A Pull Approach to Knowledge Management

Using IS as a knowledge indicator to help people know when to look for knowledge reuse

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Abstract

This paper studies the problem of knowledge management and particularly from the perspective of a small & medium enterprises (SME) under the « new industrial constraints ». We propose and argue our original approach to knowledge management which really consider some specific needs of SME. This approach starts with knowledge needs of current projects (i.e. pulled by customer demand). We propose a tool that uses the context of knowledge, and particularly the information system (IS), to help people know (by notifying them) when to look for knowledge to reuse without having to previously formalize it.

1. Introduction

Management of knowledge is becoming an increasingly important concern of the enterprise [O'Le 98], [McC 98]. However, current solutions in this area do not seem to be convincing to SME [Die 98], [Bart 97], because they do not consider their specific needs [Mah 98-2]; [Mah 97]. Working in close cooperation with KSB Annecy, an SME employing 250 people, we found it necessary to propose a process better suited to their needs. Instead of following the classical life cycle (identification, formalization, memorization, and search) that only gives results in the long term and can only focus on a limited area, we are working on a means to help employees reuse knowledge. We therefore give them contextual information to identify knowledge.

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In the part 2, we present our statement of the enterprise knowledge management problem by specifying the major reasons justifying the growing interest of enterprises in this area. We show how our solution is original and responds particularly well to characteristics of the new industrial model (flexibility, diversity, organization by project or / and make-to-order).

In the part 3, we present our pull approach of knowledge management. The part 4 presents the functioning of associated tools, as well as the techniques used, and at the end, we show how to generalize and take another example.

2. From Knowledge Management To the Pull Approach

Management of knowledge is becoming an increasingly important concern of enterprises. Initial answers, very local ones, have been given by artificial intelligence and knowledge acquisition methodologies, even before the exacerbation of the problem. But this topic is also addressed by management scientists (strategic management, competence management, etc.) and by cognitivists. Our work is situated along the frontiers of these different disciplines.

Before going further, we briefly explain our definition of knowledge (see [Mah 96] & [Mah 98-1] for more details). As "we can know more than we can tell" [Pol 97], knowledge is a characteristic of human beings (like Stewart highest level, [Ste 96]), and is situated in their heads. Also, a transfer of knowledge will in fact result to the creation of a new piece of knowledge for the second people, with no certainty that it is the same as the original, regarding the links to personal history and experience, but we will assume that it should be functionally the same. To simplify the paper, we will not mention all of that after, but it must be kept in mind during the following.

2.1 Reasons For The Growing Interest in Knowledge Management

Besides the undeniable "fashionability" of knowledge management, there are several reasons that explain the growing interest of enterprises for this area.

Thus, enterprises sometimes :

- have to preserve knowledge,
- have suffered knowledge losses,
- need a large amount of knowledge,
- need to lose knowledge.

The need to preserve knowledge is a characteristic of high technology sectors as for example, the nuclear sector [Pon 96], armaments and defense or space exploration. It is a **preventive** concern to avoid the serious danger that a loss of mastery of these technologies would represent [May 95].

To a lesser extent, beside the obvious needs of the mentioned activity sectors, knowledge may need to be preserved to avoid the consequences of its loss in the future: it is still a preventive step to avoid future risks.

However, what mostly exacerbates knowledge management problems is a **reactive** attitude [May 95], faced with previous knowledge losses, whose consequences are measured after a certain lapse of time. We are then completely disarmed (it would be necessary to act on the past), and can only issue a kind of "death certificate" such as "*We no longer know how to do it*" [Lou 92]. This problem of loss of knowledge is often explained by the departure of a person. This is a subject of increasing complaint, since many enterprises have proceeded to significant and sometimes brutal reductions of staff in recent years (reengineering, downsizing…) [Chi 97], in addition to normal turnover (departures, transfers, retirement). Moreover, it is necessary to keep in mind that this is probably only the visible part of the iceberg (losses are seen only when the reuse case occurs and only when the reuse case is noticed).

