Structuring Healthcare Practictioners Profiles and Documents with UPR Algorithms

L.LELLA[1] - A.F.DRAGONI[1] - G.GIAMPIERI[2]

[1]D.E.I.T., Università Politecnica delle Marche
[2]A.R.C.H.I. – Advanced Research Center for Health Informatics

Topics : Data mining, data processing, document processing and recognition, fuzzy and hybrid techniques in pattern recognition.
Abstract. In order to improve the communication and the cooperation among the personnel operating in the local healthcare area ASUR ZONA Territoriale 7 we are developing a knowledge management platform for healthcare practictioners. Actually the platform comprehends a tool for the automatic annotation of forum messages and a service for the generation of networks of practice. Both the systems are based on a knowledge acquisition module that analyses the textual content of messages and documents to trace the profiles of practictioners. The representations of messages and profiles can be categorized by unsupervised pattern recognition algorithms. These algorithms are capable to set the optimal number of categories, requiring only the choice of a suitable similarity function and a structural criterion.

1.Introduction

The 2003-2006 italian sanitary plan has defined the modalities of supplying the sanitary assistance of services in the local areas establishing the roles of the various medical practictioners and the way they should interact working together. Such a good level of cooperation among medical practictioners can be guaranteed only through an efficient communication. The whole medical staff has to be informed about the current research and the assistance activities perfomed by the colleagues. This awareness can favour the search of competencies necessary to support the activities of medical practictioners at best. Therefore it is necessary to develop tools of knowledge management (KM) in the organizational intranet which are able to update the profiles of all the practictioners, helping them in their job and promoting the creation of knowledge within the healthcare system..
The nature of knowledge has been well debated in literature. Several definitions have been provided which are often very dissimilar each other, but almost all the researchers seem to confirm that knowledge is strictly related with data and information. Knowledge is needed to interpret correctly data and information, but once a meaning has been assigned to them a new status of knowledge arises. The process that leads to the creation of new knowledge is known as SECI (Nonaka , Toyama and Konno 2000) and gets through the socialization, the externalization, the combination and the internalization of knowledge. Knowledge cannot be processed as information because it is continuously recreated and reconstituted through dynamic, interactive social networking activity. So the problem of knowledge sharing in organizations is essentially a problem of coordinations among actors in organizations.
As pointed out by Stenmark (2002), much of the research conducted on knowledge management systems was influenced by a mechanistic and rationalistic view of organizations, that were considered principally as machines for information processing. But this scientific management, too linked to the concept of control, didn't encourage the active cooperation of workers and the creation of new knowledge.
Great part of literature on knowledge management (Nonaka, Toyama and Konno 2000) attempts to design orders that will be efficient for companies. However managing knowledge by design is a problematic task not only for the difficulty to articulate knowledge, but the concept of design itself tends to ignore the constantly changing circum-

Corrispondenza: L. Lella, A.F. Dragoni - D.E.I.T., Università Politecnica delle Marche, 60100, Ancona, Italy llella@inform.unian.it a.f.dragoni@univpm.it
G. Giampieri - [2]A.R.C.H.I. – Advanced Research Center for Health Informatics, 60100, Ancona, Italy giampierig@asl7.marche.it

