

Development of ancient Chinese inscription rubbings knowledge base in the context of cultural communication and art appreciation

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Abstract

Purpose – To promote the cultural communication and art appreciation of Inscriptions and calligraphy which are important cultural heritages in China, with a broad crowd base and educational appreciation value, by using digital humanities methods and technologies, the paper aims to discuss how to develop a new user-oriented knowledge base according to user needs for inscription rubbings research and appreciation.

Design/methodology/approach – The paper investigates user needs and current problems on the basis of status quo and summation of extensive service experience; validates the rationality of requirements and user scenarios with user research methods including focus groups, interviews and behavior observations; then designs and develops the technical solution of data process, knowledge base construction and service platform through experimental research methods based on agile project management.

Findings – The paper proposes a new reading mode for browsing and appreciation inscription rubbing works, a diverse knowledge-integrated knowledge organizational structure, a systematic user experience and service guiding framework which can be widely applicable to the development of other cultural heritage knowledge bases. Apart from that, the paper puts forward intelligent service development goals for the future.

Originality/value – The paper proposes a new reading mode with the overall functions and user experience design and development for browsing and appreciation inscription rubbing works, a diverse knowledge-integrated knowledge organizational structure, a systematic user experience and service guiding framework which can be widely applicable to the development of other cultural heritage knowledge bases. Apart from that, the paper puts forward intelligent service development goals for the future.

Keywords User experience design, Digital humanities, Ancient Chinese inscription rubbings knowledge base, Art appreciation, Cultural communication, Reading mode

Paper type Practitioner paper



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1. Introduction

The art of Chinese inscription rubbings has spanned thousands of years and continues to be passed down to this day. “碑” (bēi) refers to the stone carved with characters, which first appeared in the Western Zhou dynasty over three thousand years ago. “帖” (tiè) refers to the papers copied from the authentic works of calligraphers or the stones with carved characters.

When those papers have been bound into books, we called them as inscription rubbings (see [Plate 1](#)). Inscription rubbings are vital mediums for Chinese calligraphic art. Scholars from China and abroad studying Chinese culture often begin their research with the study of original inscriptions ([Deng, 1998](#)). Inscription rubbings hold rich content in the realm of humanities, boasting significant historical, artistic and cultural values. They have always been regarded as treasures of Chinese culture. With the revival of epigraphic culture in recent years, the enthusiasm among ordinary citizens for appreciating inscription rubbings has been on the rise. The Tang Dynasty inscription exhibition held at the Shanghai Library in 2021 was a resounding success, drawing an overwhelming number of calligraphy enthusiasts and artists to visit. The total number of visitors exceeded 30,000, with an average of 2,000 daily visits, a clear testament to the fervor surrounding inscription rubbings.

Shanghai Library is a comprehensive research-oriented public library and an industry intelligence center in Shanghai. It is also a branch center of the National Cultural Information Resources Sharing Project, a public cultural research base of the Ministry of Culture, and one of the first key national ancient book preservation units. The collection of inscription rubbings at Shanghai Library covers nearly the entire “History of Chinese Inscription Rubbings.” Its vast quantity and exceptional quality make it akin to a “Museum of Inscription Rubbings” ([Zhong, 2020](#)). The collection of rubbings at Shanghai Library can be traced back to 1939. As of 2022, the total collection of inscription rubbings amounts to approximately 250,000 items, with over 3,000 different types of fine inscription rubbings. Among them, more than 600 of them are classified as national-level first or second-class protected cultural relics. The quality of rubbings of model calligraphy is exceptionally high, including unique examples or the finest inherited specimens, making them valuable resources for rubbings research ([Zhong, 2020](#)). Moreover, the collection of fine inscription rubbings includes over 2,500 inscriptions by notable calligraphers and over ten thousand collector’s seals, rendering it of significant academic research value. Over the past decade, publications such as



Plate 1.
An example of “碑” (bēi), photo taken by Liu Yedao, and its two copies as “帖” (tiè), held by Shanghai Library, in different time of Chinese history

“Treasures of Calligraphy: Shanghai Library’s Collection of Rare Inscription Rubbings” and “Comprehensive Catalog of Rare Inscription Rubbings at Shanghai Library” have systematically organized and digitally restored the appearance of these fine inscription rubbings. Currently, the management of inscription rubbing resources primarily involves preserving originals and scanned copies, while user services predominantly revolve around traditional offline exhibitions, which have limited coverage in terms of both audience and works. This has constrained the dissemination of knowledge about inscription rubbing culture and the advancement of humanities research.

Digital humanities emerged about a decade ago as a research and practice field. It has since brought about a paradigm shift in humanities research and promises a broader perspective for expanding and innovating future digital library services. Since 2014, Shanghai Library has invested a significant amount of resources to explore ways and methods in initiating digital humanities projects in libraries. Using the genealogy special collection in Shanghai Library as the starting point, the digital humanities project team applied cutting-edge Semantic Web technologies such as ontology, linked data and knowledge graph to aggregate metadata records, research results produced by domain experts and related web resources. These resources and data were reorganized through ontological modeling, which integrated architectures, people, places, time, events, physical objects and literature together to build a humanities research data infrastructure. The library has progressively launched public knowledge service platforms like the Revolution (Red) Literature Platform, Chinese Ancient Books Union Catalogue and Evidence-Based Platform and the Chinese Genealogy Knowledge Service Platform. These platforms offer a convenient route for humanities researchers and the public users to access the digital cultural heritage resources and appreciate the historical stories and cultural knowledge behind them.

