KNOWLEDGE SUPPORT FOR COLLABORATIVE WORKSPACES: THE CoSPACES APPROACH

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Abstract
The overall objective of the CoSpaces Integrated Project (IP) is to develop organisational models and distributed technologies that support innovative collaborative workspaces for individuals and project teams within distributed virtual manufacturing enterprises, so as to establish effective partnerships, collaborate, be creative, improve productivity, reduce the length of design cycles and take a holistic approach to implementing product phases. The project aims to achieve this through enhanced human communication, innovative visualisation, knowledge support and natural interaction [1]. This paper discusses the knowledge-related dimension of CoSpace that is handled by the CoSpaces Knowledge Component. Such a component is, indeed, a set of ontology-enabled knowledge services (named CoSKS), which provides the appropriate functionalities to support the knowledge requirements identified as part of the operational scenarios of the project. CoSKS is introduced here, through the description of the major conceptual axes guiding its development, the operational environment (or the context of work), the requirements guiding the development of CoSKS and, finally, the CoSKS conceptual architecture including also relevant topics for this discussion (e.g. the CoSpaces ontology, the knowledge items/objects, etc.). Conclusions and future work close the paper.

Keywords*: Knowledge-based Services, Ontologies, Collaborative Workspaces.*

1. INTRODUCTION

Knowledge Management (KM) has surpassed the prejudice of being merely a ‘buzzword’ to become a domain of work with concepts and tools that have proved their usefulness in several domains and slowly have found their place in both academia and market [2][3]. For instance, the Construction sector in Europe received contributions from several projects that proposed and developed KM-enabled tools to support the whole production chain [4][5][6]. However, as already highlighted by the KM researcher community, the technology alone does not offer a solution; a wider change is needed at individual, cultural and organizational levels in order to guarantee that the implementation of KM practices and tools is successfully performed.

The focus within engineering solutions today is heavily biased towards IT systems. Organisations repeatedly look to the next ‘silver bullet’, the ‘killer’ IT solution to solve problems. The CoSpaces project is attempting to shift this emphasis towards what we call a knowledge concern. It is not about simply providing IT tools to become Knowledge tools; rather, it is about considering a holistic approach taking into account organisational structures, cultures, and behaviours. By shifting the focus to a knowledge-enabled enterprise, benefits will be sought, such as improving lead-time by avoiding rework and “re-invention of the wheel”, promoting re-use within design and bid proposals, to increase efficiency within collaborative working environment, and to reduce time needed to find information.

The CoSpaces project aims to develop a generic collaborative engineering environment which can support real-time collaboration between geographically dispersed teams working within distributed virtual engineering enterprises. The CoSpaces project is exploring how advanced technologies (e.g. virtual reality, augmented reality, tele-immersive interfaces, mobile technologies, context-awareness and web services) can be deployed in creating human-centric collaborative workspaces for supporting product design and downstream maintenance and constructability processes. Building on advances in web services and context modelling technology, the CoSpaces project is aiming to create an underlying configurable and dynamic software framework so that the system can easily be adapted to suit the user and his or her context. In order to help achieving this objective, CoSpaces proposes the CoSpaces Knowledge Services (CoSKS), which is the main topic introduced in this paper.

The presentation of CoSKS is structured as follows. Section 2 is focused on the major axes driving the development of CoSpace Knowledge Services, namely Knowledge and Collaboration life cycle, and the approach supporting the Knowledge Enabled Engineering concept. Section 3 describes the CoSKS context of work within the CoSpaces Software Framework (CSF), which includes the requirements to be fulfilled by CoSKS, the CSF Portal, the BSCW tool, and some considerations about the technology and tools. Section 4 introduces the preliminary version of the CoSKS, including the requirements to be fulfilled in the CoSpaces scenario, the innovative aspects brought by CoSKS, and the most relevant conceptual elements. Section 5 discloses the CoSKS conceptual architecture. Finally, section 6 draws some conclusions about the (knowledge-related) work performed so far and presents the future work.

