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Master's Thesis

Visualization System for Learning History in
Educational Purpose

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2020

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Master of Science

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Approved by



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approved.

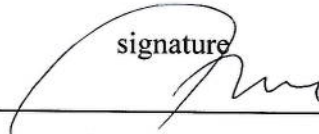
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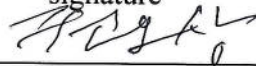
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Abstract

Thanks to the digitization of historical knowledge by the efforts of many experts for decades [1], students can now access this information on the web with just a few clicks. From the pedagogical point of view, however, scrapping those already-structured narrative is not an inherent skill that educators expect students to learn. In this paper, through collaboration with the experts in history education, we propose a visualization system, EduVis, satisfying history course objective as well as students' learning experience. Using Wikipedia [2] as a data source, EduVis covers historical events, which are relevant to three events in the history course: *World War I*, *World War II*, and *Cold War*. To implement the visual interface engaging users' exploration, we applied the text mining method [3] to extract the date and place entity from history articles. We propose two applicable scenarios using EduVis and then we ran the user study with total of 23 participants who are not experts in both history and visualization interfaces. Our results show that EduVis allows the participants to explore information from spatio-temporal point of view and enables them to draw a big picture of their findings. In addition, from the subject feedback on EduVis, we analyze our limitations and potential directions to improve the system.

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I Introduction

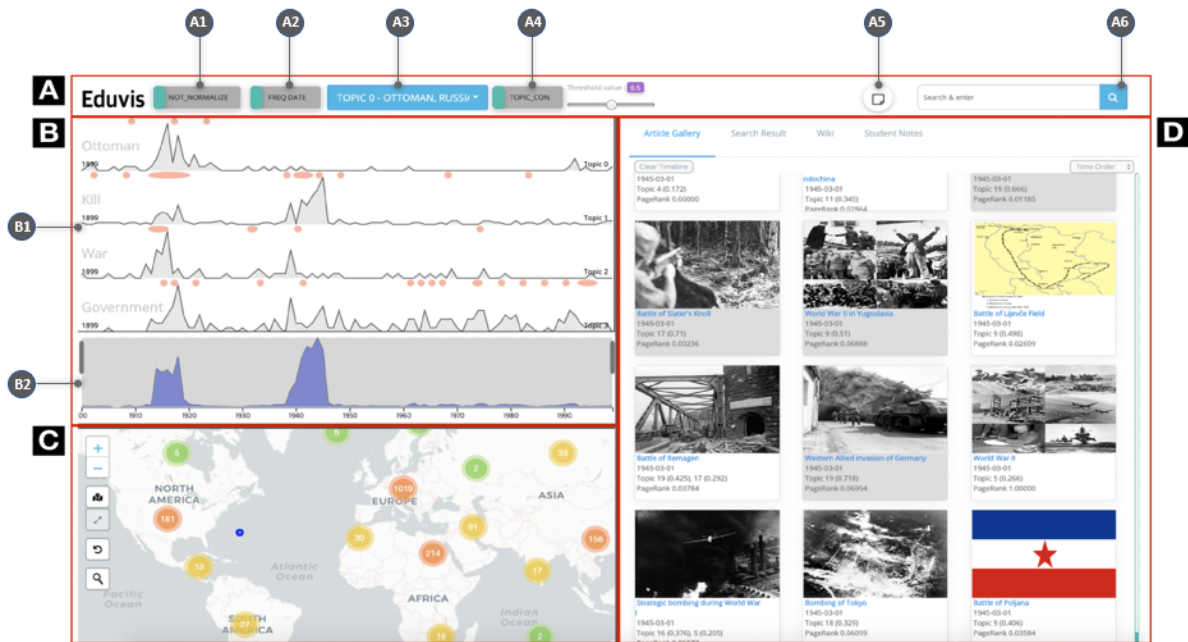


Figure 1: An overview of EduVis Interface: (A) Filters, (B) Event View – (B1) Event lines, (B2) Timeline filter, (C) Map view, and (D) Resource view.

There have been attempts to utilize visualization techniques to facilitate learners' understanding. Every day, we are looking for and learn information on the Internet by searching, the fastest method to find information. In particular, thanks to the digitization of historical knowledge by the efforts of many experts for decades [4], people can now access this information on the web with just a few clicks. However, especially for learners who are not familiar with topics or subjects, when clear keywords are not given it is not an effective method to explore such a huge information space. Because supporting exploration within this space is one of the main objectives in the visualization system, the researchers have applied visualization techniques to implement the visual systems for educational purposes [5]. In particular, graphics technology have been shown to support students' acquisition of mental action and knowledge (e.g., 3D views, geometric shapes in engineering and anatomy in medical training) [6–8].

Conventionally, students in history class tend to rely on internet and textbooks for learning history, finding information and performing class activities (e.g., essay assignments). Although large and well-organized information from internet or textbooks is helpful for their activities [4], it is not always desired in a pedagogical point of view according to our experts in history education. Within the realm of history education, scrapping those already-structured narratives is not an inherent skill that the educators expect students to learn.

In this work, we aim at designing a visual exploration system that helps students in learning history. At the same time, implementing a visual interface to support students unfamiliar with history and visualization skills is a challenging task [1]. To achieve the goal, we first perform a task analysis to extract the design considerations with three domain experts in educations, two of which have opened history courses every semester at a university. And then, we build a history collection which has relevant 3,019 Wikipedia documents on three events in the history course: World War I, World War II, and the Cold War. And we extract metadata such as geographic location, time, and topic from each Wikipedia document using the text analysis method [3, 9]. Using the derived data, EduVis has coordinated multiple views—Event, Map, and Resource. They allow users to explore EduVis’ information by location, time, and topic in the 20th century. Additionally, users can remain the annotation to help themselves externalize and archive their findings and insights gained from interactions within EduVis. Eventually, we present EduVis to enhance users’ learning experience by supporting exploration and navigation in information to find their self-interesting historical events and build their own narratives.

