Development of an Evaluation Index System for Digital Library Microservices and Empirical Study: Postprint

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Abstract

[Purpose] Based on the human-information-technology interaction perspective, this study constructs an evaluation index system for digital library microservices, aiming to provide theoretical basis and evaluation criteria for digital library microservice construction. [Method] A group AHP method based on clustering methods is proposed and utilized to construct judgment matrices for evaluating the digital library microservice index system. The membership function in fuzzy mathematics is selected as the scaling system to conduct an empirical study on 10 representative digital libraries at home and abroad. [Results] Empirical results demonstrate that the index system possesses practical application value and strong operability, and can effectively guide digital libraries in microservice construction. [Limitations] Evaluation indicators, evaluation criteria, indicator weights, etc., require further in-depth analysis according to the specific conditions and problems of each digital library's microservices. The sample size of the empirical study is small, the conclusions have limitations, and the determination of indicators and assignment of scores (using a few expert scoring methods) are subjective. Conclusion At the theoretical level, the evaluation index system constructed based on the human-information-technology interaction perspective provides a new research perspective for digital library microservice construction; at the practical application level, through the evaluation of microservices, it enhances digital library microservice quality and efficiency, thereby achieving the goal of meeting user needs and expectations.

Full Text

Construction and Empirical Study of an Evaluation Index System for Digital Library Micro-Services

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Abstract

[**Objective**] From the perspective of human-information-technology interaction, this study constructs an evaluation index system for digital library micro-services, aiming to provide theoretical foundations and assessment criteria for digital library micro-service development. [**Methods**] We propose a group AHP method based on clustering techniques to construct judgment matrices for evaluating digital library micro-service index systems, and employ fuzzy mathematics membership functions as a scaling system to conduct an empirical study of ten representative digital libraries domestically and internationally. [**Results**] Empirical results demonstrate that the index system possesses practical application value and strong operability, offering better guidance for digital library micro-service construction. [**Limitations**] The evaluation indicators, criteria, and weights require further in-depth analysis based on specific conditions and problems of individual digital library micro-services. The empirical study suffers from a small sample size, limiting the generalizability of conclusions, and the determination of indicators and assignment of scores (based on a small expert panel) entail subjectivity. [**Conclusions**] At the theoretical level, the evaluation index system constructed from the human-information-technology interaction perspective provides a new research viewpoint for digital library micro-service development. At the practical level, evaluating micro-services can enhance their quality and efficiency, thereby meeting user needs and expectations.

Keywords: Digital Library; Micro-Services; Evaluation
Classification: G250.2; G258.6

Introduction

On May 13, 2015, the State Council executive meeting determined measures to accelerate the construction of high-speed broadband networks to promote speed enhancement and fee reduction, requiring urban broadband access rates to increase by more than 40% and 资费水平 to be lowered, while introducing services such as non-expiring data allowances and data transfer gifts [1]. Broadband speed improvements have effectively enhanced the efficiency of smart mobile internet access, and reduced costs have prompted digital library users to more frequently use mobile terminals to access streaming data and download various types of digital resources. The trend of "micro-services" through platforms such

as Weibo, WeChat, Yixin, and APPs for knowledge learning and acquisition has ushered us into a new micro-information era [2].

In this micro-era, the library community has recognized the importance of micro-services and begun exploring the application of micro-media such as Weibo, WeChat, and mobile applications in libraries. By leveraging new media platforms to present themselves and serve users, libraries have gradually established micro-service models adapted to micro-communication and accessible via mobile terminals. Micro-service applications not only provide ubiquitous mobile information services, drawing user attention to "micro" matters, changes, and focuses in their immediate surroundings, but also effectively compensate for deficiencies in traditional information service methods, enhancing library service convenience. Libraries have shifted from static information provision to dynamic, interactive information services, expanding the scope and influence of library services [3]. In particular, micro-service applications have profoundly impacted the information behavior of younger generations accustomed to network-based existence, moving from semi-closed internet environments to cross-domain mobile internet, while aligning with libraries' developmental requirements for iterative service innovation. However, it should be acknowledged that domestic library micro-service construction faces numerous problems, such as simplistic micro-service functionality, low adoption rates of micro-service application tools, and declining user stickiness [4]. This paper aims to provide theoretical foundations and evaluation criteria for digital library micro-service construction.

