Us vs. Them: Understanding Social Dynamics in Wikipedia with Revert Graph Visualizations

Bongwon Suh, Ed H. Chi, Bryan A. Pendleton, Aniket Kittur
Palo Alto Research Center

ABSTRACT

Wikipedia is a wiki-based encyclopedia that has become one of the most popular collaborative on-line knowledge systems. As in any large collaborative system, as Wikipedia has grown, conflicts and coordination costs have increased dramatically. Visual analytic tools provide a mechanism for addressing these issues by enabling users to more quickly and effectively make sense of the status of a collaborative environment. In this paper we describe a model for identifying patterns of conflicts in Wikipedia articles. The model relies on users' editing history and the relationships between user edits, especially revisions that void previous edits, known as "reverts". Based on this model, we constructed Revert Graph, a tool that visualizes the overall conflict patterns between groups of users. It enables visual analysis of opinion groups and rapid interactive exploration of those relationships via detail drill-downs. We present user patterns and case studies that show the effectiveness of these techniques, and discuss how they could generalize to other systems.

CR Categories and Subject Descriptors: H.5.3 [Information Interfaces]: Group and Organization Interfaces – Collaborative computing, Computer-supported cooperative work, Web-based interaction

Additional Keywords: Wikipedia, wiki, revert, graph, collaboration, user model, visualization

1 INTRODUCTION

Human existence depends on collaborative problem solving. Nations and companies depend on collaboration to solve vexing problems such as rules of conduct, investment decisions, and resource allocation. It is therefore not surprising that visual analytics must work effectively in collaborative environments. Indeed, diverse fields that utilize visual analytics such as scientific inquiries into climate change and foreign intelligence analysis on Iraq insurgents rely on collaborative problem solving to finally reach actionable conclusions. These conclusions depend on groups of people forming a coherent picture of the problems at hand, and then developing a consensus amidst conflicting user opinions and political pressures. Recently, new collaborative knowledge systems such as Wikis are being used for collaborative problem solving and knowledge gathering [2]. As conflict and coordination costs increase in such environments, visual analytic tools may be increasingly useful for users to make sense of the status of the collaborative environment.

The largest experiment of this kind is probably Wikipedia, which has become one of the most popular knowledge repositories on the Internet. A recent study comparing it against the Encyclopedia Britannica reports that much of the Wikipedia content is of high quality in spite of issues such as vandalism and factual inconsistencies [14].

Since its inception, Wikipedia has been growing at an exponential rate [5, 6, 18, 32, 47]. Over two million articles have been collaboratively edited by more than four million users in the English Wikipedia alone. However, the high level of participation comes with corresponding costs, including conflict between user factions, vandalism, spam, and expression of political ideologies.

Keeping any social structure or organization growing often requires overhead costs, such as coordination and maintenance work [24, p.160]. Wikipedia is not an exception and our earlier work showed that the overhead cost in Wikipedia has increased significantly as Wikipedia evolves over time [18]. We showed that some of these coordination costs result from user disagreements about article content, procedures, and administrative issues.

Visual analytics may provide a mechanism for users to reduce the costs of making sense of the state of collaboration and engaging in the above activities. The result of the visual analysis could help users find major opinion groups and subjects of controversy, identify mediators and abusive editors, and understand the user conflicts within these systems.

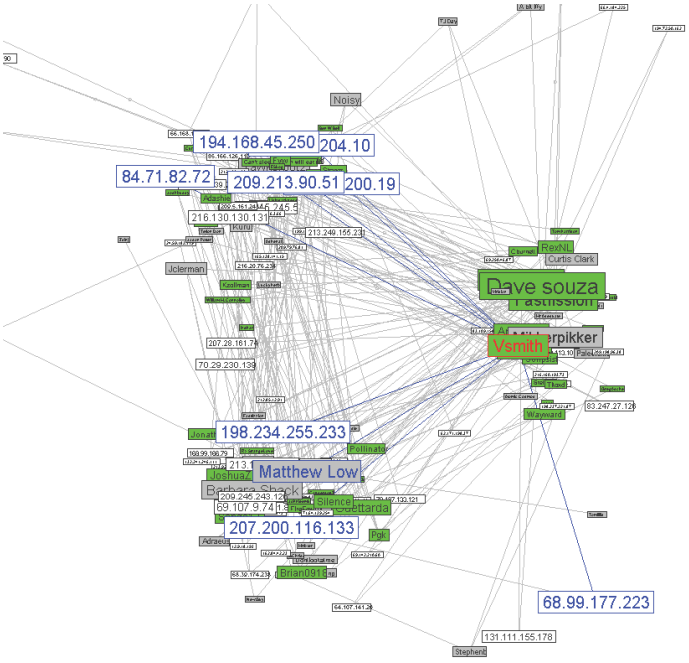


Figure 1. Revert Graph visualizes social structures in Wikipedia articles. Revert Graph for the Charles Darwin page [37]. For a discussion, see Section 6.

