ANALYSIS AND MODELLING OF A SOCIO-TECHNOLOGICAL FRAMEWORK FOR SCIENTIFIC COLLABORATION[1]

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Abstract:
The scientific development of different disciplines at the beginning of the 21th century can only be conceived in an interdisciplinary context. This fact implies both an in-depth documentation and cooperation among the scientists in the diverse knowledge spheres. Knowledge workers are not linked to a unique organization, but they are in touch with persons belonging to other organizations. In this complex relation system, the employers are involved concurrently in similar working situations, but, at the same time, they are permanently learning. That is why, Internet technologies are improved to sustain this net society, being adapted, at the same time, to individual needs and profiles. The creation of conditions for organizational culture of academic communities' development presupposes a suitable socio-technological framework. The paper analyzes the challenges and introduces models for a knowledge management experimental system for scientific communities, proposing the use of Service Oriented Architecture for the composition of knowledge, defining a modular architecture and an algorithm of collaborative knowledge generation.

Key words: *socio-technological framework; Knowledge Management (KM); Service Oriented Architecture (SOA); Knowledge Worker (KW); Next Generation Collaborative Working Environments (NGCWE); collaborative knowledge generation*

1. Introduction

The creation of conditions for development organizational culture of academic communities presupposes a suitable technological framework allowing for the knowledge worker's (KW) creativity, besides the improvement of the value system and managerial ethics based on transparency, communication and understanding. On the other side, nowadays, in the network economy, persons are not linked to a unique organization, but are in touch with persons belonging to other organizations. In this complex relation system, the employers are involved concurrently in similar working situations, but at the same time they are permanently learning [7]: on-the-job, just-in-time, just-as-required, on-demand, learning-by-doing. That is why, Internet technologies are improved to sustain this net society, being adapted, at the same time, to individual needs and profiles.

The knowledge management system (KMS) architecture is a fundamental issue in the area of KM (knowledge management) that must be well resolved in order to deliver competitive services to the users as well as to the organizations.

Müller and Schappert [19] proposed a generic architecture for knowledge management that is grounded on the basic insights of information theory respecting the division of data, information and knowledge and it offers clear interfaces to the different levels and dimensions through an abstract set of objects and operators.

Meso and Smith [18] proposed a KMS architecture that processes a combination of technology, function and the knowledge itself as well as other components which are able to perform according to the requirements of the organization. In terms of technology, KM should have features such as computer-mediated collaboration, e-mail, video-conferencing, web browsing, search engine, intelligent agent, and document management. Furthermore, in terms of its functionality, KM involved the processes for acquiring or collecting, organizing, disseminating or sharing knowledge and using knowledge among the stakeholders.

Collaboration environment provides a framework for bringing minds together, organizing their efforts, managing the process and producing outstanding results. When each member of a team collaborates on a mission or project, each would be able to contribute his or her own strength, skills and knowledge, to ensure the best results for the project [3].

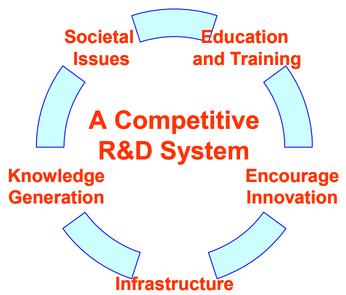
Abdullah et al. [1] proposed a KMS architecture that is developed by using four layers, which includes a protocol layer as a top level, in order to allow a user interface application with the community, and a technology layer that facilitate the community to work together, to share, re-use and generate knowledge among them. They also found that the KMS model includes the functionality and system architecture as the backbone to support the KMS process, taxonomy deployment, and cultural aspects as well as the knowledge strategies and measurement or system auditing. The functionality of system may consist of a portal, electronic document management system, workflow management, data warehouse and artificial intelligence (such as agent technology).

In nowadays economic development six main changes are to be relieved [2]:

- from linearity to complexity;
- from individual to system competitiveness;
- from resources-based to knowledge-based economy;
- from macro to micro;
- from top down to bottom up production systems;
- from mono-disciplinarity to multi- and trans-disciplinarity.

