A Visual Analytics Approach to Better Understand MOOC Forum Participation

ABSTRACT
MOOC, a novel form of distant learning, provides unprecedented research opportunities for exploring and understanding learning behaviors at large scale. Specifically, analyzing course forums is helpful for evaluating students’ feedback and their states of learning. Various related researches have been providing valuable findings. However, because of the complexity and specialty in most of the recent works, exploring students’ forum behaviors for their own courses is still non-trivial for general instructors. Thus, we present ForumTracker in this paper, to help glean insights intuitively in multiple dimensions. ForumTracker visualizes multifaceted characteristics of the forum, including both the temporal-based overall activeness and the student interactions, at different levels of details. It also enables filtering to sort out un-targeted groups. Case studies are conducted to demonstrate its usefulness. Deep insights into the learning behaviors are also reported.

ACM Classification Keywords

Author Keywords
Information Visualization; Forum Analysis; MOOCs.

INTRODUCTION
Massive Open Online Courses (MOOCs) are online courses that invite large numbers of students (on the order of thousands) to freely enroll. While MOOCs have been recognized for globalizing high-level education, their scalability makes it difficult for the large majority of students to participate in frequent and meaningful interactions with the instructors.

Forums have thus been implemented as the primary mode of interactions in MOOCs to compensate this drawback by encouraging students to seek help from peers. They would exchange their views, share resources and discuss assignments in forums. It has been suggested that an organized forum provides a sense of community and engagement [11], and that analyzing the posts in the forum could objectively reflect students’ learning features [25]. Therefore, various studies have covered analysis of student participation in MOOC forums, aiming at evaluating its correlations with student performances [6], engagements [18], etc.

However, most of these studies focus on particular aspects of forum participation. For instance, studies performing sentiment analysis may disregard social interactions involved. Besides, almost all of them are positioned as expertized analysis, i.e., researchers perform one-time analysis with specifically filtered data, targeted method and pre-determined mining patterns. Moreover, their complex models and statistical analysis constrain the readability of the results. These compromise the flexibility for online course instructors to reconstruct the methods for customized usage by themselves.

On the contrary, visualization is more beneficial in this case, since instructors could obtain hidden patterns by observing the visual displays. Currently, visual analysis for MOOCs (e.g., VisMOOC for user behavior analysis with clickstream visualization in [20]) has just emerged. While various systems have received positive feedback, few shed light on student behaviors in forums. How do students with different backgrounds or performances in a specific course engage in their studies? What kinds of opinions do the students hold about the course and do they change as the course progresses? And, from a social aspect, how do they interact with the others? These questions are essentially illustrating how students, apart from completing mandatory requirements (e.g., assignments which affect students’ grades), engage in the courses. They could help instructors revise their course designs to better fit student needs. For instance, if student sentiment levels decrease as the course evolves, the instructor may want to understand its causes (e.g., the introduction of controversial topics, ambiguous answers to some assignments, etc.), and reorganize the corresponding sections of the courses. However, due to the aforementioned complexity, specialty and pertinence, these questions remain unanswered for most of the general instructors.

This study is therefore proposed targeting at more comprehensive visual analysis of student forum participation. Specifically, we design ForumTracker, which evaluates how students with different demographic characteristics (i.e., their geographical information, course grades and forum reputation points) contribute in the forum on a temporal basis, and how they utilize this collaborative study channel to interact.

Our contributions could be summarized as the following:

- We implement ForumTracker, a new interactive visual design for MOOC forum analysis. It breaks away from the current convention of mere statistical analysis and makes the observations more intuitive. Moreover, its views are compatible for re-use and therefore provide easier exploration options to general users.
- We focus on comprehensively understanding student forum behaviors. By combining students’ time-oriented individual
behaviors and social interactions, we could more thoroughly grasp how students engage in the online interactions.

RELATED WORK
Our study draws on the forum analysis and visual analytic methods for MOOCs. The previous work is reviewed below.

