

Decentralized Collaboration with a Peer-to-peer Wiki

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Abstract—We report our experience using a peer-to-peer (P2P) wiki system for academic writing tutorials. Our wiki system supports a non-traditional collaboration model, where each participant maintains their own version of the documents.

The users share their contributions in the P2P network, which allows them to be exposed to multiple viewpoints, and to reuse each other’s work.

We collected and analyzed the contributions of the participants to these tutorials, and the results demonstrate the value of this collaboration model.

In particular, we found the popularity of a document in the system is correlated with its quality, and the similarity between contributions of peers is a good predictor of future similarities.

These properties provide helpful criteria for users to identify valuable material for reuse.

Keywords—Peer-to-peer; Wiki; Collaboration; decentralized

I. INTRODUCTION

When a group collaborates towards solving a common problem, it is usually understood that the goal is to obtain a single solution to the problem, produced by the efforts of all the participants, and agreed upon by all.

Most groupware systems^a therefore place the work material in a centralized, shared space, which all the participants contribute to. For example, in traditional wiki systems, the edits made by one user produce a version that replaces any previous existing version. Any debate over the content must be conducted in a separate space, such as the “talk page” in Wikipedia.

In a classroom setting, a common practice is to have the students first work individually or in small groups on a problem, then open up the discussion to the full classroom, in order to compare and discuss the different solutions obtained by the different students or groups.

In an e-learning setting, using a traditional groupware system such as a wiki makes it difficult to expose students to multiple solutions, and may suggest that there is always a single, best solution.

In this paper, we report our experience using P2Pedia, a new peer-to-peer wiki system (first described in [3]), for in-class academic writing tutorials, as part of an early year undergraduate course at Carleton University, on research methods for legal studies. The tutorials were meant to expose common flaws in academic writing.

Students were given a poorly written text, and asked to improve its style. This is a good example of a problem which does not have a single solution, but several possible ones. During these tutorials, the participating students were given the opportunity to work both individually and in groups, and were exposed to many different solutions to the given problem. These solutions were the documents written by their peers, and shared using P2Pedia.

P2Pedia is a wiki system built on a peer-to-peer (P2P) file-sharing infrastructure. Each user stores a local collection of wiki pages, which can be searched and downloaded by other peers.

When a user downloads a document from a peer, the document is duplicated, so that both users can separately edit their local copy, without needing to merge their subsequent versions. After an edit, the resulting situation is that the old and new versions coexist in the network. This way, when the peers are working on a shared problem, they can be exposed to many alternative ideas, which they can incorporate into their own solutions.

This collaboration model allows each participant to produce their own solution to the problem, while benefitting from their exposure to the work of others.

Beyond its intuitive appeal, we would like to more formally assess whether (and how) this decentralized collaboration model can benefit students’ learning experience.

More precisely, we can formulate two interesting research questions:

- How can the students identify valuable contributions from their peers?
- Do the students benefit from having their own solutions, versus agreeing on a common solution?

By analyzing the documents contributed by the participants

^ain the sense of computer systems meant to support cooperative work

in the writing tutorials, we have validated two ways that students can identify valuable contributions from their peers. The first is the “wisdom of crowds” effect: the most *popular* edits to the original text, which can be identified using P2Pedia’s search functionality, produce documents of high academic *quality*. Secondly, we observe that students who have made similar changes to a document in the past, tend to agree on future modifications: this shows that the *similarity* of peers, as measured by the similarity of the documents they store, is a way for students to find like-minded peers, with ideas that they are likely to find valuable.

Regarding the second question, our analysis of the documents produced by the participants shows that a common solution could *not* incorporate all of the most valuable ideas, thus suggesting that there is a clear benefit in multiple solutions. In addition, feedback from the class instructor and from the students, collected through an online survey, agree with this conclusion.

The rest of this paper is organized as follows. In section II we summarize the characteristics of P2Pedia, then briefly survey related work in section III. In section IV, we describe in detail the setup of the academic writing tutorials, and the data that we collected. We analyze data popularity in section V, and the similarity of peers in section VI. Finally, we report the results of our survey of P2Pedia’s users in section VII, before concluding in section VIII.

