NetExpert: A multiagent system for expertise location.

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ABSTRACT

Locating expertise sources in a community of interest or practice is a critical need for distributed organizations operating in Knowledge Intensive Business Sectors. This is specially true in those ones that deal with innovation activites which have to manage knowledge about the creation of new knowledge. Finding fastly a suitable expert and knowing how to reach him or her can be seen as a way to gain advantage and speed up organizational knowledge creation and learning. Usually expertise location is done through the use of personal social or knowledge networks and involves aspects such as trust and reputation. However and specially in distributed organizations relying on communication technologies for cooperation, each member of a community is just aware of its own personal social or knowledge network . This makes difficult to get to know other potential experts in the community which may pertain to other members' networks. *NetExpert* is an agent-based expertise location system that replicates the process of social and knowledge network building at a community or organization level. In so doing it is able to connect several networks and put into contact expertise that otherwise would remain hidden.

KEYWORDS

Software agent, multiagent system, assistant agents, expertise location localize expertise, social network, knowledge network, collaborative system, knowledge mapping, knowledge management.

1. INTRODUCTION

The problem of finding somebody that has the relevant expertise for solving a given problem at the right moment is of special interest to any type of organization. This problem is specially acute, however, for those organizations that operate on a flat hierarchy organization, are organized around projects through a flexible team structure and/or develop their activities in knowledge intensive sectors. Knowledge Management [1] recognizes the importance of locating knowledge as it originates and evolves within a community of people inside an organization with a common set of goals [2]. Knowledge is created, shared, and distributed by a given set of explicit or implicit rules which are common to all members of the organization. This knowledge takes very different forms, not all of them amenable to computerized treatment, not all of them easily converted into data. In any case, there is some agreement that any KM process has to

incorporate some aspects of leveraging existing knowledge, sharing it and distributing it to the relevant people within the organization. This latter aspect also makes clear that there is a special type of knowledge, i.e., the knowledge about *who knows what and who knows who knows what* that is important for at least two reasons. First to decide who may be interested in a new piece of knowledge generated in the community and second but also more important to decide which people may potentially cooperate in a given area of knowledge creation or new projects. Current IT systems for KM support (see [3] for an extensive survey and assessment) often are more related to other aspects of the KM cycle such as finding good representations of knowledge implicit in documents or devising better searching mechanisms for locating it. We explicitly address the problem of finding people with expertise in communities and the paths to reach them. We also adopt the point of view that tools addressed to giving that functionality should be as unobtrusive as possible. So, we devised an agent-based system [4] that works on behalf of each experts in the community and build his or her close network of similar experts and eventually recover the whole community social and cognitive networks. In doing so, they provide an effective means for mapping and locating knowledge within a community.

2. Personal expertise in communities: social and knowledge networks

From now own we will consider that communities in knowledge intensive workgroups are made up of individuals that possess a high degree of expertise in some given topics which are of particular interest to those communities, in fact they define the common knowledge of those communities. These people we call in the following, *experts*. An expert is someone with a great knowledge and experience about a given topic. Experts are recognized as such thanks to their activity within a community that in response to their performance in several tasks grant them the "expert" level.

A typical ability of any human and in particular of experts is the ability to interact with other people within their community. The concept of *community* is a very important one. In order to locate an expert, we will use the background knowledge of the community the expert works in. Using the term *locating* instead of *finding* has a clear reason. We must understand the operation of *locating an expert* as a composition of two operations. One is *finding him*, i.e. find ing somebody who has the necessary knowledge for solving the problem that has originated the need to search for expertise. The second operation is to *know how to reach this person*. Once we know who is the best expert to solve our problem we need to get into contact with him or her. This is not as simple as using a directory specially if we want to have beforehand some appreciation of the expert's ability to cooperate in the solution of a given problem. That is if we want to get an assessment of his or her appropriateness for the problem. Another way of putting this is saying that it is necessary to assess how much trustworthy the expert is.

The problem can be break down, then, into two parts:

- The problem of finding who has the necessary knowledge about the central topic of the problem [5]:
  Who knows what?
- The problem of knowing how we can succeed in reaching the expert.
  Who knows who knows what?

Both of them have to do with the question of trusting the result of the finding operation. That is, we have to be sure that the experts appearing in the results of a finding operation are recognized as such by the community. Trust and reputation are established through different and subtle mechanisms within any community [2] and have to do with expertise validation. However, one simple way to establish trust about the expertise of some previously unknown expert is by relying on his or her relationship with other experts that are already known to us and whose expertise has been tested in previous situations. So the problem of trust can be reduced to the

problem of finding relationships with experts known to the person who is in need of an expert. This relationship can be induced by some type of peer-to-peer assessment or it can be deduced through an analysis of the different personal networks existing around each member of the community.