To evaluate EduVis, we provide two usage scenarios and run two informal user studies reporting an exit survey result to investigate usability. We also provide our domain experts feedback that describes whether EduVis satisfies the course objectives based on the results of participants in the user studies. Also, we discuss the limitations and possible directions to improve EduVis’ learning experience based on the exit survey result.

Our main contributions are:

- Task analysis and systems goal derivation from the experts in the history education domain
- Introducing EduVis, an ILE(interactive learning environment), with pedagogical objective and considerations to target users who are not familiar to history and visual interfaces.
- Evaluating EduVis with 23 college students and analyzing the user study and post-survey results.

II Related Works

2.1 Characteristics of Wikipedia as a Data source

Wikipedia [2] is an online encyclopedia in several topics, and also has a lot of metadata like clickstream [10] and DBpedia [11] because it is a well-used source in the research area. To find new insights from Wikipedia, researchers study the characteristics of it, analyze the user activities and introduce visualization systems.

Samoilenko et al. [12] analyze differences between the Wikipedia dataset and the Encyclopedia Britannica on history topics. Regarding the reliability, they find that Encyclopedia Britannica is considered an important authoritative reference on the historical documents as well as other topics because it is published by experts, 100 full-time editors and more than 4000 contributors. In the case of Wikipedia, it is a well-used resource to researchers and the general public because it shows high credibility on not only history but also the science topics by cross-validation by users and literature [1, 13]. Also, they find that Wikipedia covers a lot of relatively recent historical events, especially in the *20th* century, while Encyclopedia Britannica focus on the early days of history. Additionally, they point out that Wikipedia shows better readability and is easier to understand than Britannica because the Wikipedia link system, which interconnects among documents, gives extra information to follow.

West et al. [14] show that users can navigate large information space to find a piece of target information using the Wikipedia links from a given article. Further, David and Ian [15] take advantage of Wikipedia to facilitate the readers' understanding of the real world documents by matching Wikipedia links to the words in each document. In this paper, we also utilize Wikipedia as a resource for EduVis due to the features of Wikipedia such as accessibility, credibility, links and bountiful history articles in the *20th* century.

2.2 Visualization Systems for Education

In a past decade, researchers has introduced visualization techniques to facilitate users' exploration and analysis in the information. The use of visual and graphic design in pedagogy is also one of these trends [5, 7, 16–18]. One of their aims is to enhance the educational processes and students' learning experience by allowing learners to interact with information [5].

Firat and Larame [5] survey the educational visualization systems in various subjects. They find that visualization and graphics techniques have been especially used in engineering, natural science and physical sciences. Graphics techniques are used for algorithm identification, perception, anatomy and medicine, and engineering, as they enable learners to reconstruct and see 3D spatial structures of objects in different perspective using 2D or 3D views [19–22]. In addition, visualization techniques (e.g. line, network, and table charts) also have been widely used by class instructors to analyze students' learning performance [23, 24]. The survey indicates that the interactive learning environment (ILE) encourages students to be more active and entertain-

ing in learning subjects. Unfortunately however, the survey do not provide any guidelines and considerations when implementing an educational visualization interface.

In different perspective of view, Liang and Sedig [8] emphasize the importance of navigation to explore ILE's information as it becomes very large and complex. They provide a framework for effective navigation when designing ILE. This framework prescribes three considerations: 1. Content structuring 2. Information navigation modeling, and 3. Interface presentation structuring. For each consideration, they present design possibilities, choice advantages and disadvantages. We actively accept these considerations in designing EduVis with our pedagogical objectives to provide effective interface for learners.

2.3 Visualization Systems for Cultural Heritage and Cultural History

Various cultural materials have been digitized for a long time, resulting in the study of visualization analysis using data from the digital heritage beyond the standard representation of traditional search-centric and grid-based interfaces. Through interactive visualization system, different exploration approaches have allowed users to navigate huge cultural collections, complex and comprehensive information [1].

Windhager et al. [1] analyze 70 visualization systems, 50 prototypes associated with a research paper, and 20 prototypes investigated as web-based standalone implementations, using cultural heritage data from a visualization perspective. Among them, they find 11 InfoVis prototypes to facilitate learning or education. They categorize data type, target users, visualization techniques, tasks, granularity and interactivity. And then they present design considerations for the visual interface using digital heritage. They find there are three types of system for casual users, experts, and both. They indicate that domain experts note that using specific keywords in search and filtering may produce more accurate and satisfactory results, but it is difficult for casual users to obtain meaningful results from the search-based. So, for the casual users, it is necessary to provide a rich navigational interface to support exploration in large digital collections rather than the search-centric interface. With visual interfaces, they find that users' learning experience to result in fun and positive participants is expected. At the same time, however, Hinrichs et al. [25] show that too much fancy interface could distract casual users' attention from the actual contents. In their survey, they also find out that only 21 papers out of 50 system for research purposes conducted user studies. Unfortunately, there is no clear mention of how many of the 11 educational prototype have performed user research. Windhager et al. [1] point out the lack of evaluation and stress the need for evaluation of visual interfaces for further studies.

There are other visualization solutions for cultural history data and learning history, which are not covered from Windhager et al. [1] because they only survey visualization tools for cultural heritage. Kimura et al. [26] and Itoh and Akaishi [27] present a visualization method for describing the relationships between Japanese historical figures in historical documents for a short time period (from 1560 to 1570) with the case studies and user study. Cho et al. [28]

propose VAIroma, which deals with the ancient period of Roman history. To our best knowledge, VAIroma is the only visualization system that has performed both user and case studies. While they evaluate the system with Architecture students, used to the area of Roman piazza, we evaluate our system with general students, not familiar with both history and visualization covering entire events in the World.

III Task Requirements

Eduvis' design is a consideration of interdisciplinary collaboration with three experts (co-authors in this work), whose expertise is education. Among the experts, two of them major in history (A professor with Ph.D. in history and an instructor with MS in history) and have taught more than one history class every semester at a university. Another expert holds a Ph.D. in education and has been counseling students and professors on education. We have met them regularly with the experts to understand the history education, for example, how the history course has been run, what is important in learning history.