II. P2PEDIA, A PEER-TO-PEER WIKI

P2Pedia is a Wiki system built on top of a peer-to-peer file-sharing application. In other terms, it is a file-sharing application where each shared file is a Wiki page.

A. P2P Architecture

Traditionally, wikis are hosted and administered in a centralized way, by a single organization.

Peer-to-peer (P2P) architectures are nowadays often used for their scalability and resilience. Here, we are mostly interested in the decentralization that such architectures offer. In P2P computing, each file-sharing application run by a peer is called a *servent*, and is simultaneously a client and a server. In pure P2P architectures, such as that of P2Pedia, all the servents have interchangeable roles.

The users (peers) of P2Pedia each run a file-sharing servent (similar to Limewire or Emule) which hosts a collection of wiki pages, which are accessed through a web browser. The peers can view and edit pages as in traditional wikis. The main difference is that when a page is downloaded from a remote peer, a local copy is saved, unlike in traditional wikis, where the local copy is only saved in the browser cache.

When a page is edited, the new version is also stored locally, and the changes are not sent to the other peers. This way, after an edit, both the old and the new version are available in the

network, unlike in traditional wikis where the new version replaces the old one as current authoritative version.

Each peer is in full control of their local collection: they can freely add, remove, or edit pages. Peers use the file-sharing search and download mechanisms to locate and exchange documents, i.e. versions of pages. The global collection of pages available in the wiki is thus distributed over all the participating peers, and copies of each document – i.e. of each version of each page – may exist on one or several peers.

The servents use a fully decentralized P2P protocol similar to the original Gnutella protocol [1], which allows them to locate pages using a *search* functionality, before downloading them through HTTP connections, just like ordinary web pages. The peers establish connections which are used to route search queries: when a peer searches for a page, it sends the query to its neighbours, who return their available answers and forward the query to their own neighbours, and so on up to a predetermined network distance.

B. Versioning process

This editing principle generates a non-trivial versioning process: instead of a linear sequence of versions, the versions branch out into a tree. An edit is recorded as a “child to parent” relationship, and stored as a link from the child version to its parent. The different pages, and their different versions, can be located by queries: users can search for the parent version of a page, or for a page’s children, or even for a page’s “descendants”, i.e. the transitive closure of the child relationship.

Users can also navigate wikilinks: clicking on a wikilink triggers a search for all the versions of the linked page.

A major challenge for the users is to choose between the available versions of a page; instead of the system or its administrators imposing a single “current” version, the burden (and freedom) of making this choice is on the user.

One of the main novelties of P2Pedia is the presence of “trust indicators”, which are offered by the system in order to help users choose between the different versions.

In traditional wikis, the role and value of each version of a page is imposed and well defined by the system: the latest version is the “current” version, whereas previous versions are all equally obsolete. In our model, each version can potentially be replicated across the network, and the distribution of these copies carries valuable information about the version. For example, the number of copies indicates the “popularity” of a particular version. The content stored by a peer may also provide an indication of the interests of the peer, and this indicator about peers can in turn be reused as a clue to the value of documents shared by these peers.

The trust indicators of P2Pedia are numerical values attached either to documents or to peers. We detail them below.

C. Trust Indicators

P2Pedia offers one trust indicator for documents, the *popularity* of a document, and three trust indicators for peers: *peer popularity*, *peer similarity*, and *network distance*.

1) *Document popularity*: This indicator relies on the assumption that the number of copies of a particular document in the network is an indicator of its quality. The idea is that if many other peers have saved this document, then it is likely worth reading and saving. The popularity of a document can be determined during a search by the number of peers that return each document as a search result.

2) *Peer popularity and network distance*: These two indicators rely on the idea that connections between peers are established purposefully by one of the peers (and accepted by the other), in the sense that the peer originating the connection trust the other peer to provide valuable content, either on the basis of social acquaintance, or on the basis of prior interactions.

The popularity of a peer, here, is the number of other peers that choose this peer as a neighbor, and can be measured by the number of incoming network connections to this peer. This indicator is returned along with search results.

The network distance represents a measure of the distance of a peer in a social network: a distance of 1 is a direct acquaintance, a distance of 2 is a “friend of friend”, etc. this indicator is measured by the number of network hops that a search response message travels to reach the query originator.

