

Structuring Organizational Memories using Multi-Dimensional Knowledge Networks

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ABSTRACT. In this paper, we present an approach for the structuring and exploitation of organizational memories. We propose a system to build organizational memories (OMBS) with multiple dimensions, each dimension being defined for a different exploitation mode. An advantage of this OMBS approach resides in the incremental construction of domain knowledge networks including numerous knowledge units and links. We begin by discussing some ideas related to the structuring of an organizational memory (OM) using flight safety as an application domain. Then we describe the purpose, the formalism and the structuring of the knowledge networks. We also propose some directions to exploit the OMBS system along its various dimensions.

1 Introduction

Over the past few years, the construction of organizational memories has generated much interest within academic and industrial communities. Recent progress in interactive information technology (mostly web-related) has provided a technological infrastructure for the implementation of these knowledge repositories. Moreover OM favor the implementation of knowledge management (KM) practices within organizations in order to enable people to "know what they know". Some authors [1] even claim that the construction of an OM should be considered as the first step in the KM cycle.

With different viewpoints being presented in the KM literature, OM are becoming "overworked and confused" (see [2]). Some authors define an OM as "the collective data and resources of a company including project experiences, problem solving expertise, design rationale, etc." (see [3]); others view it as "a repository of knowledge and know-how of a set of individuals working in a particular firm" (see [4]). Even with the latter definition, knowledge is such a vague subject that it is difficult for developers to start the construction of an OM.

There is a lack of conceptual ground on the approaches for the structuring and integration of OM (see [1]). More specifically, proposed methodologies do not offer a compromise between vague structuring guidelines (as extensions of digital libraries) and excessive knowledge formalization (AI flavored approaches). The goal of our work is to experiment with multi-dimensional networks in the structuring and exploitation of knowledge assets and try to determine a well-balanced approach through experimentation with examples from our application domain, flight safety. By multi-dimensional network, we

refer to a directed graph where the nodes represent static and "how-to" domain knowledge and where the links provide guidance on the usage of the network.

In this paper, we report on the approach we followed in the structuring and integration of OM using the knowledge network (KN) formalism. We discuss some of the choices made for the implementation of an OM for our application domain (sections 2-3), the compromise leading to the structuring approach (sections 4-5) and the schemes implemented (section 6-7). Finally we propose some directions on how to pursue this research effort.

2 A KM Perspective of Flight Safety

The Flight Safety program of the Canadian Forces aims at eliminating accidental loss of aviation resources. These measures are essential to preserve vital resources and to maintain operational potential for transportation, emergency management and/or combat purposes.

The program is based on the principle that by effectively disseminating analysis of air incidents, pilots can learn from the experiences of others and hence avoid repeating the same mistakes themselves. Understanding why safety occurrences happen (determine the cause) and develop pilot awareness (correcting their causes and implement preventive measures) are the keys to an effective accident prevention program.

From a KM perspective, the main knowledge assets of the Flight Safety program are the lessons learned from the incident reports and the expertise of the Flight Safety officers. The efforts of the program are mainly concentrated on effective and timely development of the incident reports. The efficiency of the system depends mainly on the quality of the reports (assured by open and honest reporting of the incidents) and their effective dissemination.

The expertise and experience of the Flight Safety officers conducting the analysis of incidents is also a crucial knowledge asset. As the majority of incidents have human root causes, officer's understanding of aviation principles and human factors is of great importance. However, due to their prior training and high qualifications, the program puts less emphasis on managing knowledge practices of the officer's community.

The KM cycle of the program can be described according to the following four (4) steps (see [5]): knowledge development, knowledge preservation, knowledge usage and knowledge dissemination.

Knowledge Development: this involves the gathering of local information by the Flight Safety team, the investigation and analysis of incidents to determine possible causes, the monitoring of new findings of incidents occurring at other units and the estimation of their relevance to local operational characteristics.

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Knowledge Preservation: the production and storage of reports, news letters, videos and other documents resulting from the knowledge development activities.

Knowledge Usage: to determine corrective actions and to increase pilot awareness by the assimilation of preventive measures to reduce the chances of an occurrence, to provide novice pilot with an access to Flight Safety background knowledge, to spot trends and to determine the magnitude of typical/unusual problems.