The practical experience of the Shanghai Library in the field of digital humanities has laid the groundwork for the development of the Inscription Rubbings Knowledge Base. But what are the needs of diverse users of the knowledge base and how can a platform be created to meet these needs has not been clearly researched. In this article, we launched investigations to gain a deep understanding of various user needs and scenarios so as to develop the Knowledge Base that really works.

2. Literature review

The paper investigates existing literature related to the construction of the inscription rubbings knowledge base, finds that current research results mainly come from major Chinese libraries and universities. Six relevant articles were retrieved through the China National Knowledge Infrastructure (CNKI) database, including three studies analyzing the current construction status of the overall knowledge base, and the three studies summarizing experiences in building specialized databases. In terms of overall research, Zhang Zhiqing *et al.* conducted a comparative analysis in 2005 of the building modes, collaborative methods and major databases for Chinese stone rubbings (Zhang & Ji, 2005). Li Zhuo provided a detailed comparative analysis in 2013 of the seven major inscription knowledge bases from the perspectives of data, function and history (Zhuo, 2013). In 2020, Li Hualei *et al.* reviewed the work of compiling rubbings catalogs from the perspectives of books, papers and databases (Hualei & Pan, 2020). In terms of current database development, there are three papers separately introduced the development of “Shanghai Museum Inscription Resources Digital Collection and Management Platform” (Jiang & Fan, 2018), “Beijing Normal University Inscriptions Digital Research Platform” (Hu, Peng, & Yonghong, 2021) and “Mi Fu Calligraphy Database” (Zhang & Zhang, 2019).

It’s worth mentioning that there is yet no English literature published related to the inscription rubbings knowledge base. Firstly, researchers and enthusiasts of inscription

culture are primarily concentrated in China; secondly, the work involves heavily on the accumulation of ancient Chinese textual collections and the in-depth interpretations of experts and scholars, as well as digitization, textualization and structured work on the resources, an area where foreign institutions lack relevant research and processing experience. Therefore, it is highly worthwhile offering reusable experience for other research teams worldwide.

The paper also conducted extensive research on databases focusing on inscription rubbings: (1) "Inscription Rubbings Extract" of the National Library of China (<http://mylib.nlc.cn/web/guest/beitiejinghua>). Released in 2002, the database has been built on the basis of more than 230,000 inscription rubbings of oracle bones, bronzes, stone carvings, etc. over 25,000 pieces of metadata and 31,000-odd images. Users can search or click the detail button to view related metadata and full-sized scans. (2) Zhejiang University's "Chinese Epitaph Database" (<http://csid.zju.edu.cn/>), being released in 2017, has uploaded more than 14,000 epitaph entries, providing basic retrieval, screening, metadata and full epitaph image browsing services. (3) UniHan Digital Technology's "Compilation of Historical Documents of Classical Stone Carvings" (<https://www.unihan.com.cn/books/jinshi/ldsk>), on which 15,000 stone carving documents containing 11.5 million words with annotations attached have been extracted from *Compilation of Historical Documents of Classical Stone Carvings* (16 volumes). Users can search the inscription rubbings through the title of the document and text content and filter and retrieve the titles and explanations and copy and add annotations by dynasty. (4) Beijing Normal University's "Digital Research Platform for Classical Stele Inscriptions," which provides inscription retrieval based on multiple attributes, full-text annotation search and picture browsing and supports independent entry of annotations and glyph segmentation and calculation.

In summary, the literature review shows that the current practice of inscription rubbings databases are primarily focuses on early-stage resource collection, digitization, classification and keywords-match retrieval service for the end users. There are two aspects of problems: The one is the limited research on differentiated user service scenarios and specific user requirements; the other is that most articles mention that the processing of metadata creation or knowledge extraction mainly depends on manual work, and there is insufficient automated data processing capability, thereby hindering the bulk digitization application of inscription rubbings. Therefore, the purpose of our study is to figure out the specific user requirements in different scenarios through user research and requirements analysis, and to explore a technical solution for semi-automated smart data processing, knowledge extraction, knowledge organization and user scenarios adaptation based on semantic and AI technologies through experimental research. Finally, in view of the lack of English literature related research or practice on Chinese inscription rubbings according to the literature review, this study is also committed to introduce the methods of development of the knowledge base and the service it provides for the international area.

3. Methodology

This study conducts a systematic investigation to analysis the differentiated user requirements according to different user scenarios through user research methods, and technical solution design and development of data process and knowledge base construction and service platform through experimental research methods.

Firstly, user research: there are three paths for investigation of user requirements. (1) Focus group discussions: Engaging with inscription rubbings enthusiasts and researchers of different ages and cultural backgrounds to understand their overall preferences for inscription rubbings works, reading habits, expectations for the knowledge base functionalities and usage history of current products. This helps in overall positioning and

categorization of user portraits. (2) Expert interviews: Conducting in-depth one-on-one conversations with a few typical users to obtain user profiles and scenarios. (3) Behavior observations: Recruiting experimental users to observe their usage processes, main tasks, as well as failed operations and issues during application usage. This serves as preliminary data for website usability design. For further analysis, the data collection was synchronized with the investigation.

