

An Interactive Visualization Platform for Macao

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Abstract: More and more people are interested in learning more information about Macao, a small city blended with Eastern and Western cultures. Although various types of data are available on the Internet, people still need to spend a lot of time for obtaining a holistic view of Macao. In this paper, we propose and develop an interactive visualization platform for Macao, aiming to reduce the time spent on searching information and to understand the historical events easily and interactively. The proposed interactive visualization platform can show the change of the land boundary of Macao from 1912 to the present time, the population histogram and the corresponding historical events of Macao, along an interactive non-uniform discrete timeline. The users can also add historical events to the platform, making it not only interactive but also extendable. For education in history, the platform can help students to understand the history of Macao easily because it is more interesting and interactive. For museums, the platform can be used to attract the visitors' attentions and to enhance their engagements by showing the land boundary in a visualized way and the history of Macao interactively. In addition, tourists can quickly understand the rapid change of Macao and learn more about the history of Macao interactively.

1. Introduction

More and more people around the world are interested in learning more information about Macao, a small city with a blend of Eastern and Western culture, since its rapid economic growth and development for the past fifteen years, which results from the booming of the gaming industry [1]. From 1912 to the present, the land area of Macao has gone through a huge change, going from 11.6 square kilometers in 1912 to approximately 30.8 square kilometers, while the population has grown from 83,984 in 1910 to 648,500 in 2018 [2]. Although various types of data are available on the government website, for example [2] and [3] and the Internet [4], people still need to spend a lot of time for obtaining a holistic view of Macao. It would be convenient to have an interactive visualization platform to help the interested visitors and local residents to obtain this holistic information, including the land area, key historical events and other statistical data of Macao. This platform can also be a useful tool for students, teachers, tourists, history researchers and even museum technician to understand and study the history of Macao.

In this paper, we have the following objectives: (i) design and implement an interactive visualization platform showing the change of land boundary and the key historical events along a timeline; (ii) design and implement the data model for storing the user accounts and historical events; (iii) provide a histogram to show the population of Macao from 1912 to 2017 and (iv) allow authorized users to edit and add events and statistical data to the interactive visualization platform.

There are different kind of techniques and tools available for visualizing data interactively. In [5], heat map and color are used to illustrate the trends and contrast of the progressive change of the leaves interactively, which can also be used to determine when the peak fall foliage occurs around the U.S.. The heat map and color are shown through a dynamic website using tools like Data-Driven Documents (D3.js) and GeoJSON [6], in which the users can visualize the change of the leaves at different times of the year by adjusting a timeline [7][8] located under the heat map. In [9], the authors illustrated interactively one of the most important events in the U.S. history: the Battle

of Gettysburg. The users can select the historical events at the pre-defined discrete times along the vertical timeline on the left of the map showing the battle field. The website uses the mapping and analytics platform ArcGIS to collect the real-time information of map from the satellites. Although ArcGIS is good for interactive visualization, it only creates some graphics on the map, making the map not very flexible and artistic for our objectives.

Macao Yearbook is a comprehensive chronicle of Macao [3], which shows the information of Macao on a mobile device, in a static and non-interactive way. It shows different types of information of Macao separately, such as the land area, population and weather, etc.. It does not have a capability to link different data together. This is our main motivation of developing the interactive visualization platform proposed in this paper. The static land boundary of Macao can be found on D.S.C.C. (Direcção dos Serviços de Cartografia e Cadastro) of Macao [10], this map shows the land boundary of Macao from 1912 to present in a static way using a specific color to represent the land area at a specific year, as shown in Fig. 1. Although it has all information about the land boundary of Macao, users cannot easily find the specified map they want. For example, users need to first refer a table listing the land areas in different years to find the corresponding color and then visualize the land area from the *integrated* map. This is not convenient. The ultimate goal of our proposed platform is to provide an application platform for showing the history of Macao visually and interactively so that the user can have a holistic view of Macao in a more convenient way. Moreover, the platform can let the users not only view the information interactively but also add the information to the platform.

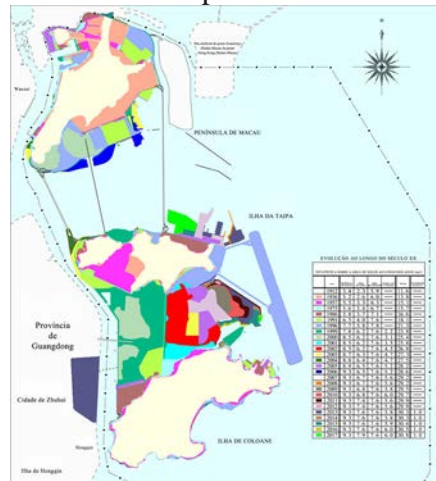


Fig. 1. Land Boundary of Macao from 1912 to 2017 [9]

The remaining of the paper is organized as follows: Section II provides the overall system architecture of the platform, followed by the design approaches of the proposed platform. Implementation results and discussions are provided in Section IV. Finally, conclusions are drawn in Section V.

