Research on Georeferencing Platforms for Historical Maps in Overseas Libraries and Their Implications for Localization: Postprint

Authors: Wang Zhiying, Tan Miao, Dai Mengfei

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Abstract

[Purpose/Significance] Historical maps hold a pivotal position in humanities and historical research; however, constrained by their image representation format and the uncertainty of textual annotations, they pose certain obstacles and difficulties for both researchers and collecting institutions responsible for indexing and cataloguing in practical reference and usage.

[Methods/Process] This study examines well-developed case studies of historical map georeferencing platforms in overseas libraries from multiple perspectives, analyzing their operational models, technological applications, and other characteristics, compares them with the status of existing domestic related projects, and summarizes insights and recommendations for the localized development of georeferencing projects.

[Results/Conclusion] Focusing on the historical map collection of Shanghai Library, this paper explores a georeferencing platform model suitable for the local context, aiming to enhance user experience and efficiency of document utilization while conducting digitization of historical documents through the construction of a georeferencing platform.

Full Text

Preamble

Research on Geo-Reference Platforms for Historical Maps in Overseas Libraries and Localization Implications

Wang Zhiying, Tan Miao, Dai Mengfei

Shanghai Library, Shanghai Institute of Scientific and Technical Information, Shanghai 200031

Abstract: [Purpose/Significance] Historical maps hold a pivotal position in humanities and historical research. However, due to their image-based format and the uncertainty of textual annotations, they present obstacles and difficulties for both researchers and collection units responsible for indexing and cataloging. [Method/Process] This paper examines mature overseas library geo-reference platforms for historical maps from multiple perspectives, analyzing their operational models and technological applications, and compares them with existing domestic projects to derive insights and recommendations for local development. [Result/Conclusion] Taking Shanghai Library's historical map collection as a case study, this paper explores a locally applicable geo-reference platform model, aiming to enhance the user experience and efficiency of historical documents through geo-referencing platform construction alongside digitization efforts.

Keywords: geo-reference platform; digitization of ancient maps; crowdsourcing; localization

Maps represent one of humanity's most important inventions over thousands of years, enabling us to better comprehend and understand the world. As primary source materials for humanities research, ancient maps reflect both history and the development of cartographic technology. The advent of the information age in the 21st century, coupled with increased computing power, has provided the conditions for map digitization and incorporated the digitization of ancient maps into the historical collection digitization processes led primarily by libraries.

Given that historical map documents span extensive time periods, geographical features may have changed through historical transformations. Moreover, a substantial portion of historical maps depict local geographic locations, making identification difficult without clear textual explanations. This underscores the significance of establishing geo-reference platforms specifically for historical maps—enabling researchers to search and browse historical maps of the same geographic location through real-world coordinates on contemporary maps, while also allowing classification by specific historical periods to facilitate regional historical research. Around 2010, numerous libraries and institutions overseas launched geo-reference projects for historical maps, with representative examples including the British Library's Georeferencer, the New York Public Library's MapWarper, and the National Library of Scotland's Scotland's Places. Currently, dozens of similar historical map geo-reference platforms exist overseas. In contrast, domestic platforms remain relatively few due to later start times and the particularities of the Chinese language. Furthermore, while mature crowdsourcing systems are widely employed in overseas library geo-reference platforms, various obstacles have emerged in their practical implementation domestically. Academic research on historical map geo-reference systems is predominantly distributed overseas, with scarce domestic research 成果, revealing a significant gap worthy of investigation and 填补. Therefore, this paper aims to analyze and summarize the developmental experiences and advantages of overseas geo-reference platforms to explore models suitable for local historical map digitization.

2 Definition and Significance of Historical Map Geo-Referencing

2.1 Definition of Geo-Referencing

Geo-referencing (also called "georegistration") refers to the process of associating the internal coordinate system of a map or aerial photograph with a geographic coordinate ground system. The most obvious effect of geo-referencing is the display of ground coordinates (such as latitude/longitude or UTM coordinates), enabling the measurement of ground distances and areas. In other words, geo-referencing means linking something to a location in physical space. The term is commonly used in the field of Geographic Information Systems to describe the process of associating physical maps or raster images of maps with spatial locations. Geo-referencing technology can be applied to any kind of object or structure related to geographic locations, such as points of interest, roads, places, bridges, or buildings [1].

