Mobile Collaborative Knowledge Management System

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Abstract

Knowledge Management (KM) is gaining more an more interest among high-ranked executives in organizations of diverse kind. Consequently, many systems have been developed claiming they are Knowledge Management Systems (KMS). In this work we present a KMS that tackles some problems most existing KMSs sit have not: Ubiquity, Collaborative Knowledge Management, Context-sensitivity. It also tackles the problem about privacy and fears people may have to reveal the knowledge they posses. The system supports its user in the processes of knowledge creation, validation, distribution and use.

Keywords: Mobile Computing, Collaborative Work, Knowledge Management.

1. Introduction

Knowledge Management (KM) has been defined as the ability to create, validate, distribute, review, share and apply knowledge. According to experts on this area, it can significantly improve the performance of the organizations in which it is applie, [1], [2], [3]. KM implementation and use has grown rapidly since the 1990s, as evidenced by the fact that 80% of the largest global corporations now have KM projects and over 40% of Fortune 1000 companies have a Chief Knowledge Officer, who is a senior-level executive who creates an infrastructure and cultural environment for KM. However, the existing research on KM has been theoretical and rather abstract [4]. According to [3], much of the published work on the subject consists of isolated empirical studies, theoretical frameworks [5], conceptual studies that define terms or identify the important issues (reflecting the views of researchers conducting surveys of practitioners) or anecdotal case studies into particular aspects of KM Systems (KMS). The KMS range from expert systems languages, database languages (Oracle PI/SQL), programming languages (C++) providing fundamental building blocks and KMS generators (Lotus Notes) to specific KMSs that have successful been built. However, the use of these systems has been limited to fixed workplaces, thus excluding scenarios characterized by mobility and social face-to-face interaction of workers. Although some researchers have noted that face-to-face encounters are a significant source of knowledge creation, only a small number of KMSs supporting mobile KM processes have been reported, [2], [4].

In accordance to Matuszewki and Balandin (2007), Fagrell, Kristoffersen, and Ljungberg (1999) the introduction of a mobile KMS into organizations can be expected to bring about dramatic changes in the way mobile business processes are conducted, which have demonstrated in practice through the implementation of a mobile KMS by [2], [4]

The following key issues have been identified while developing KMS : a) design of an appropriate interface design for mobile applications using display, gesturing and sketching metaphors; b) design of computer tools that support knowledge creation through a series of activities denoted create, validate, distribute, review, share and apply; and c) carrying out of empirical studies aimed at generating suitable designs and experimental tests to determine the advantages and disadvantages they entail, [4], [5].

In this paper, we present a work aimed at defining mediation mechanisms and implementing them in a mobile collaborative KMS-prototype application using wirelessly connected mobile technologies (Tablet-PC and PDA) to support various KM processes arising from face-to-face interactions among persons at an organization in mobile scenarios. Each such person will have a Tablet-PC or PDA that will implement an equivalent version of the mobile collaborative KMS application. The resulting application is also able to synchronize the knowledge between each participant and integrate it with stationary KMSs. It includes tools like concept maps for facilitating KM processes and employ display interfaces and interaction mechanisms based on gestures and sketches using the devices' touch-screen feature. To achieve this goal, a three-step methodology was applied: 1) Bibliographical and empirical research in the form of a ethnographic study in a real context of local mobile work from a representative organization that requires KM process support. 2) Design and implementation of a prototype of the KMS mobile application which include visual interfaces and use gesturing and sketching to facilitate knowledge creation through the construction of concept maps, over a ad-hoc network of wirelessly interconnected infrastructure for Tablet-PCs and PDAs as well as proximity detection components using IRDA technology. And 3) the identification of the mobile add values of the implemented KMS mobile application.

