Interacting with Dynamic Social Knowledge
Revealing Challenges through an Analysis of Pragmatic Aspects of Problem Solving

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Abstract: In the Social Web users interact with each other in multiple contexts expressing meanings and intentions. Knowledge production in this context can be understood as a dynamic socio-cultural process. Mechanisms that support users to explore this knowledge in an effective and efficient way may bring benefits from a personal and social perspective. However, the construction of these interaction mechanisms is dependent on new models and techniques to dynamically represent and visualize the shared knowledge. The interpretation of the content by users is influenced by meanings and intentions, as well as by the understanding of the evolution of these aspects over time. This paper analyses the evolution of meaning and intentions in collaborative problem solving scenarios using Social Network Systems. The analysis method has its roots in Semiotics and Speech Act Theory. Results indicate research challenges for new interaction possibilities by representing the evolution of the pragmatic aspects and their relations with the semantic ones. To address these open research problems we present a preliminary conceptual framework for multidisciplinary research in three interconnected perspectives: interactive, conceptual and technical.

1 INTRODUCTION

The Social Web (SocWeb) (Gruber, 2008) has a dynamic nature with respect to both content and enabled interactions. This dynamic nature affects the users' interpretation and intentions, and consequently their possibilities of interaction with the system. At the same time, the Semantic Web (SemWeb) (Berners-Lee et al., 2001) proposes to model the information in Web ontologies, aiming at enabling knowledge interpretation by artificial agents and by people. However, some of the main issues of the SemWeb include how it truly enables the connections of the Web of people who will use it, and how to turn "messy" human knowledge into a shared information space that is useful to everyone (Hendler and Berners-Lee, 2010). Therefore, an alignment of the SemWeb with SocWeb visions may bring benefits, but also open challenges in terms of requiring novel interaction methods and techniques.

In the context of the SocWeb, knowledge representation models applied to social software should take into account the dynamic aspects of the knowledge produced and exchanged by people in these systems. These models could enable richer users' interactions by representing the evolution of the pragmatic aspects and their relations with the semantic ones. In this paper, we study the evolution of semantics and pragmatics as an integrated process.

In many cases, it is desirable to maintain the history of how content, interactions, as well as the meanings, intentions and interpretations evolve over time. In collaborative problem solving, for example, usually the interactions, as well as the rationale and history of the actions taken are as important as the solution itself. However, the interpretation of content generated during the collaborative process is dependent on the analysis of the evolution of the context, from the time when the content was created. Therefore, the associated knowledge representation models should evolve, maintain and present the

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evolutionary history in a proper way, associating meanings and intentions.

The construction of such systems relies on open research issues, requiring a multidisciplinary view to deal with. In this paper, research requirements are analyzed and situated in three interconnected perspectives: (1) *Interactive Perspective*: How users will actually visualize, make sense and interact with this dynamic content; (2) *Conceptual Perspective*: How to conceptually make sense and model the dynamic aspects of the knowledge (including meanings and intentions); and (3) *Computational Perspective*: How to implement and automate as much as possible the construction of the models.

In order to explore requirements for these views, the paper presents a study of dynamic aspects of pragmatics in messages exchanged during collaborative problem solving processes, within the special education domain. Two scenarios were explored: one in the "*Vila na Rede"* Social Network System (SNS) (*www.vilanarede.org.br*), which adopts a forum structure for questions and discussions, and the other within "*Yahoo! Answers"* (*http://answers.yahoo.com/*), which adopts the structure of multiple answers to a single question. The analysis was performed in three steps: the first step is related to a quantitative analysis of the interactions; the second step involves the examination of messages using the pragmatic communication analysis artifact (Liu, 2000); and the third synthesises the results and the exploratory analysis of interaction possibilities towards requirements for research in related fields. From the results of this study we extracted general requirements and challenges for the interactive, conceptual and computational perspectives. Based on the challenges raised, we present and discuss a preliminary framework for future research.

The paper is organized as follows: section 2 presents the background in Knowledge Visualization (KV), Knowledge Evolution (KE) and Pragmatic Web; section 3 describes the study of pragmatics evolution in collaborative problem solving in SNS; section 4 presents the challenges and discusses a conceptual framework to deal with the issues; section 5 concludes the paper.

