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BORDERS: VISUALIZING TEMPORAL CHANGES IN BORDER
DISPUTES

BY

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THESIS

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ABSTRACT

Disputes and changes of international borders have been an area of study for cartographers since long ago. Now, with online maps growing faster than printed maps, the task also transfers to online map creators. Companies like Google and Bing provide personalized maps where disputed international borders are in compliance with national laws based on the users' location. Knowing these disputes, the presentation of the differences of international borders between countries as well as on geographical time is an unexplored topic in visualization. In this paper, we propose a fluid visualization method on displaying temporal border changes. We build a tool, Borders, with such fluid visualization to present border events (border disputes and land delivery) and the history of them. In Borders, there are three views, namely general view, detail view, and timeline view, focusing on different aspects of the border events and supporting user exploration of the background knowledge. To provide better learning and comprehension of the border events, contextual cues of border events are integrated in the interface explaining the causes and evolution of events. Case studies show Borders has an advantage over other tools in the fluid visualization of border changes, smooth zooming and panning effect, and rich contextual cues.

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CHAPTER 1

INTRODUCTION

Disputes and changes of geographical borders have been attracting people's attention since ancient time. With the need of the governors and the public to know the situation in neighbor countries as well as the world structure, presenting changes of regional and international borders has been a task for cartographers since long ago. In the age when there were only printed maps, various legend such as line of different colors and area of different fillings were commonly used to present territorial occupation and conflicts [6, 12, 13]. Nowadays, disputes and changes of borders still exist, transferring this task to contemporary online map creators. A good thing is the development of online interactive maps offer more presenting methods and make this task easier for online map creators.

While interactive online maps bring more choices for displaying disputes and changes of borders, there is a problem that online map providers need to face: since online maps are public and accessible from all online users, how to present the disputed borders to users from different countries holding different opinions of what the borders should be. For this problem, companies like Google and Bing provide personalized maps where disputed international borders are in compliance with national laws based on the users' location. However, instead of presenting the disputes to users, these companies are trying to hide the disputes and provide most of their users with what they want to see. As far as we know, there is no current tools presenting people with the disputed international borders or the changing of borders. With the aim to help people learn and explore the border-related events, we introduce Borders, a tool to present such border disputes and border changes over time.

However, there are some challenges in visualizing the differences of international border between countries as well as on geographical time. Events presented in maps, such as border disputes and changes, always have long evolution to current status, where temporal information plays an important

role in illustrating the evolution. Thus, how to involve temporal information and present the evolution of events in map is a challenging problem. Map visualization on conflicts has been studied [11, 10], but most of them are static visualization. In such visualization, the changing of disputed area and views from different countries are not intuitive.

In this paper, we propose a fluid visualization method with smooth zooming and panning effect to display border changes on geographical time. We build a tool named Borders with such fluid visualization to present border-related events (border disputes and land delivery) and the background of them. In the tool, there are three views, namely general view, detail view, and timeline view, focusing on different aspects of the border events and support user exploration of the background knowledge. To provide better learning and comprehension of the border events, contextual cues of border events are integrated in the interface, helping users making sense of the causes and evolution of the border-related events.

The remainder of this paper is organized as follows. Section 2 describes some related work. Section 3 introduces the data used in our visualization. Section 4 talks about the design of Borders and Section 5 introduce the implementation of some effects in the tool. The evaluation is presented in Section 6 and the areas of improvement in Section 7. Concluding remarks are presented in Section 8.

CHAPTER 2

RELATED WORK

In Borders, maps are used as a communication system. The visualization of disputed borders and border changes are also related to visualization of uncertainty and conflicts visualization. Moreover, our tool is a geographical visualization of border-related events of space and time.

2.1 Cartographic Communication

Maps can serve as communication systems. Good maps are always concerned with enhancing the map user's understanding of the subject matter of the map [14]. Guelke investigated several principles in cartographic communication, where methods such as placing information in appropriate contexts and limiting noise based on the purpose of users were discussed [14]. We followed these principles in our border visualization design. Roth conducted surveys of to develop a functional taxonomy of interaction primitives for map-based visualization, where participants emphasized the interactions with the temporal component of the map to understand how geographic phenomena change over time [15]. Peuquet and Kraak believe animations in geographic visualization are well-suited to represent changes over time if the user can interact (e.g. stop, pause, back up, go forward) with the animations [16]. To better present the changes of border events over time, we apply interaction with timeline and propose a fluid visualization method in our tool, aiming to provide views with better understanding to the border changes and better experience in the exploration.

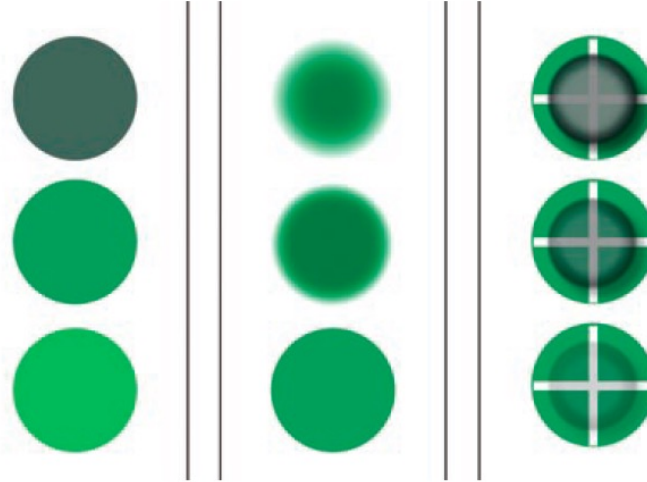


Figure 2.1: Point symbol sets depicting uncertainty with variation in (a) saturation (b) crispness and (c) transparency of symbol [1].

2.2 Visualizing Uncertainty in Geographic Visualization

In visualization of uncertainty, many methods have been investigated by researchers to represent uncertainty in cartography and geographic visualization. MacEachren et al. reviewed several methods to help analysts manage and understand information uncertainty [1]. Some visual variables, such as color saturation, crispness, and transparency, were discussed for depicting uncertainty in this work (Figure 2.1). Crispness and fuzzy shapes were also applied in the cartographic visualization to depict uncertainty in Europe literature by Reuschel and Hurni [2]. Methods such as animated (symbols fading in and out) and texture (texture signifies the area of the possible location) visualization were applied to present uncertainty of different types (Figure 2.2).