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2. Knowledge, KM, KMS and mobile KMS

Knowledge is thought to be of two types, explicit and tacit [6]. **Tacit knowledge** is embedded in human actors, routines, etc. and thus cannot be easily shared or distributed and **explicit knowledge** is coded knowledge which can be shared easily, [6]. Tacit knowledge is thought to be in people's heads and very difficult to extract them for their correspondent codify and store in machines. Derballa and Pousttchi [1], define a **KM** as a collection of processes to permit the utilization of knowledge by the members of some organization is pursuing a very global approach: **Creation** refers to a process in which new knowledge is created by combining and integrating different pieces of data, information and knowledge. **Validation** describes controlling individual or collaborative activities of review, testing new and eliminating obsolete knowledge. **Presentation** refers to the display of knowledge, i.e. different formats, data standards, etc. **Distribution** deals with sharing of knowledge among organization members. **Application** is the term for the use of knowledge in a particular context.

Gallupe [3], indicates that there is no commonly accepted **definition of KMS**. Most definitions refer to "tools" or "technologies" that support KM. However, only a few provide a comprehensive definition of tools or technologies, or combine those definitions with explanations of how knowledge is systematically managed. According to [7], the **definition** of KMS is "…a system designed and developed to give decision users in organizations the knowledge they need to make their decisions and perform their tasks. These systems extend beyond the traditional information systems in that they must provide context for the information presented... ".

Recent studies in the area of Computer Supported Co-operative Work and Human Computer Interaction have shown that mobile environments pose different problems and possibilities from the stationary setting [8], [9]. The current tendency to localize activities to an individual and stationary user has meant that flexible and unexpected interaction that often emerges out of a mobile work situation has remained generally unsupported [8]. The assumptions upon which stationary systems are based are not fully aligned with how work is carried out in mobile settings. The need to understand mobile work and to design KMS that really accommodate mobile settings is thus growing, [9].

Kristoffersen and Ljungberg's [9] way of conceiving mobility work is to distinguish between traveling, visiting and wandering modalities. **Wandering** is extensive local mobility in a building or local bounded area, in which a person spends considerable time walking around. Wandering has been described in several field studies of, e.g., product designers at a consulting firm, personnel at London underground [8], bank officers at a customer service center, software developers at an IT company, and mobile and informal face-to-face meetings which are often held outside of regular meeting rooms in places like corridors and hallways without any prescheduled agenda, and are sometimes referred to as 'mobile meetings', [10].

However, there are a few developed KMS that support KM in physical mobile face-to-face local work, [4]. Most research on local mobile work can be characterized as empirical studies [9]. Due to this lack of KM support in local mobile scenarios, informal communication and tacit knowledge-creation, sharing and use in anywhere and anytime face-to-face conversations are still very important aspects to be considered [10].

2.1. Factors to be considered on mobile KMS

Matuszewski and Balandin [2] indicate that there are many human barriers for knowledge sharing like factors that have to be considered when planning any KM initiative or designing a mobile KMS:

1. **Linking input to output**. The knowledge has to be codified before it is accessible by other users of a KMS. There is a gap between what contributors write and how it is interpreted by readers, [11].
2. **Knowledge as power**. One serious problem with knowledge sharing is unwillingness of knowledge workers to give away their knowledge because knowledge is perceived as power [7].
3. **Fear of losing face**. Ardichvili et al. [12], concluded that one of the most important barriers for knowledge sharing was the fear of misleading colleagues. They are afraid that the contribution may not be important, accurate or relevant to the discussion.
4. **Fear of revealing own secrets**. Huysman and de Wit [13], observed that some employees are resistant to share their personal knowledge in case of going public because codifying knowledge would imply opening up individually kept secrets.
5. **Hidden Competences**. Employees tend to hide personal competences to avoid unwanted assignments [14].

Employees should not be forced to use a knowledge sharing system. The system must be created to support their work and their social behavior, [2]. The system has to adapt to employees' social interactions. To gather the necessary information to construct mobile KM communities, mobile terminals are better positioned than personal computers. Besides, mobile terminals allow the access to business critical information anytime, anywhere.