2 BACKGROUND

In this section, we present the main areas related to this work. Background works in KV (section 2.1), KE (section 2.2) and Pragmatic Web (section 2.3) are used in this paper for prospecting research requirements.

2.1 Knowledge Visualization

Visualization techniques are strategies to deal with the increasing quantity and complexity of subject matters in many domains (Keller and Tergan, 2005). According to Pampalk et al. (2003) visualizations can make complex relationships easier to understand, and stimulate visual thinking.

Knowledge Visualization (KV) differs from Information Visualization (IV) techniques (Eppler and Burkhard, 2004) in many aspects, including goals, benefits, content, or recipients (Keller and Tergan, 2005). In order to precisely define KV, many proposals discuss the differences of data, information, and knowledge, as well as try to reach a precise definition of the concept of knowledge. The concept of KV "in a strict sense is restricted to externalizing aspects of knowledge by the individual […] in a 'freestyle mapping mode'" (Keller and Tergan, 2005, p. 7). Also, the term KV has a focus on structured visualizations for the representation of conceptual knowledge (Keller and Tergan, 2005).

In general, KV methods are required to make knowledge explicit and better usable, as well as to make sense of information structures (Keller and Tergan, 2005). Burkhard (2004) proposes a KV Framework consisting of three perspectives (a Knowledge Type Perspective, a Recipient Type Perspective and a Visualization Type Perspective), which need to be considered when creating visualizations that aim to "transfer" knowledge. Different techniques have been proposed to address KV, such as: Scientific Charts, Concept Maps, Knowledge Maps, (Conceptual) Diagrams, Visual Metaphors, (Heuristic) Sketches (Keller and Tergan, 2005); (Eppler and Burkhard, 2004). There are also ontology-based (Kuß et al., 2009) as well as graph-based (Maseri et al., 2007) approaches to KV. KV studies have also been applied to the SocWeb context (Hoetzlein, 2007).

In fact, an envisioned scenario for the Web (Hendler and Berners-Lee, 2010) regarding the use of SemWeb artefacts within SocWeb environments poses new issues that have not yet been deeply explored in the KV literature. Therefore investigations to clearly identify the challenges and new possibilities opened by this contemporary scenario are still required. There are dynamic aspects of the shared knowledge in social networks that are not addressed by the current KV methods. It is out of the scope of this paper to propose new KV

techniques; however, we expect to contribute by clarifying interaction possibilities for KV in a dynamic SocWeb perspective.

2.2 Knowledge Evolution

The Ontology Evolution (OE) problem has mainly emerged with the use of ontologies in the context of the SemWeb. A well-accepted definition for OE is given by Stojanovic (2004). The author defines OE as: "*the timely adaptation of an ontology to the arisen changes and the consistent propagation of these changes to dependent artifacts*". Over the last years, distinct methods and approaches to organize the evolution steps have been proposed to treat the OE problem.

Stojanovic (2004) proposes a six-step method that focuses on different aspects of the changes: (1) detecting, (2) representing, (3) defining its semantics, (4) implementing, (5) propagating and (6) validating. For each of these steps, various different approaches are proposed in the literature. Flouris *et al.* (2007) present a survey on ontology change.

The OE problem has also been addressed and considered under different perspectives. For instance, approaches defined in ontology languages for the OE (Avery and Yearwood, 2003), ontology versioning (Klein and Fensel, 2001), and community-based OE (Leenheer and Meersman, 2007). These approaches and methods for OE have resulted in the development of tools for supporting the OE process. Software applications such as *OntoStudio* (*www.ontoprise.de/en/products/ontostudio*) or *Protégé* (*protege.stanford.edu*) are generally augmented with additional functionalities through the use of plug-ins in order to support specific OE requirements. OE methods, techniques and tools are important for supporting the proposed conceptual and technical perspective.

In this work we present requirements for the development of new KE techniques that consider the relations between semantics and users' intentions.