According to our experts, the course covers a broad time range in history from ancient to modern era. The courses' learner are mainly freshmen and sophomores, and all of them are not major in history. Over the past semesters, the professor and instructor have given essay assignments in the course, aiming to ask the students to review not only using naive historical facts, but also the relationships among the events and various supplements like movie clips and image resources. After the discussions with the experts, we find their main concerns. They say that the textbooks cover various historical events, but the events are already subjectively compiled by historians. Thus, relying on the textbooks or online postings in history education may lead the students to merely repeat the written events and prevent the students from indecently thinking. And also they point out that due to the characteristic of today's web search, which suggests most clicked results first, when the learners do not exactly know what to search students may lose the chance to explore not well-known, out of Western-centrism, but meaningful events(e.g., many battles in Africa during the colonial period). We find that the educators expect students to explore and navigate self-interesting historical events and links their new findings to the main topics which they learn in history course rather than simply acquire and memorize historical facts.

According to several follow-up discussions with the experts, we derive the system design considerations as follows:

- DC1:** The system should allow users to explore their own interesting events in the domain of history.
- DC2:** The system should support users' navigation in information to build their own narratives.
- DC3:** The system should be easy to use because our target users, students, do not have any specific knowledge on visualization interface and history.

IV Design Rationale

In this section, we describe our design processes to satisfy the three considerations described in the previous section. We decide to approach **DC1** and **DC2** by providing visual interface to support users' exploration and navigation in information. To taking the conditions raised by Windhager et al. [1] into account, we regard the target users, the students taking the history class, as casual users because they are not major in history. Since students are unfamiliar with visualization techniques either, the interface should be user-friendly and intuitive. So, we chose to use the following designs into our interface with the design considerations in our mind.

Timeline view (Figure 1B) provides a temporal overview of the information. It provides a way to explore and navigate through time to support organizing narrative in time order. Timeline exploration aims to link between the continuity of events and navigation.

Map view (Figure 1C) provides a geolocational overview of the information. The users can begin exploring historical events within a world map looking for an interesting spot. Map exploration seeks to tie the learners' experiences with navigation, taking advantage of their familiarity with space.

Grid view (Figure 1D) are designed to engage casual users in browsing multi-object in linear because it is the simplest structure to explore the contents [8]. Unlike the temporal and geolocational overview, these views allow users to sequentially access a series of events one by one.

Lastly, there is one more design consideration to provide better learning environment. To help users start the exploration and set the orientation to navigate in information, we decide to provide additional cues like topical keywords and suggestions. And also, the system should support users to note their findings and questions while exploring the system to keep track their orientation. We expect the notes keep their learning iteration, called supporting knowledge generation loop [29].

V Visual Exploration System for History Education (EduVis)

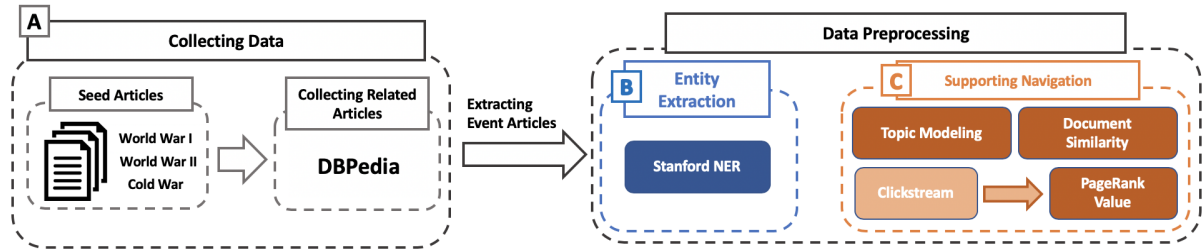


Figure 2: EduVis data pre-processing pipeline: A. Using Wikipedia as a source, we collect historical events through DBpedia based on three seed articles, ‘World War I’, ‘World War II’, and ‘Cold War’. B. From our history collection, we extract the date and location entities in order to present the historical articles in the visual interface. Additionally, we classify them using topic modeling and build two more collections, document similarities, and PageRank, to support users’ navigation within EduVis.

5.1 Data Pre-processing

After discussing course topics with domain experts, we decide to cover historical events on *World War I*, *World War II*, and *Cold War* which are the common topics in ‘*History of Modern World*’ and ‘*Evolution of Civilization*’ classes they are teaching. We choose Wikipedia as the source of our system due to its validity of historical topics [12] and wealthy historical events in 20th century [12].

We first use three main articles (‘World War I’¹, ‘World War II’², and ‘Cold War’³) as the seed documents to collect the relevant articles using DBpedia [11], a database containing semantically related articles as the records for each Wikipedia articles. As a result, we collect over 5,500 associated Wikipedia articles and decide to use 3,019 articles that have an ‘event’ DBpedia ontology type which typically indicates a historical event [30].

Next, due to ‘place’ and ‘date’ property in DBpedia are not consistently contained for each article, we extract time and location entities from articles using Stanford NER (Named Entity recognizer) [9]. After extracting all the ‘date’ and ‘place’ entities for each, we use most frequently mentioned time and location entities as representative entities for the event. For example, ‘Germany’ and ‘1945-03-01’ are mentioned 98 and 6 times respectively in the article "World War II", so we use the two values as representative location and date for event "World War II". And then extracted locations are geotagged by Geopy [31] to assign geo-coordinates (i.e. latitude and longitude) to the events.

¹https://en.wikipedia.org/wiki/World_War_I

²https://en.wikipedia.org/wiki/World_War_II

³https://en.wikipedia.org/wiki/Cold_War

We extract 20 topics which are pervaded in EduVis' historical events collection using a Latent Dirichlet Allocation (LDA) Mallet topic modeling method [3]. At the result of topic modeling, when an article is included in more than one topics and it has a higher topic weight than 0.25 for each topic, the articles are included in multiple topics. If not, the articles are included in one topic without considering how much the topic weight value is. We also calculate document similarities between documents as well as PageRank scores using Wikipedia Clickstream data [10] to support users' navigation within EduVis. Figure 2 shows our data pre-processing pipeline.

