VisCap: A Tool for Visualization of Chinese Ancient Capitals

Ellsworth Shi, Jingxian Li

University of British Columbia

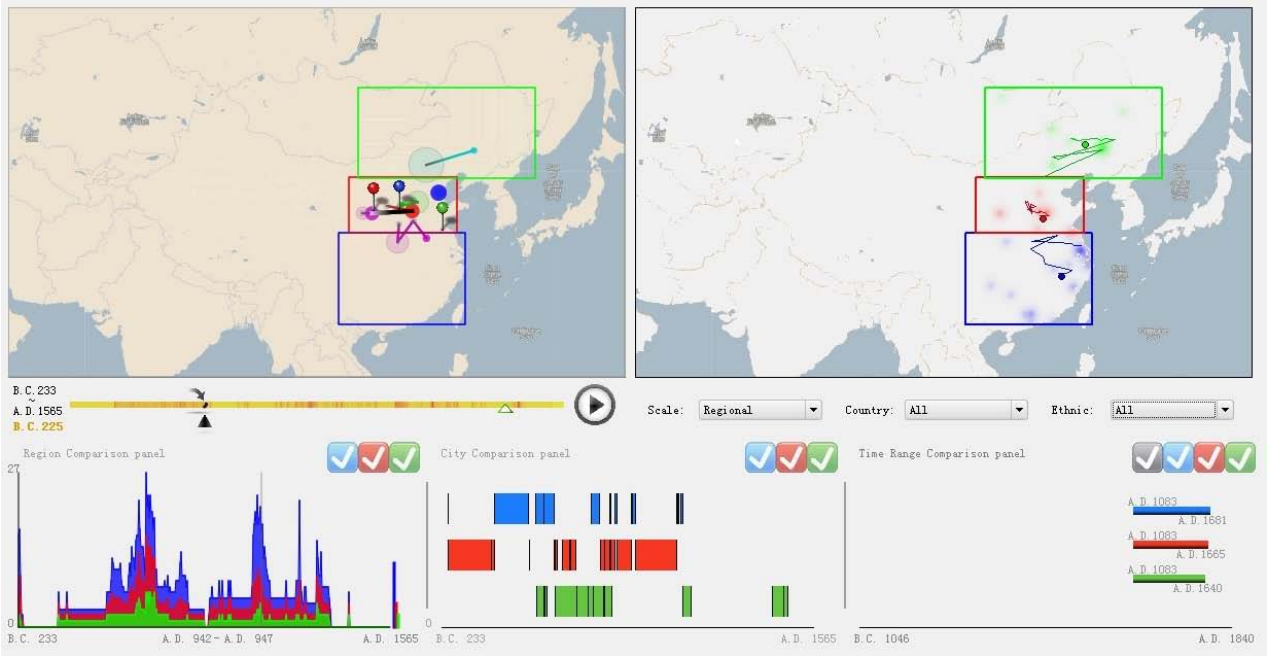


Figure 1: VisCap helps professionals as well as common users learning, discovering and having fun with Chinese ancient capitals.

ABSTRACT

VisCap is a tool for visualizing Chinese ancient capitals, a domain unexplored before that covers about three thousand years. Focused on both professionals and novices, different ways of exploration, including simple animation and advantage analysis tools are incorporated. Using information visualization techniques, various basic information, as well as underlying data relationships is displayed for users to perform potential tasks supported by the system. Multi-panel are utilized to represent data from different perspectives; different levels of comparison can be carried out, either geographical or temporal, to detect potential interesting patterns.

KEYWORDS: Geographical visualization, multi-panel, Chinese ancient capitals.

1 INTRODUCTION

China is well-known for its long national history. Different from western countries whose power of the kingdom was shared by the king and the nobles, almost all the aspects of the Chinese society, like politics, economics, education and culture were deeply controlled and influenced by the central government. Even when the whole country was split up into several small kingdoms that fought against each other, all hoping to unite the whole nation, the capitals of these kingdoms became regional centers, which are able to exert impact on the rest the territory they governed.

Because of this characteristic of centralization, it is interesting to analyze which cities were more likely to become the capital of the empire, while which were winners when the country was split up. Also it will help a lot for analyzing capitals according to different classification standards like its scope and the ethnic group. Besides information like how many years a certain city was chosen as a capital or how many capitals are there in a certain region, it is also important to obtain the pattern how the capital (thus the center) of the country moved from one region to another over thousands of years, or how the distribution of capitals during a certain time range looks like, and to link this pattern to various historical facts, which will help users better understand the history of China. The potential users will include not only professionals in this domains, but also general public who want to obtain a basic understanding of Chinese history.

The dataset to be visualized derives from the one in Wikipedia [1]. This decision involves several considerations. First, unlike professional articles or books that talking about details of when, where and how each dynasty chose cities as their capitals, this link gives a quick and concise summary of the target data. Second, dataset available on the web is always more easily accessible, allowing more users to use the application while still enabling them to refer to the traditional static tabular version for comparison or for details. Third, because history itself is objective and controversial, some of the original data is omitted or changed so that visualization can be carried out. However, by using this

dataset, we hope that to the largest degree in the future, we can always keep the dataset up-to-date by simply referring to the edit record of this web page, once historical evidence are available.

Now we are able to talk about the actual data that needs to be visualized. We collected a total of 244 entries from Wikipedia, covering about three thousand years, starting from 1046 B.C. to 1840 A.D. The justification for choosing 1046 B.C. as our start year is that it is the first year of Xizhou Dynasty, and we are not able to obtain complete and accurate data before this time point (some entries lack exact time, while others lack the today's location of the cities). 1840 A.D. is chosen as the end year because consensus has been reached in the community that this year separates Chinese history: starting from 1840 A.D., the modern China begins. From then on the governors may have different considerations regarding to the problem where to choose a capital, due to the development of transportation, military industry, etc. Also, the modern history involves more pending arguments, and we decide not to take this period into account.

Each entry contains following information:

a. Time period, including the start time and the end time;
b. Name of the capital (the capital of a kingdom may have different names in different time period even if the location of the capital didn't change);
c. Name of the kingdom (a kingdom may have different names in different time period);
d. Location of the capital, including latitude and longitude;
e. Ethnic group of the governor who established the kingdom;
f. Scope of the kingdom, whether it is national or regional;
g. The conqueror kingdom.

2 Related Work

The work domain of visualizing Chinese ancient capitals is a brand new topic for its special dataset. However, the information visualization techniques and encoding methods could draw lessons from several areas of academic work related to our project, which can be categorized into these 3 groups: historical data visualization, time-varying data visualization and geographical visualization. None of the previous work relative to these 3 areas could provide us with a complete solution for capitals visualization; however, it is important for us to learn historical data visualization methods, several effective ways to convey time-varying data and a few tips that we need to pay attention to.