2.3 Pragmatic Web

According to Morris (1938), pragmatics can be understood as the relationship between signs and humans. It concerns aspects such as intentions, communications, conversations and negotiations. While the areas of KV and KE focus on aspects related to the visualization of knowledge and formalisms that describe knowledge evolution, the Pragmatic Web is also concerned with the question of how knowledge is actually constructed and how it evolves during the collaboration among people that is mediated by Web artifacts. Originally proposed as an extension or a complement of the SemWeb, the Pragmatic Web addresses topics such as context and meaning negotiation in the Web (Singh, 2002); (Schoop et al., 2006).

The Pragmatic Web perspective has been applied to a variety of research domains, *e.g.,* multi-agent systems (Paschke et al., 2007), interaction design (Hornung and Baranauskas, 2011), self-organizing communities of practice (de Moor and van den Heuvel, 2004), or Web Services (Liu, 2009). Pragmatic Web research is often rooted in different Information Systems research frameworks and theories, *e.g.,* the Language/Action Perspective (LAP) (Goldkuhl and Lyytinen, 1982); (Winograd and Flores, 1986) or Organizational Semiotics (OS) (Liu, 2000).

The basic unit of analysis of LAP is a speech act. LAP subscribes to the notion that we perform actions through language. Thus, collaboration is coordinated by the performance of speech acts, which underlie socially determined rules (Schoop, 2001). In OS, basic units of analysis are affordances and agents. Initially introduced by Gibson (1968), the concept of affordances was expanded by Stamper (1996) to represent patterns of behavior that are governed by systems of norms in the physical and social world. Agents are entities (persons or groups of people) that can be attributed with responsibility. OS's basic ideas have been formulated as "there is no knowledge without a knower, and there is no knowing without action" (Liu, 2000; p. 26). OS subscribes to the notion that knowledge about the world, and the underlying systems of norms are constantly changing.

Considering LAP with OS (Cordeiro and Filipe, 2003) as theoretical frames of reference, and having as object of study Web-mediated collaboration and meaning negotiation, the Pragmatic Web, thus, provides an important basis for this work.

3 ANALYSING DYNAMIC KNOWLEDGE

The empirical data that has been analyzed in this work has been gathered during activities conducted in the context of a research project named TNR (*www.nied.unicamp.br/tnr*) in the domain of Web-mediated continuous learning of Brazilian special education teachers. Regarding the required training for special education teachers, the Ministry of

Education defined an eighteen-month distance learning course for regular teachers. During this course, teachers learn to discuss a so-called "case" of a student with special needs.

In Brazil, special needs are classified into 7 categories (visual, auditory, motor, intellectual impairment, intellectual giftedness, pervasive developmental disorder, multiple impairments), and in order to constitute a meaningful and representative group of 28 participants, 4 specialists of each category who expressed a familiarity with the use of information and communication technology (ICT) were chosen randomly.

In the context of this project, the initial activities aimed at learning more about the way the 28 participants use Web systems, and how they engage in different forms of Web-mediated conversations. To this end, four consecutive activities were planned. Due to space limitations, the analysis presented in this work is based on two of the four activities, namely the discussions conducted in "*Vila na Rede*" and "*Yahoo! Answers*". *Vila na Rede* is an inclusive social network that permits to post "announcements" and to comment on them. Comments are displayed in a hierarchical structure below the announcement, and may contain text, pictures, audio or video. If the creator of the announcement authorizes it, other users may "collaborate", *i.e.,* change or augment an announcement's text or media files. *Yahoo! Answers* is a Web system that permits a user to post a question and other users to post answers to that question or vote for the best answer.

Out of the 28 teachers, 16 participated in the two activities (9 participated in both activities, 6 only in *Yahoo! Answers* and 1 only in *Vila na Rede*). These teachers had no previous experience with the mentioned systems, but were already used to Web applications such as blogs, email, and forums. A "case" was posted in each system and teachers were asked to discuss and solve it.

3.1 Methods

The objective of the present analysis is to investigate requirements and possibilities for a prospective computational mechanism that explores the dynamic aspects of meanings and intentions in the contents of problem solving in SNSs. From the analysis of probable meanings and intentions of the written communication acts, we expect to explore new possibilities and extract requirements for research, design and implementation of such mechanisms, as well as to reveal research challenges to be overcome.