Address: 3333 Coyote Hill Road, Palo Alto, CA 94304
Email: {suh, echi, bp}@parc.com, nkittur@ucla.edu

IEEE Symposium on Visual Analytics Science and Technology 2007
October 30 - November 1, Sacramento, CA, USA
978-1-4244-1659-2/07/$25.00 ©2007 IEEE

In this paper, we develop a user conflict model based on users' editing histories, specifically revisions that void previous edits, known as "reverts". Our model extracts reverts from Wikipedia editing history and composes a node-link graph where a user is denoted as a node and a revert relationship as a link. Based on this model, we developed a tool called *Revert Graph* that visualizes the revert relationships between opinion groups. It utilizes a force-directed layout to cluster user groups, and provides detailed drill-down to help identify specific user opinions.

We shall show that the tool can help discover and pinpoint user patterns such as the: (a) formation of opinion groups; (b) patterns of mediation; (c) fighting of vandalism; (d) identification of major controversial users and topics. The tool can be used to identify the severity and nature of a disagreement and the number and composition of the user groups involved. Figure 1 shows some example social structures discovered and characterized using Revert Graph. We believe the tool can form the basis for conflict resolution tools in the future.

The contributions of this paper include:

- the development of a user conflict model for wiki-style online knowledge repositories;
- the creation of a visualization tool that enable analysts to understand and explore user conflicts and opinion groups;
- the presentation of user patterns and case studies that show the effectiveness of these techniques.

The rest of this paper is structured as follows: First, we present related work on Wikipedia social dynamics, collaborative problem solving, conflict resolution, and visualization of social environments. Second, we introduce Wikipedia and its particular structure and statistics. Next, we introduce the user conflict model as well as the particular visualization method we used. We then demonstrate the tool by presenting interesting user patterns and case studies we have found in Wikipedia. We conclude by discussing how the tool can generalize to other systems, future directions, and final remarks.

2 Related Work

Collaborative knowledge spaces and collaborative problem solving are big research areas with many researchers working on different aspects of the problem. In order for these collaboration spaces to be effective, we need to understand how conflicts arise and how conflicts are resolved in these systems. Here we summarize some past works in social dynamics and conflict resolution.

There appears to be a number of intuitions about why collaboration might improve analytics [24, Chapter 8]. First, an individual receiving information cues from a group of other analysts is more likely to be more efficient in exploring a domain area. Second, since the work covering a large domain area can be divided up into the light work of many, one can ensure important pieces of evidence are not missed. Third, knowledge specialization ensures that years of skilled training in one particular area might enable one to build up better ability to spot patterns. Fourth, the diversity of viewpoints can potentially overcome cognitive biases toward one single interpretation of the data.

Researchers have studied this area in the field of Computer Supported Cooperative Work (CSCW) and tried to understand distributed problem solving and cognition. Documents and spreadsheets often are focuses of collaboration. For example, various researchers have studied collaborative writing and commenting [21, 22]. Nardi and Miller found that spreadsheets are used as collaborative tools for problem solving in organizations [20]. Flor and Hutchins described how distributed cognition occurs in a team during software development [12]. Changes in social computing spaces have caused psychologists such as McGrath to examine theories of how groups collaborate over time, and how they resolve conflicts [19].

Indeed, communities of practice have changed greatly since the introduction of the Web and online communities [3, 7, 9]. Arguello et al. studied how individuals must act in order to receive a reply in a discussion forum [3]. Cosley et al. studied how intelligent task routing can help with individuals wishing to collaborate and create useful value to social groups [7]. Dibbell described how conflicts, vandalism, and anti-social behavior manifest itself in virtual worlds such as MUDs and MOOs [9]. Dourish and Bellotti studied how awareness is required for coordination in shared workspaces [10].

Viewed from this CSCW perspective, the rise of conflict and the costs of coordination are unavoidable in a distributed collaboration system [13] such as Wikipedia, and manifest in scenarios such as conflicts between users, communication costs between users, and the development of procedures and rules for coordination and resolution. Researchers have seen similar costs in other computer mediated communication (CMC) systems [8, 9]. Even though researchers have documented the growth of Wikipedia [5, 32], the impact of coordination costs for adding content and users has not been well studied, though Buriol et al. [5] discussed maintenance cost such as reverts and vandalism.

Perhaps the most relevant study to coordination and conflict cost is our previous study [18]. In the study, we discovered that the number of article edits is decreasing while the overhead (i.e., the number of edit intended for communication and policy making) is increasing. The study also introduced a model for the degree of conflict based on simple metrics. According to the study, the increased number of revisions made on article discussion pages is the most significant predictor for the degree of conflict in an article. This finding strongly hints that the degree of conflict and disagreement between users has a close relationship with the amount of total overhead. Motivated by earlier results, here we focus on developing a user conflict model for Wikipedia.