Knowledge Dissemination: to communicate findings of new incidents to other organizations and to the appropriate level in the chain of command (e.g. Wing Commander), and to provide advices and training to the personnel.

3 The Construction of an OM

We view an OM as a knowledge system combining domain collections accumulated by an organization and some structured knowledge depicting how the collections can be exploited by its various users (Figure 1).

Typically, organizations have accumulated collections ready to be exploited. For instance, the Flight Safety program has a large collection of reports describing findings of incidents over the last decades, manuals provided to pilots during their aviation training and other material (e.g. videos, news letter, web sites) promoting Flight Safety practices among the pilot community. These collections can be distributed throughout different sites.

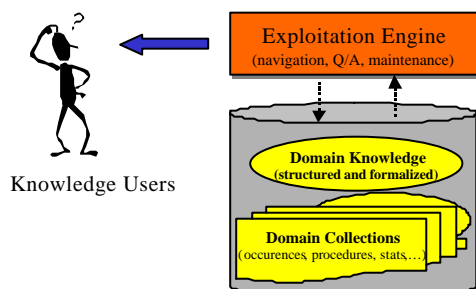


Figure 1. A diagrammatic view of an Organizational Memory

Domain collections being provided, the process of building an OM relies on the choice of scheme to integrate the collections and to exploit them. This experimental process, following either a bottom-up or top-down approach, progressively migrates knowledge from a implicit state (non proven expertise, sometimes tacit to the beholder) to a better structured and formalized formulation (section 4). The construction process implies the selection of organizational knowledge assets to be preserved, the level of structuring/formalization to be reached, and the choice of schemes to exploit the memory. In our Flight Safety case study, the sharing of experiences and the reinforcement of basic safety principles are targeted as the key assets (sections 6-7).

In our approach, we propose a paradigm for structuring domain knowledge and a framework to exploit the domain knowledge in conjunction with domain collections. Our approach relies on 3 aspects:

- To limit our structuring efforts on explicit task-oriented knowledge;
- To incrementally structure knowledge, through informal descriptions of knowledge units (KU). Our goal is to reach a compromise between rigid and formalized knowledge and ill-structured knowledge as often encountered in documents (like frequently asked questions);
- To take into account the exploitation of knowledge during the structuring phase.

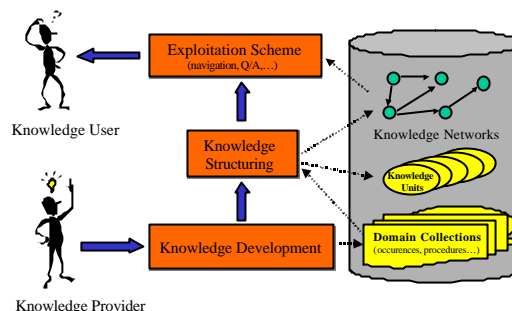


Figure 2. Organizational Memory Building Process

The process we follow to build the OM is a combination of steps to structure the KU, to expand this knowledge along various dimensions and to provide knowledge required to the exploitation schemes. Further details are provided in the next sections.

4 Knowledge Levels

Acquiring and structuring corporate knowledge has proven to be the bottleneck in the design of knowledge systems. To overcome this difficulty and to ease the work of the analyst building the OM, the choice of knowledge structuring/formalization approaches and the type of knowledge to capture are critical.

For each domain, a body of knowledge exists and is maintained in different forms (books, documents, procedures, database, expert systems) and by expert humans or employees. The issue of what knowledge should be considered as candidate for OM can be clarified if one distinguishes the different layers of knowledge existing in an organization. In our work, we classify knowledge according to three (3) different layers: basic knowledge, innovative knowledge and creative knowledge.

To have the abilities to work within a domain, one must learn or be trained, i.e. be familiarized with the first knowledge layer, the basic knowledge of the underlying domain. For example, to fly an aircraft, a pilot must learn the basic knowledge of meteorology, aeronautical navigation and must be trained to control a specific type of aircraft (as by Intelligent Tutoring systems).

Over time, changes occurred in the domain and in the environment a solutions must be devised for new situations. The basic knowledge evolves and more knowledge is available that forces the organization and employees to adapt to their work in order to improve them, keep competitiveness or just to be better. That is the second knowledge layer, the innovative knowledge. For example, all pilots must learn how to use new aircraft

instruments and develop abilities on how to react during critical flying situations.