History visualization, in itself, is pretty straight forward if only time-varying panel is provided. Using time slider to relocate the time point in the whole time range could help looking up historical data with the index of date or year. When the index of time fixes on a certain moment, what to visualize becomes a static problem. Not much related work has been done concerning fair history event data. Compare to that, there are some visualization work on how a product came into being, or showing the whole process of forming a company, such as Gamps [2] and Software [3].

The common ground for all these work is adding new staff and connects those parts into old main body. The assumption for these works is that no dramatic changes happen on patterns. In contrast, our project does have great differences when inquiring to vary time points, since kingdoms were always trying to conquer each other, making the pattern frequently change between united and divisive. Hence, we grabbed some ideas from Gamps and Software that using simple animation to highlight the appearance of new events. These ideas led our way to visualize capital moving and conquering by simple animation.

History Flow [4] presents an overview drawing to illustrate the development of Wikipedia pages. We can easily get the information about the increase number of edited pages in Wikipedia. The encoding method gives us an idea of how to visualize multi-value histogram without overlapping to each other. But, the trend illustrated by History Flow will not coincide with our dataset, since the number of capital cities will not increase as time passes.

Time-varying visualization expands several fields of research. Wolfgang Aigner [5] summarized many visual methods for analyzing time-oriented data. Cyclic graph could help to excavate periodical features those couldn't easily be seen by displaying data. Principle component-based analysis can be taken into account if we are trying to parse many attributes at the same time. Some more applications [6, 7] about time-series data processing could support pattern searching and lens filtering. To do these processing, we need to acquire complete data to construct exactly one quantity number at each time point. It can be a very good future work direction for our project if we can extract more derived data.

Some previous works of time-varying data try to improve the performance when rendering huge data [8], or how to generate high dimension rendering for time-varying data [9]. These works are related to optimization of displaying large amount of data, which is the technique far away from our work. Building a track [10] could help user to see the change even in a static view, which gives us inspiration to show capitals moving track and geometry center track. Gapminder [11] is a good example for us to learn, since it has clear data in one view and not many fantastic animations are shown, which is similar to our project. What is really interesting is its way of bringing us some information. Only by seeing those points changing location, we can figure out some meaningful phenomenon.

Geographical visualization is not quite the same as information visualization, however, the technique of drawing map can be learned from GeoVISTA [12]. It gives us inspiration on designing a good interface for geo-relative visualization, such as color encoding and panels synchronization.

3 Description of Solution

3.1 Visual encoding

Color encoding for capitals

Since the map background we choose is light color, as shown in Figure 2, we can choose many kinds of colors, except those of high saturation, for color encoding. Blue, red, green, cyan, yellow, purple, gray and pink are 8 categories for distinguishing capitals. The saturation is reduced to raise differentiation compared with background, for instance, if pure yellow has RGB of (255, 255, 0), we make yellow in our system as (200, 200, 0).

The reason why we choose 8 colors for displaying involves two considerations. One thing is to provide good ability of discrimination [13]. Human eyes could only tell the differences of colors when their RGBs differ in a certain degree. For example, people may feel hard to distinguish (255, 255, 255) compared with (230, 230, 230) and will regard both of them as white if these two patches are not adjacent to each other. When more colors appear at the same time, (240, 240, 240), (200, 200, 200) and (0, 0, 0) for instance, people will be easier to mix those two "white". In that case, there are not many choices for us to pick from if we want to make color encoding clear and tidy. Another thing comes to the fact of data itself, the situation of more than 8 capital cities

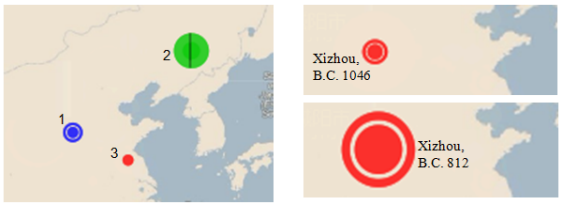
appear at the same time points is relatively few compare to the whole time range of dataset. 8 categories of color will work very well in most cases. For those special time points which involve more than 8 capitals, it is still easy for user to distinguish them by different locations and color encoding itself only aim at individual identification rather than grouping or clustering comparisons.

Figure 2: low saturation colour encoding for capitals

The strategy for picking colors for capitals is regarding 8 pigments as a pool. When a new capital shows up, it tries to pick and occupy one color that has not been picked by others. The dying out of a capital will release the color it picked. When 9th capital comes out, it should try to choose the repeated color which has been occupied for the longest time interval.

Ethnic group and capital scale encoding

In Chinese history, Han ethnic group is regarded as the mainstream of the race. Other ethnic groups are mainly derived from minorities and aboriginal tribes, whose people are more barbarous and uncultivated. A vertical line is drawn to indicate the ethnic property of this capital is minority; otherwise it is controlled by Han ethnic group. In Figure 3 (a), capital 2 is a capital in charged by minority, while capital 1 is hold by Han ethnic group. This encoding method can help discovering the territory balance changes between them as time varying.



(a)Ethnic and scale (b)Influence

Figure 3: Encoding methods for ethnic and influence

An outer ring is drawn outside the circle to illustrate its scale as a national country. Other countries whose capitals have no outer ring are regarded as regional country. As shown in Figure3 (a), capital 1 is a national capital, while capital 3 could only be regarded as a regional capital.

Influence

In this paper, we apply size encoding to show the influence of each capital. An assumption we make is that the influence (size) of each city will increase as time passes. The foundation for making that hypothesis is related to the general management model of each kingdom. A new born capital will try to strengthen their power by farming and enriching their army. The number of capitals showing up at the same time is also taken into account, since the overlap problem will disturb the user to see the events clearly. It is also logically understandable to reduce the influence of each capital when a bunch of kingdoms coexist and fight against each other. Logarithm shown in formula (1) is use to encode the size of circles.

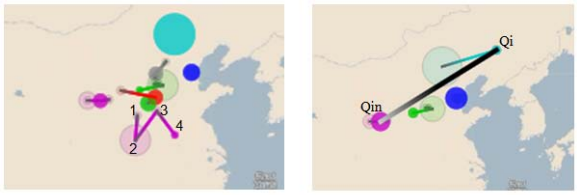
$$radius = base + \beta(\ln(\alpha AGE) / Num_{cap}) \quad (1)$$

In the above equation, *radius* is the circle size that helps drawing the capitals on the map; *base* is the basic size for each newly born capital, making sure every city could be easily seen from the map. *AGE* presents how many years one kingdom has existed. Num_{cap} means the number of capitals at this time point. α and β are coefficient for more adjustment.

Encoding method for moving track display

A track is supposed to convey the route that a capital city moves from one place to another. It should be able to transfer the location of old occupied one and current new one.