Digital Library Micro-Services

Micro-services themselves lack a strict definition, but scholars agree that micro-services are single-purpose, small-scale programs accessible via APIs [5]. Micro-service architecture (MSA) represents an architectural concept that achieves solution decoupling by decomposing functions into discrete services. MSA and service-oriented architecture (SOA) exhibit distinct characteristics in business capability, automated deployment, end-to-end integration, and decentralized control over languages and data [6-7]. The earliest micro-services provided personalized services for small and medium-sized enterprises [2]. Internationally, Twitter is the earliest and most famous micro-service platform, with other pioneers including Amazon, Netflix, and The Guardian [8-9], followed by domestic platforms such as Sina Weibo, Tencent Weibo, WeChat, and Taobao, which subsequently launched corresponding "micro-service" systems through open platforms.

For current digital library services, micro-services represent a novel concept. Library micro-services are information and knowledge services that, in the digital micro-era, center on user information needs, rely on various high-tech information technologies, and provide differentiated, personalized, and diversified services through mobile clients [2]. Unlike traditional library services, micro-services emphasize knowledge service delivery via mobile devices [10], and digital library micro-services realize functional modules with characteristics of

loose coupling, potential reusability, and independent autonomy [11]. Based on domestic and international research, this paper defines digital library micro-services as: simple applications built on micro-service architecture where digital libraries, user-centered, rely on electronic communications, network information, and digital multimedia technologies, enabling users to access convenient, personalized, differentiated, and nuanced knowledge services through mobile terminals.

Digital Library Micro-Service Evaluation

Evaluation focuses on information content and collections [13]. When processing raw data, digital resources should ensure applicability, accuracy, readability, timeliness, comprehensibility, informativeness, and low cost to provide appropriate digital resources for user groups with diverse backgrounds and changing needs. The primary purpose of digital library micro-service evaluation is determining how to provide additional assistance to help users complete tasks [13].

ServQUAL and LibQUAL are widely applied library service evaluation models [14-15]. Six evaluation indicators for digital library services include accuracy, courtesy, awareness, satisfaction, cost, and reuse [16]. Additional indicators from face-to-face library service evaluation include accessibility, reliability, service intervention differences before and after, and expectation-perception gaps. Furthermore, digital library micro-service evaluation standards incorporate information transmission lag and communication invisibility, such as response time and user control [10].

Although domestic research on library micro-service evaluation is abundant, it primarily concentrates on library micro-service quality evaluation, with few operational evaluation standard systems. As an emerging service form emphasizing public services based on technical foundations, digital library micro-services require different evaluation standard systems for different library services, as American library scientist Lancaster noted. Therefore, constructing a practical evaluation standard from the human-information-technology interaction perspective to assess digital library micro-service levels, dynamically track evaluation effects, and improve service quality holds significant theoretical and practical importance.

Evaluation Index System Construction

Digital library micro-service evaluation index system construction should follow principles of purpose, scientific rigor, operability, and guidance. Based on digital library micro-service characteristics and user demands, we constructed an evaluation index system comprising three primary indicators: human, information, and technology. The hierarchical relationships among index system components are shown in Table 1 . Each level of indicators expands from the previous level, with upper-level indicators reflected through lower-level results.

Domestic and international research primarily evaluates digital library micro-services from perspectives of user interaction, content, and services. (1) **Micro-service Subjects and Objects**: The intensity of micro-service implementation willingness among micro-service subjects directly affects micro-service effectiveness. Beyond libraries, micro-service subjects require close cooperation from operation and maintenance entities including mobile network operators, mobile application developers, and mobile terminal device manufacturers. The micro-service support capabilities of operation and maintenance entities significantly impact micro-service effectiveness from both technical and marketing perspectives. The increasing number of service subjects and service chain refinement means micro-services are influenced by multiple levels and cannot rely solely on libraries' own service levels and capabilities. Instead, they must promote collaboration among service subjects based on their functions and interactions to achieve good micro-service results [17].

