# An e-Groupware based on Multi Agents Systems for Knowledge Management

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**Abstract**—This article presents a Knowledge Management experiment in a company of four hundred employees. Our researches concerns the development of a MAS associated to an e-Groupware for Knowledge Management within the company. In Small and Medium Enterprises (SME), the development of a product requires a multidisciplinary team where professional actors work together to achieve the same goal. In this collaborative world we observe many exchanges (engineering data, report…) and interactions (meetings, decisions…). Each of these types of communication is at the origin of the emergent Knowledge. Consequently we propose an approach based upon the modelling of activities with an organizational meta-model and the use of Multi-Agent Systems (MAS) to trace Knowledge and automatically build project memories.

*Index Terms*— Multi Agents System, Design Process Model, Project Memory.

## I. Introduction

To survive in an increasingly competitive business environment, manufacturing enterprises are under unprecedented pressure to become leaner and more agile. The product range must be updated permanently and production costs the lowest possible. Product leadership companies must continue to enter new market with innovative products. This requires optimizing process and methodologies used by engineering department. The design process has to be rationalized in capitalizing knowledge, know-how and technological patrimony. A solution to this problem consists in using Knowledge Management techniques.

In [5] Dieng-Kuntz defines the Knowledge Management cycle as being composed of the following stages: clarification, broadcasting and reuse. Several works have introduced the corporate memory as a support for Knowledge Management. A corporate memory is an “explicit representation of pertinent knowledge of an organization” [20]. This memory, explaining the organizational knowledge (called equally collective Knowledge), may be considered as a knowledge base of the organization. Such knowledge base can be specific to a project and so be called project memory. Project memories are memories of knowledge and information acquired and produced during the realization of projects [3],[17].

Moreover a complementary approach in knowledge engineering claims that knowledge is a personal interpretation of information. This theory is defended in works which consist in searching for pertinent information instead of explanation. One can distinguish the works of M. Grundstein and JP. Barthès with Gameth [8], S. Mahé with Puméo [15]. For these authors, the knowledge is strongly dependant to a personal interpretation linked to a specific context. Knowledge Management is then meaningless without dealing with the context of this knowledge.

Our work is based upon these two approaches. Indeed we use a groupware where are stored results of collaborative activities which allows to build the organizational Knowledge.

Our experience in the company shows us project memories are difficult to write from interviews because this approach needs numerous time and human resources for every project. Moreover this work has to be realized by a knowledge engineer to analyze each stage and define knowledge to capitalize. Nevertheless, during projects, engineers don’t have time to answer interviews and the design activities monitoring by knowledge engineers is difficult to realize.

Consequently we have to design and develop tools to assist engineers in building project memories. This requires understanding the design collaborative activities with the view to define emanating knowledge. We have then chosen to use MAS to model collaborative design activities. On the one hand design is realized by distributed heterogeneous entities one may call agents (human or not). MAS on the other hand are composed of distributed interacting agents trying to reach theirs goals. To successfully interact, agents will require the ability to cooperate, coordinate, and negotiate with each other, much as people do. Wooldridge and Jennings [22] list qualities of an agent; autonomy, social ability, reactivity and pro-activeness.

Thus we supplement a groupware with a MAS which provide the cognitive and social approach in modelling the intelligent collective and individual behaviours.

Among the traceability approaches we have chosen one which enable to capture explicit knowledge. Indeed we attempt to store Knowledge which emerged during the collaborative activities. Each Knowledge trace will be used to build the project memory.

The issues addressed in this paper are:

- How to build an appropriate model of the design process in order to identify Knowledge to capitalize,
- How to make explicit this Knowledge through a project memory,
- How to design a MAS architecture allowing to trace Knowledge and to build project memories.

## II. Organizational oriented approach to model the design process

The first step of our work is to understand, analyze and model the product development lifecycle used in the SME. Thus we have followed several engineering projects inside an experiment of knowledge management deployment during more than one year. With regard to this experience we have analyzed design activities and validated the product development lifecycle with four phases and numerous associated stages. In order to understand and to model the lifecycle, we used the formalism RIO [10]. It is based on three concepts: Roles, Interaction, and Organization. We consider the project and its stages like RIO organizations. Inside organizations roles are generic behaviours. These behaviours can interact mutually according to interaction pattern. Such a pattern which groups generic behaviours and theirs interactions constitutes an organization. Indeed agents (human in this case) instantiate an organization (roles and interactions) when they exhibit behaviours defined by the organization's roles and when they interact following the organization interactions [4]. Moreover the RIO formalism proposes a heritage of roles and organizations. Indeed an organization can also be seen like a participant of an interaction using others entities. Anderson [1] and Singh [19] suggest to abstract an organization and to consider it like a role in another organization.