5.2 EduVis: The User Interface

This section describes EduVis interface, a web-based visual interface consisting of three coordinated multiple views (Figure 1) – Event, Map, and Resource. It provides an effective exploration environment for learning history. The system is mainly developed in D3js [32], Leaflet [33], Flask [34] and Javascript.

Event View

The Event view (Figure 1 B) has two parts: Event lines (Figure 1 B1) and Timeline filter (Figure 1 B2). As a default, the Event lines show topic trends over 100 years (from 1900 to 2000), but the users can change the period of interesting changing brush in Timeline filter (Figure 1 B2). Commonly, they show the x-axis as the time and y-axis as the number of articles.

Event lines (Figure 1 B1) presents multiple topic-line charts construed based on topic and time. To support the users' horizontal exploration on topic information, each line presents a main keyword of the topic on the left and event indicators at the top. When a user hovers over on an event line, it shows top ten keywords associated with its topic. The event indicators are described as orange dots to intuitively attract the users' attraction. While the standard unit for the event indicators is an circle containing an event per a year, which is suggested in a criteria described in section 5.2. When they appear in consecutive year, they are represented as one horizontally long oval (Figure 1 B1). When the users hover over on it, it shows a tooltip with thumbnails, titles and year of articles (Figure 4 C). Clicking one of events in the tooltip allow the users to read the target event directly in the Wiki tab (Figure 3). Additionally, the user can brush up to three-time ranges in each event line to filter historical events in the period and topic of interesting (Figure 4 B), and user interaction allows the users to turn uninteresting topic off and turn it on when needed.

Map View

The map view (Figure 1 C) displays geolocations of historical events of Wikipedia articles. The historical events are aggregated based on a map zoom level, showing as clustered markers ⁴. When clicking on a marker, the map is zoomed in if the marker has multiple locations. If it has

⁴<https://github.com/Leaflet/Leaflet.markercluster>

only one location or zoom level reaches 4, all articles in the cluster marker are displayed as blue circle around it. Basically, each circle, which indicate a historical event, represented in blue, while the events which satisfy the criteria described in section 5.2 are represented in deep blue (Figure 1 A4). Hovering over on a circle shows a tooltip with a title and time of an event. Plus, users can select region of interest in two different ways. Firstly, the users can draw a rectangle through a button (Figure 5 B) to focus the events in it (Figure 5 D). Secondly, the users can click an interesting country one by one to see the events regarding the country (Figure 4 E). Additionally, there is a geography search feature to help the users find an unfamiliar location (Figure 1 C).

Resource View and Recommendation Modal

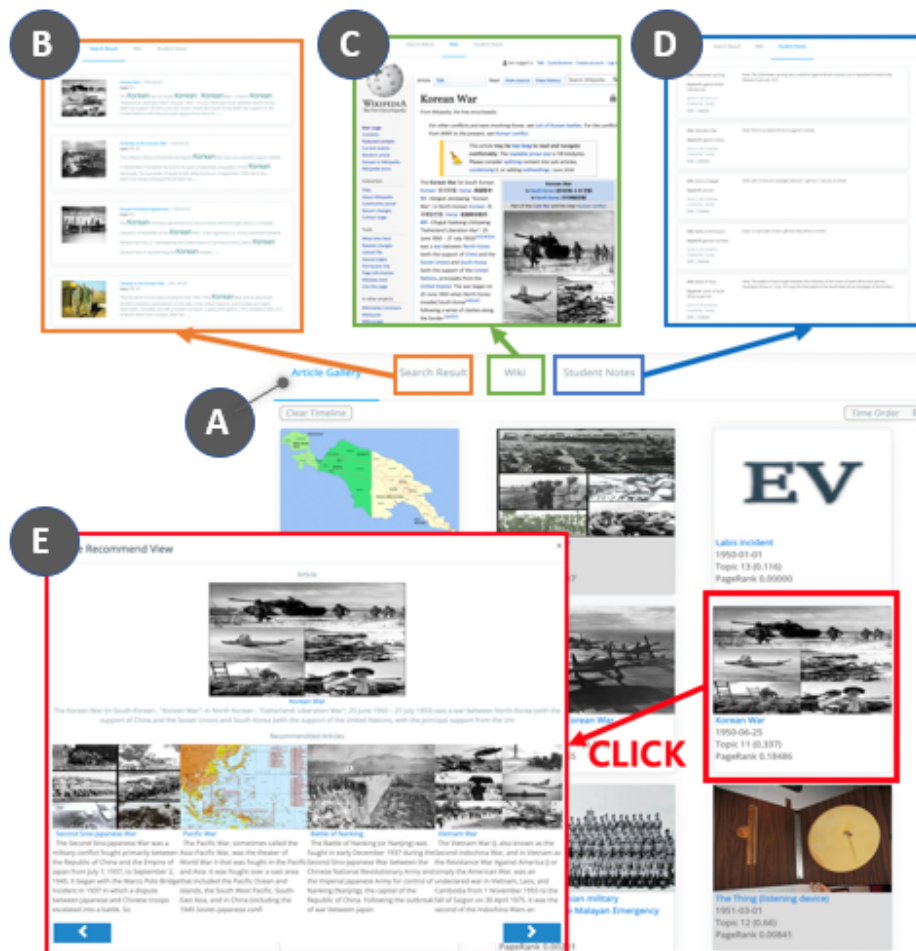


Figure 3: The resource view has four tabs: (A) Article Gallery, (B) Search Results, (C) Wiki, (D) Student Notes. When a user click an article in either article gallery or search result tab, recommendation modal (E) is popped up.

The resource view (Figure 1 D) has four tabs: Gallery, Search Result, Wiki, and Student Notes (Figure 3). Note that they occupy the same screen space on the right of the interface.