In the same symposium [2], Andreta illustrates the areas for research and development (R&D) system as in Figure 1.

Figure 1. Areas for R&D System [2]



Collaboration at work has at least four dimensions [20]: users and group members (co-workers), working processes, technologies and application areas. From the new technologies point of view, the next generation collaborative working environments (NGCWE) have to integrate all these dimensions into a suitable collaboration at work platforms, based on flexible service components, interoperable at syntactic, semantic and protocol level.

In this context, the paper proposes a modular architecture of a collaboration platform, namely a knowledge management experimental system (KMES) dedicated to research virtual communities. This collaboration platform is seen as a socio-technological framework.

The portal KMES needs to support researchers with a knowledge building architecture (KBA), which provides databases, virtual libraries and applications for collaboration, coordination, education, training and publishing. Interoperability and semantic integration will lead to an activity-based collaboration support.

2. Analysis of the Socio-technological Framework

This subchapter outlines the scientific and technical objectives that led to the conception of the Knowledge Management Experimental System (KMES) (see 2.1) and then analyses the opportunity of using Service Oriented Architecture (SOA) for designing the platform, as opposed to other approaches based on components or publish/subscribe mechanism (see 2.2).

2.1. Scientific and Technological Objectives

The proposed multilingual research portal for scientific organizations, with enabling applications for national and cross-border academic activities based on standardized and user-friendly technology has to meet the needs of persons involved in the research sector. The objectives of the framework are:

1. to support the development and management of a *common body of knowledge* shared within the research community as a way of creating a community of experts linked by their common focus on research, education and training;
2. to facilitate the development of *a new working model* for the distributed research units where the emphasis lies on creating multi-functional, highly flexible knowledge workers, on actively creating and working with knowledge resources in a participatory fashion rather than as passive information consumers;
3. to ensure *quality and relevance* of all knowledge content created and stored within the platform by creating a system that allows access to the platform in a managed and multi-layered manner;
4. to provide *a ubiquitous, user-friendly point of access* allowing access from anywhere and at any time with minimal technical requirements and knowledge on the part of the participant;
5. to allow knowledge worker's creativity, besides the improvement of the value system and managerial ethics based on transparency, communication and understanding.

2.2. Service Oriented Architecture for the Composition of Knowledge

Complexity has always been addressed according to the "divide ed impera" maxim. Division seeks to decompose the problem in independent and smaller parts, therefore easier to solve individually. The composition of knowledge is based on the composition of subsystems dedicated for managing, storing and retrieving information. The deployment of KMES components, presented in detail in chapter 4, can be done on different processing nodes, which can be hosted by different organizations, with a high geographical distribution. The question is: "which is the best solution to compose these subsystems, such as to allow KMES to adapt easily to new requirements and to assimilate new knowledge and workflows for specifying the work for creating it?".

The classical composition mechanism is the procedure call, where the target can pertain to another part, eventually a remote one. The linker is in charge of realizing the composition, either statically or dynamically, at execution. Object Orientation (OO) lightly improves dynamic linking by adding polymorphism. The component technology pushes the same logic one step further, imposing that components are treated as black boxes and only expose their interfaces. Initially, component models provided abstraction at a single level, but then they have introduced composite components, supporting the creation of hierarchies, like in Fractal [5] or SOFA [23]. The drawback is that the code explicitly refers to required interfaces and calls are always synchronous; it also determines the propagation of an interface change to all the client and required components, such that the source code of these components must also be changed. In order to improve reliability in component composition, one associated to each component a number of contracts, based on issues like interface signature, behaviour, interaction and quality [17]. In order to improve independence, some component models have proposed the connector concept, and classic wrappers or adapters serve exactly the same purpose as in Enterprise Application Integration (EAI) [16], but the direct connection still involves difficulties of evolution and adaptation. To improve the independence between components that publish and those interested in what is published, one introduced the publish/subscribe approach[4], with the advantage that parts do not have to know each other explicitly. However, there is still the problem that composition logic is spread between components; it is not clearly defined and cannot be changed without modifying the component code.

