Improving Organizational Memory through Agents for Knowledge Discovery in Database

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Abstract

In this article we describe a computational architecture called MC2 that brings together a set of tools that contribute to the knowledge management process by allowing for the creation and maintenance of an organizational memory. To achieve this end, the approach taken by MC2 is aimed at establishing favorable conditions for interaction between the personnel within an organization as well as with the system itself. In particular, we describe agents that attempt to achieve automatic knowledge discovery from organizational databases and from the manner in which that knowledge is integrated into the MC2 environment. By using these agents, organizational development is fostered through the dissemination of knowledge, yet, in such a way so as to be transparent to the holders of that knowledge without requiring additional activities above and beyond those already carried out as part of their day-to-day routine.

Introduction

Knowledge is a fundamental building block in business and is viewed as a decisive variable in the competitiveness of an organization. Aspects linked to the mechanisms for creating, representing, distributing, commercializing and exploring knowledge must be analyzed and understood in order to make a mark within a competitive environment. To the collective administration of these mechanisms we give the name knowledge management. Another concept corollary to the ever-increasing relevance of the role of knowledge in an organization is that of learning organization. Here the aspect of continuous and collective learning of the personnel within an organization is emphasized. Consequently the development the organization passes through as a result of this learning process.

To fully achieve the goals of knowledge management, as well as to oversee, induce and even to accomplish the process of organizational learning itself, a computational support system is needed that offers flexibility and reliability to the process. Information systems (IS) constitute this support and allow for dealing with large amounts of information as well as for providing the primary means in the formation of organizational memory.

In this article, we describe a computational architecture called MC2 that brings together a set of tools that support the process of knowledge management by allowing for the creation and maintenance of an organizational memory. MC2 is divided into three levels: The data level where data concerning the organization is stored; the IS level, called *participation space*, which makes computerized procedures available that seek to contribute to the formation of better relationships between the people and sections of an organization; the knowledge level that is composed of software agents that seek to aid in the creation, search and exploration of knowledge that permeates the organization on a daily basis. These two levels are strongly linked to and mutually feed off one another.

In particular, we describe one of the agents in the knowledge level that accomplishes automatic knowledge discovery from the databases of an organization and show how that knowledge is integrated into the MC2 environment. With the use of this tool, organizational development is fostered by disseminating knowledge in such a way so as to be transparent to its originators, thus, it requires no additional tasks on their part above and beyond those already accomplished in their day-to-day activities.

The State of Art

Knowledge Management and Learning Organizational

We utilize the definition of [Senge 1990] for the learning organization (LO) as being: "Organizations where people expand their capacity to continually create results that they really want, where new and expansive ways of thinking are encouraged, where collective aspiration is free, and where people are constantly learning to learn collectively". He emphasizes that LOs are organizations that are constantly expanding their capacity to create and recreate their respective futures. Another perspective in the challenge involved in transforming a company into an LO is that which focuses on the need for companies to "unlearn" or "forget the past" [Davis 1996].

Common challenges are identified in the software tools that are intended to accomplish the creation and maintenance of organizational memory [Beckman 1998], [Van Burem 1999]. In [Abecker 2000] a system is presented that supports the definition of models for the description and storage of documents, thus creating an organizational memory (OM). These models are graphically built and are the result of a collaborative effort among users. To such an end, each user has several of these previously defined models available and can use them interactively when classifying a document by fitting it to the model that best describes it, facilitating its storage and any potential future queries to it. The authors point out that for the success of this type of organizational memory there must be resources available for the storage and distribution of knowledge in compatible formats so that users with different profiles can easily contribute and query information relating to their particular work, thereby facilitating the creation of additional models beyond those already defined. The authors also point out that people must note a direct benefit in the administration of knowledge in order to continue contributing and the effort required by their contribution should be minimized so as not to unduly interfere with the flow of their normal workload.