2. Overall System Architecture

Fig. 2 illustrates the overall system architecture for the proposed interactive visualization platform, which is mainly divided into the Crawling of Data, Server Side and Client Side. Scrapy (an open source and collaborative framework for extracting the data from the websites) is used to extract the data related to Macao for importing into the database using Structured Query Language (SQL). When the client request to read the data, the server will convert the data to Javascript Object Notation (JSON) format and then input to the client side, which will use D3.js and AJAX to list the data to the Web Browser. Also, user can post (or add) new data to the server. For example, the user can add historical event to the platform in Admin (Authorized User) mode. The map of Macao in GeoJSON format can also be imported to the platform for the Client Side.

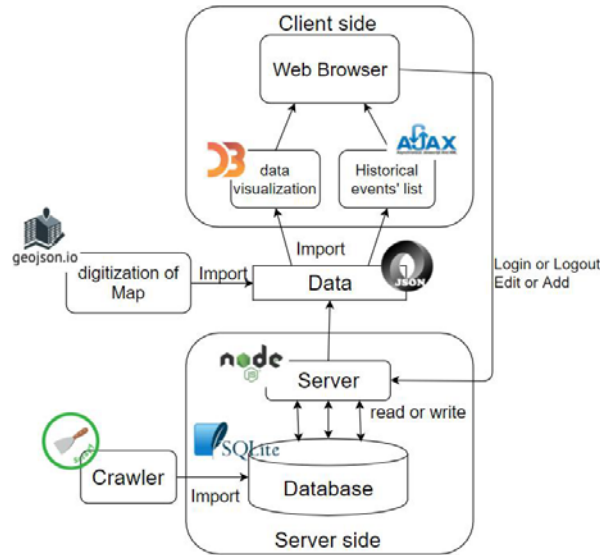


Fig. 2. System Architecture

The Server Side includes a server and a database. Node.js uses V8 engine, an open-source JavaScript engine developed by the Chromium Project for Google Chrome and Chromium web browsers. The V8 engine can increase the rate of interpreting JavaScript. Thus, Node.js handles the reading and writing between the clients and the database. SQLite 3 is used due to its I/O performance and easy to use.

When the users use the platform, the Client Side will download the coordinates of land boundary of Macao in GeoJSON format. Then, the digitization of map module draws the land boundary of Macao using D3.js. The AJAX module will read the data in JSON format and list the historical events in the Web Browser. Moreover, the users can not only read the information from the Server Side, but also add and edit the historical events or data stored in the Server Side. When the users submit the edited data through the platform, the browser converts the data to JSON format and sends to the Server Side.

3. Design Approaches

The key design approaches include the digitization of the maps, the adding of historical events to the Server Side, the use of discrete timeline for interactive visualization, data modeling and the design of auto play.

3.1 Digitization of Map

Most of the old maps of Macao are not available in digital format. Fig. 3 shows the process of digitizing a map. The digitization of the map can be done by first manually pointing out the intended coordinates on the map, such as the Google Map, and then the file containing the coordinates can be converted to GeoJSON format using the GeoJSON.io platform. Finally, the file is imported to D3.js to convert this data to the map in digital format.

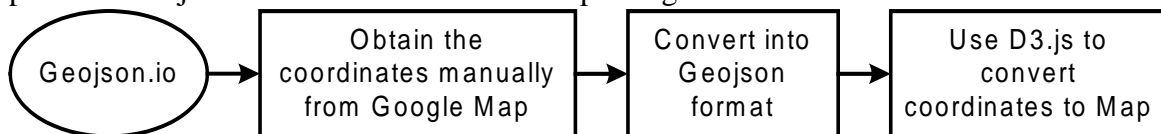


Fig. 3. Process for the Digitization of a Map

3.2 Adding of Historical Events

To make the platform self-extendable, it is desire to have the capability to add the historical events to the platform by the authorized users. Fig. 4 shows the flow of adding a historical event to the server. One of the required feature of the proposed platform is for the authorized user to add

event to the platform, making the platform more interactively and extendable. Furthermore, the added historical event is stored first in a temporary table, which will be stored in the database after the approval of an authorized user.

