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A Guided Tour of Literature Review: Facilitating Academic Paper Reading with Narrative Visualization

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ABSTRACT

Reading academic paper is a daily task for researchers and graduate students. However, reading effectively can be challenging, particularly for novices in scientific research. For example, when readers are reading the related work section that cites a fair number of references in limited page space, they often need to flip back and forth between the text and the references and may also frequently search elsewhere for more information about the references. This increases the difficulty of understanding a paper. In this paper, we propose a narrative visualization system that helps the reading of academic papers. As a first step, we adopt narrative visualization to present literature review as interactive slides. Specifically, we propose a narrative structure with three levels of granularities that the reader can drill down or roll up freely. The logic flow of a slideshow can be organized based on the paper's presentation or citations. We demonstrate the effectiveness of our system through several case studies and user studies. The results show that the system allows users to quickly track and glance related work, making paper reading more effective and enjoyable.

CCS Concepts

•**Human-centered computing** → **Visualization**; *Visualization systems and tools*;

Keywords

Narrative Visualization, Narrative Structure, Data Storytelling, Text Visualization, Related Work, Literature Review

1. INTRODUCTION

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Reading academic papers is a regular research activity for researchers to acquire existing knowledge of a given field, and to keep track of the latest developments and trends. However, effective reading can be challenging, particularly for novices in scientific research. Readers may not have enough experience to quickly locate relevant information and evaluate the importance of associated references. It also takes considerable effort and time to retrieve further information regarding citations of interest. In short, reading papers can be complex, tedious, and time-consuming.

In recent years, scientific publications such as journal articles and conference papers have been available in digital format, which enables researchers to develop various techniques to assist parsing and understanding academic papers[25, 26]. These methods tend to preserve only the key information or certain heuristic features of the source text. In contrast, augmented reading tools do not omit any details [2] by enriching the content with supplementary information. However, information provided by augmented reading and citation networks can be too fragmental to digest and remember effectively. In brief, there is still a lack of mechanisms to make academic papers easier to follow and concurrently maintain sufficient details for reading comprehension.

Narrative visualization [29], an emerging type of visualization, has the potential to meet this need. Narrative visualization turns sophisticated data into a flow of visual forms, the style of which can vary based on the characteristics of data to make the entire representation more understandable and engaging. In this paper, we propose the use of interactive slides, a common type of narrative visualization, to facilitate reading scientific papers. As the first attempt to develop a narrative visualization application, we start with visualizing the literature review section, a.k.a. “Related Work” or “Background”, of a research paper. It is because this part is content-intensive, and thus additional navigation and searching are needed. Also, the related work section is often relatively well-structured so that we do not need to employ complex natural language processing techniques.

We develop a system that processes a given research paper and converts its survey of related work into a series of interactive slides. We first study our target users—both junior and senior researchers—regarding their needs, behaviors, and preferences. Based on the results, we design two logic flows to structure the slides, namely, author-based logic and citation-oriented logic. These logic flows

resemble different itineraries of a guided tour. We are particularly interested in the usability and aesthetics of the visual narrative design, the effectiveness of our system, and users' perception of the different logic flows. Through controlled user studies that compared the use of our system with the traditional way of reading, we find that our system can practically promote comprehension of a literature review and provide a more engaging experience. Results further suggest that citation-oriented logic is slightly more beneficial than author-based logic when people do not have time to go through the original paper or when they seek additional information.

The major contributions of this paper are as follows:

- We design and implement a narrative visualization system. The system presents literature review in interactive slides and integrates additional data regarding each citation to enable users explore our system in a flexible manner.
- We investigate the characteristics of our target users and design a multi-level structure to support different reading styles. Two types of narrative logic flows are designed to cater for users' needs under various usage scenarios.
- We conduct controlled experiments to compare the strengths and weaknesses of different narrative logics, and study users' behaviors and preferences when reading with and without the support of our system.

2. RELATED WORK

The literature review is usually in the "Related Work" section of academic papers [17, 18]. Although good writing makes it easier to follow authors' thoughts, it may still take substantial effort to digest and remember the content; various techniques are studied to address these problems.

Text Mining and Visualization. Researchers have introduced text mining and text visualization to handle text data, a major component of literature review sections. Text mining computationally extracts topical, relational, and contextual knowledge from text data, such as sentiment and similarity analysis (see Manning et al. [23] for a comprehensive summary). We build our system on an open framework, and thus can easily integrate different text mining techniques. Text Visualization provides an intuitive illustration of features derived from text, e.g., word frequency, relationships between words, topics and their evolution, sentiments and so on [34]. Some text visualization techniques offer higher-level pictures of the text data and trend identification [16, 22]. Other text visualization concerns the basic statistics [28]. In this work, we adopt similarity analysis, sentiment, and basic statistic analysis and visualization [23, 31] to show authors' flow of writing and opinions.

