3D TECHNIQUES FOR VISUALIZING USER ACTIVITIES ON MICROBLOGS

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ABSTRACT

Microblogging platforms such as Twitter have recently attracted attention and gained popularity. By using them, people can easily write their opinions and comments on events in the real world in real time. Content on the timeline of Twitter immediately reflects real and virtual activities. The purpose of this paper is to provide 3D components and methods of visualization that enable us to visualize user activities and the roles they play in their networks, i.e., when and how much they tweet, how and when information spreads in their networks, or what kinds of topics they tweet in each community. This paper presents 3D interactive components for visualizing relations between users, their messages, and changes in the number of messages over time. Moreover, we explain methods of comparing variations caused by different timing and by multiple groups of users.

1. INTRODUCTION

Microblogging platforms have recently attracted attention and gained popularity. Twitter 1 is one of the biggest microblogging platforms, which has over 75 million user accounts 2, and its users have spread all over the world (Java et al. (11)). By using Twitter, people can easily write their opinions and comments on events in the real world in real time. Content on the timeline of Twitter immediately reflects both real and virtual activities.

Twitter enables users to write and read text messages called tweets that are up to 140 characters long, are displayed on user home pages, and are also shown on their followers’ home pages. They can read the tweets of their followings and also reply to such tweets. Moreover, users can select tweets by others and retransmit them, called retweets. We can obtain these data through the twitter public API in XML format.

Tweeting and retweeting sometimes cause information to spread such as that on restaurants or new products by word-of-mouth (WOM) communication. Therefore, Twitter has attracted attention as a tool for WOM. Gladwell’s "The Tipping Point" discusses three types of key people for WOM such as connectors, mavens, and salesmen (Gladwell (6)). Information on Twitter is occasionally spread by these kinds of key people. It is important to analyze the connection between users and message flows on Twitter to consider methodologies for advertising and propaganda using WOM on the Internet. For example, we may effectively bring information to the attention of others by finding WOM influencers on the Internet, and then by being followed and retweeted by them.

The purpose of this paper is to provide 3D components and methods of visualization that enable us to visualize user activities and the roles they play in their networks, when and how much they tweet, how and when information spreads in their networks, or what kinds of topics they tweet in each community.

Visualizing the time-series of data allows us to answer seven important questions (i) what kinds of elements appear at specific times, (ii) when do such elements appear and disappear, (iii) how long do they exist on a timeline, (iv) how rapidly do they change, (v) how often do they appear, (vi) what kind of order do data elements appear in, and (vii) which elements appear together? (Müller and Schumann (15)). Being able to visualize the time series of data content on Twitter enables us to display changes in thought and activities that occur in the real and/or virtual world, and allows us to analyze social phenomena.

This paper proposes five 3D-interactive components for the visualization of relations between users, their messages, and changes in the numbers of messages over time: (i) TimeSlices for visualizing user networks with the time-series of data, (ii) TimeSkewers for visualizing the content of each user such as tweets on a timeline, (iii) TimeFluxes for visualizing changes in the amount of information such as the number of tweets for each user at each timing, (iv) MessageTrails for visualizing message flows caused by replying and retweeting, and (v) TimeCloud for visualizing the global tendency of user activities on the timeline. These elements are introduced in Section 3.

Moreover, we provide methods of comparing multiple variations caused by different timing and multiple-user groups. To compare different timing, our sys-

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1 http://twitter.com/
tem provides functions for adding multiple TimeSlices with different time stamps, and it provides parallel views and overlay views in a 3D environment. They enable us to seamlessly change these viewing modes without losing user cognition. To compare different communities, our system provides functions for adding multiple layers representing different groups of users, and also provides different viewing modes such as an aggregate view, a pile view, or a split view to compare different layers that sometimes have overlapping nodes, and that change differently along a timeline. These methods are introduced in Section 4.

Our approach provides 3D interactive environments and visualization techniques using multiple 2D planes, lines, and plots in 3D space, which enable users to dynamically and simultaneously visualize user networks, changes in their attribute values, messages and message flows, and the global distribution of their activities. Our techniques enable us to observe overviews and their details from global and local aspects by seamlessly switching them. Moreover, combinations of our visualization techniques allow us to display the relationships between interactions among users and statistical changes in trends in 3D space at the same time.