The *first step* of the three-step analysis regards the analysis of interaction including quantitative aspects. The interactions (*e.g.,* comments, questions, answers) among users during the problem solving are enumerated and analyzed in a temporal order, resulting in an interaction graph. The activity of the network is also observed. One interaction may contain more than one message addressed to a receiver.

The *second step* involves the communication examination based on the pragmatic analysis presented in Liu (2000). We propose the use of this technique because it provides a structured way to analyze pragmatic aspects in messages. According to the Speech Act Theory (SAT) (Austin 1962, Searle 1976) the acts are classified as locutionary (*i.e.,* actual utterance and its ostensible meaning), illocutionary (*i.e.,* propositional contents carrying intentions) and perlocutionary acts (*i.e.,* effect on the addressee). As presented by Liu (2000), a message can be divided into two parts: the content part of a communication act that manifests the meaning of the message as it is expressed in the proposition; and the function part of a communication act specifies the illocution that reflects the intention of the speaker. An interaction between users identified in the first step can be broken down into one or more messages. In this sense, for example, a long answer is considered one interaction unit, but it may contain more than one message unit from the communication act point of view.

In Liu (2000) the illocutions are grouped into three dimensions: *time* (*i.e.,* whether the effect is on the future or the present/past), *invention* (*i.e.,* if the illocution used in a communication act is inventive or instructive, it is called prescriptive, otherwise descriptive), and *mode* (*i.e.,* if it is related to expressing the personal modal state mood, such as feeling and judgement, then it is called affective, otherwise denotative). By using these dimensions, the illocutions are classified as: 1. *Proposal* (future, prescription and denotative), 2. *Inducement* (future, prescription and affective), 3. *Forecast* (future, description and denotative), 4. *Wish* (future, description and affective), 5. *Palinode* (present/past, prescription and denotative), 6. *Contrition* (present/past, prescription and affective), 7. *Assertion* (present/past, description and denotative), and 8. *Valuation* (present/past, description and affective).

Figure 1 shows the proposed evaluation form used in the second step. For each message, two analysts attributed continuous values from 0.0 to 1.0 for each dimension, for example, 0.0 for a message

that the analyst judges to be totally denotative, and 1.0 for a totally affective one. An analyst might, for instance, attribute a confidence level smaller than 1 to a phrase (s)he could not classify confidently.

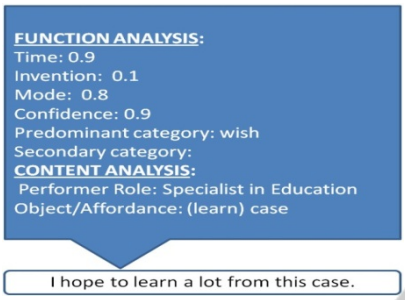

Figure 1: An example of communication message analyzed using the proposed form.

Based on the values attributed before, a predominant classification is attributed for each message, and optionally the analyst can also indicate a secondary (or alternative) classification. The analysts also identify aspects associated with the content part: the role of who performed the message ("speaker"), and the main object, affordance or proposition that the message refers to. This step was manually performed by the two analysts.

The third step is the synthesis of the results of step one and two. Graphs showing the evolution of each of the three dimensions of the illocutionary acts were produced to facilitate the analysis. A free exploratory analysis, in the format of a brainstorming, was performed aiming to investigate how the dynamic aspects could potentially contribute to interaction design for continuous learning, regarding mainly topics such as content recovery or search. Finally, a synthesis of the challenges and future research needs was performed.

3.2 Results

Figure 2 presents an interaction graph produced in the first step of the analysis of *Vila na Rede* case. The circles represent the 12 users (10 participating teachers and 2 facilitators from the research team) that performed at least one interaction, and the arcs represent their interactions. Circle sizes are proportional to the total number of interactions the respective users were involved in. The arc thickness is relative to the number of interactions performed by each pair of users.

By observing Figure 2, it is possible to identify that the users V1 and V10 were the most active ones. In average, each of the 12 users performed 9.25 interactions, and approximately 77% of all interactions where performed as an answer to a previous one. This can be interpreted as evidence that the problem solving and meanings were constructed in an interactive process, in which messages were constructed dynamically over the interpretation of previous messages.