Finally, we should be concerned about the coming wave of retirement of "baby-boomers". These departures might again reduce the store of knowledge from many enterprise within the next few years [Mah 98-1].

Our industrial partner, KSB Pompes Guinard, is particularly subject to the new constraints of globalization requiring increasingly personalized products and the need to meet the varied desires of customers in order to subsist and grow on the market. To master the increased variety of products, there is a **greater need for knowledge** on the part of the enterprise that manufactures them (Ashby's law : need for knowledge increases with the increase of variety [Ash 56]).

Many enterprises are subject to these new economic constraints [Web 93]. These constraints lead enterprises to change from mass production to make-to-order, where products are highly personalized for each customer. Enterprises have therefore to adapt their manufacturing processes to each order, rather than to repeat a well established process. This introduces more processes and more risks that must be mastered, resulting in an increased need of knowledge.

This is a priori paradoxical, but knowledge management has to eliminate some knowledge, to allow innovations [Hed 81]. To increase our innovative capacity, it is sometimes necessary to forget all we know: to start from scratch to design a new product. This is necessary during a radical technology change, for example.

By the same reasoning, it may be necessary to eliminate knowledge that has become obsolete and that is deeply rooted in procedures or in people's heads, and that still imposes constraints, even if its justification no longer exists. For example, we can cite the (QWERTY) computer keyboard, inherited from typewriters, and designed with the purpose of slowing the typing rate to avoid jamming the mechanism of early typewriters (that did not support fastest typing). This constraint has no reason to exist today.

A complementary problem is obvious in this example : this keyboard has become a standard, and it would be very difficult to challenge it. In the short term, users would have to re-learn to type on a keyboard, but in the long term, it would be beneficial for everyone to forget it and to use another one, this time conceived to facilitate typing rather than slowing it. It is the same in the enterprise where we can find some constraints that are still applied and are consequences of choices made at the time of their creation (not always consciously) and that have no reason for continued application.

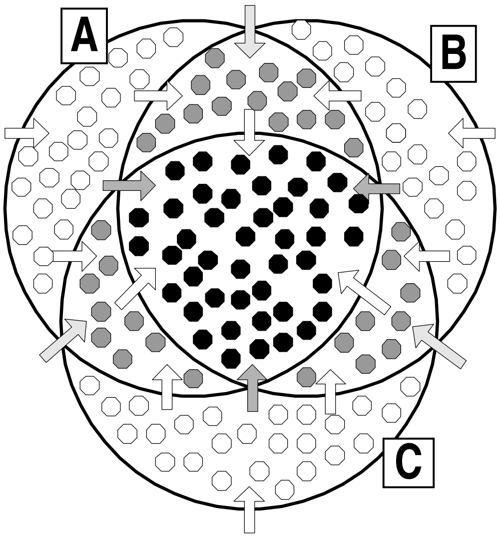
2.2 Several types of collective knowledge

Management of knowledge is above all a management problem. A certain number of actions are the direct responsibility of the human resources department or of management in general [Sve 87]. For example, favoring work in groups **increases the shared part of collective knowledge** rather than the part distributed to different persons (which corresponds to the *collective practice* notion of Cohen & Bacdayan [Coh 95]). When increasing the shared part of collective knowledge, knowledge loss with people departure decreases. Indeed, distributed knowledge requires all the persons that possess a part of it to come together to put it into practice. On the other hand, shared knowledge can be put into practice by a single person (our definition of "shared knowledge" is the same as Reix [Rei 95]).

Let us consider three persons PA, PB, PC and the sets of knowledge that they possess, respectively A, B, C, here are our definitions for entirely shared knowledge, partially shared knowledge, distributed collective knowledge and individual knowledge (see figure 1).