2. RELATED WORK

Four main methods have been proposed to enable the evolution of information structures to become visualized; however, these have their own pros and cons. The first is (a) using animation to dynamically display changes in structures (Toyoda and Kitsuregawa (23), Nakazono et al. (16)). Although this enables users to dynamically observe changes in structures, it reduces user recognition, because they lose the context in previous situations. Users occasionally miss where changes have occurred and when they have changed throughout the entire space. The second is (b) mapping a timeline to one of the axes in a 3D environment (H.Chi et al. (9)). This enables users to observe global differences between multiple graphs. However, it is difficult to check local differences in detail. The third is (c) using multiple tiled views to display multiple Web graphs (Toyoda and Kitsuregawa (23), H.Chi and K.Card (8)). Users can compare the differences between Web graphs in parallel, enabling them to comprehend global differences. However, it is difficult to intuitively understand time intervals between Web graphs. Users occasionally cannot determine how long it has taken for changes to have occurred. The fourth is (d) overlaying graphs for different time periods on one view (Nakazono et al. (16), Brandes and Corman (1)). This is advantageous for comparing graphs in detail; however, is difficult to display global changes in structures.

LifeLines (Plaisant et al. (20)) and TimeMachine (Rekimoto (21)) enable users to display recorded events in personal histories on timelines. VisualLinda [12], and TimeTunnel (Notsu et al. (18)) use the combination of 3D space and a timeline to visualize the time series of events or attribute values. They effectively use 3D spaces to simultaneously represent two kinds of relations including time relations to avoid disrupting user cognition caused by them having to reconstruct their mental models.

Minard’s famous chart for showing the terrible fate of Napoleon’s army in Russia is a classical example of mapping changes in values over time (Tufte (24)). ThemaRiver (Havre et al. (7)) and Wormplots (Matthews and Roze (14)) provide methods of visualizing changes in values of multiple attributes in 2D or 3D spaces. Dwyer and Eades (2) visualizes a flow graph, and simultaneously demonstrated time-dependent changes in the values of elements on a flow graph using 3D space.

There has been research on visualizing both time-dependent changes in elements in a graph and message flows in it (Koike et al. (13), Dwyer and Eades (2)).

MovingPhenomenon (Kim et al. (12)) visualize levels of activities or the distribution of moving objects using scatter plots in 3D environments. They enable us to display time-dependent changes in distribution from a global viewpoint.

Many systems for different data domains use a 2.5-D representation to visualize multiple situations in a 3D environment. The 2.5-D representation is used for three kinds of visualizations that involve: (i) visualizing different content (Fung et al. (5), Erten et al. (3)), (ii) visualizing time sequential changes (H.Chi et al. (9), Brandes and Corman (1), Nocke et al. (17)), and (iii) using different visual representations and/or models (Shen et al. (22)). Our framework supports the functions for (i) and (ii); however, the function for (iii) is still not supported, and we intend to explore this in future work.

Techniques for coordinated multiple visualizations such as linked views of a histogram or a ThemaRiver and multiple 3D graphs also enable us to observe time-sequential changes in graphs. However, it is difficult to freely add arbitrary numbers of graphs. Moreover, multiple tiled views require adequately sized display areas.

3. VISUALIZATION OF USER ACTIVITIES

This section presents 3D techniques for visualizing user networks, tweets including replies and retweets,
flows of replies and retweets, and changes in the strength and distribution of user activities. We utilize the IntelligentBox system (Okada and Tanaka (19)) as the platform to implement these. This is a component-based visual software development system for interactive 3D graphics applications.

3.1. TimeSlices

A TimeSlice (Itoh et al. (10)) is a plane for visualizing a user graph arranged on a timeline, which is one axis in 3D space. It represents a snapshot of the states of user networks with specific timing (Figure 1).

![Figure 1: TimeSlice and TimeSkewer](image)

**Figure 1:** TimeSlice and TimeSkewer

A graph on the TimeSlice consists of followers and the followings of a specified user. To display these, we first input a twitter user name or id, and select whether we only obtain followers or followings, or both of these. We can also obtain friends of friends by inputting the depth level, or by selecting the visualized nodes and expanding them.

