Learning Communities supported by Autonomic Recommendation Mechanism

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Abstract - Peer-to-peer (P2P) offers good solutions for many applications such as large data sharing and collaboration. Thus, it appears as a powerful paradigm to develop scalable distributed applications, as reflected by the increasing number of emerging projects based on this technology. However, building trustworthy P2P collaborative tool is difficult because they must be deployed on a large number of autonomous nodes, which may be part of the virtual community and to make the collaboration effectively happen among the nodes. Within this scenario, this article presents an autonomic recommendation mechanism of knowledge chains, which is based on the apprentice profile and his current knowledge to recommend the best learning strategy after the analysis of the learning community in this peer-to-peer environment.

Keywords: Autonomic Computing, Personal Knowledge Management, E-learning Systems, Peer-to-Peer Architecture

I. INTRODUCTION

Learning Communities are groups of links that organize people, groups and institutions in an equalitarian and democratic way, around a common objective [1]. A Learning Community can dilute disciplinary and organizational barriers and national borders. Due to its principles of non-hierarchy, freedom, free formation and construction based on similarities (such as, for example, interests) and trust, it is an approach that allows its members to obtain and spread data, information and knowledge faster.

Since the Learning Community can be mapped and represented, it is possible to develop an autonomic system that are able to adapt to unpredictable situations, preventing and recovering from failures, continually optimizing themselves and autonomously taking care of their own safety. The essence of autonomic computing systems is self-management, the intent of which is to free system administrators from the details of system operation and maintenance and to provide users with a machine that runs at peak performance 24/7 [6].

In this context, this article aims at presenting a proposal for a recommendation system with autonomic properties, which can improve and preserve the acquisition of knowledge chain in a Learning Community, observing and respecting the real desire of the apprentice, where the knowledge chain was created and where it is necessary. We believe that if the Learning Community inherits autonomic properties, then they will facilitate the recommendation by the tool. This article brings us to how was developed the features for the autonomic computing architecture in the search mechanism: self-configuring, self-healing, self-optimizing and self-protecting (sometimes referred to as "self-CHOP")[8] in a collaborative tool called KCE (Knowledge Chain Editor) [15]. To evaluate the proposed autonomic recommendation system, a case study was performed with students from a pos-graduation course at a conceived University in Rio de Janeiro without prior knowledge about knowledge chains and the KCE tool.

The case study aimed to evaluate the search and retrieval of best learning strategies recommended by the autonomic agent in the peer-to-peer architecture for communication. Shortly, this case study intended to examine qualitative KCE use to validate our model and identify possible improvement points.

The students who participate of the case study were training in the KCE tool to perform the tasks required during the study execution. In a nutshell, each participant had to work to build new knowledge chains and sharing them. After that, each of them answered a questionnaire about questions

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related to task performed and the KCE tool. Finally, reports were generated through the tool for the study case organizers analyze user behavior and the tool during the case study.

The protocol used to conduct this case study is defined in [21] and [22]. It was used due to the richness of examples source that uses the principles and techniques of case studies proposed by the protocol authors.

II. Knowledge Chain Editor

Knowledge Chain Editor (KCE) [15] was developed to assist in the knowledge acquisition to promote the construction, dissemination and sharing of knowledge. This system was based on a process for personal knowledge construction through knowledge chains sharing [16]. The knowledge chain (Figure 1) is a structure composed of a list of knowledge object. The knowledge chain shows the strategy adopted by the author of that to learn the knowledge describe by each knowledge object. On the other hand, any apprentice can follow this strategy to achieve successfuly the learning represented by the knowledge chain.