Secondly, experimental research: Implementing agile development methods based on agile project management, prototype development and system trial operation. (1) Using daily station meetings, burnout charts and product backlog management, the expert users can see how their requirements are translated into development activities and understand the expected delivery time. (2) With the rapid feedback after prototype development and optimization iterations, the selected key users can get available product versions at an early stage, experience new functions in time and provide feedback. This rapid feedback cycle helps to find and correct problems as soon as possible and improve the quality of user service. (3) With a long-term system trial operation online, the efficiency of the prototype system can be more finely tested and continuously optimized through the service to the public users. In short, this method ensures that the software system always focuses on solving users' practical problems and meeting their expectations, so as to provide services closer to users.

4. Data collection and analysis

About three months before the prototype development, the research in this paper was conducted by recruiting volunteers from readers of Shanghai Library and researchers from the ancient books research department. Considering the ages, cultural and educational background of the volunteers who are enthusiasts and amateurs of Chinese Inscription Rubbings, a total of 15 readers selected as key users were surveyed for user requirements according to user scenarios through one focus group discussions, and expert users interviews were conducted with two librarians engaging in metadata cataloging and two professional researchers studying on Chinese Inscription Rubbings for system functions except for user requirements according to user scenarios through multiple focus group discussions. After three months of development, the prototype system went live for trial operation online, more than 1,000 public users access the system during one month, by behavior observations, recording and analysis with the content analysis and data statistics methods through the records of the access log files of the system. This process resulted in the formation of two main user profiles, based on which the demand scenarios were analyzed as follows:

1. Enthusiasts and amateurs

This group comprises individuals interested in calligraphy as a hobby or for learning purposes. They enjoy observing and copying inscription rubbings. The age distribution is skewed towards individuals over 50 years old, with more than 50% being middle-aged or elderly users. They mainly appreciate inscription rubbings by attending offline exhibitions and purchasing calligraphy copybook. Their utilization of online platforms requires guidance. The following are their needs: (1) Art Appreciation: Selecting calligraphers, specific works, or styles for admiration. (2) Calligraphy Copying: Replicating inscriptions or selecting specific characters for practice. (3) Knowledge Exploration: Studying interpretation, historical context, stories behind the works and related figures. (4) Comparative Analysis: Delving deeper into cross-work and cross-figure research, such as studying different writing styles for the same characters, variations in rubbings of the same inscription, or works from calligraphers across different periods.

2. Professional researchers

This category includes cataloging staff at libraries, researchers of ancient literature and scholars of historical and humanities studies. The basic browsing behavior of professional researchers is similar to that of ordinary enthusiasts. In addition to this, they also engage in more in-depth interaction with the inscription works, including literature verification, character explanations, investigation of historical evolution, chronological phases, geographical distribution, evolutionary patterns, social literary value, cultural relic preservation, and more. Their work involves not only the inscription rubbings themselves but also extensive reference to recorded data and related historical documents, including the history of inscription rubbings' transmission, biographies of authors, colophons and related literature. Their research goals encompass cataloging, publishing, education and knowledge dissemination.

5. Results

Based on the literature research and user requirements analysis, this paper mainly identified some common trends in user demands which give enlightenment about how to focus on typical points for designing and developing an Ancient Chinese Inscription Rubbings knowledge base: (1) reading ability and expectations of different users; (2) reliance on and expectations of digital platforms; and (3) increased personal value demands of a special knowledge base.

5.1 Reading ability and expectations

The reading ability and expectations of users have been significantly increased. Through focus group discussions, we gathered insights from users of varying ages and cultural backgrounds. These discussions highlighted the growing desire for in-depth exploration of inscriptions, revealing a need for detailed annotations and linked knowledge to enrich the appreciation experience while traditional users mainly copied and appreciated classical inscription rubbings. Expert interviews provided deeper insights into the specific preferences and expectations of advanced users, such as the need for comprehensive stylistic analyses and contextual information. Observational studies confirmed these findings, showing that users spent considerable time on in-depth content and sought interactive features to enhance their understanding. As users' appreciation abilities improved, they sought more diverse works from renowned artists, analyzing stylistic changes in writing across different dynasties and more interactive experience.

5.2 Reliance on and expectations of digital platforms

Users have higher reliance on and expectations from digital platforms. Early users expended considerable effort in searching for works and understanding textual interpretations offline. With the development of internet technology, users gradually shifted their research activities online. They expect online platforms to serve as reading guides, helping them understand works more efficiently and actively providing potential reading lists. They seek an all-in-one reading platform that integrates various functions. Therefore, they have higher expectations for convenient synchronization features, user-friendly interface operations and comfortable reading experiences.

In focus group discussions, participants emphasized the importance of seamless digital experiences and the ability to access comprehensive information quickly. Expert interviews revealed that researchers relied heavily on digital platforms for efficient data retrieval and analysis. Observations of user interactions with current digital platforms showed frequent use of search functions and frustration with cumbersome navigation and lack of integrated

tools. These insights underline the necessity for intuitive design, robust synchronization capabilities and personalized user experiences.

5.3 *Increased personal value demands*

The increased personal value demands are evident. Users have evolved from passively receiving knowledge to actively providing useful information for others, contributing personal knowledge and seeking acknowledgment. They hope to freely annotate their readings, even share knowledge and participate in the process of knowledge production.