Augmented Reading and Citation Networks. While text mining and visualization try to improve reading comprehension via re-presenting the source text, augmented reading approaches the problem by introducing external information. Such supplementary content can be offered as a text snippet popup, e.g., translation in another language [5] with related search results from the Internet [9], or as a peripheral multimedia display [4]. However, it is still difficult to recognize the relationship among citations, the logic in which they are organized, or their relevance to the paper at a glance.

To solve this problem, researchers have introduced visualization of citation networks [6, 15, 20]. Some are dedicated systems. For example, Matejka et al. [24] developed Citeology, a tree-like system demonstrating how conference papers referenced one another. It revealed the development of research in these two areas. A citation network can also take a different form to the conventional node-link graphs. Qazvinian et al. for instance visualized a clustering model of a single article's citation list, to obtain a good picture of the target article's contributions [27]. Stasko et al. [32] adopted

an attribute-based layout so that users can easily retrieve papers that satisfy a given criterion, e.g., author, concept, and keyword. Zhao et al.'s system CiteRiver [12], by comparison, are better for discovering explicit and implicit relations among citations. However, many citation visualizations only support a self-initiated information search for analytical uses with a lack of guidance. This may pose a challenge to less-experienced researchers who try to follow the storyline laid out by the authors. In contrast, narrative visualization have a better balance between control and autonomy.

Narrative Visualization. Narrative visualization consists of a flow of visual forms with internal logic [29]. Segel and Heer presented the first systematic study of the design space of narrative visualization [29]. In addition, Amini et al. systematically study data videos to understand what elements are featured in narrative visualization [3]. As narrative visualization is traditionally crafted by designers and often appears in journalism [29], researchers tried to derive design guidelines for narrative visualization, investigating how visual techniques [13] and the order of presentation [14] may influence viewers' comprehension. However, these studies only aimed at composing a sequence of simple imageries such as charts. Their findings may not apply to more complex text data.

In our system, we incorporate not only visual narrative tactics, such as visual structuring and transition guidance, but also narrative structure tactics such as ordering and interactivity [29], to provide an integrated reading experience. In addition, our system provides supplementary information beyond the source text. Among the seven genres [29], we choose a slideshow style since it is most commonly used for paper presentation to structure the content of a literature review. To the best of our knowledge, our system is the first to automatically turn text data into interactive slides.

3. PROBLEM IDENTIFICATION

In this section, we analyze the opportunities and challenges of building a narrative visualization system for literature review. We surveyed a set of tutorials on writing scientific papers, to gain insights from the authors' perspective [8]. Furthermore, we observed and interviewed eight researchers (ages ranged from 23 to 32; 2 females) from three research areas in computer science about how they read academic papers. As representatives of our target users, six of these researchers were relatively senior with over four years of research experience, while the rest were second-year postgraduate students. We gathered information on their common practices, expectations, and frustrations.

3.1 How to Read "Related Work"

The "related work" part of an academic paper often contains references to existing knowledge as well as authors' discussions on how such knowledge compares to the proposed research [8, 33]. When going over the literature review section, individual readers may have different goals in mind, and thus behave differently.

Different Users. As revealed by our interviews, senior researchers generally know what can be found in a literature review section, and can decide whether it is worth reading carefully. As the senior interviewees suggested, mechanisms for assessing and comparing citations would be helpful for them. In comparison, it is harder for junior researchers to make such judgement. All the postgraduate students we interviewed mentioned that it took them several days to digest the very first paper on their reading list. During the process, novice researchers could easily be overwhelmed, as they may not know what information should be prioritized and thus have to read every sentence carefully. Our junior interviewees expressed the need for quickly capturing the general problem addressed in the paper and ways to filter references based on authors' opinions.

