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Abstract

Online discussions are popular in virtual classrooms since they provide students with opportunities for more effective interactions than possible in traditional classrooms. However, grading online discussions is well-known to be a time-consuming task. In this paper, we propose a method for automating the partial grading of online discussions using social network analysis techniques. In particular, we propose to use a centrality index, which reflects the number of responses to a student's messages as a proxy measure to evaluate the quality of students' posts and hence determine participation levels in discussions. The method was tested for grading discussion board assignments in a virtual class from an online graduate school. Although, the method was found to perform quite well in a range of situations, its use is advocated mainly as a grading aid because in certain conditions inaccurate grades may result. Furthermore, use of the tool can also be envisaged for improving performance levels in online discussions because of its potential as facilitation and motivational aids.

Keywords

Social network analysis, online discussion, asynchronous communication, constructivism, social learning, virtual classroom

INTRODUCTION

Today's educational arena is characterised by multiple delivery formats ranging from traditional face-to-face classes, to mixed (or blended) face-to-face and online classes, and fully online classes. Online or virtual classes use a variety of communication methods which can be classified as synchronous or asynchronous communication tools. Broadly speaking, synchronous communication implies real-time (or same time) communication between the sender of a message and the recipients while asynchronous communication does not. Examples of synchronous communication tools used in virtual classrooms include: instant messaging (chat), voice over IP (VoIP), video broadcasting, virtual blackboard, etc while asynchronous communication include: online threaded discussion, interactive lessons, video clips, email, blogs, etc.

Virtual classrooms, especially those that are fully online and utilise asynchronous learning tools, are convenient because of the promise of "anyplace and anytime class", and this is probably the main reason why students sign-up for these classes. However, convenience should not be the only factor to be considered when enrolling in virtual classes, as they have the potential to accommodate most learning styles and hence generate better learning outcomes when compared to traditional classes. Furthermore, virtual classes can enhance students' understanding of complex materials via multiple representation of information delivered in visual, interactive experiential and/or participatory techniques instead of the single format of lectures (Thomas 2003).

Online threaded discussions are a popular form of computer-supported collaborative learning (CSCL) in virtual classrooms because they provide students with the opportunity of more effective interactions and participations than in traditional classrooms (Lipponen et al. 2003). Hence, online discussions are considered as the foundation of virtual classrooms (Goldberg, Vroeginday & Burke 2007).

Online discussions provide the means to implement the constructivist view of learning in which learners construct their own knowledge by actively adapting and modifying their "experience of the world". Cobb (1994) identified two contrasting forms of constructivism: cognitive constructivism based on Piaget's genetic epistemology (1970; 1980) and social constructivism based on Vygotsky's social development theory (1978). Cognitive constructivism emphasises the "construction" aspect while social constructivism emphasises the

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"social interaction" aspect, and they both share many common perspectives about teaching and learning, namely active development of cognitive skills rather than passive reception of knowledge.

Although, online discussions support both forms of constructivism, the potential for social constructivism is greatest due to the interaction inherent in discourse. However, despite all the positive aspects of online discussions, numerous disadvantages exist, namely (Guan, Tsai & Hwang 2006): (1) low levels of participation, (2) no real cooperative development of ideas between students, (3) difficulty to follow threaded discussion because of information overload, (4) absence of non-verbal cues such as gestures, facial expression, and tone of voice which may lead to misunderstanding, (5) not beneficial to those who cannot write, and (6) slow progress of discussion because of the need to wait for responses from others or questions are never answered. Thus, whether online discussions facilitate learning is controversial and widely debated (Guan, Tsai & Hwang 2006; Lipponen et al. 2003).

The factors affecting the role of online discussions in facilitating learning are complex as the quality of discussions can be influenced by a range of factors such as: (1) characteristics of participants, (2) characteristics of discussion topics, (3) purpose, design and organisation of the discussions, (4) and characteristics of the facilitator coordinating the discussions. Quantitative and qualitative analyses have been undertaken by researchers mainly to understand the nature of online discussions to find out how to best design them, and methods used include (Dennen 2008): (1) participation measures (to find out who participated and how many times), content analysis (to discover major concerns and topics of discussion), structural analysis (use of social network analysis and sequential analysis to discover structure), micro-ethnography (use of extensive data collected by means of surveys and interviews to provide a description of the discussion and the contextual surrounding) and dialogue analysis (use of details to examine context, complexity and inter-relatedness of messages).