Focus group discussions revealed a strong desire among users to contribute to the knowledge base by sharing their insights and annotations. This participatory approach was also echoed in expert interviews, where researchers expressed interest in collaborative tools and recognition for their contributions. Observational studies showed that users frequently attempted to annotate and share content, indicating a clear demand for these functionalities. These findings highlight the need to incorporate features that support user-generated content and foster a community of knowledge sharing.

5.4 *Conclusion*

The findings of new trend of user requirements urge us to systematically consider the real purpose of developing a knowledge base, adopt new metadata schemes and technical architecture, use ontology to integrate more relevant knowledge to provide knowledge services instead of only providing resource access services, redesign the processing and publishing process of large-scale images, systematically design the content organization framework to support diversified user needs and scenarios, fully support functions such as resource retrieval, image appreciation, text close reading, data analysis and finely design user-friendly reading mode for good user experience.

6. Discussion

6.1 *Goals of developing the knowledge base*

- (1) Revealing inscription rubbing resources at the granularity of characters and establishing contextualized knowledge organization system. It can be observed from the result part that the needs for appreciation of inscription rubbings are becoming increasingly diversified and profound, encompassing not only the calligraphic writing but also the understanding of associated knowledge. The knowledge structure encompassed by inscription art is rich and diverse. It includes aspects such as characters, script styles, images, seals, colophons, calligraphers, collection history and stories of transmission. Users' appreciation of inscription rubbings is built upon the foundation of individual characters. Starting from characters, various levels of cultural exploration such as calligraphy copying, organizing phrases and understanding textual interpretations can be undertaken. A multi-dimensional knowledge organization system rooted in characters needs to be established as well as a comprehensive ontology model that seamlessly integrates the literature features, content characteristics and historical context which lacks research from the literature review.
- (2) Automating inscription rubbing digitization and reuse. Current OCR (Optical Character Recognition) and data management for inscription rubbings rely heavily on manual work, causing inconsistent accuracy and inefficiencies that limit their large-scale use. Improved OCR methods and streamlined workflows are crucial to effectively digitize and structure information about origins, historical context, stories,

seals, notable figures and other metadata. This would enhance the accessibility and utility of these valuable cultural assets.

- (3) Establishing front-end framework and user experience standards. To enhance user experience, the project aims to establish a front-end framework and UX standards. It is found in literature review that the current knowledge bases are developed based on conventional document-focused approach which falls short in satisfying broader user needs. By focusing on UX design, which is pivotal in web development but underutilized in ancient text domains, the paper will consolidate best practices in functionality, layout, interactions and visual design. Extracting essential UX elements, it will devise a straightforward, user-friendly interface adaptable to various image-centered knowledge repositories, fostering flexible user interactions.

6.2 Metadata schema, ontology and technical architecture design

To satisfy users' needs for searching and appreciation of inscription rubbing resources, it is essential to employ ontology methods to comprehensively describe and reveal the physical, historical, cultural and artistic attributes of the rubbing resources, along with the intricate connections between steles and rubbings, calligraphic works and rubbings, and among rubbings themselves. Furthermore, semantic technology is utilized to facilitate knowledge organization, and IIIF framework is adopted to publish, display, share and annotate them.

1. Metadata schema design

The knowledge base takes the "Treasures of Calligraphy: Collections of Rare Books and Inscription Rubbings in Shanghai Library" as its knowledge source, references the metadata standards for rubbings formulated by both the National Library of China and Peking University Library mentioned in the literature research, and reconstructs a metadata description standard that encompasses various documentary levels, including steles, rubbing prints, along with collection histories and contextual knowledge. This design serves as a foundation for the subsequent ontology design. Structured in a three-tier hierarchy of metadata items, elements and element modifiers, the metadata scheme comprises ten major items: title, responsibility, subject, epigraphy, block printing, engraving, version, collection, relation and appreciation. Among these, the subject item consists of three sub-elements: content subject, personal subject and temporal-spatial subject. The content subject includes two modifier elements: "subject terms" sourced from a controlled vocabulary and "keywords" functioning as free terms. In designing metadata items, the epigraphy item and the block printing item are specifically tailored to depict the epigraphic characteristics of stele rubbings and the block-printing features of calligraphic transcript rubbings, respectively. Furthermore, the collection, relation and appreciation items are employed to present the rich collection histories, contextual backgrounds and ancillary resources and scholarly literature pertinent to the stele rubbings.

2. Ontology design

The Shanghai Library's Ancient Chinese Inscription Rubbings Knowledge Base, operating within the library's humanities research data infrastructure, organizes knowledge following an integrated ontology design and application profile principles (Xia, 2021a). This profile caters to the unique requirements of inscription rubbing resources by integrating them into a Metadata schema under an overarching ontology model. Inscription rubbings, seen as specialized ancient texts, expand upon the ancient book ontology with classes such as Work, Version, Item and Annotation. Specific elements like titles and content annotations fall under Work attributes, while individual rubbings and related stone carvings are classified as distinct Instances, distinguished by the "type" property. Varied rubbings across time also

constitute separate Instances, interconnected via “bf:instanceOf”. Each rubbing copy is an Item, linked to its Instance through “bf:itemOf”. Background information, often varied due to researcher perspectives, is documented as Annotations, detailing content, source and authorship for scholarly use. Additionally, a class for individual character images (shl:Script) incorporates details like character, source rubbing, font, image position, acknowledging possible multiple representations for common characters within a rubbing. This schema harmoniously integrates inscription-related data, connecting historical, geographical and personal details across the knowledge base.