MOOC Forum Analysis
Various work has been done analyzing student forum participation in MOOCs. One of the dominating branches is the characteristics of every individual’s posts. For instance, [18] used sentiment of student posts to predict their engagement and disengagement, and [24] took advantage of computational linguistic models to measure learners’ motivations and cognitive engagement from the text of posts. Wen et al. [25] also performed sentiment analysis in MOOC forums to monitor students’ trending opinions toward the course. Another interesting field is students’ behavioral differences and their correlations with the students’ performances. Cheng et al. [4] proved that students who voluntarily participated in forums achieved better exam grades and performed better overall. [11] studied superposter behaviors in MOOC forums, which discovered that superposters’ responses were speedier and received more up-votes than average, and that superposter activity was correlated positively and significantly with the forums’ overall activity and health. [17, 23] both demonstrated that students’ final grades were significantly related to the number of new posts they made to the online discussions. Besides, some work also concerns about the inter-student interactions. Ref-ray and Chanier [19] computed cohesion with social network analysis (SNA) to highlight isolated people, active sub-groups and various roles of the members in the group communication structure. [21] also processed SNA to identify students who were actively participating in course discussions and those who were potentially at the risk of dropping off.

We deal with both individual contributions and interactions in our work. While the work mentioned above all deliver convincing results, their statistical methods could be confusing for users with no technical background (e.g., humanity instructors may find papers using data mining techniques difficult to understand), and therefore may be too complicated to be re-used. In contrast, our work is more perceptually friendly, and therefore more suitable for general instructors.

Visual Analysis for E-learning
Various visual systems for e-learning have been designed for different purposes. For instance, Williams et al. [26] developed a narrative structure to visualize the access histories of the students, with the aim of supporting the development of personalized e-learning systems. E-learning tracking [10] demonstrated a set of (loosely coupled) visualization tools that helped display and analyze student interactions with online courseware. The study mainly focused on student access of the course materials, and the navigation path that a student followed throughout the course. SST [2] was an interactive visual tool for student temporal activity patterns. VisMOOC [20] worked as a visual analytic system to help analyze student video watching behaviors with clickstream data from MOOC platforms.

Besides these, there are also some works on students’ online communication activities. VISM [13] visualized the sequences of user interactions and subgroup formulations in a radial tree layout. Students in different levels of the radial tree showed the complexity of each thread, and the arrow between two nodes showed the direction of information flows. ViMoodle [1] presented both all the semantic content (e.g., discussions, subjects of forum posts, etc.) with world cloud, and a map of relationships and frequencies of activities among students and instructors with social network graph. However, there was no formal interaction embedded in either VISM or ViMoodle. Another course management system, CourseViz [16], presented a 3D plot displaying the discussion posts in conjunction with the “topics”, “participants” and “date of post” in different axes. While it helps instructors to quickly and more accurately grasp information about social, cognitive, and behavioral aspects of students, its 3D view compromises its scalability. Since the radii of the spheres representing threads varies with the thread follow-up rates, they might soon overlap greatly as the forum grows in its popularity. Moreover, its matrix based student performance view would not be suitable for MOOCs either, as encoding each of the thousands of students as a row would make the matrix too large to perceive. Other related work includes TrA Vis [15] tracking individual user’s communication activity progress, DBAT [7] and MTRDS [9] focusing on temporal dynamics of online discussions with tree structures and simple flow maps, etc. However, none of them are designed for MOOC analysis, and thus are typically used for communications with less than one hundred of interactions. Similar to CourseViz, they will suffer from visual clutter when enlarged to MOOC scale.

Our work will focus specifically on MOOC forums, and will be designed to be compatible for massive data.

PROBLEM CHARACTERIZATION
Forum participation refers to students making contributions (threads, posts, or comments) in every sub-forum, which is a sub-section focusing on specific topics. Other students can up-vote a contribution if they agree with its expressed opinion, or down-vote if otherwise. The following discussions are based on the course forum structure in Fig. 1. Note that this forum structure is for Coursera1, one of the biggest MOOC platforms, since our case studies are conducted based on the courses opened on Coursera. However, it is common enough to be extended for analysis of courses in other MOOC platforms.

![Figure 1. Coursera forum structure, including students’ each single contribution (thread, post, comment) in every sub-forum.](https://www.coursera.org/)

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1https://www.coursera.org/
We summarize their general objectives as to assess (1) how individual students generally participate in the forum ("an essential ingredient of an effective online course" [14]). The MOOC instructors in our university also confirmed their interests in students’ forum behaviors, with whom we have been collaborated since 2014. In our interviews with respect of their needs for analyzing student learning behaviors, they have frequently expressed their curiosities about how students participate in the forum discussions. They mentioned that forums were important channels to collect explicit feedback from students. Thus, they would check the content in forums frequently and wished to analyze the complete data after the courses ended. Their particular interests motivate us to design a visual analytics system to help them quickly explore forum discussion data and gain insights into learner behaviors.