There are two types of networks specially relevant for this type of assessment:

- **The knowledge Network:** This type of network contains relationships among people who share knowledge about their work. A relation between any two people in the network means that these two people have a similar knowledge about a given set of topics. The concept of Knowledge Networks as used in IKNOW [5].

- **The social Network:** This network contains relationships among people who know each other. If there is a link between two people in such networks, that means that they are mutually acquainted or even friends. The concept of Social Networks was used in Referral Web [6].

An isolated person has only a partial and biased awareness of the social structures existing around him or her. A given person only knows his or her own Knowledge and Social Networks [5]. Communication and information technologies favour distributed work, consequently our knowledge of other people's networks gets reduced by using distributed collaborative environments. On the other hand, the number of people that get into touch by means of the new communication technologies for distributed work is even greater than in previous cooperative situations. Both aspects contribute to a reduction in the awareness of the extension and membership of other social and cognitive networks, even the ones originated from people that belong to our *own* networks. Some support for revealing these networks around each member of a community could be clearly of help. In the following sections we describe *NetExpert*, an agent-based system for locating expertise within a community which relies on the dynamic construction and management of such networks.

1. A multiagent system for expertise location

NetExpert is a multiagent system that allows to localize experts within a virtual or real community. *NetExpert* was originally devised to serve the expertise location needs of a community formed by researchers. However, their used is now being extended to other types of communities. *NetExpert* allows the discovery of which members within a community are experts in some topics and how they can be reached through chains of other experts. *NetExpert* tries to solve the problem described in the introduction of finding trusted experts by exploiting social and knowledge networks.

NetExpert is currenlty integrated in the *I2CAT Collaboratory* [7,8,9], a research project developed by the Agent-Based Intelligent Collaborative Environments Group of the Software Deparment at the Technical University of Catalonia (UPC), a part of the Center for Internet Research, cANet (http://www.canet.upc.es).

We will describe the *NetExpert* system from the outside in, starting from the view a typical user has from it, its funcionalities and then the architectural and implementation details.

User Interface

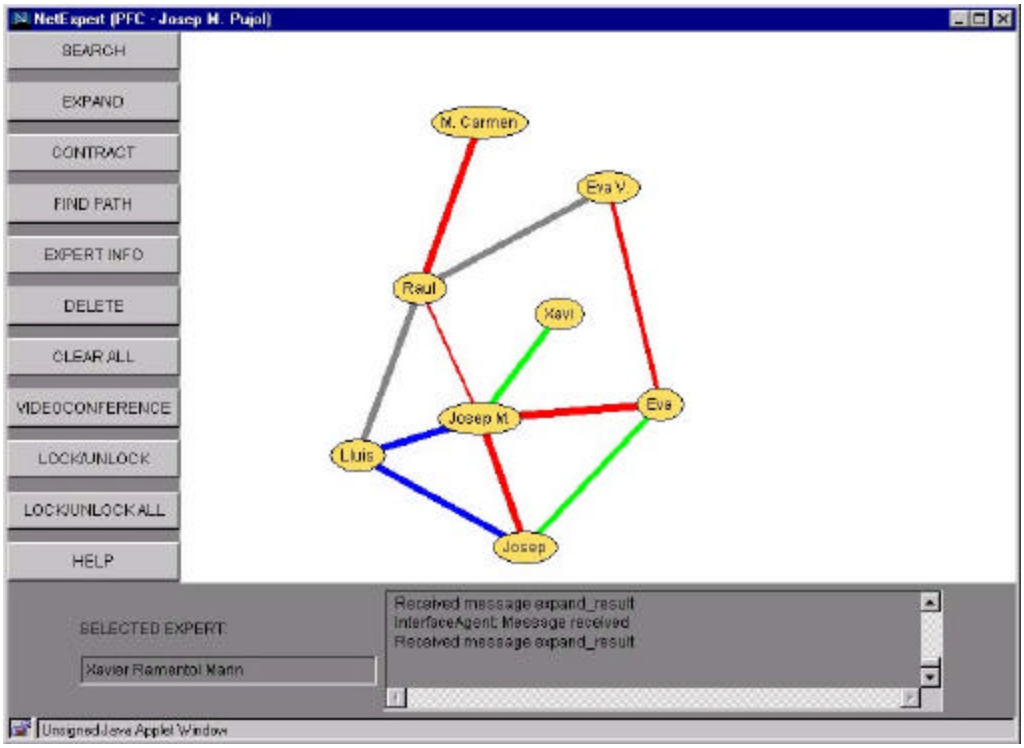


Figure 1: Applet User Interface, main frame.