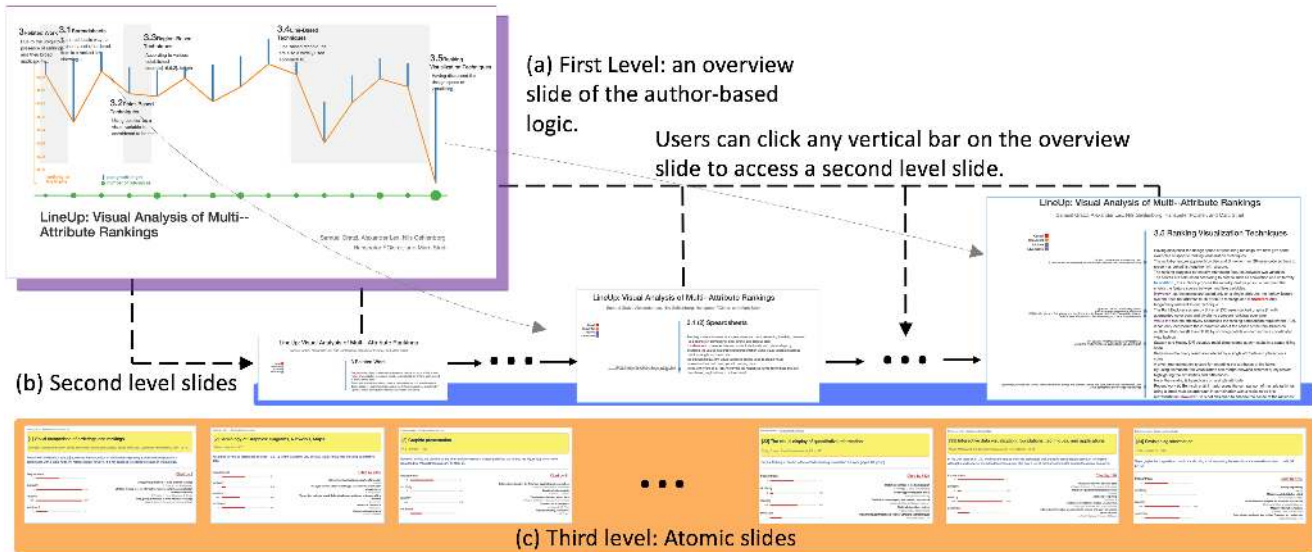


Figure 1: Three-level structure for author-based logic: (a) First level: an overview slide. Each blue bar represents one paragraph. (b) Second level: each slide represents one paragraph. (c) Third level: each atomic slide represents a reference.

Different Scenarios. Readers may treat the literature review section differently as the scenario changes. For example, as a reviewer, people often need to read the related work carefully and critically. In contrast, people tend to read creatively when seeking inspiration from the literature. There are also occasions when people try to acquire writing and presentation skills from well-written papers. In that case, the focus of analysis may shift to the organization of content and the use of language.

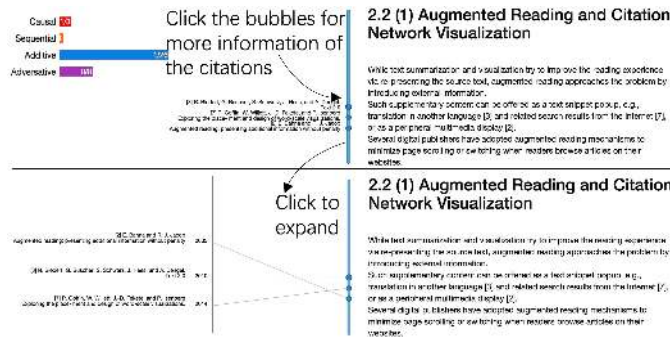


Figure 2: Second-level visual design of the author-based logic. The vertical bar can be expanded into parallel coordinates that rearrange the citations by the time of publication.

3.2 How to Read beyond “Related Work”

As indicated in the interviews, it is very common for both junior and senior researchers to trace certain points cited in a research paper back to its original writing. If researchers find a reference interesting, they may also retrieve information regarding its authors, affiliation, year and venue of publication, impact such as citation number, articles that cited or were cited by the referenced paper, etc. However, it can be time-consuming to search for and filter such information on the Internet. This is particularly true for junior researchers who may not be able to easily assess the value of each reference in the literature review.

3.3 Design Principles

Based on these findings, we derive a set of design principles for building a narrative visualization system to support paper reading.

- The system should incorporate various visual narrative tactics (e.g. visual structuring, highlighting, and transition guidance) as well as narrative structure tactics (e.g. ordering, interactivity, and messaging) [29] to make the reading experience smoother and more engaging.
- The system should consider different user characteristics and usage scenarios. The whole system should be legible and intuitive, as our target users may not have much experience with data visualization. We should only adopt well-established and widely-used visual designs which also appear in traditional media such as New York Times.
- The system should integrate all relevant information-internal or external-into one coherent, clearly-organized framework, so that readers can quickly locate the needed information.
- The system should provide preset plots for users to follow through effortlessly and also the autonomy to conveniently navigate to different parts of the narrative.

