Application Practice and Implications of the International Image Interoperability Framework in Foreign University Libraries: Postprint

Authors: Chen Dan, Zhang Yi

Date: 2023-04-01T00:00:00+00:00

Abstract

[Purpose/Significance] By analyzing and summarizing the application of the International Image Interoperability Framework (IIIF) in foreign university libraries, this study provides references for domestic university libraries in constructing IIIF digital resources. [Method/Process] Taking university libraries that have joined the IIIF Consortium as research subjects, this paper summarizes and concludes the application experience of IIIF in foreign university libraries from several aspects: image sources, image viewers and image servers, website functionality, technical parameters, project foundation, and management teams. [Results/Conclusion] University libraries need to focus on the open sharing of library resources when implementing IIIF practices, adopt a project-based and technology-driven approach, develop IIIF construction plans according to image content and user needs, while also tracking IIIF development trends in a timely manner and utilizing community resources to provide assistance to digital humanities scholars.

Full Text

Application Practices and Implications of the International Image Interoperability Framework in Foreign University Libraries

Chen Dan, Zhang Yi
East China Normal University Library, Shanghai 200241

Abstract: [Purpose/Significance] This study analyzes and summarizes the application of the International Image Interoperability Framework (IIIF) in foreign university libraries to provide reference for domestic university libraries constructing IIIF digital resources. [Method/Process] Taking university libraries

that are members of the IIIF Consortium as research subjects, this paper summarizes the application experience of IIIF in foreign university libraries from six aspects: image sources, image viewers and image servers, website functions, technical parameters, project basis, and management teams. [Result/Conclusion] University libraries should focus on the open sharing of library resources in IIIF practice, rely on projects and employ technology as means, conduct IIIF construction planning according to image content and user needs, and simultaneously track IIIF development trends in a timely manner to utilize community resources for supporting digital humanities scholars.

Keywords: IIIF; university libraries; image resources; digital resources

The International Image Interoperability Framework (IIIF) is an emerging open data framework that defines common standards for describing and delivering images on the web [1], while addressing issues such as the difficulty in discovering, reusing, citing, exchanging, and comparatively analyzing digital resource images [2]. Proposed in 2011, the framework was officially established on June 18, 2015, by 29 non-profit institutions including the British Library, the National Library of New Zealand, Europeana, Oxford University Library, and Harvard University, aiming to ensure global interoperability and accessibility of image storage and to provide unified display and use of online resources such as books, maps, scrolls, manuscripts, musical scores, and archival materials carried by images [3-4].

IIIF has outstanding features and achievements in image management and display, including the ability to migrate from existing systems, recombine resources provided by various parties, and enable direct user annotation [5]. Currently, many world-leading libraries, archives, and museums have adopted this framework, particularly some university libraries (such as Stanford University Library and Cambridge University Library) that have achieved remarkable results in applying IIIF to digital resources [6]. In China, few university libraries have used IIIF for digital collection construction; Xiamen University Library was among the early adopters. Xiamen University Library employs the Loris2 image server to publish high-definition images of over a million digitized special collections, while developing specialized IIIF extension modules based on its own needs and integrating the IIIF image viewer OpenSeadragon to provide online browsing of special collections [7]. By the end of 2019, Fudan University Library also introduced IIIF to provide library users with access to collection image resources. When users search records in the library catalog or visit the "Virtual Library of Seal Literature," digital image records that support IIIF feature an IIIF icon, which users can click to open the IIIF viewer and access images [8].

Overall, foreign university libraries started earlier with IIIF application and have accumulated more experience. Meanwhile, scholars have already summarized the application of IIIF in some foreign public libraries [9-10]. This study focuses on foreign university libraries that apply IIIF, using web surveys and literature research methods to summarize the application experience and recommendations of IIIF in university libraries.

1 Introduction to the IIIF Technical Framework and Consortium

IIIF encompasses two concepts. First, IIIF is a set of open standards that help archives, libraries, and museums achieve fine-grained interoperability of image resources from different institutions through their image APIs. Second, IIIF also refers to the community of users and developers who continuously work to enrich the IIIF ecosystem and advocate for broader adoption of these standards —the latter concept is also known as the "IIIF Community" [11]. The IIIF Community comprises libraries, museums, archives, software companies, and other organizations that jointly create, test, refine, implement, and advance IIIF performance specifications [11].