Figure 1 shows the main frame of *NetExpert* applet user interface. Some experts with their relationships, can be seen. Each color shows a different kind of relationship, that will be explained in the following.

Functionalities

NetExpert offers several of the typical funcionalities of a knowledge sharing system that have relevance for expertise location [2] as searching and communication as well as other ones that exploit directly the creation of social and cognitive networks.

a) Searching

NetExpert allows to search for an expert through keywords as a conventional search engine. There are four possible types of search.

1. **Name:** Search by expert's name. The results include contact details (e-mail, phone, videoconference and personal webpage).
2. **Knowledge profile:** Search by knowledge profile, i.e., a description of the topics the expert is knowledgeable in. Further on the details on how this profile is automatically built are given
3. **Web:** Search by using only information appearing in experts' personal web pages. This includes text and links.
4. **Resources:** whatever file the webpage of an expert contains it is analyzed and put into relationship with search query.

b) Communication

Once an expert is located information about him or her can be obtained and there is the possibility of using a videoconference to meet him virtually. There is also the possibility of connecting him through mail, chat or a WAP phone call. Other information associated with an expert are the different documents and resources he has generated, this information is also recuperated by the searching component automatically whenever a search for an expert is initiated.

c) Exploring Knowledge and Social Networks

NetExpert allows exploring the Knowledge and Social Networks existing around any expert. Two basic operations are available, expansion and contraction. Expansions show which people share knowledge or acquainted with the selected expert. The resulting graph depends on which kind of network that has been chosen (social or knowledge network). Contraction hide all neighbours of the selected expert. These two types of operations help in locating the expert although their main utility is in helping to get a better idea of which are the people that share knolwedge with him . Another important functionality has to do with finding the best way to reach the expert. We discuss it in further detail in the following section.

Finding the optimal path to an expert

The optimal path is the best *referral chain* [6] that goes from one member of the community to other one through the relationships that exist in their shared Social Network. Path optimality is calculated by means of an heuristic that will be described further on.

Once an expert has been found, it may happen that is someone new for the user and so this last person may have difficulties in reaching the first one. An expert *A*, would like to meet *C* but *A* doesn't know who *C is*. If *A* uses the Social Network, he can discover the acquaintances of *C*. Let's suppose that one of these acquaintances of *C* is *B* who happens to know *A and C*. *A* could use his acquaintance to meet *C*. We describe how to find the best path. The "shortest" path is calculated by using a heuristic that takes into account both the number of edges in the graph between two people and the strength of their relationships. Relationships between individuals tend to form *small worlds* [10,11], that is, networks with low degrees of separation between their members. The Social Network of *NetExpert* tends to form a small world as well. One propriety of small worlds is the short *characteristic path length*. No path is excessively long. This is a well-known property of small worlds as discussed in [10,11].

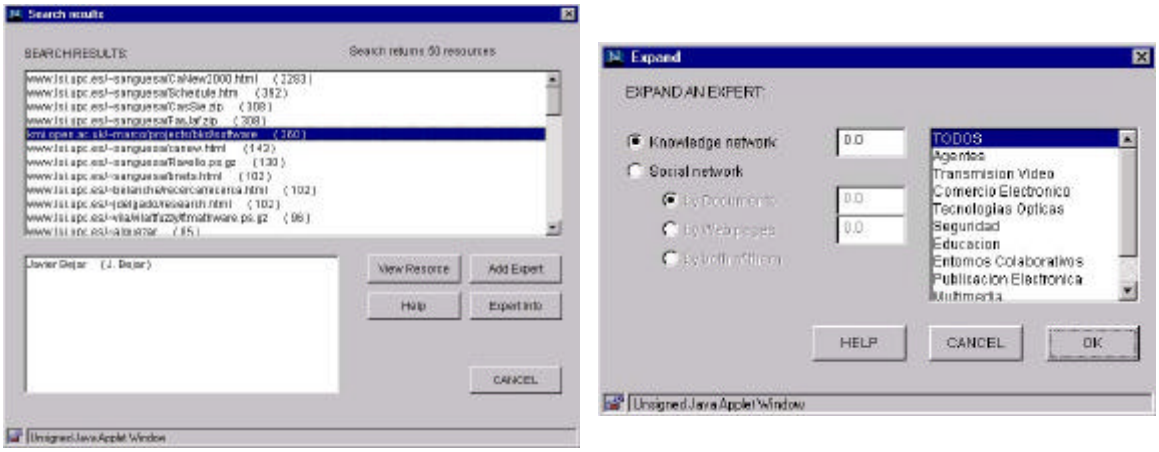


Figure 2: The left frame shows the results of searching by resources. On the right one the result of expanding the hetwork around an expert can be seen.