Users, as micro-service objects, are direct perceivers of micro-service quality who assess and provide feedback on micro-services through interaction processes. Therefore, in digital library micro-information services, micro-service quality dimensions must also be evaluated based on user experience. Users' psychological factors during interaction—including cognition, emotion, and willingness—directly affect user experience, thereby influencing micro-service quality evaluation and user satisfaction. User factors such as usage frequency, browsing time, participation level, and the behavioral capability to acquire knowledge via mobile terminals directly impact micro-service effectiveness.

(2) **Micro-Service Quality**: Micro-services establish interaction between libraries and users through internet technology. Users can engage with libraries in interactive activities including user information, resource retrieval, information express delivery, and consultation through mobile networks and terminal devices. Micro-service quality represents users' subjective perception and evaluation of objective information quality indicators—such as content characteristics, functionality, and efficacy value—obtained through micro-service interactions. Micro-service quality evaluation indicators derive from users' real experiences during micro-service interactions, constituting a series of outcomes from interactive experiences. It represents users' experiential perception of information product functions, roles, values, and other attributes during information interaction, combined with their background information and experience. Micro-service quality is both users' fundamental experience of micro-service interaction "usefulness" and "value," and their deep understanding and reflection on micro-service interaction results' utility and value [18].

Micro-service interaction parties must timely "swap roles" to seriously experience and consider each other's cognition, emotion, and needs, thereby improving micro-service effectiveness. The richer, more understandable, and controllable the information micro-services provide via WeChat, Weibo, and APPs, the better the performance in user resource 停留时间, page views, and active user data,

effectively enhancing user satisfaction with micro-services. WeChat, as a library' s external information service window, extends library services to the public through information 推送, enabling full utilization of library resources. Micro-services are popular because they facilitate efficient information transfer during users' fragmented time. Therefore, digital library micro-service information must be reliable, complete, and accurate, and more importantly, must effectively integrate libraries' original massive resource information into short (even around 100-character) text or combined with images, maintaining timeliness and appropriate volume to avoid user information loss while effectively improving user satisfaction.

(3) **Micro-Service Technical Environment Quality**: Digital library micro-service interaction platforms comprise mobile clients, APPs, WAP sites, RSS feeds, WeChat public platforms, and official Weibo accounts. Technical environment quality dimensions are divided according to users' feelings, experiences, and perceptions of micro-service interaction platforms' basic functions and process performance during micro-service interactions. Smooth, stable information exchange during micro-service interaction processes ensures efficient information transmission. Operation interface aesthetics, clear navigation, retrieval systems conforming to user habits, and source code and display adaptation for different terminal devices directly affect user satisfaction. Micro-service technical environment quality should also ensure mobile network security with good access quality and data transmission quality. Through reasonable use of MSA micro-service platform architecture technology, cloud storage technology, and big data processing technology, multiple platforms can exchange data or achieve system integration, ensuring data can be shared and reasonably utilized.

Evaluation Method and Process

The Analytic Hierarchy Process (AHP) primarily involves decomposing complex systems into several constituent factors according to problem requirements, grouping these factors by their relationships to establish a hierarchical structure; conducting pairwise comparisons of system factor importance using a specific scale to construct judgment matrices, determining relative importance rankings of factors to upper-level factors; and obtaining decision factor importance rankings to objectives based on the hierarchical structure [20]. To reduce subjectivity in decision results, this paper proposes a group AHP method based on clustering techniques to construct judgment matrices [21], employing fuzzy mathematics membership functions [22] as a scaling system to evaluate digital library micro-service indicators. The specific algorithm 流程 is shown in Figure 1 [Figure 1: see original paper].

(1) **Construct judgment matrices and calculate weights**: The Delphi method is used to conduct hierarchical importance comparisons of evaluation system indicators, with relative importance of indicators as-

signed using the 1-9 scale method. Eight digital library experts (four library and information science professors and four digital library directors) provided scores to construct single-level comparison judgment matrices A_n×n. The completed expert judgment matrices are normalized.