To improve flexibility and independence, control flow should not be the responsibility of each component. Such an approach is orchestration, which extracts the control flow from the components and considers that composed parts provide services. This approach has been made popular by the web service domain [22] but spans to any applications built out of components that do not call each other, irrespective to the nature of the component (service or not) and irrespective of the communication means: method call or messages, synchronous or asynchronous. Orchestration hypothesizes that services have the same nature, have been developed to be composed, do not overlap in their functionalities and do not need to be synchronized during their execution. The service oriented architectures support a wide geographical distribution of the deployed software artefacts and of the actors participating at the collaborative creation of knowledge, based on the technologies characteristic for the Internet of the Future [9]; the flexibility and extensibility of platforms increase by adopting new generations of web services - discovered at runtime, on the basis of semantic web.

A similar approach was proposed by Pohl in [24], where he calls it Knowledge Management Enterprise Services, meaning an implementation of SOA, focusing on the exchange of data within the context of a particular knowledge domain. However, Pohl does not intend to use these services for a collaborative working environment, but for the rapid development of applications based on reusing code based on sharing an information model.

3. Multiple Actors for Knowledge Management

The proposed architecture, fully based on XML standards, is a completely decentralised one, allowing participants to access the platform from anywhere using a simple browser interface. This interface allows for remote administration, control, content creation etc.

Four main KW types are addressed, corresponding to multiple knowledge platform actors: content manager, community manager, information resource facilitator and project manager. They are depicted in *Figure 2*, together with their associated use cases with the Unified Modelling Language (UML). Experts in the interdisciplinary research fields are also considered knowledge workers, which are both consumers and creators of knowledge; they can play various roles in respect with the platform.

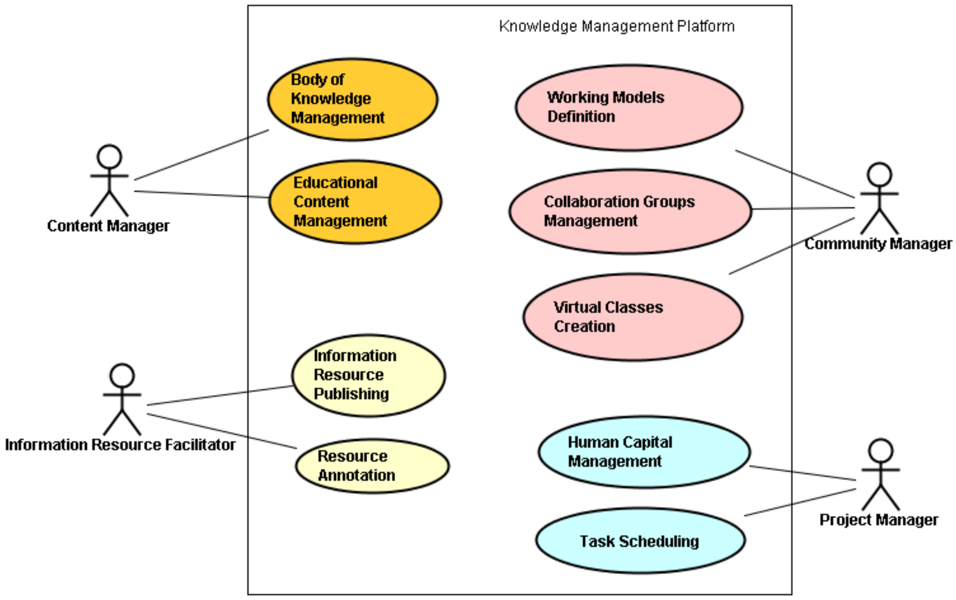


Figure 2. UML Use Case Diagram for the Knowledge Management Platform

The difficulty stands in the fact that complex systems based on SOA, as the one designed here, generally have multiple actors, assigned for the various competencies that are required. Similarly, the LD-CAST system described in [12], dedicated for supporting entrepreneurs and enterprises with legal and fiscal information, has 5 actors for the platform administration and management: Business Process Designer, Knowledge Engineer, Service Provider Administrator, Service Provider Clerk, and Administrator.