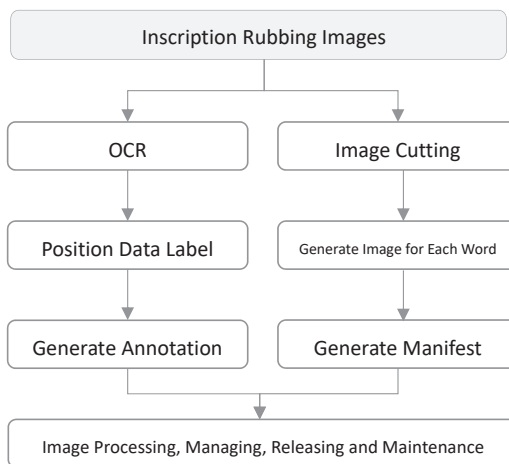
3. Technical architecture design

Within the Shanghai Library’s humanities research data infrastructure, the Ancient Chinese Inscription Rubbings Knowledge Base adheres to the structure of a literature knowledge base. This framework includes a document tier, featuring resource objects (inscriptions and single-character images) and metadata, an entity tier for entities like figures, locations, timelines, events and objects, plus an interface and service tier. The document tier leverages IIIF technologies and components for image handling, publishing, browsing and annotation of rubbings and character images. Linked data facilitates metadata dissemination and interconnections among entities. RESTful APIs enable seamless data exchange across the tiers.

6.3 Image processing, management and release workflows

To streamline image and metadata handling and counter inefficiencies from fragmented image processing workflows, the knowledge base introduced an image processing, management and publishing back-end built atop Lightroom (See Figure 1). This system enables end-to-end image handling, from editing to real-time publication, featuring:

- (1) Batch Import & Format Conversion: Supports TIFF, JPG, PNG conversion to IIIF-compatible P-TIFF, with automatic watermarking during conversion.
- (2) Flexible Image Storage & Processing: Offers dual folder structures (“Volumes” for nested hierarchies and “Collections” for unrelated images) to cater to varied atlas management needs.



Source(s): Figure by authors

Figure 1.
Inscription data
processing flow

- (3) Collaborative Editing: Integrates Lightroom's editing tools with external software like Photoshop for in-depth edits, with concurrent metadata display for synchronized updates.
- (4) Integrated Publishing: Post-update, images and metadata are instantly pushed to IIIF servers, with URIs recorded for immediate front-end viewing.
- (5) Single-Ideograph Handling: Conducts OCR on characters, isolates them for individual images and records their coordinates within the whole rubbing for precise retrieval, comparison and appreciation.

First, character areas and centers in rubbing images are identified, with recognized characters marked alongside their coordinates for later manual verification to ensure accuracy. Next, characters are extracted from the marked regions, individually cropped and sequentially named per established rules, forming distinct image files linked to their positional IDs, corresponding text and rubbing details. These segmented characters, annotated with character info, location and source, undergo image processing. Their annotations and manifests, compliant with IIIF standards, are then created and stored in a database. This setup enables character-level retrieval and linking back to their original context within full-sized images via call numbers and URLs, allowing for location highlighting in the comprehensive view.

6.4 Content organization framework

The Shanghai Library Ancient Chinese Inscription Rubbings Knowledge Base begins by helping users find target inscriptions and characters. It then expands into various knowledge organization methods and uses multiple visual aggregation modes to explore and present different knowledge structures. This creates a web-like framework supported by multi-dimensional topics and multiple ontology data (see [Figure 2](#)).

The Knowledge Base supports users in finding inscriptions and understanding characters and then builds on this with diverse knowledge organization methods. It employs various visual aggregation modes to highlight distinct knowledge features, establishing a multi-dimensional thematic framework with diverse ontological data and interconnected networks. This framework centers around four key sub-scenes: "Characters," "Inscription Rubbings," "Celebrities" and "Stretch Knowledge," with nearly 30 types of metadata aggregated into these themes. Connections are made between themes based on inscription IDs. Users can navigate from the theme aggregation page to details pages and related external sites, facilitating efficient cross-scene content circulation.

6.5 Overall functionalities

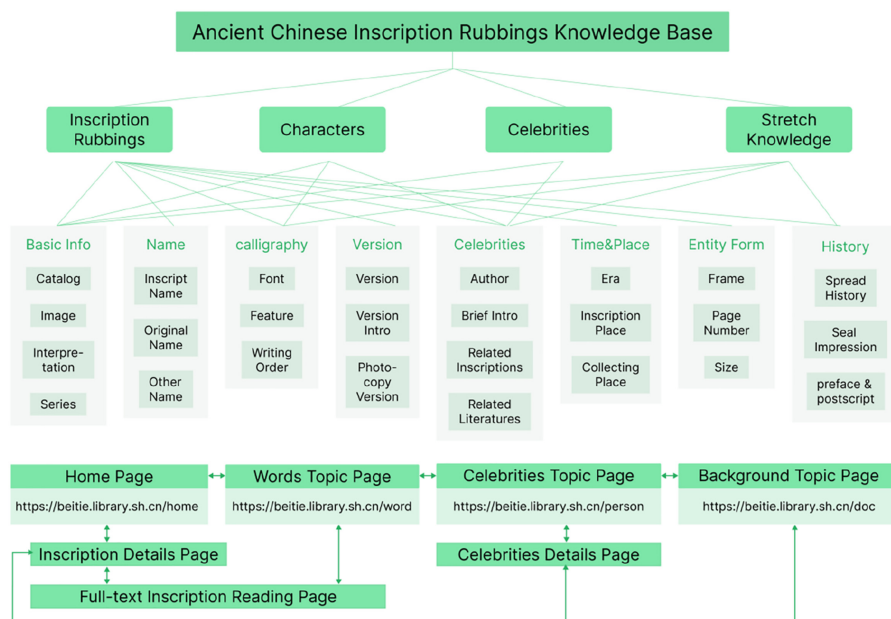
6.5.1 Knowledge browsing.