2.2 Historical Map Geo-Referencing Models

Geo-referencing work for historical maps differs from traditional modern map technology. To achieve cross-comparison and even overlay between historical and contemporary maps, historical map images must be assigned spatial information to align them with real-world geographic locations. The basic process typically involves adding control points with real-world locations to historical maps; once sufficient control points are established, the historical map can be transformed to align with geographic reality. Today, most geo-referencing work for historical maps uses standard GIS programs, including commercial software such as ArcGIS, MapInfo, and Global Mapper, as well as open-source software like QGIS, GRASS, GDAL, MapRectifier, or MapWinGIS [2], with few employing customized applications.

2.3 Significance of Public Libraries Establishing Historical Map Geo-Reference Platforms

As scientific institutions responsible for collecting, organizing, preserving, disseminating, and providing access to documents, public libraries bear the function of protecting human cultural heritage and developing intellectual resources. Digitizing historical map collections and building geo-reference platforms accessible to readers can enhance public libraries' capacity to preserve urban history and collective memory. Through geo-referencing, early maps can be visualized through more efficient interfaces. Old maps can be integrated with Google Maps, Google Earth, and related web mapping applications with which users are familiar. It may also allow historical maps to be transmitted to other websites using open standards such as the Open Geospatial Consortium's Web Map Service (WMS) or WMTS protocols. Furthermore, through digital mosaicking and the linking of individual map sheets, stitched versions of paper maps can be transmitted to other applications.

Historical map geo-reference platforms can provide readers with better and more efficient research models through enhanced retrieval and user experiences. For example, platforms support direct comparison of historical maps with other georeferenced maps, enabling multiple maps to be displayed side-by-side simultaneously, while historical maps can also be overlaid on modern satellite imagery for comparison with contemporary maps. For public libraries, historical map geo-reference platforms enable institutions like libraries and archives to form historical map collections at relatively low cost using geo-referencing technology, thereby improving resource accessibility and discoverability. Compared to previously single scanned maps, the advantages of geo-reference platforms are considerable, offering greater public appeal and professionalism. As internet technology continues to develop and network users become increasingly accustomed to mainstream online mapping tools, integrating historical map collections into geo-reference platforms aligns with digital humanities research trends.

3 Research on Overseas Library Geo-Reference Project Platforms

Given the heavy workload involved in geo-referencing historical maps, which often includes crowdsourcing or multiple proofreading processes, most existing historical map geo-reference platforms worldwide are long-term projects built by national or public libraries. The British Library's Georeferencer was initially established in 2011, while the New York Public Library's MapWarper and the National Library of Scotland's Scotland's Places were founded around the same period. These projects have accumulated substantial practical experience since their launch. The three projects each have distinctive features in platform architecture, functional forms, and operational schemes, resulting in different platform effects and user experiences.

In terms of operational methods, although all three projects planned to implement crowdsourcing schemes at their inception, Georeferencer has more fully leveraged the advantages of crowdsourced collaboration, achieving relatively high completion rates. This paper selects the strengths demonstrated in each project's practice and analyzes them from three dimensions—project operation methods, platform technology presentation, and linking of different collection categories—combined with practical results and application scenarios to derive insights.

3.1 Application of Crowdsourcing Models in Geo-Reference Projects: The Georeferencer Example

The British Library's Georeferencer project began collaborating with Klokan Technologies in 2011 to customize its online geo-referencing tool for crowdsourcing the geo-referencing of its scanned historical maps. Completed and reviewed old maps are integrated into the Old Maps Online platform built by Klokan

Technologies, which supports location and era-based retrieval, enabling cross-reference between old and new maps and their simultaneous presentation on a single map. The Georeferencer collection includes various maps published between the 16th and 20th centuries, including first-edition Chas E. Goad Co. fire insurance plans providing detailed information about buildings, land use, and urban design in early 20th-century Britain and Ireland; two atlases concerning British involvement in the American Civil War and World War I; and a series of transportation-themed maps (automobile, railway, and aviation) primarily comprising topographic and military maps, with coverage expanded to other parts of the world rather than limited to a single region.