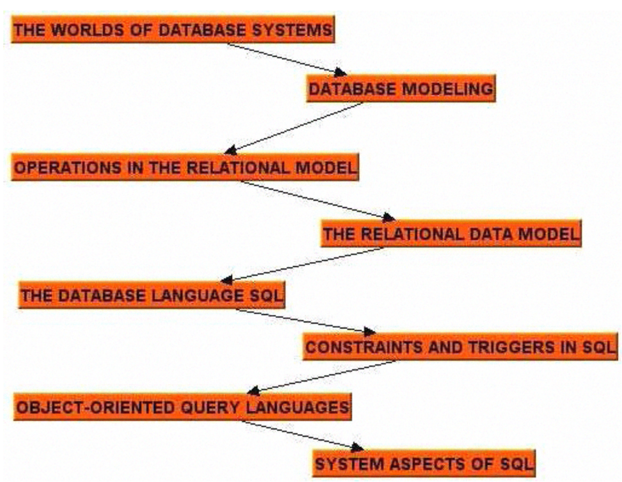

Figure 1. A Database Knowledge Chain example

Each knowledge object (Figure 2) is a structure formed by a set of attributes grouped into categories: General (name, description, keywords, author, creation date, etc), Life Cycle (history, current status, etc.), rights (intellectual property rights and conditions of use), relationships (relationship between knowledge objects), classification (the unit for a classification system) and Annotations (comments and ratings of the unit and its creators).

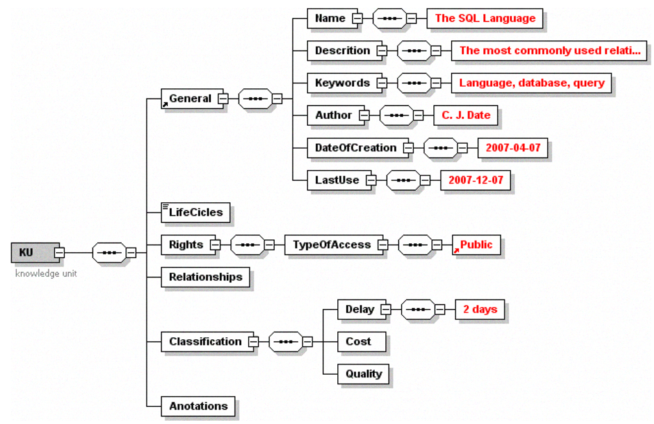

Figure 2. The "SQL Language" Knowledge Object

We have defined two roles in KCE: apprentice and author. The author creates in KCE the knowledge chains that represent what he has already know. The apprentice is one that needs to acquire new knowledge and will use the KCE to search a knowledge chain that will fit with his needs. A user can be an apprentice and an actor. If he is looking for a specific knowledge, he acts as an apprentice. And if another apprentice search and retrieve a knowledge chain of that user, so that user is the author in this relationship. The apprentice can perform a simple search (keywords) or semantic search (ontological concepts). The system starts the search process by sending messages to other network nodes. Each node performs a search internal checking the existence of knowledge object similar to the knowledge required and returns to the apprentice what was found (Figure 3).

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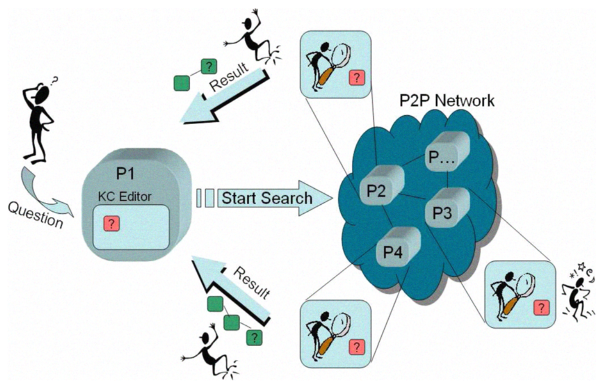


Figure 3. KCE Collaborative Structure

The main feature of the KCE is to promote sharing knowledge among the nodes of a peer-to-peer environment. This collaboration is feasible thanks to the peer-to-peer platform called CoppeerCAS [9], on which the KCE was developed. The absence of a central server allows the KCE works connected directly to other nodes.

III. The Recommendation System Features

The recommendation system of knowledge chain for the apprentice was developed through the implementation of self-CHOP (self-configuring, self-healing, self-optimizing and self-protecting) features [8] in the KCE software agent responsible for identifying and linking Learning Community users among them based on the current knowledge and profile similarity of each apprentice. Our objective is to provide the better knowledge chain that deal with the apprentice needs through learning community mapped by the user agent. Next, we will correlate the self-CHOP features to the learning community problems address.