The project with its lifecycle is seen like an organization containing several sub-organizations called phases and stages. These sub-organizations are interdependent since they belong to the same organization. Consequently each lifecycle stage is an organization being able to be divided into sub-organizations. The figure 3 shows the organization 'feasibility study' with tree roles which represent tree organizations. The role 'to write the schedule of conditions' is detailed in figure 4.

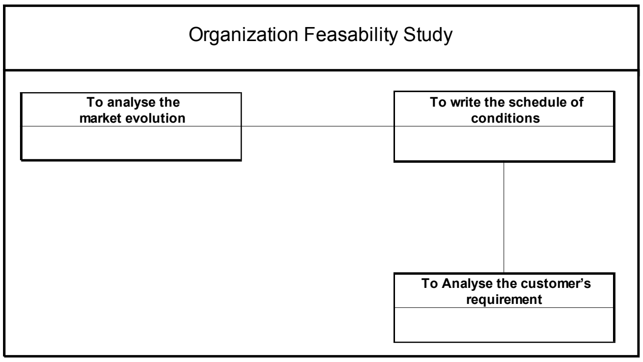


Fig.3 Knowledge related to the project progress

As we have seen previously, the design process is a system inside which exist numerous processes. Indeed in a concurrent engineering context, projects are lead by several professional actors with different professional fields. For each of them we observe some specifics professional processes. On the other hand we believe that each professional process is bound to a capitalization process. Indeed in the design process, engineers have and share their knowledge to achieve task in a collaborative way and also develop learning issued by the capitalization process. Consequently, we attempt to identify with RIO, Knowledge used by professional actors.

From experiences and observations made in the company, we define, for each organization corresponding to a stage, several roles according to the professional actors. We attribute to those roles the competences they use to fulfil tasks of the stage. The competence is defined at the individual level: "it is the capacity for an individual to implement his knowledge and to develop its know-how within a professional framework" [13]. The concept of competence associated to a role allows selecting Knowledge by professional fields since a role can belong to two different professional fields whereas the competence is related to a specific professional field. The table 1 presents different Knowledge corresponding to two different roles belonging to different professional fields but with the same competence for a specific stage of the lifecycle. Competences are related to professional fields even if one competence can belong to two different professional fields.

| Prof. Fields | Competence | Role | Knowledge |
|---|---|---|---|
| Engineering and design department | To chose the good material for the product | Plastic injection mould engineer | 1/ Design of the plastic injection mould, 2/ Constraints of the product to be injected |
| Plastic injection unit | To chose the good material for the product | Plastic injection unit technician | 1/ Use of plastic material |

Tab.1 Association between Professional Fields and Competence

Each competence is described with a set of knowledge. The interaction between several roles highlights two types of results; exchanges between professional actors and the emergence of knowledge. Thus, in an organization, a role uses one or more competences which require one or more knowledge. A role interacts with other roles to achieve a task and thus develop the collaborative work and create its result.

In the stage *'to write the schedule of conditions'* in the feasibility study phase, we observe three roles (Fig. 3). The role 'Technical commercial assistant' uses one of its competences: *To formalize the requirement of the customer.* This competence requires three elements of Knowledge which are used to satisfy the organization. Moreover, the other two roles use two competences with one element of knowledge for each. These roles have a common competence; '*to define the product design constraint'*. The figure 4 presents the result of the interaction among these three roles; here it is the schedule of condition.

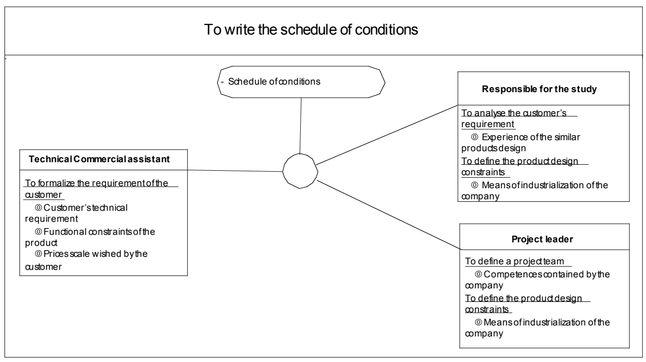


Fig.4 RIO model for the stage "To write the schedule of condition"

Thus the modelling of project engineering activities allows identifying for every organization the knowledge used by the professional actors according to their competences. The RIO formalism helps us to cartography Knowledge throughout the project. It is also necessary to define a structure to contain the identified Knowledge.