The key idea of showing moving track is a static graph combined with transparent effect for old occupied cities. In Figure 4 (a), it is clear to see that Chu has moved its capital three times, with the route of 1→2→3→4. The transparent old city could make user understand the direction of moving.



(a)Moving track (b)Conquering

Figure 4: Encoding methods for moving track and conquering

The size of the transparent old city indicates how long did the kingdom stay. As time passes, the size of old city will reduce, which means the reduction of influence of the old capital. Formula (2), calculates the size of abandoned city is similar to formula (1).

$$radius = \max\{peak - \beta(\ln(\alpha YEAR) / Num_{cap}), base\} \quad (2)$$

In the above equation, peak represents the size of circle when this city was abandoned. *YEAR* indicates how many years had this city been abandoned. *base* prevents the old city from being disappeared on the map.

Animation for conquering

In our system, simple animation has been applied to display the action of conquering. In Figure 4(b), the thick gradient black line is drawn from conqueror to the capital being conquered. The black line is used only when illustrating conquering; the moving track lines will never appear to be black since they are painted with their capital color, black excluded. A simple animation of 8 frames can simulate the action expressly, and user can easily catch the active and passive capitals. The static gradient line could also tell us the conquering relation, the gray end (Qin in picture) is the conqueror and the black end (Qi in picture) is the destructed kingdom.

Time slider encoding

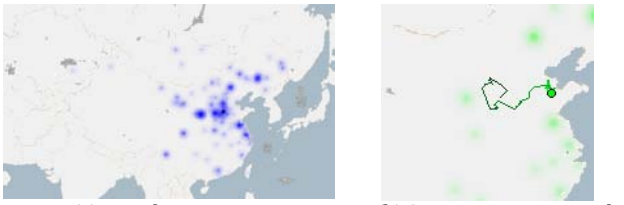
Normal time slider has nothing to do with color encoding; however, the time slider in our system is event-preferred and can show the importance of each time point, as shown in Figure 5. History, to some extent, is constructed by a large amount of events. Learning history is learning historical events and their

relationships. From this point of view, the time point when lots of events happened should gain more importance. In our system, the capital new born, moving, destruct and conquering are the events we should pay attention to. Our time slider is encoded with color ranges from yellow (not in high saturation) to red. Red indicates important years containing several events, while yellow represents years lacking incidents to focus.

Figure 5: A view of time slider

Distribution encoding

Distribution is a visualization method for presenting accumulated geographical data. In our system, distribution helps discovering the place or region where capitals are frequently built. To construct a good looking distribution map, we apply Gaussian distribution formula to draw each capital for accumulation. When time range is specified, all capitals in this range will be taken into account to draw accumulated distribution. In order to avoid different views caused by painting sequence, all the capital distribution of the same time range and same region are painted with the same color, such as red or blue. When a new capital is trying to accumulate to the distribution map, we draw a transparent and radial gradient circle with a certain radius. The distribution map is constructed by blending those transparent circles, as appeared in Figure 6 (a). The transparent rate of 0.12 is chosen for the center of each circle. Make the circle brink with transparent rate of 0 and gradually change the transparency according to 2D Gaussian distribution formula.



(a)Distribution map (b)Geometry center track

Figure 6: Capital distribution panel encoding

Geometry center track

Geometry center could be calculated for a specific distribution map. A small circle with a black boundary filled with the same color as the distribution points is used to locate the geometry center, see Figure 6 (b). The geometry center will move when time range translates, keeping the interval of the time range constant. In Figure 6 (b), the moving track of the geometry center is encoded by a polygonal line. And the track line will become darker when that line segment become older.

3.2 Info-VIS techniques

The interface of VisCap consists of 7 panels: main panel, capital distribution panel, time slider, filters, region comparison panel, city comparison panel and time range comparison panel. Main panel and capital distribution panel are both used as geographical display, region comparison panel and city comparison panel can function as 2D and 1D derived data display respectively, the three comparison panels provide several comparison mechanisms for user to better analyze the data. Time slider, filter, region compare panel and time range compare panel can be used to filter the data in the aspect of time range, location regions, scale and ethnics.

Main panel and time slider

These two panels can collaborate to inquire time point data and illustrate it by geographical map. As the pin of the time slider moves to a specific time point, the main panel will show static capital locations by different colored and sized circles. Each circle in the main panel could be chosen by clicking on the corresponding circle. When one capital city is clicked, the information of this capital such as the kingdom name, capital city name and its present geographical location will pop up and show in text, as show in Figure 7. This visualization method could give users freedom to learn which capitals appear at the same time and what is the relationship between them. This information is not easy to conclude just from the text books.

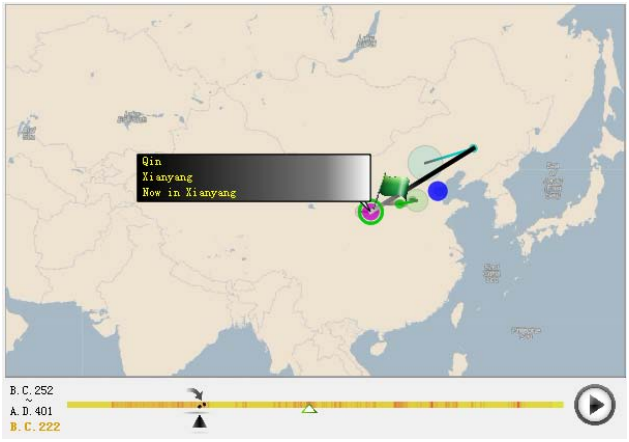


Figure 7: Time point inquiry for main panel

At each time point, simple animation in the main panel will also be triggered if there is any event to be highlighted.

The time slider could change between two modes, one is the one-pin mode, shown in Figure 5, aiming at time point inquiring. Another mode, appears in Figure 7, called time range mode, helps inquiring time range and playing a short movie for the given time range. User can switch these two modes by dragging the green triangle pin in or out of the slider. The short movie playing for a given time range can be regarded as a sequential inquiry of the time points in the time range. The upper arrow gives the label of current time point when playing, and the playing will automatically slow down the pace when it currently goes through a high event density time point (colored in red). The playing will never jump to the next year before the animation of current year is finished, and user can arbitrarily pause at any interesting time point or restart the playing by right click on the play button. When it is playing, the two pins for time range are immovable. User can translate the two pins at the same time (keep the same time interval) by slide the left pin. The right pin can move between the left pin and the end year of dataset to change the length of the time range.

Region comparison panel

There exist two functions indeed when operating region comparison panel. One is shrinking the dataset geographically for further analysis according to the dragged rectangle in the main panel. Another function is comparing at most three different regions' histogram with x-axis covering all the time in the time range given by time slider. Figure 8 gives a screenshot of region comparison panel; the histogram is multi-value and accumulated to avoid mutual overlapping. The height of the histogram represents the number count of capital cities in picked region in a short time interval. This accumulated histogram is hard for comparing some really close numbers. However, to give more

convenience for comparison, our system provides the comparison based on the same baseline for three regions at the right part of the histogram when cursor moves to the time where it needs the detailed comparison.