4. DATA PREPARATION

In this section, we describe how we prepare data for guiding users to read a paper effectively. We prepare the source text of the literature review sections of the target papers in a semi-automatic way. We split the source text into subsections and paragraphs which are further broken down into sentences and words. We locate the citations and match them to the reference list. Then we use the following methods to collect augmented information for each reference. By decomposing the Google Scholar search results of each cited paper into smaller information units based on HTML tags, we extract data regarding its year of publication, the author(s), the number of citations, etc. We also obtain a list of all the work that has cited the referenced paper from the result page. After that, we clean and correct the data collected to make them fully structured. We use similarity as an attribute. We compute the similarity between two adjacent paragraphs, each paragraph and the entire target paper, and each referenced work and the target paper. More

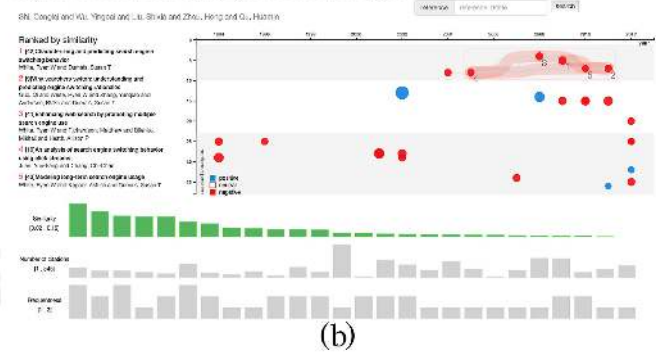
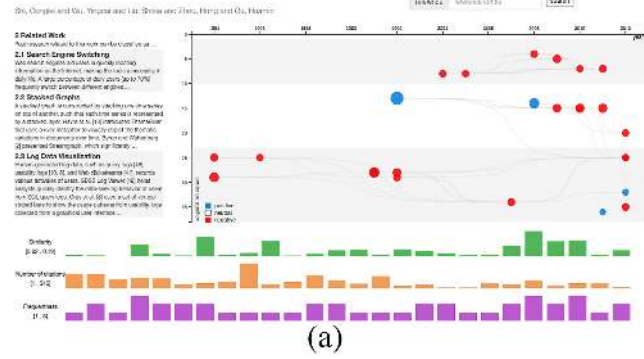


Figure 3: Slides for citation-oriented logic: (a) the overview slide of the paper “LoyalTracker: Visualizing Loyalty Dynamics in Search Engines”; (b) a second-level slide that focuses on one attribute. The five most similar references are highlighted.

specifically, we use the most commonly used tf-idf method which obtain the tf-idf vector v_i for any given piece of text i :

$$tf(t, d) = 1 + \log f_{i,d}$$

$$idf(t, D) = \log \frac{N}{|\{d \in D : t \in d\}|}$$

$$v_i = tfidf(t, d, D) = tf(t, d) \times idf(t, D)$$

Then we use the cosine similarity of two vectors as the similarity scores between the two corresponding pieces of texts [23] as follows:

$$\cos(\theta) = \frac{v_1 \cdot v_2}{\|v_1\| \|v_2\|}$$

To specify the authors’ opinion of each citation, we calculate the sentiment of each sentence, i.e., positive, negative, or neutral, using the sentiment analysis tool provided by [31].

Our system is implemented as a web-based application (with MEAN.JS) that allows users to explore the information interactively (see the supplementary video for details).

5. NARRATIVE VISUALIZATION SYSTEM

To offer researchers a better reading experience, we design a three-level interactive slideshow system with precompiled logic flows (Fig. 1). The first level is an overview slide; the second level consists of a linear sequence of slides; and the third level presents each citation, together with its augmented information. Fig. 4 shows the relationships among these three levels and illustrates three viewing styles enabled by the three-level system.

We carefully design two logic flows to tell the story of related work from different perspectives, namely, *author-based logic flow (ABLF)* that preserves the original plot of a given paper and *citation-oriented logic flow (COLF)* that focuses on the evidences and their relations. Each logic flow has a unique visual design for the first and second levels, whereas both the logic flows share the same set of atomic slides in the third level.