We summarize their general objectives as to assess (1) how would individual students generally participate in the forum and why, and (2) how do they involve from a social aspect. Following these, the detailed questions could thus be further described as:

Q.1. How the forum participation varies as the course progresses? Students may involve in the forum differently at every stage of the course. Specifically, there might be some behavioral variations with respect of both the post amounts and the sentiment levels around special days (e.g. course page launching date, the course start date, assignment release and due date, etc.). Understanding these patterns could help analyze how students utilize the forum to perceive different content. For instance, students posts’ sentiment level changes are implications of their attitudes toward the newly updated course materials.

Q.2. What do the students discuss about in the forum? This considers the original posts from the students. While the general temporal pattern provides an overview on the behavioral variation trends, it may be too abstract for the instructors to pinpoint the causes of the pattern. Therefore, more detailed information should be included for them to better assess the forum discussions at different levels of details.

Q.3. How students interact differently to the posts of others in the forum? The major functionality of forums is to provide places for learners to communicate with others by asking and answering questions about course materials, and expressing thoughtful opinions on some course-related topics. Those interactions could reflect learners’ engagement in the courses and their understanding of the course materials. The social impact of mutual interactions is also worth investigation. Most of the interactions in the forum are one-time based, i.e., a student may just accidentally reply to the other one, and the interaction terminates without follow-ups. Compared with them, multiple interactions between students are more informative. For instance, students discussing back and forth in one thread may show shared interests specifically to a certain topic, and those who have interactions in different threads may reflect a more stable mutual assistance relationship. These self-initiated groups could reveal more insights about what kinds of students would like to tighten their relationships by exchanging ideas repeatedly and why.

Q.4. How do the behaviors of different student groups vary? While the former questions aim to analyze all students as a whole, the findings may not be representative enough for every individual. We could imagine that, if the amount of contributions per day in the forum keeps decreasing over time, it might merely reflect that a lot of students have just dropped out and therefore have stopped making contributions, while the remaining ones still constantly participating in the forum. In addition, students from different areas may also react to the same course materials differently due to cultural diversities. Therefore, specifically analyzing the students of interest becomes necessary for a comprehensive understanding.

**VISUAL DESIGN**

In order to help analysts solve the aforementioned questions, we design ForumTracker to interactively explore the data in different aspects. In this section, we describe our design rationales and explain the functionality of three views (i.e., Forum Statistics View, Forum Content View, and Social Network View) in detail.

**Design Rationale**

To make the system suitable for instructors to approach the problems, we follow the three design rationales stated below:

R.1. Effective analysis among multifaceted characteristics: Instructors care about multiple aspects of students’ forum activities. To help them comprehensively browse and analyze various patterns that interest them, it is critical to gather both quantitative (e.g., the number of themes students discuss about) and qualitative (e.g., their attitudes toward a certain topic) features (Q.1 and Q.2). Besides the engagements from an individual point of view, the social impacts involved are also necessary characteristics to evaluate (Q.3).

R.2. Intuitive visualization and LoD exploration: In order to reduce the learning curve of ForumTracker especially for instructors who are not familiar with visual analytics before, we stick to views with simple and intuitive visualizations, instead of informative yet complicated ones. Since multifaceted information mentioned in R.1 may introduce complexity if all presented concurrently, we focus on explorative solutions for instructors to seamlessly analyze the forum data at different levels of details: to both glean an overview (Q.1) and more specific patterns (Q.2).

R.3. Flexible user group selection: One major goal of ForumTracker is to help compare the forum behaviors for different groups of users, according to Q.4. Rather than exploring some predefined groups, it is necessary to provide an interface that allows users to arbitrarily select user groups based on their features.

**Feature Statistics View**

This view is designed to display all related features of students so that analysts can conduct visual queries to select a specific group of students they are interested in. To achieve this goal, a widely used visualization technique (R.2), parallel
coordinates, is thus chosen to represent the multidimensional data (shown in Fig. 7(c)). Several features are extracted from the user log data as independent dimensions. These features, including demographic data (i.e., geographical information and grade), the forum activity data (i.e., reputation, the sum of square roots of votes across all contributions made by a student who participates in the forum [11]), and video clickstreams (i.e., the frequencies of video playing, pausing, and seeking events) [20], cover different aspects of learning behaviors. They are chosen according to the feedback from the interviews with the instructors. Nevertheless, users can freely add more features they find useful.

The brushing interaction on each axis intuitively enables filtering student groups according to their values for different features (R.3). All the other views will be refreshed accordingly, only showing the data for the selected students.