3) *Peer similarity*: The similarity between two peers is measured by the similarity of the document collections stored by the peers. The rationale of this trust indicator is the same principle used in collaborative filtering (or recommender systems): the fundamental assumption [5] is that if users A and B tend to rate items similarly, they share similar tastes, and hence will rate other items similarly.

As mentioned above, here we do not use explicit “ratings” of documents, but consider that if a peer shares a document, it thus expresses an implicit positive rating of this document. The “rating similarity” of two peers P_1 and P_2 is then measured by the Jaccard coefficient^b of the sets of documents in the repositories of P_1 and P_2 :

$$sim(P_1, P_2) = \frac{documents(P_1) \cap documents(P_2)}{documents(P_1) \cup documents(P_2)} \quad (1)$$

III. RELATED WORK

A. Wikis in a Learning Context

Several studies have investigated the use of wikis as a support for collaborative learning. Although wikis are generally found to be useful tools for collaboration, a number of drawbacks and limitations with their collaboration model have been pointed out.

Cole [2] reports on a failed attempt at using a wiki for a university course, where none of the students contributed any content. As reasons for not contributing, the students cited reasons including not wanting to be the first to post content on the wiki, or a lack of confidence to make valuable material. Wheeler et al. [10] reports on the creation of shared course material by students and note that, “although happy to post their contributions to a wiki space for other group members to read, [the students] are resistant to having their contributions altered or deleted by other group members”. Minocha and Thomas [6] found that students were also reluctant to modify the work of others.

With P2Pedia, participants are essentially working for themselves, simply exposing their work for others to use; this avoids problems with deleting or altering the work of others.

Dishaw et al. [4] report experiments where students worked in virtual groups using either a wiki, or else a word processor with the “track changes” functionality in combination with emails to produce reports. The participants found the word processor and email more useful and easier to collaborate with than the wiki. Interestingly, P2Pedia features both a “track changes” mechanism and a “download” functionality quite comparable to emails. This study therefore makes us quite optimistic about the usefulness of our collaboration model.

B. Decentralized collaboration

Most existing Wiki systems, including distributed Wikis deployed in P2P networks, support a centralized collaboration model, where a single “master version” of each article is available at any given time. An example of such P2P Wiki systems is Piki [7], which is deployed in a Distributed Hash Table (DHT).

The decentralized collaboration model of P2Pedia is similar to that of distributed Version Control systems (DVCS), such as Git [9]. These systems are primarily used for software development, and are popular in the open-source community. They allow projects to be “forked”, which means cloning a repository and subsequently modifying the clone, rather than directly incorporating modifications into the original repository (which may have its own evolution).

Rahhal et al. have proposed a semantic wiki based on the same principles, which they termed a “Multi-Synchronous Semantic Wiki” [8]. Such a system would support decentralized collaboration, but lacks a “search” functionality, which is one of the key aspects of P2Pedia, since its trust indicators can help users identify valuable content. In contrast, a collection of repositories joined by a DVCS (or a multi-synchronous wiki) is not inherently searchable. A search functionality may be offered by a separate hosting solution such as Github^c (for open-source software).

^balso known as “Tanimoto coefficient”

^cwww.github.com

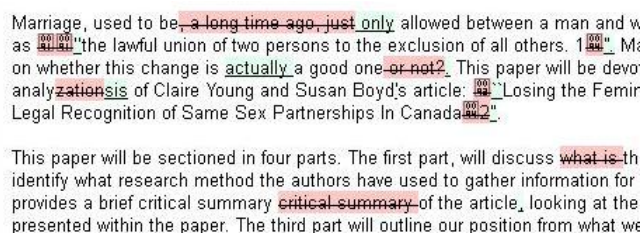
IV. ACADEMIC WRITING TUTORIALS WITH P2PEDIA

A. Tutorial setup and workflow

We report on academic writing tutorials that took place as part of an undergraduate course in the Department of Law at Carleton University, in the Fall semester of 2011. There were 12 tutorial groups, of approximately 20 students each, and each group had a separate tutorial session. The tutorial sessions were held in classrooms with one computer per student, and one for the instructor, and lasted 80 minutes.