2. KNOWLEDGE AND COLLABORATIVE WORK

One of the key objectives of CoSpaces is to develop an innovative distributed software framework which will support the easy creation of collaborative workspaces for distributed workers and teams to support collaborative design and engineering tasks. This distributed software framework should allow the users to dynamically create distributed, knowledge-rich, worker-centric, adaptable and scalable collaborative workspaces, on-demand, so as to establish effective partnerships that are able to collaborate, be creative, improve productivity, and to take a holistic approach to implementing product phases. The collaborative workspaces built on top of the CoSpaces distributed Software Framework (CSF) environments will provide interactive virtual meeting places for problem solving, conflict resolution, knowledge sharing and receiving expert advice on-demand and will offer seamless and natural collaboration amongst distributed knowledge workers and teams [9].

The objective of the knowledge system component is to facilitate the collaboration of teams when trying to solve a certain engineering problem. The system should be able to provide the users with the most accurate information, which should enable users to use it in order to solve engineering problems.

The knowledge support component offers support to workers and teams who are engaged in collaborative design and engineering tasks. The specific aspects of a context, which will be considered in CoSpaces, are presence and location of users, current and past actions and tasks, availability of shared and individual data, and expertise of users.

Such context aware services are essential to reduce the complexity of shared multi-users engineering environments. They enable users to concentrate on their task by providing the task-specific information in the actual individual, group or process context and by filtering the noise of unrelated status and activity information that is often produced in distributed cooperative work sessions.

Sessions of active collaboration generally follow a well defined workflow. For example the tools and datasets used for weekly design review meetings will usually remain the same (the data in the sets changes, of course). Even the basic tasks will be similar, e.g. modification of parameters or geometry. Between these sessions of active collaboration the management system stores the key properties of the sessions. These can be restored when starting a new session and beginning a common workflow.

The knowledge support component will be able to support the collaboration lifecycle (Figure 1) on all five stages depicted on figure 1. Orthogonally these four stages could be mapped into knowledge dimensions which deal with accessing and capture knowledge.

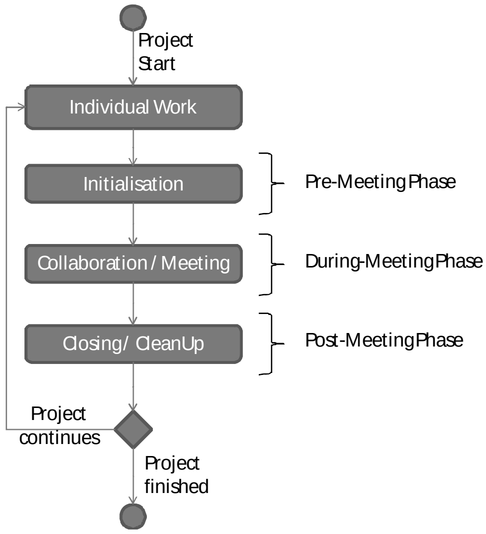

FIGURE 1
THE COLLABORATION LIFE CYCLE OVERVIEW.

The Individual Work phase deals with the identification of an engineering problem. Such phase comprehends a detailed description of the problem using natural language, performing annotations using CAD drawings and contextualising the current issue.

The Initialisation phase, also called pre-meeting, deals with the preparation of the agenda and the selection of the best experts to attend the meeting. The agenda preparation is supposed to be a semi-automated process, where a set of pre-existing templates are used in order to ease the development of the agenda. The system should also present a selection of best candidates to attend the meeting, where the user should choose the one's that best fit the purpose of the meeting.

The Collaboration/Meeting phase attempts to enable the participants to reach a common understanding regarding the issues previously identified. The system should help the users to find the right resources as guidelines solve a particular issue. This phase also comprehends the annotation of the several decisions that were made during the meeting.