stances under which knowledge is in use, i.e. the ever changing environment. So the traditional rhetoric about knowledge management as a phenomenon consisting of distinct phases (gathering, collecting, capturing) for constructing, distributing, storing knowledge as defined by Huber (1991) and Pentland (1995) is now little relevant. Instead, concepts conceiving knowledge management as knowledge sharing, knowledge search and knowledge transfer have become important (Kautz et al. 2001).
The cognitive dimension of knowledge gives rise to a wholly different view of the organization, not seen as a machine for information processing but as a "living organism" characterized by the presence of a spontaneous and not imposed order.
Viewing orders as emerging in a spontaneous way, they became the product of the action of many people but they are not the result of a single human design (Hayek 1973). As underlined by Hayek, in any group of workers of more than the smallest size, collaboration will always rest both on spontaneous order as well as on deliberate organization. However sometimes the complexity of the circumstances to be taken into account requires the rejection of any type of predefined order, yielding to the reduction of the control capacity of the company, but in this way organizations can benefit from the specialized knowledge possessed by the individual members.
The so called "knowledge based organizations" can be seen as open and dynamic systems (Burns and Stalker, 1961) whose major issue is to find creative ways to represent and integrate knowledge across their lateral units (Nonaka 1994).
Luckily Internet, Intranet and Web technologies allow practical capture, sharing and leveraging of information and knowledge. Organizations can utilise Intranets and KM systems to share individual, departmental and organizational information, enhance communication between communities, maintain virtual discussion and support collaboration within and across organizational, departmental and global boundaries. But all these technologies must be used in a proper way, considering the three main perspectives of knowledge management suggested by Stenmark (2002) : the information perspective, the awarness perspective and the communication perspective, means that they must induce the workers to provide new information, they must advice the workers of the presence of new useful information and they must favour the developing of communitities of practice where knowledge is shared among the workers and continually grows.
The tools presented in this article are aimed to enhance the creation of communities whithin an organization.
The first is a tool for the automatic annotation of the messages posted in an organizational forum of discussion. The system allows to detect all the messages already present in the forum archive which are related to the posted request. In this way a person can get in touch with much more people, not only with the ones that answer directly to his message as it happens in classic forums.
The second is a knowledge management system that continuously update the profiles of the users, optimizing their searches and detecting groups of peers with similar experience and objectives.
In collaboration with the Advanced Research Center on Health Informatics of Ancona (Italy), we are going to test these knowledge management tools within the local healthcare system community. The local healthcare agency ASUR Zona Territoriale 7 provides for 240 practictioners and more than 1400 specialists who operate in 15 different municipalities. So the number of users is sufficiently high and distributed to justify the use of knowledge management tools that can effectively lead to an improvement of the coordination and cooperation between peers (Dieng 2000). We think that the adoption of the knowledge management services will favour the sharing of knowledge and information within this particular healthcare area.
Both the systems are based on a knowledge acquisition module realized on the basis of a psychologically valid model of discourse comprehension (Kintsch, Patel and Ericsson 1999). This module represents the content of a text with a graph of words extracted from it, a graph that is used to update a statistical model of the knowledge acquired by the system. This knowledge representation is used to represent the semantic domain that characterizes the forum and the cognitive models of the users of the knowledge management system, and it is also used to optimize the analysis of new texts.

2. The Knowledge Acquisition Module

It is generally made a distinction between two different types of knowledge : the explicit one and the tacit one (Nonaka 1994, Polanyi 1967), the first can be expressed in words, numbers and images and it can be shared through the modern communication technologies.
The tacit knowledge is instead constituted by mental models that cannot be articulated easily, but which influence the way a person perceives the world around him. For example though we are able to recognize a face, we are not able to explain it easily in words. This type of knowledge is highly subjective and difficult to formalize. This makes its extraction, communication and sharing much more difficult (Hildreth and Kimble 2000, Bhatt 2001).

Polanyi assumes that this sort of knowledge is linked to the act of focusing the attention on particular perceived aspects of the reality. In particular he makes a distinction between the proximal and distal attention. The first kind of attention is the one we associate with ourselves, with our perceptions, while the distal one comprehends the rest of reality around us. Both the distal and the proximal attention constitute the tacit knowledge of a person. In a recognition problem, human cognitive processes associate the proximal knowledge (for example the perceived aspects of a face) with the distal knowledge (a certain known person).

Polanyi's example seems to suggest that the tacit knowledge can be partly structured as an associative network.

This is a representation of knowledge constituted by a graph whose nodes represent concepts or entities and whose weighted arcs represent implicit relations more or less strong among the concepts or entities. The knowledge contained in this representation can be updated dinamically and retrieved through suitable procedures of dynamic inquiry that allow to consider also the context in which happens the retrieval of information. A common way to execute the retrieval is the diffusion of an activation signal (McClelland and Rumelhart, 1986). This signal starts from the nodes representing the perceived items and spread through the network until the values of the activation signal at each node become steady. Thereafter the nodes characterized by the highest values of the activation signal are retrieved because they are considered strongly correlated with the perceived information.

Also the search of information and competencies in an organizational intranet can be considered as a recognition process. Even in this case the perceived distal aspects represented by the documentation or the employees that satisfy the query must emerge and derive from the proximal perceived aspects represented by the objectives and the tasks of the employee who makes the search.