Individual knowledge correspond to pieces of knowledge that only one person possesses. A piece of distributed knowledge is in fact a set of pieces of knowledge taken among individual knowledge pieces of several persons.

For example, if a process of monitoring a control operation can require some knowledge from Paul and Peter ; neither Peter nor Paul can monitor the control alone, since they possess only a part of the knowledge required for that. As a contrary, in case of shared knowledge each one can monitor the control alone.



Individual Knowledge
(& Distributed Collective Knowledge)

Partially Shared Knowledge

Entirely Shared Knowledge

Knowledge creation
(colors : w.r.t. number of learners)

Figure 1. Collective Knowledge Typology

Individual knowledge :

- of PA : A - A∩B- A∩C - A∩B∩C
- of PB : B - A∩B- A∩C - A∩B∩C
- of PC : C - A∩B- A∩C - A∩B∩C

Entirely **shared** collective knowledge is all the pieces of knowledge that everyone possess : A∩B∩C

When more than one person possess a piece of knowledge but not all the people, it is some :

Partially **shared** collective knowledge =

$$(A\cap C - A\cap B\cap C) + (A\cap B - A\cap B\cap C) + (B\cap C - A\cap B\cap C)$$

A piece of knowledge can require several pieces of knowledge, taken among several sets of individual knowledge. We then speak about **distributed** knowledge (among several persons). To put the piece of knowledge into practice, all concerned persons (each of them possessing a separate part) have to participate.

Increasing the shared part of collective knowledge give a response to knowledge management problem. But providing a « common box » of formalized knowledge where everyone can look for and pick out something is not always the best solution for enterprises. Indeed, approaches that do so can be very costly, if only people could accept to spend some time on it. More, regarding the high cost of formalizing, the area of the enterprise that can be covered by these approaches is generally very narrow and it would then be better to speak about some dedicated tools rather than of knowledge management.

Some tools, like those regrouping and indexing documents have a wider application area in the enterprise. But, like the previously cited approaches, people have to look for knowledge actively.

In our view, this hypothesis is not true in the enterprise. Indeed, we have studied barriers to knowledge reuse in the enterprise [Mah 97] which showed **that the crucial problem in the situation is to know when certain knowledge is available for reuse**. Indeed, people in the enterprise do agree to spend some time to look for previous knowledge, providing they know its existence. From our point of view, it is therefore necessary **first to give, at the right time, reasons to look for knowledge** and, second, to provide a means to find it. Current methods respond to the second question, while we are working on an answer to the first.

3. The Proposed Approach : the Pull-Approach

From the enterprise point of view, the problem studied is therefore management of its knowledge and particularly of its reuse. That is, we are looking for means to reuse it with **the minimum number of preliminary stages**. In this way, we diverge from classic approaches that need to formalize knowledge before being able to reuse it. In a context of growing complexity and with the shortening of the knowledge lifecycle, an approach enabling knowledge reuse without the preliminary formalization step, is not only complementary, but also greatly favors reuse, especially for SME.

KSB Pompes Guinard designs and manufactures pumps for oil installations, nuclear plants and defense (navy). It makes to order on a worldwide market. The variety of its projects has lead us to propose an original knowledge management approach that we call the "**pull approach**" (by analogy with the term used in production management) and is very well suited to by project organized enterprises. A project corresponds here to the processing of **an order** from definition stage to delivery stage, including all the design and manufacturing stages. In a strongly competitive and evolutive context, this pull approach allows us to respond to the short-term needs of current projects, while more classical methods restrict themselves to the obvious problems of the limited lifetime of knowledge, of the difficult choice of limits [Fou 97], and of the time needed to make it available.