This innovative knowledge comes from creativity and expertise validated after much experimentation. This knowledge is precious because it contributes to the community's global understanding of their domain. Normally, this kind of knowledge takes time to be formed since tacit knowledge and unproven skills must be leveraged, clarified, formalized or validated. That is the third knowledge layer, the creative knowledge.

From the above distinction of knowledge layers, tools are needed to determine where to apply the innovative knowledge level or on how to stimulate the creation of new knowledge. Also it must overcome basic training knowledge as knowledge can not be reduced to information primitives. To effectively achieve the KM functions, "organizations must create a set of roles and skills to do the work of capturing, distributing, and using knowledge" [6]. We aim to build a tool to facilitate the "active collection and diffusion of knowledge (knowledge pump)" [7], with a special emphasis on the development of the innovative knowledge layer.

5 The Structuring of OM

Some authors (see [8], [9]) propose methods and techniques to build an OM as the starting point of a KM process. Without the distinction of the three knowledge layers as mentioned above, the OM structuring task is difficult. One obstacle is the mass of knowledge for a domain such as Flight Safety being proportional to the many years of college studies, training and pilot experience. Moreover, this kind of basic knowledge is normally well structured and formalized. Some powerful intelligent tutoring systems are already developed to carry out this task. As this basic knowledge has already been specified in the criteria to hire employees, it is not an essential function for an OM system to pursue active development of these knowledge assets. Frequent reinforcement of these principles should be sufficient to ensure adequate operations. For instance, it is fair to assume that most pilots fully understand the effects of weather conditions on navigation. So reminders on a few critical principles (ex: how to avoid convective clouds, appropriate clothing in case of emergency) will bring corrections to observed deficiencies.

The important knowledge to leverage intellectual operations is rather the innovative knowledge. It is the knowledge in evolution that must be captured, formulated and disseminated through an organization. For the Flight Safety domain, this knowledge mainly resides in the findings of incident analysis and in the proposed corrective actions. To do that, we need an OM that describes the actual tasks of the operators (in our case the pilots) as well as the actions and skills required in each specific situation. Employees must be encouraged to review this knowledge and to leverage the tacit knowledge or informal expertise of other employees, based on their work experiences. The task review process must be carried out periodically and occasionally, especially when environmental changes are observed.

Finally the creative knowledge normally appears when there is a problem solving challenge, for instance inductive speculation by observing similar incidents or deductive

speculation by applying some rules/heuristics in a situation. An initial form of creative knowledge may be tacit knowledge. An OM can help to leverage this knowledge by showing to users the relation between tasks or situations, by associating each situation with related actions. Users can then examine and survey many cases and current experiences before finding a new solution. The generation of creative knowledge can be stimulated in several ways in an organization but this activity is different from *knowledge elicitation*, i.e. the process of making clear tacit knowledge. From our point of view, individual tacit knowledge is the kernel of creative knowledge, if not, where would it (tacit knowledge) come from? This point of view is a little different from the one of [10] who emphasis on the conversion of tacit knowledge to explicit knowledge (i.e. the organizational knowledge).

In [11], the authors propose an approach to build up an organizational memory from existing documents to avoid employee's resistance and work disruption. This is an adequate approach to start up the building of an OM; however tools are required to support cognitive analysts to achieve this task.

6 Organizational Memory Building System

An Organizational Memory Building System (OMBS) is a tool to help in the structuring of an organizational memory and in depicting the exploitation schemes. In the OMBS infrastructure we are developing, we offer a framework to describe the KU which can be exploited along various dimensions. Current efforts support the exploitation of three (3) types of knowledge assets: "know-what" (concepts of the domain), "know-how" (internal processes) and "know-who" (knowledge providers, sources of information, relevant agencies, etc...).

6.1 Knowledge Units

In the current implementation of the OMBS, we distinguish two kinds of KU: "Static" and "How-to" KU.

Static KU contain domain concepts, facts and information describing the specifics of situations. For instance cloud conditions or instrument descriptions and settings are represented as static KU. It is presumed in the system design that the only way to learn about static knowledge is to memorize it, no provision being made on how to reason about it.