In addition to research on understanding the effect of online discussions on the facilitation of learning, there is also a need to undertake research to find simple and objective ways for grading online discussions. When online discussions are a mandatory component of a virtual class, assessing the quality of students' contributions can be quite time consuming. Assessing students' contributions in terms of number of messages posted can be misleading because of the complimentary nature of some messages. In addition to summative evaluations (assessment of what has been posted), a useful grading tool should also provide formative feedback (how to improve) to students.

In this study, we propose to use social network analysis (SNA), a sociological approach for investigating social structures, for assessing the quality of students' contributions in online discussions for grading purposes. Our aim is not to use SNA for an in-depth qualitative assessment of online discussions as SNA is too structured and organised to capture the nuances of the contents of posted messages (Dennen 2008), and hence cannot be used by itself as a complete and fully-automated grading tool. Instead, we propose to use it as a simple proxy measure of students' participation (in terms of quality of contributions), to be used in conjunction with other manual grading methods, in order to assist the grading process in terms of objectivity and speed.

RELATED WORK

Social Network Analysis (SNA) is a sociological approach for analysing patterns of relationships and interactions between social actors in order to discover underlying social structure such as: (1) central nodes that act as hubs, leaders or gatekeepers, (2) highly connected groups, and (3) patterns of interactions between groups (Wasserman & Faust 1994). SNA has emerged as a powerful approach for understanding how an individual's position in his/her social network influences a wide range of outcomes such as: job satisfaction, occupational mobility, job performance, leadership, power, coalition formation, and social influence (Wasserman & Faust 1994) .

SNA has been used to study social interaction in a wide range of domains. Examples include: collaboration networks (Acedo et al. 2006; Newman 2001; Otte & Rousseau 2002), directors of companies (Davis & Greve 1997; Davis, Yoo & Baker 2003), organisational behaviour (Borgatti & Foster 2003), inter-organisational relations (Stuart 1998), computer-mediated communications (Garton, Haythornthwaite & Wellman 1999), innovation networks (Gloor et al. 2008), creativity of new product development teams (Leenders, Kratzer & Van Engelen 2007), cigarette smoking (Hall & Valente 2007), health informatics (Anderson 2002), business process performance (Hassan 2009), terrorist networks (Yang 2008), and many others.

In the field of education, SNA has been used to study various areas such as: classroom interactions (Martínez et al. 2003), team performance in information system development classes (Yang & Tang 2004), etc. In the area of online discussions, there have also been numerous studies and some of them that are related to our work in one way or another are discussed next.

One of the earliest attempts to evaluate online discussion threads using SNA was the work of Saltz et al. (2004). They suggested the use of "student social graphs" to better understand students' interactions with a web-based course. Rather than using a count of the number of messages posted by the student, they proposed to use the student's centrality measure for grading participation. They developed a prototype system which extracted the data from the discussion threads and used the extracted data for visualisation purposes. Saltz et al. only hypothesised that a centrality measure would be a better measure of participation since they did not actually test the proposed measure in an online class setting.

Russo and Koesten (2005) used SNA to understand interaction and learning outcomes in online classes. In particular, they analysed discussion threads and the results of a survey to find out the relationship between network characteristics and two learning outcomes: affective learning (attitudes students develop about the course, the topic and the instructor) and cognitive learning (comprehension and retention of knowledge). Although cognitive learning was found to be related to network factors, this was not the case with affective learning.

Based on a extensive review of assessment methods of discussion boards and cognitive learning, a multidimensional metric was developed that included 12 key areas, namely (1) social learning, (2) cognitive processing, (3) quality of discussion, (4) initial question, (5) role of educator, (6) navigation, (7) challenges for students, (8) types of users, (9) attitudes towards discussion, (10) response time, (11) learning outside of school, and (12) learning performance (Kay 2006). Although this is a very comprehensive theory-driven metric that has wide applications for grading online discussions in general, its application in our context (explained later) is limited due to the data-hungry nature of the metric. Data are required from several sources such as: discussion boards, statistical data accumulated by the learning management system, and attitude surveys conducted at the end of each topic.