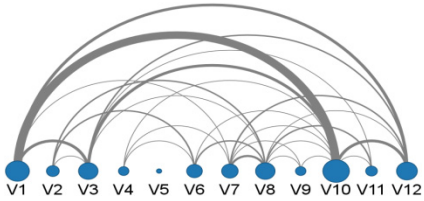

Figure 2: Interaction Graph of *Vila na Rede* Case.

In the second step, the content of the messages was analyzed using the results of step one as a starting point. Figures 3 to 5 present the evolution of the *time* (Figure 3), *invention* (Figure 4), and *mode* (Figure 5) dimensions during the problem solving process in the *Vila na Rede* activity. Some interactions analyzed in the first step consisted of two or more illocutionary acts. A total of 170 illocutionary acts (contained in 110 interactions) were identified and plotted on the horizontal axis of Figures 3 to 5. The dashed lines in Figures 3 to 5 represent the polynomial trend lines of each dimension. Looking at the trend line we can visualize the evolution of the dimensions in the problem solving process. For example, in Figure 4, in the interval 61 to 101, there is a predominance of descriptive messages, while after message 151, the prescriptive messages predominate.

Figures 6 to 8 present the evolution of the *time* (Figure 6), *invention* (Figure 7), and *mode* (Figure 8) dimensions during the problem solving process in the *Yahoo! Answers* activity. Each interaction analyzed in the first step consisted in average of 8 illocutionary acts. A total of 318 illocutionary acts (contained in 39 interactions) were identified and plotted on the horizontal axis of Figures 6 to 8. The vertical axis represents the respective dimension values attributed to each communication message using the form of Figure 1. The dashed lines in Figures 6 to 8 represent the polynomial trend lines of each dimension.

3.3 Possibilities and Needs for Novel Interactive Mechanisms

When cross-referencing the function analysis with the content analysis, aspects regarding the problem solving processes can be observed.

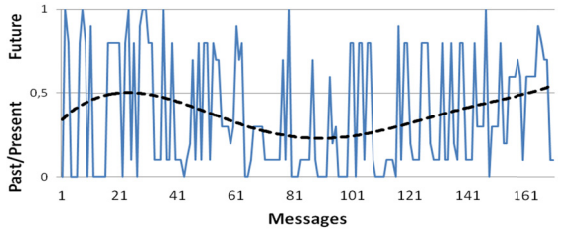

Figure 3: Time dimension evolution graph of Vila na Rede.

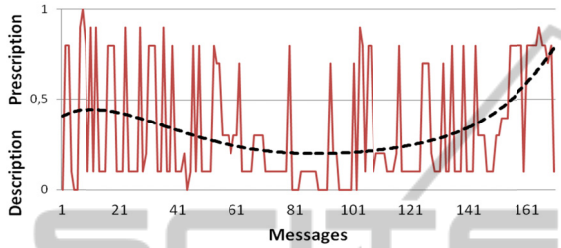

Figure 4: Invention dimension evolution graph of Vila na Rede.

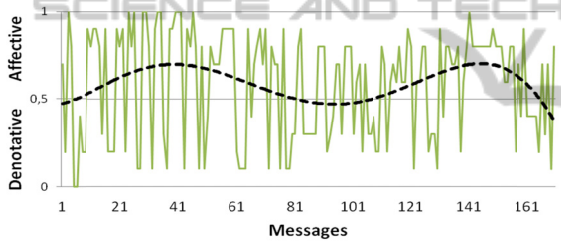

Figure 5: Mode dimension evolution graph of Vila na Rede.

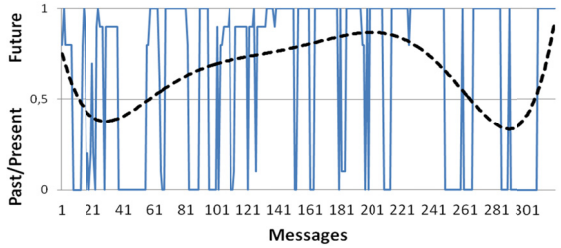

Figure 6: Time dimension evolution graph of Yahoo! Answers.