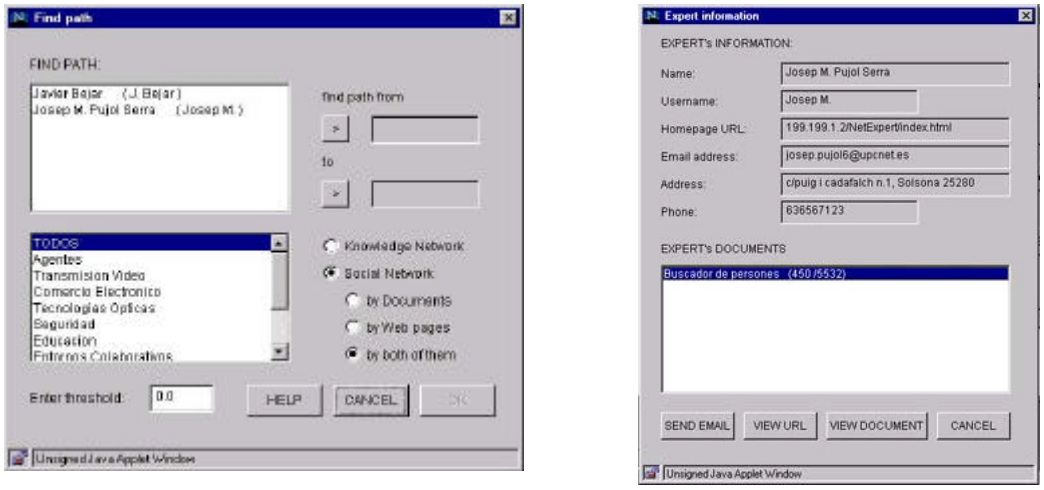


Figure 3: On the left frame the results of one search by resources. On the right frame and expand operation.

3. INFORMATION SOURCES FOR EXPERTISE LOCATION

NetExpert uses a lot of information to generate its knowledge and also uses knowledge generated by the rest of the *Collaboratory*. In the following discussionwe are going to see both systems as a unit, because they are actually very related. *NetExpert* uses all the knowledge created by the *Collaboratory* although it doesnt't create all of it, other pieces of knowledge coming from other functionalities of the *Collaboratory.*

People in the *I2CAT Collaboratory* are expected to contribute and consult documents, URLs, and messages. What the *Collaboratory* offers them is a recommender system utility that gives them recommendations on new contributions to the common document base. Users can rate this recommendations following a *collaborative filtering schema* [12,13,14]. Information that has some relationship to a user's competence and interests can be extracted from the contents of these documents and from users' votes as well as other sources (for example the contents of users' personal webpages). As the *Collaboratory* works on the *Knowledge Pump* metaphor [15] it is expected, and in reality this is what happens, that each member contributes documents to the Common Repository of the *Collaboratory* and consults documents from it. This activity can be used to build a complementary knowledge profile which is more accurate than the one obtained by analysing personal webpages. In personal pages, information that is not representative of the real knowledge of the author could exist. This would introduce noise in the process of building the corresponding knowledge model On the other hand. the knowledge model extracted from a personal webpage is crude but is also wide at the same time. This is an excellent quality in order to search for an expert afterwards.

NetExpert creates a *Knowledge profile* that contains a description of the expertise areas of any member of the community. Expertise is described in terms of the most important terms appearing in the documents contributed by the user to the *Collaboratory* repository. In order to represent this profile a technique, called Vector Space Model with TFIDF [16] is used. The knowledge profile of a member of the community is built using differents sources. Documents contributed by an expert are treated as if they had received a positive vote from the expert. In fact, the contribution is an implicit positive vote. The creation and maintenance of the profile is automatically done with the exception of an initial profile which is explicitly filled in by the user ticking those subjects that most closely describe his or her interests and competences. The list of subjects is not automatically built and varies from one community to the other. In the case of the *I2CAT Collaboratory* it contains subject words corresponding to research areas in the Internet Community. Work is under way in order to provide for semi-automatic means to create initial taxonomies and make them evolve in response to the use of the different functionalities of

the *Collaboratory*, including *NetExpert*'s expertise location abilities. Apart from this information other sources are used to complemente the expert profile and to build the needed social and knowledge networks. We discuss them in the following.