Wu et al. presented a visual analytics system, BoundarySeer, to help users gain insight into the changes of boundaries such as Antarctic ozone hole [17]. It used a trend view with stacked graphs to display the changes of boundaries over time. However, most visualization used in the previous work are static and not intuitively showing the changes of data. Compared to the static presentation of uncertainty, we're more interested in the fluid presentation of them, especially when the data is spatiotemporal such as border disputes and changes. In our tool, the fluid visualization is implemented to show border

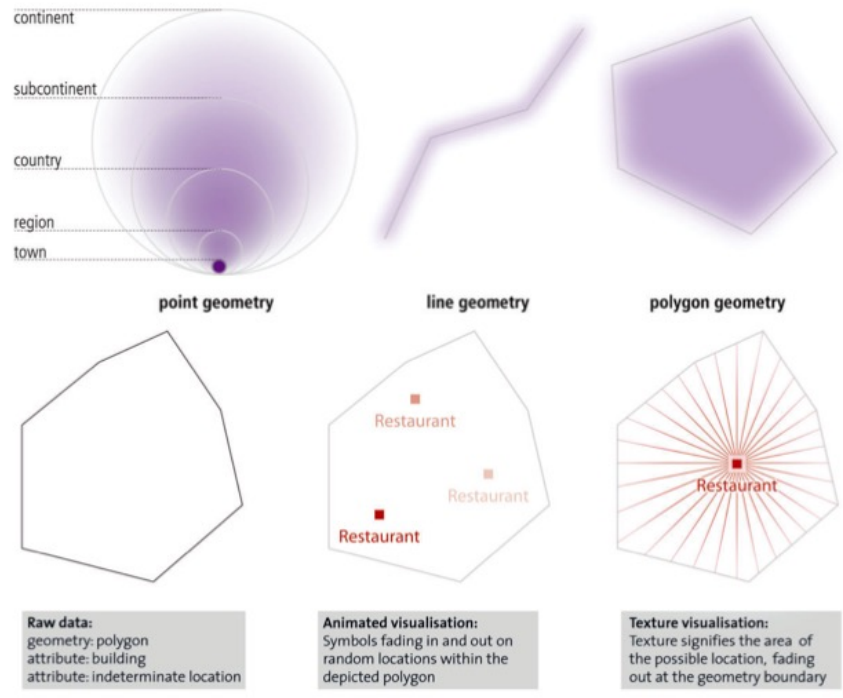


Figure 2.2: First row: adaptation of fuzzy shapes for single vector geometries. Second row: Animated and static visualisation methods of settings with an indeterminate location. Third row: examples of detailed distribution of literary spaces [2].

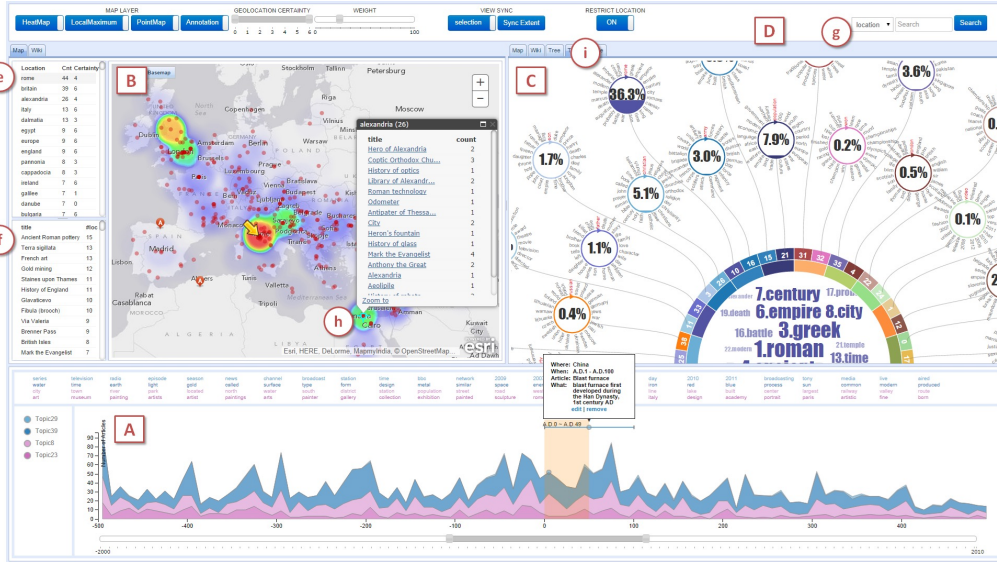


Figure 2.3: VAIroma Interface [3]. The interface has three main views: Timeline view (A), Geographic view (B) and Topic view (C).

changes over time or from one country’s view to another.

2.3 Geographical Visualization of Space and Time

Geographical visualization build on maps is a commonly used method for event communication over space and time. Cho et al. proposed VaiRoma, a visual analytics system, to construct a narrative of Roman history from ancient times [3]. It used a timeline view, a geographic view, and a topic view to help users make sense of events, places, times, and relationships between them (Figure 2.3). Another work by Lu et al. focused on event cuing with media data using maps and timelines [18]. In their interfaces, much information was shown in the timeline mapped with the geographic view, showing the changes in the framework of topics and documents. Thudt et al. proposed a map-timeline representation to map the travelling time and location in visual mementos [4]. As shown in Figure 2.4, instead of presenting a map and a timeline separately, they integrated the map and timeline together by constructing the timeline with specific circular map segments. Unlike these work where static visualization is displayed when time period or point is selected in timeline, our work focuses on presenting fluid visual-

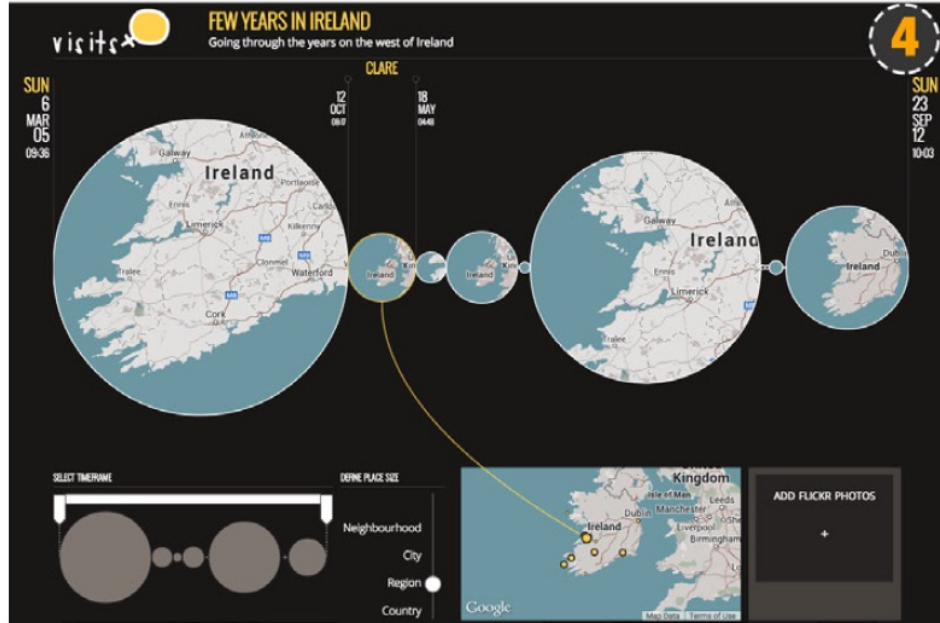


Figure 2.4: A map-timeline in visual mementos [4].

ization by playing the time changing in the timeline. We want the evolution of events be intuitive presented using smooth transition. Ferreira et al. presented an interface that supports comparative analyses and allows users to visually query taxi trips on a map [19]. Even though the interface can show taxi trip changes in one region between two time periods, it couldn't display the whole changing process over time, which we achieve by interactions on the timeline. Eccles et al. used a 3D geographical visualization, GeoTime, to display the evolution of a story with nodes and lines in geographical time [5]. It added a dimension, time, on regular geographical visualization to present the story over time (Figure 2.5). However, the 3D interface may not be such concise and make exploration a little harder for the users. To keep a concise interface, we use regular map in our tool and apply fluid visualization with timeline interactions for presenting border event evolution.