The British Library's success lies in its full utilization of new media promotion channels to ensure crowdsourcing participation and enthusiasm. The concept of crowdsourcing was first proposed by J. Howe in Wired magazine in June 2006 [3], and since then, the foreign library community has extensively introduced crowdsourcing models into library construction. Practice has shown that crowdsourcing can improve resource utilization, enrich collections, reduce library manpower burdens, expand the scope of collaborative construction and sharing, and enhance resource discoverability. Georeferencer is time-consuming and labor-intensive, and also requires participants to have certain map observation skills and language proficiency—since the old maps and illustrations being compared involve different languages, and old map symbols are difficult to decipher, making it challenging to establish control points on Google Maps. This makes the project challenging for users, which is an important factor in motivating genuine enthusiasts to participate, while also expanding the project's scope worldwide rather than limiting it to Britain.

The British Library publishes crowdsourcing tasks on the globally renowned image-sharing website Flickr to attract a broad user base to participate in the project. The project motivates participation through contribution rankings and features real-time progress bars on the project webpage, allowing participants to see the impact of their contributions and encouraging further participation. As of August 19, 2020, project progress had reached 95%, with 53,145 maps having been geo-referenced.

3.2 Old-New Map Overlay Comparison: The MapWarper Example

The MapWarper project was initiated in 2010 by a geospatial information librarian at the New York Public Library in collaboration with the geographic data analysis company Topomancy. The project aims to provide geo-referencing services for images or maps to match them with real-world map coordinates. All project data is open-source. Currently, the New York Public Library, Harvard University, Stanford University, the Leiden Archives, and other libraries and institutions are users of the MapWarper project [4].

The project covers detailed records of New York and New Jersey's urban layout, buildings, and internal structures from 1852-1922 collected by the New

York Public Library, with special inclusion of approximately 1,000 maps of East Coast American cities (16th-19th centuries) and 700 topographic maps of the Austro-Hungarian Empire (1877-1914 [Figure 1914: see original paper]). The project applies the "rubber sheeting" method (also called "warping") in GIS to georectify original maps, aligning pixels in historical maps with precise latitude and longitude on modern virtual maps to refit them into new base maps [5]. Users must then crop out borders and other non-map information from old map pages and overlay the maps into composite layers (layering). These layers constitute new library resources that can be freely downloaded and browsed in programs like Google Earth or Quantum GIS.

Compared to other historical map geo-reference platforms, the New York Public Library's MapWarper is one of the more successful projects in authentically reproducing old maps on modern maps for two main reasons: First, through outsourced collaboration with Topomancy, it not only improved the efficiency of geographic data analysis but also ensured the professionalism and accuracy of data analysis. Second, the project goes beyond simple digital scanning of original maps by leveraging interdisciplinary collaboration to deeply excavate and digitize map information. For New York City maps, these "features" include prison boundaries, landmarks, hydrological information, building footprints, addresses, and anything conveyed through text, color coding, or other symbols on the maps [6].

To date, the New York Public Library has completed digitization of thousands of historical maps and, with funding from the National Endowment for the Humanities (NEH), created the "NYC Chronology of Place" to record place names and other historical geospatial information. Through this project, readers can quickly understand the changing landscape of New York City during specific historical periods through simple searches.

3.3 Multi-Type Document Regional Linking: The Scotland's Places Example

Scotland's Places is a free historical map retrieval platform jointly provided by three institutions: Historic Environment Scotland (HES, formerly the Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS), merged into HES in 2015), the National Records of Scotland (NRS, formerly NAS, renamed in 2017), and the National Library of Scotland (NLS). By searching place names, clicking on maps, or entering postal codes, users can browse thousands of records about Scotland. Search results aggregate collections from all three institutions, helping users easily find maps, photographs, and written records of selected locations. The project initially launched in October 2009 using records from RCAHMS and NAS, and by December 2010, had merged 18,000 map records and images from NLS.