The primary goals of IIIF are threefold: first, to provide unified and rich standards for scholars to access image resources worldwide; second, to define a set of common application programming interfaces that support interoperability between image repositories; and third, to guide the development, cultivation, and documentation of shared technologies among IIIF community members, such as image servers and viewers that enable users to view, compare, and annotate images [12-13].

1.1 Technical Framework

IIIF is based on HTTP technology and provides various Application Programming Interfaces (APIs) to enable open harvesting of internet image resources [10]. These APIs include the Image API, Presentation API, Content Search API, and Authentication API, with the first two being core APIs and the latter two being extension APIs [4, 14].

IIIF also requires specialized image viewing clients/image viewers and image servers to support image display and storage functions. The image viewers recommended on the IIIF official website include Mirador, UniversalViewer, Diva.js, IIIF Curation Viewer, IIPMooViewer, OpenSeadragon, Leaflet-IIIF, TIFY, CanvasPanel, OpenLayers, and Micrio Service. Image servers mainly include Cantaloupe, IIP Image Server, Loris, Ruby Advanced Image Server (RAIS), ContentDM, Djatoka, FSI Server, digilib, Riiif, Hymir IIIF Server, and go-iiif [15-16]. Generally, image viewers can only browse images from a single institution, but IIIF image viewers not only fully support IIIF open standards but can also present images from any institution that supports IIIF standards [17]. Institutions provide IIIF storage endpoints for their resources and allow anyone to share resources through IIIF-compatible viewers, which has led to an unprecedented number of institutions making their resources publicly available to support sharing [18].

1.2 Consortium

IIIF includes a large and growing community of interested individuals and institutions, as well as a consortium dedicated to leading and maintaining IIIF,

known as the "IIIF Consortium" (IIIF-C), whose responsibility is to support the development and application of IIIF [19]. IIIF-C is the formal entity responsible for business affairs, promoting organizational work within the IIIF community, and supporting technical development of the IIIF community. It was established in Oxford, UK, in June 2015 to provide guidance and maintenance for the IIIF community [20]. The difference between IIIF-C and the IIIF Community is that IIIF-C members sign a memorandum and commit to donating $10,000 annually to support IIIF development. The IIIF Community has a broader scope, including institutions that have applied IIIF APIs in their repositories, software developers, technology companies that create IIIF-compatible software applications, and participants actively involved in community discussions, but does not include IIIF-C members [21].

IIIF-C currently comprises over 40 founding members worldwide, including national libraries, universities and university libraries, museums, art galleries, institutional organizations, EU projects, non-profit databases, foundations, etc., among which there are 33 university members including Cambridge University, Stanford University, Brown University, Harvard University, etc. (as shown in Table 1) [22]. These university members started early with IIIF application and have mature development. As IIIF-C members, they play an important leading, guiding, and advancing role in IIIF application, and their practical experience is representative. The majority of university members have libraries as the units practicing IIIF. This study selects foreign university libraries as research subjects and uses their digital image resource repositories that employ IIIF as the main data source to summarize their IIIF application practices and explore the application status of IIIF in university libraries.

2 Application Status of IIIF in Foreign University Libraries

2.1 Image Sources

2.1.1 Self-built Resource Repositories The vast majority of university libraries use their digital resource repositories as the objects of IIIF practice. These digital repositories are mostly self-built libraries, i.e., images scanned from the library' s or university' s own digital resources, which are integrated and presented using IIIF interfaces. The second column of Table 2 summarizes the names of digital resource repositories built by some university libraries that are members of IIIF-C and support IIIF. For example, the Harvard Digital Collections established by Harvard University Library provides over 6 million digitized objects for free public access, including ancient art, modern manuscripts, and some audio-visual materials. All image content in this repository is published using IIIF standards, and each content object has IIIF manifests. Through these manifest links, images can be opened in any IIIF-compatible image viewer and can also be embedded in any database supporting IIIF interfaces [23].

In addition to building new resource repositories, university libraries can also upgrade existing digital repositories to support IIIF standards. The Sheridan

Libraries of Johns Hopkins University upgraded its existing Digital Library of Medieval Manuscripts (DLMM). The 2017 version of DLMM adopted IIIF viewers to assist image browsing and manipulation. The Sheridan Libraries believe that IIIF viewers not only provide users with a universal platform for viewing high-resolution manuscript images but also make the library part of the IIIF team, enabling better sharing of data wealth [24]. Some university library digital repositories do not support IIIF for the entire repository, but only partially. For example, in the University of Michigan Library Digital Collections, only the University of Michigan Museum of Zoology Collection [25] and the Mushinouta Awase Maki scroll collection [26] support IIIF image display.