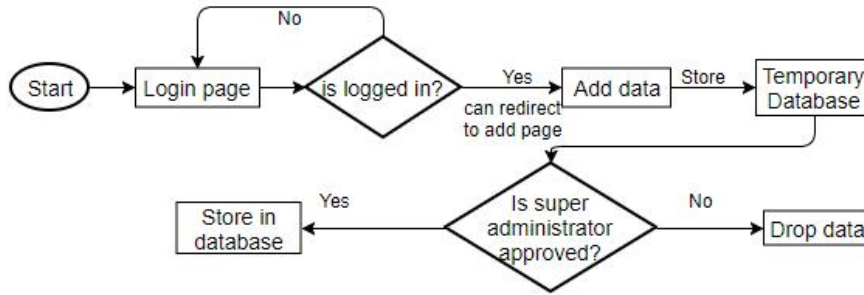


Fig. 4. Flow of Adding of Historical Events

3.3 Interactive Visualziation

A non-uniform discrete timeline is used to control the viewing of the land boundary and related historical events. The use of discrete timeline results from the availability of the data for the land boundary. When the user selects a particular time at the timeline, the platform will display the land boundary of Macao in the corresponding time, the population and the corresponding key historical events. In addition, users can click the name of selected historical events for more details about the events and the histogram of population to redirect to the government website for the source data. This not only provides interaction between users and the platform, but also provides a holistic view of Macao for the users to link different types of information.

3.4 Data Modeling

Three tables for Account, Customer, Register and History are used for the database design. They are primarily used to record the historical events and keeps the users' account information. The History Table records the related information and detail description of historical event, including the date and location of the event. When the users edit the existing historical events, new contents are stored in Register table in order to avoid overwriting the existing information. The entity relationship is that one account can only have one user's information and multiple edited record of history. One account can add or edit multiple historical events.

3.5 Design of Auto Play

The platform also provides the function of Auto Play (Animation) Mode, which can show the change of land boundary and the corresponding series of historical events in pre-defined times. This functionality can be useful for users without prior knowledge of Macao and want to have a quick overview. Fig. 5 shows the design of Auto Play mode. When the timeline arrives at a discrete point, the map area will show the land boundary in the corresponding discrete time. The timeline moves to the next discrete year at a fixed speed. The speed of Auto Play can be also adjusted to generate animation to tell a story about Macao, with proper interpolation in between different years.

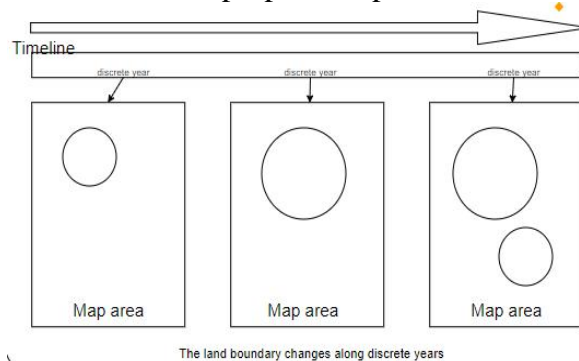


Fig. 5. Design of Auto Play (Animation) Mode

4. Implementation Results and Discussions

4.1 Implementation Results

Fig. 6 shows the interface design of the proposed interactive visualization platform. It consists of the Header, Map area, Histogram area, Content area and Historical Event List and a timeline. Map area has three modes, namely Interactive Mode, Animation Mode and Full Map mode. The information for the land boundary, population, and key historical event can be visualized by the users in a single page. This is convenient for the user to have a holistic view of Macao. When the platform is in the Full Map mode, it shows the map at the present time, the histogram of the population and the list of all historical events in the current year.

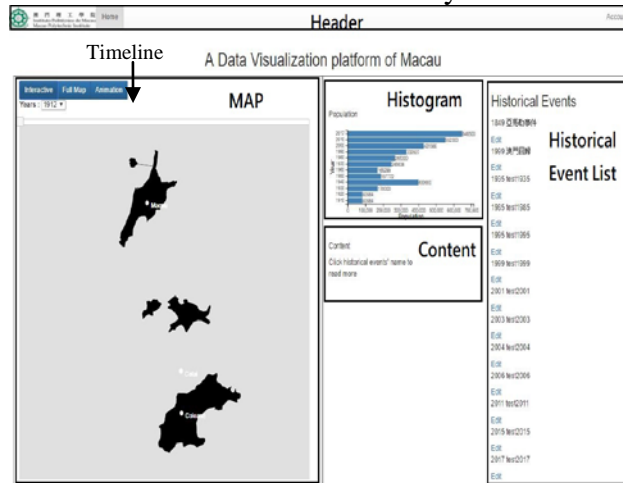


Fig. 6. Interface Design of the Platform

When the platform is in the Interactive mode, the map initially shows the land boundary in 1912 and added a timeline and a dropdown list showing the available years for selection. Fig. 7 (a) shows the land boundary in 1912 and Fig. 7 (b) shows the land boundary in 2000 after moving the timeline button to the year of 2000. When the platform is in the Animation (or Auto Play) mode, the map in the Map area will automatically change the land boundary from 1912 to 2017 at a fixed time interval. Moreover, the map can be enlarged and reset to its original size.