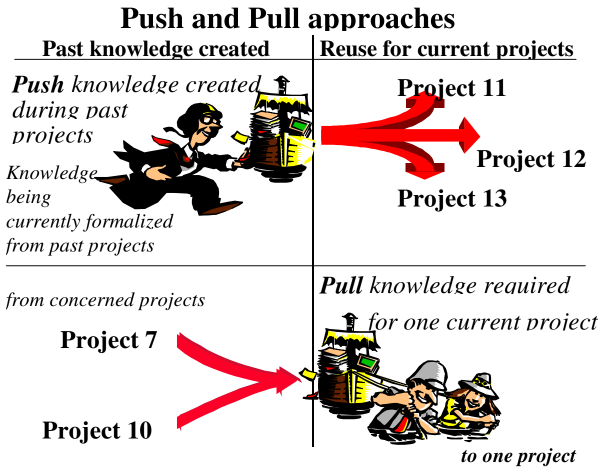


Figure 2. Push And Pull Approaches To Knowledge Management

Figure 2 illustrates the difference between the push and pull approaches, the first one starting with knowledge of the past and the other starting with current project needs. The push approach, that corresponds to most current knowledge management methods begins with the formalization of pieces of knowledge (strategically chosen [Gru 96] for reasons of limited capacity [Mar 91]). It then makes these pieces of knowledge available in a search and retrieval system (it is necessary to come and look for them), or they are integrated in processes for a systematic application. In these two cases of the push approach, knowledge must be chosen (with uncertainty of the future usefulness), formalized and integrated (in a search and retrieval system or directly in processes). It is only after these stages, that knowledge - - only that chosen - - becomes reusable (if the case ever actually occurs). With this approach (push), and if we start from scratch, we would have to formalize during a long period (in years) before expecting to see any tangible result. After prolonged use of a push approach, there is still a significant delay between production of knowledge and its availability to be reused.

Its **rate of uselessness** (speed with which the knowledge becomes obsolete or useless), and its **probability of reuse** (probability of occurrence of a reuse case with the piece of knowledge in the future) determine whether a benefit exists in applying a push approach to a piece of knowledge. If the rate of uselessness is high, there is no advantage in formalizing the piece of knowledge; it could become useless before being ready for reuse. Similarly, if its reuse probability is weak, it will not be of benefit to apply the push approach to it.

On the other hand, in the pull approach, we start with the needs of today and look for knowledge with no preliminary stage (without choosing, nor formalizing…) before reusing the knowledge. Since knowledge is not formalized, it is necessary to use an indicator to point it out. Employees are then notified of knowledge existence regarding the indicator, but pieces of knowledge can not be provided directly to people. Persons will then have to meet each other to exchange knowledge (or to search in a project archive).

In this perspective, the task the system has to accomplish consists in **bringing people together** for them to **directly exchange knowledge** – which is beyond the system's capabilities -- or to orient them to archives of past projects. In our approach, knowledge is not formalized, rather it is the **context** of practice that is modeled. For that purpose, we use certain data of the automated part of the information system (AIS) as an **indicator** to evaluate the possible existence of reusable knowledge. A particular set of knowledge is applied in a particular context of action. When **a similar action context occurs**, this **knowledge must be reusable**. We can then put actors in relationship so they can exchange their knowledge.

Our model of knowledge context consists in defining views on a set of databases that represent a part of the context of action corresponding to a business process. For example, we can compare a new order with the history of orders, to orient persons that will process them to those that have processed similar cases, in the past (or to archives of projects if these persons have left). In this case, we look for characteristics of the product to be created in an already existing database in the enterprise. Then, with our tool, for each criterion we undertake a search for correspondences with similar projects already realized. This allows us to provide for each stage of the new project, the list of persons that have worked on corresponding stages of similar past projects.

The pull approach thus helps to reuse knowledge in the present, while the push approach could only do so in the future and that only if forecasts had chosen the right knowledge to be reused, which is not the easiest thing to do in the "new industrial model" where "the only certainty is uncertainty" [Non 95].

This approach leads to **increasing the amount of knowledge shared** in the enterprise, since persons have to communicate it to each other. In this way, the pull approach also counteracts the loss of knowledge linked to a person's departure.