To visualize connections between users, we have adopted automatic and dynamic graphlayout algorithms to visualize graphs based on a kind of force-directed model (Fruchterman and Reingold (4)). We can select and move nodes and edges to interactively check details on relationship such as the degrees of separation between nodes. Moreover, we can zoom and pan a canvas to interactively change the focusing point in very large graph spaces.

**TimeSlices** can adopt various kinds of representations for nodes and edges. We provide images, 2D texture labels, and spheres and labels for the nodes described in Figures 2 (a-c), as well as cones, solid tubes, and lines for the edges described in Figures 2 (d-f). The directions of edges to distinguish between followers and followings are represented by using colors and/or acute shapes.

This also enables us to filter visible nodes according to the number of in- and/or out-links, or their ratios so that we only focus on hub and/or authority nodes. Such filtering functions enable us to find key people, and spam or bot user accounts.

**TimeSlices** can be dragged and we can seamlessly change their positions along a timeline. Such manipulations generate an animated time sequence of changes in the graph and content on it (Figure 1). A Timeslice displays the tweets of all users with selected timing. The number of actions such as #tweet, #reply, #replied, #retweet, or #retweeted around the selected timing is mapped to the size, color, or transparency of nodes and edges. Such functions enable us to display which users are active or have strong connections with others in a particular timing.

We can interactively add new TimeSlices along a timeline, and generate multiple views for visualizing graphs with different timing in the 3D environment to compare time-dependant differences as described in Figure 4 (a). To avoid different layouts on the same nodes belonging to different TimeSlices and to avoid drastic movements by nodes in the animation, the positions of nodes on different TimeSlices can be completely synchronized with one another even if users drag a node. Panning and zooming manipulations are also propagated to other TimeSlices.

The system visualizes a histogram on the timeline representing the number of tweets, replies, and/or retweets at each timing (Figure 1). We can dynamically change the scope of the visualized range of time along the timeline by zooming or panning it.

3.2. TimeSkewers

A TimeSkewer is a line for visualizing events such as tweets, replies, and retweets on a selected user,
as shown in Figure 1. Moreover, the TimeSkewer can only display tweets with specified keywords, or replies or retweets for selected persons. By using these functions, we can observe when people talked about certain topics and who they were.

3.3. TimeFluxes

A TimeFlux is a line of spheres or solid tubes for visualizing the changes in the number of activities such as tweets, replies, and retweets about selected users within a given period of time, e.g., one day or three hours, as shown in Figure 3 (a). We can map #tweet, #reply, #replied, #retweet, and #retweeted to the radii, colors, and transparencies of spheres or tubes. We can add two or more TimeFluxes to one person to display multiple attribute values, or different keywords. In the case of using #reply, #replied, #retweet, and #retweeted, we can select target users to communicate with. By using these functions, we can observe when and how much a person has communicated with particular people on specific topics.

3.4. MessageTrails

MessageTrails form a flow graph for visualizing message flows caused by replying and retweeting, as shown in Figure 3 (b). We can select target users and source users to reply and retweet with, and can select particular messages to find the path the messages have spread along. We can also specify keywords to filter MessageTrails. They can have different colors depending on the types of messages such as reply or retweet, target or source users, or selected messages. The directions of the arrows are represented by using the same method as that in Figures 2 (d-f). Optionally, a MessageTrail can display messages of replies, retweets, targets of replies, sources of retweets, and their time stamps. By using these functions, we can observe how specified topics have spread, and how long they have continued.

3.5. TimeCloud

A TimeCloud is a 3D scatter plot mapped on user networks and a timeline for visualizing global tendency on user activities such as tweets, replies, and retweets, as shown in Figure 3 (c). Each plot can change color and transparency according to the kinds of messages, or numbers of messages within a given period of time, e.g., one day or three hours. We can use filters for keywords. By using these functions, we can observe the sizes and positions of user groups that have had interest in the keywords, and when the topic has attracted attention.