The tutorial workflow was as follows.

- 1) Initially, the provided text was published on the instructor's node. Students were grouped in small groups of three to five students, so that there were four subgroups in each tutorial groups. The connections between the nodes were set up so that the students could access the work of their neighbours in the small groups.
- 2) Each student downloaded the initial document, then worked individually to improve its style.
- 3) After approximately 20 minutes, the students were asked to search the network and download the versions written by their peers from their subgroups. The students were given ten minutes to read the edits made by their peers, which could be highlighted by a "diff" functionality, as illustrated by the screenshot in Figure 1.
- 4) The students then got together by subgroups, and collaboratively created a "master" version merging their different edits. For this step they sat together, and worked on a single computer. This second phase of editing lasted approximately 15 min.
- 5) The instructor then lead a group discussion with the whole classroom, of the different solutions proposed by the different subgroups.



Marriage, used to be, a long time ago, just only allowed between a man and w as the lawful union of two persons to the exclusion of all others. This paper will be devoted on whether this change is actually a good one or not? This paper will be devoted analysis of Claire Young and Susan Boyd's article: Losing the Femin Legal Recognition of Same Sex Partnerships In Canada.

This paper will be sectioned in four parts. The first part, will discuss what is th identify what research method the authors have used to gather information for provides a brief critical summary of the article, looking at the presented within the paper. The third part will outline our position from what we

Figure 1. P2Pedia screenshot: "Diff" highlighting of the changes between two versions.

B. Collected Documents

After the tutorials, the different versions of the documents written by the students were collected^d.

A total of 241 different versions of the document were collected, 208 versions from the individual editing phase, and 35 versions from the group editing phase.

^dWe note that students could opt-out of the study, and that this research has received clearance by Carleton University's Ethics Review Committee

The first sentence of the document to be edited, which we will use as an example throughout this paper, was the following:

Marriage, used to be, a long time ago, just allowed between a man and woman, but it is now defined as "the lawful union of two persons to the exclusion of all others."

C. Atomic edits

The different versions written by the peers were analyzed using a "diff" tool, which tracks the changes between two versions of a document by listing the minimal additions and suppressions to go from the first version to the second. We applied the diff tool at the granularity level of whole words, and tracked the exact location of each atomic edit with respect to the original text. For example, an atomic edit might list the words "Marriage, used to be," as being removed at character position 0, or the word "was" being inserted at position 38 (the position refers to the position with respect to the original text; the inserted word may be only at position 10 in the new text).

This way, each document version can be represented as a set of atomic edits. As we will see, the collection of atomic edits has much more interesting statistical properties than the collection of documents: due to the limited editing time, each student only produced one or two versions of the document, and only downloaded those of her immediate neighbors to read them, as per the tutorial workflow; on the other hand, each document version contained dozens of atomic edits, and these edits were often made by many students: some appeared in over 50% of the document versions.

In the following sections, we give some general properties of the atomic edits and their statistical distribution.

D. Edit inclusion

Two atomic edits, while not identical, can have some level of similarity. For example, an edit can include another edit: deleting the words "Marriage, used to be," at position 0, includes the edit that consists of deleting only the word "Marriage" at the same position. Such inclusions were considered when counting the frequencies of edits: when counting the frequency of the edit ["Marriage" deleted at position 0], we also incremented the count when the edit ["Marriage, used to be," deleted at position 0] occurred. The opposite is not true, of course. On average, extending the set of edits in a document with "included" edits increased the number of edits by approximately 40%.

The edit frequencies discussed below were calculated after extending the lists of edits with "included" edits.

E. Frequency of atomic edits

Interestingly, we observe that the frequencies of the different edits appear to follow distribution very similar to that of words

in a natural language, which follow the so-called ‘‘Zipf’s law’’: the frequency of the n^{th} most frequent word is inversely proportional to n . This law is visible when term frequencies are plotted on a log-log graph.

Figure 2 shows the frequencies of atomic edits, plotted against their frequency rank on a log-log scale, with the line indicating the slope of a function $y \propto \frac{1}{x}$ (on a logarithmic scale). We note that there is a ‘‘cutoff’’ of the higher frequencies, and that the Zipf-like distribution applies for edits after the first 32 values (out of 5500).