5.1 ABLF: Author-Based Logic Flow

The author-based logic flow inherits the authors’ organization of the related work section, and uses paragraph as the basic information unit. The reason why we use this logic flow is that it is rather easy to follow, especially for less-experienced researchers, since it reflects how authors normally plan out a literature review section. In situations where readers want to pay closer attention to how the

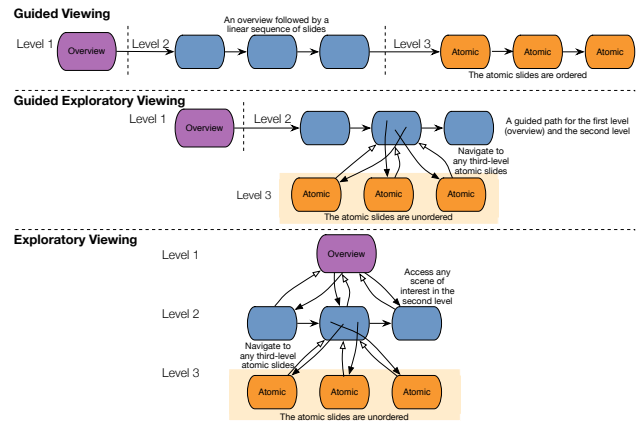


Figure 4: Three viewing styles enabled by the three-level system: guided, guided exploratory, and exploratory.

proposed research is built upon existing work, such as reviewing a paper, this logic flow is particularly helpful. People who intend to learn more about scientific writing can also benefit from a visual narrative of the authors’ line of reasoning.

In the **first level**, we sketch out all the paragraphs on the overview slide, and evaluate the significance of each paragraph using several metrics. This gives readers a holistic view of how the survey of literature progresses. The overview slide represents all the paragraphs of the related work section with a “bar” chart (Fig. 1a). The height of a vertical bar encodes the length of the corresponding paragraph. Bubbles inserted onto the x-axis in alignment with the bars are used to indicate the number of references in the corresponding paragraphs. The vertical distance from the bottom of each bar to the x-axis indicates the content adherence between the paragraph and the core content of the paper. This design enables users to get a sense of the composition of the literature review. We separate paragraphs in different subsections with alternating background colors (white and grey). Clicking on a subsection headline will take users to the second level of the narration.

In the **second level**, each of the subsequent slides corresponds to a paragraph (Fig. 1b). To show internal logic within one paragraph, we highlight transitional words and phrases (collected from [1]) in the text and use different colors to distinguish their nature, i.e., causal, sequential, additive, or adversative. Bubbles on the vertical

divider represent references appearing on the left side of the slide. The size of the bubble indicates the total number of citations of the reference. This allows users to quickly locate the high-impact citations. As shown in Fig. 2, users are able to click on the vertical divider to expand it into parallel coordinates to rearrange the citations by the time of publication.

5.2 COLF: Citation-Oriented Logic Flow

The citation-oriented logic flow restructures information around a critical component of a literature review—the citations. As known, authors of academic papers usually reference existing work as evidence to support their claims. As discussed in Section 3, on the one hand, people may want to check the references to ensure the validity of the paper they are reading. On the other hand, researchers need to survey the literature for their own work by identifying relevant citations in the related work sections of others’ papers. For either purpose, readers may want to know more about a reference of interest, its relations with other cited work in the paper, and the authors’ judgement on its contributions and limitations, if any. Information such as the associated researchers or research groups, venue and year of publication, number of citations, and trend of the research topics, may also be valuable to the readers. The citation-oriented logic integrates data both from and beyond the source text into an analytical representation, saving users’ time and effort.

The **first level** of the citation-oriented logic flow provides a big picture of the citation network (Fig. 3a). The references are placed in a two-dimensional space based on their years of publication and locations in the related work section in the form of a node-link diagram. The node size suggests the total number of citations. The categorical colors indicate the authors’ sentiment toward this reference. On the bottom of the overview slide (Fig. 3a), a set of bar charts enable users to compare different attributes of the citations, i.e., similarity of the cited paper to the target paper, the total number of citations, and the number of occurrences in the source text.

Each **second level** slide focuses on one of the attributes (Fig. 3b). On the node-link diagram, we draw a path through the top five citations according to the ranking, group them with a bounding box, and remove the links unrelated to these references. Users can click on a node to get more information from the atomic slides. The default narrative sequence corresponds to the arrangement of the attributes on the first-level slide. As the importance of different attributes may vary by person, users can customize the presentation order. When the mouse hovers over a node (Fig. 5), the metadata of the associated citation will pop up, along with the links between this reference and other work. The other work which has citing relations with this reference are also highlighted. We filter out unrelated information to help users focus on a specific reference. Alternatively, users can specify a reference by typing its citation ID or title in the search box. Compared to ABLF, COLF skips all the sentences that contain no reference and introduces more supplementary information from external resources.