It is better to start with a pull rather than a push approach. Indeed, with the pull approach, employees see that knowledge management can contribute something to their everyday concerns. They can even benefit from it immediately. If the push approach is used first, there is a risk of discouraging people with a process in which they do not see the return on investment (for the time that it requires) before a prolonged period. The push approach will also be better accepted by employees, if it comes after and in addition to a --pull-- approach of knowledge management that has already shown its results in the enterprise.

Moreover, beginning with the pull approach provides a basis for trying out a push approach undertaken later. By considering pieces of knowledge reused in the present by the pull approach, the choice of knowledge to which to apply the push approach is derived automatically. The priority is then given to pieces of knowledge that are reused in the present. This combination will avoid the need to base the choice on currently unreliable forecasts (in a context of uncertainty). The synergism of the combination of the two approaches goes even further. Indeed, by processing knowledge reused in the present, formalization is facilitated: a side effect occurs from socialization to externalization [Bea 96] since to apply knowledge in practice, the person will have to reconstruct her / his mental models, it will then be easier for her / him to verbalize knowledge [Poi 97]. This is very important, considering the highly significant cost of the formalization stage [Mah 98-1].

4. Tools for the Pull Approach

We have seen in the previous part that we want to help people to reuse knowledge by informing them **when** there is potentially reusable knowledge.

For that purpose, we need some tools that can bring information to people's desks. Regarding this aspect, our tool can be technically viewed as a kind of so called « push technology » but for this aspect only. Indeed, current push technology correspond to push approaches mostly for advertising purposes. In our case, information to be pushed is considered only when an ongoing project that requires it exists.

We work on the context of the knowledge rather than on the knowledge itself (avoiding a preliminary formalization stage, and focusing on its action context).

We look for this context in the automated part of the information system currently existing in the enterprise. This AIS is composed of several different systems, sometimes connected through partial replication of data (this is the case in our experimental example). Following is an example of the processing of an order.

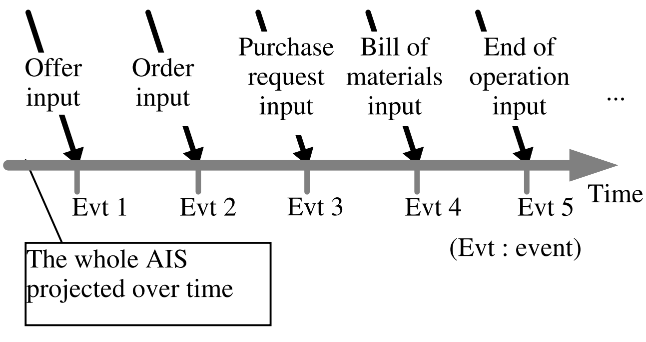


Figure 3. Events In Information System

In figure 3, we can see a representation of input examples that are performed during the processing of an order. These inputs occur at precise moments in the standard processing of an order. We consider these inputs as events that unfold at specific instants in the business process. By discovering these input events, we have an indication of currently used business processes and their stages.

It is then important for the notification to be performed at the right time, that is, when people need it. This functioning is close to the notion of active database (an insertion or modification event triggers an action), but we do not employ this technology which is not the objective of our work. The next section elaborates on the nature of notification agents that send message to people.

4.1 Notification Agents

Figure 4 shows the architecture connecting notification agents and the enterprise's already existing applications. Access agents are shown that allow notification agents to access already existing applications data. We have separated access agents that are specific to distinct databases. Moreover, one access agent can be used by several notification agents.