The Closing/Clean-up phase, also called post-meeting, deals with the composition of the minutes. This phase is performed by a semi-automated process, which suggests the user with a set of conclusions from the meeting based on the several decisions that were achieved during the meeting. This process uses a set of pre-existing templates as the basis for the meeting minutes.

3. THE CONTEXT OF WORK IN COSPACES

Figure 2 shows the CoSpaces Software Framework (CSF), highlighting the points of relevance for CoSKS. From the CoSKS perspective (label ❷), two components are very relevant, namely the CoSpaces Portal (label ❶) and the document management system

(BSCW). Additionally to those, the technological choices and constraints brought by CSF are also analysed as part of the context in which CoSKS must work.

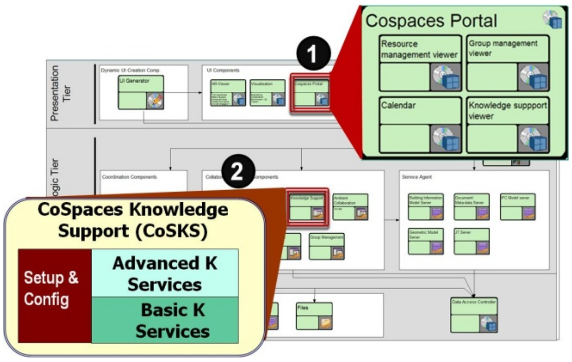

FIGURE 2
THE COSKS WITHIN THE CSF ARCHITECTURE

Throughout the CoSpaces Portal the users (manager and ordinary users) might have access to the knowledge-related functionalities provided by CoSKS, through the element named *Knowledge Support Viewer* (❶), which is a kind of *Knowledge entry door*. Such a component provides management and exploitation of the knowledge produced in the CoSpaces collaborative environment. The CoSpaces Knowledge Support (❷) is organised conceptually in three main parts, namely:

- *Setup & Config*: handles the needs related to setup and configuration of the CoSKS component (e.g., creation of users/passwords, servers' addresses, etc.);
- *Basic K-Services*: the vital services for the normal operation of the CoSKS. Without them, the CoSKS cannot work properly. Some examples are: knowledge items indexation, ontology-based search, calculation of semantic weights, browsing of CoSpaces ontology, store / retrieve knowledge objects, etc.; and
- *Advanced K-Services*: intended to extend and enrich the CoSKS capabilities. They are to be built upon the Basic K-Services. Some examples are: the management of templates (of agendas and minutes) in a series of meetings and support to knowledge capture and capitalization considering a given knowledge context.

It is worth emphasising that CoSKS must interoperate with the document management tool called BSCW, which is *omnipresent* within the CSF environment. From CoSKS viewpoint, BSCW is the place where knowledge objects will be stored/retrieved. As such, CoSKS must implement services that will access BSCW repository, through its respective API.

Another important vector in the CoSpaces context is the fact that Construction is one of the industries providing evaluation scenarios to assess the results of the project. As such, families of Construction projects will give the inputs to the operation of the CoSKS component. The basic idea is that during the normal development of a construction project, the COSKS will be in a position to help improving the quality of the management process, through the capitalisation on lessons learned, problems found x solutions proposed, etc., coming from similar projects already completed. A key aspect will be the representation of the knowledge produced during the lifetime of a Construction project and the subsequent exploitation of such knowledge.

4. THE COSPACES KNOWLEDGE SUPPORT COMPONENT

This section describes the main parts related to the development of the CoSKS, namely: (i) the requirements to be fulfilled by CoSKS; (ii) what are the innovative aspects brought by CoSKS; (iii) CoSKS conceptual architecture; and (iv) the respective CoSKS technical architecture. It is worth noticing that this is an on-going work and, as such, this is not the final definition of CoSKS.