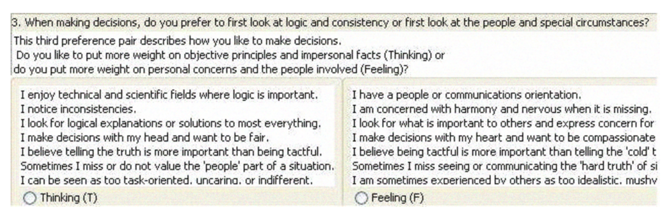
A. Self-Configuration

This property define the methodology to deal with new user in the learning community, learning community reconfiguration due to new users and learning community qualification based on collaboration that happened. Our main concern is to link apprentice to author with more probability to collaborate due to profile and current knowledge similarity. This way, knowledge chain from author linked to the apprentice would be recommended by KCE tool with more weight than knowledge chains from user without similarity. With this methodology, we intent to retrieve knowledge nearest of what the apprentice expect to find.

1) Profile Similarity

To implement the ability to identify and link the new apprentice to the community members who have a profile closer to him, the user profile is built in KCE with psychological characteristics and temperamental types known as Myers Briggs Type Indicator (MBTI) [12].

Each user build his MBTI profile filling a questionnaire at the time of user registration. This questionnaire consists of four questions that determines whether the user is: Introversion (I) or Extraversion (E), Intuition (N) or Sensing (S), Thinking (T) or Feeling (F) and Judging (J) or Perceiving (P). Thus, the user will have a profile with four psychological characteristics, where sixteen different profile are possible. The figure 4 presents one of the four questions presented to user determine where he is 'thinking' or 'feeling'.


3. When making decisions, do you prefer to first look at logic and consistency or first look at the people and special circumstances?
This third preference pair describes how you like to make decisions.
Do you like to put more weight on objective principles and impersonal facts (Thinking) or
do you put more weight on personal concerns and the people involved (Feeling)?

I enjoy technical and scientific fields where logic is important. I notice inconsistencies. I look for logical explanations or solutions to most everything. I make decisions with my head and want to be fair. I believe telling the truth is more important than being tactful. Sometimes I miss or do not value the 'people' part of a situation. I can be seen as too task-oriented, uncaring, or indifferent. Thinking (T)	I have a people or communications orientation. I am concerned with harmony and nervous when it is missing. I look for what is important to others and express concern for I make decisions with my heart and want to be compassionate I believe being tactful is more important than telling the 'cold' t Sometimes I miss seeing or communicating the 'hard truth' of si I am sometimes experienced by others as too idealistic, mushy Feeling (F)

Figure 4. KCE profile questionnaire

Note in the figure above an explanation for each characteristic to facilitate the user to understand the psychological characteristic or the temperamental type present to him. After the user answered the four questions, this four psychological characteristics represent the user´s MBTI profile. The figure 5, shows a textual definition for the ENTP profile that is formed by the characteristics 'extraversion, intuition, thinking and judging'.

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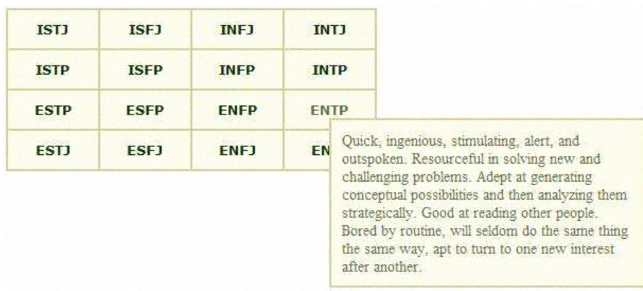

Figure 5. Textual definition of an MBTI profile

In a according to [12], the profile define the features of the user and probables carrers, whose are presented to the user through the KCE tool as shown in the figure 6. The tool allow the user edit que profile any time.