Other authors [Hijst 1996] focus on how organizational memory can be administrated. For them OM is an explicit and persistent representation of the knowledge and information in an organization. Any part of the knowledge or information that contributes to the performance of the organization can be stored in it. In the four knowledge treatment processes dealt with by the authors (knowledge acquisition, storage, distribution, and knowledge combination), we encountered, not by coincidence, difficulties and solutions similar to those encountered by Abecker and his colleagues. We point out those regarding the fact that both approaches indicate that participation must be active and permanent. To do this, the user should be motivated to contribute his knowledge and there should be a return for him in doing so, that is, the person should notice a benefit to his work resulting from the use of organizational memory. Besides the effort of the user's contribution being minimized to the extent possible, it should also be automated so that he needn't set aside his professional tasks in order to accomplish those relating to organizational memory. The tools should provide a means to that end so that cooperation is effected automatically and interacts to the maximum with their actual work.

Inductive Learning Algorithms

In order to get assistance in the creation of OM, it is necessary to depend on software tools that can generate knowledge from organizational data and information. In the realm of Artificial Intelligence (AI), inductive learning algorithms [Langley 1996], [Mitchell 1997] support the creation of example-based concepts. These examples represent past situations and are usually described by attribute/value pair lists. It falls on the algorithm to seek out correlations between characteristics (attribute/value pairs) within these examples and to induce from the correlations generic concepts representative of the examples, which can then be used to classify other analogous examples not yet observed.

Concept acquisition algorithms have C4.5 [Quinlan 1986] as their most representative and popular example. This algorithm type, taken from a group of examples, generates a decision tree that represents concepts within the domain being worked. They are considered supervised algorithms because the examples indicate the class to which they belong, leaving the algorithm to discover a generic concept that represents each class indicated by the examples.

In unsupervised algorithms, also known as *conceptual clustering*, the examples do not pertain to any known predefined class. Here, the task is finding clusters of who is similar to whom. These clusters are said to be conceptual because the characteristics for each cluster defines the concept of the cluster represented. COBWEB [Fisher 1987] and FORMVIEW [Furtado 1997] are instances of this class of algorithms. Besides conceptual clusters, FORMVIEW constructs concepts following different perspectives in order to discover relationships between different contexts, called bridges.

The function of both algorithms is knowledge acquisition through concept formation. These concepts, when placed in an organizational context, come to reveal knowledge that until then was merely implicit within the organization, thereby contributing not only to feeding OM but supplementing organizational learning as well.

The Problem

The brief state of the art accomplished above allowed us to determine that the creation of an OM and by consequence the development of organizational learning requires that those involved in the process be motivated to participate. Without their active and continuous participation, the reception as well as the dissemination of knowledge would be compromised. It is necessary to create the means that will allow users to extract knowledge from their daily tasks and yet in doing so does not unduly interfere with their professional responsibilities so that the process of creating an OM does not become an overly tiresome prospect or an utter waste of time.

Additionally, we believe that if everyone in the organization is well aware of the utility of organizational knowledge, they will more readily and more willingly contribute. Therefore, the creation of automatic knowledge discovery tools based on user activities along with their dissemination throughout the organization may be a strong motivating factor toward participation as well.

Along these same lines, the use of inductive learning algorithms like concept acquisition and conceptual clustering constitutes an interesting alternative toward creating organizational memory. Our research work concentrates on this aspect of the process and how a tool of this type may be integrated into an environment specifically designed to create an OM. In what follows, we describe the interactive environment of creating an OM called MC2 and how knowledge engineering tools, and more specifically, those designed for database knowledge discovery, are integrated with it.

The MC2 System

A Global View

MC2 is a web-based information tool and a managerial strategy that supports the formalization of a learning culture and an organizational memory (see www.mc2.com.br).

In general, the objective of MC2 is to assist the administration of knowledge. People are required to share their experiences, ideas, knowledge and activities linked to learning such as: book summaries, project structures and methodologies dealing with their activities. The aim is to promote positive attitudes and to build a participation culture that result in the creation of important and highly valuable knowledge bases.