2.4 Visualization of Conflicts

Visualization of conflicts has been a topic that attracts researchers for a long time. When presented in printed materials, maps always use various legend, such as lines of different color, areas of different filling, and different shapes,

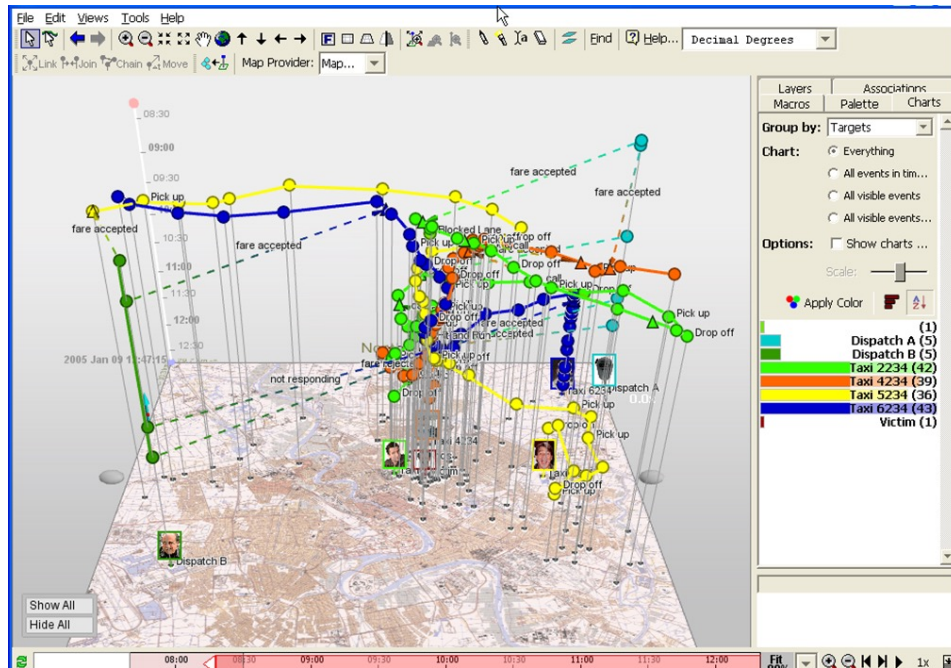


Figure 2.5: GeoTime for analysis of events in time and space [5].

to present the conflict [6, 12, 13]. Figure 2.6 shows examples of the use of such legend [6]. However, it's uneasy for printed materials to show conflicts at all zoom level — some conflicts may be too small to be clearly presented in a map. To display conflict or border changes at a location over time, small multiples (a series of similar graphs placed together using the same scale, see Figure 2.7) and its combination with timeline (Figure 2.8) are sometimes used [7]. Although small multiples works well for showing the changes over a short period of time such as several years, but it takes much paper to present changes over a long time. The combination of small multiples and timeline (Figure 2.8) doesn't do well in presenting small changes in borders. Moreover, the overlap of maps when frequent changes happen make it not intuitive for frequent border changes. The arrow is another feature that is used in printed map, especially war maps (Figure 2.9), to present marching direction. Apart from presenting marching directions, arrows are also good highlight of border changes. We apply arrows in our tool for the direction of border changing.

The topic of border visualization also draw attention of researchers online. Thenmap, a repository for historical borders, created an API that allows users to fetch historical geodata, e.g. the French colonies in 1949 [20]. Schol-

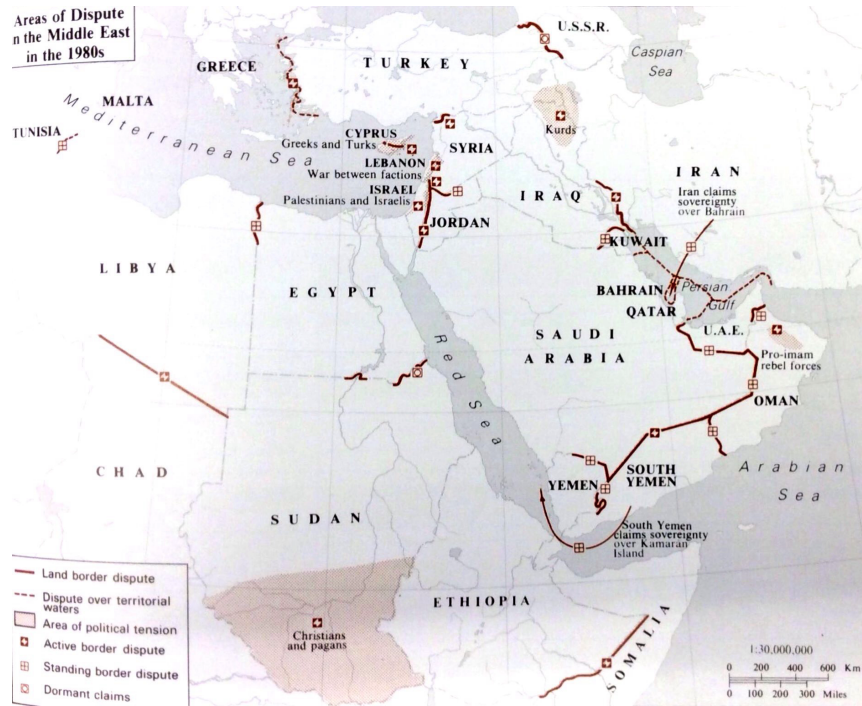


Figure 2.6: In printed maps, various legend, such as line of different color, area of different filling, and different shapes, are used to present conflict [6].



Figure 2.7: Examples of small multiples in presenting border changes over time [7].