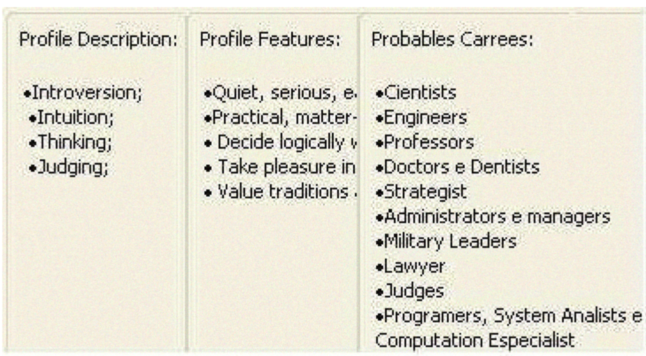

Figure 6. User profile

To determine the similarity between two user profiles, we compare the four psychological characteristics those form the profile. Hence, a user with the INTJ (introversion, intuition, thinking and judging) profile is 100% similar to any user that has the INTJ profile; 75% similar to any user who has a profile with exactly three of the four psychological characteristics in INTJ and so on. Thereby, this similarity percentage defines the weight of the relationship between the two compared users. If the similarity is 100% then the maximum weight is 1, whereas the relationship weight is 0.75 if the similarity is 75% and so on. Likewise, we can define for each user a Qualified Personal Learning Community, where each relationship has a weight whose can bring an user together or move him over, as shown in the figure 7.

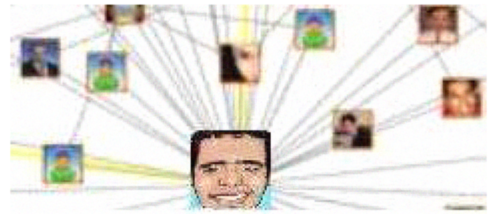

Figure 7. Personal Learning Community Qualified

2) Current Knowledge Similarity

The user´s current knowledge is represented through knowledge chain as described in Section II. And the user´s current knowledge similarity was implemented comparing each knowledge object in the knowledge chain of the users in a sintatic and semantic way.

To compare the knowledge object sintatically, we applied a set of similarity functions in all knowledge object textual attribute: name, description and keywords. The technique presented in [19] and used in this work is a set of similarities functions called the Edit Distance or Levenshtein Distance. This distance gets two strings of characters as input and computes the distance between them, i.e., which is given by the minimum number of insertions, deletions and substitutions of characters that are necessary to transform a string into another.

In this paper, we will not deeply show the algorithm and equations used. The Edition Distance is used to compare of concepts names and properties names. For example, the Edition Distance between "porteiros" and "portaria" is done by changing the word "porteiros" in the word "portaria", which are required five operations:

(1) replace the letter “e” to “a”;

(2) delete the letter “i”;

(3) add the letter “i” after the second letter “r”;

(4) replace the last letter “o” to “a” and;

(5) delete the letter “s”.

Thereby, we have the Edition Distance equal to 5 divided by the size of the largest string that is 8, resulting in the value of 0.375. The greater the Edition Distance, the less the similarity between the strings. Likewise, two knowledge chains are compared calculating the Edition Distance

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between the first knowledge object of one knowledge chain with the first knowledge object of the other knowledge chain and repeat the process for the second knowledge object of these two knowledge chain, and so on. Then the distance between two knowledge chains is the sum of the distances between the knowledge object in the same level of the chains. The greater the distance between two strings, then the greater the distance between the user owners of the chains. Note that when comparing two chains and one is greater than the other, this does not interfere in the similarity between them. We consider that this situation can represent a user who has more knowledge than another, where collaboration can occurs.

To compare two knowledge objects semantically, we take into account the knowledge object hierarchy to compare the ascendent and the descedent of them, i.e., two non-leaf knowledge objects are semantically similar if all its immediate children is highly similar. The same idea is also used for the immediate parent of the knowledge objects. This function examines the similarity of semantic in the context of the knowledge object, i.e., to calculate the degree of similarity of two concepts A and B, it is necessary to calculate the degree of similarity of their immediate ascendent/descendent.