3. Design principles of the mobile KMS

According to [1], one of the most prominent challenges in mobile collaborative KMS is the availability of support different processes of KM in the moment that is needed in order to ensure an uninhibited knowledge flow (creation, sharing, use, review, etc.) while the workers are on the move. Tablet-PCs and PDAs are an appropriate technology for providing high mobility and portability, and for creating ad-hoc wirelessly networks through peer-to-peer interconnections based on context and proximity. Furthermore, gesturing and sketching on these mobile technologies represent metaphors that have demonstrated to be beneficial to the design of collaborative systems, [10]. Additionally, concept maps have been used like a knowledge visualization tool, which can be combined with mobile technology to provide integration between knowledge and information visualizations. Researchers shown that the concept map-based knowledge model can be used to organize information in a way that makes them easily browsable and searchable, [15].

3.1. Visualization, gesturing and sketching

Amann and Quirchmayr [16], indicate that information visualization plays an important role in KM due to the amount and complexity of information that needs to be displayed as well as the adaptation to special requirements and restrictions (e.g. limited screen size of PDA). In accordance with [17], a good approach for presenting information on PDA devices is using advanced **information visualization techniques** for displaying and navigating structures of complex information spaces.

According to [18] an application implemented on Tablet-PCs and PDAs with touch-screen interface must imitate the pen-and-paper metaphor, so users can interact naturally with the computer in varied situations, thus freeing them to concentrate on the tasks at hand instead of worrying about the interface. A pen-based interaction (PBI) system offers a more natural and intuitive interface less disruptive of creative processes of knowledge.

Essential to the functioning of PBI is the use of **gestures**. In [19] a survey intended to illuminate the problems and benefits that users experience with gestures-PBI, it was found that the most frequent actions were deleting, selecting and moving, and that users consider these actions to be efficient as a form of interaction, as well as convenient, easy to learn, utilize and remember, and potentially an added advantage for the interface.

Furthermore, a powerful mean for supporting communication is **sketching**, [20]. Face-to-face communication involves the use of diagrams and drawings in a medium that permits users to share views while they converse, a process that helps eliminate ambiguities and rapidly communicate new or complex ideas, [20]. The visual-interaction process may simply entail the formation of images and sketches, with paper and pencil or any other similar technological tools, to investigate, discover, understand and explain concepts, facts and ideas.

In spite of this potential, there are not many research projects addressing the KMS support to visual-interactive artifacts. Knowledge visualization is a relatively new area of research that has received more attention recently due to the interest from the business community in KM, [15].

3.2. KM and visualization by concept maps

Research into human learning and knowledge construction led to the development of concept maps: a graphical tool that enables anybody to express their knowledge in a form that is easily understood by others, [15]. Concept maps are two-dimensional display of knowledge that is comprised of concepts (represented within circles), connected by directed arcs encoding brief relationships (linking phrases) between pairs of concepts. These relationships usually consist of verbs, forming propositions for each pair of concepts. Concept maps represent organized knowledge dependent on its context; consequently maps having similar concepts can vary from one context to another and are highly idiosyncratic.

The strength of concept maps lies in their ability to measure a particular person's knowledge about a given topic in a specific context. Therefore, concept maps constructed by different persons on the same topic are necessarily different, as each represents its creator's personal knowledge. Similarly, we cannot refer to the correct concept map about a particular topic, as there can be many different representations of the topic that are correct. When concepts and linking words are carefully chosen, these maps are powerful tools for observing nuances of meaning. Their rich, expressive power derives from each map's ability to allow its creator to use a virtually unlimited set of linking words to show how meanings have been developed. There are no restrictions on what words can be used to form concepts or linking phrases. Concepts tend to be nouns and linking phrases are usually verbs, and it is recommended that both consist of as few words as possible.