## III. TO ORGANIZE KNOWLEDGE IN PROJECT MEMORIES

As we have seen previously, the product development lifecycle is composed by numerous stages inside which professional actors develop their competences in using Knowledge. Indeed professional actors and particularly the project leader define the sequence of stages for each phase. This sequence must be capitalized; it presents the project progress and defines a system of reference to position the professional knowledge.
To introduce the project progress into the project memory we present the project context i.e. its origins, its organization, its objectives, its participants... Therefore for the type of knowledge related to the project progress we obtain two elements of knowledge (Fig. 1): The ***project context*** and the ***project evolution***. The project context brings all the knowledge characterizing the project gathered in three titles: *Objectives*, *Environment* and *Organization*. The ***project evolution*** makes it possible to describe all the project stages. This type of knowledge defines the system of reference for the knowledge capitalization.

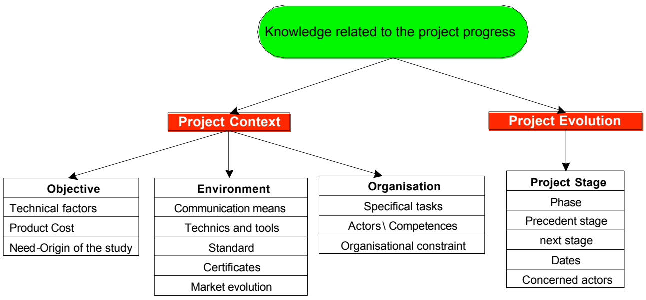


Fig.1 Knowledge related to the project progress

After analyzing and modelling the collaborative design activities in the company [16], we have deduced that professional actors used one or several competences to fulfil their engineering tasks. For each competence, we can observe the combination with one or several Knowledge. Consequently we propose another type of Knowledge which is related to the professional competences. This one is defined initially at the individual level, "it is the capacity for an individual to implement his knowledge and to develop its know-how within a professional framework" [13]. In addition the collective competence is made by interaction with professional actors working together in the same service and in the same project team for a common realization [11],[21].
The model Knova-Sigma [18] presents a knowledge capitalization centred on human professional competences. We enrich this model by adding the type ***professional experience*** composed by three types: successes, difficulties and failures (Fig 2).

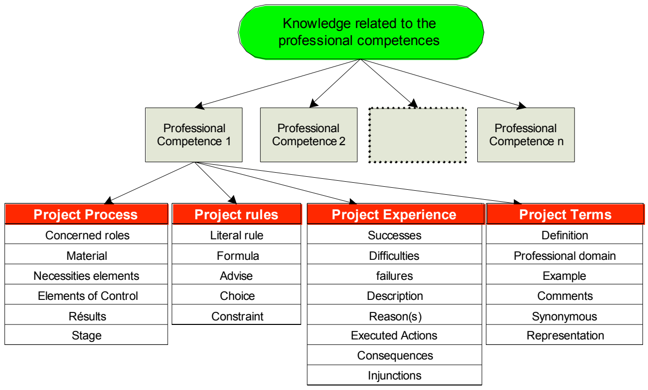


Fig.2 Knowledge related to the professional competences

A test of project memory redaction by the professional actors shows us this work is long, difficult and provides uncorrected results if they are not submitted for a collective approval. Indeed the information capitalized was mainly related to the professional actor's point of view. We have to define some referents professional actors which are experts and can validate Knowledge of Project Memories.
Our experience in the company shows us that it is difficult to write project memories from interviews with professional actors throughout projects. Consequently we have decided to design and to develop a system to assist engineers in building project memories.

## IV. TRACEABILITY OF KNOWLEDGE LEADS BY AGENTS

One traceability process [6] is to analyze interactions during meeting in order to:

- Identify concepts,
- Characterize psycho-cognitive, cooperative and sociological criteria [14],
- Regroup those criteria to keep track of cooperative problems

This traceability process allows capturing the implicit emanating knowledge during meeting. This paper presents a different approach with a traceability process to capture explicit knowledge. Indeed we limit our action to store the knowledge from the collaborative activities. Each Knowledge trace built is used to define the project memory.
We have seen in section II that the design process is a system inside which exist numerous professional processes. Among these processes there is the Knowledge capitalization. Indeed throughout the design process, engineers have and share their knowledge to achieve task collaboratively in a geographical distributed sites. Consequently we propose to introduce a multi-agents based model to provide the cognitive and social approach in modeling the intelligent collective and individual behaviors [7] which composed the design process.
With the RIO formalism (section II) we have observed that professional actors play different roles in different organizations (stages) and for each of them they develop competences in using knowledge. Moreover we are able to organize this Knowledge (section III) according to the professional competences.
With regard to these concepts, we propose an architecture called KATRAS (Knowledge Acquisition Traceability Re-

used Agents System) which the aim is to capitalize from the encountered roles during projects.