2.1.2 Other Sources In addition to practicing IIIF on self-built resources, some university libraries also obtain digital content from image databases and open-source websites to enrich their IIIF digital resources. For instance, the content in the Digital Collections of Cornell University Library (CUL) includes not only text content migrated from the Digital Library eXtension Service (DLXS) that the library has discontinued, but also streaming media audio-visual files from the ARTstor database and the open-source video website Kaltura. In addition, CUL plans to add content from the HathiTrust Digital Library project, the CUL institutional repository eCommons, and custom digital collections created on other platforms such as Drupal to the website. Each image in the repository not only uses IIIF viewers for browsing and manipulation by default but also supports direct opening in the ARTstor database. In the ARTstor database, users can not only cite items and print previews but also create groups for managing images [31, 42]. IIIF allows resources from other institutions to be embedded into one' s own institutional repository, enabling university libraries to enrich their repository content through this method.

2.2 Image Viewers and Image Servers

2.2.1 Image Viewers Fu Yue' an briefly introduced some commonly used IIIF image viewers [4], and Geng Manman comparatively analyzed four image viewers (OpenSeadragon, Leaflet-IIIF, Mirador, UniversalViewer) [9]. The author' s investigation found that the IIIF image viewers most commonly used in university libraries are Mirador, OpenSeadragon, and UniversalViewer.

In terms of application in university libraries, many have adopted Mirador as the default IIIF image viewer, such as Harvard University, Cambridge University, the University of Toronto, and the Sheridan Libraries of Johns Hopkins University (see the third column of Table 2). Mirador was initially developed by Stanford University and is currently jointly extended and developed with Harvard University, the National Gallery of Art, and several other institutions worldwide [17]. Mirador is an open-source, web-based, multi-window image viewing platform that supports zooming, displaying, comparing, and annotating images from image repositories scattered around the world. It is configurable, extensible, and easy to integrate, and can be optimized to display resources

from repositories supporting IIIF APIs. Mirador provides a tiled window environment for comparing multiple image resources, supports synchronized content structure and visual navigation using OpenSeadragon, and annotation in OpenAnnotation-compatible formats [43]. OpenSeadragon provides deep zoom functionality support for Mirador to render very large objects [44], and Cornell University Library directly uses OpenSeadragon as its default IIIF image viewer. In addition, Indiana University Library and North Carolina State University Library use UniversalViewer to present IIIF images.

Many university libraries provide multiple optional IIIF image viewers, allowing users to choose their preferred viewer to open image files. For example, although the University of Edinburgh uses OpenSeadragon as its default viewer, it also provides Mirador and UniversalViewer icons below each image, and users can click the icons to open the image in the corresponding viewer [45]. The Brown University Library Digital Repository not only provides Mirador and UniversalViewer but also offers multiple view forms according to different image content. In addition to the common book view (BookView), it also provides portfolio view (PortfolioViewer), detailed image view (DetailedImageViewer), medium resolution view (MediumResolution), and other view forms [32]. The "Digital Archive of Rare Materials of Kyoto University" established by Kyoto University Library in Japan also uses UniversalViewer and Mirador [41]; while the Kansai University Digital Archives allows users to choose UniversalViewer, Mirador, and IIIF CurationViewer to open and manipulate images [40].

From a practical operation perspective, users only need to obtain the IIIF manifest of an image to directly copy it into IIIF image viewers such as Mirador or UniversalViewer for opening and manipulation. For images in the Stanford University Library' s digital repository (Stanford Digital Repository), users can use any IIIF-compatible image viewer to open images. All resource fields in the repository have an IIIF icon, which users can drag to any IIIF-compatible image viewer to open the image. Different browsers allow different operations on images. Since Stanford University developed Mirador itself, it recommends using Mirador as the primary tool for accessing IIIF resources [27].