Other studies that are related to online discussions include: (1) investigation of the nature of online discussions using content analysis to formulate guidelines for developing better discussion forums and improving learning (Guan, Tsai & Hwang 2006), (2) developing a new classifier for online discussions (Feng et al. 2006), (3) developing an integrated tool that uses SNA, content analysis and text mining for analyzing peer interactions (Li & Huang 2008), (4) investigation of peer facilitation techniques (Hew & Cheung 2008), and (5) analysis of social networks emerging from user comment activities which have more complex structures than friendship and affiliation networks (Gómez, Kaltenbrunner & López 2008).

Apart from the work of Saltz et al. (2004), whose work is closely related to what we propose to do, all others are different. Hence, we propose to further extend their work by verifying the robustness of their proposed metric for assessing participation levels in a number of online discussions in an actual virtual classroom.

METHOD

Virtual class

The virtual class under study was a graduate class on Database Management Systems and Applications taught in semester 1 2009 at an online graduate school headquartered in Singapore. The class was part of a fully-online Masters program in the management of Information Technology. The class consisted of 16 students (1 female and 15 males) who were geographically dispersed across the globe (Australia, Canada, Hong Kong, India, Japan, Malaysia, Singapore, South Africa, and United Arab Emirates). A highly customised version of WebCT, a Learning Management System, was used to organise course materials and enable students to access them from their home or work locations. Course materials were organised as nine segments (or topics) covering a range of major database concepts and areas.

Assessment consisted of three online discussion board (DB) assignments each worth 10% of the total subject marks, two team project assignments worth 20% and 25% of subject marks and a final examination worth 25% of subject marks. DB assignments were due after every 4 weeks (i.e. in weeks 5, 9, and 12) of the course. In order to perform a DB assignment, students were expected to: (1) read the assigned course materials for the 4-week period, (2) post their answers to specific questions selected by the Professor Facilitator on the DB, (3) read the posts of their peers and post comments on the DB, and (4) post a reflective summary on the key contributions of their work.

The class was led by a Professor Facilitator whose role is to: (1) select the topics for discussions, (2) select the assignments, (3) write the final examination paper, (4) facilitate the online discussions, (5) grade all assessment components, and (6) answer any academically-related query students may have. When facilitating online discussions, the role of the Professor Facilitator is to provide encouragement and hints (rather than give answers to students), and ensure that discussions do not go off topic (which occurs very rarely in practice in these virtual classrooms).

The object of interest in this study is the DB assignment, more particularly how to facilitate the grading of the DB assignment since a large class (class size vary from 15 to 40 students) can generate a very large number of messages and hence grading can be quite a daunting task. In the online graduate school, the grading of DB assignments is based on three criteria: (1) reflective insight (how well key issues and concepts are summarised and hence understood), (2) quality of contribution, and (3) activeness (extent of participation in discussions and contributions to peer learning).

Proposed measure of participation

It is obvious that SNA cannot be used to grade criteria 1 and 2 (reflective insight and quality of contribution) since these two criteria can only be assessed by a human being who must read the reflective summaries and the answers to the questions posed in the DB exercises on a student-by-student basis. Thus, we propose to use SNA to grade only criteria 3 i.e. the extent to which the student has been an active participant in the discussions. Although, the participation of the student is determined to a large extent by the number of posts made by the student (the greater the number of posts, the more active the student), common sense dictates that complimentary messages (e.g. "Thank you for …") and other messages of low value ("I agree …") should be discounted from the participation or activeness grade. The problem to be solved then amounts to detecting these low-value superficial posts made by students.

A simple way to detect superficial posts is to measure the reaction of other students in the class. In general, the following assumptions can be made about student responses: (1) if the message is a compliment or an "I agree" message, then most probably no one will respond to that message, and (2) students will respond to messages when they have something to add to what was said, or they disagree, or they require further clarification, etc. Based on these assumptions, we hypothesize that the more responses a student obtains for his/her posts, the more active the student is.