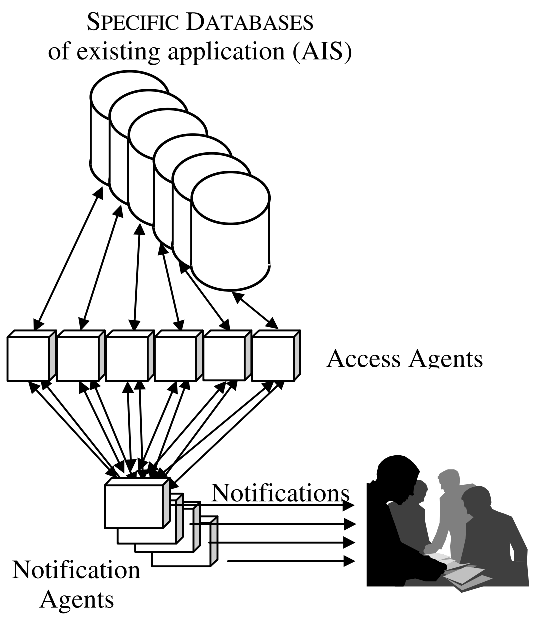


Figure 4. Agent Architecture, AIS, And People

The principle of operation is described in the following. Notification **agents** send **messages** to **persons** inside the enterprise, warning them of the existence of possibly reusable knowledge. To achieve this, agents scrutinize databases to discover predefined similarities between characteristics of a current object (being inserted) and those of previous objects (already in the concerned database). For example, considering the project object in an existing database, a notification agent will look for similarities in functional requirements of the product being made compared to those of previously made products (each project corresponding to an order of product, as seen before).

- **Message**

The message has to provide the necessary information for the person who receives it to be able to find knowledge practiced in the past and reuse it. For example, this can be references to a part of a project and the name of persons having taken part in it. The person working on the new project will be able to go and consult the archives of the relevant project and contact the corresponding persons.

- **Triggering**

Notification is triggered by the arrival of an event: the recording of a new object in a database.

- **Predefined Similarity**

Similarity measure is performed on a set of attributes defined in the notification agent. This is defined in a query that we call a **correspondence query** (CQ).

The correspondence measure is performed between characteristics of the new object and those of previous objects of the same nature. For example, in the functional requirement attribute of the project object, we will look for elements that are in both current and past project(s).

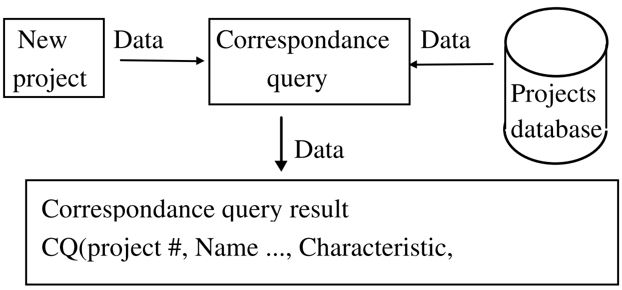


Figure 5. Example Of Correspondence Query

A correspondence query performs a join between the new project and past projects in the projects database (which corresponds to a specific database of figure 4.). The join predicate is however non-trivial; an equality test is not sufficient We define a similarity function for that purpose but it will not be very precisely detailed here since we are still working on this aspect at the moment. But we can however precise the directions we follow. A simplified version of similarity evaluation can be the same as similarity evaluation phase of case based reasoning (CBR) methods since we have several attributes that can be compared with values already in the database in order to find past projects that best correspond to the considered new project. As in case base reasoning systems, we also add the new project to the project database (it is in fact a side-effect of the AIS). We will also have to define some weighting for attributes. They should be initialized but can be refined with respect to the feedback given by users about the pertinence of the notification performed. It is through this measure of similarity that the system could adapt itself to the user needs and enhance the pertinence of the notifications. There are other problems concerning the similarity evaluation that are due to the various data sources that we use. We have also to prepare the data that we can find in the database in order to let it be more adapted to multiple criteria evaluation techniques. For example, we can define which attributes are significant, which values or combination of values are significant. Another example is to consider extreme or rare values as significant. We are studying these aspects at the moment and we intend to test several heuristics of this type on the data we have in the enterprise.