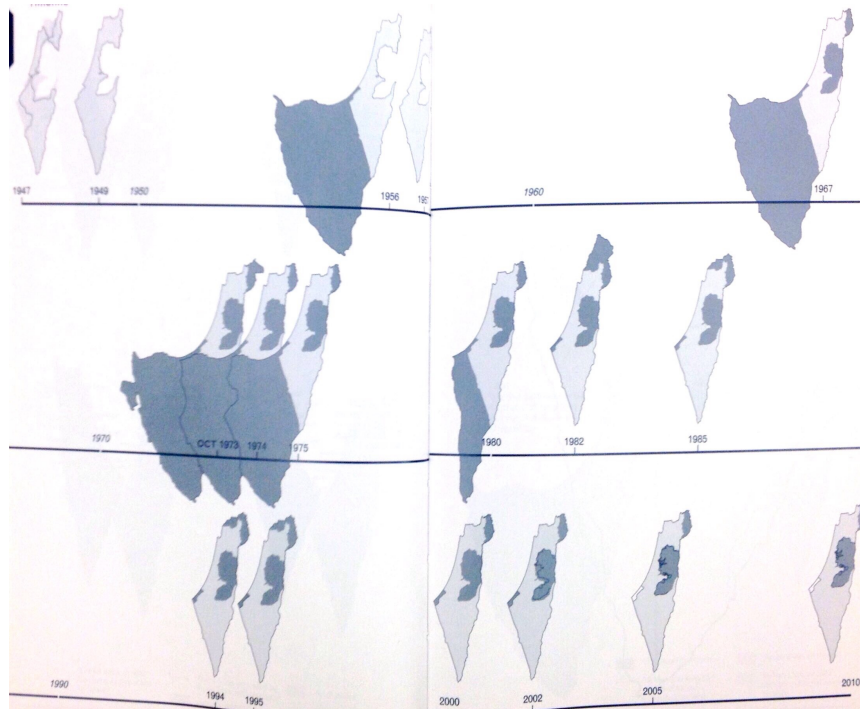


Figure 2.8: Combination of small multiples and timeline in displaying border changes [7].



Figure 2.9: Arrows showing attack direction in war maps [8].

ars in MIT noticed the personalized maps provided by Google Maps and compared the borders seen from different countries [21].

Rod et al. created an interactive visualization to display armed conflicts of different types, where their active years are displayed in a map interface which enables exploration and animation (Figure 6.2) [11]. WarViews by Weidmann visualized and time-animated geographic data on civil wars [10]. In the dynamic version of WarViews, users could see timeline animation, control layer visibility, and get geographical information to better understand the background and involvement of conflicts (Figure 6.1). Animation on timeline is applied in both work, but the process of the region changes is still displayed statically. In our work to visualize border disputes and changes, we focus more on the fluid visualization in presenting the border transition process. We also combine something that is not considered in the previous conflict visualization work - contextual news cues - in our visualization to support a better comprehension and sensemaking of the events.

CHAPTER 3

DATA

The data in our tool is obtained from MapWatch, a system for detecting and cataloging personalization of international borders in online maps [22]. MapWatch identified several disputed border areas, and we present four of them in our tool. Apart from the border disputes we obtain from MapWatch, we also present a border exchange between Belgium and Netherlands in Borders. The data of this peaceful border exchange is obtained from online news [23]. In total, we present five border events (4 border disputes and 1 border exchange) in our tool — Aksai Chin and Arunachal Pradesh between India and China, Crimea between Ukraine and Russia, the border between Morocco and South Sahara, South China Sea, and the border exchange over muse River between Belgium and Netherlands.

3.1 Border Disputes

Aksai Chin Aksai Chin is one of the two main disputed border areas (the other is Arunachal Pradesh) between China and India [24]. It is administered by China but is also claimed by India. The Sino-Indian War occurred in 1962 as a fight for the control of Aksai Chin and Arunachal Pradesh between China and India but there is no division of territory that appeases all sides [25, 22]. Both Google and Bing Maps personalize the borders to display respective territorial claims for users in these two countries while users from all the other countries see dashed border for the disputed area.

Arunachal Pradesh Arunachal Pradesh is another main disputed border area between China and India. Most of Arunachal Pradesh was ceded to Britain by the Tibetan government with the Simla Accord (1914). However, the legality of that treaty isn't recognised by China - China claims most of the state as South Tibet [26]. Similar to Aksai Chin, Google and Bing Maps

users from China and Indian see borders claimed by their country, and the other users see dashed borders.

Crimea Crimea has long been a area of dispute between Ukraine and Russia since 1991 [27, 28]. After Russia annexed Crimea in March 2014, even though the UN passed a general assembly resolution [29] stating the invalidity of the annexation, the localized Russian Google Maps view includes Crimea within its borders [22].

Western Sahara Conflict The Western Sahara conflict is an ongoing conflict between Western Sahara and Morocco. The conflict is the continuation of the past insurgency by Polisario against the Spanish colonial forces and the subsequent Western Sahara War between the Polisario and Morocco [30]. Bing Maps display a dashed border between Western Sahara and Morocco for all users except for those from Morocco.

South China Sea The territorial disputes in the South China Sea have involved many countries and become the major flashpoints of existing conflicts in Asia [31]. The Chinese government published the early map displaying the dashed line in South China Sea in 1947 [31, 32]. Now Chinese users of Google Maps see a ten-dash line in South China Sea while the other users don't see any line there.

3.2 Border Exchanges

Border exchange between Belgium and Netherlands Netherlands and Belgium will have a friendly exchange of land - a piece of nature which is about 15 soccer fields' worth that juts into the Meuse river dividing the two nations [33]. The portion of land belongs to Belgium but linked only to the Netherlands. Crimes happened in in the peninsula cause difficulties for both countries – there is no easy path on the river for Belgian police and judicial authorities to get there, and its also uneasy for Dutch to be there because it was Belgian. There hasn't been any border change for this event in Google or Bing Maps, but the exchange is supposed to happen in 2016.

CHAPTER 4

DESIGN

Based on related work and experiments, we explored zooming and panning effect to provide smooth transitions between border changes. The inspiration for our zooming and panning design is got from the Ken Burns effect [9]. In the interface of borders, we provide three views, namely general view, detail view, and timeline view. The three views focus on different aspects of the presentation of border events and fit for different purposes of users. Multiple interactions are provided in Borders to support user exploration in border events.

4.1 Ken Burns Effect

In our disputed border visualization, we wish to present smooth panning and zooming when moving to the selected border event location from another, giving the users more time to digest where the border event is located and on what granularity the affected territory is. We get much inspiration from the Ken Burns effect, a type of slow panning and zooming effect, and fading transitions between frames used in video production from still imagery [9].

Inspired by Ken Burns Effect, we apply similar methods in our interfaces. We provide smooth zooming and panning in the transition between place to place. After smoothly zooming to a location, the background layout will fade in and then the fluid visualization will be displayed. the implementation of zooming and panning in Borders will be introduced in detail in Section 5.