The gallery tab (Figure 3 A) lists Wikipedia articles with their meta data, including title, date, topic, topic weight, and PageRank value. This tabs allow the users to sequentially access a series of events one by one. The users can sort articles by time, importance of topic weight or PageRank value, and topics. As suggested events have different representation in event lines and map views, they are colored in gray here. The search result tab also lists articles as a response to the users' search in the search bar (Figure 1 A6). When the users select one in the gallery tab or search result, it shows a pop-up window presenting the select article and related articles which recommended by document similarity or clickstream data (Figure 3 E). Wiki tab is automatically opened when the users finally click one interesting event. Lastly, the student notes tab allows the user to see comments that he or she has recorded while exploring EduVis (Figure 3 D).

Filters

At the top of the interface (Figure 1 A), there are the toggles for various functions to configure advanced EduVis setting.

At first, the EduVis logo on the left upper corner works as the reset button. (A1) can be used to normalize the y-axes of the event lines with the maximum number of the articles shown in the event view. We provide (A1) if they want to observe accurate number of documents in event lines. When (A1) is on because the number of documents for each topic is not evenly distributed, it is often hard to notice changes in the line with a small number of documents are in its topic. Users can choose whether to use all dates or only one representative date associative with an event when drawing the event view (A2). For example, when (A2) is off, the event 'World War II' is only associated with 1945-03-01 and the users can find it only one point of time in the event line which it is included. But when (A2) is on, the World War II event is linked to several dates, so it appears several times in the event line. Using (A3), the users can decide which topics to show or hide in the event view. With (A4), the users can select to receive suggestions based on either the topic weight or PageRank value. When topic weight is used, the suggestion criteria is the topic weight of the articles in a topic. Simply speaking, in the 'topic weight' status, EduVis suggests topic related events. And when the page rank is used, the suggestion criteria is the PageRank value computed by the clickstream network. Differently speaking, in the 'PageRank' status, EduVis suggests events which have many back-link. The slide bar (right to the Figure 1 A4) is used to set criteria value as a threshold to recommend documents in three previous views.

5.3 Interactions between Coordinated Multiple Views

EduVis employs coordinated multiple views, so they are tightly linked to each other, which means interactions in one view affect to affect others.

One important interactions in the event view is selecting interesting time period on the Event lines and Time Filter. Once a time period is selected, only historical events occurred in

the period of interesting are drawn in the map view and the gallery article tab. When the (A2) option is on, if any of the dates associated to the events are included in it, they also appear. In the same context, when the users select region of interesting by drawing a square or clicking countries in the map view, other views are updated accordingly. Especially in case of drawing a rectangle in the map, light red areas in the event lines briefly indicate where the filtered events are which topics include them (Figure 5 E). In addition, when the users click an event element circle in the map, not a clustered marker, the article gallery is auto-scrolled to present the document associated with the selected event highlighting in yellow. Lastly, in the article gallery tab, when a user hover an article, the center of the map view is moved to its location. Then, the clustered marker associated with it is scattered in spiral, and the target event is highlighted in red (Figure 4 F).

VI Usage Scenario

This section presents two usage scenarios conducted by real users, one graduate and one undergraduate student from Computer Science, along with history education specialists. They represent ordinary students, not history experts. Below two usage scenarios describe how EduVis can be used to explore and navigate through various events and to interpret the relationships between events.

6.1 Usage Scenario 1: Building a narrative while exploring information

A rich visual context can attract users to construct a historical narrative through unexpected discoveries. In this case, the users start the exploration from the event view. In the event lines, they find two interesting topics, the topic 11(Chinese) and topic 18(Japanese) as figure 4 A, because they are related to two neighbor countries of their own. They use the topic-selection button in the system header to delete all but two topics. And then, interestingly, they brush up the period of approximate between WWI and WWII, from 1920 to 1940 in the timeline filter. Although this behavior was not in line with our expectations, they noted that since they already knew that Japan had engaged in the Second World War and colonized several countries in Southeast Asia in that time. They reply that they become curious about what happened in two countries between these times. They find that there is no events in the topic 18 in this period (Figure 4 D). The users see the results in the map view and article gallery. They find a bunch of events are only in east Asia (Figure 4). While they explore the events country by country, they find there are several wars and battles between Japan, China, the Soviet Union, and other east Asia countries.

As a result, they find a war called “the Second Sino-Japanese War”(Figure 4 G). After reading the Wikipedia article, they learn that “Sino” indicates the “China”, particularly the ancient-to-modern history of China, and it was Japan’s war to colonize China. However, Japan failed to colonize China until the end of World War II. They wonder why Japan entered World War II while Japan fought China. They find the answer in another event, ‘Japanese attack on Pearl Harbor’ which goes through the links in the article. They find a flow that led to the Pacific War, as Japan was engrossed in colonial expansion ignoring warnings from USA although they had been in good relations since World War I. In this scenario, the users explore events, create their own questions, and build the narrative using their findings within EduVis.



Figure 4: The first usage scenario shows how the users explore EduVis with starting no intention.

6.2 Usage Scenario 2: Building a narrative for a given question

The second scenario describes how to use EduVis when a question is given as a general situation. For example here, *“Bismarck famously said that a European war would start from “some foolish thing in the Balkans”. What “foolish things” happened in this region in the decade before World War I?”*⁵