Time slider can use two pins to zoom or translate the histogram, since the left and right time boundaries are corresponding to the time range set by time slider.

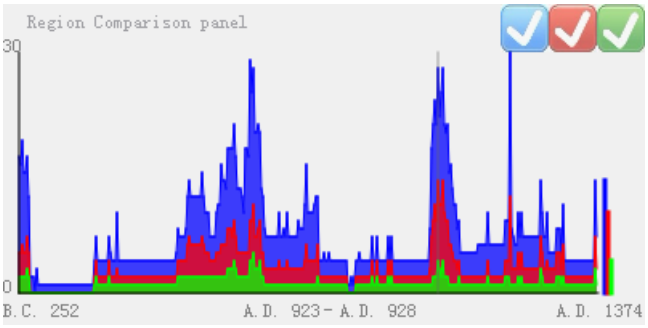


Figure 8: Region Comparison panel with histogram

City comparison panel

This panel is similar to the region comparison panel, because it can also zoom and translate according to the time slider. The differences are that the 3 objects for comparison are cities that picked from the main panel. This panel could help analyzing the occupied time line for each city, which means we can view at what time the city we choose is constructed as a capital and what kingdom or dynasty chose it, as shown in Figure 9. The time line could also used to compare and analyze why so many kingdom choose one city as capital in some specific time period but not other times.

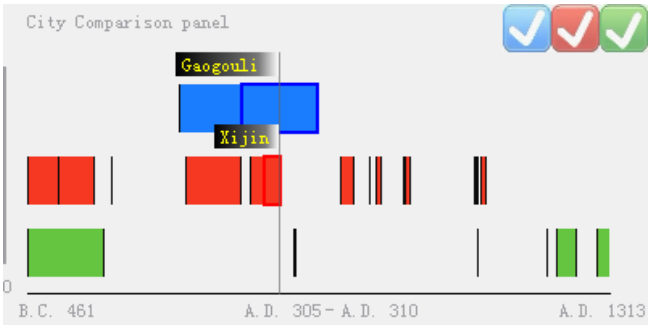


Figure 9: City comparison panel with occupied time line

Time range comparison panel and capital distribution panel

Capital distribution panel is responsible for distribution displaying. The time range specified in time slider will generate a distribution map in capital distribution panel for the whole Chinese region. Time range comparison panel provides with up to three freely defined time range, each time range will generate a distribution in capital distribution panel and they can be compared with the distribution map generated by the time slider (the yellow bar at the bottom shows the time range chosen by time slider, as shown in Figure 10, and not movable in time range comparison panel). The difference for these 3 time range compared with the time range defined by time slider is that these distributions take region rectangle into account, which means that if the user drags a rectangle to shrink the data into one special region, the time range of corresponding color will only draw the distribution and geometry center for that specific region.

Each time range bar in the panel can be resize by dragging the end node and translate by dragging the body of the bar. Dragging on the empty place in the panel will translate all three time range bars at the same time. To build the geometry track, user only need to translate the time ranges bar by dragging from old time to new time points. Each formed distribution can be hided or shown by clicking the button on the right-above.

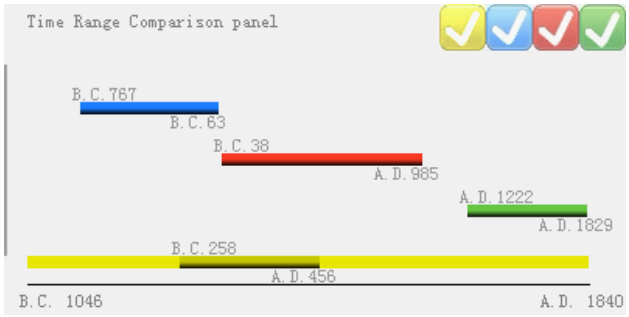


Figure 10: Time range comparison panel view

Filters

Three comboboxes are provided for users to filter dataset. The *scale* combobox could filter out regional and national capitals, the country one can choose one kingdom and view all the capital cities it built as white circles in the main panel. Ethnic could help filtering out different ethnic groups and see very interesting distribution map for each of them.

Panel synchronization

To achieve good interface, the synchronization of all the panels and components is critically important. The 7 components in our interface response closely to each other. As time slider changes its time range, all the panels except filters will response to that: the main panel will jump to a new time point, the capital distribution panel will display a new map, the region comparison panel and city comparison panel will zoom or translate, and the yellow time range in time range comparison panel will vary. Besides, filters will re-domain the dataset for all the panels to display and process. Interesting time points found in comparison panel could be chosen in that panel, then the time slider will jump to that time point and the main panel can display what happened at that year. Time range bar changed in time range comparison panel will immediately lead to an update of distribution map.

4 MEDIUM-LEVEL IMPLEMENTATION

Qt is a cross-platform application framework that is widely used for developing application software with a graphical user interface (GUI) with APIs for C++ programming. It can be regarded as a widget toolkit for building user interface, however, it can be also understand as a purely C++ framework, compared to D3 or preVis, in the aspect of visualization programming.

The rendering of each panel and encoded staff is finished in *paintEvent()* by drawing basic shapes such as lines and circles. This provides us with high freedom of design, since we can make any strange shape or glyph for encoding if we want! Qt is good at its mechanism of SIGNAL and SLOT, which helps sending and receiving signals and values easily between any two widgets built in our program.

In brief summary, no vis-toolkit is applied to develop our interface system and no previous feature we have built upon. Only C++ framework is used.

5 RESULTS AND SCENARIO OF USE

In this section, we explore possible scenarios of use by elaborating necessary manipulation of different panels. Also, we present some interesting results we found, either coinciding with our existing knowledge or uncovering some surprising facts about Chinese ancient history.

Comparison of capital densities between different regions

Both geographically and culturally, China can be divided into several regions, each of which has its unique landscape and culture. Today most people might have a rough idea which regions were once home to many kingdoms' capitals, while which regions were not so popular from the perspective of suitable for being chosen as a capital. Now with VisCap, the task of comparison of capital densities between different regions becomes easy by utilizing both the Main Panel and the Region Comparison Panel.

First, select a type of color by clicking on the square buttons on the right up corner of the Regional Comparison Panel. Once it is clicked, the main panel is ready to receive the user's command that specifies an interested region, which is denoted by a rectangle in the selected color. When the rectangle is specified, number of capitals at different time point is displayed in the region comparison panel (Figure 11), with horizontal axis representing time and vertical axis representing the number of capitals in that region. In region comparison panel, the time point (range) represented by the location where the cursor hovers is highlighted with a vertical line, with detailed time information displayed in the center under the horizontal time axis (Figure 11 (b)). At the same time, the number of capitals in each selected region is displayed again separately at the rightmost side of the panel, which makes it easier to compare accurate number of capitals in different regions when multiple regions are specified (Figure 12).