Given the current setting discussion setting (i.e. mandatory component of the class, students post their answers to specific questions on the DB, and students respond by posting their comments on the posts of their peers), it is appropriate to represent the network as a directed network since when student B responds to student A, the relationship is only from B to A and not vice-versa as well. In such a situation, an appropriate SNA measure to gauge activeness is the *prestige* of the student as measured by the *inDegree* centrality index which reflects the number of arcs terminating at the student's message (i.e. number of responses to the student's message). Thus, our hypothesis is re-stated as: the higher the *inDegree* index, the more active the student is.

SNA provides other measures of centrality (such as *outDegree*, *closeness*, *betweenness*, *eigenvector*, etc) and it is quite common to use several of these measures (and may be combine them to obtain an aggregate measure) depending on the objective of the research. However, in our study, the only relevant measure is the *inDegree* index; all the other centrality measures are not justified as we are only measuring the number of responses a student obtained. For a detailed description of these centrality measures, the reader is referred to Wasserman & Faust (1994).

Our hypothesis is inspired by the work of Saltz, Hiltz & Turoff (2004) who suggested the idea but they did not test it empirically. In this study, we take their work one step further by testing the hypothesis in an actual virtual classroom. Only qualitative tests can be performed, since the only type of test that can be done is to check for each student whether their centrality measure (prestige in this case) reflects the "value" of the content of their posts.

Online discussion data

For each DB assignment, online discussion data were copied from the HTML pages in the WebCT learning management system and pasted to an Excel spreadsheet. The contents of the spreadsheet were copied and pasted as values only to another spreadsheet to capture the tree-like structure of the discussion threads in columnar format. The resulting Excel spreadsheet was further manipulated by deleting all rows (messages) that were not relevant to the assignment in question. A custom-written Java program was used to process the tree-like data in the spreadsheet to output student pairs (i.e. the names of the originator and responder of message) on a message-by-message basis. In case there was more than one response to a message, several student pairs were generated. Another custom-written Java program was used to convert the list of student pairs into a network file according to the DL format for further processing by UCINet (Borgatti, Everett & Freeman 2002), the software used for most of the social network analysis in this study.

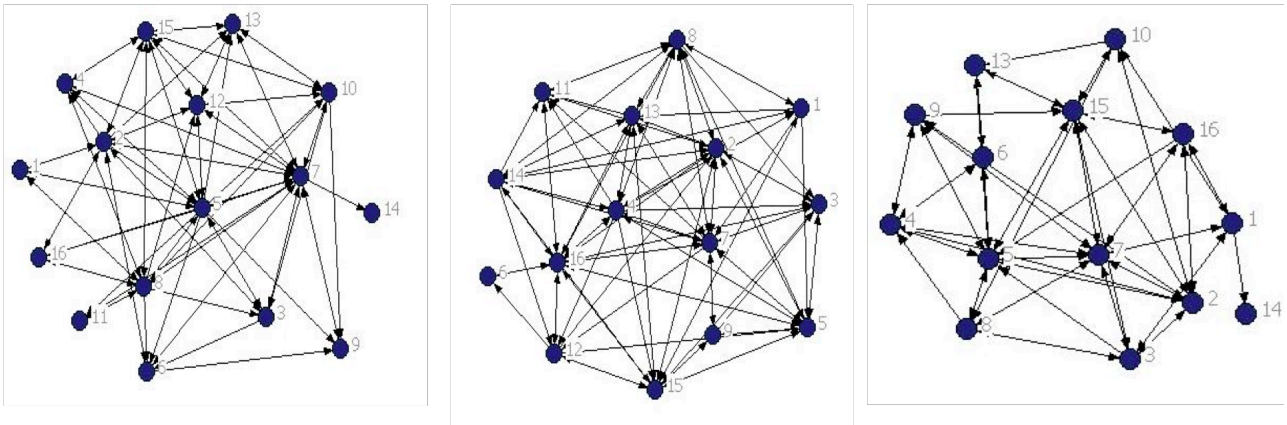
In terms of data cleaning, not much was required as student names and their messages could be unambiguously identified. The only form of data cleaning done was to exclude all messages originating from the instructor in the data and reverse the direction of the arcs so that they are from respondents to originators of messages (rather than from originators to respondents as was the case when processed in the manner described above).