Figure 3 shows four layers (or levels) where knowledge resides in. At the Domain level we find the knowledge related to the application domain of a given industrial sector (e.g., for Construction we can think of zoning regulations, planning permission, etc.). At the Corporate level we find the company specific knowledge (its intellectual capital), which is found both formally in company records and informally through the skilled processes of the firm. At the Community level there is knowledge shared inside a given community; it may include both project records and the memory of processes, problems and solutions. The user level represents the dimension where actors (engineers, managers, secretaries, etc.) generate/share/exploit knowledge.

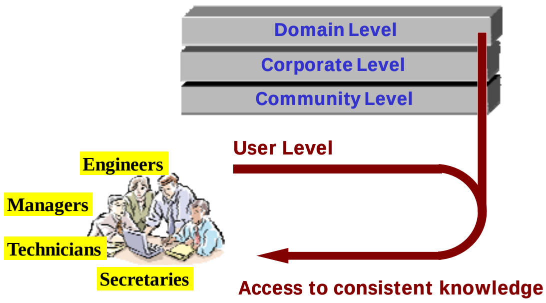

FIGURE 3
THE KNOWLEDGE LEVELS IN COSPACE (ADAPTED FROM [7]).

4.1 THE COSKS REQUIREMENTS

As previously stated, the CoSKS realises (within the CoSpaces Software Framework) the knowledge support dimension during a collaboration process, which can occur either in an isolated way or as part of the development of a long project. Additionally, other requirements must be considered by CoSKS. They are shortly summarised in Figure 4, categorised into three main classes, namely Functional, Architectural, and Technical requirements.

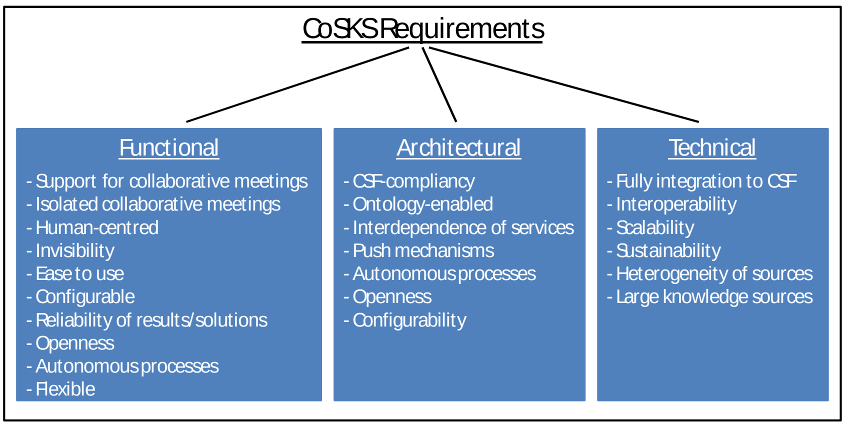

FIGURE 4
THE KNOWLEDGE LEVELS IN COSPACE

4.2 INNOVATION AND RESEARCH

The scientific foundations of the knowledge management system rely on the principle that the system should be dynamic enough to manage new types of context elements. It is proposed that the system should be based on a predefined ontology as a way to classify and establish relationships between an initial set of knowledge elements that should be contextualised according to the ontology. Such an initial set of contextualised knowledge elements will serve as a basis for making possible the search to knowledge elements more accurate during the system life-cycle.

The system should allow the introduction of new knowledge elements contextualised according to context element types that are not previously tackled by the ontology. The ontology should adapt according to the new context types and take such types into account. Such re-adaptation of the ontology against new context types is to be performed using user feedback i.e., the relations of the new context types should be "tuned" accordingly with the suitability of a certain knowledge element within the search query made into the system.

4.3 COSKS CONCEPTUAL ELEMENTS

The conceptual elements (internal ones) considered in the development of CoSKS are the CoSpaces Ontology, the Knowledge Items / Objects, Semantic Contexts, Semantic Vectors, and Templates (Figure 5). The external entities providing inputs to or interacting with CoSKS are the Knowledge Support Viewer (i.e., the Knowledge Portal), the BSCW (the *Basic Support for Cooperative Work* software tool, provides support for cooperative/collaborative work), and the Protégé Ontology editor.