To carry out an effective retrieval of information and competencies the system that manages the organizational knowledge must be able to model and keep updated the cognitive and cultural profile of each employee to support him in the most effective and efficient way in his research tasks. The cognitive model of each employee should be represented by an associative network of words and concepts. This should be dinamically updated on the basis of the content of the documents daily checked by the employee and judged by him strongly correlated with his activities. For this reason we have used suitable models of discourse's comprehension in order to extract the knowledge from the texts read by the employees.

In this way the knowledge management system can contact the employees characterized by similar cognitive profiles, favouring the growth of the Communities of Practice (CoP), that are groups of people which can cooperate in the pursuing of their tasks (Wenger and Snyder 2000, Broendsted and Elkjaer 2001).

It is also possible to represent the knowledge of a group of employees who are involved in the same activities, for example a group of employees that frequently attend a discussion forum. The knowledge arose from the analysis of the posted messages in this case represents the experiences and the goals shared by the community of employees.

A good psychologically valid discourse's comprehension model that is based on associative knowledge representations is the Long Term Working Memory defined by Kintsch and Ericsson (1999). The model comprehends two main blocks which are the Working Memory where the meaning of the analysed information is constructed, and the Long Term Memory that contains all the knowledge acquired during the previous analysis and experiences.

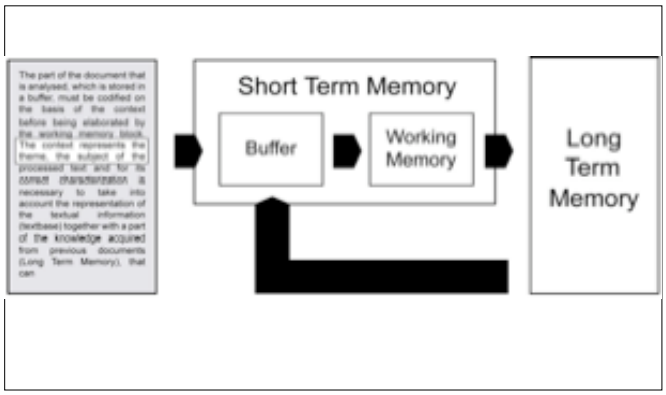
Kintsch and Ericsson first noticed that given the strict limits of capacity of human working memory, tasks that require an enormous amount of resources (like discource's comprehension) cannot be carried out. In these cases the working memory should be subdivided in a short term part that has a limited capacity and a long term part that is a part of the Long Term Memory. This can be represented by an associative network which is a graph that connects entities and concepts by the use of weighted and not labelled links. The content of the STWM automatically generates the LTWM, because the objects present in the STWM are linked to other entities in the LTM by fixed and stable connections called retrieval cues. The adoption of this model yelds two project problems. The creation of the LTWM and the definition of the retrieval cues.

Kintsch has defined two different methods for their definition. The first is a manual technique that cannot be automatized. The second, that is the so called creation-integration method, is based on the latent semantic analysis and a vectorial representation of knowledge called semantic space but presents great limitations.

The LTWM is an associative network of propositions and in the creation integration model is not clearly specified how many words and propositions have to be retrieved from the semantic space in order to define the long term part of the working memory. So we have defined a different implementation of the LTWM model. The absence of suitable textual parsers able to convert the paragraphs of a text in the correspondent atomic propositions has driven us to develop, at least in this initial phase of

the project, simple models of associative networks of words.

Figura 1. The architecture of the knowledge acquisition module.