1. Home Page

The home page displays all rubbings in a waterfall layout by default, with optional grid and list views. The grid view highlights images, while the list view focuses on data and knowledge. Users can filter and sort rubbings by script style, historical period and calligrapher to match their preferences.

2. Individual Character Theme Page

Each character is linked to its text image through structured processing of all rubbings and displayed to readers. Users can select or search any character to explore its variations across



Source(s): Figure by authors

Figure 2. Content organization framework

different periods, calligraphers and works. Clicking on a character takes the user to its corresponding location in the rubbing, with the text highlighted.

3. Celebrity Theme Page

This page displays all related celebrities and authors with spatial-temporal visualizations, grid and list views. Data is integrated with the Shanghai Library’s Names Database (<https://names.library.sh.cn>). Users can learn about the celebrities’ profiles, their distribution over time and space, and related works. They can also navigate to other digital humanities systems to view more works by these authors.

4. Stretch Knowledge Theme Page

This page aggregates and presents historical origins and background knowledge related to the rubbings. Users can enjoy a comprehensive reading experience to gain a deeper understanding of the works.

6.5.2 Retrieval system. The Shanghai Library Ancient Chinese Inscription Rubbings Knowledge Base features a “one-Search Box” retrieval strategy based on a networked knowledge organization structure, enabling users to perform compound queries through a single search box. The knowledge base links two primary dimensions – inscriptions and interpretations – with 14 metadata elements, including characters, fonts, dynasties, versions, bibliography, history, inscriptions, seals and background. Users can enter any relevant content into the search box, which accurately matches and displays corresponding inscription entries in the results list. Keywords are automatically identified as filter tags, helping users manage multiple criteria visually. For complex searches, users can use the “Advanced Search” option to input up to nine criteria such as title, author, dynasty, version, source and interpretations. Additionally, the knowledge base dynamically calculates and

displays popular search term recommendations, providing users with multidimensional knowledge outputs.

6.5.3 *Inscription reading.* On the Inscription Details Page, users can explore knowledge from various angles, including inscription features, spread history, inscription date, background information, related celebrities and relevant literature. By clicking “View Full Texts,” users access the full-text view for in-depth reading. Users can also mark favorite inscriptions and track them via their personal center.

The full-text interface is built on the IIF framework, extended for inscription reading demands and user interaction habit. Users can navigate pages, zoom in on images without quality loss, and personalize layout preferences. They can adjust inscription display settings, choose explanation modes and access related knowledge data (see Figure 3).

6.5.4 *Comparative analysis of multiple images.* Differences in rubbing techniques and the use of paper and ink vary significantly among inscriptions rubbings from different periods. Even for rubbings from the same period, there are differences in the artistic effects of rubbings from different regions (Tong, 2022). Conducting comparative analysis to identify similarities and differences among artworks is a major challenge for researchers and enthusiasts. This system, utilizing the IIF framework, allows users to simultaneously display multiple rubbings within the same browsing interface. Users can drag and drop the rubbings they wish to compare into any large image viewing window, enabling side-by-side comparison of multiple images. They can freely adjust window sizes or select specific pages as needed within the scene interface (see Figure 4).