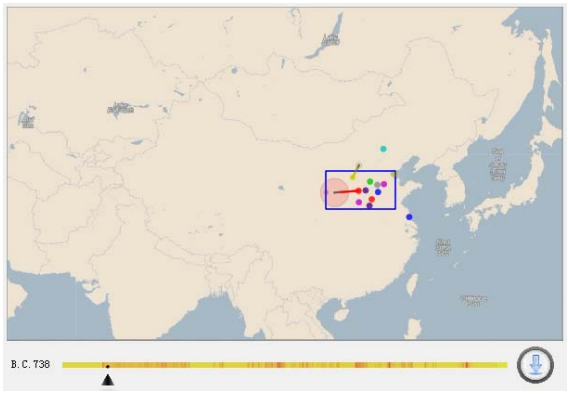


Figure 11 (a): Selecting Huabei area to see its capital densities

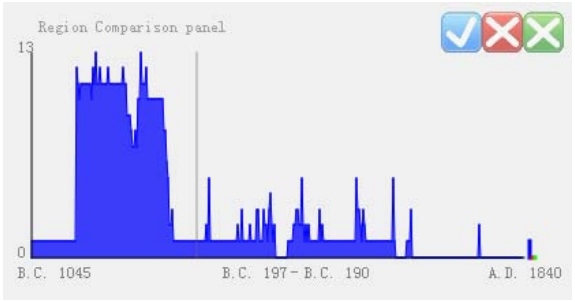


Figure 11(b): Number of capitals of Huabei Area

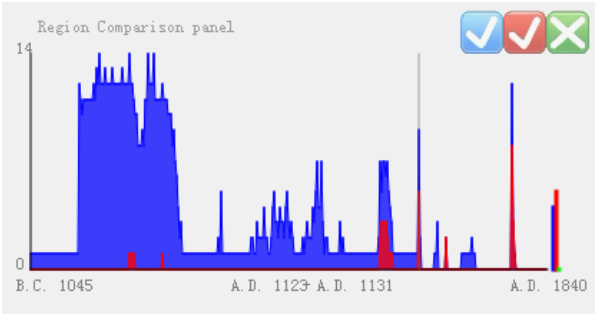


Figure 12: Comparison of number of capitals between two regions

A selection of highlighted time point (range) by left-clicking the vertical line results in a jump of the time pointer in the time slider from the previous time point to the one selected in the regional comparison panel. Since the number of years represented in the default time range exceeds the number of pixels contained in the region comparison panel, one pixel may represent more than one year. For example, in Figure 11 (b) one pixel represents a time range of eight years. If more precise distribution pattern is required, the second time pointer in the time slider can be used to define a particular time range. In Figure 13, the time range selected in the time slider starts from 560 B.C. to 481 A.D, and the time range displayed in the region comparison panel changed accordingly. This time, the time range selected in the region comparison panel reduced to 4 years.

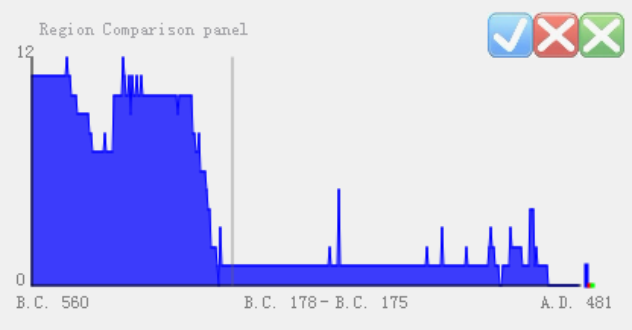


Figure 13: Zoom-in of time range

Using the method described above, we select three regions for comparison (see Figure 14). The first one, denoted by the blue rectangle, roughly covers the Huabei area today. The second one represented in the red rectangle is the vast south part of China. The last one, displayed in green, is the west part covering even larger area. From Figure 14, understandable results are obtained. Huabei area (blue), the cradle of Chinese civilization, is popular over thousands of years, with numerous kingdoms setting their capitals in this area, believing it was a good place to govern a prosperous country. Though the area of the red rectangle is much larger than that of the blue one, much less capitals are found in the south part of China, most of which appears after 1000 A.D. (the Song Dynasty), exactly the time when the economic center of the country started moving from north to south. Last but not the least, the vast are of west of China, made up of the world's highest plateau and the world's second largest desert, is the forbidden zone for life. This area only has one capital through the range of about three thousand years. Clicking on the highlighted vertical line, the main panel displayed the time range when that capital appears. Further details show it is the capital of Xiliao, which lasted only two years.

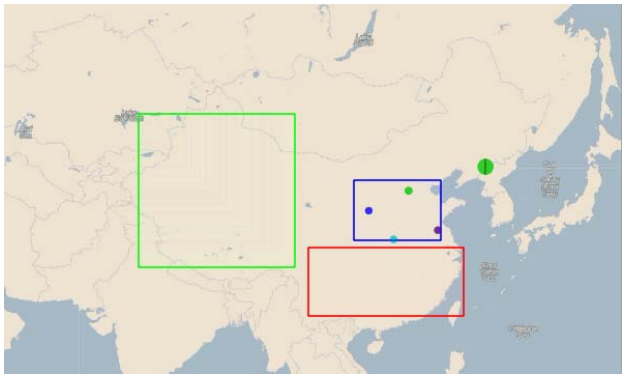


Figure 14 (a): Selection of three different areas for comparison of capital densities

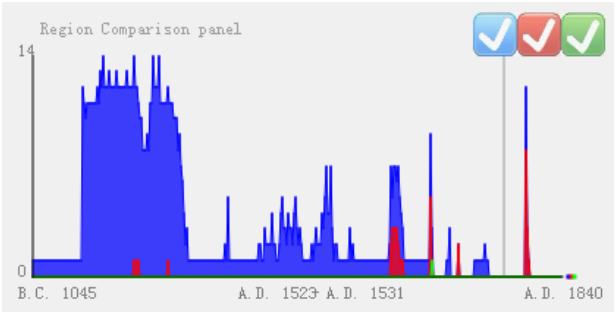


Figure 14 (b): Number of capitals in three regions shown in 14 (a)

Comparison of time ranges of being a capital between different cities

It is always a hot topic in history community, as well as for common Chinese people to compare different ancient cities and give various of rankings, for example which cities had the longest time once being a capital. We support this task by providing city comparison panel, which not only helps analyzing the how long a city being a capital, but also displays the time distribution. Through this, comparison of different cities, especially their time range and distribution pattern becomes extremely easy.