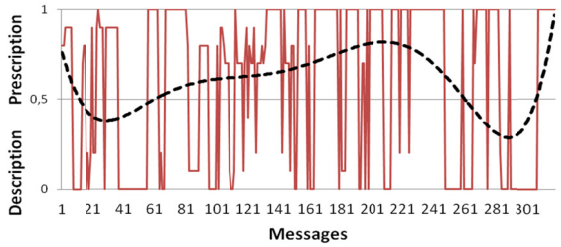

Figure 7: Invention dimension evolution graph of Yahoo! Answers.

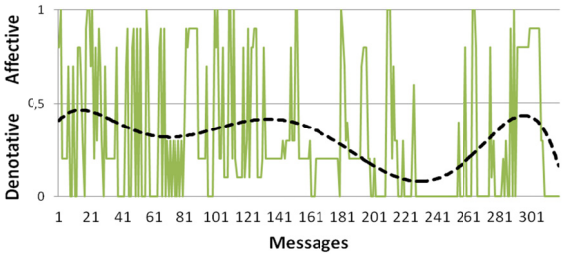

Figure 8: Mode dimension evolution graph of Yahoo! Answers.

The content analysis links messages to the discussed issues (from the observed affordances). For instance, as marked in the object/affordance field of Figure 1, the speaker was talking about the case under discussion. At each moment of the discussion, there is a single or at most few dominant topics. After determining these "dominant topics", they were cross-referenced with the graphs of the function analysis. Some major aspects observed during this third step of the analysis were:

- In *Vila na Rede*, at the beginning of the discussion, the specialists in education made assertions, some valuations and few requests about the case discussion itself. These aspects are especially interesting, for example, when users want to recover portions of dialogs that deal with discussion and planning.
- In *Vila na Rede*, the middle part of the discussion is dominated by valuations (present, description and affective) and assertions (present, description and denotative) regarding facts and alternatives for the case solution. This part of the dialog can potentially support the identification and visualization of facts and alternatives that support the solution.
- In *Vila na Rede*, at the end of the discussion, the specialists focused on a synthesis of a solution plan (future, prescription, denotative). This part of the solution is important to visualize the formulation of the solution itself.
- In *Yahoo Answers!*, at the beginning of the solution process, messages focused on requesting additional data about the case from the person who posted the question (*i.e.*, proposals: future, prescriptive, denotative), this was followed by messages with assertions regarding the case (present, descriptive, denotative). This part of the solution processes is very important, for example, for someone who wants to understand the case, when some case details are not present in the primary question.
- In *Yahoo Answers!*, the middle part of the process focused on presenting solution plans

(Special Education Pedagogic plans). Some plan proposals (future, descriptive, denotative) contained many items, and followed a structured format. This part of the processes is important for someone who wants to visualize the concurrent proposals, for example.

- In *Yahoo Answers!*, the end of the process focused on assertions (present, descriptive, denotative) and valuations (present, descriptive, affective) concerning the case and solutions. This was followed (at the very end) by the prescription (future, prescriptive, denotative) of a final plan. This part of the solution is important to visualize the final plan, as well as the valuations about the case and alternatives (*e.g.*, some answers valuated the role of the family and the school in the described case, and proposed alternatives to work with this aspect).
- It was possible to visualize blocks of messages with the same (or close) values, *e.g.,* messages 11-17 and 71-77 in Figure 3. Many blocks occurred simultaneously in more than one dimension and were related to the same affordance and/or were performed as answers to the same message. More data is required to understand the significance of these blocks for a problem solving process. However, these blocks are likely to represent correlated messages and once identified, they could be explored, for instance, by recovery and visualization techniques.
- By including the pragmatic analysis, a more refined classification of the messages is possible. For instance, it is possible to visualize and recover sequences of messages that valuate or judge one specific alternative.
- A more refined analysis of users' participation is possible. One possibility is to differentiate when a user requested information about one specific technique to solve a problem, or valuated alternatives, or did a lot of assertions about the techniques. This is especially important in social networks when we are looking for someone that has experience with a specific problem. Thus, it is possible to identify someone who commented about one topic, and also what the declared intention was (proposal, assertion, *etc*.).
- The identification of the illocutions can also be used as a parameter in the syntactic and semantic disambiguation process. For instance, the word "who" could be an interrogative pronoun in a request (*e.g.,* who did that), but also a relative pronoun in an assertion (*e.g.,* that's the guy who did this).
- Palinodes and contritions were the least frequent in the processes of the analyzed cases. Nevertheless, they are extremely important in some situations. In the *Vila na Rede* case, one specialist proposed a synthesis of future actions, however in the subsequent messages she apologized for a mistake in one of the proposed actions.
- The analysis also revealed that there were assertions, valuations and proposals that were not related to the problem in focus, such as greetings and messages about the use of the computational systems. The identification of such messages might enable to filter, or even highlight the messages associated with the "core" problem (substantial messages). Anther possibility is to filter "transversal" issues, such as the use of the functionalities of the systems (communication and control messages).
- Although comparisons between *Vila na Rede* and *Yahoo Answers!* are out of the scope of this paper, the pragmatic analysis also revealed important aspects regarding what forms of conversation or dialogue are supported in each system. For example, in *Vila na Rede*, questions and comments are displayed in a hierarchical structure. This resulted in less illocutions per interaction/post and more diverse illocutions types, while the *Yahoo Answers!* discussion was predominated by proposals to solve the posted question in long post messages that contained a high number of illocutions.