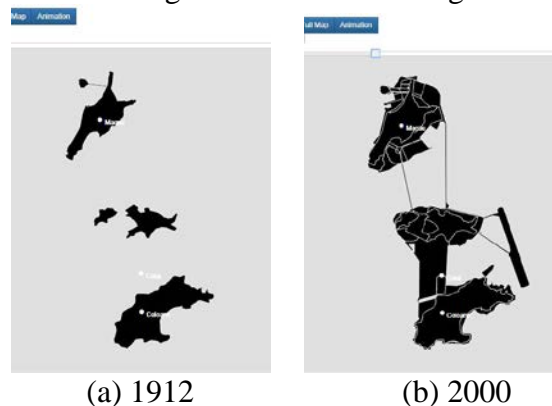
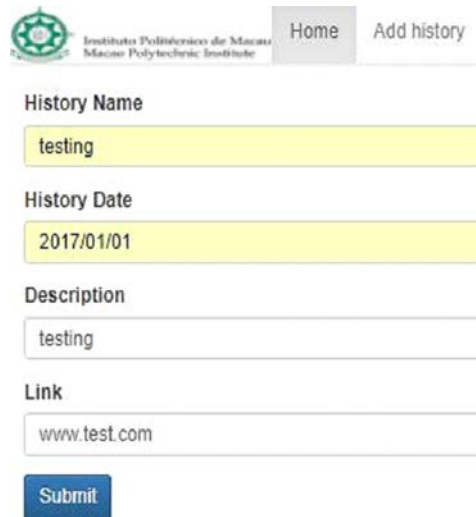


Fig. 7. (a) Land Boundary in 1912 and (b) Land Boundary in 2000

Fig. 8 shows an example of adding a historical event to the platform, including the title, date and the source of the event. After a normal user adds and edits the historical events in the platform, the contents must be first approved by the Administrator (or authorized user) before importing into the database. Administrator can cancel and approve the adding of the historical events. This feature is unique and convenient for authorized non-technical users to update the content of the platform without requiring modifying the implementation of the platform.



The screenshot shows the top navigation bar of the Macao Polytechnic Institute website, featuring the institute's logo and the text 'Instituto Politécnico de Macau' and 'Macao Polytechnic Institute'. To the right are links for 'Home' and 'Add history'. Below the navigation bar is a form titled 'History Name' with a text input field containing 'testing'. Below this is a 'History Date' field with a date input field containing '2017/01/01'. The 'Description' field contains 'testing'. The 'Link' field contains 'www.test.com'. At the bottom of the form is a blue 'Submit' button.

Fig. 8. Adding of Historical Events to the Platform

4.2 Discussions

This platform can collect data for Macao automatically from different web pages and utilizes D3.js to convert the data to the platform. It provides useful tools for history education, museums and tourism. For history education, students can be better engaged in learning the history of Macao using this platform because it is interesting and interactive. For museums, the platform can be used in the museum to visualize the land boundary and history of Macao interactively, which can enhance the visitors' interests in understanding the history of Macao. In addition, tourists can quickly understand the rapid change and learn more about the history of Macao using this platform.

There is no similar application or platform developed for Macao. The Government of Macao only shows the static data for the land boundary, population and scattered historical events. This platform has a user-friendly interface, and organized information about Macao. People can easily find the information they want in a visualized way and interactively.

There are still some improvements for the platform. The main issue is the lack of accurate data for the maps at the early years, especially for the maps before the digital age. The accurate coordinates of the past and the present land boundary is not available on the government website or the Internet. Perhaps a sound effect can also be added to the platform for attracting the users' attention, especially for young learners. Of course, we can always improve the background design by changing the backgrounds according to the years of interest.

5. Conclusions and further works

An interactive visualization platform for Macao has been developed and implemented. A data model has been implemented to store the historical events. On the interactive aspect, a timeline has been used to control the land boundary and list of historical events according discrete times. In addition, authorized users can add and edit events stored in this platform. A population histogram is also added in the platform to show the growing of population in Macao for the past century. Finally, the platform has a simple and user-friendly interface, aiming for convenience from different categories of users. The platform can be used to enhance students' engagement in history education and the promotion of Macao tourism. The main limitation is the data available for drawing accurate land boundary of the map for the early years.

For further works, the accuracy of land boundary of Macao can be improved and sound effects can be added. Moreover, the animation for the change of land boundary can also be improved, for example using interpolation techniques for smoothing the transitions between non-uniform discrete time intervals. Finally, the interface can be modified to have a better artistic view.

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