Several attempts for classifying these roles have been done. Lin and Krogstie [15] identified social and technical actors, for a framework for semantic annotation of business processes. Kajko-Mattsson et al. [13] defined 24 roles for the development, evolution and maintenance of SOA-based systems, which are classified into 7 categories: front-end and back-end support, management, design, quality assurance, administration, and strategy. Such studies prove that new platforms have different actors that the traditional IT systems, which have a common responsibility for maintaining the system up-to-date and coherent. As they work with different tools, languages and they focus on different architectural views, new procedures are necessary for assuring the system evolution.

4. Modelling the Architecture of the Socio-technological Framework KMES

Knowledge building in the research community has inherent knowledge management problems due to its global dimensions and high degree of complexity. The growing body of information with little or no quality control may in fact lead to increasingly uninformed decision making resulting in confusion and ultimately poor outcomes. The management challenge is not only to find ways to conserve the use of a scarce resource, but to cope with its over-abundance.

Partnerships in research rely on information sharing and active networking. Collaborative efforts reduce duplication, increase transparency and work against the fragmentation of research. It is more effective if the results of past efforts are readily available to inform new programmes. The effective use of ICT can address many of these problems by putting in place systems, which recognize the role of experts in this field, as knowledge workers who are both consumers and creators of knowledge. In *Figure 3* there is an overview of the scientific collaboration portal architecture.

Knowledge work necessitates continuous learning as well as constant teaching and knowledge sharing. The functional application modules are: *KMES-Factory* for content production, *KMES-CSCW* for communication, collaboration and coordination, *KMES-People* for community management, *KMES-Lib* for library and resources management and *KMES-Edu* for adaptive e-learning. They are presented in detail in 4.2. The KMES architecture is based on modularity and integration, configuration and security, adaptability and availability, expert collaboration and knowledge management. The modules of the architectural structure are foreseen as an integrated collection of Web services that allow flexible access to the relevant knowledge resources in the system. The proposed architecture, fully based on XML standards, is a completely decentralised one, allowing participants to access the platform from anywhere using a simple browser interface. This interface allows for remote administration, control, content creation etc.

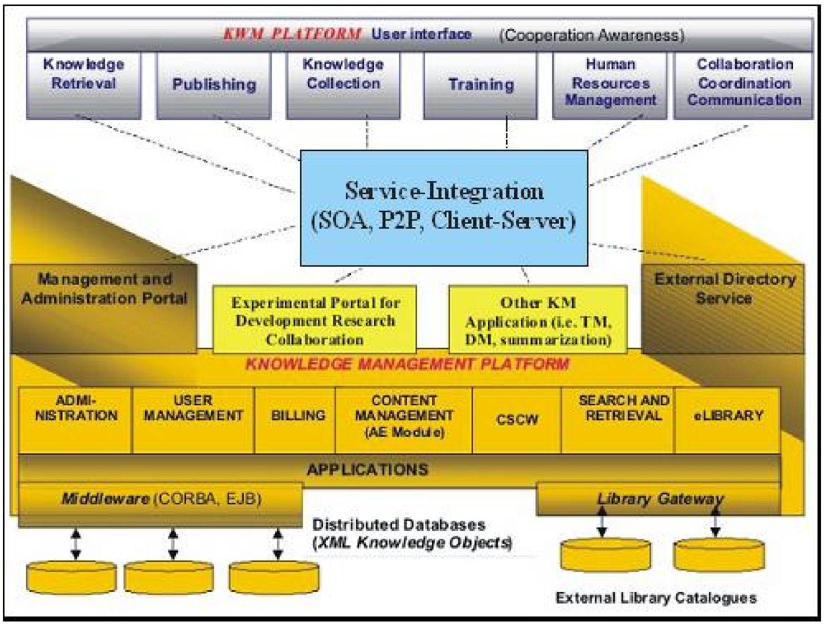


Figure 3. Architecture of the Socio-technological Framework KMES

4.1. Applied Principles and Architectural Styles

The term *knowledge work management* (KWM) denotes all activities of an organisation, on a strategic and operational level, that aim to create optimal conditions for efficient, effective and attractive knowledge work. There are six fields of activity that are of special relevance in the realm of KWM and learning arrangements [11]: new work organisation, knowledge product management, organisational learning, competence development, knowledge worker performance and productivity, performance management.