Starting from these possibilities we extracted requirements for the construction of features in SNSs that deal with and take advantage of the dynamic pragmatic aspects. A major requirement is the possibility for the users to visualize, explore and make sense of the dynamism of the pragmatic aspects of problem solving.

Users should be able to recover or filter parts of the solution processes using adequate parameters and be able to interact with the results in a useful way. For illustration purposes, consider the following hypothetic scenario: Someone wants to know what are the previous solutions for a specific problem discussed in the SNS, including, for example, the rationale and the evolution of the solution, who gave opinions and valuations, when, what were the alternatives and why they were not adopted (valuations about discarded alternatives), *etc*. How do users specify what they need; their information requirement? Should they directly specify the illocution classification, *e.g*., valuations about extra-scholar activities to support deaf students in the last 2 months? How to visualize the results? How to explore the results (*e.g.,* select a term to show who was referred and when in the

discussions)?

The questions presented are a small subset of possible issues that need to be explored. Most of these issues demand a multidisciplinary approach, which may involve techniques, methods and theories of various research fields.

4 CONCEPTUALIZING DYNAMIC KNOWLEDGE

In this section, we present a preliminary research framework for conceptualizing pragmatic aspects of dynamic knowledge. This framework is the result of an exploratory investigation of areas, methods and technologies related to dynamic aspects of knowledge in the SocWeb. The scope of this section is not to provide a well-defined process or an exhaustive list of methods that can be directly translated into a solution. Rather, the framework presented here is intended to point out areas, technologies, and needs for deeper investigation.

Figure 9 presents the three perspectives of the proposed framework. Examples of candidate areas and technologies are shown for each perspective. The Figure shows that there is a significant overlap of the perspectives. Each item is classified according to the perspective where it is expected to contribute most. For example, in our proposed framework, SemWeb technologies are most relevant for the computational perspective, although they also might inform the conceptual or interactive perspective.

In the interactive perspective, two major challenges to be addressed are: 1. how to provide alternatives of interaction design to enable the user to recover, explore and manipulate data and models regarding pragmatic aspects, and 2. how to explore pragmatic aspects to provide better interfaces when exploring knowledge considering the temporal aspects. In this sense, new interaction design techniques have to be investigated.

IV and KV techniques are particularly important for providing means to visualize huge amounts of complex information (interactive perspective). However, it is necessary to articulate these techniques with theories and novel frameworks for understanding knowledge (conceptual perspective). The approaches so far explored in the literature are not able to accurately answer the question of whether the knowledge structures used really make sense for the target users.

Another issue to be addressed in the interactive perspective is how to capture the users' declared intentions. In some systems, users may declare their intentions through interactive interfaces, thus one of the main difficulties here is how to design appropriate interaction alternatives according to the context.

Participatory Design practices (and user-centered design) may provide alternatives of interaction with users. By working with users at design time, it is possible to determine how users make sense of the representations, and what the appropriate design options are, for example, regarding searching, filtering, visualizing and exploring information using pragmatic dimensions similar to the ones presented in section 3.