4.2 The User Interface

We provide three views in the interface of our tool, namely general view, detail view, and timeline view. The three views focus on different aspects of



Figure 4.1: In Ken Burns effect, action is given to still photographs by slowly zooming in on area of interest and panning from one area to another [9].

the presentation border events and fit for users' different purposes in viewing them. The general view focuses on displaying the geographical distribution of border events in a global range. The detail view is in border level and focuses on presenting border details. The timeline view shows the history of border events over time, paying more attention on presenting the the events on geographical time.

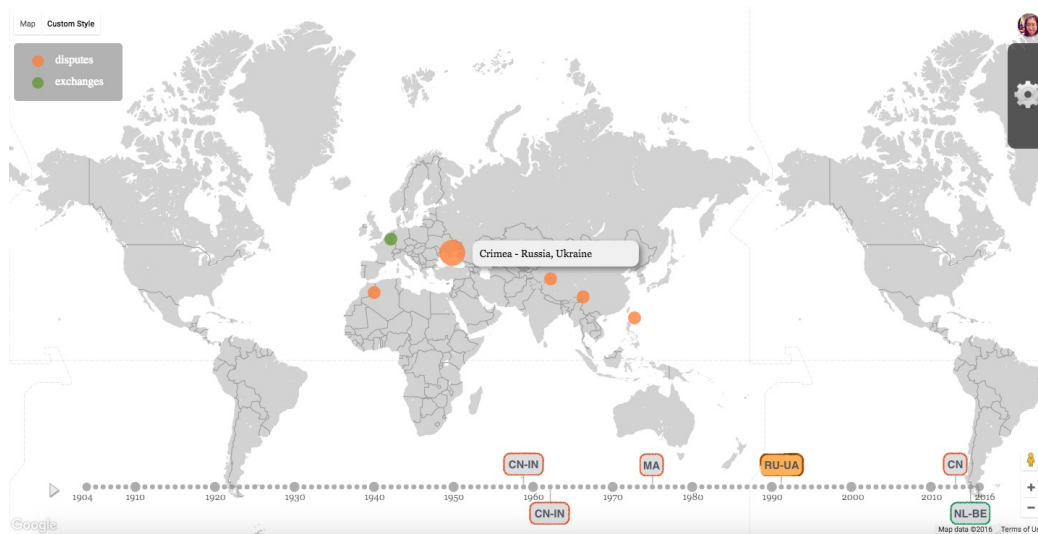


Figure 4.2: General view presents the geographical distribution of border events in the world in 2016. The mouse is hovered over the dispute of Crimea between Ukraine and Russia. The tooltip shows countries related to the border event and the corresponding label in timeline is highlighted.

4.2.1 General View

The general view presents the geographical distribution of border events. As shown in Figure 4.2, it is a world map with all border events labeled in the corresponding location as small circles in orange or green based on the border event type. We present two kinds of border events in our tool, one is the border dispute, which we use orange to represent, the other is the border exchange, where we use the color green.

The time of each border event is labeled in the timeline, which is on the bottom of the interface. When the mouse is hovered over a border event (a small circle) in the general view, a tooltip that contains the related countries will appear next to the border event, presenting countries involved in this border event (see Figure 4.2). Meanwhile, the corresponding label in the timeline will be highlighted.

4.2.2 Detail View

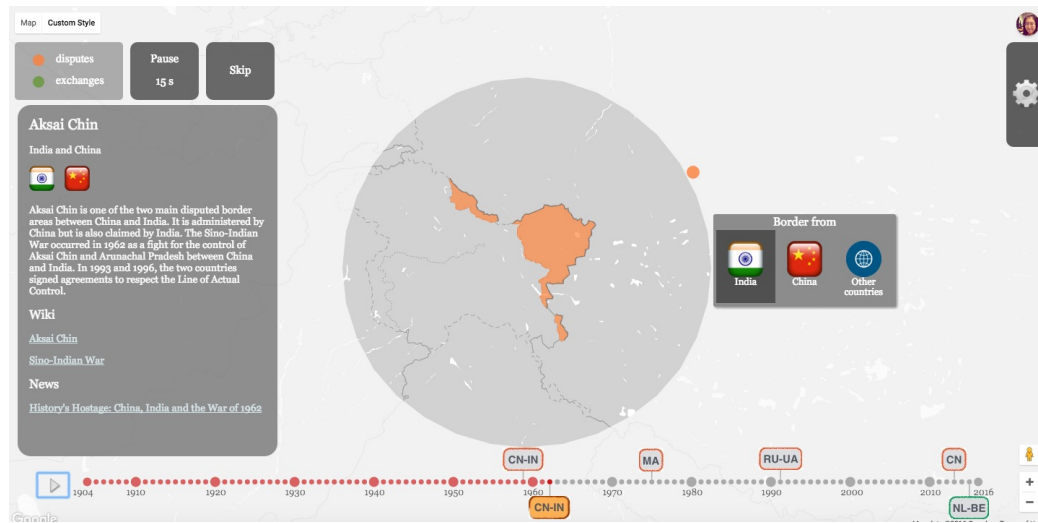


Figure 4.3: Detail view showing borders of Aksai Chin in Indian view. There is a lens in the middle highlighting the border event. View from different countries can be selected from the small window beside the lens. Corresponding label in the timeline is highlighted in the same border event color. The context panel on the left presents the background and contextual cues of the event.

When a border event is clicked, the interface will switch from the general

view to the detail view (Figure 4.3). The detail view presents more detailed background of the the selected border event, including countries involved, fluid visualization of border changes, and contextual cues.

Figure 4.3 shows the interface of the detail view. The lens in the middle of the interface highlight the area of the border dispute or exchange, with the corresponding region in color orange or green. The small window beside the lens lists countries involved in the selected border event, by clicking which users could see fluid visualization of border changes from one country’s view to another country’s view. At the left of the lens, the context panel presents the background of the border events, including a brief summary of the border event, links of related Wiki pages, online news, and other sources such as reviews and papers.

In the detail view, the corresponding label in the timeline will also be highlighted. By clicking the small circle that stands for the border event again, users can exit the detail view and go back to the general view.

4.2.3 Timeline View

The timeline view, which can be activated by clicking the *play* button at the left of the timeline, aims to display the history of border events in the world on geographical time. Once the timeline is played, it will go through the years and pause at those that have border events to present some details.

When it comes to a year of border events, if zooming is enabled, the interface will smoothly zoom in to the area and show the detail view of the border event. It will automatically display the fluid visualization of border changes (view of the first country listed in the country window). Then, the interface will smoothly zoom out and go on proceeding in the timeline. If zooming is not enabled, the interface will pan to the border event location and show the context panel directly in the general view instead of zooming to the detail view. This is for users who want to know some background information about the events but prefer not to see how the borders change.



Figure 4.4: Zooming setting in the interface. The whole setting panel will appear when mouse is hovered over the setting label.