Complementary sources of information

Another way for the system to represent the knowledge and the interests of a member is through the analysis of his personal webpage. A knowledge model is built for each page or resource based on an elaboration of TFIDF. Personal webpages normally reflect the knowledge and interests of its author. This is more true when these pages are built according to knowledge management uses in mind. In certain environments, research communities for example, experts tend to include in their personal pages publications and other sources directly related to the knowledge they generate. To analyze webpages *NetExpert* uses WebMining [17]. WebMining is an independent system that analyzes the web and creates generic content models.

Generating knowledge for expertise location

From the profiles previously described the social and knowledge networks can be built The social network is a graph where every two related nodes (experts in the community) are people that know each other, irrespective of whether their share knowledge or not. In order to build this network we have devised some heuristics that are able to rate the degree of acquaintance between two members of the community. These heuristics consider the following concepts in order to build the social network:

- **Documents published within the community:** All authors of a published document are assumed to know each other. The more quantity of published documents in common they have, the stronger the relationship between their authors is.
- **Relations among personal webpages:** Personal webpages are a source of useful information in order to know more about their author and his relation with other members in the community. In a personal webpage we can find references to other personal webpages of other community members.

  These references can be:

  - Email addresses towards other members of the community.
  - Links towards the main page of personal webs.
  - Links towards resources, that are included in other personal webpages. In this case, the depth of the resource referenced by both personal webs is taken into account to fine tune the degree of relationship.

Two criteria are used for building Social Networks: One of them is relationships among personal webpages and the second one is document ownership. These criteria are dependent on the community. In our test case, the *I2CAT Collaboratory*, these community is formed by researchers in several disciplines related to Internet. Researchers are people who publish a high number of documents, papers, reports, etc. and very often have a good personal webpage, in the sense of being a highly structured and accurately completed one. Other kinds of communities may need other significative criteria in order to build the corresponding Social Network but this is left for further research.

4. INTERNAL ARCHITECTURE OF NETEXPERT

NetExpert is built upon a multiagent architecture, therefore is also a distributed architecture. Each Agent and each non-Agent software component could be in heterogeneous platforms.

Figure 4 shows the internal architecture of *NetExpert*.