Visual analytics [29] offers a potential solution for understanding conflicts and coordination costs in collaborative social spaces. For example, researchers have visualized conflicts between political blogs [1] and entities in political news [4]. Researchers have also used visualization to understand social spaces by visualizing relationships amongst people in chat rooms [30], friends [17], and other social networks [23].

Visualization also offers a potential way to understand the dynamics of content creation between users of a collaborative space. Viegas et al. showed how visualization can be used to understand the editing history of a single article in Wikipedia [31]. The tool was able to reveal some social patterns such as vandalism, negotiations, edit wars, and anonymous edits.

Visual analytic tools not only can help us characterize the collaboration space such as Wikipedia, but they also potentially could offer benefits to end-users who need to understand how others in their social groups are performing, what they are paying attention to, and what conflict patterns might exist during collaboration. In other words, visual analytics applied to these social spaces will enable a kind of situation awareness [11] of the analytical topic area. These tools reveal social structures and user behavior that shed light on how we can characterize conflicts and coordination costs.

In this paper, we employ a novel method for constructing the conflict model between users in Wikipedia, and apply visual analytic techniques to understand the social relationships between these users. We show how the tool is able to find interesting patterns such as the formation of opinion groups and mediation patterns, and controversial editors.

3 Introducing Wikipedia

Before we explain how we have identified conflict between users in Wikipedia, we first introduce relevant Wikipedia structures and policies, and describe the data that we used in the analysis.

3.1 Wikipedia Data Analyzed

In this paper, we used a complete history dump of the English Wikipedia that was generated on July 2, 2006. The dump included over 58 million revisions, of which 2.4 million are article entries in the encyclopedia, totaling approximately 800 gigabytes of data. To process this data, we imported the raw text into the Hadoop [15] distributing computing environment running on a cluster of commodity machines. The Hadoop infrastructure allowed us to explore new full-scale content analysis techniques quickly. We also cloned Wikipedia's own metadata databases for direct analysis. This database allowed us to inspect Wikipedia statistics in their native format.

3.2 Wikipedia Organization

Here we briefly introduce the internal organization of Wikipedia:

Pages: To manage the work on the encyclopedia while still presenting a usable encyclopedia interface to non-participants, Wikipedia organizes its editable pages into several categories. The encyclopedia content itself is kept on article pages, while discussion of ongoing changes and other disputes to a specific article are kept on an associated discussion, or "talk" page. Similarly, individual contributors have a unique user page, and an associated user "talk" page to enable discussion with or about a user. There is also a revision comment field, which is a free-form text field supplied by each user when submitting an edit, intended to describe what kind of changes were made.

Policies: Most activities on Wikipedia are governed by various policies. Users are encouraged to follow a general policy to Be Bold [36], i.e., take action themselves when there is an apparent reason. Another policy is to refrain from altering content so that it presents a non-neutral point of view [41]. A further policy asserts that material should be attributed to a reliable published source [35]. Together, these and other policies are also subject to the same editing and review process that governs the encyclopedia content, but play an intrinsic character in determining the social norms that the communities is expected to adopt.

Users: Users of Wikipedia fall into distinct categories. Since it is not required for a user to register to edit most pages, many users are anonymous. Users may establish a user account, which allows them to maintain a consistent identity across different sessions and network addresses. Additional permissions can be granted to such users. The most significant of which is the role of Administrator, who has the ability to change many settings, such as locking a page for editing, banning abusive users, and the ability to access content which has been otherwise deleted from the encyclopedia.

3.3 Coordination and Maintenance Cost in Wikipedia

Users interacting with each other create conflicts and incur coordination costs. These interactions take place on user and discussion pages, which constitute a category of work we label "overhead". Overhead work represents the coordination costs of working in such collaboration spaces. One form of overhead consists of edits made to non-article pages. These overhead activities can be roughly divided into three categories: (1) maintenance work such as formatting and fighting vandalism, (2) developing administrative procedures and policies for Wikipedia, and (3) communication cost between users such as edits on article talk, user talk pages.

Our recent study [18] found that work going into editing article pages has been steadily decreasing from 95% to 65% (see Figure 2). Meanwhile, work going into communication purposes has been increasing to about 15–20% of total edits. Vandalism has also been increasing but still accounts for less than 1% of edits.

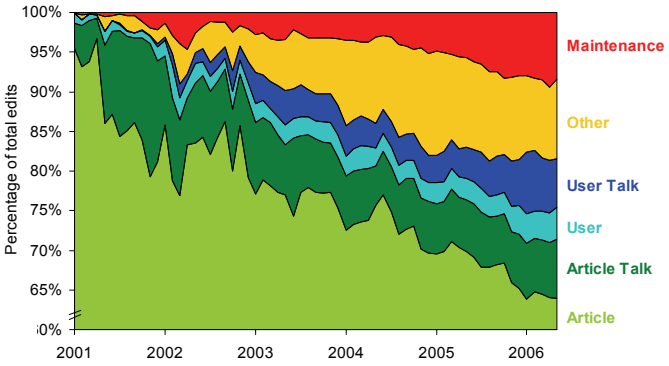


Figure 2. Changing number of edits over time made on various types of pages in Wikipedia

Recent research shows that Wikipedians spend a significant amount of their effort on coordination and conflict resolution [18]. This strongly indicates that there exist underlying social processes that govern coordination. In this paper, we focus on exploring the social dynamics, which is crucial to understanding the coordination and conflict resolution process in Wikipedia.