To encourage participation it is necessary to implant in the organization an effective means and adequate structures where new assignments, roles and responsibilities can be put into actual practice. The general architecture of MC2 can be seen in Figure 1. It is modeled with Intelligent Agents that have the characteristic of using the information handled by individuals in the context of their work processes and convert this information into knowledge for use in decision-making.

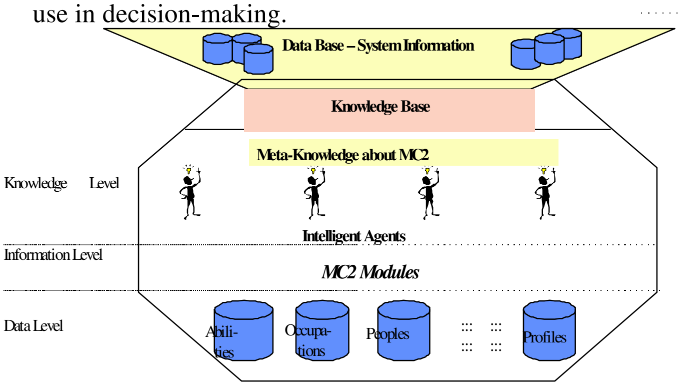

Figure 1 MC2 Architecture

MC2 is divided into three levels: the data level where data concerning the organization and its personnel is maintained, the IS level that we call the *participation space*, which tries to make computerized procedures available that try to facilitate relationships between people within an organization; and the knowledge level, where tools are stored in expressions for tasks that are accomplished daily by the individuals of the organization while they are working and undertaking their professional activities. The tools that comprise the participation space can be seen on the screen-capture shown in Figure 2:

- *Corporate University* through its modules gives support for personal development of the members of the organization.
- *Expression Modules* support various ways of documenting and accessing useful information for organizational development such as experiences obtained individually or in group, acquired abilities, problem resolutions, topics for further discussion, etc.
- *Knowledge Circles* are modules that allow people interested in certain subjects to learn and to share specific knowledge. This module concentrates on all knowledge contributions available within the system (articles, tests, book summaries, etc).
- *Queries Modules* allow the members of the organization to find answers to frequently asked questions such as those concerning personnel, problems and solutions, abilities, norms and basic concepts of the organization.
- *Communication Modules* allow the individuals of the organization to exchange ideas and experiences from their daily lives, besides serving as a resource for managers of the organization to communicate with employees.
- *Support Modules* allow for the customization of the MC2 system to fit the reality of different institutions as well as to support the perfect implementation and use of the MC2 strategy.

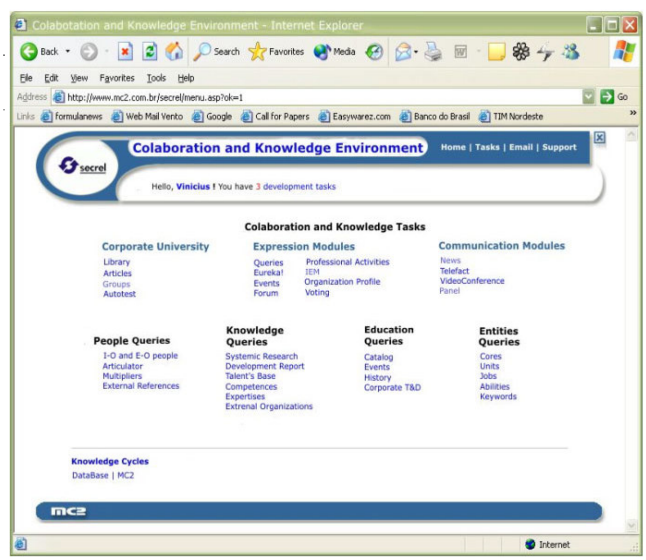

Figure 2. MC2 with their expression modules

The MC2 Managerial Strategy

As we have already mentioned, the MC2 managerial strategy is based on the participation concept. The possibility of participation is permanent in relation to any subject matter or perspective of the company and is accomplished through various possible channels. The result then, in this context, is that when referring to people, we mean not only their technical competence but all their talents, experiences, vision, initiatives and capacity for action when joining together with others in order to develop their personal projects, thus assuring that the entire process translates into permanent organizational learning [Furtado, 2000]. That is: people are empowered to grow as the organization develops; to change, in the effort of improving it.

