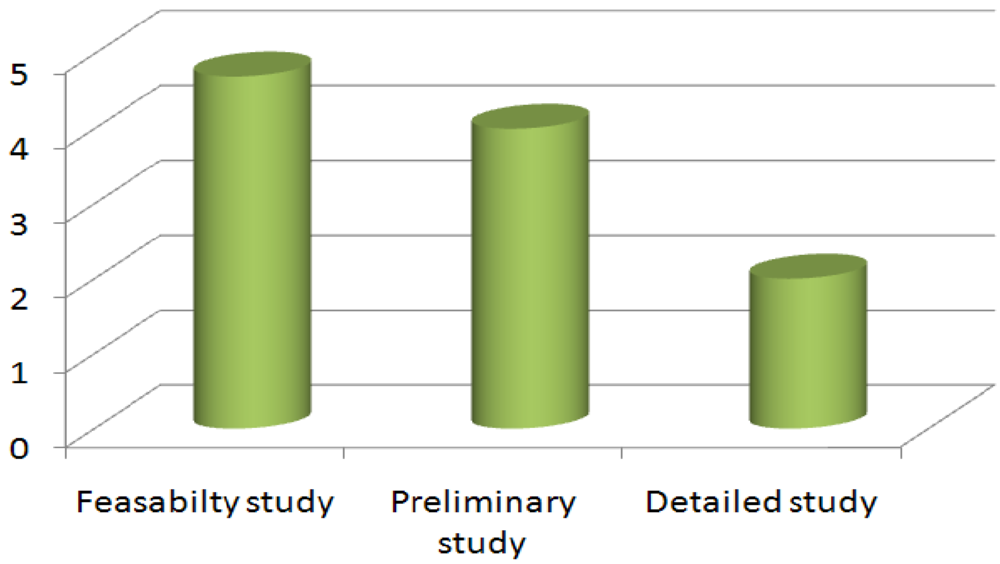

Figure 14. Knowledge reuse per phase

We study also the time factor and Fig. 15 shows the same project duration for two groups from the same category (beginner). Group 1 uses the tool to realize the project and group 2 doesn't. Group 1 takes less time than group 2 to finish each phase of the design process. For example, for feasibility study, group 1 takes 22 days to finish it and group 1 takes about 13 days. These preliminary results show that this software tool provides relevant knowledge that help in reducing project realization time.

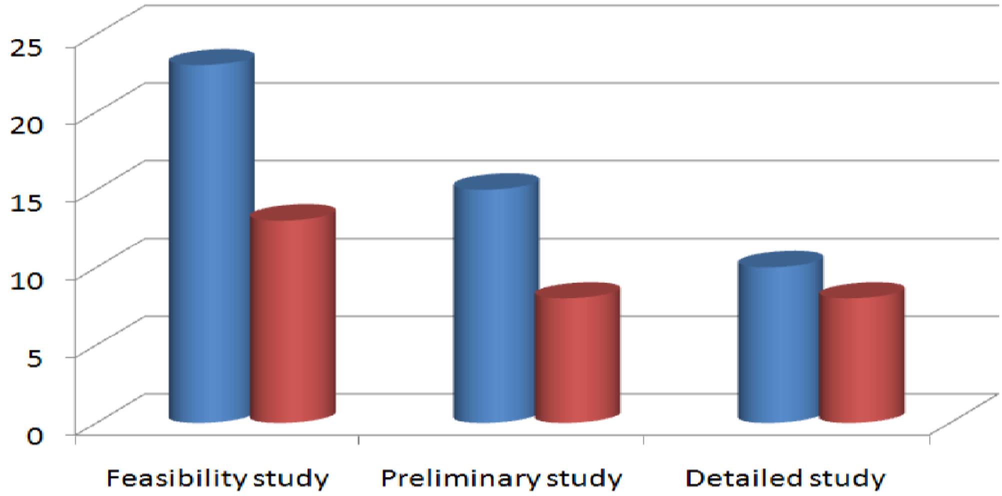

Figure 15. Tasks Optimization

V. Related work

A knowledge management system has an effective solution in order to focus on the process of capitalization and reuse knowledge. This system is defined as follows: "*knowledge management systems (KMS) are computer systems developed to support and to improve the processes of creating, storing, research, transfer and application of knowledge*" [Alavi, 2001].