Finally, we have defined the similarity between two knowledge chains where its inverse proportionality value will be added to the similarity profiles described in the previous sub-section 1 (Profile Similarity). This new value update a user´s Qualified Personal Learning Community that is showed to the user as Figure 8. Through this interface in the KCE tool, the user has the oportunity to visualize the author closest with him in that moment. This author list can be changed if the Qualified Personal Learning Community of this user was updated. Besides, the user has the oportunity to visualize the closest author´s current knowledge chain through the magnifying glass on the left of the author name.

Figure 8. Personal Learning Community

It is important to note that isolated people or those that stand distant in a learning community do not contribute to maintain the knowledge flow active. Bringing together people who have similar interests is a good strategy to enable the knowledge flow. With this rule, when the new user performs a search for such knowledge chain, the software agent priorize results from authors linked with the apprentice who performed the search.

3) Updating the Personal Learning Community

Considering persons already on the network, self-configuration is also important. Two network members should not be very distant in terms of accessibility. At this point we take into account the six-degree separation theory [23] according to which a person needs no more than six other contacts to reach anyone in the world. When a person is at a distance greater than this, the network suggests new relationships to improve the knowledge flow between them. This suggestion is also based on profile and current knowledge similarity described above.

The self-configuration also happens between users already linked. In this case, when there is collaboration between two users, the relationship between them is increased 1 (one) weight. But when the user indicates that the knowledge chain recommendated by the KCE tool from another user is irrelevant, then the relationship between them is decreased 1 (one) weight.

Encouraging knowledge exchange between people who have similar profile and current knowledge can improve the knowledge flow in the autonomic learning community, contributing towards its spread on a larger scale and towards the innovation process. Moreover, information sharing can improve and refine its meaning: the aggregation of information done by groups often result in better

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information that could be acquired by any member of the group [20].

B. *Self-Protection*

This feature is used to address issues related to the network structure, and a possible loss of knowledge. The first problem is related to 'junk knowledge'. In a learning community there can be people (or groups) that disseminate old ideas and old concepts and, when faced with new ones they cut it down and do not allow its flow over the network. For them, addicted ideas have priority over new ones. The network needs to protect itself against this situation. In the recommendation system proposed, if the apprentice identify irrelevant knowledge chain recommended by the tool, then he can mark it as 'junk knowledge'. This information is used by the software agent to mark the knowledge chain author with negative score in the link between him and this apprentice. Therefore, the importance of this author knowledge chain will be less than any knowledge chain on the learning community, since knowledge chain from author who are not connected with the apprentice has score zero (0), author who provide knowledge chain to the apprentice accumulate positive score, while a knowledge chain labeled 'junk knowlegde' have -1 (one negative) weight for each rejection. Under this assumption, we can ranked the knowledge chains after a search performed by the apprentice, preventing him from knowledge assessment negatively.

C. *Self-Heal*

The self-healing feature is used to address issues related to four problems found in the network: Cluster, Centralizing Nucleus, Bridges and Knowledge Centralizers. Clusters are organizations of people in virtual community that do not overlap [10]. This became a problem when there is little interaction of cluster with other community members. The KCE tool prevent this type of problem using the organization of apprentice into groups just to recommend knowledge chains closest to his desire. This does not preclude others authors knowledge chains be retrieved in the search.

The problem with bridges happened when people who is a link between two distinct groups of the virtual community. In KCE, knowledge chains from authors link to an author linked to apprentice are used by KCE to form a second category of knowledge chains recommended, starting with a score of 0.5. In other words, beside a search in members directly linked to the apprentice, the tool performed a search in non-common members between the apprentice and his members directly. It is important, because we can not return what the apprentice wants, but knowledge chain of members with profiles or expertise desired by the apprentice to be a reference for apprendice. Likewise, we also avoid a problem known as Knowledge Centralizers which happenend when members of a learning community centralize knowledge and do not distribute it adequately through the peer-to-peer archicture, where each node is a knowledge chain server. With Peripherals Nodes, where members who are weakly linked to community, we avoid they been neglected or under-used in the learning community through the second category described above.