5.3 Atomic Slides

An atomic slide is a narrative of information related to a specific paper cited in the literature review section: the sentences that presented this reference in the target paper (Fig. 6a), the numerical attributes of the reference (Fig. 6b), and the citation information of the reference (Fig. 6c). It adopts a simple, concise poster style genre of narrative visualization to divide its space into smaller sections that each tells “its own sub-story with charts, pictures, and text” [29], and thus is more suitable for our purpose.

We use simple horizontal bar charts (Fig. 6b) to illustrate the number of times the reference is mentioned in the source text (a.k.a.

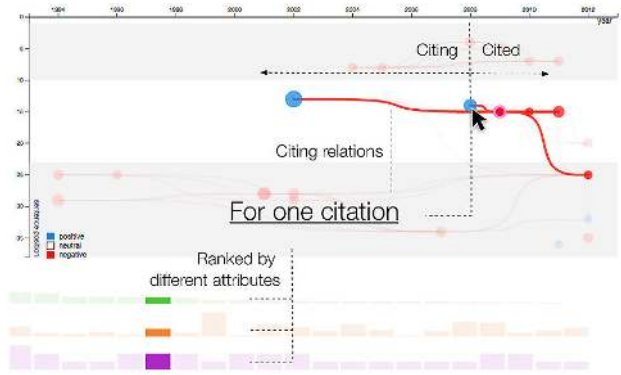


Figure 5: When hover on one node, the other nodes that have citation relations with the target node are highlighted.

frequentness), its similarity to the target paper, its recency in terms of publication time, and the authors’ sentiment toward this reference. We mark the minimum and maximum values of each attribute among all the references so that it is easier for users to judge the importance of a cited work. Other design like radar charts could also be adopted. In addition, the title and authors of the most relevant papers that have referenced this work according to Google Scholar are listed opposite to the bar charts (Fig. 6c). These are potential papers for further reading. Our system highlights part of the atomic slides depends on how a user navigates to the third level.

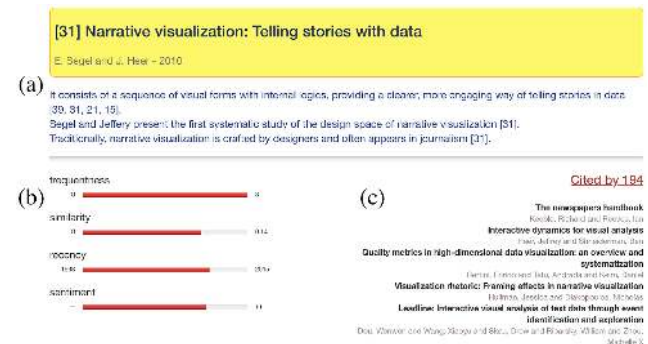


Figure 6: Visual design of the atomic slide. The atomic slide is divided into three areas: (a) the sentences cite this reference, (b) the numerical attributes of the reference, and (c) the citation information of the reference.

6. USE CASES

In this section, we demonstrate the utility of our system by conducting two use cases.

Case I: Exploratory Viewing with Author-based Logic. Cathy is a first-year graduate student who just starts working on visualization of rankings. She finds the paper entitled “LineUp: Visual Analysis of Multi-Attribute Rankings” [10] on Google Scholar and wants to know if it is relevant to her topic. Since Cathy is new to the area, she plays the automatic slideshow in the author-based logic to see how other researchers define the problem. The very first slide gives Cathy an overview of all the paragraphs in the literature review section (Fig. 1a). She finds section 3.5 quite notable at a glance. The blue bar for the only one paragraph of Subsection 3.5 is the longest, and it also has the shortest distance to the green line

at the bottom. This suggests that the paragraph is very close to the theme of the whole paper. It also contains more references than the other paragraphs, as suggested by the size of the green bubble right under the blue bar. Therefore, Cathy quickly skims the content as the slideshow moves forward in the second level and only pauses when the Subsection 3.5 slide shows up.

To Cathy’s surprise, reading this longer-than-average paragraph is easier than she has imagined. The system has highlighted all the transitional words and phrases that indicate causal, additive, sequential and adversative relations, making it easier for her to follow the authors’ line of reasoning. For example, adversative words such as “while” and “however” stress the limitations of existing research that the authors want to address in their work. Cathy notices that these are exactly the same types of problems she is interested in solving. After reading this paragraph, Cathy is curious about other publications that target the same problem. She starts to browse the names of the literature on the left side. She clicks on the divider in the middle, and the references are now sorted by their years of publication on a parallel coordinate. She finds two references published one or two years before the LineUp paper whose titles contain the keyword “ranking.” She decides to explore more about these two papers. She clicks on the title of each paper and sees on the atomic slides that both papers have a high similarity score with the LineUp paper. She reads the abstracts and confirms that they are indeed relevant. It saves her a lot of time to explore the potential solutions.