This MAS architecture is based on three levels:

- The first level ensures the traceability of users activities inside an e-Groupware platform. In this level we find the type of agents called `Professional Agents'. These agents exist for one project. They monitor roles of professional actors throughout projects. Their objective is to ensure a traceability of the collaborative actions carried out by professional actors in order to capture emergent knowledge.
- The second level gathers mechanisms of Knowledge capitalization. In this level we find the type of agents call `Knowledge Inductive Agents' (i.e. KIA). The aim of KIA is to capitalize from knowledge traces of engineering activities communicated by the PA agents. The capitalization is done according to the project memory model presented in section II. Communities of KIA exist for each project.
- The third level contains the agents type 'Knowledge Deductive Agents' (KDA). These agents exist for every projects, their aim is to synthesize the Knowledge structured according to project memories for all projects.

**Professional Agents**

Professional agents monitor roles of professional actors played inside organizations. Indeed they follow professional actor's process inside the project organization in order to identify Knowledge. In section II we have shown the RIO modelling of the collaborative activity leads by professional actors during the design process; in this section we present how agents perceive the organization inside which professional actor evolve in order to identify Knowledge and build knowledge traces.

Indeed PA agents have two principal functions:

- To follow collaborative actions in the e-Groupware framework in order to identify Knowledge,
- To interact with engineers to validate the knowledge traces.

Professional Agents (i.e. PA) are created as soon as professional actors are assigned in a project. There is one agent for each professional actor by project (figure 5).

PA evolve in the environment project (Project phases and stages) which is the system of reference and give a context of the Knowledge elements. Consequently their actions depend on the stage where their corresponding professional actors are. Thus PA agents build their RIO organization. PA agents perceive the components of their organization from actions issued by professional actors in the e-Groupware. They know the stage of the design process, the role played by the professional actors and their competences (Defined by the product development lifecycle). With regard to these elements, PA agents identify Knowledge in spreading some researches methods related to the six types of Knowledge presented in section III. The Knowledge researches are operated on: the technical documents stored in the e-Groupware database, the history of actions leads by professional actors (project managing, forum, chat), the vocabulary used…Afterwards when PA agents identify a type of Knowledge, they build a Knowledge trace in order to capture the emergent Knowledge.

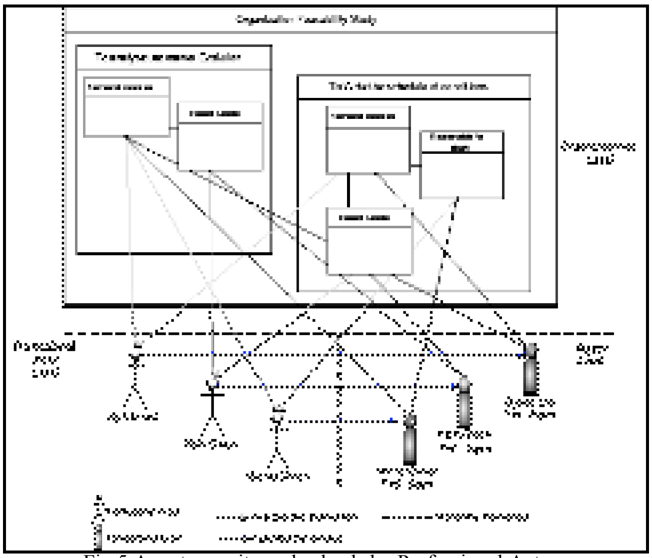

Fig.5 Agents monitor roles leads by Professional Actors

To describe the characteristic of PA agents, we used the role cards of E. Kendall [12] with a description of agents functions, collaborations and interactions (table 2).

| | |
|---|---|
| Agent type | Professional Agent |
| Responsibilities | To monitor Professional actor's process, to identify Knowledge, to build Knowledge traces |
| Collaborators | PA agents, KIA agents |
| External Interfaces | e-Groupware |
| Expertise | Query and trace management |
| Interactions | Request and subscribe |

Tab.2 Kendall's classification for the Professional Agents

Moreover we have seen previously that several Professional actors work together to achieve a task; in this case we have several PA agents in the same stage. When they have identified one type of Knowledge, they interact to share it. If a PA finds a type of Knowledge, it communicates it to other PA agents in the organization. Thus each agent builds a Knowledge trace composed by the identified emergent Knowledge associates to a role and a competence. The competence is deduced by the name of the stage. Indeed in the example of the stage 'to write the schedule of conditions', PA associate this name like a competence for every role in the organization.