One drawback of the traditional parallel coordinates visualization is that it cannot show the student distributions among different features. Thus, we further add a histogram on each axis, to roughly brief users with the student proportions in a certain range, and help them conduct selections thereby.

**Forum Content View**

**Overview**

Forum content exploration is a crucial part during the analytics process since students’ contributed content, timing and sentiment levels can reflect their learning habits and attitudes toward the course. Following R.2, here, we propose a three-level exploration procedure for forum content. At the highest level, we use a stream graph [3] to give an overview of the forum usage overtime (Fig. 7(c)). Each stream layer shows the use of a sub-forum, and the height at each day stamp represents the number of active threads (a thread that is newly posted or it receives replies on that day).

![Figure 2. Forum Flow Bar design, with A being the timeline bar, B being the sub-forum bar chart, and a an active thread.](image)

**Forum Flow Bar for Sub-forums**

For further exploration on a specific sub-forum, at the second level, we design a glyph based bar chart, Forum Flow Bar, to provide an overview of the sub-forum participation patterns. Specifically, we would like to analyze the individual contributions (e.g., the sentiments they convey, the dates they are created on, the threads they are posted in, etc.), and integrate them to reveal the overall temporal variations of forum activities. Thus, the individual details and the global features could be efficiently combined.

In this sense, we first encode an active thread (recall it refers to a thread in which there are some posts on a specific day) as a small glyph. We encode active threads, instead of every single post, to convey a general impression of how diverse the discussions are, as posts in the same thread are typically convergent in topics. Moreover, clearly stating threads as glyphs helps the users to easily locate a unique thread on a selected day. The glyph color represents the text sentiment score of a thread’s current replies, with blue being the least positive and red representing the most positive, as in Fig. 3. Since the geographical distribution of MOOC students diverges, the forum contributions are multilingual. Therefore, instead of implementing sentiment analysis algorithms on our own, we compute them with Repustate2, a well-developed tool that supports multiple languages. Though the algorithm is not published, an overview of how it works is available in their website. The output score for each contribution ranges from -0.5 to 0.5. In the cases where a thread receives multiple replies in one day, the overall sentiment score is taken as the average of all replies’ scores. Furthermore, to still preserve the number of replies received, the border shade of the glyph represents the hotness (the number of replies) of the thread on that day and the darker the border is, the hotter the corresponding thread.

We construct the overview with these glyphs by arranging them with respect to their activated time and the sub-forums these threads belong to. Concretely, we represent the time with a horizontal axis (region A in Fig. 2). For each sub-forum, threads activated at the same time point are stacked vertically below the time axis, resulting in a glyph bar chart (Fig. 2B). These thread glyphs are longitudinally sorted according to their sentiments from the bottom to the top. This way, it is intuitive that the bar height represents the sub-forum’s activities on a specific day. As the glyphs’ sizes (and therefore the size of the entire bar chart) can be easily adjusted, the overview could even be shrunk into a pixel-based design in extreme cases where the count of active threads is enormous. The scalability of the view is therefore guaranteed.

![Figure 3. Sentiment levels encoded as colors, with blue being highly negative and red being highly positive.](image)

**Thread Content List for Content**

For each specific day, we construct a thread level exploration procedure, where a glyph displays the high level view. Within each thread, a set of slots is designed to store a thread’s related information. These slots default to many standard features (e.g., a thread’s title, number of replies, sentiment levels can reflect their learning habits and attitudes toward the course. Following R.2, here, we propose a three-level exploration procedure for forum content. At the highest level, we use a stream graph [3] to give an overview of the forum usage overtime (Fig. 7(c)). Each stream layer shows the use of a sub-forum, and the height at each day stamp represents the number of active threads (a thread that is newly posted or it receives replies on that day).

![Figure 4. An example of the Thread Content List. When a2 is selected, all glyphs of the same thread are highlighted (a1 and a2), and its thread description tooltip (A) and Thread Content List (B) are displayed.](image)

While Forum Flow Bar is an abstract overview of all the sub-forum activities, it does not show why students act particularly active on one day, or why a thread receives highly positive

2https://www.repustate.com/
replies. Thus, as in Fig. 4, when a thread is brushed, we emphasize its information by highlighting all the corresponding glyphs (a1, a2) and displaying its descriptive tooltip (A). They are further taken as the indicators for the third level, where Thread Content List (Fig. 4B) is displayed. We expect it to give users a detailed contribution history in a thread up to the selected day. In the list, every contribution (b) is displayed as a set of its contributor’s country, grade and reputation point (i.e., the selected filtering factors in Feature Statistics View), as well as the posted content (or a preview paragraph in the cases where the contribution is significantly long), so as to make the contributions be easily recognized as being from a certain kind of students. For visual clarity, contributions that are categorized as “Post” are displayed normally, while “Comment” is slightly indented (c). Besides, the contributions generated exactly on the selected day are colored red (d).