The platform uses a unified XML data standard to achieve metadata linking between different institutions. By connecting place names with modern maps,

historical maps, and documents, it provides diachronic and 溯源 map services. Scotland's Places aggregates survey maps, administrative division maps, geographic maps, property maps, urban planning maps, and other categories from 1843-1960, offering list-based retrieval, place name retrieval by county/parish, and postal code search. In practical use, search results can provide both list view and map view, with results displayed as pins on modern maps to achieve intuitive comparison between history and reality. Since Scotland's Places is a geo-reference platform covering all of Scotland, it makes very detailed divisions of historical county/parish names, allowing historical and modern maps to be displayed simultaneously on the same screen for user comparison.

Compared to other historical map geo-reference platforms, Scotland's Places is characterized by linking multiple document types rather than being limited to single document types related to old maps, providing researchers with richer research materials while also completing digital classification work for other documents like manuscripts through geo-tagging. Historical maps rarely exist in isolation but rather as components of regional historical and cultural research. Once a system structured by geographic information is formed, it creates conditions for subsequent linking and filling of other document types, better supporting humanities research. Regarding this special function, the platform originally planned to open crowdsourcing projects for historical maps and manuscript documents, but according to a 2018 official announcement, the project has been delayed and has not yet resumed.

3.4 Summary of Overseas Public Library Geo-Reference Project Experience

From the three overseas public library cases above, we can summarize the respective advantages of national libraries or public libraries in building historical map geo-reference platforms. In terms of operation methods, the British Library's Georeferencer project demonstrates that crowdsourcing, as an emerging approach, has gained practical affirmation and become the primary model for foreign libraries to encourage user participation in collaborative knowledge construction and sharing. For historical map geo-reference platform construction, completing geo-referencing work is a crucial component. Constrained by the documentary characteristics of historical maps, completing related work requires participants to have certain historical 专业知识 and geographic 常识.

In terms of historical map registration accuracy and final presentation methods, MapWarper's experience demonstrates that by adding a certain number of precise control points and appropriate cropping, local areas of historical maps can be precisely overlaid onto modern maps, and features like transparency adjustment facilitate humanities research based on geographic location and historical evolution. Historical map geo-reference platforms are mostly used in urban geographic research, with most overseas platforms initiated by a city's public library based on local characteristic collections. Urban history geography primarily studies the rise, development, and evolution of cities using geographic

space as the carrier. Cities are essentially the concentrated accumulation of human activities over long periods, an accumulation of social life order within certain historical conditions and spatial scopes [6]. Similarly, research on historical maps rarely exists in isolation but as part of regional historical and cultural research.

4 Domestic Development Status and Localization Implications

4.1 Current Status of Domestic Historical Map Geo-Reference Project Development

Compared to overseas developments, domestic historical map digitization started relatively late, and geo-reference project development has not yet achieved scale. Academic research related to historical geography primarily focuses on organizing and displaying historical geographic data within GIS, with relatively few technology platforms for general users [7].

More mature domestic historical geographic information system projects include the China Historical Geographic Information System (CHGIS), a collaboration between Fudan University's Center for Historical Geographic Studies and Harvard University funded by the Luce Foundation. Launched in 2002, CHGIS aims to establish a continuous basic geographic information database for Chinese historical periods, providing researchers with GIS data platforms, temporal statistics, search tools, and models for daily research and teaching. The project focuses on providing basic historical geographic information and has not yet developed specific data for urban historical geography research, making it substantially different from the historical map-based geo-reference projects discussed here.

The Wuhan Historical Map Resource Database, initiated by the Wuhan Surveying and Mapping Research Institute, contains over 50,000 historical maps collected by the institute, Hubei Provincial Archives, Wuhan Municipal Archives, and other institutions, covering Wuhan City and parts of Hubei Province [8]. The project involves historical map scanning, DRG (Digital Raster Graphics) production, quality inspection, thematic information collection, and other processes. After completion, the database enables self-service queries in archival departments while generating certain economic benefits for development institutions.