In "How-To" knowledge are embedded the skills and expertise to be used by an employee in a given situation. This kind of KU is task-oriented and contains the procedure to follow through (actions and/or tasks). It refers to others Static KU when necessary. This knowledge can include both "how to do" and "how to think" descriptions. The frame of a "How-to" KU has the following attributes:

Task name: a descriptor of the nature of the activity. It can also be perceived in some situations as a goal to achieve. From a system point of view, it is the index by which is described the underlying knowledge.

Domain: and ontological description of the sub-domain. For instance engine shutdown procedures would be associated to the AVIATION /NAVIGATION / ARRIVAL sub-domain.

Demo link : a reference to videos, photos, graphs, diagrams and other pedagogical material. A link allows activation of the multimedia resource.

1. the **organizational dimension** reflects the work flow between the KU in the underlying organization. The workflow links allow users to examine the works of other employee which are related to the actual KU. By considering this organizational dimension of all KN in an OM, users understand how an organization attains its goals.
2. the **lexical dimension** provides users with explanations on domain terms. The multitude of work-centered terms for an application domain can hinder the understanding of the users of the system. Even for the same organization, terms can have different meanings. Also abbreviations and acronyms, as frequently encountered in the military world, can cause confusion among users. So for each application domain must be prepared a lexicon containing frequently domain terms and abbreviations (as well as acronyms) being frequently used. To some extent, an ontological research is required to come up with a widely accepted glossary. User can refer to the domain terminology through the static KU.

Figure 4 (next page) illustrate an example of KU frame. A KU frame is opened in ‘*Detail View*’ mode. Users can fill in the various fields to create the KU. If the *Reference-Cases* field points to a document, clicking on it will open the pointed document. If the *Demonstration* field points to a multimedia resource, clicking on it will open the pointed resource. A subtask name is automatically added by the system in the *Subtasks* field whenever the user establishes a subtask link.

7 Exploitation of the Knowledge Networks

The essential functions of a KM system are to improve work-centered tasks, applying the innovation when possible and sharing knowledge between employees. These functions combined with an appropriate compensation policy can motivate employee to leverage creative knowledge. Links between "how-to" KU must be established by the analyst to accommodate different usage (or dimensions). For instance, in our OMBS formalism, an employee can lay his expertise before leaving his job; this expertise will help a novice or a new employee to learn (by using pedagogical links). Other employees can also share knowledge by using organizational links.



Figure 4. Example of a knowledge unit frame (detail view)

The logical links can help employees in problem solving activities by stimulating their reasoning on the underlying situations. If available, demonstration videos, photos, graphs or diagrams can also be linked to each task to make the description more concrete and therefore help the learning process in an effective way.

By referencing to the classification of [1], our system is intended to be knowledge-based and case-based corporate memory. It allows to reason about KU describing experiences and cases already encountered. We are currently in the process of developing exploitation schemes for our system that will allow users to manipulate KNs according to its two capabilities: retrieval of KU and navigation along various dimensions.

The retrieval scheme consists of matching KU of the system with a partial description of what the user intends to search for in a network. This partial description is called "pivot unit". A pivot unit contains the description of what the user intends to search for in a network. By introducing this pivot in the system and do partial matching of the various attributes structuring the units, the user can obtain the units most relevant to the partial description. As most of the attributes contain textual descriptions, statistical (Tf-Idf, n-grams) and semantic (e.g. edge-counting) similarity techniques can be used to exploit the units through the retrieval scheme as described by [12]. Finally the

navigation scheme currently relies in the capabilities of the system to visualize elements of the networks and browse through the networks following various dimensions.

8 Conclusion

In this paper, we presented an approach to build an organizational memory. We distinguish three knowledge layers: the basic knowledge, the innovative knowledge and the creative knowledge. We argue that the last two layers are essential for the KM and that an OMBS is needed to help organization starting up the first task of KM. Next, we set up the system objectives that insist on the ease to use and the supporting of KM functions. The structure of our OMBS is then described with its multi-dimensions and visual interface. Possible exploitation schemes are also discussed. In the near future, we will complete the implementation of the exploitation schemes and expand the system to its fourth dimension, the logical dimension. We believe that this dimension can help user in problem solving activities and for leveraging the creative knowledge. We also foresee the merge of KU and KN in a knowledge space as a mechanism for exploiting KN.

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