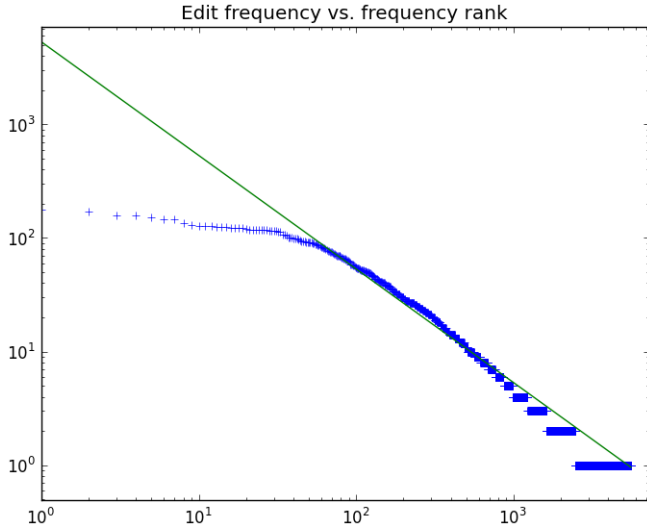


Figure 2. Frequency of the different atomic edits

F. Similarity of documents

As was mentioned earlier, the short duration of the tutorials and their rigid workflow mean that the distribution of articles across peers has little significance: essentially, each peer produced a single version, of which copies are found on the nodes of the peer’s immediate neighbours, in the small groups.

Thus peer similarity, here, would be quite meaningless. However, by using the finer granularity of atomic edits, we can consider each document version as a peer’s ‘‘repository’’ of atomic edits, and evaluate the similarity of peers based on the similarity of these repositories.

Figure 3 shows a plot of the Cumulative Distribution Function (CDF) of the similarities between all the document versions from the individual editing phase. Most pairs of documents have a reasonable similarity, with less than 5% of the comparisons yielding no edits in common at all, and also very few highly similar documents.

V. DOCUMENT QUALITY AND POPULAR EDITS

A. Edits and Document quality

We now address the following research question: is the popularity of the edits contained in a document an indication of the quality of the document?

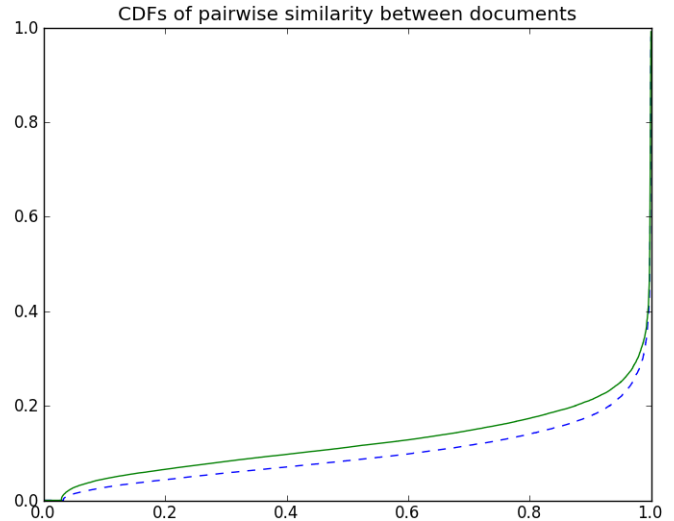


Figure 3. Pairwise similarity of documents: CDF. The dashed line shows the similarity of edits excluding their ‘‘included’’ edits (as discussed in section IV-D), and the continuous line shows the similarity of edits after the included edits were added.

In the specific context of these writing tutorials, the students’ goal was to improve the language of the documents, i.e. the grammar, spelling, and general writing style. Therefore, the quality of these particular texts can be evaluated in a somewhat objective way by a human expert.

In order to evaluate the correlation between popularity and quality, we automatically assigned scores to the documents, based on the popularity of their edits, and compared a sample of these scores with the evaluation of a human expert, namely the class instructor.

