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Recognizing Community Interaction States in Discussion Forum Evolution

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Abstract

The web forum is a key tool in the building of new knowledge among students in Learning Management Systems. Students' posted messages, in fact, build up a relationship network which supports a collaborative reflection about the forum topic. In this network two interaction levels can be distinguished. The former is the interaction between peers (the students), the latter between students and instructors (teachers and tutors). The role of the second interaction is particularly important as a feedback mechanism in the discussion dynamic but it is subjected to two kinds of limitations. The first one is the huge number of messages that makes difficult, for tutors and teachers, to quickly evaluate the progress of their students and the second one is the subjective bias of the tutors that influence the evaluation. In order to limit these two inefficiencies a multiagent system can be used to monitor such evolution and recognize the state in which the forum is. Such system is based on metrics derived from the textual and social network analysis that, feeding a rule engine, gives the instructor a more objective view of the forum evolution.

Introduction

The web forum is a tool where opinions about some topics of common interest are shared between peers. In Learning Management System (LMS), according to a constructivist view of learning (Jonassen et al. 1999 and Scardamalia and Bereiter 1994), the forum is the place where new knowledge is built among students.

Students' opinions, in fact, build up a relationship network which supports a collaborative reflection about the discussed topic. Such process is not spontaneous but must be catalyzed by the external intervention of the tutor that posts the seminal message, promotes valuable arguments, closes off unproductive discussion and so on (Salmon 2000). In order to enhance the efficacy of the tutor's action the forum evolution must be monitored. Unfortunately, the huge number of messages and the tutor's subjectivity makes difficult to correctly evaluate such process. An automated support is needed.

Supporting the tutor can be done in many different ways. Many systems (Barros and Verdejo 2000, de los Angeles Constantino-Gonzalez et al. 2003 and Israel and Aiken 2007) are based on metrics that model the interaction in the discussion. On the other hand, a linguistic oriented analysis, in order to analyze the evolution of collaboration, is adopted (Rosé et al. 2008). Our approach, instead, is based on metrics, inspired by the textual analysis and social network analysis, that describe the forum in terms of global vocabulary evolution and users' commitment (Rossi et al. 2008).

More precisely, such evolution can be seen as a succession of different phases where the discussion productiveness changes. The very idea is to use quantitatively metrics in order to measure the necessary conditions characterizing each phase. In this way, a rules engine checks the indices and suggests the tutor the phase in which the forum probably is; i.e. the students are discussing together or have simply posted a message to answer to the tutor's seminal message.

Forum model

A discussion forum can be seen as a virtual place where a community of users interacts posting messages. The system evolves as the number of messages grows.

It starts from an equilibrium state where no messages are posted. Then, when the first message is posted, a discussion thread begins and the system goes through a disequilibrium state where the community interacts answering to the initial message and to the following ones. When no more messages are appended to the discussion thread, since nobody has anything more to say, the system reaches a new equilibrium state.

More precisely five main phases can be identified. First of all there's an initial phase where no message are posted. Then it follows a starting phase where the users begin to answer to the initial message of the thread. In this phase the number of messages is comparable with the number of the new users that post for the first time in the thread. Finally, the discussion begins and the number of messages and new relations abruptly rise up (discussion phase). Such phase can evolve in two really different ways. The first one is a consolidation phase. In this case the discussion became more specialized and is carried on inside a clique of users. So it is characterized by a lot of new messages and few new relationships. The second one is a starving phase. It can happen because the forum has reached the final state or the community is not interested in discussing the proposed topic; anyway, the tutor should act in order to close definitively the discussion or to stimulate it. Obviously, the starving phase can follows the consolidation phase too.

In order to track such process the forum evolution is modeled as finite states automaton where the states correspond to the phases described above and the transition between them are based on the changes of global parameters. It is worth to noting that automaton states differentiate from the forum phases because are based on necessary conditions. In this way the rules engine simply suggests the tutors that the conditions, observed during many years analysis and related to a particular state, are satisfied. Such conditions are written in terms of metrics that describe users' commitment and the vocabulary evolution in the forum.