A SOA (Service Oriented Architecture) separates functions into distinct units, or services, which developers make accessible over a network in order to allow users to combine and reuse them in the production of applications. XML is used for interfacing with SOA services.

P2P (peer-to-peer) architecture is any distributed network architecture composed of participants that make a portion of their resources (such as processing power, disk storage or network bandwidth) directly available to other network participants, without the need for central coordination instances (such as servers or stable hosts). Peers are both suppliers and consumers of resources, in contrast to the traditional client-server model where only servers supply, and clients consume.

The research portal offers participants a common multi-lingual application environment for the creation and development of digitalized, granulated knowledge, its conveyance and its permanent storage. The management challenge is not only to find ways to conserve the use of a scarce resource, but to cope with its over-abundance. Partnerships in research rely on information sharing and active networking. Collaborative efforts reduce duplication, increase transparency and work against the fragmentation of research. It is more effective if the results of past efforts are readily available to inform new programmes.

4.2. Description of KMES Subsystems

Knowledge work is a creative work and requires creation, acquisition, application and distribution of knowledge, using intellectual abilities and specialized knowledge, requiring a high level of education, training and experience resulting in workers' skills and expertise and a strong and flexible support by ICT (*Information and Communication Technologies*). Knowledge work necessitates continuous learning as well as constant teaching and sharing of this learning with colleagues.

The application subsystems of the proposed socio-technological framework KMES are:

- *KMES-Factory* for content production,
- *KMES-CSCW* for communication, collaboration and coordination,
- *KMES-People* for community management,
- *KMES-Lib* for library and resources management,
- *KMES-Edu* for adaptive e-learning.

According to the mappings of the "4+1" Views model to UML diagrams proposed in [10] the development view can be illustrated as a UML component diagram (see *Figure 4*) with connectors that can be later realized through Web services; it shows the point of view of the developers at a high level of abstraction.

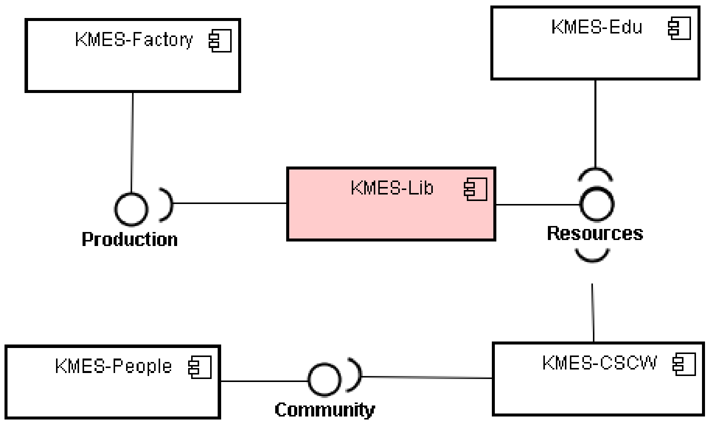


Figure 4. UML Component Diagram of KMES

KMES-Factory manages the production, publication and quality management of multi-lingual XML based content within the research community. Specific objectives include: definition and establishment of a workflow management system that will shorten and simplify the typical content production process – the adoption of structured processes can significantly increase the efficiency of work [26]; development of a template database alongside the content database which will allow for the creation of fully reusable and standardised (XML-based) content products; provision of an efficient content creation mechanism, which will ensure a balance between quality and costs.

KMES-CSCW deals with the creation, management and integration of a common communication and collaboration platform amongst the research community. Specific objectives include: the creation of conditions whereby participants are able to build collaboration groups in the context of research teams; the promotion of active participation in the overall communication process through the provision of a responsive and easy-to-use communication platform linked to the other components of the research platform allowing e.g. collaborative knowledge creation between different organisations; an improvement in the collaboration process through the creation of interactive, decentralised participatory work spaces; evolution of improved work practices, which enhance creativity, innovation and responsiveness. The definition of working models, which is the responsibility of the Community Manager, will orchestrate the way a group of individuals work on a shared task and will increase the awareness of the collaboration process, as shown in [14].