- **Set of persons who are notified**

If the CQ has found a similarity between the new project and previous project, there is a similar action context and the relevant people have potential pieces of knowledge to exchange. The people involved must be located and notified.

Each of them will then be able to evaluate if it is really important or not to study reuse of knowledge from the previous project in that of today. Both those previously involved as well as the new persons can have an opinion on this subject : the new persons can feel lost faced with an unknown requirement constraint, and those from the past could have acquired some strong ideas from their experience, even if it does not appear obvious now to the new people.

The person who inputs a new object is always notified of the existence of similar past objects when he / she receives the result of the CQ. It is not difficult to note the name of the relevant person at this time.

The task of locating persons from past projects is more difficult. To know who worked on a stage of a project, we can base ourselves on the project management database. We therefore introduce a new query that we call **linking query** (LQ) which allows us to find persons who have worked on a project, from the list of projects of the CQ.

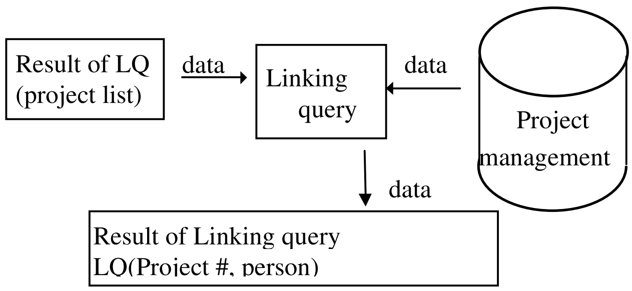


Figure 6. Example Of Linking Query

The notification must therefore be sent to the person who has performed the input, as well as to those in the result of the Linking Query (LQ).

If there is no result from the correspondence and linking queries, we can perform some requests to other agents that are not presented here (see section 3.3. for an example).

4.2 Database Schema Integration

We want to reuse data from the enterprise's currently existing information system. Thus we have to access different existing data systems functioning on various platforms.

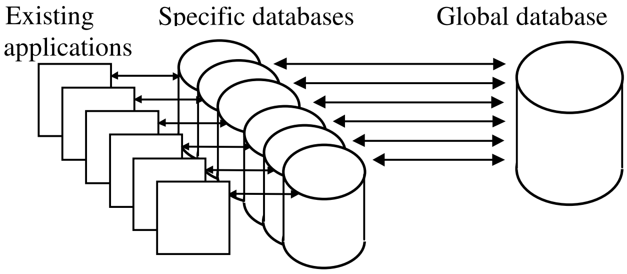


Figure 7. Integration Of Already Existing Application Schemas

To access all the schemas of already existing enterprise applications, there are several possibilities:

- Federate all the databases in a common database
- Replicate all the databases in a common database
- Replicate all the database schemas in a common (meta) database and define generic access agents for each database.

Federate All The Databases In A Common Database

The first possible solution to solve the problem of simultaneously accessing data located in several heterogeneous existing databases is to group the databases into a single centralized one. This means that it is necessary to transfer the data of each database to a new database and modify applications to make them directly access the new database. This step has the advantage of simplifying queries based on data from several applications. However, it is necessary to modify applications to allow them to access this common database instead of a specific one. In our case, some applications would be very expensive to transfer to a global database. For other applications, this step is already under way. Therefore, this solution is not sufficient to access the totality of the databases in the enterprise.

Replicate All The Databases In A Common Database

A second possibility is to replicate all the data of each database in a common one. This is possible for all the databases of the enterprise since each of them is implemented with a data export function. Moreover, it would allow the creation of the necessary data warehouse for preserving data beyond the time when it is archived by some applications. Indeed, historical data must be kept accessible since it is the basis for looking for similarities between past and current projects.

Replicate All The Database Schemas In A Common (Meta) Database And Define Generic Access Agents For Each Database.