Case II: Guided Viewing with citation-oriented logic. Mike is a post-doctoral scholar. He is drafting a project proposal on search engine visualization, and needs to conduct a thorough literature survey in this domain. He starts the search with one of the most recent publications “LoyalTracker: Visualizing Loyalty Dynamics in Search Engines” [30] and opens it with the citation-oriented logic. To save time, Mike plays the slideshow. On the overview page (Fig. 3a), Mike scans through all the references of LoyalTracker in the node-link diagram. He notices that although the oldest reference dates back to 1994, more than half of the cited papers were published after 2006. With this observation, Mike thinks that he can track down some more up-to-date research from LoyalTracker. The slideshow proceeds to the second level and the first slide examines the referenced papers in terms of their similarity to LoyalTracker. Mike observes that the top five papers with the highest similarity all appear in Subsection 2.1 Search Engine Switching. By examining the links among citations, Mike finds that the citation network of Subsection 2.1 is rather self-contained, implying that LoyalTracker studies a novel problem in the visualization community. He creates a separate bullet point and marks down these references in his reading note. The slideshow moves to the next page that ranks all the references according to the total number of citations. Mike identifies the most influential paper, “Themeriver: Visualizing Thematic Changes in Large Document Collections” [11] which has over 500 citations in 10 years. The Themeriver paper appears in Section 2.2 of the LoyalTracker paper and receives positive comments from LoyalTracker’s authors, so Mike makes a note that he should cite this paper when discussing stacked graphs.

Later, Mike learns on the frequentness ranking page that, among all the referenced work that cited Themeriver, a paper with the name “Textflow: Towards Better Understanding of Evolving Topics in Text” [7] is the most similar to the LoyalTracker paper. He picks Textflow for further reading to discover more relevant references using our system.

7. CONTROLLED EXPERIMENT

We carried out a controlled lab study to compare the use of two logic flows with reading without the support of our system. The

participants were asked to answer a set of questions regarding the related work of the given papers.

7.1 Participants and Study Setup

To avoid potential individual differences introduced by the research background and experience of the participants, we used a within-subject study design. The dataset used for the controlled experiments includes three papers in the field of visualization, i.e., “LineUp: Visual Analysis of Multi-Attribute Rankings” [10], “LoyalTracker: Visualizing Loyalty Dynamics in Search Engines” [30], and an internal technical report. The related work sections of the three papers have 3 to 5 subsections, and 6 to 15 paragraphs. We counterbalanced both the condition order and stimulus assignment to conditions (author logic, citation logic, and without system support). We recruited nine participants for the controlled experiment (4 females). The participants were all postgraduate students or researchers in computer science and engineering between the age of 22 and 28. Based on their responses to the background questionnaire filled out prior to the study, the participants’ research experiences ranged from 1 to 6 years. There was a big variance in the number of papers they had read, from fewer than 10 to over 80 papers. One participant indicated that she had some (less than four months) experiences in the field of visualization.

7.2 Procedure and Task

Before the main task, we introduced the procedure of the experiment, the usage of our system, and the interface of our system to the participants. Then, for each logic, we guided the participants to get familiar with the visual design of all the interactive slides. After the training, the participants were allowed to use up to three minutes to scan the related work part of the given paper. After this, they proceeded to the main task, which required them to complete a quiz of eight single-choice questions regarding what they had just read such as “Which paragraph contains the most similar references to this paper?” and “Which reference below is NOT a visualization of log data?” This was to simulate the ordinary process of paper reading and literature exploration. We used the same set of questions with slight paraphrasing and content adjustment for all three papers and shuffled the order of the items. For all conditions, the participants were free to view the PDF files of the given papers and search on the Internet whenever needed. We adopted the “think aloud” protocol to gain a better understanding of how people performed the tasks. The participants were asked to specify the source(s) of information that contributed to their response to each question, i.e., the Internet, the system, the PDF document of the paper, or pure guessing. They were also required to rate their confidence with each answer on a 5-point Likert scale. The main task had no time limit. Participants could take a break after each session. Upon the completion of all three conditions, we interviewed the participants and asked them to rate the usability (adapted from [21]) and aesthetics (from [19]) of the system on a 7-point Likert scale.