Social Network View

Figure 5. Encodings for student interactions in MOOC forum, with node A and B being students, C being (vA,vB), the response from student A to B. Node color encodes grade of the corresponding student, and size encodes the interaction level, namely w(vi, vj).

Overview

Social Network View is for evaluating the interactions between students in the forum (R.1). We use directed graph, a commonly used method for social network analysis (R.2), to represent such interactions (Fig. 5).

Specifically, we denote every student that has contributed at least once in the forum as a node vi. For vi and vj, if vi replies to vj, whether in vj’s thread or post, we add a directed edge (vi, vj) between vi and vj. The weight of (vi, vj), w(vi, vj), is the number of replies from vi to vj. This eventually results in a directed graph G(V,E), where V contains all vi and E all the (vi, vj). It is intuitive to find that the degree of a node represents the amount of the interactions a student participates in, in which the out-degree represents the responses from the student, and in-degree is the responses he gets from the others.

We define a student’s level of interaction as his or her corresponding out-degree, i.e., how willing the student is to respond to other students. We encode it with the size of the corresponding node: the larger the out-degree, the bigger the node. Moreover, we encode the course grade with the color of the node (denoted as ci for node vi) to investigate the correlations between students’ interactions and their grades, since the latter strongly indicates how the course requirements have been carried out. The higher the grade, the redder the node is. Or equivalently, the lower the grade, the greener the node is. Note that, since sometimes the instructor would set a lowest grade g for students who have at least participated in the course somehow, while in contrast those who never log into the course would get zero grade, it is very likely that no one gets grades between g and 0. In this case, for the zero-scored nodes, we set their colors as grey to avoid leaving a range of color unused. To evaluate the level of interactions, we run Fruchterman Reingold Algorithm [8] for a low node overlapping rate and therefore a better view of the size and color.

For visual clearness, we reduce the number of links by integrating (vi, vj) and (vj, vi) as {vi, vj}, whose weight w(vi, vj) is the sum of w(vi, vj) and w(vj, vi). We encode the weight (i.e., the interactions between two students) as the width of the link. To still preserve the direction information, we encode the color of a link {vi, vj} as the weighted sum of ci and cj, where the weights are w(vi, vj) for ci and w(vj, vi) for cj.

The highlighting function is enabled to help clearly see whom a highlighted user has interacted with, such that a massive social network could still reveal a single student’s involvement in the forum, despite of the possible visual clutter (see Fig. 6).

CASE STUDIES

To fully demonstrate ForumTracker, we apply it to two Coursera courses offered by our university in this section. Specifically, we demonstrate a comprehensive exploration with the first course, and supplement with some unique insights (e.g., the impacts on forum activeness evoked by instructors’ involvements) with the second one.

Analysis for CH

The first course, referred as CH, mainly covers the discussions of Chinese history. It was offered from June 15 to August 4, 2013. 30827 students registered for it, 9343 of which at least participated in the course in some approach (e.g., watched a course video, contributed in the forum, etc.), while the others never involved in any form of learning during course period [22]. Among those participated students, Americans and Chinese account for the largest proportions (32.4% and 18.9%, respectively). Most of these students, though participated, received the lowest grade, which might resulted from their ephemeral engagements only in the beginning [12]. For students contributed in the forum (1152 in total), their reputations range from -4 to 78. Detailed distribution is in Fig. 7(a).

The participation of these students in the forum varies with time. As in Fig. 7(c), while there exists local peaks in the
Figure 7. **ForumTracker for CH**, with (a) the Feature Statistics View for student distributions, (b) Social Network View for interaction evaluations, and (c) the Forum Content View, with Assignments serving as a periodical support, Lectures holding numerous inquiries in the first week, and Study Groups being the focus only in the beginning, when students actively seek to collaborate with others. (d) is the Forum Flow Bar for Assignments.