RESULTS

The number of messages posted and responses received (*inDegree* or *prestige* index as computed by UCINet) per student for each of the three DB assignments in the virtual course are shown in Table 1. Student names have been replaced by numbers so that they cannot be identified. Results are sorted by *inDegree* and number of messages posted in descending order so that very active students are displayed in the top rows while less active ones are shown at the bottom of the table. Messages posted by students can be categorised into two groups: mandatory messages (answers to questions asked in DB exercises, and reflective summaries) and optional messages in response to messages posted by the class. DB assignment 1 required 6 mandatory posts (answers to 5 questions and the reflective summary), while DB assignment 2 required 3 mandatory posts (answers to 2 questions and the reflective summary), and DB assignment 3 required 4 mandatory posts (answers to 3 questions and the reflective summary).

Table 1: DB assignments results

DB assignment 1			DB assignment 2			DB assignment 3		
Student #	Num posts	inDegree	Student #	Num posts	inDegree	Student #	Num posts	inDegree
7	64	52	7	40	26	7	26	30
2	39	18	16	38	26	15	26	26
6	21	15	2	23	24	5	28	21
12	17	15	3	8	21	2	20	14
16	27	14	5	16	18	3	16	11
5	32	11	8	20	14	8	10	9
8	23	11	4	20	13	4	5	9
3	19	11	15	12	12	9	7	6
13	19	11	14	13	11	16	9	5
4	18	11	13	6	11	13	6	5
15	21	10	11	3	10	1	10	4
9	11	10	9	5	6	6	4	4
10	13	5	12	5	5	10	3	3
11	7	3	1	7	4	14	0	1
1	13	2	6	2	4	11	1	0
14	7	1	10	0	0	12	0	0
Median	19	11		10	11.5		8	5.5



(a) DB Assignment 1 (b) DB Assignment 2 (c) DB Assignment 3

Figure 1: Social networks

Figure 1 consists of three graphs (sociograms created using NetDraw) containing similar information to Table 1 (except for the number of posts which is missing), but in visual form. The nodes of the sociograms represent students (the same numbers are used to identify students in the graph and the table) while the arcs represent communications (responses) between students, with the direction of arrows representing the direction of

communication. For example, in DB assignment 1, student 14 (located at the right middle part of the first sociogram) received only one response which came from student 7. This information can be verified to be correct as it is in accordance with the last row of DB assignment 1 of Table 1 which contains the details of student 14 (the table does not show originators of messages).

After having computed the *inDegree* index of students, we verified the suitability of this index for the purpose of assessing the level of students' participation on the discussion boards by reading and responding to messages posted (and received) on a student-by-student basis in order to determine its general acceptance. Due to space limitations, we will discuss only key cases encountered during the verification process.

For DB assignment 1, students had to post a minimum of 6 messages, 5 answers to questions asked for the assignment and a reflective summary. Based on a simple quantitative measure (i.e. number of messages posted), student 14 can be identified as the worst performer in the bottom row of Table 1 as the student posted only 7 messages (6 of which were mandatory responses). The proposed qualitative measure (*inDegree* index or number of responses received) also identifies the student as the worst student as he/she obtained only 1 response and hence the justification for an index of 1. This is a straightforward case where both the quantitative and qualitative measures demonstrate the low level participation of the student.

An interesting case is that of student 1 (second last row of the table). Based on a quantitative measure, he/she would have obtained quite a high score as 13 messages were posted. However, using the proposed qualitative measure, an unusually low index of 2 was determined. This is because only 2 students responded to his/her posts (as can be seen from the table and the sociogram). An examination of the contents of his/her messages, more especially his/her responses to other students revealed the low content of these messages and hence the low index is justified. Examples are: "Sorry …" (3 times), "Thanks" (2 times). The last message was empty (may be by accident). This case shows clearly that it would be erroneous to grade a student's participation performance in online discussions based only on the number of posts made by the student.