4 Conflict User Model

To understand disagreement between users, we need to build a model of how users engage in disputes. One way to discover disagreements is to look in the revision log and analyze the substance of each user's edits. However, we found this approach rather impractical for large data sets such as Wikipedia, because it requires accurate identification of the intention of each edit, which is not viable for machine-only processing. Many edits may have non-obvious intentions based on the context in which it was made.

Instead, we use users' editing history to approximate disagreements between users. Specifically, we use revert revisions as a way of identifying disagreement and conflicts between users. The user survey from the previous study enabled us to collect insight that Wikipedians often treat being reverted as an indication that another user strongly disagrees with an edit [18]. We employ revert as a proxy for dispute and develop a user model based on revert activity, described in the next section.

4.1 Reverts in Wikipedia

A revert is defined as undoing the actions of another editor in whole or in part [44]. Reverts are often used to fight vandalism to bring articles back to their original state. However, users also use reverts to block other users' contributions. Edit wars [40] are a typical example, where disagreeing users repeatedly revert each others' edits. Revert is a very reliable sign that one user clearly opposes other's edit, and, therefore, is a reasonable proxy for underlying conflict and disagreement.

We identify reverts in Wikipedia by two different methods. In the data driven method, we computed a unique identifier of every revision made to every article using the MD5 hashing scheme [25], which is commonly used to check that data objects are identical. We use the hashing function to generate a small fingerprint of each revision, which is suitable for rapidly comparing all revisions of an article. Using MD5 values for all revisions of an article, we can identify when a later revision

exactly matched the hash of a previous article, indicating a revert. The advantage of this method is that it does not depend on users to label reverts, which is not always done consistently.

However, the disadvantage of this method is that it does not pick up partial reverts, in which only some of the text in an article is reverted. To capture partial reverts we used a user-labeled metric, counting revisions whose revision comments included the text "revert" or "rv" (a commonly used abbreviation of revert). The combination of both the data-driven and user-labeled methods provides converging evidence on the true change in reverts over time.

Table 1 shows that the statistics for reverts calculated by the two methods have slightly different characteristics. The MD5 identity revert discovery technique captures more revisions than user-labeled (comment) reverts (3.7M vs. 2.4M), suggesting that a substantial number of reverts are not labeled by users as such. The union of the two methods provides the most accurate view of reverts, resulting in 3,917,008 reverts marked by either comments or MD5 hashes. In other words, approximately 6.7% of all changes in Wikipedia goes to restoring articles to previous versions.

Vandalism in Table 1 is calculated by a similar method to the comment method for reverts. We looked through the revision comments of each article for any form of the word "vandal" or "rvv" ("revert due to vandalism"), which are put there by users when removing vandalism. We showed that vandalism appears to be increasing as a proportion of all edits, though it remains at a fairly low level (1-2% of all edits) [18].

Users Total	3,769,347
Users who made at least one revert	402,454
Revisions Total	58,545,791
Reverts (MD5 hash method)	3,711,638
Self-reverts	582,373
Pages with at least one revert	721,866
Pages with 50 reverts or more	9,973
Reverts (Comment method)	2,422,482
Vandalism (Comment with vandal, rvv, etc)	577,643
Reverts (Union of both methods)	3,917,008

Table 1. User, Revision, Revert and Vandalism Statistics

4.2 Revert-Based User Conflict Model

Our user model is based on the revert history between users assuming reverts are proxies for dispute and disagreement. However, we found a number of issues when applying reverts to build a conflict model.

Using reverts to identify conflicts is hard because 1) multiple users are often involved in chains of reverts; 2) edit history is typically long and tedious to browse; and 3) there exist various types of reverts such as the "revert duel" (repeated reverts between two users), self-reverts, reverts by multiple-account users (or sock puppets), and so on. To address these challenges, we made a number of design choices for our conflict model:

- *Disregard Self Revert*: Self-reverts are disregarded.
- *Degree of Conflict*: the amount of dispute between two users is measured by the number of reverts between them.
- *Conflict Group*: When two users make reverts on edits made by another user, but not against each other, the two users are presumed to have similar opinions. We will discuss this principle in more detail in the following section.
- *Identity Based Revert*: the MD5 method is used to identify reverts. When two revisions have the same textual content, we define the later edit as revert.
- *Immediate Revert Only*: When an article page is reverted to an older version other than its immediate last version, the intention of the revert is ambiguous because it is not clear whether the revert is exclusively toward the last edit. We only count the revert relationship between the reverter and the editor who made the immediate last edit regardless of this ambiguity.