The part of the document that is analysed, which is stored in a buffer, must be codified on the basis of the context before being elaborated by the working memory block. The context represents the theme, the subject of the processed text and for its correct characterization it must be considered not only the information present in the document, but also the one that can be retrieved from the structure that represents the knowledge cumulated during the analysis of the previous documents presented to the system (Long Term Memory).
For the implementation of the working memory block we have considered scale free models (Albert and Barabasi, 2001), due to the fact that recently it has been found that the human knowledge seems to be structured in this way (Steyvers and Tenenbaum, 2001). The textual analysis is performed through the sequent steps.
The new text is analysed paragraph by paragraph. The buffer contains not only the words of the analysed paragraph, but also words retrieved from the long term memory using the diffusion of an activation signal starting from the nodes in the LTM that represents the words in the paragraph. The buffer, the working memory and the part of the LTM block that is activated can be compared to the LTWM defined by Kintsch and Ericsson. During the acquisition of the content of the paragraph a stoplist of words that must not be considered (as articles, pronouns etc.) is used.
For each word present in the text the paragraphs where it appears, or where it has been inserted after the retrieval procedure, are memorized. When the entire text has been parsed and the data of all the N not filtered words have been memorized, the formation of the network of concepts in the working memory begins. The model adopted is similar to the one defined by Bianconi and Barabasi (2001). The process starts with a net consisting of N disconnected nodes.
At every step t=1..N each node (associated to one of the N words) establishes a link with other M units (M=5). If j is the selected unit, the probability that this node establishes a link with the unit i is:

$$P_i = \frac{U_i \cdot k_i}{\left(U_1 \cdot k_1 + \ldots + U_N \cdot k_N\right)} \qquad (1)$$

where ki is the degree of the unit i, i.e. the number of links established by it, while Ui is the fitness value associated to the node, and it can be computed as the ratio between the number of paragraphs that contain i AND j and the number of paragraphs that contain i OR j.
This graph is generated not only on the basis of the content of the analysed document but also on the basis of the model of the user (LTM) that condition its conceptualization (Dragoni, Tascini, Lella and Giordano 2004).
The long term memory is an associative network that is updated with the content of the WM. Whenever a link of the working memory corresponds to a link present in the LTM, the weight of this one is increased by 1. The cognitive models (LTMs) obtained by the knowledge acquisition module have been compared with analogous representations obtained by a comprehension test performed on a group of human subjects who read the same documents analysed by the system. The results of the test demostrated that the representation of the system was more similar to the representation obtained from the group of people which aximilated better the contents of the visioned documents (Licata, Lella and Giordano 2004).

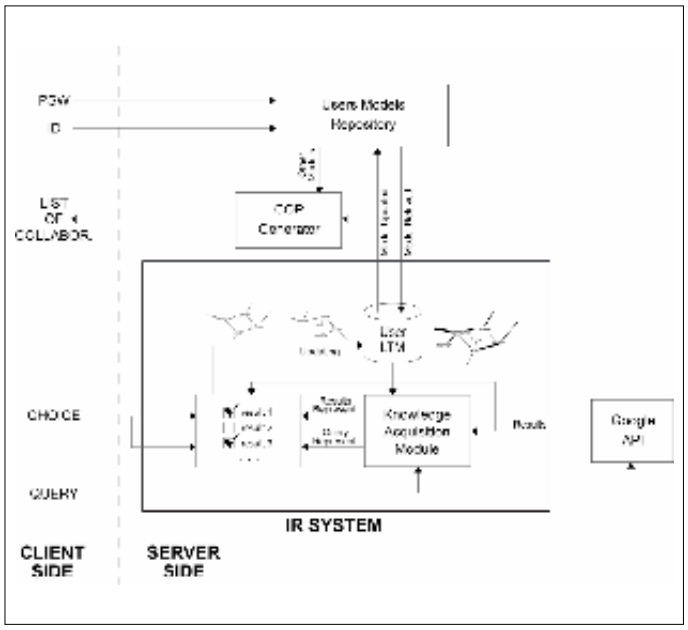
3. A System for the finding of competencies

In order to favour the communication and the collaboration among the healthcare practictioners we can use suitable tools that allow to quickly identify all the employees that have the right competencies to support the execution of a given task such as the diagnosis of a disorder or the choice of the most appropriate therapeutic intervention for its cure. Such knowledge management tools must be based on the modelling of the knowledge and the activities of all the practictioners. For example the profiles of the employees can be updated by the assimilation of the documents daily read by them.
Suitable incentive techniques must induce the employees to select the documentation they

judge related with their activities, allowing the modelling of the actual state of their activities and competencies.
The knowledge management system developed by A.R.C.H.I. exploits the profiles of the users to improve their Internet searches.

The profiles are updated on the basis of the content of these documents, among the ones retrieved by the system, which are judged effectively correlated with the presented queries. In this way the users, noticing that the searches performed through the system improve in time adapting to their knowledge and their objectives, they are induced to use it often enabling a frequent updating of their cognitive profiles.