3.3. Context and proximity in mobile scenarios

According to [21], context and proximity is defined as any information that can be used to characterize the situation of an entity (person, objects, etc.). Dix et al. [21] describe four generic forms of context and proximity that influence interaction with mobile devices: infrastructure, system, domain and physical context. The physical aspect is related with the possibility that mobile devices are likely to be aware of their physical surroundings. For instance, the mobile devices may know that they are proximate to other devices, which is critical for support mobile collaborative face-to-face applications in local mobile scenarios, [21].

Our proposal explores two forms of context and proximity defined by [21]: the domain and physical. The domain aspect in local mobile scenario is relatively complex because it combines individual and group processes of KM in a very fluid way. In respect to the physical aspect, users serendipitously move around the organization forming temporary collaborative groups and holding ad-hoc interactions, due to the automatically proximity detection of their mobile devices, which can be done by the use of IRDA mechanism. The information about when two or more users will set up, who belonged to those groups and what interactions occurred characterizes the domain and physical context – proximity in the local mobile work scenario.

4. Description of the mobile KMS

The requirements specification for the design of this application has been based on an ethnographic study done over a population of lecturers belonging to a university department. The system should help the group of lecturers in charge of designing and offering a post-graduate course about sales management to identify, make explicit and share important knowledge about 1) the interests and expectations of potential "customers" (people who may want to take the course), 2) how to transmit their expert knowledge to novel lecturers 3) identify the aspects of the courses than can be improved. The lecturers are professionals who are experts in the domain of the lectures they normally hold, and they do not have a permanent office in the university (part-time lecturers). The system should be able to support the individual work as well as the collaborative work. In order to permit collaborative work PDAs and Tablet-PCs where the system is running are connected with Wi-Fi technology thus building an ad-hoc network by proximity. Additionally to the Wi-Fi network we would like to detect when 2 participants of the KM session are in closer proximity. For this, the IRDA communication mechanisms of mobile devices will be used. These devices are able to exchange data when they get some 5-10 centimetres close. This means that a data transfer for collaborative work will only take place if the participants agree on it. (see Figure 1) . After this, they can start working together creating knowledge collaboratively or exchanging knowledge they already had.

Figure 1: *exchange of data by proximity with IRDA*

Basic Functionalities: As we said, in this system, knowledge is represented by concept maps in which nodes represent concepts and arcs the relationships between them. These graphs will be created and managed over a workspace provided by the application by means of freehand writing and gesture input. For creating nodes, participants should handwrite the concept over the workspace of the application and encircle it with a gesture, as shown in the figure 2.

Figure 2: *Creating nodes. in the figure of the left the user draws a circle around a text. This is interpreted as a node creation by the system.*

Writing a line from one node to another will create a relationship between the 2 nodes. This relationship can be labeled with freehand writing, as seen in Figure 3. For this, an already created link is selected, then the text is written in any place on the screen, and finally, the link is clicked again. A node or a link can be edited by selecting the desired element and re-writing the label. For editing the concept map the system provides following functionalities: **Select**: by clicking once over the element. **Delete**: by "drawing" a cross over a selected element. **Move**: by dragging a selected element.

A node can be "exploited" by double clicking over it. This will cause that a new workspace will be created where the user can input new information. This new information page will be associated as being the content of the node. Since the page can contain new nodes and these can be again exploited, a hierarchical structure (a tree) of nodes can be created. In order to have an overview of the structure the user can activate the "tree vew", which will display something like the example shown in figure 4. Using this view the user can navigate though the structure using the pen-based gestures to the right and left in order to zoom-in and zoom out respectively, and up and down to scroll-up and scroll-down the current tree view. The user can also create links between two nodes while working inside this view.