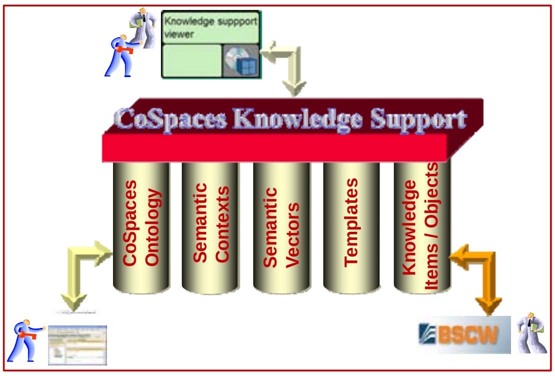

FIGURE 5
THE KNOWLEDGE LEVELS IN COSPACES

The CoSPACES Ontology

This ontology focuses on concepts as they relate to CoSpaces main objective, which is to support innovative collaborative working practices within distributed manufacturing organisations. Therefore, the ontology must provide the basis for a consistent knowledge representation of knowledge items from the industrial domains represented in CoSpaces.

Figures 6a and 6b depict, respectively, the motto driving the CoSpaces ontology and the first level of the hierarchy of concepts. The terms written in bold on the left represent concepts on the right hand side of the picture. Terms between parentheses represent subtypes of concepts. The terms Review, Decide, and regarding relates a process to a concept, i.e., they represent relations among concepts. The ontology, by its very nature and relevance, deserves to be described in a more detailed way, which cannot be done here.

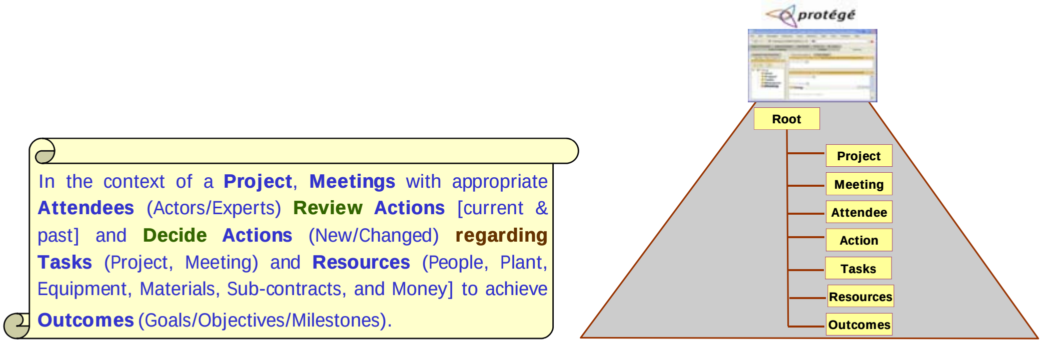

FIGURE 6A & 6B
THE ONTOLOGY MOTTO & ITS HIGHEST LEVEL (ADAPTED FROM [8] & [9])

Semantic Vectors

These are elements used to semantically index the knowledge items, based on ontological weights. Briefly, a list of ontological concepts that best matches a query is ranked according to the ontological weights assigned to each concept.

There are three ways to calculate such a weight, namely: equivalent terms-based, taxonomy-based, and fully ontology-based. The equivalent terms represent the keywords related to each concept (synonyms or words/expressions that can be associated to that concept). They are then used as "indexes" to access the concepts, therefore using purely "statistics" (the greater the number of equivalent terms of a given concept found in the query, the heavier the concept becomes).

The taxonomy-based way takes the previous weight and refines it using the "as is" relation to navigate around the heaviest concepts and augment the weight of neighbouring concepts (this augmentation is based on a configurable table of factors guiding generalization/specialization of the taxonomy).