Our scoring function $S1$ uses the frequencies of the edits: for each edit in a text, we assign a score equal to the popularity of this edit (i.e the number of times it occurs across the different document versions), and sum the scores of all the edits in each version. We then ranked the documents by this score and chose ten documents corresponding to scores at the 10%, 20%, .. 100% percentile ranks, and submitted these documents to our expert for evaluation.

We also experimented with variations of our scoring function, which mostly produced identical or nearly-identical rankings of the papers. We include here the results of a second scoring function $S2$, which considered only the most popular edits: each edit was assigned 1 point if it was among the top 300 popular edits (meaning it appeared in at least 10% of the documents), and 0 otherwise. The edit scores were then added up for each document, as in the scoring function $S1$.

The results are summarized in Table I, which shows the ranking of the documents according to the expert, and according to our two automatic scoring functions. The expert considered that several documents were of equivalent quality, and instead of assigning absolute scores to each document, he ranked them in five tiers, from the best to the worst.

TABLE I
EVALUATION OF THE SAMPLE DOCUMENTS BY THE CLASS INSTRUCTOR
AND BY AUTOMATIC SCORING FUNCTIONS. THE LETTERS A,B,..J
IDENTIFY THE DOCUMENTS OF THE SAMPLE.

Rank	Expert	S1	S2
1	A	A	A
2	B, C	B	B
3		D	F
4	D, E	F	D
5		G	E
6	F, G, H, I	H	C
7		E	G
8		C	H
9		I	I
10	J	J	J

In order to estimate numerically the correlation between these different evaluations, we evaluate the correlation between the rankings that they produce, using Spearman’s rank correlation coefficient^e.

The correlation value of $S1$ with the expert correlation is 0.61, and the correlation of $S2$ with the expert evaluation is 0.77. We estimated the significance of these figures by estimating the correlation of the expert ranking with 1000 randomized rankings. Our true correlation coefficients were found to be within the top 5% of all the values obtained by randomization, which confirms the statistical significance of our figures with at least 95% confidence.

We can thus conclude that the most popular edits are the most likely to make the best quality documents. This suggests that it could be valuable to use the most popular edits to make a synthetic “ideal” version. We explore this question in the next section.

B. Edits and multiple solutions to a problem

One important observation here is that many of the edits are incompatible, i.e., they cannot be applied to the same text. A simple example of incompatible edits would be a pair of edits where different words are inserted at the same position.

Using simple compatibility criteria, such as the one stated above, we analyzed the compatibility of the most popular edits. Among the top 100 popular edits, we found 33 pairs of incompatible edits. Among the top 300 popular edits, we found 324 pairs of incompatible edits. This is consistent with the characteristics of the problem: as the class instructor noted,

“[the] goal was not to have students create a perfect edited version that matched some pre-established notion of what the text should look like. Rather, the goal was to challenge students to identify ways to improve the sample text. There was no single right answer to this exercise.”

^eSpearman’s rank correlation coefficient is obtained by replacing each value of each random variable by the rank of that value, then applying Pearson’s correlation coefficient to the obtained “rank” variables.

As the most popular edits were incompatible, this implies that it is not possible to make a single “ideal” document, but that several potential “best” documents could be made by combining the compatible edits together. An interesting question is then: what is the minimal number of documents that can accommodate the top k most popular edits?

This problem can be expressed as a graph coloring problem, and is thus NP-complete; but it can be solved for a small value of k . We found that the 100 most popular edits can be accommodated in 3 different versions. The 300 most popular edits – corresponding to all the edits that occur in at least 10% of the documents – require at least 7 different versions. We note that mathematical solutions to the problem would not necessarily lead to grammatically correct text, which simply means that the minimum number of documents with good english is likely to be higher.

In a way, this analysis provides elements to answer our main research question, regarding the value of our decentralized collaboration model. In this exercise, if the participants had been forced to choose a single solution, they would have had to give up on many of the popular (and valuable) changes that they had identified in the individual editing phase.

Again in the words of the class instructor,

“The major benefit of the P2P system for our class was that students could see their peers’ work in real time and then use the knowledge they gained from that experience to improve their own work. By using the P2P platform we were able to give students access to each other’s work, while also encouraging group collaboration. Ultimately, this could be used to allow students to improve their work through exposure to the work of their peers, while also promoting the importance of the students’ individual work.”