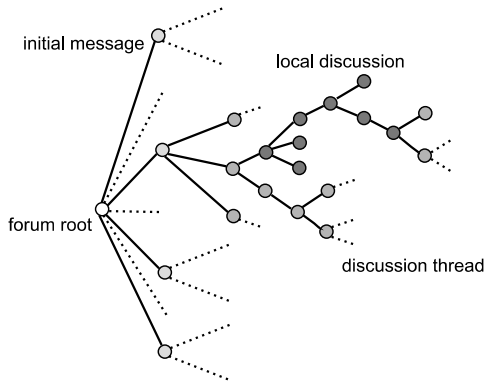

Figure 1: Forum structure and definitions.

According to the dynamic nature of forum two kinds of measures are used: cumulative (from day 0 to day t) and punctual (just in day t). In order to simplify notation, punctual measures are expressed in lower-case letters while cumulative in upper-case. For instance, said $M(t)$ the set of messages posted up to day t and $|M(t)|$ its cardinality, the set of new messages posted just in that day is m(t). The generic message is said m. The following relationship holds:

$$|m(t)| = |M(t)| - |M(t-1)| \qquad (1)$$

Generally speaking, a web forum is a collection of messages M written by a set of users U and disposed in discussion threads T in a tree like disposition consisting in an initial message, the messages answering to it, the subsequent messages and so on.

A message is a ordered sequence of word-token. A word-token is a delimited string of character and its set is called N. A set of word-tokens equal among them are the instances of a word-type. The set of word-types is the forum vocabulary V. The vocabulary can be partioned in subsets V_n where n is the number of occurrences of the word-types belonging to it (e.g. V_4 is the set of word-types occurring only four times in the forum). Particularly interesting is the set of halomorphemes (also known as hapax legomena or hapax for short) V_1, i.e. the word-types occurring only once. Moreover, sequences of word-tokens delimited by periods are called sentences. The set of sentences of the generic message m is said s_m.

Because a corpus of documents and web forum are very different objects, some basic assumptions must be made to bridge the gap between them. The main assumption it is the correspondence between the text in a corpus and the discussion thread in a forum. The next assumption is the partial correspondence between fragments in a text and messages in a thread. With this two assumptions is possible to extend the text analysis tool to the web forum analysis.

The connection with social network analysis is more straightforward. When a user i answers to the message posted by the user j a new relationship r_{ij} is considered born. More formally, the generic r_{ij} element of the matrix R is the number of messages that i answers to the message of j. The number of elements of R greater than zero is said R_+.

Adopted indices and status analysis

The indices used by the rules engine to detect the current status and guess possible trends in the forum evolution rely on indices derived from textual analysis and social network analysis.

The behavior of such indices were studied in the context of 26 forums belonging to the LMS adopted by four faculties of the University of Macerata with 1200 online students (Accorroni and Bentivoglio 2009). Every observed behavior further reported will be referred to such analysis. The regularity of numerical results and the corresponding subjective judgment of the tutors help us to identify the necessary conditions to evaluate the forum status.

The first group of indices are global lexical parameter that should help the instructors to have a global view of the forum vocabulary evolution. This strategy, in fact, is based on the hypothesis that the vocabulary evolution reflects indirectly more complex phenomena such users' commitment and the birth of a common conceptual space. The first index is related to the lexical extension L. It is defined as:

$$L(t) = \frac{|V(t)|}{|N(t)|} \cdot 100 \qquad (2)$$

Such index is useful to detect the maturity level of discussion. In fact, it has been observed that, when the index drop down and begin to get closer to the equilibrium value, the discussion phase begins to start. Since for large forum such value it is around 15.25% (2,47 standard deviation) the threshold value can be identified around 20%.

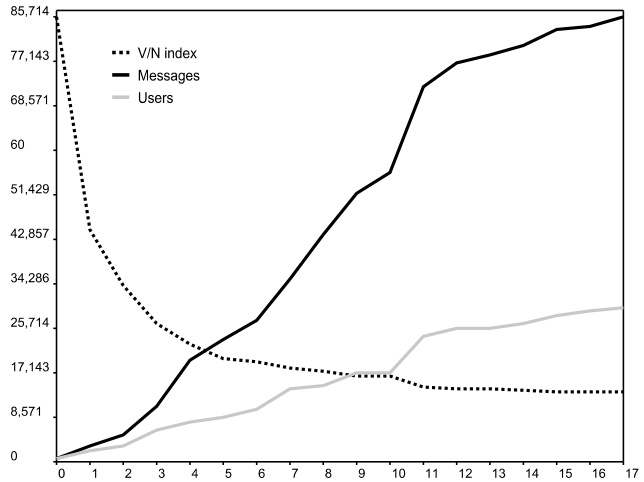

Figure 2: The V/N index or lexical extension.