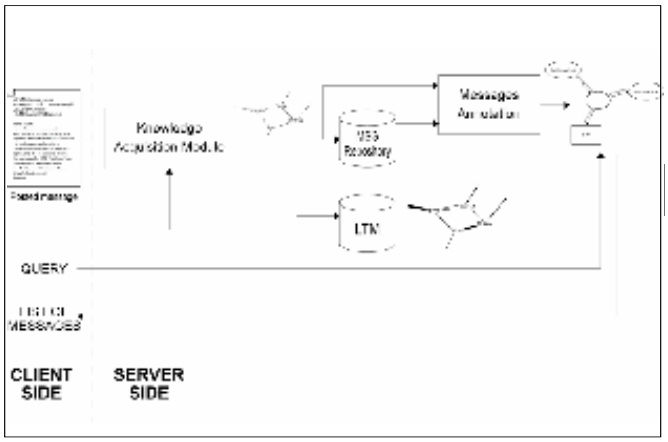
Figura 2. The system for the finding of competencies.



In figure 2 it is described the diagram of the web application that optimize the searches through the continuous updating of users' profiles. Once the authentication procedure has been fulfilled by the identification of the password and the user ID, the profile of the user is retrieved from the repository of the employees' knowledge representations. The cognitive profile is structured as an associative network of words. On this network can be applied an activation signal that starts from the nodes corresponding to the words used in the query, if already present in the network, in order to select the part of the network which is the most correlated with the search and the actual interests of the user. This " sub network" is compared with the representations of the documents retrieved by the browser Google, with the aim of filtering and order them on the basis of the actual interests of the employee.
After the ordering of the results the user can select those documents that really concerns the subject of interest. If the associative network that represents the model of the user already contains one of the links of a graph representing the content of a selected document, its weight is increased by 1. If the graph contains a new link this is added by scratch in the associative network.
After updating the models of the users, these are grouped according to a certain similarity criterion. The similarity is evaluated through a structural comparison between the two associative networks that is by the ratio between the number of links they have in common and the overall number of links. In this way, after the updating of his model, a user can contact other employees who reached a similar experience level.
Also the part of the associative network that is updated is stored as a representation of the actual interests of the employee. In this way the employees who are working in similar projects or have similar objectives can be grouped. Probably this is the better way to promote the collaboration between peers.

4. A system for the automatic annotation of forum messages

Figura 3



As depicted in figure 3 the system is based on the same knowledge acquisition module introduced in section 2. This is used to analyse each new posted message. The scale free graph of words that represents its content is compared to the representations of the previous messages through the same structural criterion explained before. In this way

the messages about the same topics are grouped and can be quickly visualized (Lella, Tummarello and Morbidoni 2004).
The graph of the last message is used to update an associative network that in this case represents the domain knowledge related to the forum. This system is used to analyse the messages of a thematic forum. This justifies the use of a single model to represent the cumulated knowledge. In this way the associative network can be updated coherently, respecting a precise schema that links all the treated themes.
Each visitor of the forum can also answer to previous messages. In this way the system keeps all the characteristic of a classic discussion forum, extending its informative capabilities.
In fact each user can find immediately the answer to his question among the messages present in the archive without waiting for the direct answers of the other users.
The analysed messages are structured within an RDF graph that connect them by similarity relations characterized by a rate between 0 and 1 calculated with the same structural similarity criterion explained before. In this way a user can select all the messages with a similarity rate above a certain threshold.

5. Enhancing knowledge representation through UPR algorithms

The similarity rates computed by the structural criterion defined above can be used to determine groups of employees who can cooperate in their activities and groups of messages regarding the same arguments. This categorization is the final step towards the definition of potential communities of practice and structured repositories of messages where the employees can find immediately the information they need.
In both cases we have a set M of n items (n employees or n messages).
The descriptions of the interests of the n employees are the graphs of words representing the content of the last documents considered interesting by them or their last queries. The descriptions of the n messages are the graphs of words representing their content.