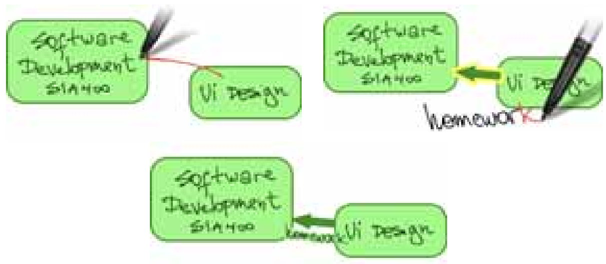

Figure 3*: Writing a label for a link.*

Knowledge Validation: The validation process can be done individually or collaboratively. This will mean that a user will edit and change the concept graph. The validation process will gain in quality if it is done in a situation of high face-to-face interaction where the participants make explicit and share their knowledge working in a shared synchronized workspace.

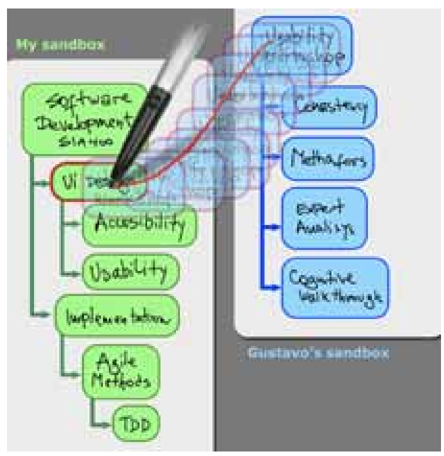

Figure 4 : *The tree view.*

Knowledge Presentation: The presentation process is supported by the following features: 1) a shared workspace which is activated when working collaboratively; 2) the use of concept maps with different levels of depth, which are easily navigable; 3) a tree view of the information structure including all concept maps and relationships between nodes located in different pages (levels); 4) use of a visual representation for better distinguishing the associated nodes which have been linked during the sharing process.

Knowledge Distribution: The distribution process of the knowledge organized in concept maps organized in different layers is supported by two functionalities: The first and more basic one is that a participant can share the whole content of a node (recursively) by defining the sharing properties of the node accordingly. In this way, every time the participant is online with others, all members will receive a copy of the last version of all nodes marked as "sharable". All sharable nodes belonging to another user will appear as a parent node on the first level labelled with the user's name. Inside this node all sharable nodes and its shared links will appear.

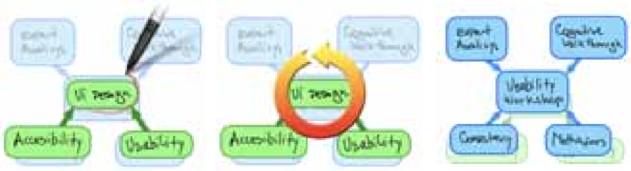

Figure 5: *Contrasting coupled nodes. Green nodes belong to one user and blue ones to another. The coupled nodes are shown in the middle, one over the other. Doing a circle gesture over the coupled node will change the foreground-background order of the nodes view.*

The second way to distribute (share) the knowledge is based on coupling the nodes belonging to different users. This can be done when working with the tree view (figure 4). Here, the user can drag the node belonging to one use and locating it over the node belonging to him/her or another user. This might be done when a semantic relationship between the nodes belonging to two different users has been identified and there is an interest to compare relationships with other concepts that both users have established independently. By doing this, a user can validate her/his own knowledge with the knowledge created by others (figure 5).

Knowledge Application.: Knowledge application means that the knowledge that has been collaboratively created and refined, and has been made explicit by concept maps can be used to respond to a any requirement of KM the organization may face. The system allos its users to iterate over the knowledge creation, presentation and distribution processes in any order.