4. METHODS OF COMPARISON

Comparing situations with different timing and different user groups is an important task for observing changes in social phenomena in detail. We have taken into consideration two kinds of relations, such as inter-time relations and inter-community relations, and provide methods for comparing them.

4.1. Inter-time relations

Inter-time relations are visualized by multiple TimeSlices in different positions on the timeline. Our system allows users to add and compare multiple TimeSlices. It enables us to explore changes in graphs by using animation, and by comparing multiple TimeSlices as described in Figure 4 (a). Our system also provides overlay views and parallel views to compare TimeSlices in detail in 3D space (Figures 4 (b and c)). These kinds of views enable us to interactively explore information through different perspectives.

An overlay view is represented by changing eye positions, and by changing projection modes in a 3D environment. We normally use perspective projection in 3D environments. The same nodes in different TimeSlices are then displayed in different positions because of perspective. To solve such problems, we prepared an orthogonal projection mode, where the same nodes in different Timeslices completely overlapped positions with one another as can be seen in Figure 4 (b). We also provided a function to change the transparencies of TimeSlices to avoid background ones from being hidden.

Our framework enables us to seamlessly change a normal view to a parallel view. To achieve this, the system can automatically slide TimeSlices. After that, users can obtain a parallel view by changing eye positions and projection modes, in the same way as that in the overlay view in 3D space, as can be seen in Figure 4 (c).

4.2. Inter-community relations

Inter-community relations are visualized by using multiple TimeSlices on different communities that are graphs generated from different groups of users.

Our framework provides three types of views to compare these, which are similar to the ideas introduced by Fung (Fung et al. (5)) and Erten (Erten et al. (3)), i.e., (a) aggregate, (b) pile, and (c) split views. An aggregate view visualizes two communities in one TimeSlice (Figure 5 (a)), where edges in different communities are in different colors. A pile view visualizes two communities in different stacked TimeSlices (Figure 5 (b)), where common nodes in differ-
different communities have red edges, as seen in Figure 5 (b). A split view visualizes two communities in different TimeSlices side-by-side (Figure 5 (c)). In pile and split views, the positions of two TimeSlices along the timeline are synchronized with one another. Users can also add sets of TimeSlices to the timeline.

Several methods of drawing two or three overlapping graphs have been introduced (Fung et al. (5), Erten et al. (3)). We provide three types of methods for layouts: (a) merge, (b) pivot, and (c) independent layouts. We treat the same nodes in different communities as one node in the merge layout mode, and create a union of nodes in different communities. We then calculate their layouts (Figure 5 (a)). As two graphs in this mode are treated like one graph, nodes in the results never overlap. This is advantageous for exploring the relationships between nodes in two groups. However, it needs a large space to visualize the results. We treat the same nodes as one node in the pivot layout mode, and independently calculate the layouts of nodes for two communities (Figure 5 (b)). The shared nodes are treated like pins in the results of this method, and the others are spread around these pins. The independent layout mode independently calculates the layouts of all graphs for communities (Figure 5 (c)). Therefore, the visualized results with this method appear compact. This is advantageous for independently exploring changes in each community. However, if we use this method in aggregate view or pile view, nodes and edges belonging to different communities can easily overlap. As the same nodes in different graphs are treated independently in this layout mode, it is difficult to identify which nodes are shared in both communities. To avoid this situation, the system can add red edges between the same nodes in the same way as seen in Figure 5 (b).

Our framework visualizes inter-community relations using a combination of the view and layout types.

Figure 3: TimeFluxes, MessageTrails, and TimeCloud

Figure 4: Comparison of multiple TimeSlices

Figure 5: Visualization of multiple communities.
5. CONCLUSIONS

We have proposed 3D visualization techniques. They enable us to interactively explore user activities including their relationships, communications with others, transitions in the volume of sent messages, and message flows on Twitter. These combinations enabled us to observe user relationships, communications, and statistical changes in trends in 3D space.

In this work, we only focused on a visualization method of structural analysis. However, a combination of structural analysis and content-based analysis methods is required for analyzing social connections in detail. We intend to provide methods of analyzing and visualizing the content of messages.

6. REFERENCES