Another necessary condition for the transition between the starting phase and the discussion phase is the presence of messages answering to student's messages and not only to the initial message posted by the tutor. Such condition is simply tested verifying that the number of posted messages is greater than the number of users:

$$|M(t)| > |U(t)| \tag{3}$$

This seems to be counterintuitive because we would expect a condition based on a check over the messages tree: i.e. checking the presence of a message responding to a message responding to the initial message. The problem of this last approach relies on the observed tendency that students, instead of the more natural respond-to-this-message option, open a new thread to post an answering message. The proposed approach tries to take in account the scarce attention and inexperience of students in their first (and, often, not only first) approach to e-learning.

The transition towards the consolidation phase involves a simpler message structure and a more accentuated ratio between new messages and new relationship: i.e. users prefer to send message always to the same group of people instead to make new relationships.

In order to capture the first property a second group of indices, related to the message characteristic in terms of structural complexity, are proposed. The first index is the average number of word per sentences at day *t*. It is computed making the ratio between the overall number of word-tokens and the overall number of sentences in the forum contained in the message posted in the day *t* and, formally, defined as:

$$n_s(t) = \frac{|n(t)|}{\sum_{i=1}^{|m(t)|} |s_i(t)|} \tag{3}$$

Because the number of word-tokens are usually a necessary condition for the syntactic complexity of a sentence the n_s index is designed to show the degree of such characteristic. In fact, if the value is high, the sentence generally shows a more complex and argumentative linguistic structure. The second index is the average number of words per message. It's simply defined as the ratio between the overall number of word-tokens and the messages in the forum:

$$n_m(t) = \frac{|n(t)|}{|m(t)|} \tag{4}$$

The last one is the average number of sentences per messages and it is defined as:

$$s_m(t) = \frac{\sum_{i=1}^{|m(t)|} |s_i(t)|}{|m(t)|} \tag{5}$$

In particular, the s_m index tendency to decrease, when the analyzed forums reaches the consolidation phase, was clearly observed.

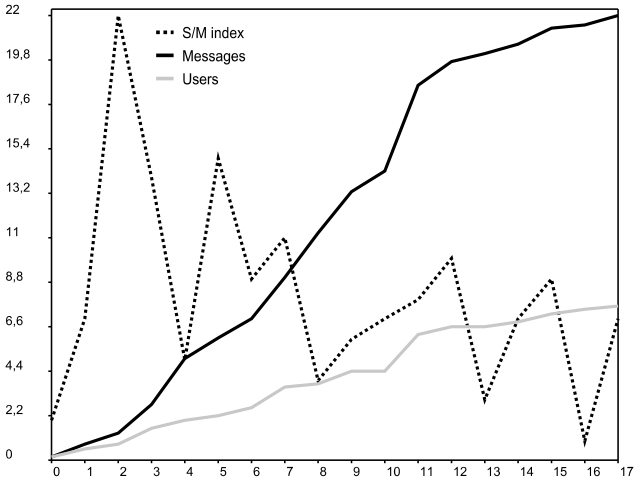

Figure 3: S_m index behavior.

In fact, albeit such index tends to have a quite erratic behavior, its envelope tends to decrease in time if the forum approaches a consolidation phase. More precisely it enters in a well identified oscillation band whose range is between 3 and 10 sentences per messages. In order to avoid such annoying behavior a smoothing function, consisting in a three days moving average (said s_{3m}), is applied. The resulting value is evaluated by the rules engine.

Another possibility is to face directly the users' commitment in the forum. The first indices are the user number and the message number. Their cumulative

distributions in time, when compared together, are a possible indicator of the current phase in which the forum could be. If the messages per user is growing probably the forum is far from the starting phase or the starving phase. Anyway, the analysis can be smarter. The previous indicator tells us that a discussion has begun but they said nothing about the quality of the discussion from a relational point of view.