After building Knowledge traces, PA send them to the Professional Agent Referent. This agent manages the Knowledge engineering interface to validate Knowledge (fig. 6).

PA-Referent presents to the Professional Actors appointed like referent (expert of their domain) Knowledge traces via the Knowledge Engineering Interface. The referents validate or delete the Knowledge Traces. After validation, Knowledge traces are communicated at the Knowledge Inductive Agents community in order to build the project memory.

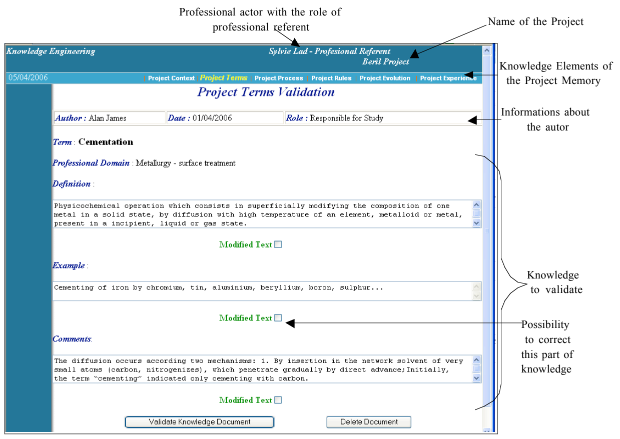


Fig.6 Knowledge Engineering Interface

## Knowledge Inductive Agents

As we saw previously Knowledge Inductive Agents receive knowledge to be filed from PA agents. This knowledge is sent as XML sequences. The figure 7 presents a XML sequence of a Knowledge trace related to the type 'Project Process'.

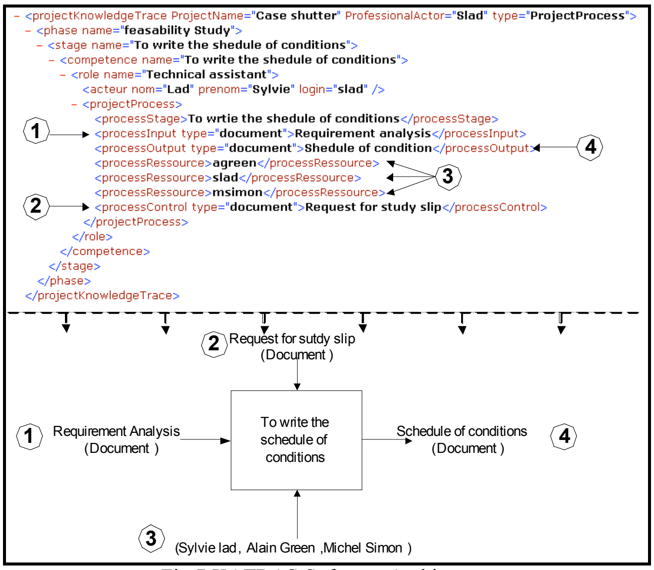


Fig.7 KATRAS Software Architecture

From this sequence we can define a process with the idef0 formalism [2].
There are six KIA agents by projects. They correspond to the six knowledge elements presented in the project memory model. Their roles are to structure the knowledge they receive in order to build the project memory (table3).

| | |
|---|---|
| Agent type | Knowledge Inductive Agent |
| Responsibilities | To build the project memory from the Knowledge traces |
| Collaborators | PA agents |
| External Interfaces | None |
| Expertise | Storage, Knowledge Organization, XML management |
| Interactions | Request, FIPA ACL |

Tab.3 Kendall's classification for the KIA Agents

PA agents address Knowledge traces to the corresponding KIA in function of the type of knowledge contained in the trace. From this Knowledge traces KIA build a part of the project memory.

Knowledge is organized according to a XML grammar define likewise the project memory architecture. From this knowledge base the KIA agents build a project memory in Web format readable in the knowledge engineering interface (fig. 7). The project memory is presented like knowledge slip in the same provision that the knowledge validation by the professional actors referents.
Another task of the KIA agents is to transform knowledge in XML format to PDF format in order to professional actors can print it and consult project memories on paper support.