From the given problem, the users extract two keywords, ‘before World War I’ and ‘the Balkans’ which is expecting period and place. Users can roughly find where the target period is by looking at the early peak point in the timeline filter. They rearrange the brush in the timeline filter to the early 1910s (Figure 5 A). And then they move to the map view to explore which events had been occurred in the Balkans. When users are not familiar with the geographical location, they can find the target place, the Balkans in this case, using the map-search function (Figure 5 C). After finding the location, they brush around the Balkans on the map (Figure 5 D). These series of interactions allow users to explore historical events occurring in interesting regions in terms of temporal and geographical perspectives. As the result of their interactions, the article gallery (Figure 5 D) shows the relevant events. In the article gallery, because they do not know from which events to explore first, they decide to sort the events in importance order (Figure 5 H). Also, because users want to check events in importance order regardless of topic, users hit the (A4) in the filter to change the status from “Topic weight” to “PageRank” (Figure 5 F). At the first row, they find four events, ‘Assassination of Archduke Franz Ferdinand’, ‘the Balkan Wars’, ‘First Balkan wars’, and ‘Second Balkan war’. Because the latter three events contains the keyword, ‘Balkan’, they choose to read the first one. Not surprisingly, they find the ‘First Balkan war’ and ‘Second Balkan war’ at the recommendation modal. They learn that the Serbian Nationalism became prevail in Serbia after winning the war and eventually the radicals shoot the Franz Ferdinand who were the hindrance to them. They also find the event ‘Assassination of Archduke Franz Ferdinand’ which was the first element in the gallery tab. It leads Austria-Hungary to declare war against Serbia, and eventually triggered a series of events between the Austrian-Hungarian allies and Serbia’s, the beginning of World War I. In conclusion, they find the series of events lead to World War II, called the foolish things, and they choose the event ‘Assassination of Archduke Franz Ferdinand’ as the most foolish thing.

⁵<https://alphahistory.com/worldwar1/world-war-i-essay-questions/>

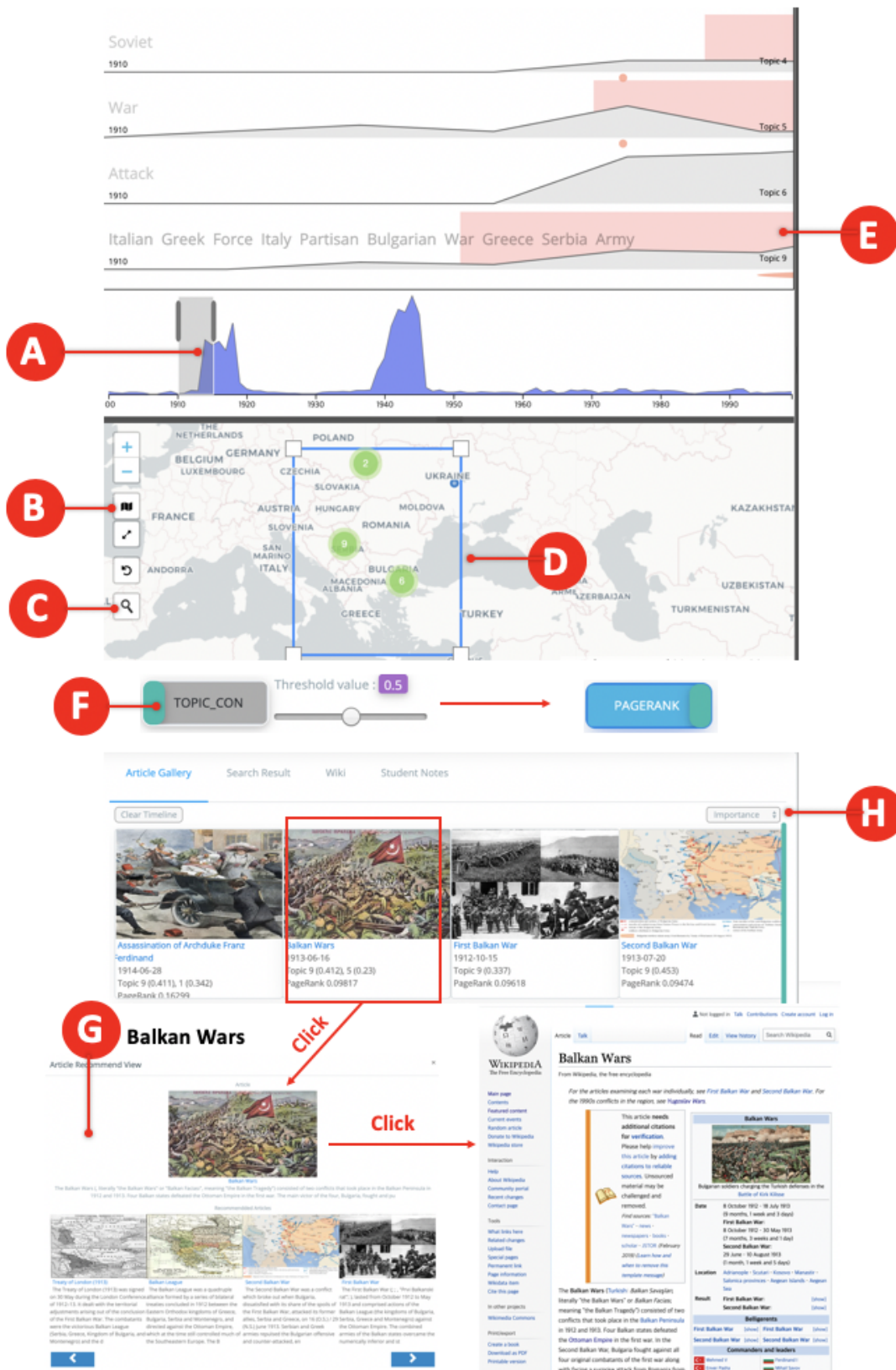


Figure 5: The second usage scenario shows the general situation of when a question is given. The users can explore information in spatiotemporal perspective using EduVis.

VII User Study

7.1 Participants, Tasks, and Procedures

To evaluate Eduvis, we conducted two user studies. In the first study, we recruit 7 participants (all males, avg. age: 22) in the history class, who are our main target users. To investigate further if EduVis can be useful for casual users who are not taking the history course, we perform another user study with 16 participants (6 males and 10 females, avg. age: 23) in campus. None of them are taking a history course this semester, but four of them took the history course before. Only one participant has experience of using a visualization system, a disaster management system, in her course work. The all participants are from various engineering majors, namely, Computer Science, Life Science, and Management engineering. The only difference between two user studies is the environment setting. For the target users, we run the user study assuming classroom environment with laptop, a 15-inch MacBook Pro (Intel i7, 2.9GHz, 16GB memory, Intel HD Graphics 630). And for the casual users, we run the study assuming general environment with a desktop machine (Intel I7-6400, 3.4GHz, 16GB memory, GeForce GTX 970) with a 30-inch monitor (2560x1600).