The Silk Road Historical Geographic Information Open Platform is another domestic project involving historical map geo-referencing. This platform uses spatial information technology and other related technologies, combined with traditional historical and archaeological methods, to spatially locate environmental, ethnic, economic, transportation, cultural, and other elements along the Silk Road, using GIS technology to build a 2000-year spatiotemporal database along the Silk Road [Figure 2000: see original paper]. Led by Professor Zhang Ping of

Capital Normal University with support from scholars from various fields, the platform's basic data 主要包括 basic geographic data, historical map data, and image data. The platform test version was released in June 207 (likely 2017) and completed technical platform sub-project acceptance in 2018. As of September 2020, searches show the platform contains relatively few historical map images, with only 17 historical map images returned in an empty search.

The platform offers many researcher-friendly functions: place name queries, map overlay and analysis functions, mapping functions, online map registration functions, and map story presentation functions. Historical maps from early periods contain rich historical geographic information about rivers, hydrology, transportation, and settlements that is difficult to find in traditional historical documents. However, due to limitations in surveying and mapping technology and standards, comparison and extraction with today's map information is challenging. Therefore, historical geographers have explored various methods for historical map digitization and related data extraction. The first step in historical map digitization requires map registration. The Silk Road Historical Geographic Information Platform has built a Silk Road map database equipped with online map registration software, allowing users to upload maps from the database or their own maps/images for online registration, facilitating map information extraction and utilization [9]. However, the platform also has shortcomings, such as unfriendly comparison views between historical and modern maps; although modern maps mark the city location of historical maps, they do not provide same-scale comparisons; and while historical maps can be overlaid on modern maps, transparency cannot be adjusted to compare old and new map appearances.

4.2 Localization Implications and Recommendations for Historical Map Geo-Reference Projects

Overlaying digitized geo-referenced maps with region-related historical information can greatly enrich materials for historical geographic research or urban history research, making it easier for researchers to find evidence based on time and geographic elements. This data can also be applied to other humanities disciplines, forming the digitization and interdisciplinary integration required by digital humanities.

4.2.1 Differences Between Chinese and Western Historical Maps and Geo-Referencing Difficulties Chinese and Western map drawing technologies developed along different trajectories due to distinct cultural backgrounds and historical conditions. Western cartographic traditions took shape in ancient Greece and developed rapidly during the Renaissance and Age of Exploration. The late Ming Dynasty's Western learning spreading to the East brought Eastern and Western map drawing into collision, and differences in drawing concepts and techniques have indirectly led to gaps in workload and professional requirements for geo-referencing, creating certain difficulties for platform construction.

Current research on ancient Chinese traditional maps primarily focuses on map collections. According to Wang Qianjin's summary in "The Distribution and Social Functions of Maps in Ancient Chinese Books," "Among the four categories of classics, 31 types of books contain maps, particularly in the classics section, historical geography, political texts, military texts, divination texts, and encyclopedias" [10]. Different types of maps serve different functions. Regarding textual information recording in Chinese historical maps, the complexity of Chinese character structures makes place name information in older maps difficult to recognize. Furthermore, historical maps contained in ancient books require cataloging and identification based on surrounding text, making geo-referencing of individual maps relatively difficult. In existing crowdsourcing projects for ancient text cataloging, such as Shanghai Library's Sheng Xuanhuai Archives Project [11] and Guangzhou Library's Guangzhou Da Dian image data text project [12], participation rates remain low. Regarding geo-referencing work, historical maps have lower accuracy compared to modern maps, making them difficult to identify for readers without professional backgrounds. Additionally, landforms and municipal planning in the same region may appear completely different across dynasties and years, increasing the difficulty and workload of historical map geo-referencing.