By selecting different colors in the city comparison panel and corresponding cities in the main panel, the time ranges during which each city was a capital are displayed using bars. For ease of reference, the selected cities are shown with a pin sticking on the map. Just as in the region comparison panel, detailed time range will be displayed at the same place once the mouse hovers on the corresponding location. Also, the whole time range can be adjusted dynamically with two time pointer in the time slider. The time range is divided into smaller segment according to different kingdoms. If the mouse hovers over at a time range when selected cities were capitals, information of the kingdom will be displayed (Figure 15 (b)).

In Figure 15 (a), three most famous ancient capitals, Xi'an, Luoyang and Beijing are selected, with the former two located in the central part of China, and the last one in the north. Figure 15 (b) shows the time range distribution of three cities when they were capitals. First, we find that all the three cities have a very long time being a capital, although the time range is not continuous. Then with a closer look at the distribution pattern, it is interesting to find that the pattern of Beijing (green) contrasts greatly with those of the rest. The time range of Beijing mainly covers the two ends, while for Xi'an and Luoyang the middle part is occupied. Beijing, located far north, is not a safe place because it could be easily under siege by nomads from the north. After around 1000 A.D. it became capitals because it is nomads who built these kingdoms. And after that, the Great Wall was built to defend against attack, which made Beijing an ideal place for capital from then on.

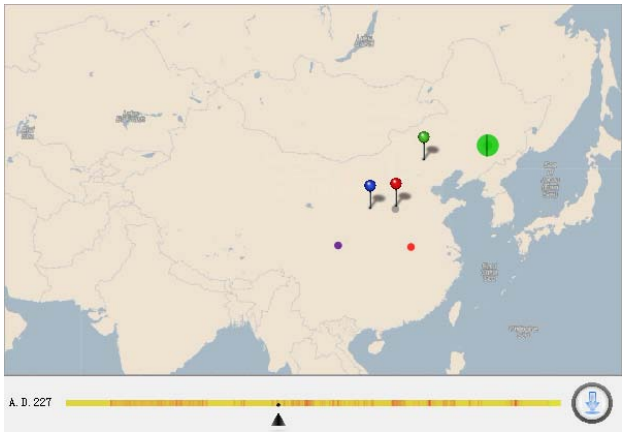


Figure 15 (a): Selection of three cities

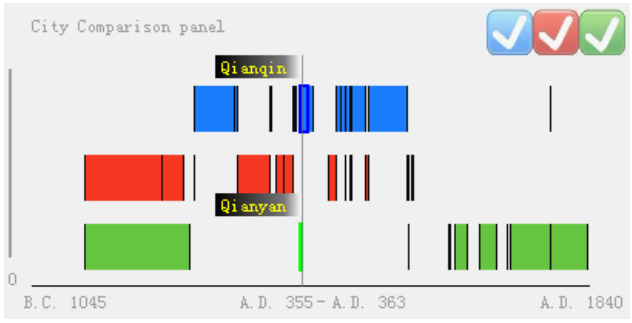


Figure 15 (b): Time ranges of three cities as being a capital

Comparison of capital accumulative distributions between different time ranges

Sometimes, it is helpful to get an understanding of the distribution patterns of capitals during different time range. This is important because it helps users find out how the civilization spread across the whole country, and ties the distribution pattern with historical facts. It is widely agreed that Chinese civilization mainly starts from Huabei area, where the land is suitable for cultivation because of the Yellow river. Then as time passed by, the civilization started spreading from the center to the surrounding area, farther and farther away.

The time range comparison panel makes the above task efficient and effective. In this panel, three time ranges at most, represented by three colored bars, can be enabled. By moving bars' endpoints or the whole bars, the time ranges represented can be easily changed. The capital distributions during each time range are displayed in the distribution panel with corresponding colors. By enabling or disabling each time range, a more clear representation of distributions can be obtained. The location of a small circle with same hue but higher saturation is calculated to denote the center of gravity of all the capitals of corresponding color (Figure 16 (b)).

In the following example, three time ranges, all of which last about 600 hundred years, are selected, with blue bar representing time range from 816 B.C. to 218 B.C., red for range from 43 A.D.

to 641 A.D., and green for range from 1116 A.D. to 1714 A.D. (See Figure 16 (a)). This results in the accumulative distribution of capitals shown as in Figure 16 (b). By enabling only one time range, a more clear representation can be obtained in Figure 17. This set of figures nicely show how the civilization spread across the whole country as time passed by. During the first time range, all the capitals form a cluster at the Huabei area. While at that time, the rest part of China was considered to be dangerous: land had not been reclaimed and people were uncivilized. During the second time range, the situation became a little different. The distribution of capitals became more scattered, especially for the north area where a lot of new dots appeared. Many historians call this period “national migration and integration period”, when lots of pastoral nomads in the north started wars for more lands from Kingdoms built by the Han ethnic group. From wars and other types of communication, the nomads learned lots of techniques related to agricultural and ways to govern a civilized country, and they started building their own countries in the north. The last figure significantly differs from the former two. Dots being even more scattered are observed, especially for the south part of the country. Just as stated previously, around 1000 A.D., the economic center of the country moved from north to south, where huge economic prosperous of southern China was witnessed. This may explain the reason why from then on many capitals appeared in the south.

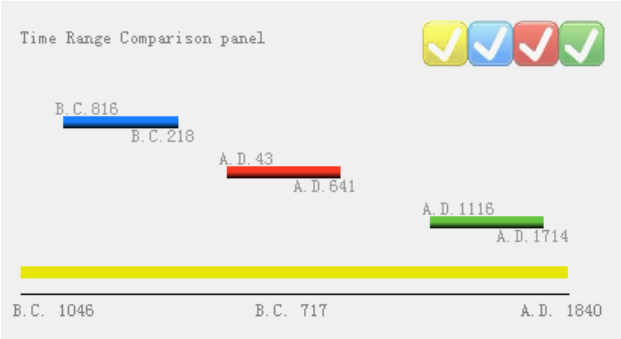


Figure 16 (a): Specifying three time ranges

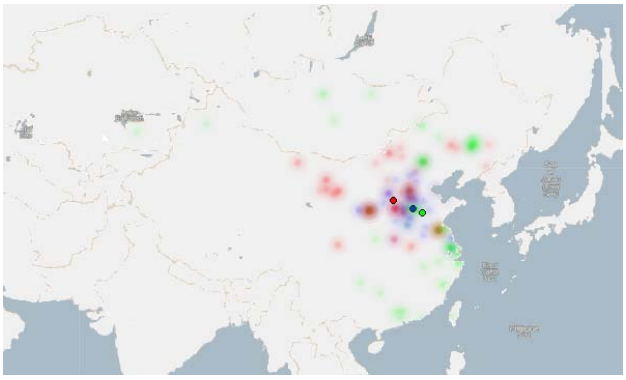


Figure 17 (a): Capital accumulative distribution during three time ranges shown in 17 (q)

Exploration of center of gravity of capital distributions between different regions

In history community, it is an important topic how the center of China moves over nearly three thousand of years. The center of a country moves due to a lot of reasons, the most important ones being climate changes, natural disaster, economical and cultural development, etc. By using visualizing techniques, we hope it will be easier to find out any potential pattern and see if our finding is identical to the current research results.