Stream graph before assignment due dates indicating local maxima of activeness, overall, its width shows that the amount of daily active threads decreases as the course evolves, especially after the first week. This may result from both the high drop out rate in the first week [12], and the shift of students’ interests: they only actively express their expectations about the course, and build social networks with students who have similar backgrounds via the forum at the beginning. The vacant gap between assignment 4 deadline and the final exam is attributed to a technique difficulty, which led to the collapse of most sub-forums except for Technique Issues (Fig. 7(c) I).

Diving into the sub-forums, General Discussion (Fig. 7(c) A) always appeared to be students’ main focuses and received most contributions, whereas Week 01-04 (G-H, respectively) serve as temporary platforms. These four sub-forums were not opened until the corresponding weeks began, explaining why there was not even one contribution to them prior to the week start dates. These sub-forums’ activeness also dropped quickly when the weeks are finished, showing that CH students tended to stay with up-to-date topics and to disregard the ended ones.

There are other sub-forums serving similarly as one-way tickets due to their specific topics. For instance, students spent a great amount of time in Study Groups (C) before the course even officially started for communal needs, and their enthusiasms for this sub-forum faded away quickly since they have found their group mates and therefore switched to more accustomed platforms. For instance, Beijing and Shanghai students announced QQ group (a Chinese instant messaging software service) promptly in their threads. Posts in the second half of the course were mostly responding to those threads that intended to propose specific off-line gatherings, but not to call for long-lasting study groups. The rest of the students seemed to stick with the sub-forum only to confirm their availabilities.

Besides, such topic-oriented activeness variations are also found in Assignments (Fig. 7(c) B, or (d) for its Forum Flow Bar), where burst activeness (i.e., the quantity of daily active threads stands out from its neighbor days) is always found during week transactions, i.e., when an assignment for the past week meets its due, its official answers posted and a new one released. When selecting threads on these transacting days, we find in Thread Content List that they were mostly about reviewing the assignment in the last week, discussing the confusing sections in the official answer sheets, and asking questions about the new one.

Figure 8. Three sample threads in Assignments, with (a) being an individual’s question that was easily solved, (b) representing a common confusion re-visited by multiple students, and (c) the instructor’s clarification on (b).

Hovering on a glyph, the distribution of the highlighted glyphs (i.e., those representing the same thread as the hovered one) shows that the lifetime and the popularities of the threads are
diverse. Some questions were due to individuals not understanding the materials thoroughly. For instance, while the student posted $A_1$ in Fig. 8(a) expressed that he was “very confused” (which led to negative sentiment level), all the thread nodes referring to $A_1$ hold lightly shaded strokes, indicating few follow-ups. In fact, the question was solved straightforwardly when a reply ($A_2$) referred the confused student to a specific slide in the lecture note, and the confused one expressed his highly positive appreciation later on ($A_3$). Others, in contrast, reveal commonly shared confusions. For instance, the thread in Fig. 8(b) questioned the mismatch between the course material and every candidate option provided in an assignment question. It was activated throughout the second week, with most glyphs bearing fairly dark strokes. This indicates that this thread evoked hit discussion and kept receiving multiple replies everyday without reaching a close end. The question was so frequently complained that the instructor later posted a thread to clarify it (Fig. 8(c)), in which he announced to grant full marks to all choices of the question. This post itself is also an interesting one, as the hybrid nodes in red and blue reflect particularly unique standpoint: while all the rest students expressed their appreciations to this decision, a student commented this as ‘worthless’ and showed curiosity to the initial purpose of the question. Since this was the only post that activated this thread on that day, it led to the blue glyph $C_1$ while the others were in warm colors. These threads were rarely replied when the week was over.

Curiously, comparing to Assignments and other always-opening sub-forums, Lectures (Fig. 7(c) D), where students exchange their thoughts on lecture materials, experiences a much more significant decrease in the activeness after the first week. The threads reflect a large amount of inquiries on the first week’s lectures, resulting in more active discussions (e.g., “Playing with statistical numbers”, “I found the ‘evidence’ offered that the West was less socially mobile completely lacking”, etc.). These discussions provide the instructors with guidances on improving the course materials, including specifying the requirements and clarifying the concepts of the course.

As for the social interaction, from Fig. 7(c), it is clear that the nodes that are larger tend to be in red or dark orange, and we could therefore conclude that students with a high level of interaction mostly receive high grades. This goes align with [5], in which the authors confirmed that forum participation is correlated with higher grades and higher retention. An exception is point A, whose color is grey but still with a relatively significant size. The response content of A indicates that his high response count is resulted from him chatting with all follow-uppers in his own thread, and in other ones’ threads about irrelevant topics. He can be seen as a “socializer”, i.e., the ones chatting around without actually participating in a collaborative study, which is rare as showed in the graph.