4.2.2 Exploring a Localization Model Using Shanghai Library's Modern Map Collection as an Example For these reasons, domestic public libraries undertaking similar geo-referencing projects for old maps need to consider solutions more suitable for local contexts, addressing the particularities of domestic documents and user groups. This paper uses Shanghai Library as an example to explore the possibility of developing a Shanghai urban historical map geo-reference project, drawing on overseas geo-reference platform 成果.

According to statistics, Shanghai Library possesses a substantial historical map collection of approximately 14,000 ancient and modern maps, including rare and unique items such as the 1855 British Concession land planning map, 1864 and 1865 Shanghai British-American International Settlement maps, and the "Kunyu Quantu" (Complete Map of the World) personally determined by Ferdinand Verbiest in the late Ming Dynasty [13]. Currently, these precious map collections have few channels for public display, and interested readers rarely have opportunities to view them. Shanghai Library also holds a large quantity of Shanghai local documents: 8,454 volumes of Shanghai-themed literature published after 1985 and 21,429 historical Shanghai images, providing possibilities for map linking.

If developing a Shanghai urban historical map geo-reference project, the following four points could be considered:

(1) **Introduce necessary outsourcing cooperation to enhance professionalism and efficiency.** Geo-reference platform construction involves cooperation with real map network providers to develop online platform frameworks supporting search, control point addition, old-new map over-

lay comparison, and instant sharing functions. Domestically, providers like Baidu Maps and Amap could be referenced. The platform's desired manual geo-referencing functions and display forms for completed historical maps must be clearly defined.

(2) **Categorize and organize documents, link multiple document types, and enhance historical humanities services.** Due to the large collection size, Shanghai-related historical maps need to be classified by period or theme for batch geo-referencing. Classification must also consider map languages: after Shanghai opened as a treaty port in 1843 (the 23rd year of the Daoguang reign), Western institutions, commercial firms, and cultural groups from Britain, France, the United States, and other countries successively entered the city. From 1844 to 1849, the British, French, and American concessions were established successively, and Western map drawing enterprises gradually developed. Language diversity in map markings is a characteristic of Shanghai's historical maps. If possible, based on geo-referencing Shanghai historical maps, linking with other document types such as old photographs and local documents could enrich the platform's historical humanities value.

(3) **Optimize crowdsourcing schemes to enhance implementation feasibility.** Overseas library geo-reference platform experience demonstrates the feasibility of crowdsourcing channels for geo-referencing work. Conducting user participation surveys beforehand to identify popular themes and geographic locations familiar to users can improve participation enthusiasm. For users participating in historical document crowdsourcing, motivations 主要有两点: interest in local historical research and voluntary assistance to libraries. Participating in crowdsourcing projects can also bring a sense of achievement and belonging, with the fundamental purpose of improving existing resources and knowledge. In a historical map geo-reference project, tasks that can leverage crowd power include not only adding control points but also reviewing and correcting initially registered maps. This requires platforms to subdivide the entire process when planning crowdsourcing models and give participants the freedom to choose tasks.

(4) **Integrate organically with new media promotion to establish reward mechanisms that enhance public participation and enthusiasm.** Through new media dissemination, projects can be discovered and joined by more people. Drawing on the British Library's Georeferencer project, geo-reference platform promotion can be integrated with library collection promotion to attract broad user participation. Since geo-referencing work is essentially a public welfare project, reward mechanisms emphasize psychological motivation. Common methods include recording contributions through contribution rankings and setting real-time progress bars on webpages so participants can see the changes brought by their contributions.

Through analysis and research of mature overseas library historical map geo-reference platform cases, and comparison with existing domestic projects, selecting appropriate references for platform construction while understanding Chinese historical map registration difficulties is crucial. This paper uses Shanghai Library's modern historical map collection as an example to explore a localization model suitable for domestic public libraries. Given that this is a massive, meticulous work requiring long-term commitment—overseas projects have lasted ten years or more—with platforms continuously updated and improved to meet researcher and general user needs, historical map geo-reference platforms for Chinese historical maps, as a means of protecting and rediscovering urban and national historical memory, will likely see more attempts and development in China in the future.

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Note: Figure translations are in progress. See original paper for figures.