4.3 The Interactions

There are interactions in our tool that aim to help users explore the border events and provide them with better experience. We provide a zooming setting which support enabling and disabling zooming in the exploration. Interactions with the country selection window, timeline, and context panel can assist users make sense of the border events.

4.3.1 Zooming Options

Smooth zooming to the POI can be helpful to users who want to see the fluid visualization of border events. However, for those who prefer to focus on high-level view (general view) and don't want much details, the zooming can be a waste of time. In our tool, we provide a zooming setting on the top right corner of the interface to enable or disable zooming in the interactions (Figure 4.4). When the zooming effect is on, the interface will smoothly zoom in and out in both detail view and timeline view. When the zooming option is off, in the detail view, the interface will skip zooming and show the border event location directly. In the timeline view, if zooming effect is off, the interface will stay in the general view instead of entering the detail view for each border event.

4.3.2 Viewing Borders of Different Countries

In the detail view, users could see highlighted territory in a border event and also a country window showing related countries in the event. By clicking the



Figure 4.5: Borders of Aksai Chin viewed from India, China, and all the other countries. The orange regions are the disputed area of and near Aksai Chin. In the Indian view, solid borders are more close to China (left). Users from China see solid borders near India side (middle). Users from all the other countries see dashed borders in Aksai Chin (right).

countries, users could see border claimed by different countries as well as the fluid animation of the territory changing. Figure 4.5 shows the three border version viewed from India, China, and all the other countries on Aksai Chin, a disputed border area between China and India. India sees solid border on the Chinese side while China sees solid border on the India side. For all the other countries, they see dashed lines as the border of the disputed area.

4.3.3 Viewing Border Events of a Certain Year

In our tool, we provide an interaction to enable users view border events before or in a selected year. In the timeline, if a specific year is clicked, the interface will show all the border events before or in this year in the general view. As shown in Figure 4.6, the year 1980 is selected in the timeline. Border events that happened before 1980 are displayed in the visualization, showing the structure of border events in the world of the selected year.

4.3.4 Pause and Skip

In the timeline view, we save 15 seconds for users to read the content in the context panel for each border dispute or change. As shown in Figure 4.3, when we come across a border event in the timeline and zoom in to the detail view of it, after the visualization has been played, a *pause* button and a *skip*

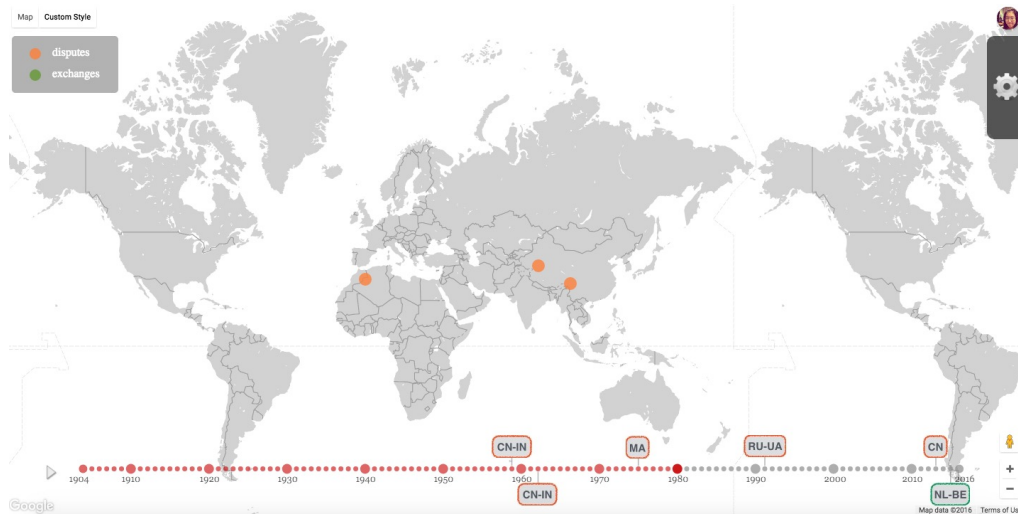


Figure 4.6: Year 1980 id selected and border events happened before or in the year are displayed.

button will be shown on the top of the context panel, with a 15 seconds counting down appearing in the pause button. If users wish to have more time reading the content in the context panel, they can click the pause button and pause the counting down; otherwise, they can click the skip button to quit the detail view ahead of time and go back to the timeline view.

4.3.5 Accessing Contextual Cues

In the context panel, we provide a brief summary of the border event and some online sources related to it. The sources contain Wiki pages introducing the history of the event, online news, and other sources such as academic papers and reviews. From the links in the context panel, users could access the online sources directly.

CHAPTER 5

IMPLEMENTATION

We use Google Maps API and D3 library for the implementation of Borders, which is presented in a webpage interface. We will focus on the implementation of two parts, smooth zooming/panning and fluid visualization of border changes, in this section.

5.1 Smooth Zooming and Panning

Since there is no method to change the speed of zooming and panning in Google Maps API, we implement smooth zooming and panning effect by ourselves based on the Ken Burns effect.

We use high resolution images for the smooth zooming effect. For each border event location, we take map tiles of this location from different zoom levels and compose a high resolution image. In the process of smooth zooming, we start by putting the image at scale 1 in the background, and smoothly transform it to the corresponding scale. CSS3 transitions are applied here to achieve the smooth zooming effect — we change the transition time and image scale to control the zooming speed.

Google Maps API has a *PanTo* method which can move to a position with users able to see the movement. However, the speed in *PanTo* is still too fast for the smooth effect we want. To achieve the smooth panning, we use the Javascript *setTimeout* method with recursion. No matter what zoom level we are at in the map, we want it spend the same time on the same screen distance in the panning process. We first transform the latitude and longitude of start and end points to pixel coordinates on the screen, and compute the time for the panning. Then, we decompose the panning to many short-distance panning and use recursion in *setTimeout* to move smoothly from the start point to the end point.

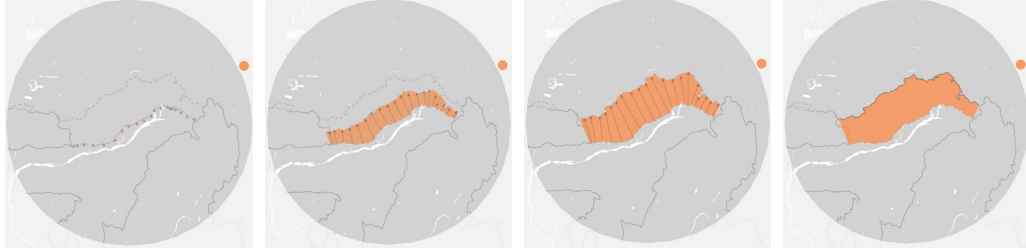


Figure 5.1: Screenshots of fluid visualization of Arunachal Pradesh’s border change from Chinese view to Indian view. Start of the fluid visualization: the initial border is the Chinese view, with dashed border on the upper part and solid border on the bottom part (left one). Arrows push the border move to the other side (left two). The border transitions just finish (right two). Arrows disappear gradually and the solid upper border on the current Indian view.