2.2.2 Image Servers While image viewers can be directly observed from the repository, the image servers used by repositories are more difficult to identify directly, with only some university libraries providing introductions to the image servers they use. For example, the Cambridge Digital Library established by Cambridge University Library uses the IIP Image Server, which uses an evaluation version of the Kakadu JPEG2000 software to decode JP2 images [48]; the University of Toronto Libraries Digital Collections image repository uses the Loris image server, which retrieves images from the repository and provides a caching layer [49]. Different image servers vary in programming language, supported versions of the IIIF Image API, and whether they are open source, allowing university libraries to select image servers according to their needs [4, 9].

2.3 Website Functions

2.3.1 Navigation and Image Retrieval Stanford University, the University of Toronto, and other university libraries provide not only search functions but also navigation directories based on fields to facilitate better resource discovery for users. Stanford University Library integrates all IIIF resources, allowing users to filter required resources using multiple fields such as resource type, library location, language, author, and subject [27]. The portal website of Cornell University Library' s Digital Collections aggregates digital collection resources in a single interface to help users more conveniently obtain and discover these resources, allowing users to conduct categorical searches and navigation browsing [31]; Oxford University Library' s Digital Bodleian uses the Dublin Core Metadata Standard to set unified search conditions during the resource metadata processing stage [12]; Harvard University Library' s digital repository uses the Library Cloud API to support searching of the library cloud and obtains results in standardized MODS or Dublin Core element set formats [23].

2.3.2 Image Manipulation IIIF-supporting images can be manipulated differently depending on the image viewer used. Taking Mirador as an example, after opening the image viewer, users can drag the IIIF icon into the viewer or copy the IIIF manifest into the viewer to open the image. Mirador supports multiple operations on images, including: zooming in, zooming out, and rotating images; adjusting image brightness, contrast, color saturation, grayscale, and inversion; adding annotations in various shapes and colors; and adding multiple slots to facilitate image comparison [27].

2.3.3 Image Download The vast majority of university libraries' IIIF digital resources provide download functions, such as the University of Toronto, Cambridge University, and Cornell University. Cambridge University Library not only provides image download functions but also supports downloading image metadata [30]. The Brown University Library Digital Repository provides downloads of images in multiple resolutions, including high-resolution, medium-resolution, and low-resolution versions, while users can also download MODS, metadata, and image information files [32].

2.3.4 Image Upload In addition to downloading images, some university libraries also provide image upload functions. Yale University' s "Ten Thousand Rooms Project" platform is a collaborative workspace for pre-modern text research. Based on the Mirador viewer, the platform allows users to upload images of manuscripts, printed materials, inscriptions, and other sources, while also supporting transcription, translation, and annotation projects around images [50-51]. The Brown University Library Digital Repository also supports users uploading their own image files, some of which can support IIIF display. Uploaded images are made publicly accessible by default [52].

2.3.5 Other Functions In IIIF practice, other functions can be added. For example, the Cornell University Library Digital Collections provides a map display function. Some resources in the repository have location data fields, and the library provides a map interface for discovering geographically data projects, with resources displayed on the map according to location information [53].

2.4 Technical Parameters

IIIF uses APIs based on HTTP technology to achieve image presentation, retrieval, and other functions, relying on image viewers and image servers for IIIF support. In addition to the technical requirements specified by IIIF standards, university libraries can set various technical parameters for images according to their needs. Cambridge University Library' s requirements for static image preservation match the ISO/TR 18492:2005 Long-term preservation of electronic document-based information standard, using the 6-1 lossless profile for JPEG2000 encoding [48]. In Harvard University Library' s IIIF practice, in addition to providing IIIF Uniform Resource Identifier (URI) links for all library original data sources, it also relies on the Library Cloud metadata center to provide fine-grained open access to bibliographic metadata sets [23].

2.5 Project Basis

Project-based support is a common method used by foreign university libraries in building IIIF digital resources, relying on projects from schools, libraries, or other institutions to digitize library resources and provide IIIF support. In 2015, Cambridge University Library received funding from the Andrew W. Mellon Foundation to conduct a research project on using IIIF as a means to deliver digitized images and data. The project' s goals were to investigate relevant potential issues and develop a clear plan and roadmap for future IIIF adoption within the university and broader applications. The main research content involved gaining in-depth understanding of workflows and tools and exploring digital preservation requirements, with a particularly important step being the evaluation of various technical parameters of the JPEG2000 image format and where and how to use it appropriately. The project' s vision was to develop a Cambridge Digital Library prototype implementing IIIF, containing approximately 1,000 digital samples. Ultimately, Cambridge University Library not only built an IIIF-compatible digital library prototype but also directly integrated it into the library website. This digital library currently has nearly 250,000 images, and all related data can be obtained through IIIF [48].