Replication is only performed on schemas of existing databases, not on data. With each schema, we add several complementary pieces of information that are useful for consolidating the whole :

- semantics
- links between redundant attributes (inter-schema synonyms)
- information needed for the construction of access agents

We have built some tools allowing regular replication of database schemas to monitor modifications performed on previously existing applications (suppression or insertion of a table or an attribute).

This solution is more complicated, but has the advantage of requiring no modifications to existing systems. It is just necessary to consult data; the functioning of the application is not modified at all.

We have seen that the applications found in the enterprise are varied and there is no general conceptual model. We have started, in the enterprise where we have concentrated our experimental efforts, to construct the global data model, beginning with the conceptual diagram definition corresponding to each existing application.

4.3 Generalization and another example

The model that we have defined is very general and allows us to define a notification agent based on data other than project requirements and management data..

For example, we can use this model for managing knowledge offers and requests. We have seen in (Mahé, Rieu 97) that using a system based on a great number of electronic mail distribution lists to which people subscribe and send messages requesting and offering knowledge would be too restrictive and that it would be better to base notification on the content of the message rather than on the chosen list.

This can be performed with a database where knowledge offers and requests are stored as they are formulated by people, combined with a notification agent. This agent compares a new knowledge offer or request with previous knowledge offers and requests already stored in the database. There is no subscription to perform as long as each offer or request added in the database is equivalent to a subscription to a distribution list.

Considering a new knowledge offer, the notification agent will have to look for similarities to previous knowledge requests. But it can also look for similarities to previous knowledge offers that signify that its sender is concerned with that piece of knowledge.

Reciprocally, a new knowledge request must be compared with previous offers and also with previous requests that may have been answered since their creation.

A database of peoples' competencies has begun to be used to search for competencies (and persons) related to a knowledge need. This database can be used by this notification agent in addition to the offer and request database.

4.4 Toward Automatic Creation of Agents

For the moment, the definition of notification agents is performed manually, but we are interested in automatically generating notification agents with data mining techniques. These agents should be approved before being activated. Once the global schema is defined and consolidated [Baru 97], it may be possible to automatically generate some suggested agents. This would require the definition of translators to produce access agents that would provide access to the heterogeneous data of the AIS.

The global schema have also to give sufficient information in order to define a kind of generic similarity function for these agents regarding the functioning of data mining techniques used to generate these agents.

Conclusion

Starting from the experiential observation that classical formalizing approaches for knowledge management are not well suited for our enterprise partner (industrial S.M.E. employing 250 people), we have sought to propose a new knowledge management approach that responds adequately to the everyday concerns of people in the enterprise. Our pull approach has the advantage of providing results rapidly, contrary to the push approaches that requires a long investment before seeing the first results.

Our approach is particularly well adapted to the diversity and to the functioning of enterprises that make to order, with highly personalized products, and especially to S.M.E.. At the moment, this approach seem to be well accepted at KSB Pompes Guinard in Annecy.

We do not store knowledge on an artificial medium; rather we help persons know **when** they have to try to reuse knowledge. This was the main barrier to knowledge reuse in the pilot enterprise during our study. We also provide guidelines advising people what to do once notified (persons to contact, projects). It is crucial information in action, because it is unacceptable to be constantly wondering if what we are about to start might have been already done and could be reused (and whom to contact...).

By thus favoring knowledge reuse, we also combat the loss of knowledge, by increasing the part of knowledge that is **shared** by several persons.

Our pull approach is not exclusive. On the contrary, it prepares the terrain for a push approach by fostering a positive image of knowledge management in the enterprise, and by revealing the importance of the possible need to formalize knowledge to find it more easily. Moreover, its side effects can be used to guide a push approach. In this case, the cost of knowledge formalization will be considerably decreased.

We are now working on the evaluation of the techniques we can use to measure the similarity between a new element and previous ones that should be compatible with the automatic definition of notification agents.

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