The structural criterion Γ explained before can be used to compare each couple of objects leading to the definition of an initial similarity matrix M.
The goal of UPR (Martinez-Trinidad, Ruiz-Shulcloper and Lazo-Cortes, 2000) is to find the set of the fuzzy or crisp equivalence subsets of M $\{K_1, K_2 \ldots, K_r\}$ where r >1 is not known beforehand.
Two objects are needed to make this operation. A suitable similarity function and a clustering criterion.
The similarity function Γ between the graphs O_i and O_j has been defined as the ratio between the number of links they have in common and the overall number of links of O_i.
The clustering criterion express the way Γ can be used. This criterion justifies the association of a certain object within a specific cluster or the presence of a group of objects in the same cluster.
The clustering criteria have in general as parameters:

- a matrix $\left|\Gamma_{ij}\right|_{n \times n}$ where $\Gamma_{ij} = \Gamma(O_i, O_j) \in L$.
- A property Π that establishes the way Γ can be used.
- A threshold $\beta_0 \in L$.

where L is a totally ordered set.
The $O_i, O_j \in MI$ of two different objects are β_0-*similar* iff $\Gamma(O_i, O_j) \geq \beta_0$ and the description of an object $O_j \in MI$ is β_0-*isolated* if $\forall O_j \neq O_i \in MI; \Gamma(O_i, O_j) < \beta_0$.
A crisp clustering criterion generates a family $\tau = \{NU_1, \ldots, NU_c\}$ of crisp subsets (nuclei) of the initial description MI of the considered objects.
For the definition of potential communities of practice is convenient to adopt a β_0 -complete maximal criterion that generates nuclei characterized by the following properties :

a) $\forall O_i, O_j \in NU_r \Gamma(O_i, O_j) \geq \beta_0$

b) $\forall O_i \in MI; [(\forall O_j \in NU_r \Gamma(O_i, O_j) \geq \beta_0) \Rightarrow O_i \in NU_r]$

c) Each β_0 -isolated element is a β_0 - complete maximal nucleus (degenerated)

This means that an object Oi which belongs to must be connected with all the elements Oj of the nucleus. This condition fits well to the main feature of a community of practice. In any compact social group each member knows and establishes a relation with any other member of the group.
Instead for the definition of categories of messages is convenient to adopt a -strictly compact clustering criterion that generates nuclei characterized by the following properties :

a) $\forall O_j \in MI[O_i \in NU_r \wedge \max_{\substack{O \in MI \\ O \neq O_i}} \{\Gamma(O_i, O)\} = \Gamma(O_i, O_j) \geq \beta_0] \Rightarrow O_j \in NU_r$

$\exists O_i \in NU_r; \forall O_j \in NU_r; \exists O_{i_1}, \ldots, O_{i_q} \in NU_r :$

b) $[O_i = O_{i_1} \wedge O_j = O_{i_q} \wedge \forall p < q[\max_{\substack{O \in MI \\ O \neq O_{i_p}}} \{\Gamma(O_{i_p}, O)\} = \Gamma(O_{i_p}, O_{i_{p+1}}) \geq \beta_0]]$

c) There isn't a NU_r' satisfing a) and b) such that $NU_r \subset NU_r'$.

d) Each β_0 -isolated element is a β_0 -strictly compact nucleus (degenerated)

In this case there is a directed graph of similarity relationships that can be totally traveled via the relation *most* β_0 - *similar to*, starting from at least one element of NU_r. So there is al least an element $O \in NU_r$ such that starting from O it is possible to reach any other element of NU_r via the relation *most* β_0 - *similar to*.
Those objects are represented by those posted messages that cover all the themes treated by the messages that belong to the same nucleus related to a certain semantic domain. In this way it is possible to reach all the messages of a certain cluster starting from the most general ones.

Conclusion

The knowledge management tools presented in this work can improve the cooperation between healthcare practictioners, favouring the sharing of knowledge and information.
The analysis of the textual content of messages and documents through the introduced knowledge acquisition module can allow to trace the activities, the experiences and the objectives of the workers. This knowledge can be subsequently used to optimize their researches and to detect potential communities of practice where the employees can share their ideas and opinions for the achievement of their tasks.
The categorization of employees and messages can be effectively done by the use of suitable UPR algorithms.
The effects of the introduction of this technology have to be investigated through the monitoring of the network of relations between the practictioners. The analysis of the evolution of this particular kind of social network will demostrate the validity of the approach in the managing and the creation of knowledge within an organization.