For the proper operation of the MC2 software there is an implantation strategy in which MC2 is aided. This strategy makes use of ontology where fundamental concepts of the organization are defined such as the functions, abilities and requirements expected of personnel in the exercise of their jobs. These ontologies are known in MC2 as critical knowledge lists (CKLs). There are three types of CKLs: common, which contain themes that everyone in the organization should know. Job CKLs, designed to relate the indispensable knowledge for the exercise of each position or function, and Personal CKLs, a list of necessary knowledge for the essential development of each collaborator.

Besides the formal aspect regarding the necessary concepts to be defined, it is worth pointing out some of the essential roles that should be exercised by people in the organization so that MC2 is implanted satisfactorily. These roles are:

- **Articulator**: is the person responsible for the professional development of others and for managing the resources that will make possible the maximization of this development.
- **Multiplier**: is the person who establishes a formal, permanent and parallel commitment to their normal activities, delving more deeply into and disseminating knowledge relative to a particular theme from one of three CKLs.
- **MC2 Consultant**: is the person to whom the organization assigns the tasks of coordinating, implementing and administrating the MC2 system.

Modeling the MC2 Knowledge Discovery Agent

Having briefly described the MC2 system, we shall now focus on defining the process of the knowledge discovery agent's operation as well as its architecture.

Agents have been used to automate tasks and to carry out processes not requiring user input. The use of the Knowledge Discovery Agent (KDA) in MC2 is intended to contribute to knowledge acquisition within an organizational learning environment by carrying out a database knowledge discovery process. In this process the KDA explores databases containing information on the business activities of an organization.

The KDA sweeps the company's business databases in order to, through learning algorithms, detect facts and information not explicitly outlined in its normal rule of operations. Such information can become knowledge, and per chance, may be used in making decisions, thereby forming a knowledge base that can feed organizational memory. To proceed we shall describe how this agent is modeled, describing its architecture, and its operation.

KDA Architecture

To model the KDA, we followed the model proposed by [Russell, 1995]. To the authors, an agent is anything that is able to perceive its environment through a sensor and is capable of interacting with that environment by means of a determined action.

In the case of the KDA, sensors monitor user intervention to various MC2 system events. For each of these interventions the agent tries to find data that might serve as parameters for its action. Based on these parameters, the agent will accomplish knowledge discovery. For such, the KDA uses inductive learning algorithms like those described previously.

Thus, we have the three parts of the architecture: Environment, Sensor, and Action as can be seen in Figure 3.

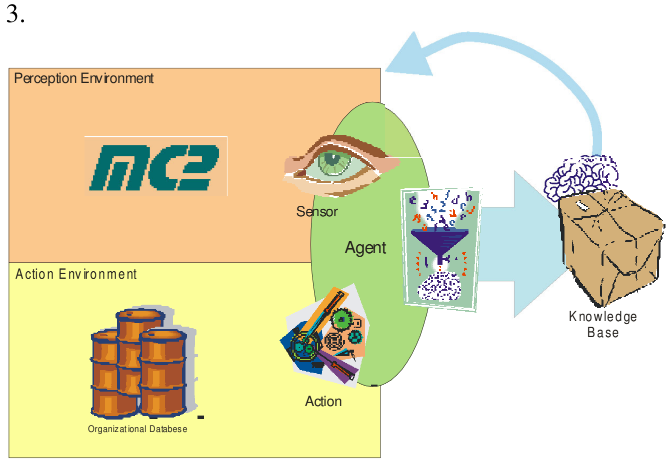

Figure 3 MC2 Agent Architecture

To proceed we will describe each of these parts and how they contribute to the agent' s action as a whole.

Environment

The KDA environment is divided into two parts: the perception environment and the action environment. The perception environment is where the KDA carries out its monitoring activities that detect events to be broken down into particular actions. This environment is the participation space of the MC2 system.