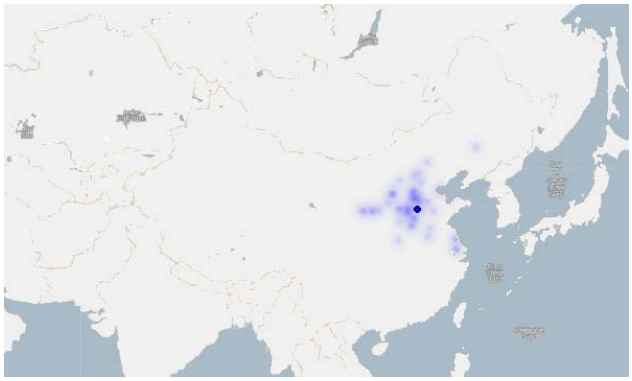


Figure 17 (a): Accumulative distribution, 816 B.C. ~ 218 B.C.

Figure 17 (b): Accumulative distribution, 43 A.D.~641 A.D.

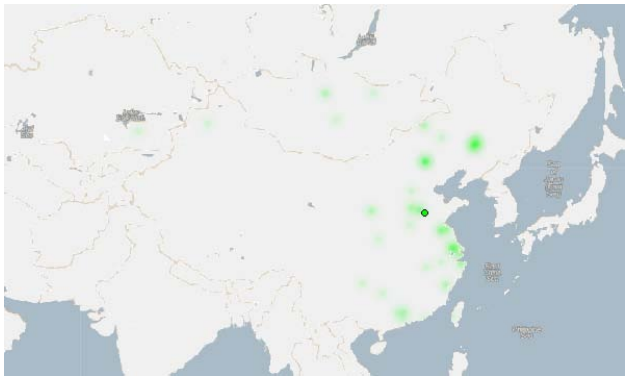


Figure 17 (c): Accumulative distribution, 1116 A.D.~1714 A.D.

First, the length of the time range needs to be decided. If the length is too long, then more capitals will be included, leading to a more stable center of gravity; if otherwise, the center becomes sensitive towards single capital’s appearing or disappearing. An empirical length range between 300 and 600 works fine in our case. Figure 18 shows how the center of gravity of capitals moves in about three thousand years, which confirms previous research results.

We admit that this task is not perfectly supported, mostly because what data we use and how we interpret it. From most historians’ point of view, only kingdoms that lasted a long time or exerted great impact on the history of China can be considered. Yet in our case, all the kingdoms are considered, no matter which ethnic group the emperor of the kingdom belonged to, whether they

governed the whole China or their territory was just a city, whether they lasted several hundred years or just a few months. We did consider assigning different weights to different kingdom, but how to calculate the weights is hard to determine due to lack of sufficient domain knowledge and also tends to be subjective, which exceeds the scope of this project.

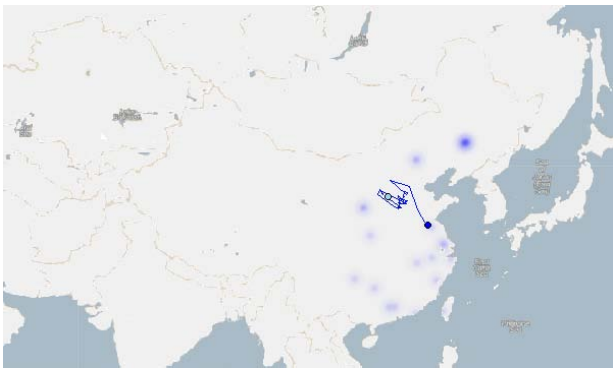


Figure 18: Moving of gravity of capitals

How a kingdom moves its capital?

Kingdom's moving a capital is less intuitive when using traditional static image interfaces because users lack direct information of for how long each city was its capital. By utilizing visualization techniques, this task becomes much easier. Selecting a country from the filter toolbar, all its capitals will appear on the main panel, colored with white. This static image (Figure 19 (a)) provides a general overview of which cities did the kingdom choose as its capitals. For the more detailed process, a short animation could be used to dynamically display how it moves its capital, in what sequences, and how much time each city was the capital of this kingdom. The moving track is maintained to help users further analyze the process (Figure 19 (b)). In this example, the Nansong dynasty is selected and all its capitals are displayed. The ancestor of Nansong kingdom is Beisong Kingdom, which was conquered by Jin Kingdom, normads from the north east China. The royal family fled to the south and builds a new government, hoping to regain the lost land by a counterattack. Unfortunately, the dream never realized, and as the nomads attacked to the south step by step, the Nandong kingdom had to move its capital again and again.

While generally animation is considered not suitable for information visualization, we still decide to use it because it provides an efficient and intuitive way to perform this task, especially for novices who only need a general picture of how the process happens.

Population distribution of different ethnic group

For a long time China is a country maintaining high level of ethnic diversity. A lot of research work tries to analyze how different ethnic groups, especially the Han ethnic group, which is the major group, and other ethnic minority groups communicate with and learn from each other. Here we help the users comparing the distributions of countries built by Han ethnic group and by ethnic minority groups. Select the whole time range, and select "Han" and "Ethnic minorities" in the Ethnic filter, two figures appear respectively (Figure 20 (a) and Figure 20 (b)). From them, it is obvious that the distribution patterns between these two types of countries are different. On the whole, capitals of countries built by Han ethnic group were in the east, south and central part of China, while capitals of countries built by ethnic minorities group were located in the north, west and central, which reveal the fact that most of the ethnic minorities group building countries were nomads from north. Of course, it is always possible to display the distribution patterns of capitals of any particular ethnic group.