The Swiss Federal Institute of Technology in Lausanne and the University of Venice jointly launched an international digital humanities project in 2012 called the Venice Time Machine Project, which is part of the Time Machine Europe project [54]. In 2017, the two universities jointly created the first version of the Time Machine Box, a server installed at scanning sites where all scanned documents and metadata are saved and can be easily accessed through the IIIF protocol. The Time Machine Box allows any research organization to ana-

lyze existing images and allows the use of IIIF-standard-compatible algorithms for document segmentation or handwriting recognition operations. By October 2017, the Venice Time Machine Project had completed the digitization of 190,000 archival documents, 720,000 image files, and 3,000 books covering 200 years of Venetian history, obtaining over 2 million digital images [55].

2.6 Management Teams

The vast majority of universities have libraries leading IIIF practice for university digital collections. Generally, university library technology teams are responsible for the specific development and management of IIIF resources and collaborate with other departments. For example, the University of Toronto Library' s Information Technology Services Department and its Digital Projects Team are responsible for the construction and service of its digital repository. The Digital Projects Team focuses on collaborating with faculty to design and develop network resources and services, while also being responsible for creating and maintaining digital collections [29].

The Cornell University Library Digital Collections repository was jointly established in December 2015 by CUL' s Digital Scholarship and Preservation Services Department, Information Technology Department, and Library Technical Services Department, primarily using Blacklight, SOLR, Fedora, and IIIF as technical support. The website is currently maintained by the Digital Consulting & Production Services Department [42].

3 Implications for IIIF Application in University Libraries

3.1 Open Sharing of University Library Resources

When constructing IIIF resources, university libraries must first determine whether to digitize their collection image resources or obtain images from other websites or databases. Digitizing the library' s special collection resources is a common form of IIIF application in university libraries. IIIF is an open standard, and IIIF-supported image resources also support global sharing and collaboration. Therefore, university libraries need to evaluate the openness and socialization of their special collection resources and select image resources suitable for IIIF standards. Using IIIF standards to achieve open sharing of the library' s unique resources can not only enhance the value of special collection resources but also promote worldwide communication, exchange, and collaboration.

3.2 Relying on Projects and Employing Technology as Means

University libraries can rely on their own or collaborative projects to carry out IIIF resource construction. Adopting a project-driven approach allows for seeking cooperation and support from various aspects such as resources, technology, and funding, and gradually advancing the overall project through the comple-

tion of sub-projects, which has strong operability [12]. In terms of technology, IIIF structurally expresses image data in non-textual data, requiring clear specification of metadata requirements for each resource type [5], which enables users to more conveniently and quickly retrieve needed image files. For facilitating resource discovery and retrieval, image resource metadata compilation is a crucial component. Using the Dublin Core metadata set to describe image resources is the most common and straightforward method. In terms of IIIF resource expansion functions, adding map displays, providing multiple view modes, and allowing user participation in resource construction can all promote the application and development of IIIF.

3.3 Conducting IIIF Construction Planning According to Image Content and User Needs

When using IIIF to build digital image resources, libraries need to consider several issues in advance. First, what are the image content and background owned by the institution, requiring analysis of existing image resources? Second, it is necessary to understand user experience expectations and user needs, and to confirm existing technologies and infrastructure frameworks, discovery environments and workflows, as well as permissions and required access controls [56]. In terms of selecting tools such as image viewers and image servers, since IIIF supports viewing and manipulating resources from any source that meets IIIF standards in any image viewer, users can freely choose viewers [4]. However, generally speaking, each IIIF resource platform needs to set a default viewer for readers to use, and different IIIF image viewers have different characteristics, such as whether they are open source, whether they support annotation, and whether they support metadata display [9]. Foreign university libraries more often select the Mirador viewer, while domestic Fudan University Library also provides an IIIF-compatible image viewer based on open source—Mirador viewer for users to access images [57]. To meet users' diverse browser needs, resource platforms can also provide multiple image viewers for selection. Xiamen University Library deployed the Loris2 image server to implement IIIF image interfaces, while using Omeka S as its special collection digital resource management platform. Omeka S is an open and flexible open-source management system with open data structures and interfaces, capable of flexibly adding or removing functional modules, customizing user interfaces, and allowing third-party data calls [7].