The KDA action environment is where information is stored regarding the business of the company, its structure, customers, suppliers and personnel (usually its database). This allows the organization to obtain more knowledge concerning their methods, operations and finances.

Sensors

As sensors, we define the KDA procedures for monitoring the events of some of the modules of the MC2 participation space. These events serve as stimulus so that the KDA can carry out its actions. The events constantly monitored by the KDA are:

- Knowledge Circles
- Groups
- Query Database

The Knowledge Circle concentrates on all contributions carried out in MC2 by its members on a particular theme; such as Forum participation, comments on titles in the collection, queries made, and new ideas, allowing members to learn and share their contributions. The agent then monitors the creation, alteration and inclusion of new members in the circle, in such a way so as to try to discover a profile of these members and thus, aid in the selection of new circle participants.

Another event that is monitored by the agent is the creation of the Query Database. In this base the user formalizes questions and topics on a particular theme and addresses them to particular people or groups of people who might be able to answer their questions. In this case the agent also monitors the inclusion in the database of queries and tries to anticipate answers to the questions that per chance the user inputs into the database.

Different from the Knowledge Circle, the Groups module registers a meeting of people with the purpose of carrying out tasks or deliberations. Yet, like the Knowledge Circle, the agent tries to discover the profile of these members, aiding in the selection of new participants.

Action

As mentioned previously, the KDA has as an action environment the organizational database. So that the agent may take action, some parameters, captured from the perception environment, are necessary. These parameters are actually the attributes the knowledge discovery algorithms implemented in the agents that were needed to accomplish their processing. The choice of these attributes is an important task since the results can mean relevant knowledge to the user that may or may not be related.

For each event cited before, the agent identifies data that can serve as parameters for the agent's action. In the case of the Knowledge Circle and Discussion Groups, the theme of the circle and the individual CKLs are examples of such parameters.

For the Query Module, the agent tries to use keywords from questions and uses them as parameters for the algorithms. The agent operates in a similar fashion in the Groups module, where the parameters used by the agents are the themes as well as the CKLs of its members.

The attributes collected are used to compose the structure of the examples, which will feed the machine learning algorithms. Such a procedure of KDA is very similar to those developed in the context of metadata definition to data warehouse creation (Inmon, 1998). The idea is to generate an example training set from business metadata representing important concepts of the domain. It is important to emphasize that the agent's action can also be run manually. If a user so desires, attributes may be chosen at will to carry out knowledge discovery.

Product

The result of the agents' action is a knowledge base formed from the result of knowledge discovery that can feed organizational memory. This knowledge base is made up of production rules and concept hierarchies that are the products of the inductive learning algorithms implemented in the agents.

The use of production rules consists of representing the knowledge domain with a group of IF-THEN rules, representing a particular concept through these rules. The concept hierarchies are intended to classify a group of observations based on certain attributes.

Depending on the event that triggers the agents (knowledge circles, groups, queries), there will be differing utility to the user. In the case of Knowledge Circle and Groups, the main purpose is to discover profiles.

Example

To exemplify our proposal, we shall describe the knowledge acquisition process based on the database of CAGECE (State of Ceará Water and Sewage Company), taking as an example the Human Resources Knowledge Circle module. In this case the agent' s function is to try to determine the profile of the circle members, thereby aiding in finding new members with the same profile. To do this the agent will utilize criteria obtained from the knowledge circle itself along with personnel attributes found in MC2 itself.

Thus, we can divide into two groups, the attributes that will be used by the agent to carry out concept formation. We have parameters taken from the knowledge circle itself that are mapped onto a meta-knowledge layer with attributes of the organizational database. The others will be attributes pertaining to the users themselves that can aid in categorizing their profile such as: number of registered articles, forum contributions, registered professional activities, query responses, etc. This way, observations will be formulated based not only on the organizational database, but also on MC2 data itself.