Knowledge Engineering aims to collect, analyze, structure, represent and reuse Knowledge.

Much research has been done in this domain; Gandon [Gandon, 2002] adopts an approach for the management of an organizational memory [Matta, 2000] [Foghouli, 2020], combining ontology engineering, semantic Web and Multi agent system in an integrated solution. He tackled the problem of knowledge reuse based on the user profile which is a description of their interests, activity, etc. However, he did this without taking into account the role of the user in the design process. Tacla [Tacla, 2003] developed a model for the cooperative construction of project reports. In this model, after an initial modeling of the domain, the acquisition of the knowledge is made in an ascending and integrated way, from the daily activities of the individuals. Tacla's research provides a path for the re-use of the knowledge by explaining how to capitalise upon it, but it did not tackle the automatic assistance of users to help them by reusing knowledge. Some works focused on the user task to put such assistance [Revilla, 2000]

[Melo, 2020] into context [Prie, 2000], while others tried to capture general web navigation episodes on static signatures [Corvaisier, 1997] [Jaczinski, 1998], or, as in Takano, Yurugi and Kaenaegami [Takano, 2000], used past procedure cases to develop their use in specific applications. Champin [Champin, 2000] suggests exploiting the tracking of use of tacit knowledge by the designer by means of the mechanisms of reasoning from case.

These last works rely on the Case-Based Reasoning paradigm [Jaczinski, 1998], [Pretschner, 1999] [Khan, 2019]. These works aim at tracking and reusing experience but for our case we want to reuse knowledge contained in the ontology via concepts, attributes and relationships. Other research works focused on information research by the source's description [Callan, 2000], [Champin, 2004] [Li Yang, 2021] or by selection of minimum number of sources for a given request [Aksoy, 2005]. These works don't take into account the user profile in the search process and the context of the design process. Several approaches were developed to define the user profile; we can quote the adaptive approaches [Pruski, 2011] [jun yan, 2021], the semantic approaches [Billsus, 1999], [Xu, 1998][Chenliang, 2021] and the multidimensional approach [Kostadinov, 2003][Feddaoui, 2018][Lanza-Cruz, 2023]. All these works try to adapt to the user's preferences and interests by searching for information. In our research we try to search for knowledge which is the interpretation of information by a human in a given context according to the user's role in the product design project which consists of the main criterion of developing a framework to allow knowledge reuse during development process. The framework handles knowledge, which should be structured and organized in ontology using organizational approach.

VI Summary and Discussion

In this article, we introduced a framework based on ontology and mechanisms for knowledge reuse during product development. The objective is to facilitate the reuse of knowledge and minimize the duration of projects. . The framework exploits the capitalized knowledge in the best way and provides most relevant for users in order to facilitate their tasks. It offers the relevant knowledge to the right person on the right time. The framework is supported by a tool that brings an automatic help to the actors to facilitate their tasks and a personalized search for the knowledge.

Experiments are performed and preliminary results are presented to show the effectiveness of reusing knowledge during product development lifecycle.

Potentials and advantages of this tool has been reported by students. For example, based on questionnaires provided to students, the tool allows to consult the knowledge of the current project, namely the project memory as well as the knowledge of all projects. They found that this tool proposes a personalized consultation what avoids, according to them, the secondary knowledge. The students mentioned also that this software tool is very useful for the beginners by guiding them in every stage of the design process and proposing them a useful help via the automatic assistance and personalized search. The knowledge transfer allowed the students to have an idea on the work to be realized, to collaborate between them in a formal way and to adopt certain knowledge of which they share together.

They found this help very useful for the innovative projects. However, they highlighted that the tool does not allow managing knowledge for the activities which are not described in OntoDesign. Indeed, certain students do not want to limit themselves to the usual activities of the product design process. This establishes one of the major limits of the tool. These limitations constitute our ongoing work.

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