We employ these principles to build our visual analytics tool called Revert Graph.

5 Revert Graph – Visualizing User Conflict

Revert Graph is designed to visualize social relationships between Wikipedians as a node-link graph. The tool not only visualizes the conflict model generated from editing history, it also provides useful functions to investigate interactions between users.

5.1 Layout Principles

Revert Graph is a tool that enables an analyst to quickly understand the relationships and patterns of activity that embody the conflict between users. Our layout algorithm simulates the social dynamics that result from the user conflict model. We accomplish this by visually gathering users with similar or compatible opinions together, while separating disagreeing users. We implemented this approach using a force-directed graph layout algorithm [16] that assigns forces such that the edges (representing revert relationships) act as springs, while the individual users are represented as particles with gravitational fields (as shown in Figure 3).

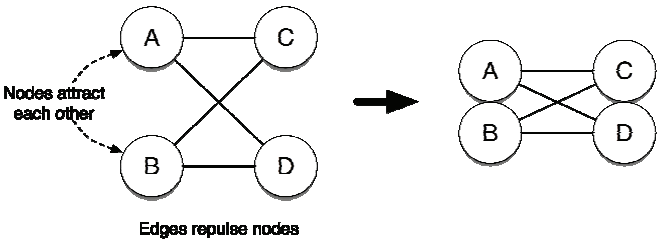


Figure 3. Force directed layout structure employed in Revert Graph. Users (represented as nodes) attract each other unless they have a revert relationship. A revert relationship is represented as an edge, thus pushing such users apart. Left figure: Nodes are evenly distributed as an initial layout. Right figure: When forces are deployed, nodes are rearranged in two user groups.

Initially, the tool loads a group of users participating in editing an article as a uniformly distributed node-link graph. As the simulation runs, forces in the graph stabilize, and social structures between users begin to emerge, as shown in Figure 4.

Node size is proportional to the log of the number of reverts or revisions. Nodes are color-coded based on users' registration status. An administrator is drawn as a *green* node, a normal registered user as a *grey* node, and an unregistered anonymous user as a *white* node, respectively.

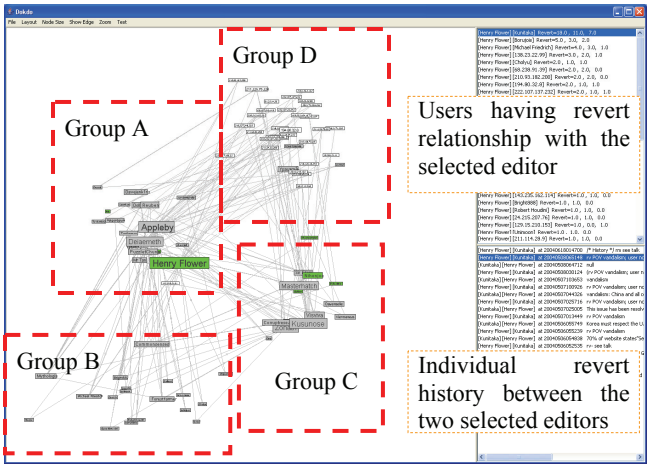
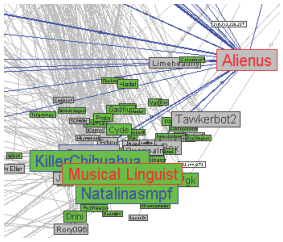


Figure 4. Revert Graph for the Wikipedia page on Dokdo [39] Revert Graph uses force directed layout to simulate social structures between users. The tool also allows users to drill down into an individual revert revision enabling detailed investigation about the nature of the conflicts. **Group A**: mostly users with Korean point of view, **Group B**: mostly users with Japanese point of view, **Group C**: mixed point of view, **Group D**: primarily non-registered users.

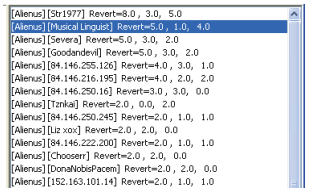
5.2 User Interface

The majority of the screen is devoted to three windows: Revert Graph itself is in the center; a list of revert relationships for the selected user is on the upper right; and the selected individual revert history is on the bottom right (Figure 4). Revert Graph also provides ways to change zooming level, node size, and other visual options. Revert Graph is designed to help identify user groups representing opinion groups, the specific motivation of revisions, and the conflict detail.

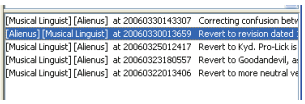
Suppose a user wants to investigate conflicts and disagreements inside a Wikipedia article. The tool allows the user to specify an article she wants to explore by typing the name of the article. Then the revert history of the article is retrieved from our database and a node-link graph is formed and displayed on the screen. A force-directed layout module then clusters user nodes based on revert relationships. Figure 4 shows an example.