KMES-People is the organizational DIRECTOR component and reflects the need to put in place a knowledge-based system, which will allow for the decentralised management of human capital within the research community. This component will store general information about a scientist and his/her rights in the system and will be linked to the other components. It has as specific objectives: development of a sophisticated multi-lingual search tool which allows participants the search for individual and highly granulated specialist knowledge and experience; provision of a mechanism whereby individuals and organisations can track and update information about contacts and where such tracking is linked to other components of the platform; automation of this system, which ensures that information is managed in a way that is acceptable to the participants with appropriate control and management layers to ensure proper use. A common ontology of competencies is absolutely necessary for this purpose, as the problem arises from the fact that different communities use different classification criteria for characterizing their skills and work. A similar problem was treated by the FP7 project called SEEMP, creating such a core ontology for allowing the interoperability between non-homogenous e-Government systems for the employment sector, pertaining to different countries among Europe [8]. These were concepts were mapped on those used in the current work inside various employment agencies.

KMES-Lib component allows publication and universal access to a rich resource of journals and other publications, reports and documentations. The specific objectives for this component are: establishment of a meta-database of European multi-lingual documentation in the field of research and to use this as a tool for librarians in this sector; creation of a powerful interface within the research platform where library collections throughout the region can be searched from one place and linking this to a centralised document delivery and electronic billing; developing a specialised set of multilingual thesaurus tools allowing participants to search for material catalogued and indexed in other languages.

KMES-Edu component offers flexible learning solutions to the users. The specific objectives of this component are: creating possibilities of virtual users for selection of their instructional components, personalizing their learning environments; offering flexible solutions for dynamic adaptation of the instructional content according to the individual needs in real-time education. Traditional Learning Management Systems (LMSs) are currently replaced by e-Learning 2.0, supporting collaborative learning through blogs, wikis and social software [25]. For this purpose, the functionality of KMES-Edu will be leveraged by those offered by KMES-CSCW for collaboration between researchers, educators and students.

5. Collaborative Knowledge Generation

This framework is built on a technological infrastructure, a KBA, which addresses modern demands in expert collaboration and knowledge management. Rather than creating a sophisticated technological platform remote from the targeted institutions that are seen simply as consumers or 'end-users', the proposal takes the innovative approach that by using the proposed workbench, the target workforce bring their own knowledge resources to the wider research community. Thus, they become *an integral part* of the knowledge platform itself.

Content modules are produced and managed by *KMES-Factory*. *Annotation Engine Module* (*AE Module* in *Figure 3*) is the part of *KMES-Factory* that classifies and organizes dispatched texts, using XML. It has an important role in the *KMES-Factory*: without a good design of this software module, the user could be "lost" in the information of the previous text discussions. Diversity and the great volume of information of the discussion bases for research collaboration claim a good classification for relevant content filtering. The filter is built on a number (greater than 50) of discussion databases, already classified by a human expert. The filtering algorithm computes the similarity of a new text with the texts in the knowledge base.

Here are the processing steps:

- *Identification of the users' language*. For each language "known" by the filter (e.g. English and Romanian) dictionaries with more than 500 frequent words (conjunctions, prepositions, articles, adverbs, auxiliary verbs, etc.) are stored. The segmented text is compared with each word in these dictionaries and the best score identifies the language; if there are identical scores for different languages, Cavner and Trenkle's method may be used [6].
- *Text segmentation in lexical units*. The new text is "cleaned" by taking out the functional words (those more than 500 frequent words in the dictionary). A parser has to identify types of tokens of the text: natural language words, URL-s, calendar dates, e-mails, IP addresses, DNS (*Domain Name Server*). Segmentation means parsing the cleaned text. The initial text will be annotated by these tags.
- *Comparison between the new segmented text and the knowledge base texts*. The order of the words of the text is not maintained; a profile is computed by sorting the words according to their frequency of appearance. These profiles are computed for the new segmented text and for the texts from k**nowledge base (**KB), too. The "distances" between the profile of the new text and the profile of each KB texts are computed. This "distance" is computed as the sum of the differences of the ranks (positions) of the same word of the two profiles.