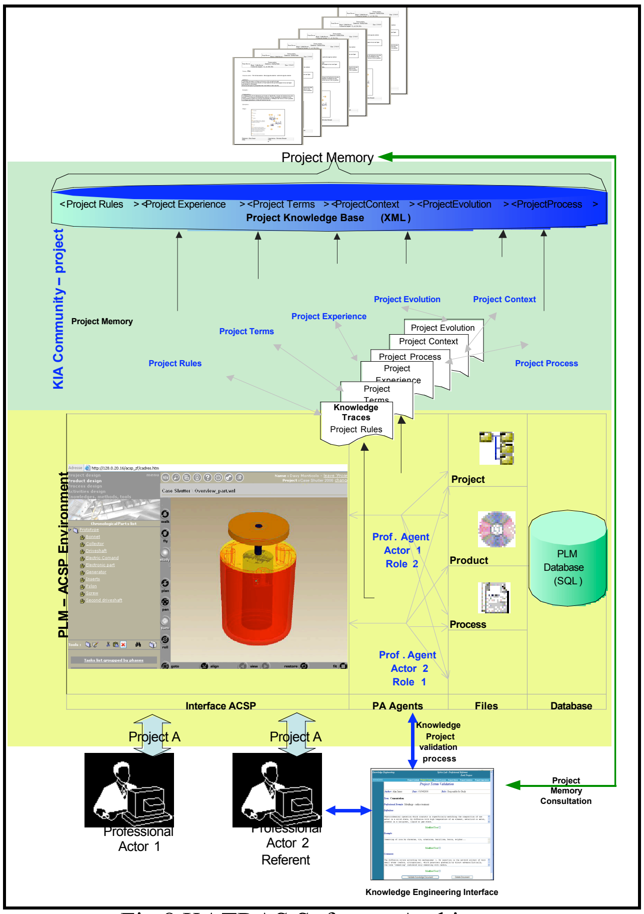


Fig.8 KATRAS Software Architecture

## Results and possibilities

The KATRAS architecture implementation is carried out by using the Madkit agent platform [9]. At the present time communication between communities of PA and KIA agents are implemented. Professional Agents are able to trace the collaborative work of every encountered role. The whole of the KIA agents corresponding to the six knowledge elements of the project memory model are operational. These agents receive knowledge and are able to build project memories in XML format and to transform this knowledge using XSL-FO to provide a project memory in PDF format. This first development allows:

- To trace knowledge from the design activities traces carried out by the roles encountered throughout several project,
- To build project memories from this knowledge submitted between the two types of agents,

- To propose to the professional actors a consultation of these memories either in pdf format or in web format.

Up to now in the company, we have built five project memories from finished projects. Professional actors appointed like referents have participated to the validation at the end of each project. Our first reports of the use of the projects memories allow us to draw up a table of some examples of use case (Tab. 2).

| Project Memory use case | Knowledge element consulted |
|---|---|
| To research the meaning and the representation of a technical element | Professional Terms |
| In the case of routine design, to find design parameters of a product element | Professional rules for the professional competence 'designing the product elements' |
| To reuse wrapping models for new pieces | Professional rules for the professional competence 'developing and optimising the wrapping' |
| To research solutions for quality problems | Professional experience for the professional competence : « injecting a plastic piece » |
| To anticipate the study planning | Project evolution |
| To choose a new project team | Project context |
| To define a new industrialization process | Professional process for the professional competence « industrializing the product elements » |

Tab.4 Example of Project Memory use cases

## V. Conclusion

The design of a product is a multi-field project where engineers with different professional fields collaborate. These professional actors carry out tasks defined in the product development lifecycle. Each task requires the contribution of know-how and knowledge in order to achieve the laid down goals. In using a e-Groupware platform professional Engineers save informations and knowledge related to the projects.

Our approach consists in analyzing roles played by professional actors in order to define emanating knowledge to capitalize. Thus, we propose a Multi Agents System architecture allowing to trace the engineering activities from professional actor's roles through the e-Groupware. From these activities our PA agents identify knowledge and interact with professional referents actors to validate it. The next step consists in building project memories and make it readable for the professional actors (KIA agents).

Our next work will consist in implementing the last type of agents 'Knowledge Deductive Agents' to realise a synthesis of all project memories and to assist professional actors during new project in using knowledge capitalized.

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