(a) A user node, Alienus is selected in Revert Graph



(b) Drill down to list of revert relationships Alienus is involved in



(c) Drill down to revert history between two users

Figure 5. Enlarged view of the Terri Shiavo page [43] in Revert Graph. (a) User first clicks on a specific user node; (b) Revert Graph shows a list of revert relationships that Alienus is involved in; (c) Clicking on a specific relationship in the list shows only the revert history between those two users.

As social structures emerge from the force-directed layout, the tool provides users to drill down the graph allowing investigation to the level of an individual revert (Figure 5). When a user node is chosen in the graph, the upper right window displays the list of users that have revert relationships with the selected user, sorted by the number of reverts between them (Figure 5 (b)). When a revert relationship is selected in this list, the bottom right panel is updated to show individual revert records between the two users involved in the revert revision, as shown in Figure 5 (c). Also, the nodes representing the users are highlighted in Revert Graph to provide visual feedback. Allowing further drill down, clicking an item in the bottom right window launches a web browser showing the specific individual revert record.

Using these capabilities, we were able to identify a number of interesting user conflict patterns using this tool. In the next section, we will describe these conflict patterns in several case studies.

6 User Conflict Patterns and Case Studies

Based on the revert-based user conflict model, we investigated conflicts and disagreements in Wikipedia using Revert Graph and explored to discover social patterns in them. This section presents interesting conflict patterns we have found in Wikipedia.

6.1 Methodology

We used Revert Graph to examine conflict patterns in Wikipedia articles. We selected 901 high conflict articles with more than 250 reverts for analysis. These articles contain a large amount of discussion with extensive editing history, which present a challenge for analysts in making sense of conflict dynamics [18].

Based on the user model, Revert Graph generates a node-link diagram to visualize users and their revert relationships. We then analyzed the graph for any interesting pattern that might emerge.

To examine a potential user conflict pattern in an article, the analysis involved detail investigation of the article revision history. However, we often found it hard to determine users' point of view by browsing only the revisions. To get more clear insight on users' position on the issues of an article, we browsed through information such as revert comments, article talk pages, user pages, and users' edits on other pages.

We now describe user conflict patterns we found in this study.

6.2 Pattern One – Node Clusters And Opinion Groups

Revert Graph rearranges its user nodes based on revert relationships between them. The force-directed layout simulation evolves the graph to gather user nodes together based on underlying social dynamics. We analyzed node clusters to understand cohesiveness in node groups.

The Wikipedia page on Dokdo is one example where we were able to find interesting user groups. Dokdo is a disputed islet in the Sea of Japan (East Sea) currently controlled by South Korea, but also claimed by Japan as "Takeshima" [39]. Figure 4 shows opinion groups discovered on the Dokdo article. We manually labeled users based on their points of view as exhibited by their editing history. To obtain users' points of view on the topic, we browsed their user pages, user talk pages, revision histories, revision comments, as well as specific reverts. For example, users in group A in Figure 4 exhibit the following patterns: (1) claiming Korean heritage on their user pages, (2) supporting the Korean claims in discussions on the users' talk pages, (3) preferring the term "East Sea" over "Sea of Japan", (4) preferring "Dokdo" over the alternate "Takeshima" or the more neutral "Liancourt Rocks".

We observed users in Group C disputing the points of view of Group A. This group includes users who (1) dispute the official U.S. position (which supports the Korean occupation), (2) openly

refute the Korean point-of-view on their talk pages, as well as 3) directly claim Japanese heritage or affiliation on their user pages.

Unlike Group A and C, users in Group B showed mixed opinion on the issue. Group D, depicted only in the figure but not tallied in the table, is not considered in this analysis because they primarily have very short edit histories and 31 out of these 34 users are non-registered users.

Our analysis is summarized in Table 2, which shows that the identified user groups indeed represent distinct opinion groups.

Number of users in user group	A	B	C	Total
Users with Korean point of view	10	6	0	16
Users with Japanese point of view	1	8	7	16
Neutral or Unidentified	7	3	6	17

Table 2. User Groups on the Dokdo article.

As shown in this conflict pattern, node clusters identified in Revert Graph correspond to opinion groups that are not only cohesive but also represent major points of view in these topic areas.

6.3 Pattern Two – Mediation

Another common pattern revealed by Revert Graph is a group of users attempting to mediate between user groups with divergent points of view. These users are not active in expressing a particular view, but rather trying to moderate the discussion towards a neutral version of the article. Users in these mediator roles usually revert edits from many other user groups. This group rejects revisions that do not satisfy Wikipedia content policies such as neutral point of view [41] and attribution [35]. For example, in the Terri Shiavo controversy depicted in Figure 6, users in the center group, which is marked by a dotted circle, revert edits made by other user groups. Their comments revealed that they believe those edits did not satisfy Wikipedia policies.