D. *Self-Optimization*

Optimizing the available communication resources is also important to garantee that the users linked with the apprentice is really person with the profile nearest of the apprentice. This autonomic properties work in balancing the virtual community by suggesting new relationships to solve problems or to avoid problems that could affect the knowledge flow. New links arise when there is collaboration between users through knowledge chain exchange, previously not linked. Relationships are strengness when collaboration happens between members already linked. And finally relationships are weakened when the apprentice point a knowledge chain as 'junk knowledge'.

IV. Primary Results

A case study was conducted with post-graduate students without prior knowledge about knowledge chains concepts and the KCE tool, where each participant was suppose to create a knowledge chain about a particular subject that they had studied in a common domain defined by the case study organizers. After, the participants shared these knowledge chains and finally they used the search mechanism to learn another subject in the same domain defined by the organizers. It is important to note that the

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specific subject was hand out among the participants, where all this subjects belongs the same domain.

This work uses the personal knowledge management approach focused on sharing knowledge to facilitate and promote the learning process. The main goal of this case study was to evaluate the search and retrieval of the best learning strategy recommended by the autonomic agent in the peer-to-peer architecture for communication. The case study implementation had five phases:

In the first phase, the participant built any class diagram. After the organizers quality approval, he applied in this diagram four design patterns [3], where three patterns (creation, behavior and structure) were given to him after been learned in the classroom and the fourth pattern was given to him without be learned. The number of design patterns for each participants were made in a way that occurs overlapping in the patterns distribution among the participants, without overloading the work of each them. The goal of this phase is to make the learner start the build of his own class diagram using his three design patterns learned.

In the second phase, the participants were training in the KCE tool to use it as the personal knowledge management in the design patterns domain building a knowledge chain about the three design patterns learned and applied in the participants class diagram. The goal of this phase is to fill the knowledge base of our peer-to-peer environment, where all participants can perform searches in order to retrieve the knowledge chains desirable in the next phase.

In the third phase, the participants were persuaded to use the autonomic search mechanism to look for a knowledge chain that contain his fourth design pattern that need to be learned to be applied in his diagram class. As it was said in the first phase, the number of design patterns for each participants were made in a way that occurs overlapping in the patterns distribution among the participants. Then, we can guarantee that each design pattern was learned for at least two participants. Thereby, a search for any pattern will find at least two results in our environment. The goal of this phase is to allow knowledge chain sharing among the participants acquiring knowledge about his fourth design pattern that need to learn through a knowledge chain retrieval by the KCE tool that contain all learning strategy for design patterns.

The fourth phase was the stage where the participant finalized his class diagram after study his fourth pattern learning strategy retrieved by the tool and applied it on his diagram. After, the apprentice submitted all required documents (questionnaires for assessment, some reports and his conceptual diagrams) in order to assess the participants, the tool and the case study.

The fifth phase was the stage where the organizers of the case study evaluated the documentation delivered by the participants and events observed during the case study.

A. *Study Case Data Analyzing*

The documents delivered by each case study participants via KCE tool are:

- A report with the profile defined by the apprentice in the tool;
- The apprentice knowledge chain image before making any search;
- The image of the final apprentice knowledge chain at the end of the case study;
- The images of the apprentice Qualified Personal Learning Community with all updates it has had;
- The images of knowledge chains recommended in each search performed by the apprentice, those accepted and those rejected by the apprentice;
- The questionnaire answered by participants.

Initially, case study organizers analyzed the apprentices' profiles to validate the Qualified Personal Learning Community created by the tool. After, they had to analyze whether the knowledge chains recommended by autonomic agent was consistent with the participants profile and the current knowledge available on the environment. Then, the updates made on the Personal Learning Community after the knowledge chains be accepted or rejected by the apprentice, analyzing the new weights assigned to the relationships of the learner. Finally, we analyzed the questionnaires answered by participants, which consist of KCE assessment,

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their satisfaction with the knowledge chain search and their criticism.