In fact, fixed the number of messages that a user can post, a student can behave in two ways: it can answer to a lot of different students (making a lot of relationships) or concentrate the discussion with a limited number of peers. Actually, it ha been observed that such behavior generally changes over the time. In the first part of the discussion phase the number of relations grows then, when the social relationship are well established, the messages begin to be exchanged only in restricted groups and, as observed, the quality of the discussion get higher; the forum enters the consolidation phase.

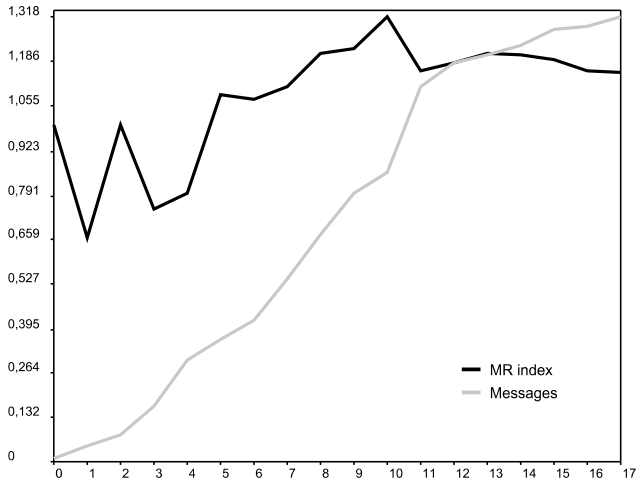

Figure 4: MR index behavior.

In order to track this process and identify the prevalence of one behavior over the other the message-relationship ratio can be used. The index is the ratio between the number of messages posted to people that are yet in the clique, difference between the total messages and messages that build new relationship, and the number of users. More formally the $MR(t)$ index is defined in this way:

$$MR(t) = \frac{|M(t)| - R_{+}}{|U(t)|} \qquad (6)$$

Generally, in the initial phase of the forum, the *MR* index drops because students must build their relationship network instead of making deeper discussion. Then, albeit R_{+} continues to grow, *MR* rises on (or becomes stable) because the students begin to exchange messages with the same people. In this way, the level reached by the *MR* is a quantitative index of the relationship that a generic student has with his clique. More precisely, it is the average number of messages that a student exchanges with people that has already met in the forum.

The necessary condition for the transition from the discussion phase to the consolidation phase are identified in the decreasing of number of sentence per message to 10 sentences and, at the same time, in the threshold of one message exchanged in the clique per student. Again, we would expect a greater number of messages exchanged on average in such phase. However, two observed behaviors justify empirically such value. The first one is that students post a very few message on average (in order of three messages) so the consolidation phase relies on few active person and the average of *MR* index tends to be lower as we expected. The second one is the fact that, according to observations, such value helps effectively to identify the transition between the two phases.

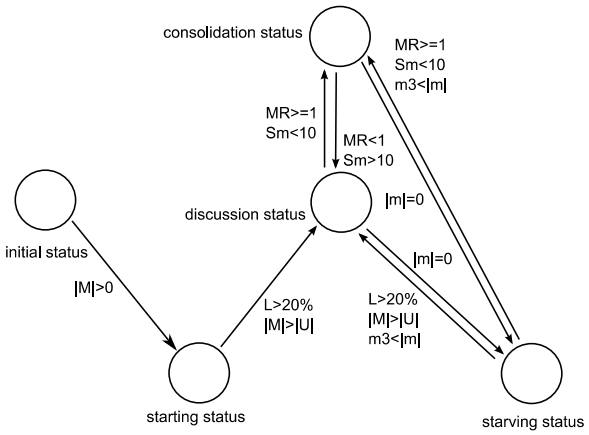

Figure 5: Finite state automaton used to detect forum status

The starving state is reached when, from the discussion or consolidation state, the number of daily messages is zero. If the parameters assume values compatible with the discussion (or consolidation) state and the three days moving average of daily message is lower than the current number of daily messages, the starving state is interpreted as a momentary pause in the community and the automaton comes back to one of the active states. If such conditions are not satisfied the forum is considered still in the starving state.