(2) **Normalize each column element of the judgment matrix using formula (1), then sum the normalized matrix rows using formula (2) to obtain row vectors, normalize them using formula (3), and calculate the maximum eigenvalue using formula (4) [21]**: i, j 1, 2, i, j 1, 2, i, j 1, 2, (AW) W

(3) **Conduct standardization and consistency tests using C.R.=C.I./R.I., and delete judgment matrices failing consistency tests**. The calculated consistency index is C.I.=0.14. According to tables for different matrix orders, the average random consistency index is R.I.=1.45, yielding C.R.=0.097 (when C.R.<0.1, the judgment matrix consistency is considered acceptable) [22], resulting in a new judgment matrix R_n×n.

(4) **For the new judgment matrix R_n×n, use formula (5) [22] to obtain a new similarity matrix**. The similarity matrix obtained cannot be directly classified and must be transformed: R^2=R×R, R =R^2×R^2, R =R ×R =R . Therefore, R is selected as the fuzzy equivalence matrix, i.e., R*=R , enabling clustering. Based on the classification of individual expert ranking vectors and this study' s requirements, three categories are selected: Category 1 includes three experts numbered 5, 6, 7; Category 2 includes one expert numbered 4; Category 3 includes four experts numbered 1, 2, 3, 8.

(5) **New expert weights _i are obtained using formula (6) [21]**, where _i represents the weight of the i-th expert, t represents the number of clusters, and _p represents the number of individuals in each class. The calculated weight for Category 1 experts is 0.473, Category 2 experts is 0.094, and Category 3 experts is 0.155.

(6) **New primary indicator weights are obtained using formula (7) [21]**, where W_j represents new weights, K_i represents the weight of the i-th expert, and W_i represents original weights. Normalization is performed using formula (8) [21]. The final evaluation index system weight summary is shown in Table 2 .

Sample Selection and Evaluation Process

Sample Selection

A CNKI search using "digital library" in titles reveals research hotspots in descending order: university digital libraries, public digital libraries, and commercial digital libraries, with public digital libraries ranking high and having large user bases. Considering broad representativeness of research samples and consulting eight experts, we selected ten well-known domestic and international

digital libraries with high rankings and large user bases as empirical samples, as shown in Table 3 .

Evaluation Process

First, an expert evaluation group was established, comprising four library and information science professors and four digital library directors. The expert group possesses profound theoretical research foundations in digital library evaluation and rich practical experience in digital library micro-service technology and operation. Experts individually experienced the micro-service content of the ten digital libraries, simultaneously using relevant technical evaluation tools and recording quantitative data. Combining user experience, quantitative data, and industry expertise, the expert group scored evaluation system indicators using a five-point Likert scale (poor, fair, good, better, excellent). A triangular membership function (see formula (9)) served as the scaling system for empirical research on ten representative digital libraries domestically and internationally.

Data Results

Expert group scores were aggregated and fuzzified using formula (9), with d-c=0.5 and b-a=0.5, where a, b, c, d {1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5}. Indicator data were calculated using weights from Table 2, with final scores obtained via the maximum membership degree principle, as shown in Table 4 .

Discussion and Analysis

We discuss and analyze the evaluation data from ten digital library micro-services across three aspects.

(1) **Secondary indicator data reveal that key indicators affecting comprehensive digital library micro-service scores are technical implementation and interaction process quality**. This indicates that the core of digital library micro-services is front-end technology directly perceivable by users that affects their experience, representing the key to reducing user bounce rates and improving satisfaction. Simultaneously, providing rich data resources available for download is crucial for enhancing user loyalty. Comparing domestic and international libraries, foreign digital libraries score higher in technical support and push service result quality, reflecting that domestic digital libraries must improve micro-service technical support capabilities and emphasize digital resource construction from the human-information-technology interaction perspective. Domestic digital libraries score higher than foreign ones in technical implementation indicators, demonstrating that with the rise and openness of WeChat, Yixin, Weibo, and various micro-service platforms, China' s digital library micro-service technology implementation has achieved a leading position.