We may highlight three steps that the agent will carry out to effect its function: Sensing, where the agent notes the instant of its action and captures the concepts involved in taking action; the linkage of concepts with database attributes, where the agent uses meta-data to link the MC2 concepts to attributes within the organizational database; and the action that involves the execution of processing the algorithm. To proceed, we shall show how the agent will act in this example of a Knowledge Circle with a Human Resources theme.

Sensing

As already cited, there are certain events that the agents constantly monitor; one of which is the Knowledge Circle. For each new circle created the agent enters into action. In our example the agent' s action is to try to determine the profile of the members of the knowledge circle in two perspectives. The idea is to create concept hierarchies, based on criteria captured from the Knowledge Circle, for aiding the identification and selection of people with potential for participation in that circle.
The capturing of criteria becomes an important action since it can directly influence the concept formation accomplished by the algorithm triggered by the agent. The agents' main function in sensing, besides noting the instant of its action, is to capture those criteria correctly. In our Knowledge Circle example there are two types of attributes that the agent will use and that determine the perspectives to be used: attributes about the organizational database and attributes about the MC2 database. The organizational database attributes, which are mapped onto the meta-knowledge layer, contribute to the creation to the *professional perspective*. Basically, these attributes are related to the following parameters: Theme and the CKLs of current members.
CKLs are composed of keywords that define indispensable knowledge for the execution of each position or function. These keywords form the group of attributes to be used by the algorithm. Using the Human Resources Knowledge Circle, we take into account that this same circle is composed of three users, for example. These users have the themes in their CKLs indicated in Table 1.

User	CKL
A	Finance
B	Finance, Project Management, Human Resources
C	Psychology, Project Management

Table 1 CKLs of the Knowledge Circle Members

Beside the attributes found in the Knowledge Circle (theme and the CKLs of the members), attributes about MC2 database will lead to attempt at creating the profile of a circle member from the *participation perspective*. These attributes determine the degree of a user's participation in MC2 like the number of written articles, forum contributions, registered professional activity, query responses, new ideas, and son on.

Linking concepts to database attributes

In order for the agent to correctly correlate concepts captured by sensing from the organizational database, we shall use what is called a meta-data layer. This layer's main function is to serve as a link between the concepts declared in MC2 and the fields, tables, and attributes in the organizational database. Actually, this layer maps all existing keywords in the MC2 system and links them to related attributes in the organizational database.
Each organization has its own keywords that is important not only for the action of the agents but also for the operation of the MC2 system itself, since these words are distributed throughout the system to facilitate searches and to attribute concepts. Due to its importance in any implantation of the MC2 system, it is necessary to register the concepts (keywords) used by the organization. It is at this point that the mapping of concepts to database attributes takes place. For each inclusion of a keyword, the MC2 consultant can associate its existing attributes to the organizational database.
There are other passive relational concepts with organizational database attributes that may also be used as parameters by the agents: CKLs, abilities, job positions etc. Like keywords, concepts that are unique to a particular organization can also be mapped to attributes in the implementation of the MC2 system.
Conforming to the Human Resources Knowledge Circle example, we have the following concepts relating to attributes:

Concept	Attributes Related to the organizational database
Human Resources	Burrow, Sex, Department, Job, Seniority
Psychology	Social Level
Finance	Salary Range
Project Management	Number of Projects Accomplished

Table 2 relationship between concepts and attributes mapped in the meta-knowledge layer

Action

After collecting the necessary parameters (attributes) the agent forms a group of observations that FORMVIEW will use to carry out processing. Tables 3 and 4 show some defined observations related to the professional and participation perspectives.