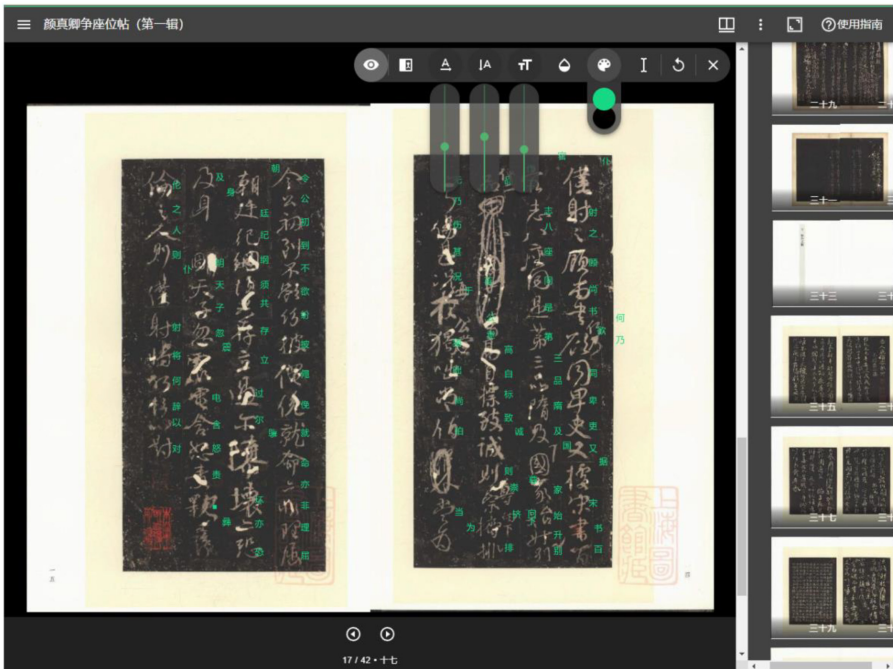
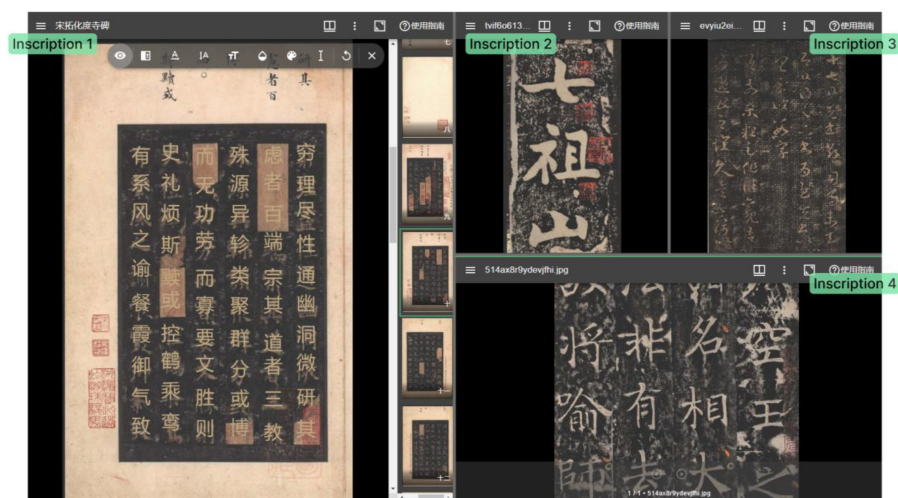


Figure 3.
The full texts
inscription reading
interface

Source(s): Webpage screenshot of the knowledge base by authors



Source(s): Webpage screenshot of the knowledge base by authors

Figure 4.
The multi-images
comparative analysis
function

6.6 The new reading mode

6.6.1 User-friendly reading mode. For enthusiasts of epigraphic culture, interpretations are essential for identifying characters and understanding the content of inscription rubbings. However, many inscription databases lack interpretations or present them in formats that are difficult to read and compare with the original inscriptions. To address this, our system developed a companion-style interpretations reading feature, providing modern Chinese interpretations in a contextual manner while respecting diverse reading habits and allowing flexible adjustments.

To overcome layout challenges caused by varying calligraphy styles and character spacing, we designed a lightweight interactive tool for in-depth reading. This tool enables users to read the original inscription alongside modern Chinese explanations for each character, facilitating intelligent mapping between the image and interpretations to enhance reading efficiency. Users can adjust the position, size, color and transparency of annotations to ensure they do not obstruct the original text.

Recognizing different reading preferences, our system offers multiple display modes. Users can choose between “Side-by-Side Comparison” and “Proximity Display” modes with a single click, or quickly hide interpretations when appreciating inscriptions from a calligraphy perspective to maintain the overall visual experience.

6.6.2 Multidimensional knowledge fusion. Associative thinking is crucial for reading Chinese ancient books, and related knowledge enhances readers’ understanding of the work’s essence and artistic expression. However, many knowledge bases present related data on separate detail pages, disrupting the seamless connection between viewing and associative thinking. The inscription reading interface integrates related resources and data from other Shanghai Library knowledge bases through Restful APIs or HTTP URIs, presenting them uniformly within the calligraphy work image viewer. Users can expand the collapsible structure on the left for supplementary reading of the calligraphic text when necessary.

Currently, the knowledge base integrates over 20 types of related resources and data from Shanghai Library’s existing knowledge databases, including detailed information about creators, original locations, backgrounds and historical knowledge of inscription rubbings.

Building on this, we aim to expand to more diverse associated resource databases or Linked Data sets published worldwide.

6.6.3 Systematic user experience design. The effectiveness of user services ultimately depends on user perception. However, cultural heritage knowledge bases often overlook this perspective, impacting user interaction experience and exploration depth. This paper proposes four user experience principles – noise reduction, comfort, intuitiveness and feedback-tailored to inscription rubbing services. To recreate the immersive focus of offline reading and avoid function overload disruptions, a lightweight front-end design prioritizing core modules and streamlining less-used functions is introduced to reduce noise. Providing a comfortable reading experience is one of the goal of the knowledge base. It has established design specifications for color, typography and card components based on the “comfort” design language. Previously, users had to navigate through three to four pages to access the reading interface from the homepage, which was inefficient. To streamline this process, we’ve added shortcut buttons to the thumbnail images on the homepage. Clicking these buttons allows users direct access to the reading interface.