5.2 Fluid Visualization for Border Changes

To provide an intuitive view of how the border changes between different countries or over time, we propose a fluid visualization method to present border changes using arrows and the border line. When the border is changing from one version to another, as shown in Figure 5.1, there will be some arrows growing from the original border and pushing the changing border to the current location. The arrows present the direction of the border changing. Meanwhile, the area covered by the growing arrows is highlighted in orange (dispute color) or green (border exchange color). This is to give viewers some hints on what is the disputed area or exchanged land. When the border change is completed, the arrows will disappear gradually, leaving a solid line on the current border and the related area colored.

For each border event, we take screenshots of borders seen from different countries from Google Maps API and get the coordinates of the border path. The coordinates are used to create paths for arrows and border change, which are drawn on svgs and made superposed with the border in Google Maps. We apply the Javascript transition method for the arrow growing and border changing.

CHAPTER 6

EVALUATION

In this section, we present the evaluation of Borders by comparing it with another two tools that visualize geographic data on conflicts, WarViews and ViewConflicts [10, 11]. WarViews (Figure 6.1) is a tool that supports the exploration of geographic data on civil war and ViewConflicts (Figure 6.2) is a software for visualizing spatiotemporal data on armed conflicts. We compare Borders with WarViews and ViewConflicts from three aspects: (1) for what goals the tools are designed (*goals*), (2) main audience of the tools (*audience*), and (3) the visualization features and interactions in the tools (*visualization design*).

6.1 Goals

Even though focus on different datasets, Borders, WarViews, and ViewConflicts share a similar goal - to provide audience a better tool to facilitate a better understanding of the origins and dynamics of the conflicts. They aim to make the datasets accessible and more understandable to users by supporting exploration in geographical visualization.

6.2 Audience

Compared to borders and WarViews, ViewConflicts take conflict researchers as its main audience - it presents several conflict generating factors identified by peace and conflict researchers and puts conflicts into specialized categories. Borders and WarViews focus more on the general public, aiming to help a wider audience take advantage of the datasets by exploring the tools. For instance, Borders and WarViews can be used as supplementary assistance in conflict case studies or classroom demonstrations [10]. To

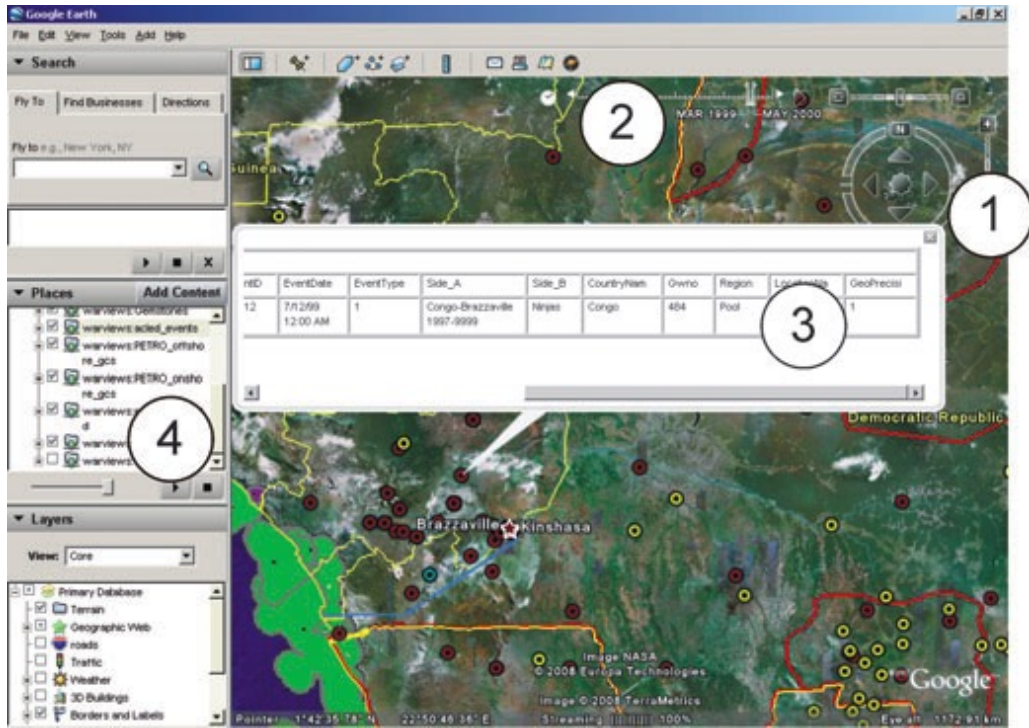


Figure 6.1: The WarViews interface [10].

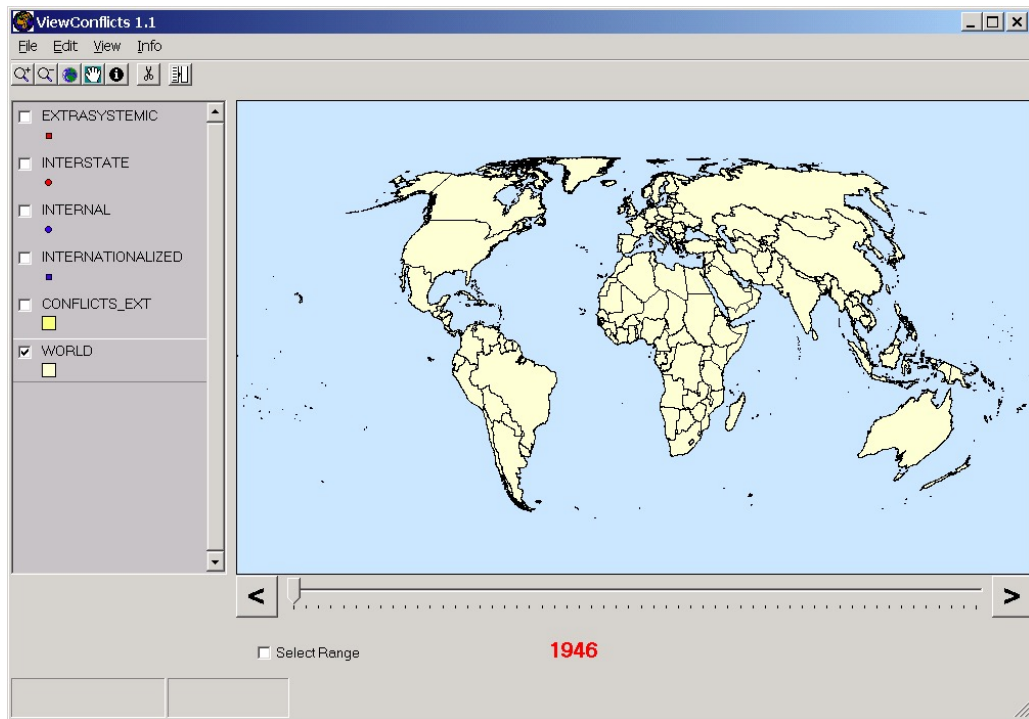


Figure 6.2: The ViewConflicts interface [11].