5. Mobile add values for mobile KMS

Although the Laptop is often included in the definition of mobile devices, in [1] the authors do not consider it as mobile exclude due to its special characteristics: it can be moved easily but is usually not used during that process. For that reason they argue that the Laptop cannot be seen as a truly mobile device. According to the same criterion, Tablet-PCs and PDAs can be employed in the context of mobile KMS. The term Tablet PC describes a modification of the Laptop, which can be used in stationary as well as mobile settings. PDA refers to a handheld computer with core functionality similar to a personal information manager. In order to verify the contribution that mobile technology can make to KMS, [1] referred to the theory of **mobile added values (MAV)** to analyze the contributions of mobile technology for supporting KM in the different phases of the KM process. They state that for the success of mobile offers it is not sufficient to merely make a conventional offer available with new media. Thus, MAV answer the question: What can mobile do, what stationary cannot? Or: What does mobile have that stationary does not? MAV only represent a potential, and a mobile solution does not have to take advantage of any MAV. [1] introduce the MAV with ubiquity, context-sensitivity, identifying functions and command and control functions:

- **Ubiquity**. It is the possibility to send and receive data anytime and anywhere. This is achieved by the mobility of the users. It permits the reception of time-critical and private information which affects reaction time and convenience aspects of knowledge creation.
- **Context-Sensitivity.** It describes the delivery of customized products or services fitting the particular needs of the user in his current situation. This is particularly enabled by three features: personalization (preference profiles), interactivity (information exchange) and location (creating specific services for the user in his current location or by referencing location of other users).
- **Identifying Functions**. The ability to authenticate the user as well as the device is already immanent to a mobile network. Together with the aforementioned typical 1:1-attribution of a mobile device to its user this provides a capability to authenticate the actual user with feasibility already sufficient for most applications.

Derballa and Pousttchi [1] examined each KM process regarding the MAV that can be generated through the use of mobile devices:

- **Knowledge creation** is supported through the mobile added value of ubiquity as that aspect allows the creation of knowledge regardless of spatial and temporal restrictions. Context-sensitivity and identifying functions act as supporting factors in that context. They facilitate the documentation of the knowledge creation process. Using those values it becomes possible to gather information about how the context knowledge was created as well as about the participating users.
- **Knowledge validation** or review benefits from the aspect of ubiquity as the verification of knowledge becomes possible immediately in the moment an event has occurred that leads to a new judgment of existing knowledge.
- **Knowledge presentation** is supported according to characteristics of the interfaces of users and paradigms (sketching, gesturing, virtual buttons) implemented in used mobile devices.
- **Knowledge distribution** is improved by the ability of mobile technology to deliver knowledge everywhere (MAV ubiquity), adapted to the relevant context (MAV context-sensitivity), and appropriate for the individual user (MAV identification functions). Taking that into account it becomes possible to employ a push approach and

deliver the knowledge to the user instead of having the user actively retrieving knowledge.

- **Knowledge application** is enhanced indirectly by the fact that mobile technologies make it possible to have relevant knowledge delivered to the individual user regardless of spatial and temporal restrictions and thus ensure that "insufficient knowledge in time ofaction" is avoided.

The results of the analysis conducted by [1], demonstrate the substantial impact of mobile technologies on the different processes of KM.

Additionally, a basic function expected to be fulfilled by mobile technologies is the automatic detection among mobile equipments, which facilitates the interaction among people in a face-to-face scenario. This principle is due to the fact that mobile systems should react according to the context where they are being used and according to the needs of the applications to be implemented.

6. Conclusions

Various aspects of KM processes that can be operationalized and mediated through Tablet PCs and/or wirelessly interconnected PDAs will be conceptualized to enable the design and implementation of a mobile KMS that provides effective support for the creation of knowledge and for the various KM processes: validation, review, sharing, presentation and use. The mobile KMS will be expected to: a) integrate with knowledge repository-type stationary KMSs and search tools for retrieving stored knowledge objects; b) incorporate solutions to certain human factors that tend to hamper KM processes (poor quality information, personal preferences, fear of revealing own secrets, etc.) and introduce incentives that encourage users to employ the processes in a satisfactory manner. The results of the comparative testing applied to equivalent versions of the mobile KMS application implemented both for Tablet PCs and PDAs should serve to identify the advantages and disadvantages as regards usability and utility that will determine which of these technologies is the best option for KM process support.

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