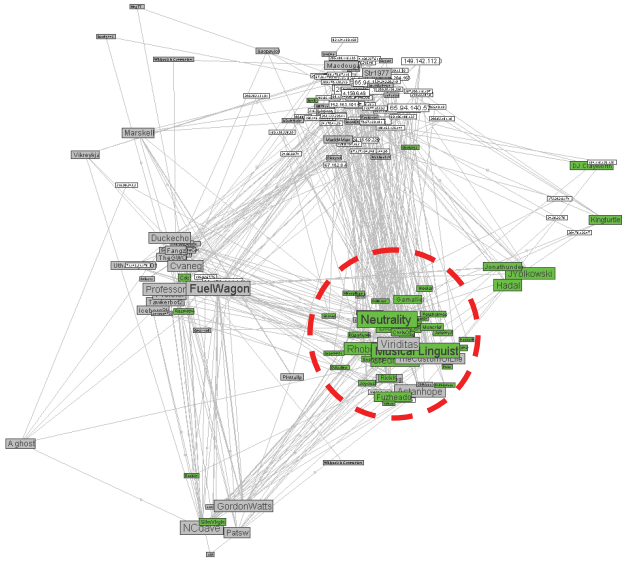


Figure 6. A mediator pattern in Revert Graph applied on Terri Shiavo page [43]. Users in the center group (marked by a dotted circled) revert edits by users in other user groups.

User nodes in Revert Graph are color-coded based on their roles, such as whether they are administrators. Therefore, it is easy to identify that mediators are often administrators as in Figure 6.

6.4 Pattern Three – Fighting Vandalism

Fighting vandalism is an issue in Wikipedia. As shown in Table 1, about 24% of total reverts are made due to vandalism. Revert Graph uncovers clear patterns of vandalism and anti-vandalism efforts. As shown in Figure 7, two user groups emerge in each of these examples, where users in one group reverts revisions from the other group. This first group usually includes many administrators (green nodes) while the second group often contains mostly anonymous users (white nodes).

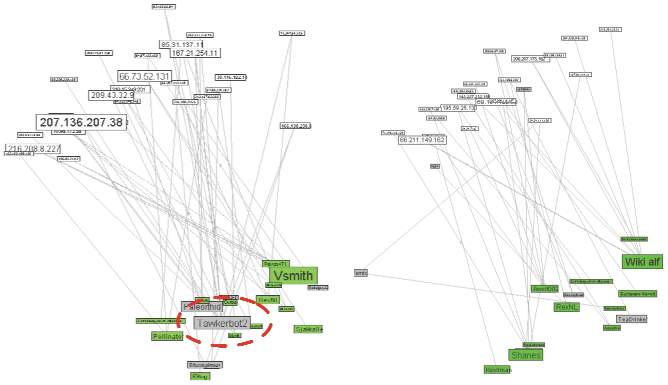


Figure 7. Examples of the vandalism pattern in Revert Graph. The left is Revert Graph applied on Acid rain page [33] and the right is on Uranus page [45]. Two types of user groups are clearly identifiable in each graph. The majority of the upper groups are anonymous users and vandalized articles. The bottom group, which mostly consists of administrators, are fighting vandalism.

In addition, we found that an anti-vandalism robot Tawkerbot2 [34] is often actively engaged in this pattern. The left image of Figure 7 shows that the robot (indicted by a dotted circle) does a decent job of fighting vandalism.

6.5 Pattern Four – Controversial Editor

In Revert Graph, the size of a user node can be mapped to the number of reverts or revisions. In addition, the thickness of the edges represent the degree of revert relationships between users. Together, these features increase the visual saliency of editors who engaged in many reverts, providing an intuitive way to quickly identify users who may be involved in high degrees of conflict. For example, Figure 8 shows how certain controversial editors are easily identifiable in the Revert Graph. They are usually self-appointed experts, or have strong points of view. In the left side example, a few editors appointed themselves as the ultimate source of knowledge relating to Darth Vader. In the right side example, several editors expressed strong personal opinions on Windows Vista.

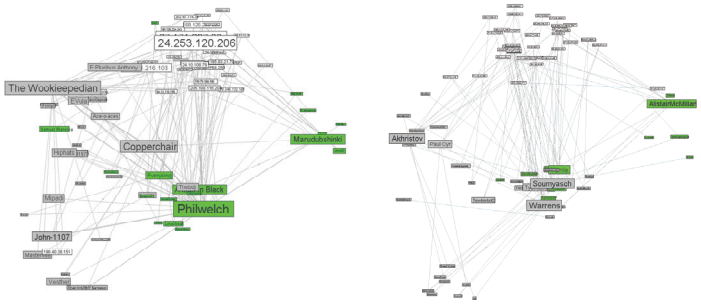


Figure 8. Controversial editors are visually identifiable in both Revert Graphs. Left: Darth Vader page [38]. Right: Windows Vista page [46]

As another example, editors in Figure 1 are involved in debates on Charles Darwin. These editors with heavy revert relationships are visually salient and easily identifiable.