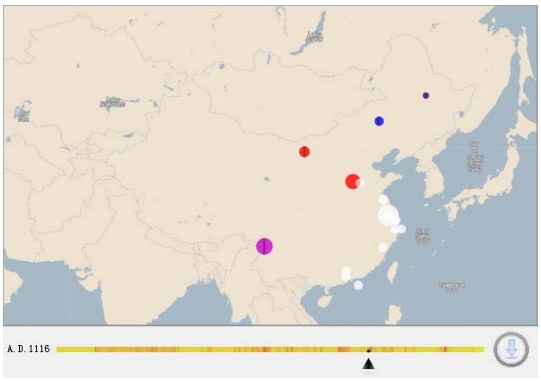


Figure 19 (a): Nansong's capitals

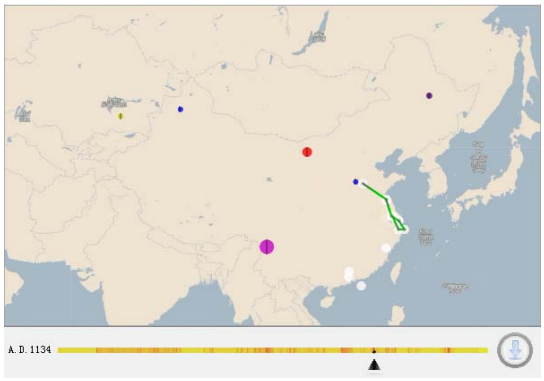


Figure 19 (b): Track of Nansong moving its capital

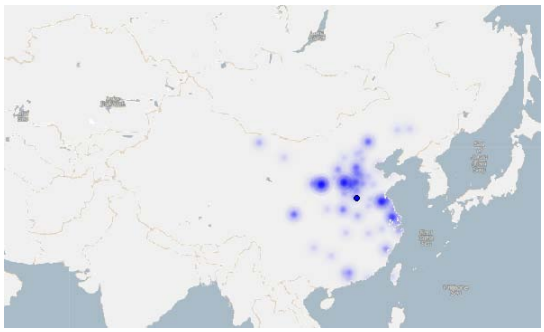


Figure 20 (a): Distribution of capitals of Han ethnic group

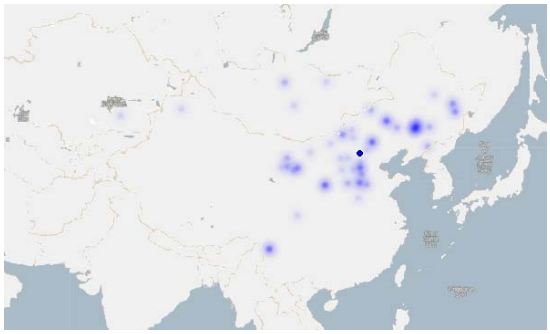


Figure 20 (b): Distribution of capitals of ethnic minority group

6 DISCUSSION AND FUTURE WORK

Strength

To our best knowledge, VisCap is the first information visualization application targeting at the domain of Chinese ancient capitals. And we are glad that now there is a tool for users to know more about China, an ancient country that has several thousand years of magnificent history.

We defined various useful tasks that are essential when learning Chinese history, most of which are closely tied to what the community and even common people are interested in. We define the potential users to be not only professionals, who may need advantage exploration methods of the given data, but also common users who know little about Chinese history and just want a quick grasp of general idea.

By using visualization techniques, some basic information can be obtained instantly or by very convenient interaction. Both geographical information as well as some statistics exploration methods is provided to help users foster a comprehensive understanding of what they are interested in. More importantly, different panels are extensively correlated to show the same piece of information from different perspective, helping users taking different angles to explore the data. Last but not the least, the tool we use gives us lots of flexibility towards how to encode the data and how to define way of interaction, because Qt allows designers to draw everything using basic geometric shapes like lines and dots, etc. From classical HCI point of view, all the interaction methods fully utilize positive transfer (transforming timeline, selecting regions, etc) to assist users with a quick-start. Instant feedback (showing time and vertical line when the cursor hovers over the region comparison panel and city comparison panel) is generated to better provide details necessary during the exploration.

On one hand, the system supports confirmation of existing discovery in an efficient way, because the interface is not complicated and there are not so many widgets to play with. While on the other hand, it does an excellent job helping users discovering new properties or patterns. In the last week, both of us have discovered a lot of interesting facts. For example, when playing with the city comparison panel, we are extremely surprised that, two famous ancient capitals, Luoyang and Xi'an didn't share a single year when two different countries chose them as their capitals respectively, which probably due to the fact that the two cities are so close to each other that it is not possible for two countries to occupy them, one for each respectively. And it is not likely for text books to cover these details. We really enjoy this "explore-surprise-analyze-confirm" pattern of learning.

Weakness

The system presented in this paper has involved with color blind problem, which can be checked [14] by uploading the screenshot of the interface. The main problem for the color blind is unable to distinguish between red and green. They will regard the red, orange, yellow and green as "Yellow" color, and cyan, blue and purple as "Blue" color. Thus, change the green into gray color will help the color blind to distinguish among "Yellow", "Blue" and "Black/white". However, we cannot make 8 clearly different colors for capital identification, and that would be the common problem for those visualization tools using many colors.

The track of capital city moving will appear unclear when a kingdom moved its capital from one to another and moved back. Some capitals even moved nowhere but just changed the name. For these cases, our system by now hasn't put forward a good algorithm to draw a clear moving pass, since some moving routes of the capital are too complex to encode even by applying self-referenced curve.

For the current edition of our interface, some functions for analyzing derived data are not released, which makes our interface not powerful enough. The problem like "which places are the good choices for capitals" could be analyzed according to the frequency of been conquered and the average life time. Several other imagines could be good choices for future work if we can fetch more data, such as commerce with foreign countries.

Lessons learned

Visualization is a process, not an end. Most of the time, even designers are not exactly sure what the data will look like in the final system and what possible interaction methods are useful for exploring potential relationships and patterns. If comparing with our proposal, one may find that some of the design choices are changed. As we gained more and more knowledge about the domain, task and data, some new design choices kept coming up. Sometimes we didn't know if the data does follow certain patterns before building the module, which might be risky, but I believe this might be the way how interesting discoveries are found in information visualization projects.

It might be better if some design details, such as what colors to choose in order to pass the color-blindness test, are settled down in the early design stage. Choosing several colors and continuing design, hoping to solve these detailed problems after all the functions are built is not a good idea, because we found ourselves keeping adding new functions and did not have any time again for carefully considering this problem.

Future work

First, there are still some small bugs in the system and we'd like to fix them in the first place. Also current color solution needs to be carefully considered not only to pass the color-blindness test, but also to provide a more appropriate visual encoding choices and appealing interface.

About the data, we still haven't incorporated the ancestor relationship due to that we've already running out of colors. Besides, the problem whether different weight should be assigned to different capitals needs to be carefully thought about. If the solution is yes, then what should be considered when calculating the weight? Whether a city is a nation capital? How long does the kingdom exist? What else?

About the task, currently the region comparison panel supports selecting rectangular regions. We also believe that supporting selection and comparison of regions corresponding to today's provinces is helpful. What's more, both of the maps in the main panel and the capital comparison panel cannot be zoomed in or out. We think of this functionality as an important one because by zoom-in the visual occlusion problem could be easily solved.

Last but not the least, we are still hoping to get the system accessible by the public so that more people can try it by themselves and explore what they are interested in.

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