	Ext rati me	Exec. projects	Salary range	Posit.	Depto	Social Level	Adm. time	Nb clie ntes
P1	0	4	Up to 1500	Direc t	Marketi ng	Middle	Up to 3	4
P2	4	5	Up to 1500	Empl.	HR	Middle	4-7	5
P3	2	10	More 2000	Direc t	HR	High	Up to 3	10
P4	0	20	Up to 1500	Direc t	Marketi ng	High	4-7	20
P5	0	23	More 2000	Direc t	Finance	Middle	More 10	23
P6	0	18	Up to 1500	Empl.	HR	Middle	More 10	18

Table 3: Subset of observations of the professional perspective for FORMVIEW processing

	Forum partic.	Articles	Answer queries	Prof. Activ.	New ideas	Votes	Group partic.	Nb. Partic.
P1	0	4	6	4	2	0	5	4
P2	4	5	7	3	0	0	11	5
P3	2	11	4	2	0	2	3	10
P4	0	2	3	2	2	3	10	5
P5	0	3	3	2	1	1	8	5
P6	0	8	5	7	1	1	10	5

Table 4: Subset of observations of the participation perspective for FORMVIEW processing

Based on these observations the agent triggers the algorithm, in this case, FORMVIEW, to carry out the concept formation. As a result of the processing we have the concept hierarchies (Figure 4) that will be made available to current circle members. The user, if he or she so desires, may observe how other people, holders of the same knowledge are grouped following the two perspectives.

As we can observe in Figure 4, on the right side, there is a concept hierarchy representing the participation perspective and on the left side, there is the professional perspective. Some categories are named by the users like the category 'HR older than 10" representing the concept of people working in the Human Resource department with more than 10 years in the organization or the category 'High Participation" in the perspective participation representing people with high level of participation in MC2. These two categories are linked by means of bridges which represent the set inclusion relationship. Bridges indicate that entities represented by a concept in a perspective imply another in a different perspective. For instance, the bridge shown in Figure 4, indicates that the personnel from human resource department with more than 10 years of experience have high level of participation in the use of MC2 tools.

Observing these concept hierarchies the current circle members can indicate new members based on this profile, and even discover if a particular user has a profile to be able to participate in the Human Resources Knowledge Circle. Additionally, the agent will automatically send messages to people with this profile, inviting them to take part in this Knowledge Circle.

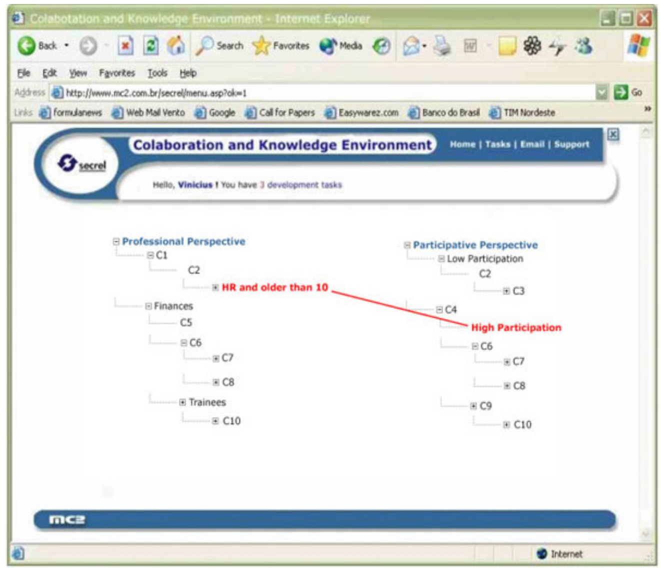

Figure 4 Example of concept hierarchies generated by KDA in MC2

Conclusion

In this article, we describe agents that aid in the creation and maintenance of organizational memory that is characterized by the use of knowledge engineering and automatic knowledge acquisition algorithms. Among the benefits of this work we may cite that which allows for the automatic generation of knowledge that until now has been implicit within an organization. This knowledge is related to the activity goals of an organization and contributes toward memory creation and organizational learning.

Another advantage is to create profiles, categories and classifications to better understand the business end of the company, such as suppliers, customers, employees and products. Another contribution of the approach here presented is to aid in bringing the user closer to MC2 system. By using the algorithms FORMVIEW, C4.5 and COBWEB to exploit company databases—that is to say in his work environment—the user is stimulated to contribute with the idea that the knowledge captured and deposited in MC2 is related to their practical work activities.

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