In addition, the feedback from the students (see section VII) also seems to indicate that a large proportion of the students would not have submitted the group-edited versions for evaluation, but would have rather made their own tweaks to these versions. This suggests that the students also see value in having their own solution, which is usually not possible with traditional groupware.

VI. PEER SIMILARITY

We study here the following question: if two peers make similar edits on one document, are they likely to make similar edits on a different document? If this is true, then the similarity between users’ documents can be used as basis for collaborative filtering, for example, the application could recommend edits to a user, that the user is likely to incorporate. More generally, we hope – although we cannot analyze this in this setting – that this extends to documents: users that have similar collections of documents will tend to agree on their

“rating” of other documents, i.e. their decision to keep those documents or not.

In order to address this question, we divide the set of edits in two parts: the edits that apply to the beginning of the text (up to a certain character position), which we will call the set A of edits, and those that apply to the end of the text, the set B of edits.

Then, for each pair of documents^f, we calculate how similar their edits were on the beginning of the text, i.e. how similar their edits from set A were. Then, for those documents that have similar edits on the beginning of the text, we can estimate the similarity of the edits they made on the end of the text, i.e. the similarity of their edits from set B .

We note $u_{d,A}$ the set of edits from A in a document d , and $u_{d,B}$ the set of edits from B in the same document.

The similarity of d_1 and d_2 on the beginning of the text is obtained by comparing the vectors $u_{d_1,A}$ and $u_{d_2,A}$, and their similarity on the end of the text is obtained by comparing the sets $u_{d_1,B}$ and $u_{d_2,B}$. We measure the similarity between sets of edits using the jaccard coefficient (defined in equation 1, in section II-C3), as it is the similarity metric that P2Pedia offers to measure the similarity between peers. For all pairs of documents (d_1, d_2) we can thus compute two random variables X_A and X_B :

$$\begin{aligned} X_A &= \text{jaccard}(u_{d_1,A}, u_{d_2,A}) \\ X_B &= \text{jaccard}(u_{d_1,B}, u_{d_2,B}) \end{aligned} \quad (2)$$

We can then measure the correlation of the random variables X_A and X_B . As we are particularly interested in the cases where $u_{d_1,A}$ and $u_{d_2,A}$ are similar, we keep only the top 50% most similar pairs of documents (with respect to set A).

Calculating Pearson’s correlation coefficient for X_A and X_B gives us a value of 0.44, i.e. a high positive correlation. This correlation can also be seen graphically, by plotting one X_B as a function of X_A . This plot is shown in Figure 4.

Again we can assess the statistical significance of this value by applying a randomization test. Here we computed the correlation of X_A with 1000 random permutations of X_B , and obtained correlation values confined to the interval $[-0.02, 0.02]$. This shows that this correlation is statistically significant with very high confidence^g.

VII. USER PERCEPTION

After the tutorial, we proposed an online poll to the student in order to collect direct feedback on the usability of the

^fnote that with a few exceptions, the documents and peers are matched one-to-one

^gWe note that these extremely low values for the randomization test may be surprising, compared to those that could be obtained when validating the correlation of our scoring functions; these values are due to the fact that the variables X_A and X_B have very many values (several thousand), which makes it extremely unlikely that high correlations will occur by chance. In contrast, with only 10 values there is approximately a 5% chance of obtaining a correlation above 0.5.

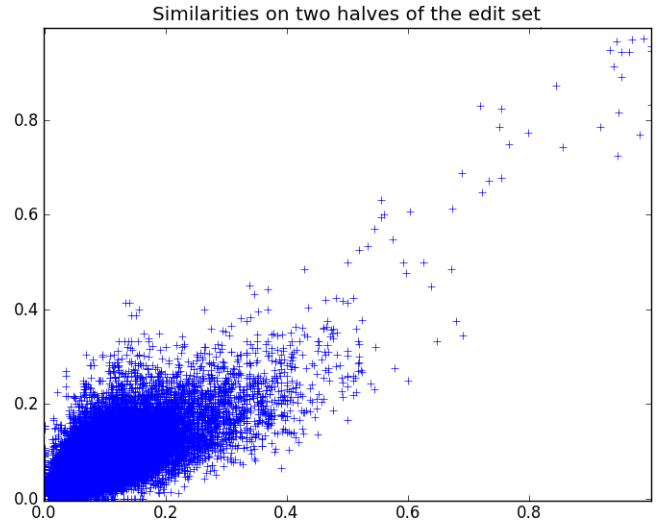


Figure 4. Similarity of the edits on the end of the documents, plotted as a function of the similarity of the edits on the beginning of the documents.