(2) **Comprehensive scores show that U.S. public digital libraries rank first with high scores across most indicators**. U.S. public digital library micro-services provide all resource information free for access and download, while simultaneously opening APIs for resource interaction and sharing, using APPs and WAP sites for information integration, and leveraging third-party micro-service platforms like Twitter for user services and interaction. Domestic digital library micro-services exhibit varying gaps in these aspects, particularly in free resource reading/downloading and open API resource interaction/sharing. U.S. public digital library micro-services establish a benchmark for strengthening micro-service construction globally. This study also notes uneven development of digital library micro-services both domestically and internationally, indicating that greater attention should be paid to micro-services as an important user traffic entry platform for planning, constructing, and enhancing digital library micro-services.

Overall, digital library micro-services generally exhibit the characteristic that public digital libraries outperform commercial digital libraries, which in turn outperform university digital libraries, demonstrating that national governments, non-profit organizations, and institutions can play crucial driving roles in digital library micro-service construction.

(3) **Digital library micro-services should emphasize harmonious development of "human-information-technology"** . U.S. public digital libraries possess professional micro-service operation and maintenance teams that enhance core competitiveness. University digital libraries, targeting core user groups, generally implement differentiated service strategies, strengthening digital library subjects' micro-service willingness and improving user behavioral capabilities. Information forms the foundation of digital library micro-services, with commercial digital libraries effectively improving user satisfaction by transmitting rich digital information to users timely and accurately. Technology serves as the guarantee for digital library micro-services. As an emerging service form, U.S. public digital libraries effectively employ advanced information technology to ensure efficient, timely, accurate, and massive information transmission while establishing broad traffic entry points from user perspectives. Domestic digital libraries should follow the development pace of foreign digital library micro-services, continuously learn from advanced foreign experiences, and sustainably improve domestic digital library micro-service levels.

Conclusion

From the human-information-technology interaction perspective and addressing digital library micro-service characteristics, this study constructed a digital library website micro-service evaluation index system. The Analytic Hierarchy Process determined indicator weights and verified indicator accuracy and reliability. At the application level, empirical analysis selected ten representative

digital libraries domestically and internationally as samples to validate and analyze the constructed index system. Empirical results demonstrate that the index system possesses practical application value and strong operability, offering better guidance for digital library micro-service construction.

Micro-service applications align with libraries' iterative service innovation development requirements. Digital library micro-service evaluation research constitutes a multi-level problem involving numerous factors and complex relationships. To increase decision result accuracy, this study proposes a group AHP method based on clustering techniques to construct judgment matrices, employing fuzzy mathematics membership functions as a scaling system for digital library micro-service indicator evaluation. However, several limitations require future research: evaluation indicators, criteria, and weights need further in-depth analysis according to specific digital library micro-service conditions and problems; the empirical study' s small sample size limits conclusions; and indicator determination and score assignment (using a small expert panel) entail subjectivity.

Future research will reduce subjective factors by programmatically accessing micro-service open platforms to obtain objective data and distributing large-scale questionnaires to obtain subjective data. Fuzzy data envelopment analysis will screen evaluation indicators to better meet digital library micro-service construction requirements, thereby improving digital library micro-service quality and efficiency through micro-service management and evaluation to meet user needs and expectations.

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Author Contributions

Bi Qiang: Proposed the research proposition and framework, revised the paper.
Liu Jian: Drafted the paper, constructed indicators, and conducted empirical research.
Ma Zhuo: Processed data and wrote the English abstract.

Conflict of Interest

All authors declare no conflict of interest.

Support Data

Support data is self-archived by authors, E-mail: tomosliu9999@126.com.
[1] Bi Qiang, Liu Jian. wenjuan.doc. Expert questionnaire for digital library micro-service evaluation index system.
[2] Bi Qiang, Liu Jian. wenjuandafen.xls. Expert scoring summary table for digital library micro-service evaluation index system.

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