7. Significance of study

This paper explores an innovative technical solution of the inscription rubbings knowledge base construction and service. Firstly, it establishes standard metadata schema and an open integrated ontology application profile for the inscriptions knowledge domain. The design approach of the integrated ontology or supper ontology can be used to build the inscription metadata schema and ontology as well as the interface framework (Xia, 2021b; Zeng, 2023). This approach significantly lowers the professional barriers for developing such knowledge bases. Secondly, it develops a lightweight image and metadata management plugin based on Lightroom, enabling an all-in-one operational process for image processing, management and publication. The use of this tool effectively reduces the workload for literature cataloging and maintenance personnel, making automated and streamlined cataloging feasible. Thirdly, by creating user-oriented scenarios, establishing a front-end service framework for inscription reading tools, and defining systematic user experience dimensions, the paper constructs a service framework that emphasizes noise reduction and employs lightweight design principles. This framework can be widely applied to structured image resource interaction and presentation, while avoiding the problems of bloated, complex and unwieldy literature service tools. Finally and most importantly, regarding user experience, the paper innovatively combines user experience elements from the internet service industry with the field of ancient literature. It introduces four dimensions of user experience: noise reduction, comfort, intuitiveness and feedback, thereby exploring design principles for achieving user-centric and more intelligent user services.

The development of Ancient Chinese Inscription Rubbings Knowledge Base is also an important contribution to the field of digital humanities. As a form of cultural heritage, inscription rubbings is the important and indispensable components of Data Infrastructure of digital humanities. Furthermore, the artistic, cultural and historical values of Chinese Inscription Rubbings warrant further propagation and promotion through digital humanities methods and technologies. To provide comprehensive support for cultural appreciation, research and dissemination, a holistic exploration and validation of data processing procedures, content organization frameworks and user-facing service functionalities using digital humanities methods is essential. Shanghai Library holds a unique advantage in its collection of inscription rubbings and its experience in Digital Humanities platform development which can be taken as a best practice to show how the ancient cultural heritage can be well utilized in the digital intelligence Era. Supported by a team of historical research experts for scholarly verification, along with user participation in surveys and usability

testing, it is poised to explore and validate comprehensive solutions for different user requirements. This paper seeks to combine the construction methodology, workflow and technology of the Inscription Rubbings Knowledge Base at the Shanghai Library to offer insights for the development of calligraphy-related knowledge bases. This endeavor aims to contribute to the international dissemination of inscription rubbings culture.

The Ancient Chinese Inscription Rubbings Knowledge Base has the potential for future development. Firstly, the quantity and diversity expansion of Structured inscription data. The current knowledge base has initiated its journey with a selection of high-quality inscription works, focusing on in-depth refinement of linked knowledge and service innovation. After the preliminary validation from the industry and the market, the next phase will focus on increasing the quantity and diversity of digitized resources, systematically formalizing a greater collection of inscription holdings and linked knowledge, providing a feast for readers. Secondly, the deep integration of technology and user services with AI. Rapidly advancing AI deep learning, semantic and IIRF technologies can significantly enhance areas such as automated OCR, image-depth annotation and semantic annotation for inscription rubbings resources. The infusion of AI and related technologies will greatly expedite the digitization, structuring and intelligent processing of inscription rubbings resources. In terms of user services, comprehensive intelligent services will effectively enhance user engagement and cultural awareness, ushering epigraphic art into a new era of revival and development. Thirdly, The international exchange and collaboration. Epigraphic art is an essential component of cultural heritage and a vital form of expression in Chinese calligraphy. Currently, due to obstacles in reading characters and knowledge processing, epigraphic culture remains relatively niche in the realm of international cultural heritage. However, with the maturity and widespread adoption of large language models like ChatGPT, epigraphic works can now take the international stage through more vibrant formats such as structured content, automated translation and interactions with virtual characters. We anticipate that the development of the Shanghai Library Ancient Chinese Inscription Rubbings Knowledge Base will serve as an opportunity to engage in deep collaborative exchanges with international research teams, exploring cross-language and cross-cultural sharing of cultural heritage.

8. Conclusion

The Shanghai Library Ancient Chinese Inscription Rubbings Knowledge Base currently contains 2,525 inscription rubbing images and 18,043 structured glyph images. Through user service innovation, knowledge organization upgrade and data processing flow standardization, the preliminary practice and verification of personalized service and standardized data processing mode based on inscription collections have been completed. The knowledge base was launched on the Internet for users all over the world in early 2022. In September 2022, with the opening of the East Branch of the Shanghai Library, the knowledge base is applied to providing readers with knowledge services and interactive game exhibition support services in the Art Museum. After a period of operation, it has been welcomed by readers of different ages. The Ancient Chinese Inscription Rubbings Knowledge Base has become the first window website in Shanghai to offer free online access to inscriptions and related knowledge for readers. Currently, there are more than 50,000 users accessing the website through various terminals, greatly facilitating readers to appreciate high-definition inscriptions and obtain relevant knowledge. In addition to reader services, the construction of the knowledge base provides reusable construction experience for the development of calligraphy cultural heritage knowledge bases. (1) Metadata and integrated ontology standards, functional modules, knowledge organization framework, data processing workflows and user service framework have been established, which can be applied as a

reference for developing other systems. (2) The knowledge base has high expand-ability, supporting the import of various types of calligraphy works in the future, and developers do not need to repeat development work, thus enhancing the integration of Shanghai Library's cultural heritage resources. In addition, the construction of the Ancient Chinese Inscription Rubbings Knowledge Base also facilitates the innovative dissemination of traditional Chinese culture, expands the user base for calligraphy resources and promotes the artistic value of calligraphy.

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