Having gone through the overall forum engagements, we also evaluate behaviors of students in different domains to concretely understand classified students’ learning patterns.

With the social graph proving participation disparity with respect of grades, we filter students with different course performances out of all the general students. In accordance with the course policy, we filter those who have got the certifications of completion (i.e., completed group, with grades $\geq 60$). We first notice from Fig. 9(a) that the forum thread activeness trend of completed group is similar to that of general group (Fig. 7(c)), reflecting students who at least finished learning more than half of the course materials fill up most of the forum activities. Meanwhile, the peaks’ heights are reduced. This indicates rather than popping up randomly or only showing up at the very beginning, completed group tended to stably involve in long-lasting forum participation. On the contrary, the significant peak followed by rapid curtails in the stream graph for the remaining students shows that they stopped making contributions quickly after the course started (Fig. 9(b)). Moreover, among all the sub-forums, Assignments experiences the least changes when switching the student group selection from general (Fig. 7(d)) to completed (Fig. 9(c)), showing that contributions in Assignments are mostly from completed group. This biased attention makes sense, since students receive grades from their assignment performances.

The highly biased reputation distribution is also worth exploration. Though widely ranged, the reputations of most students remain 0 (Fig. 7(a)), and those greater than 5 accounts for the top 10% among all the students. These students share distinctive features as summarized in Fig. 10. For instance, the dense distribution of lines around high grades (Fig. 10A) indicates most students with high reputations normally perform well. Also, Chinese students (Fig. 10B) take a smaller proportion in this case: while Americans account for around one third and Chinese one fifth for all the participated students, the ratio becomes USA: CHN: all filtered students = 5: 1: 15 for those with high reputations. This goes align with the commonly-agreed term that the Chinese are more restrained in social groups.

Fig. 11, dominated by nodes in warm colors (i.e., students with high grades), also proves the relation between reputations and grades. Moreover, we notice a thick link (a) in the figure with mixed color standing out from all the thin and red ones, indicating a special bound between student A and B.
Referring back to the texts, we find it is due to their discussions in a thread initiated by B named “Disappointed”. They both expressed serious concerns about the objectiveness of the statistics presented in the course, and repeatedly emphasized their observations about China against those on the opposite positions. Though B had few interactions with others (and seemed to have dropped out shortly after this post), this dedicated debate raised its reputation high enough to be in the 10%. This serves as an example on how the social network could help target students with strong views.

Besides the forum, clickstreams are also correlated with students’ grades. Filtering play, pause and seeking (i.e., select ranges where the line densities are low), we find students with large amount of clickstreams normally have better grades.

### Analysis for GT

The theme of the second course GT, offered during June 3 to July 24, 2013, is about the scientific facts in food. Among 85394 registered students, 31528 are participated ones, and 3761 join the forum. Similar to CH, 28.5% participated students are from USA. However, students from China only accounts for 2.35%. This could be due to the course content differences: many Chinese students in CH expressed their interests in learning Chinese history from a different perspective, while GT does not have such factors. GT has a larger range of reputation, from -23 to 125.

While GT shares several common features with CH, the topic dissimilarities yield various differences. For instance, in Forum Content View, the daily activeness drastically drops after the first week (Fig. 12T), and stays almost stable thereafter. Assessing its causes leads us to sub-forums that go through similar reductions, i.e., General Discussion (Fig. 12A), Study Group (C), Lectures (D), and Assignments (B). While the first three are expected, Assignments, surprisingly, deviates from the periodic usage found in CH. Specifically, a significant peak appears right before the due date for assignment 1 and 2, which is at point a in Fig. 12. The amount then decreases, and the peaks thereafter are neither significant nor aligned with deadlines. We speculate this phenomenon owes to the setting of the assignments. In CH, each assignment contains three controversial multiple choice questions, whereas those in GT are designed as real world experiments (e.g., cooking in a specific flow). The peak may occur because the hands-on experience appealed to the students at the first place, resulting in enthusiastic discussions about the outcomes and possible reasons for their subtle differences. However, due to the lack of seriousness, they may stop devoting themselves into it afterwards, which results in the drop. Similarly, the miss of peaks on due dates could be attributed to the fact that experiments, comparing with multiple choices, require more preparations and clarifications, which leads to continuous discussions.