References

Albert R., Barabasi A. (2001), "Statistical Mechanics of Complex Networks". Rev. Mod. Phys., no.74, pp.47-97.
Bhatt, G.D. (2001), "Knowledge management in organizations: examining the interaction between technologies techniques and people", Journal of Knowledge Management, vol. 5, n.2.
Bianconi G. And Barabasi A.L. (2001), "Bose-Einstein Condensation in Complex Networks", Physical Review Letters, vol. 86, no. 24.
Broendsted J. and Elkjaer B. (2001), "Information Technology as a fellow player in organisational learning", In: Proceedings of the 9th European Conference on Information Systems, Global Cooperation in the New Millenium, Bled, Slovenia, June 27-29.
Burns T. and Stalker G.M. (1961), "The Management of Innovation", Tavistock Publications, London.
Dieng R. (2000), "Knowledge Management and the Internet", IEEE Intelligent Systems.
Dragoni A., Tascini G., Lella L. and Giordano W. (2004), "Knowledge Extraction Using Dynamical Updating of Representation", Proceedings of the 3rd workshop on RObust Methods in Analysis of Natural Language Data, University of Geneva (Switzerland), August 29th 2004.
Hayek F.A. (1973), "Law, Legislation and Liberty", vol.1: Rules and Order. Chicago, IL: University of Chicago Press.
Hildreth P. and Kimble C. (2000). "Communities of Practice in

the distributed international environment", Journal of Knowledge management, Volume 4, Number 1, 2000, p. 27-38.
Huber, G.P. (1991), "Organisational Learning: The Contributing Processes and the Literatures", Organization Science, vol. 2, no. 1, pp. 88-105.
Kautz K. and Thaysen K. (2001), "Knowledge, Learning and IT Support in a Small Software Company". In: Proceedings of the European Conference on Information Systems", Bled, Slovenia, June.
Kintsch W., Patel V.L. and Ericsson K.A. (1999), "The role of long-term working memory in text comprehension". Psychologia, 42, pp.186-198.
Lella L., Tummarello G. and Morbidoni C. (2004), "Enabling Semantic Web Forums using Dynamic Representation Schemas", Proceedings of S.W.A.P. 2004, University of Ancona (Italy), December 10 2004.
Licata I., Lella L. and Giordano W. (2004), "From Ontologies to Ontogenetic Models: Knowledge Extraction Using Dynamical Updating of Representation", Proceedings of Dynamic Ontology, Faculty of Sociology, Trento University (Italy), September 8-11 2004.
Martinez-Trinidad J.F., Ruiz-Shulcloper J., Lazo-Cortes M. (2000), "Structuralization of universes", Fuzzy Sets & Systems 112/3, pp. 485-500.
McClelland J.L., Rumelhart D.E. (1986). "Parallel distributed processing". Cambridge, MA: MIT Press.
Nonaka I. (1994), "A Dynamic Theory of Organizational Knowledge Creation", Organization Science, Vol.5, No. 1, February 1994.
Nonaka I., Toyama R. and Konno N. (2000), "SECI, ba and leadership: a unified model of dynamic knowledge creation", Long Range Planning (32), pp. 5-34.
Pentland, B. T. (1995), "Information Systems and Organizational Learning: The Social Epistemology of Organizational Knowledge Systems", Accounting, Management & Information Technology, vol. 5, no.1, pp. 1-21.
Polanyi M. (1967), "The Tacit Dimension", in Knowledge in Organizations, L. Prusak, Ed. Boston, MA: Buttreworth-Heinemann, 1997, pp. 135-146.
Steyvers M., Tenenbaum J. (2005). "The large scale structure of Semantic Networks: Statistical Analyses and a model of semantic growth". Cognitive Science n.29, pp. 41-78.
Stenmark D. (2002), "Information vs. Knowledge: The Role of Intranets in Knowledge Management", in Proceedings of HICSS-35, IEEE Press, Hawaii, HI.
Wenger E.C. and Snyder W.M. (2000), "Communities of Practice: The Organisational Frontier", In Harvard Business Review, Harvest Business School Publishing, Boston, MA, January-February, pp. 139-14