7.3 Quantitative Analysis

We ran a repeated-measures MANOVA. Results showed that there was a significant difference in the quiz performance based on the reading method used ($F(2,9) = 4.21, p < 0.05, \eta^2 = 0.36$). Univariate testing indicated the effect for the number of correct answers among the three conditions ($F(2,9) = 7.58, p < 0.05, \eta^2 = 0.49$), the number of results by guessing ($F(2,9) = 3.82, p < 0.05, \eta^2 = 0.32$), and the level of confidence ($F(2,9) = 8.18, p < 0.05, \eta^2 = 0.51$) to be statistically significant. Post-hoc pairwise comparison suggested that, the participants answered significantly more questions correctly using the citation logic than the other two

Questions	M	SD
Easy to learn	6.00	0.91
Simple to use	6.38	0.52
Comfortable to use	6.38	0.52
Effective	6.13	0.64
Easy to navigate	6.50	0.76
Easy to find information	6.25	0.71
Pleasant interaction	6.75	0.46
Aesthetic	6.25	0.89
Clear	6.25	0.89
Clean	6.50	0.76
Organized	6.50	0.53

Table 1: Questionnaire Results (7-point Likert scale).

conditions ($p < 0.05$). People relied significantly less on their own judgement and were significantly more confident given the citation logic than without any support of our system (both $p < 0.05$). The author logic was marginally better than reading without our system in terms of correctness ($p = 0.09$) and confidence ($p = 0.1$), and led to marginally lower confidence than the citation logic ($p = 0.07$). The difference regarding the total task completion time was not significant ($F(2, 9) = 2.36, p = 0.13, \eta^2 = 0.22$), but the relatively large effect size suggests that the effect may be significant given more participants. Table 1 summarizes the results from our questionnaire. The participants rated our system in terms of usability and aesthetics on a 7-point Likert scale.

7.4 Structured Interview

In the post-study interviews, we asked the participants to share their experiences during the study, evaluate the effectiveness of system functions and compare the logic flows.

Experiences. All of the participants said that they enjoyed using the system. They found the narrative visualization aesthetically pleasing, easy to understand, and convenient to use. They also considered the three-level structure a good way to organize information with different granularities. All participants thought that the system enhanced their comprehension and recall of the literature review than just reading the text. They found the quantitative assessment of the references especially useful for gaining a comprehensive overview of all the related work and selecting papers for further reading. Half of the participants suggested that the system could improve their writing skills to some extent.

Comparisons. Overall, 6 out of 9 (66.7%) participants favored the citation-oriented logic. There are three possible reasons. (1) References are particularly important in literature reviews. (2) The quiz questions were easier to solve using the citation-oriented logic given that the supplementary information is available at a higher level than the other two logics. (3) The visual design used in citation logic is more familiar to the general audience with no visualization background. In general, participants preferred the author-based logic when they wanted to have a deeper understanding of the author’s reasoning and writing skills. They preferred the citation-oriented logic when they needed the big picture of all the references and their relations for further exploration.

8. DISCUSSION

Although we only focus on publications in computer science in the scope of this paper, our methods can be applied to research papers in other areas. Most of the literature review sections in academic papers have no more than 30 paragraphs and 90 citations, which can be sufficiently handled by the current designs. In case of

longer text or more citations, the scalability of our system can be improved by introducing more levels into the narratives.

Our work has some limitations. While the multi-level structure is rather clear to the users, they still need time to master all the inter- and intra-level navigation features to make the best use of our system. Although our system allows users to switch logic freely when reading a paper, we disabled this function in the controlled experiment. When logic switching is allowed, users’ behaviors may be different and their reading effectiveness and efficiency may be further enhanced, which we plan to study in the future.

There are also many areas for improvement of individual logics. For example, in the current version of the author-based logic, we only use a limited set of basic transitional words and phrases as indicators of the authors’ reasoning, and merely apply simple visual encoding. The efficacy of the system highly depends on the text mining and Natural Language Processing (NLP) algorithms adopted. The text mining methods currently in use may not be accurate enough.

9. CONCLUSION AND FUTURE WORK

In this paper, we proposed a narrative visualization framework to facilitate effective reading of the related work section of a research paper. We surveyed the existing approaches for improving paper reading experiences and explained the advantages of our interactive slideshow system. Specifically, we introduced a three-level structure, two logic flows, and the visual designs. We presented two use cases to demonstrate the effectiveness of our system. We also conducted controlled user studies to evaluate its usability and aesthetics. The results showed that interactive slideshow system can provide a more engaging reading experience.

We will explore more narrative techniques to enhance reading and understanding of complex text data. In addition, we will introduce crowdsourcing mechanisms and monitor how the system performance improves as the user input grows over time. Furthermore, we will explore how readers may use various logics in combination. Based on the results, we can apply machine learning algorithms to recommend the most effective composition of logic flows as well as more appropriate materials for further reading to users.

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