![Figure 10](image1.png)  
**Figure 10. Feature distributions for CH students with reputations ≥ 5.** Most of the students have relatively high grades. Also, comparing its geographical distribution with the one for all students, Chinese accounts less for students with reasonably high reputations.

![Figure 11](image2.png)  
**Figure 11. Interactions among CH students with reputation ≥ 5.** Most of the students have relatively high grades. A unique bound is found from the particularly thick link a, which results from students A and B continuously sharing firm ideas in a thread initiated by B.

![Figure 12](image3.png)  
**Figure 12. The forum thread activeness for GT.**

Based on the observation that several students got considerably low reputations, we filter those with reputations smaller than zero, as in Fig. 13. We find their grades are slightly differentiated into two ranges: 0 to 20 and 65 to 100. Those with low grades posted either complaints about the course before dropping out (which were against by those enjoying the course), or flag content that involves radical sentences (even threads titled “Any Terrorist or Muslim?” in extreme cases).
However, for students with high grades and low reputations, their activeness levels do not seem specifically low, nor do their contributions show impoliteness. In contrast, they participated seriously, and their low reputations should be due to their comparatively more mighty opinions in few posts, where they questioned particular aspects of the course. These contributions may be down-voted by those who had a different point of view. For instance, one student with grade being 100 and reputation -16 posted one thread about unsatisfying feelings of the course, and earned -100 votes, while another fully-graded student, whose reputation is -7, complained about instructors’ pronunciations, and was down-voted by those regarding this as a minor issue.

As for students with high reputations, we find that they achieve high contribution rates by interacting with other people frequently, and it is common to find a high reputation student filling up almost half of contributions in a thread. Also, while not all contributions could be identified as “useful” (i.e., answering questions or sharing course-related sources), most contributions are very on topic, and the less useful ones are normally interesting. For instance, the student who received the highest reputation (i.e., 125) created a thread called “Food jokes”, and it received multiple replies, including his own. Because of these threads’ existences, students with high reputations could trigger the forum’s overall activeness, which agrees with the findings in [11].

**DISCUSSION**

Through the case studies, we not only verified some findings from previous work, but also identified new insights into learning behaviors, which could be used to help instructors better understand their students and improve the course settings in the future. We thus conclude the effectiveness of ForumTracker in exploring forum data.

However, through the whole collaboration with instructors, we find that there still exist some limitations in the system. First, while the Forum Content View and Social Network View are both linked with Feature Statistics View for selection, these two are currently separate. However, the activeness and interactions may in fact be connected. We could imagine that frequent interactions may increase forum activeness. To evaluate the relations between them, we would like to bridge the two views in the future by, for instance, allowing directly connected updates of both (e.g., display the network structure up to a selected date, etc.).

Second, our method is purely perceptual based, and the perceived information could therefore be subjective. For instance, while users could get a general impression of how the activeness change over time, the concrete overall changing rate or its significance could not be easily quantified. However, this rate could be a more accurate measure of the influences of the new course content on students’ engagements. This may be alleviated by strengthening our visual system with some statistical outputs, such that the visual perception could be verified and supported.

Another limitation is about the lack of evaluation on joint patterns of clickstreams and forum behaviors. In Feature Statistics View, three features from clickstreams are considered, with which we expected to explore the correlations between two main practices in MOOCs, i.e., students’ video watching and forum behaviors. However, we later found that without the temporal information, pure counts of clickstreams could not filter the students meaningfully. For instance, we can hardly know which videos triggered frequent seeking events, and therefore could not refer to forum participation in the corresponding week. The temporal patterns of clickstreams are needed to further help instructors get insights.

**CONCLUSION AND FUTURE WORK**

In this paper, we propose ForumTracker, an interactive visual system designed to help users, especially instructors, understand the students’ participation in MOOC forums. We characterize common concerns of forum behaviors, and design three visual views for analyzing a forum’s overall activeness, sentiment levels and social interactions involved. Case studies with two Coursera courses exemplify the usefulness and the effectiveness of the design.

Our proposed system still has room to improve. A primal improvement needed is to add other modules to the system, such to support further verifications of patterns through statistics methods, and thereby make it more reliable than that in the current setting, which relies purely on manual observations. Besides, we would like to allow simultaneous update of all views when a query occurs in any of the three views. We expect this to enable correlation explorations from more angles. A joint analysis with video clickstreams to reveal the temporal patterns is also another future work we will focus on.

**REFERENCES**


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