3.4 Tracking IIIF Development Trends in a Timely Manner

According to the latest information on the IIIF official website, IIIF can currently handle audio-visual materials. The third version of the Presentation API (Beta) allows time-based media to be added to canvases while allowing users to add annotations to specific time points or temporal segments of these materials [10]. Meanwhile, although there is not yet an IIIF specification standard for 3D objects, an IIIF 3D Alliance Team has been established. The team' s

goal is to collect members' requirements for 3D data interoperability, explore the possibilities of viewing, searching, discovering, and annotating 3D data by evaluating the 3D technology requirements of the web cultural heritage community [58]. University libraries applying IIIF need to track IIIF development trends in a timely manner and attempt to apply new IIIF developments to their repositories. Libraries joining the IIIF community can also participate in IIIF development discussions and practices, sharing source code with other members through Google Forums, Google Calendar, Google Drive, GitHub, etc., to jointly promote IIIF development.

3.5 Leveraging Consortium Resource Advantages to Support Digital Humanities

After joining the IIIF community, university libraries can not only add their own resources but also use resources from other member institutions in the consortium. Using resources from the community, university libraries can combine their own needs with machine learning and other means to help scholars discover needed resources. For example, the IIIF Curation Finder, an IIIF-compatible image search tool developed in Japan, has added facial collection functionality and introduced machine learning for automatic image tagging, employing classification algorithms developed for the OpenImages Dataset V2 that includes adding tags to images [59]. Through this facial collection, users can retrieve facial information in related images through keyword searches and can better conduct comparative research, promoting the development of digital humanities.

4 Conclusion and Outlook

Based on a brief introduction to the IIIF technical framework, this study conducted in-depth research and exploration on the IIIF application status of well-known foreign university libraries, and summarized certain experiences and implications based on IIIF application practices. These experiences and implications can also be referenced by institutions other than university libraries. For university libraries, issues such as how to present, interact with, and share digital resource images are particularly prominent, and IIIF is a viable solution. IIIF has many advantages in digital collection image construction, such as plug-and-play IIIF server and client software, allowing content integration from other resources, enabling user self-annotation, obtaining support and content from the global network, and promoting citation and controlled resource sharing [56]. Foreign university libraries have accumulated rich experience in IIIF application, but currently few libraries in China use IIIF for digital collection construction, and even fewer university libraries. Although IIIF application in China is still in the exploratory stage [2], domestic scholars have begun to catch up. Some public libraries (such as Shanghai Library [60]), digital humanities institutions (such as the East China Normal University Digital Humanities Research Support Platform [61]), and university libraries (such as Fudan University Library and Xiamen University Library) have already applied IIIF to image re-

source construction. To facilitate exchanges among domestic IIIF scholars, an IIIF-China WeChat group and official Bilibili video account have been established. The community encourages participants to translate IIIF lecture videos into Chinese and publish videos with Chinese subtitles on the official video account for interested scholars to learn and exchange. The IIIF-China community is also preparing to establish IIIF Baidu Tieba, Douban IIIF groups, IIIF resource Baidu Netdisk, and other exchange areas to promote IIIF development and practice in China. Therefore, it can be expected that the role and advantages of IIIF in digital image resources are gradually being discovered. Through further summarization and research of practical experience, the scope of IIIF practice in China will gradually expand, continuously promoting digital resource construction and digital humanities development.

References:

[1] SNYDMAN S, SANDERSON R, CRAMER T. The International Image Interoperability Framework (IIIF): a community & technology approach for web-based images [EB/OL]. [2020-01-03]. https://iiif.io/community/faq/.

[2] ZHANG Yongjuan, LIU Wei, YU Jianrong, et al. Research on seal resource integration and knowledge discovery based on IIIF and semantic knowledge graph [J]. Library and Information Service, 2020, 64(7): 127-135.

[3] National Library of China Research Institute. Establishment of the International Image Interoperability Organization [J]. Journal of the National Library of China, 2015, 24(4): 66.

[4] FU Yue' an. International Image Interoperability Framework and its application in digital resource integration [J/OL]. Library Tribune: 1-9. [2020-04-09]. http://kns.cnki.net/kcms/detail/44.1306.g2.20191021.2140.006.html.