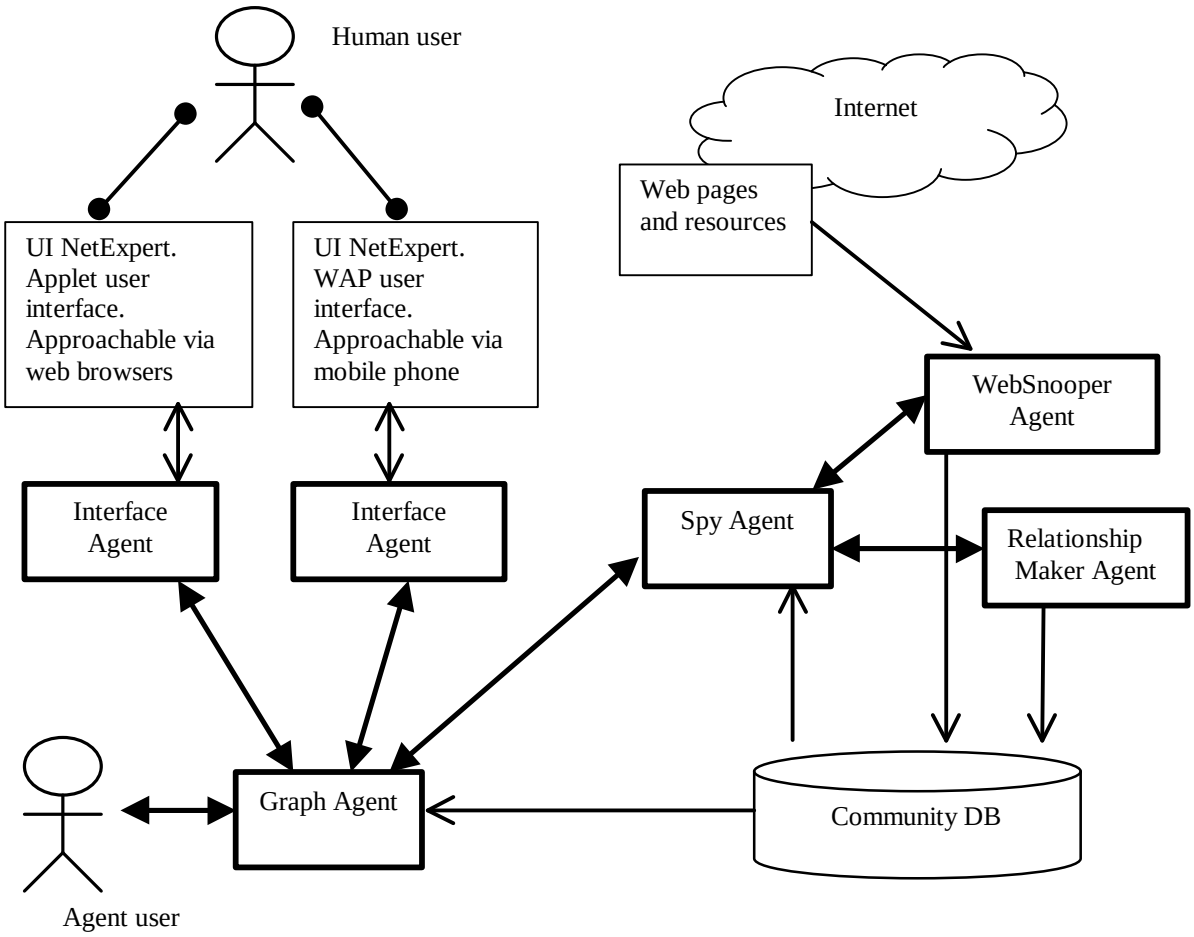


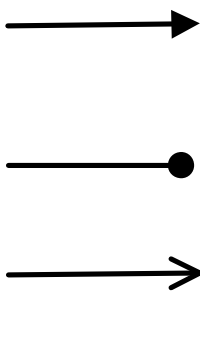
Figure 4: NetExpert's internal architecture

Two kinds of users can exist in *NetExpert*.

- **Human users:** These users have two ways to access into *NetExpert*, via WWW or via WAP pages. All the ways to access *NetExpert* use lightweight clients, a web browser or a mobile phone with WAP technology respectively.

- **Agent users:** These users are artificial agents roaming the web and can obtain knowledge and information stored in *NetExpert* by interacting with the Graph Agent.

There are a lot of components in the *NetExpert*. The communication among them is described below:



Communication through ACL (Agent Communication Language) messages. This is the communication between software components that are agents.

Communication through UI (User Interface) between humans and software components.

Communication between agents and non-agent software components. The communication is made invoking methods, such as conventional programing.

Figure 5: Communication types.

Grey components in the diagram architecture are agents. *NetExpert* is a multiagent system formed for five agents. We are going to do a brief description of them.

- **Interface Agent:** This agent is an adaptor between UI and Graph Agent. Everybody who enters the system through an UI needs an adaptor. Each user within the system uses a UI, and each UI needs an Interface Agent to communicate with the Graph Agent. Each simultaneous user of *NetExpert* has a UI and Interface Agent. A lot of processes may exist but these are executed into user's computer, on the client side.
- **Graph Agent:** This agent is the one that encapsulates all *NetExpert*'s knowledge and information. Whoever wants to obtain information or knowledge from the system must address a request to the Graph Agent.
- **Spy Agent:** This agent is the one in charge of monitoring any change in the Community Database. If a change happens, the Spy Agent will act consequently.
- **RelationshipMaker Agent:** This agent is who takes charge of building and keeping the relationships among community members.
- **WebSnooper Agent:** This agent is who takes charge of analyzing the web pages of members. WebSnooper Agent uses the WebMining system [17] to analyze web pages.