Once they are welcomed in the experimental room located in a university building, they are asked to read and signed the consent about participating in this study and recording their activities. We also ask them to fill out a demographic questionnaire. When the participants are ready, they have a 30-minute training session including reading a manual, watching a four-minute-long video, and using EduVis without any restrictions. After the training session, we give two tasks which are designed with our experts who are the instructors of the history class at our university. The first task (Task 1) is to find three interesting events and the second task(Task 2) is to describe characteristics of the events in early 1910s, Africa using EduVis. The goal of Task 1 is to find out how EduVis supports the participants to explore self-interesting events. The objective for Task 2 is to identify how Eduvis helps the participants explore the events in a region that is less covered during the class. Between the two tasks, the participants are allowed to take up to 10 minutes break. After finishing the tasks, we request them to complete a exit survey on their learning experience using EduVis. The entire process take about 100 minutes including break time and we pay 15\$ for their participation. To distinguish the participants in the first study and second study, we use ‘T’ for the target users and ‘C’ for the casual users respectively.

7.2 Result Analysis

Observation on Free Use of EduVis (Task 1)

Task 1 requires users to find self-interesting events using EduVis. We find two main patterns. When participants (T1, T2, T3, T6, C1, C2, C3, C6, C10, C11, C12, C14) already have a target(time or location) in their mind, their exploration starts by specifying the range in the

event view or map view to find an interesting event. In many cases, they show the spatial exploration using their familiarity to countries. For example, many participants look for events occurred in countries where they are currently living in. Once the participants find an interesting event in the region, they tend to explore events in neighbor countries without changing the time range. One participant (C12) successfully find the event which her foreign friend has told a story occurred in Egypt, ‘Battle of Abu tellul’, and she is very pleased to find it. The participants also explore the events to answer their own question. For example, the participant (C2) explore two countries–Taiwan and Japan, because she wonder why people in Taiwan are so close to Japanese today although they are also colonized during World War II. For this, she selects two countries in the map view, and find and read articles that are related to both countries, ‘Tapani incident’, to understand the contemporary relationship between the two countries.

Without any intention, the participants show that they can also find interesting events through given topics and the map view. Three participants (T6, C12, C16) start to explore the information after filtering topics in the top menu. And (T5, T6, C2) explore events centered around countries of interest (e.g. countries where they had traveled or countries that have been an issue today) in the periods of the World War I and World War II. For example, one participant (T5) show interest in the existence of the Muslim in past China by finding ‘Muslim conflict in Gansu’ and another (C2) recognize ‘Christmas truce’ with a surprise, a peaceful time during the cruel World War II. Four participants(C5, C9, C11, C13) comment that although they accidentally reach to their findings, the events become a new source for further exploration. Regardless of any interesting to local, temporal, and topical perspective, a rich visual context allows the participants to explore the time periods with peaks in the event charts or high-density areas in the map.

Observation with Task 2

Task 2 analysis is conducted with one history expert. All participants, the target users and casual users, commonly show spatio-temporal approach. They control the range of period in the timeline filter and make a brush around Africa. They successfully find two or more characteristics among the events in early 1910s, Africa.

Some participants go further analysis about their findings. One participant (C11) try to interpret her findings with more detail in spatial perspective. She found three events the ‘Ekumeku Movement’, ‘Battle of Zanzibar’, and ‘Battle of Kakamas’ in West, East, and South Africa respectively. By this approach, she found that which part of Africa is colonized by what countries. For example, from the three events, she found that West Africa was taken from Great Britain, East Africa was middle of Great Britain and German colonies, and South Africa was from German. From these wars, she also find the task solution that Africa became a battlefield between imperialism nations to get more profits and between colonies and imperialism nations to be independent from European countries. Three participants (T2, T4, C2) use topic as an orientation. From the keywords in the topic 14, which contains the most of events in early 1910s and Africa,

they find three countries, France, Germany and Belgium. They identify the battles related to not only these three but also Great Britain and Ottomans which are the main combatant nation in World War I. Especially (T1), after he find the French occupation of Morocco and the Zaian War, two consecutive events, he analyze the relationships between France and Morocco. He find that although France invaded Morocco at the former event, after France won the Zaian War against Zaian who was supported from Germany, France started to invest infrastructure in the Morocco and they formed an economic bond. In addition, he find no war and no battle before 1910 in Africa and he make a hypothesis about this finding with his knowledge about Imperialism era which he learned in the history course. He set up a hypothesis that by the late 19th century many African nations had been already invaded by imperialist nations and that they would have been busy to exploit colonies so they have not fought each other before 1910, Africa.

Expert Feedback

To evaluate if EduVis is an effective learning tool for history class, we ask feedback to our experts. For evaluation, we supply the participants' answer for two tasks at the user studies. At first, the experts view EduVis as a tool that can provide students with opportunities to explore new findings which is not covered in conventional materials given in the class. They append that EduVis allows the participants without bias.

In particular, the experts are encouraged with the cases of T1 and T6 who voluntarily seek to find and interpret the events in a region, where a less number of events happen in the event view. The experts also recognize that T1, T6, and C13 attempt to draw a big picture on the relationships between historical events in the early 1910s based on their findings. In conclusion, the experts remark that *“The participants' work is not simple acquisition of historical facts and cannot be achieved by accessing conventional materials (e.g., books written by historians). The participants definitely show a potential on performing creative thinking in learning history by interactively and actively selecting, arranging and interpreting events.”*

Exit Survey Result

After two tasks, the participants are asked to complete the exit survey questions about EduVis interface on a 7-point Likert scale (1: strongly negative to 7: strongly positive). There are three question groups, accessibility, overall experience and usability.