Message trend analysis

Along with the status analysis, a message trend analysis is performed. It has been noted, especially when the number of messages is huge that is difficult to understand at glance the real messages posting dynamics. Knowing such dynamics is a good feedback for tutors in order to evaluate their actions or to understand where the forum is going to be; i.e. if the messages are constantly decreasing it can be interpreted by the tutor as a tendency to reach the starving phase.

A short term analysis simply highlights if the messages number is increasing or decreasing respect the previous day. A medium term analysis compares the current number

of messages with a three day moving average. In this way it is possible to identify a change in the trend. Such results are taken together in account to make a message trend estimate.

Forum status description generation

The visual inspection of the indices plots are quite useful in parameter tuning but quite unpractical for tutors, so a different strategy has been adopted. Along with the graphical representation, a report in natural language is displayed. Such report is built by an agent in order to give information about the current status of the forum and the trend of messages number. Moreover, the messages are built in order to distinguish if the forum has changed from one state to another or is still in that state. In this way, a sort of short term memory is simulated in the agent and a richer interaction is achieved with the tutor.

Formally, the message is composed according to the following structure expressed in extended Backus-Naur form:

```
message      = forum_status [conj , msgs_trend ] ;
forum_status = init | init2start | start | start2discussion |
               discussion | discussion2consolidation |
               consolidation | starving ;
conj         = and | but | in_fact | moreover ;
msgs_trend   = up_trend | down_trend | inc | dec |
               no_msgs ;
```

The terminal symbols are translated according to the available languages; for instance:

```
init2start   = "The forum entered the starting
               phase ";
dec          = " the number of messages is
               decreasing";
in_fact      = "in fact";
```

As example, a message like "The forum entered the starting phase and the number of message are increasing" tells the tutor about the fact that students have begun to post the messages in the forum with a great effort. On the other hand, a message like "The forum is in the consolidation phase but there is a clear downtrend of message posting" alerts the tutor that the interest of students about the topic is decreasing.

Applications

The described rules engine is implemented in the context of a multiagent system based on the JADE framework (Bellifemine, Poggi and Rimassa 2000). More precisely, the system activates different kind of agents to monitor a different aspects of the LMS: e.g. for every user a personal agent monitor the user's behavior in real time or, in this case, an agent, on the basis of a daily scheduled plan, performs the forum analysis and store the result in a journal. The resulting data are displayed by the tutor on a personalized panel in form of graphic plot and verbal description.

From a technological point of view the multiagent system is not integrated with the LMS but resides on a different machine, or cluster, and communicates with the LMS via web services. Results are received by the LMS in the same manner and displayed according the adopted strategy. This architecture permits to optimize the computational effort and make the system LMS independent.

The feedback from tutors, with the enhancement given by the verbal description, is rather good. Interpreting the forum status by visual inspection only, in fact, was very difficult for someone. Moreover, such description saves a lot of time spent in comparing the different parameters among them.

Conclusion and future direction

Despite the forum characteristics are not always ideal for a statistical text analysis, our approach is giving promising results to support the tutors in their effort. Anyway, several issues must be covered in the future.

The first one is a deeper integration between textual and social aspects of the forum. In this way the user's commitment and the evolution of the vocabulary can be better analyzed.

The second one is the possibility for tutor to modify the rule of the engine. This has not yet done because it is planned in the context of a larger system which tracks all the activity in the LMS and not only in the forum. So, the system developed for the forum is a step towards a more general and powerful architecture.

The last one, clearly descending from a broader monitor system is the integration with the student's profiling. According to this strategies, the value reported by the developed metrics and the detected status can be used to feed a personal agent who interacts with the student as a chat-bot. This is an interesting perspective because the human tutor's approach was mainly direct towards the community as a whole while the software agent's approach is more individual oriented.

For instance, if the student's behavior can be interpreted as excessively solipsistic, the agent can help him to take awareness of this supposed condition according to the current state of the forum. In this way, the agent action is modulated according to the user's behavior and to the community's behavior. The result is a more effectiveness in the interaction with the user.

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