tool, and on the collaboration model. Unfortunately, only a small proportion of the students took the time to answer (21 students, so around 10% of the participants to the tutorials), which makes the results anything but statistically significant. We report a few interesting results nonetheless, and leave a statistical confirmation of the figures for future work.

A. Usability

71% of respondents found the interface easy to use (29% unsure); 66% found it easy to search and download their peers’ versions (5% disagree, 29% unsure).

B. Benefit of the activities for the students’ learning experience

66% thought that reading their peers’ work contributed to their learning experience (5% disagree, 29% unsure), 33% thought that the group editing activity contributed to their learning experience (24% disagree, 43% unsure). Overall, 60% thought the writing exercise was useful, and 77% thought that P2Pedia was an appropriate tool for the exercise.

C. Single vs. multiple solutions

We introduced several questions for the purpose of evaluating whether it was beneficial to allow, ultimately, multiple solutions to the problem.

53% thought that it was easy to reach an agreement (a solution that everybody agreed on) in the group editing phase (14% disagree, 33% unsure); if they had to submit the result of the tutorial for evaluation, the students would either submit the group edited version (48%), or make their own tweaks to the group-edited version (48%), and 5% would choose to write their own version entirely. Finally as for the solutions, 62% thought that the instructor should select the best solutions and

offer them as (multiple) solutions, whereas 38% thought the instructor should either write their own or select the best one to post as a single solution.

These responses suggest that while many students see a benefit in collaboration, either by being exposed to the solutions of others, or by actively working together in a group editing activity, a large part of them would still like to submit their own, personal solution; and it seems reasonable that the students would also want to see multiple solutions provided by the instructor.

VIII. CONCLUSIONS AND FUTURE WORK

We have reported on a successful use of P2Pedia, a peer-to-peer wiki, for academic writing exercises. The collaboration model of P2Pedia allowed the students to work on their own solution to the proposed problem, while being exposed to each other's work.

The data collected during these tutorials also provided some insight into the value of our "trust indicators", which are key features of P2Pedia in the perspective of larger-scale deployments.

In a larger deployment, we foresee a key challenge arising from the amount of data produced by our decentralized collaboration model: as each peer may produce a different solution, the total amounts of data shared in the system can be huge, and there is clearly a need for some automatic sorting, or filtering, of this data, in order to facilitate the discovery and reuse of valuable elements.

Our analysis shows that data popularity is strongly correlated with *quality*, which makes this indicator a good tool for sorting the data. In addition, we show that peers that have produced similar data in the past will tend to agree on their future contributions, which makes similar peers good candidates for collaboration. In a way, this analysis shows that the similarity of peers according to our criteria fulfills the conditions necessary for making valuable *recommendations*, in the sense understood in the field of collaborative filtering [5].

However, our experiments had several important limitations.

For one thing, the tutorials followed a somewhat rigid workflow; the participants were not freely experimenting with the features of P2Pedia as they might in a more unrestricted setting. The tutorials only lasted for a short time, which did not allow for sequences of edits longer than two or three versions, or for a meaningful use of the trust indicators: the participants were never faced with the problem of choosing between many versions of a document. In addition, they were assigned groups, which means that the peer-to-peer connections did not reflect any real-life social connection between the users.

This has the benefit of clearly exposing the properties of the students' collective work, but it makes it difficult to evaluate how the users might collaborate in a less guided context and over a longer period.

Therefore, although we have strong arguments showing the value of our trust indicators, further research is needed to understand how users will make use of them in a more "freeform" use of P2Pedia.

Another limitation of our study is the low response rate of our online survey, which limited the statistical significance of its results.

In future work, we are planning new experiments with P2Pedia, in academic and non-academic contexts, in order to further validate the usability of P2Pedia and its collaboration model.

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