To perform the qualitative analysis was used the following criteria: for an question be considered as 'Yes' or 'No', it was necessary have 80% of participants' answers. The answers 'do not apply' and 'no answered' were disregarded. From the questions constructed for the case study, we have defined hypotheses, which were evaluated. The following are some important assumptions:

- The KCE has a friendly interface. - Inconclusive
- The functionalities of KCE worked properly. - Inconclusive
- The project was carried out correctly by the participants making use of the KCE. - True
- There reuse among users. - True
- Users are able to externalize their knowledge appropriately. - True
- Users were able to collaboratively build the knowledge of other members. - True
- The graphical interface meets the needs of the User. - Inconclusive
- The approach encourages and promotes communication among students. - Inconclusive
- The approach helps in the construction of knowledge. - True
- The approach promotes an increase in productivity. - True

For analysis of the assumptions, in general the results were quite significant, because the majority, over 80%, the hypotheses relevant were considered true. The participants, both learners and tutor were motivated with the approach of the knowledge chain.

We have analyzed the images of the apprentice Qualified Personal Learning Community with all updates it has had and, we observed the need of adjusting the weights used to qualified the Learning Community in a way that similarity of profile and current knowledge chain have a fair weight to the effective recommendation. Another weakness was the absence of an indicator when a user has more knowledge to another and the tool have to identify that a knowledge chain contain another knowledge chain.

In a qualitative analysis, the case study result points that the KCE lacks some features:

- The participants felt the lack of some features of interface using the right mouse button;
- Delete an object using the graphics is an extremely slow process;
- The manipulation of knowledge chains through the interface is very complicated , as we can see in the figure 9;
- Do not possible manipulate objects from different knowledge chain to construct a new knowledge chain.

All problems those occurs with the tool during the case study were overwhelmed by the participants, whom continued with the tasks.

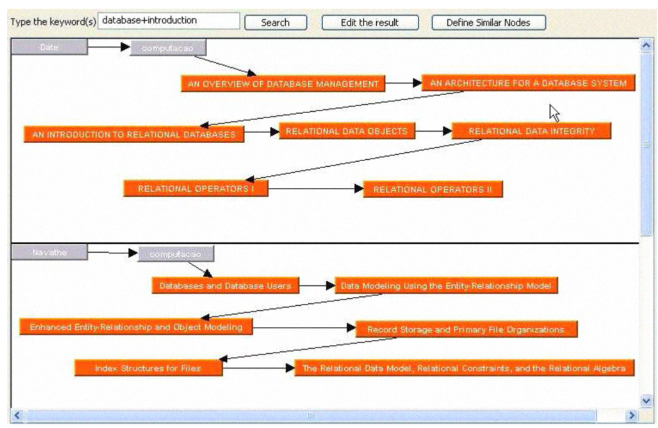

Figure 9. Example of the Search Mechanism

V. CONCLUSIONS

This article presented a collaborative tool called KCE (Knowledge Chain Editor) to support Knowledge Chain exchange whose are learning strategy designed in a accordance with 5W1H to permit the apprentice obtain a desirable knowledge through a autonomic recommendation search mechanism. The self-CHOP features were implemented through a software agent in the CoppeerCAS

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platform [9] to allow each node in the peer-to-peer architecture be autonomic based on the user's profile and current knowledge and based on the feedback give by the apprentice. During the paper, we explained how the rules were implemented in a way that more the apprentice uses the knowledge chain search mechanism, more precise will be the KCE´s autonomic recommendation search mechanism.

The challenge of establishing an e-learning and a personal knowledge management tool is generally difficult once few people really know how important the collaborative process is. However, the primary results from the case study applied, have proved how involved the users were. Our next goal is to perform a case study in a real environment and in variable contexts after update of KCE tool with the improvement identified in the case study.

For further works, the system will have a new search mechanism to solve the following problem of the apprentice: "What can I learn from my current knowledge?" Thus, based on the current knowledge of the apprentice, the KCE returns the knowledge object that best fit with the user current knowledge chain. We also identified the need for a mechanism to check the consistency of the knowledge chains spread by the peer-to-peer environment in order to get rid of redundancies, corrupted or useless files.

As another future work, we will implement a predictive analysis model based on user behavior to assess the cooperation level and support decision. In short, predicting the trend through the discovery of predictive patterns with our temporal knowledge base where information about profiles, knowledge and the relations between them are stored.

VI. Acknowledge

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