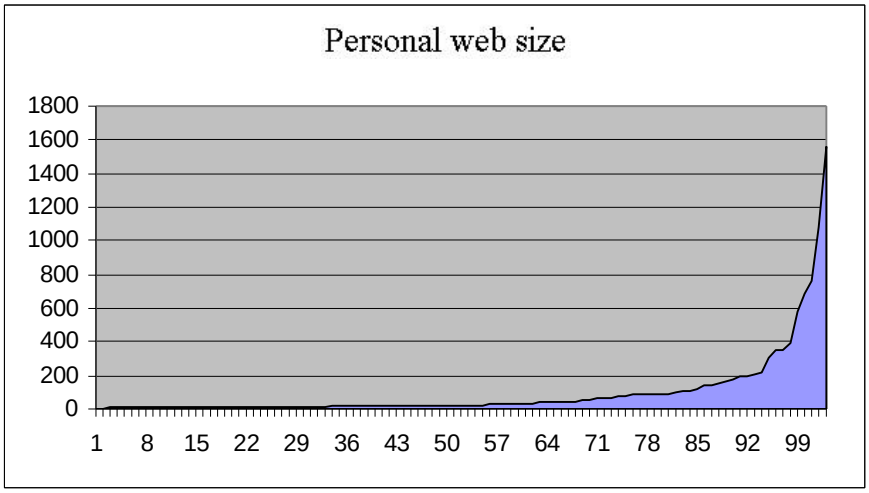
Agents have been developed with JATLite [18]. However the communication language between agents is not KQML. Instead the standard communication language in JATLite has been used, that is, FIPA ACL [19]. JATLite with FIPA ACL has been devoleped at EPFL [20]. All the agents and non-agents software components have been written in JAVA in order to insure the portability among heterogeneous platforms. The community database is MySQL Database Engine. There are implementations of MySQL in the majority of existent platforms: Unix, Linux, Windows.

5. EXPERIMENTS

NetExpert has been tested with a user group formed by the faculty of the Sofware Deparment at *Universitat Politècnica de Catalunya* (UPC). This test only was addressed at assessing the construction Social Networks as Knowledge networks needed information created in the *Collaboratory* and at the moment of testing not enough people had contributed documents to ensure a significant sample.

This Software deparment has 170 members, 104 of whom have a personal webpage, the other 64 having none. The sample was then, 104 individuals.

Figure 6 shows personal webpage size for each indivual in the sample. The individuals are ordered by personal webpage size. Size of a webpage is measured as the number of resources that a personal webpage has resources being links and documents.



Average: 100.47 **Std deviation:** 218.96 **Median:** 24

Figure 6: Personal web size

We can see that there exists a huge variability. The majority of the people have a small personal webpage, and few people have large personal webpages. The boundary between small and large personal webpage size is fuzzy. We could consider the frontier close to one hundred resources per webpage. The median is 24 and fitfy percent of members of Sofware Deparment have a very small personal webpage. The following figures show the social relationships found by *NetExpert* from the analysis of personal webpages.

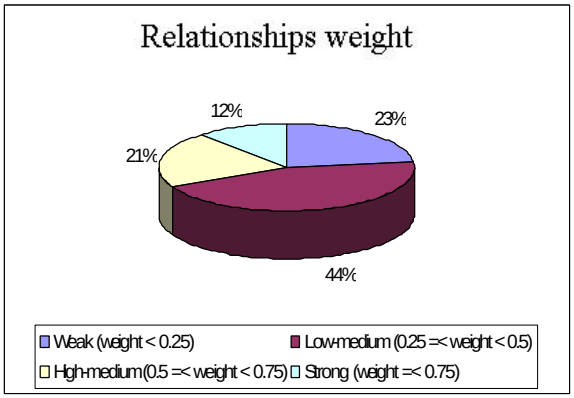


Figure 7: Relationships weight

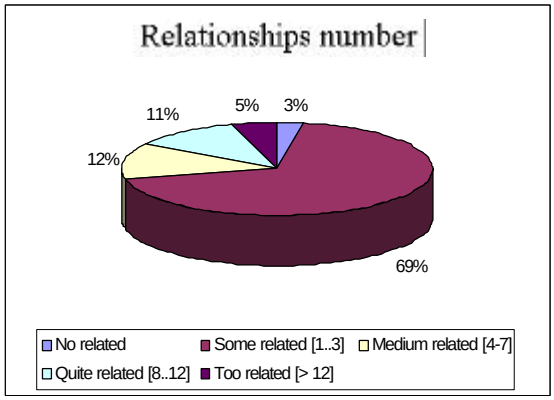


Figure 8: Relationships per individual

NetExpert found 190 relationships among the 104 members of the Software Deparment. Relationships between people have a weight between 0 and 1, [0..1].

Figure 7 shows the weight of the relationships. Most of them are low-medium ones, between 0.25 and 0.50. The percentage of weak relationship and high-medium relationships are almost the same.