Although both students 1 and 11 posted 7 messages each, student 11 obtained more responses than student 1 and hence was given an index of 3 because of more substantial and better quality posts than student 1. This is another example in favour of the proposed qualitative measure for grading.

Without getting into the repetitive and lengthy details of the verification process performed on a student-by-student and assignment-by-assignment basis, it was observed that in general, the *inDegree* index shows a positive linear relationship with the number of posts apart from a few exceptions. One exception is when messages of low content are posted and in such cases a lower score is computed than would be otherwise computed using solely the number of posts. This is a desirable situation as this is precisely the aim of the proposed measure of performance. However, there are also exceptions which are undesirable situations.

One undesirable exception occurs when a student posts incoherent and poorly explained messages which results into a large number of responses from other students seeking clarification. Although the student receives a high number of responses, the student is clearly not a good performer. Such a case was detected for student 9 in more than one assignment. In that case, relying solely on the proposed measure would be misleading.

Another undesirable exception was detected in the case of student 5 in assignment 1 since the student only received an index of 11 despite having posted a large number of messages (i.e. 32). Inspection of the contents of his/her messages found them to be of very high quality, but nevertheless the messages did not seem to provoke many responses from his/her peers. This seemed to be a puzzling situation as no apparent reason could be detected at first sight. However, closer examination revealed the reason to be the timing of the posts. Most of the messages were posted at the last minute, and since the assignment was over for most students, not many responses were made. Thus, although at first sight this seems to be an undesirable situation, it is in fact desirable as the student was penalised for timeliness.

DISCUSSION

Based on the results obtained, the method for measuring the level of students' participation in online discussion seems to be promising and hence could be implemented as a tool for automating that particular task. However, given the fact that under some circumstances, its use does not reflect the true level of participation, caution should be exercised not to base grading solely on the proposed method or tool. An appropriate way to use the method is as a guide for grading and overriding the score when justified.

Apart from providing summative feedback to students, another potential use of the tool is as a means for providing formative feedback to students so that they can improve their performance. For example, all along the entire duration of the assignment, students' scores could be automatically computed and displayed to students in real time so that they can find out their grades to motivate them to do better.

One of the factors affecting the level of students' participation in online discussions is the efficacy of the facilitation services provided by the facilitator or instructor (Rovai 2007). Thus, another potential use of a real-time tool could be as an aid for facilitating discussions. The tool can aid the facilitator in pinpointing less active students who can then be motivated to improve.

The tool is not without limitations. One of the problems with online discussions is that undesirable distractions can be caused due to inaccurate contributions or contributions that are unrelated to the main focus of the discussion. In our situation, this limitation is not an issue because: (1) the index is not meant to measure the accuracy of the responses since this is measured by another criterion, and (2) the reason for measuring the performance level is to encourage students to maintain a web presence and be active in discussions. However, in other situations, there might be a need to check if contributions are focused and productive. The proposed tool in its current state is unable to cope with such situations. Thus, in order generalise the application of the tool, more work needs to be undertaken in this direction in the future. Another limitation of the tool is that it has been tested in only one class. Its use needs to be extended to more classes across various disciplines to further verify its usefulness and find out if there are more conditions under which the use of the tool is not warranted.

CONCLUSION

We have proposed a method for using SNA techniques to automatically grade the level of participation in online discussions in a virtual classroom. The method was tested in a virtual class from an online graduate school across three discussion board assignments. In general, the method was found to be useful except for certain conditions where inaccurate results might be produced. Given this situation, more research needs to be undertaken to verify the accuracy of the method in a variety of classes and also to detect the conditions under which the method does not operate well. The usage of the tool can be viewed more as a grading aid for measuring participation levels rather than the replacement of a human grader. Furthermore, apart from its grading usefulness, another use of the tool is for improving participation levels through improved facilitation especially when used as a facilitation aid by the instructor to identify those students who are lagging behind as well as the motivation of students to do better when participation scores are displayed in real time.

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