The fully ontology-based method exploits all the relations that start from the heaviest concepts to augment the neighbouring concepts (augmentation process is similar to the taxonomy-based one).

Knowledge Items and Objects

Knowledge Elements (KELs) are pieces of knowledge focusing on specific topics. Entity and Constraints forms enable the collection of knowledge about product breakdown and product limitations. Activity and rule forms enable the collection of knowledge about process breakdown and flow control. Finally, illustration forms can be linked to any of the other forms so as to record any corresponding past experience.

These forms are an example of how to organize structured KELs. Other examples of KELs found in industrial companies may include documents about lessons learnt, best practice examples, expert manuals and expert contact information, etc..

The smaller the KEL, the more the process of delivery-in-context makes sense. The objective is then to select the right K-EL which applies to the user context. If all KELs are merged in one big document, without any way to discriminate them, the in-context delivery process will make no sense or will be time consuming. This one big document approach will be applicable in all user contexts, and the individual user will not know (or will delay discovering) which knowledge in the document really applies to the context.

From the analysis of the use cases coming from the CoSpaces, several types of KEL were identified as follows:

- Issue – This feature represents the problem which is intended to be resolved;
- Actors – Type of user involved in collaboration activities; and
- Artefacts (audio, video, images, documents, etc.).

Semantic Contexts

In order to define the context model to be used within CoSpaces, an approach was explored which starts from the study of existing KELs and describing their context of use.

Semantic contexts allow recognition of new circumstances where the model can be usefully applied. In order to achieve our objective of in-context K-EL delivery, we focused on representation of an engineering context, which is the abstraction of those elements of circumstances in which a K-ELs is learnt, that allows recognition of new circumstances where the K-ELs could be usefully applied. We studied real examples of K-ELs coming from CoSpaces use cases and we identified how to describe their domain of applicability. The result from this approach was the identification of relevant context dimensions. Context dimensions are properties or attributes that describe the context.

The following context dimensions arose from the analysis:

- Process: describes the stage of the project life-cycle associated to the KEL (Conception, Design, Produce, Maintenance, etc.).
- Product: name of the product(s) which is related with the KEL.
- Project Type: type of the project(s) which is related with the KEL.
- Project Phase: knowledge items might have different meanings in different phases of the project.
- Role: type(s) of role associated with the KEL (e.g., Architect, Engineering, Foreman, Project Manager, etc.).
- Discipline: type of discipline associated with the KEL (Duct, Structural, Electrical, HVAC, Architectural, etc.).

Templates

They are intended to support the collaboration event itself. CoSKS will suggest customisable starter templates for three classes of meetings, namely initial, ordinary (technical / management), and review.

Each template can be viewed as a structured document holding information objects (such as content blocks, action phrases, authors / actors, action target dates) that can point to knowledge items and can refer concepts from the ontology.

5. CoSKS CONCEPTUAL ARCHITECTURE

The CoSKS component operates within the CSF environment, where users play a key role. Therefore, these two entities (users and CSF) are also depicted in the CoSKS conceptual architecture, helping to present it in the right context (Figure 7). Three rectangles isolate each one of these entities.

On the left side is the users' area, showing three classes of users, namely ordinary user, administrator, and ontology manager. The latter is responsible for the creation of the CoSKS ontology using the Protégé tool. Other two classes represent the CSF users (ordinary and administrator).