[5] ZENG Lei, WANG Xiaoguang, FAN Wei. Smart data in the field of libraries, archives, and museums and its role in digital humanities research [J]. Journal of Library Science in China, 2018, 44(1): 17-34.

[6] WARNER S. IIIF introduction and opportunities at Cornell [EB/OL]. [2020-01-15]. https://www.slideshare.net/simeon-warner/2015-01-cornellvrwgiiif.

[7] CHEN Xiaoliang, SU Haichao, LIU Xinshun. Exploration of structured data for library special collections [J]. Library Journal, 2019, 38(6): 44-48, 91.

[8] Fudan University Library. Introduction to IIIF image service [EB/OL]. [2020-03-03]. http://www.library.fudan.edu.cn/2020/0305/c1313a156261/page.htm.

[9] GENG Manman. Development and utilization of library image resources: International Image Interoperability Framework [J]. Research on Library Science, 2019(18): 37-45.

[10] ZHANG Yi. International Image Interoperability Framework and its application analysis [J]. Digital Library Forum, 2019(5): 42-49.

[11] IIIF. IIIF frequently asked questions (faqs) [EB/OL]. [2020-01-03]. https://iiif.io/community/faq/.

[12] IIIF. About IIIF [EB/OL]. [2020-02-21]. https://iiif.io/about/.

[13] WEN Feng, LUO Yahong. Virtual extension: Construction and enlightenment of Oxford University Library' s "Digital Bodleian" [J]. Research on Library Science, 2018(19): 89-96.

[14] IIIF. Technical details [EB/OL]. [2020-01-03]. https://iiif.io/technical-details/#core-apis.

[15] IIIF. Apps and demos [EB/OL]. [2020-01-03]. https://iiif.io/apps-demos/.

[16] KOU Jingjing, WU Zhenxin. Research progress on long-term preservation practices of foreign image resources [J]. Library and Information Service, 2017, 61(23): 138-144.

[17] Stanford Libraries. What is IIIF? [EB/OL]. [2020-03-03]. https://library.stanford.edu/projects/internation image-interoperability-framework/viewers.

[18] Harvard University. About IIIF [EB/OL]. [2020-02-21]. https://iiif.harvard.edu/about-iiif/.

[19] IIIF. Community [EB/OL]. [2020-10-04]. https://iiif.io/community/.

[20] IIIF. Next steps for the International Image Interoperability Framework [EB/OL]. [2020-10-04]. https://iiif.io/community/consortium/next_{steps}/#180411-final-version.

[21] IIIF. IIIF consortium frequently asked questions (faqs) [EB/OL]. [2020-10-04]. https://iiif.io/community/consortium/faq/#why-iiif.

[22] IIIF. IIIF consortium [EB/OL]. [2020-02-21]. https://iiif.io/community/consortium/#the-iiif-consortium.

[23] Harvard University. IIIF at Harvard Library [EB/OL]. [2020-03-10]. https://iiif.harvard.edu/collaborators/harvard-library/.

[24] Johns Hopkins Sheridan Libraries. Digital library of medieval manuscripts [EB/OL]. [2020-02-21]. https://dlmm.library.jhu.edu/en/digital-library-of-medieval-manuscripts/.

[25] University of Michigan Library. University of Michigan Museum of Zoology, herpetology predator and prey collection [EB/OL]. [2020-03-21]. https://quod.lib.umich.edu/r/rept3ic?Page=index.

[26] University of Michigan Library. Mushinouta awasemaki [EB/OL]. [2020-03-21]. https://quod.lib.umich.edu/a/asialibrary1ic?Page=index.

[27] Stanford Libraries. Digital collections [EB/OL]. [2020-01-12]. https://searchworks.stanford.edu/catalog?F%

[28] Harvard Library. Harvard digital collections [EB/OL]. [2020-03-08]. https://library.harvard.edu/digital-collections.

[29] University of Toronto Libraries. Collections U of T [EB/OL]. [2020-01-08]. https://collections.library.utoronto.ca/index.html.

[30] Cambridge University Library. Cambridge digital library [EB/OL]. [2020-03-10]. https://cudl.lib.cam.ac.uk/.

[31] Cornell University Library. Digital collections [EB/OL]. [2020-01-15]. https://digital.library.cornell.edu/.

[32] Brown University Library. Brown digital repository [EB/OL]. [2020-03-10]. https://repository.library.brown.edu/studio/.

[33] Indiana University Library. Pages online [EB/OL]. [2020-03-15]. https://pages.dlib.indiana.edu/.