make the datasets understandable by the general public, both Borders and WarViews provide additional information in the visualization to its users. WarViews presents a supplementary information table on geographic data features such as event date, country name, and region name. However, information in the table are directly pulled out from the database without further interpretation. Different to WarViews, Borders present the country and date information in the timeline as well as using tooltip in the map. To help users better making sense of the border disputes, Borders provides a brief summary and some contextual cues, including Wiki pages, online news, and academic papers, about each border event in a context panel. By placing information in appropriate contexts, maps can enhance users' understanding of reality [14]. We believe the context presented in Borders can help users understand the origin and evolution of the events.

6.3 Visualization Design

Borders, WarViews, and ViewConflicts share some common features but have more differences at the same time in the design of visualization. We compare the three tools from the aspects of interface design, visualization of uncertainty, and contextual cues contained in the tools.

6.3.1 Interface Design

WarViews has a static and a dynamic version. In the presentation of maps, from the perspective of cartographic communication, it would be reasonable to limit graphic noise to those delineations not necessary to the communication of the message [14]. As shown in Figure 6.1, the dynamic version of WarViews keeps the geographic features and add visualization in a satellite map, which looks a little distracting when exploring the conflict in the map. ViewConflicts abandons the geographic features and gives the land a uniform color (Figure 6.2). Similarly, with the focus on presenting border disputes and exchanges, we diminish noise in Borders by using customized Google Maps and setting different universal colors to the land, borders, and water.

All the three tools have timelines that can be animated to show the change of the conflicts over time. The difference is that in both WarViews and

ViewConflicts, the timeline animation focuses on one single event, showing the evolution of conflicts in the area exactly where users move to, while in the timeline view of Borders, we present all border events in time order with switches between the timeline view and the detail view to show the border changes. The timeline view in Borders shows the border events worldwide instead of focusing on one. If users are interested in exploring one border dispute, Borders provide the detail view to show the changes in one disputed area. We offer more options to view the visualization based on the different purposes of users, aiming to better fit their needs in the exploration.

6.3.2 Visualization of Uncertainty

For the presentation of conflict and conflict area, WarViews and ViewConflicts both use points and polygons to mark and highlight the area. Borders also uses colored polygons to cover the disputed area and highlights borders of the area. One difference is Borders provide views from different countries on the disputed borders and area, since one purpose of Borders is to present the different view from different countries. We provide a country window in the detail view (Figure 4.3), where users can choose in which country's view they would like to see the disputed borders. Another difference between Borders and the other two tools is that we apply fluid visualization on the change of the disputed area (in both timeline view and switching view of countries) while WarViews and ViewConflicts don't present the transition of conflict area. We believe the transition of borders is important if we want to present the evolution of border disputes and changes over time, because it can intuitively show the previous layout and the new one with the transition.

6.3.3 Contextual Cues

As mentioned in the audience part, compared to WarViews and ViewConflicts, Borders provides summaries and more contextual cues of border-related events. Borders provides a brief summary and some contextual cues, including Wiki pages, online news, and academic papers, about each border event in a context panel. This can help users interpret the visualization and make sense of the border events in their exploration.

CHAPTER 7

AREAS OF IMPROVEMENT

Even though Border, WarViews, and ViewConflicts share a similar goal as to facilitate a better understanding of the origins and dynamics of the conflicts, we can see they focus on different datasets and provide different visualization effects. The contribution of Borders lies in three parts - the fluid visualization of border changes, smooth panning and zooming when the timeline is played, and the rich contextual cues.

With the aim to visualize the temporal changes in disputed borders, it's important to present the location of borders before and after some important time points in Borders. Even though the timeline is widely used in geographical visualization for the presentation of changes over time [10, 11, 3, 4], the changing process at one time point has been rarely presented. We highlight the process of this transition - the border moving from one side to the other side - using a fluid visualization method. The fluid transition of borders is also presented when users choose a different country in the country window. By presenting the transition process, we hope users can better figure out which country is getting more territory (in the timeline view) and how the border changes from one country's view to another country's view (in the country window).

When the timeline is played in Borders, smooth panning and zooming are applied when it moves from one disputed border location to another. This is to provide a better user experience in viewing the timeline animation by giving them more time to digest where the border event is located and on what granularity the affected territory is. Moreover, users can make sense of how the different disputed border are distributed in geographical space in the smooth transition. The smooth panning and zooming effect in Borders is derived from the Ken Burns effect in video production, and they enable the timeline view to present all the disputed borders worldwide instead of focus on only one in the animation.

Appropriate context placed in a map is important for communicating information to map viewers in cartography [14]. It is the same in geographical visualization. As a tool to help audiences facilitate a better understanding of the origins and dynamics of the disputed borders, Borders contains much contextual cues about each border-related event. The brief summary, links of Wiki pages, and online news support the further exploration and learning of the users.

While Borders have features that compose a better presentation of border changes, there are still improvements for the tool. Some border disputes, such as the Crimea one and the Morocco one, are presented by open borders instead of closed borders in our tool. This is because these border disputes were detected as open borders in Google and Bing Maps. In Borders, disputed territory is not highlighted for such border disputes with open border. However, it may cause the inconvenience that users need to infer the land in dispute from an open border, which is not intuitive for them. We plan to figure out a way to close the borders and make the border transitions consistent across all disputes in our tool. Moreover, we are using prestored images for zooming effect in Borders, so currently it's not very adaptable to different screen size.

For future work, we plan to fix the problems discussed above. We will also interview experts on geographic information systems, cartography, and map-related foreign policy and get their feedback on Borders. We also plan to conduct user studies with the general public to assess the usability of Borders. There are many territorial disputes and exchanges in the world. For now, only five of them are displayed in Borders. We plan to look through the Wiki page of territorial disputes [34] and select some major ones to present in our tool.

CHAPTER 8

CONCLUSION

In this paper, we present Borders, a tool to help the general public explore and facilitate a better understanding of the origins and evolution of disputed borders. We propose a fluid visualization method with smooth zooming and panning effect to display temporal changes in disputed borders. Contextual cues are integrated in Borders to support further exploration of the causes and evolution of the border-related events. We compare Borders with another two tools, WarViews and ViewConflicts, that visualize geographic data on conflicts, and discuss the contribution and areas of improvements of Borders. User studies will be conducted as future work to assess the usability of Borders.

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