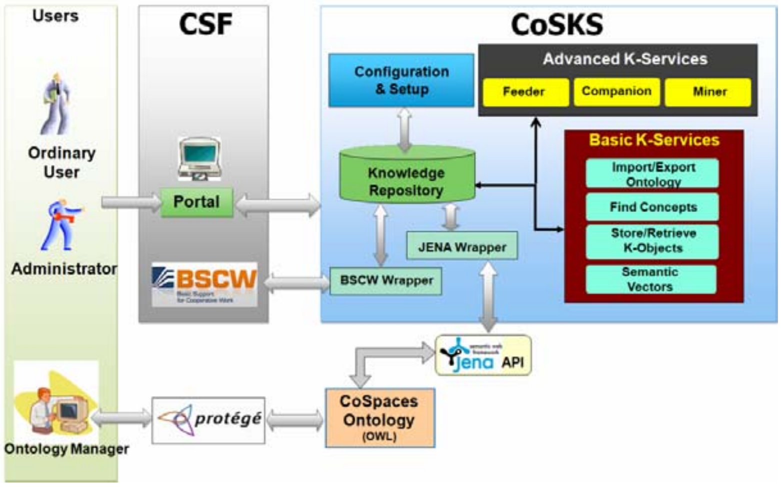

FIGURE 7
THE COSKS CONCEPTUAL ARCHITECTURE

On the centre we have the CSF area, showing the CSF Portal and the BSWC. The former will support the collaboration processes of the users, who will create/maintain/share/exploit knowledge during those processes. The latter is intended to be used as the repository of knowledge items created/maintained/shared/exploited by CSF users. Finally, on the right side we see the CoSKS area, displaying its conceptual architecture. Major elements showed here are the following:

- Configuration & Setup: supports the mandatory configuration of basic elements to guarantee the integration of CoSKS into CSF (such as ports, servers addresses, etc.) as well as the very operation of the CoSKS (e.g., definition of users' access rights).
- Knowledge Repository: represents the "conceptual" repository used to store knowledge-related resources, such as the ontology itself, the CoSKS database, Knowledge objects, semantic vectors, templates of meetings minutes, just to name a few.
- Basic K-Services: the vital services that guarantee the operation of CoSKS. Some examples are: import/export OWL ontology, calculate ontological weights (based on semantic vectors), concepts-based searching, and store/retrieve knowledge objects.
- Advanced K-Services: high level knowledge services. Some examples are: management of 'semantic contexts', management of meeting minutes as part of a series of (project) meetings, historical analysis of 'similar' projects, lessons learned advisor.
- BSCW Wrapper: provides the access to knowledge items. This wrapper also provides a sort of independence of the BSCW in the sense that if the repository of knowledge items change, than the only component to be changed in the CoSKS is this wrapper.
- JENA Wrapper: provides the access to the CoSpaces ontology imported/ exported from/to Protégé. The independence argument presented for the BSCW wrapper is also applied here.

6. CONCLUSIONS

In this paper, we outlined an approach to integrate knowledge management with collaborative engineering activities. The CoSKS component has been introduced as an element to work within the CSF operational environment and, as a single component to support the knowledge dimension of CoSpaces. The major conceptual axes guiding the development of CoSKS is the Knowledge Enabled Engineering approach, the evolution of knowledge items along their lifecycle and the knowledge aspects raised as part of collaboration processes.

Collaboration usually involves three main phases, namely the preparation, the collaboration itself, and the post-collaboration phase. In the first phase, collaborators are (either pro-actively or motivated by the system) working on the preparation of the collaboration. In the second phase the collaboration really happens through a kind of event, such as co-located or remotely-based meetings. The last phase targets the accomplishment of actions and to-do list produced during the second phase.

The CSF itself suggests some requirements, constraints, and technical choices that will be followed by the CoSKS. The CoSKS offers a set of knowledge-related services accessed by the users via the CSF Portal or accessed by other software components through the appropriate API. The CoSKS is ontology-enabled set of services; as such, the ontology is in the very centre of the development. Such ontology is conceived to fulfill the requirements guiding the development of CoSKS together with the three conceptual axes supporting the work. Protégé is the ontology editor adopted here and JENA API seems to be the most recommended way to explore OWL-compliant ontologies. The CoSKS conceptual architecture adopts a two-layer approach where the knowledge services are classified into basic and advanced services.

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