[34] NC State University Libraries. Rare and unique digital collections [EB/OL]. [2020-03-21]. https://d.lib.ncsu.edu/colle/collections/.

[35] Penn State University Libraries. Pennsylvania newspaper archive [EB/OL]. [2020-02-23]. https://panewsarchive.psu.edu/.

[36] Penn State University Libraries. Colenda digital repository [EB/OL]. [2020-02-23]. https://colenda.library.upenn.edu/.

[37] University of Michigan Library. Digital content & collections [EB/OL]. [2020-03-21]. https://www.lib.umich.edu/digital-content-collections/.

[38] Edinburgh University Library. Art collection [EB/OL]. [2020-03-21]. https://collections.ed.ac.uk/art/.

[39] University of Oxford Bodleian Libraries. Digital Bodleian [EB/OL]. [2020-03-10]. https://digital.bodleian.ox.ac.uk/.

[40] Kansai University Library. Kansai University Digital Archives. Face Collection [EB/OL]. [2020-04-15]. http://codh.rois.ac.jp/face/.

[41] Kyoto University Library. Digital archive of rare materials of Kyoto University [EB/OL]. [2020-04-15]. https://rarebooks.kulib.kyoto-u.ac.jp/en.

[42] Cornell University Library. About [EB/OL]. [2020-01-15]. https://digital.library.cornell.edu/about/.

[43] Mirador. Home [EB/OL]. [2020-03-15]. https://projectmirador.org/.

[44] Harvard University. Mirador [EB/OL]. [2020-03-15]. https://iiif.harvard.edu/mirador-viewer/.

[45] Edinburgh University Library. IIIF [EB/OL]. [2020-03-21]. https://collections.ed.ac.uk/art/iiif.

[46] University of Tokyo. IIIF discovery in Japan [EB/OL]. [2020-03-21]. http://iiif2.dl.itc.u-tokyo.ac.jp/s/iiif/page/home.

[47] Culture Japan [EB/OL]. [2020-10-04]. https://cultural.jp/.

[48] Cambridge University Library. The dynamic digital library-a IIIF scoping project [EB/OL]. [2020-01-15]. https://www.lib.cam.ac.uk/research/digital-humanities/case-studies/dynamic-digital-library-iiif-scoping-project.

[49] BABCOCK K, LEE S, RAJAKUMAR J, et al. Where do we go from here: a review of technology solutions for providing access to digital collections [EB/OL]. [2020-10-05]. https://journal.code4lib.org/articles/15000.

[50] Yale University. Ten thousand rooms project [EB/OL]. [2020-02-21]. https://tenthousandrooms.yale.edu/project/tekagami.

[51] LI Youren, SONG Yingchun. Analysis of digital humanities research on China in North America and Western Europe [J]. Shandong Social Sciences, 2018(7): 54-58, 63.

[52] Brown University Library. Brown digital repository [EB/OL]. [2020-03-10]. https://repository.library.brown.edu/studio/.

[53] Cornell University Library. Digital collections [EB/OL]. [2020-01-15]. https://digital.library.cornell.edu/.

[54] Venice Time Machine Project [EB/OL]. [2020-03-21]. https://venicetimemachine.it/.

[55] Time Machine Europe [EB/OL]. [2020-03-21]. https://timemachine.eu/.

[56] IIIF. IIIF community [EB/OL]. [2020-10-04]. https://iiif.io/community/.

[57] Fudan University Library. Introduction to IIIF image service [EB/OL]. [2020-03-05]. http://www.library.fudan.edu.cn/2020/0305/c1313a156261/page.htm.

[58] IIIF. 3D technical discussion group [EB/OL]. [2020-10-04]. https://iiif.io/community/groups/3d/.

[59] IIIF Curation Finder [EB/OL]. [2020-10-04]. https://iiif-curation-finder.example.com/.

[60] Shanghai Library. Shanghai Library genealogy [EB/OL]. [2020-10-04]. http://wrd2016.library.sh.cn/channel/stjp/.

[61] East China Normal University Digital Humanities Research Support Platform. Modern Chinese painting and calligraphy print database [EB/OL]. [2020-10-04]. http://dhrsp.ecnu.edu.cn/.

Author Contributions:
Chen Dan: Main content writing;
Zhang Yi: Proposed the research topic, paper revision.

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