Figure 8 shows the number of relationships per individual. The great majority of people, 69 percent, are classified as somewhat related. They have between 1 and 3 relationships with other members of the Department. Only 3 percent of the individuals have no relation at all, and 5 percent of individuals can be considered to have many relationships.

NetExpert found good relationships among 92 percent of members of Sofware Deparment. Maybe the class *somewhat related* is too large but we must remember that Social Networks are not totally formed yet. Information about published documents in the community was not available in this test.

Figure 9 shows a part of the Social Networks of Software Deparment.

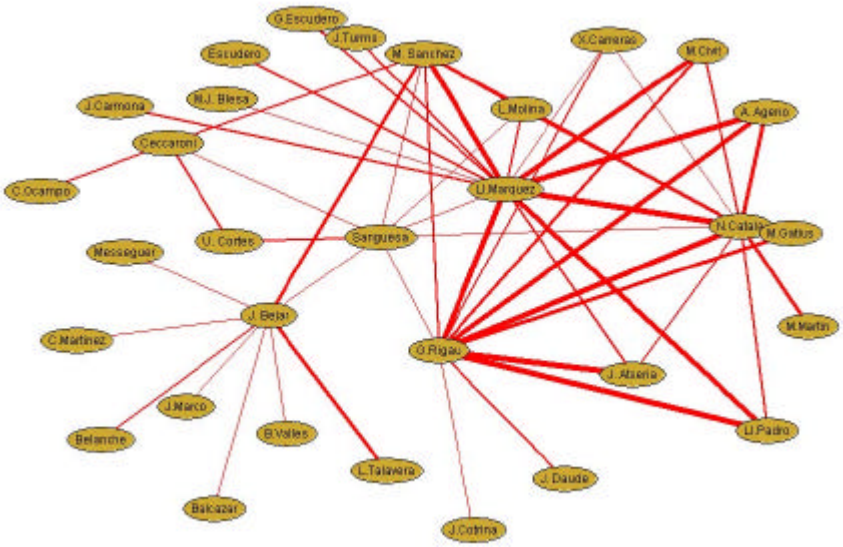


Figure 9: Fragment of Social Network

This network is formed by expanding from members R. Sangüesa and U. Cortés. Each expansion implies showing all the acquaintances of the member where expansion starts. Each acquaintance of members R. Sangüesa and U. Cortés were then expanded again. Any member in this network, or graph, has a path between him and U.Cortés or R. Sangüesa shorter than 3 links (or distance 3).

6. DISCUSSION AND FURTHER RESEARCH

NetExpert, an agent-based expertise location system has been implemented and discussed. It is based on the idea of exploiting social and knowledge networks in order to facilitate searching and reaching experts within a community. The difference between *NetExpert* and other collaborative systems like IKNOW [5] or ReferralWeb [6] is that it is able to merge and use each type of network that these systems build (in the first case only social networks and in the second one only knolwedge networks). IKNOW and ReferralWeb resort to webpages to create profiles but NetExpert uses also the documents that each expert publishes and consults within the community. Moreover, in analyzing webpages NetExpert not only uses the actual contents of pages but also information about links which is an additional enhancement.

Some authors [21] claim that profiles built only with the aid of words may be too shallow for describing adequately the expertise a member of the community has. This may be true but the alternative is to have a fully developed ontology describing competences in the community. Up to know type of knowledge description has to be built manually through a tiresome process. Although the benefit of going through such a process may be measured in a higher precision in the searching process results the present performance of *NetExpert* seems to indicate that our approach is sufficient. However, we are presently investigating ways to create semi-automatically ontologies from the analyisis of webpages and documents [22]. We hope to use these newly generated ontologies to complement present profiles and then we wil measure the new system performance against the present one. But this is still a starting line of work.

NetExpert has been used in a real environment, the *I2CAT Collaboratory* (http://upclsi1.i2.cat/colaboratorio/) as other systems for expertise recommendation, for example, Expert Recommender [23,24]. In contrast to this one for example, the creation of the knowledge and social network is completely automatic while McDonald and Ackermann use personal interviews to extract that knowledge. It would be interesting to use both approaches on the same community in order to compare the quality of the results and performance.

Another aspect currently under study is the integration of trust and reputation mechanisms for validating the competences of experts and their recognition within the community in a more ellaborate fashion than proximity. The expertise ranking abilities of another system [25] will be used to assess these aspects.

Finally, *NetExpert* has been implemented as a multiagent system which points towards an easier way to escalate its functionalities. In that sense, current work is addressed towards the complete decentralization of the several agencies actually involved in *NetExpert.*

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