The first group is the result of evaluating the system accessibility to all participants. We expect that EduVis is easy to use because we implement the interface considering the previous researches' advice. While they evaluate 5 points for 'Easy-to-learn', which is not critically high, EduVis is evaluated 6 points for 'Easy-to-use'.

The second group is about the overall experience of EduVis. The participants evaluate that EduVis is fun experience to explore the historical events. At the same time, they showed a

EduVis post-survey result

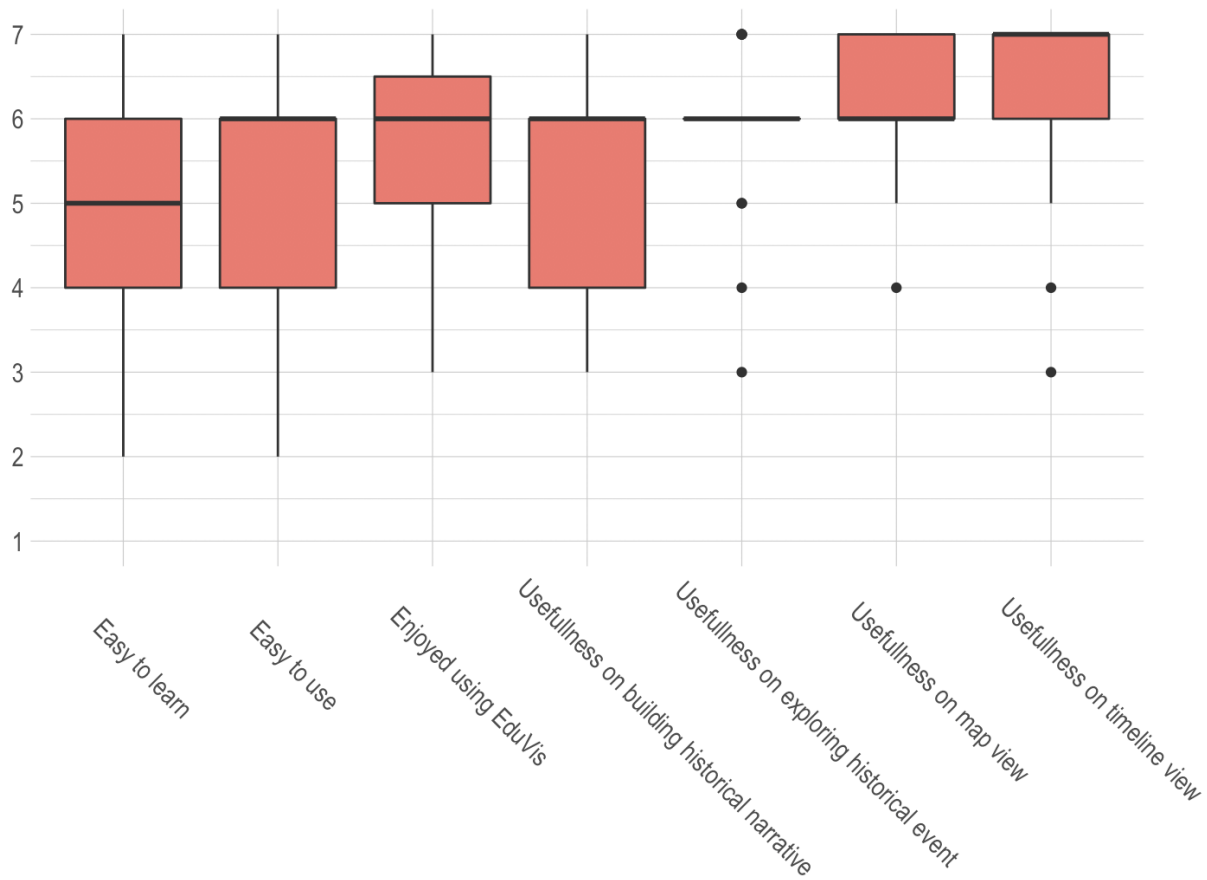


Figure 6: Exit survey results regarding EduVis

positive response that they want to use EduVis if it is accessible online. They also remarked that if EduVis have more data, not only Wikipedia but also the web postings which they can find using conventional web search it would be very helpful tool for learning history.

The last questions group is concerning about usability of EduVis in terms of learning history. The participants satisfy with map and event views because a vast amount of information are sorted by local and time as opposed to an ordinary web search. They assess that because the events are sorted in time, it is helpful to explore and build narrative. However, one participant point out that when she want to find simple facts,web browsing could be more convenient.

VIII Discussion & Conclusion

We present EduVis, an visual exploration system, which aims to satisfies the course objectives in history class as well as user experience. And then we ran the user studies for two user groups, target groups who are taking history course and casual groups who are not currently taking history course to evaluate the participants' learning experience about EduVis. In this section, we discuss the limitations first and the potential directions to improve EduVis.

At first, the small size of EduVis history collection is one limitation. Due to the smaller size of articles related to Cold War relatively than WWI and WW2, participants had less focus on that period in the Task 1. And also small size collection directly affect the PageRank values. Because the distribution of the PageRank values is skewed, the participants might struggled to find well-known events by controlling the slider. This limitation is expected to be solve when we add more historical documents into EduVis.

Another limitation is from the process of setting main date and location entity for each articles to draw them in visual interface. As described in section 5.1, we use the place and date information which have the most frequently mentioned for each event, but it is difficult to assess the accuracy between our solution and the actual date and location of events. In particular for learners, the inaccuracy may directly affect reliability and usability of EduVis. We expect to be able to overcome this issue by leveraging students' collective intelligence in the history class.

In conclusion, we presented the visualization system, EduVis, as a result of collaboration with experts in education to satisfy the course objective as well as the student's learning experience. To provide intuitive and easy interface for the learners, we derive the design considerations from our experts and we actively accept conditions which are presented by previous researchers for visual interfaces targeting casual users. As a result, we implement EduVis and ran the user study for target users and casual users. From the result of the user studies, experts in history education find students' different approaches – spatial, temporal, and topical approaches – to explore the historical events with conventional search-centric method.

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