In the conceptual perspective, one of the major questions is how to employ adequate theories that support modeling the conceptual aspects of pragmatic knowledge. These models have to guarantee conceptual consistence and provide theoretical grounding to what is implemented in the computational models (computational perspective), and presented to users (interactive perspective).

Semiotics can provide us with theories and a conceptual basis for future works (conceptual perspective). For example, the Norm Analysis Method (NAM) (Liu, 2000) provides a systematic way to understand and model the human behavior in society. However, some research issues have to be addressed, such as practical applications that provide better interactive and computational models, and the question of how to deal and model norms changes and evolution.

In the proposed framework, SAT and LAP are part of the conceptual background regarding the analysis of pragmatics. Methods associated with SAT and LAP might be explored, and they may contribute to the development of methods and techniques towards a (semi-)automatic content analysis. The propositional attitudes (*i.e.,* the effect of the illocutionary acts), which were out of the scope of this paper, should be investigated through the analysis of the perlocutionary acts. Moreover, theories developed in sociology and anthropology, especially those applied to Social Network Analysis (SNA) may complement the conceptual basis.

In the computational perspective, two of the major issues to be addressed are: how to produce computer interpretable representations of the pragmatics, and how to automate the construction of these models to provide scalable solutions over time.

SemWeb technologies can be a starting point to the implementation of such solutions. For instance, concepts of Web Ontology Language (OWL) may have to be adapted or extended to deal with the pragmatic aspects. Moreover, in this context, the KE

field has produced a set of methods and techniques to computationally deal with domain evolution through the use of SemWeb ontologies. However, research in this field is required to cope with the evolution of concepts and models related to pragmatics.

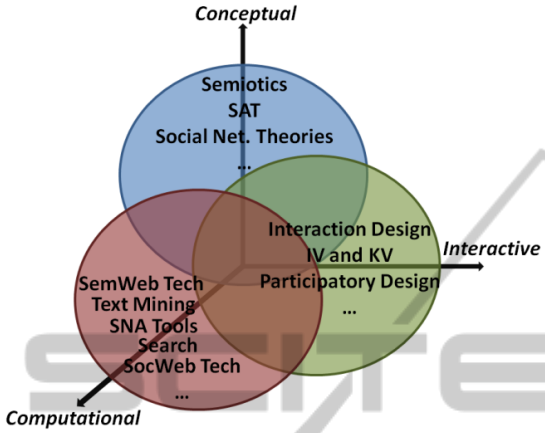

Figure 9: Areas and Techniques in the three dimensions.

Text mining techniques and tools are also particularly important for providing scalable solutions that include models or ontologies modeled from large volumes of content. It is not feasible to analyze thousands or millions of documents to produce ontologies. Text mining technologies can utilize statistics, graphs, ranks and other representations that support the knowledge engineer in the construction of complex models, like ontologies, conceptual graphs and mind maps. However, compared to modeling exclusively based on semantics, pragmatic aspects introduce additional complexity that need to be faced.

5 CONCLUSIONS

Collaborative problem solving in SNS can potentially produce a huge amount of complex information. This information is of great value, for example to users in the context of continuous learning who want to recover information about past problems. However, the correct recovery and understanding of this information is influenced by pragmatic aspects that evolve over time. These aspects have a dynamic nature, and involve the examination of the intentions in the discussions, which is a complex issue.

In this paper, we presented a study of problem solving processes carried out in SNSs. The results pointed out new interaction possibilities, but also requirements for future research in related areas. The research needs were translated into a preliminary research framework structured in three perspectives: interactive, conceptual and computational. This framework indicates that novel approaches are necessary for dealing with the dynamic aspects of knowledge in these systems. Moreover, we stressed the importance of providing solutions that are able to conceptually and computationally articulate semantics and pragmatics as an integrated process over time. These solutions may demand, for example, studies in Organizational Semiotics and new KE and KV techniques.

We hope that this preliminary research framework contributes with ideas towards facilitating meaningful Web-mediated interactions. Further work involves gathering more empirical data to test and refine the analysis method, coping with the challenges described in the previous sections, and investigating novel KV and KE methods based on the background disciplines.

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