7 Discussion

The Revert Graph visualization helps identify important social patterns in Wikipedia such as groups with differing viewpoints, mediation, vandal fighting, and user conflicts. The above scenarios demonstrate the effectiveness of the revert-based conflict model, which is based on simple revert relationships between users. These results show how surfacing information about user behaviour built up through natural system usage can lead to valuable insights that can help make sense of the evolution of pages and the motives of users.

We believe this paper may help shape the development of conflict resolution tools, which are expected to play an important role in online collaborative systems. These results are most directly applicable to other wiki-based systems in which reverts are tracked as part of system usage. Wiki systems are being deployed in a wide variety of domains, including intelligence analysis [27], corporate memory [28], and scholarly research [26]. Tools such as Revert Graph could be useful in quickly identifying differing opinion groups and promoting situational awareness.

The user conflict model and Revert Graph techniques described here may be applicable to other online communities where conflict relationships between users can be identified. We demonstrated that it may be possible to identify conflicts and viewpoints by using negatively-valenced relationship data collected automatically through normal usage of a system. We believe that the principles behind Revert Graph may be applicable to other, non-wiki based systems where identifying conflict, user factions, and shared viewpoints is important. Some examples include detecting and visualizing collusion and user factions in social collaborative systems where content or users are rated (e.g., digg.com, Slashdot.org).

In addition to the four social patterns described above, we also offer some interesting observations that might be useful in designing these tools. First, we found that there were unexpected controversial sub-topics in Wikipedia articles. For example, in the Charles Darwin page [37], we observed that several users were in dispute over a trivial detail relating to the fact that Abraham Lincoln and Darwin share the same birthday. To our surprise, "September 2005" was a controversial article. We found that high degrees of conflict in that article were caused by news articles reporting disputes in Middle East countries. Discovering these types of unexpected conflicts would be a hard task without the aid of Revert Graph.

Second, disagreements between groups of users often spill over to other related articles. For example, during our investigation of the Dokdo article, users who made reverts on the Dokdo page were also found to have made reverts on other Korean-Japanese pages such as the "Sea of Japan" page. Some users involved in conflicts in the "Anarchism" page also joined the disputes in the "Anarcho-capitalism" page. This observation strongly implies the usefulness of a topic-based conflict model.

Third, we observed various social processes for reaching consensus. As well as using article talk pages and user talk pages, Wikipedians also 1) discuss with third parties, 2) conduct surveys, 3) request mediation, and 4) call for arbitration [42]. Among them, we found that user talk pages were very useful in understanding disagreements and conflicts between users. We believe further effort in modeling user talk pages would provide a deeper insight into the social dynamics of Wikipedia.

Fourth, editors often get confused between "neutral point of view" and "vandalism". For example, introducing a new point of view to an article can be controversial because it can be hard to determine whether it improves the neutral point of view of the article or if it is just vandalism. Sometimes we found it hard to determine this difference ourselves. Improved tools for situation awareness, such as Revert Graph, should enable editors to quickly get a gist of these kinds of conflict patterns.

8 Limitations

As shown in the case studies, there are various types of disagreements and conflicts in Wikipedia. One limitation of our tool is that, while some conflict patterns are discovered (i.e., vandalism, mediation, etc), not every aspect of social dynamics in online collaboration systems was fully addressed. For example, sources of disagreements, types of conflicts, and motivation for editing are deeper questions that require further research. The answer for those questions would provide useful guidelines for designers of online collaborative communities.

Another limitation is that the force-directed layout does not always produce optimal user groups, because it requires sufficient revert relationships in the data set. Since Revert Graph relies solely on revert relationships, the tool cannot detect conflicts between users who were not involved in reverts.

9 Conclusion

Visual analytics can provide useful tools for users to make sense of the state of complex collaborative environments. Wikipedia and wiki-style spaces serve as important examples of how complex collaborative environments develop and evolve over time. The rapid growth of Wikipedia presents a challenge for analysts to understand conflicts and other social dynamics.

To address this challenge, we have been building a model of how conflicts occur in Wikipedia and how conflicts are resolved. We used this model to develop a visualization tool called Revert Graph to facilitate analysts to understand user conflicts and explore opinion groups revealed in the visualization. We also demonstrate the effectiveness of the tool by presenting interesting user patterns and case studies that we found in Wikipedia.

The tool can answer questions such as the severity and form of the disagreement as well as the shape and size of opinion groups. The case study revealed conflict patterns such as the identification of (a) the formation of opinion groups, (b) patterns of mediation, (c) vandalism, and (d) major controversial users and topics.

Further research is needed to understand how visual analytics can help analysts to understand a wide variety of problems in collaborative spaces. We believe that the approach taken here may inform the development of other conflict resolution and situation awareness tools for collaborative environments.

Acknowledgements

We would like to thank Peter Pirolli, Stuart Card, and Mark Stefik for valuable advice, and to James Forrester who helped facilitate this research.

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