The text of KB with the less "distance" is chosen as the best match of the profiles. Therefore, *an automatic classification of the texts* can be processed.

Example:

N Profile = {w1, w2, w3, w4}; N-Rank=p => pw1=1, pw2=2, pw3=3, pw4=4
// The new text contains the words: w1, w2, w3, w4, with this frequency order K1Profile = {w4, w7, w9, w1, w10}*
K1-Rank =p' => p'w4=1, p'w7=2, p'w9=3, p'w1=4, p'w10=5
K2Profile = {w3, w1, w5, w7, w2}
K2-Rank =p" => p"w3=1, p"w1=2, p"w5=3, p"w7=4, p"w2=5
Distance (N, K1) =Σ (pwi-p'wi)=pw1-p'w1+pw2-p'w2+pw3-p'w3+pw4-p'w4=1-4+2-0+3-0+4-1=5
Distance (N, K2) =Σ (pwi-p"wi)=pw1- p"w1+pw2-p"w2+pw3-p"w3+pw4-p"w4=1-2+2-5+3-1+4-0=2
=>NProfile matches to K2Profile and the text N will be in the same category as the text K2.

The system provides an automatic link between the *creation of content* and *collaboration amongst authors* by putting in place a functionality that allows authors of a common piece of content or knowledge chunk to link discussion groups with individual pages or elements of a document. The record of communication amongst collaborators following the creation of such a knowledge chunk can in turn be archived within the overall knowledge platform and becomes, in turn, part of the systems overall knowledge repository. Such efforts include the exchange of information and experience, the building of consensus, the creation of new knowledge through collaboration and rapid decision-making. Our framework gives the possibility of collaborative knowledge generation: innovative solutions in unpredictable situations, provided by human and social factors. This genuine social capital must include spiritual and mental dimensions.

6. Conclusions and Further Work

This paper proposes an architecture that addresses the needs for finding and maintaining information for users in scientific collaborative settings and that helps to structure and share new knowledge in working environments. Our architecture also facilitates the building of a value and norm based system of knowledge transfer and learning for human agents.

The KMES architecture is based on modularity and integration, configuration and security, adaptability and availability, expert collaboration and knowledge management. The modules of the architectural structure are foreseen as an integrated collection of Web services that allow flexible access to the relevant knowledge resources in the system.

Collaborative web portals provide enhanced support for users within the restricted domain of a collaborating community or an organisation. However, the growth of web-based communities outside of formal organisations, the emergence of virtual organisations and the growth of dynamic team-based working within organisations means that users increasingly have to manage their involvement in a number of separate web portals as well as with the publicly available Web.

Our framework is not only a sum of communicational and informational technologies; it is also seen as a "human" net that integrates in its structure and functionality the users' interaction. Thus, it has an "integrating vocation" for scientific research, connecting results of different research processes, developed with diverse methods. The outcome of this process is a level of knowledge that is not identical with the sum of knowledge parts, being superior. The leap is from a mechanical level of totalling to a holistic one of a spiritual type.

The proposed architecture raises several issues that require further investigation in order to assess usability and scalability of this architecture for deployment on the Internet. The further investigations are concerned with integrating this platform with the capabilities of Semantic Web ontologies and of artificial agents.

Development of a KMS implies [21], as a first stage, creating the initial knowledge building architecture that consists of infrastructure evaluation and alignment of the KM to the business strategy. The second stage is dedicated to analysing, designing and implementation of the knowledge management socio-technological system. The installation of the software tools in an operational environment is the third phase. The last stage consists of performance evaluation and measure of the return on investment (ROI). Socio-technological systems architectures development has to be linked to the organizational KM objectives. These objectives can be achieved through a hierarchical, top-down or decentralized communication structure, and/or process guided, and/or as a support for communities of practice.

Developing a functional system in accordance with the proposed architecture of the framework, involves the phases outlined above. A project of this size requires special financial and human resources, as an European research project is.

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