

Research on Intelligent Response Services in Smart Libraries within IoT Environments - Postprint

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Abstract

[Purpose/Significance] The Internet of Things (IoT) has connected, strengthened, and enriched interconnections among things. Based on ubiquitous connectivity, clarifying the relationship between (context) perception and (intelligent) response facilitates a deeper understanding of the service connotation of smart libraries and further elucidates the path for intelligent enhancement of service capabilities. [Method/Process] First, we clarify the service research orientation of smart libraries in IoT environments, define the intelligent enhancement of service capabilities, and analyze the connotation of intelligent response services based on context awareness. Second, we explicitly propose an information service “perception-response” loop in IoT environments. Finally, we propose an intelligent response service framework for smart libraries. [Results/Conclusion] IoT amplifies the intensity and breadth of context awareness, making the user-centered connection network more explicit and enriched. The five-layer framework of intelligent response services—“context awareness-context modeling-context computing-resource response-intelligent adaptation”—provides a reference and action framework for smart library service design.

Full Text

Research on Intelligent Response Services of Smart Libraries in IoT Environments

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Abstract: [Purpose/Significance] The Internet of Things opens up, strengthens, and enriches connections between things. Based on ubiquitous connection,

clarifying the relationship between (contextual) awareness and (intelligent) response helps to better understand the service connotation of smart libraries and further clarify the intelligent improvement path of service capabilities. [Method/Process] Firstly, it clarifies the service research orientation of smart libraries in IoT environments, clarifies the intelligence of service capability improvement, and analyzes the connotation of intelligent response services based on contextual awareness; secondly, it explicitly proposes an information service “perception-response” loop in IoT environments; finally, it proposes a smart library intelligent response service framework. [Result/Conclusion] IoT amplifies the intensity and breadth of contextual awareness, making the user-centered connection network more visible and enriched. The five-layer framework of intelligent response services—“contextual awareness, contextual modeling, contextual computing, resource response, and intelligent adaptation”—provides a reference and action framework for smart library service design.

Keywords: IoT; smart library; intelligent response service

Classification Number: G250.7

“Perceiving China” is a localized, personified, and warm metaphor for the development of the Internet of Things (IoT) in China. Through the penetration of sensing technologies, IoT opens up connection channels between real-world objects, achieving seamless integration of the physical and information worlds. From the Internet, World Wide Web, social networks, mobile internet to IoT, the scope of connections has expanded to its maximum potential. Various real-world objects are connected to networks, making connections and interactions ubiquitous. “IoT Plus” is not merely a technology, but a force that profoundly influences individuals, organizations, and social development. From the perspective of things (technical devices) connecting everything, how will IoT impact library and information science work, which centers on connecting people with information/knowledge? How can we better conduct intelligent information services in the ubiquitous network space created by IoT? These are typical reflections on service transformation triggered by technological forces. In the perception and connection space constructed by IoT, this paper elaborates on the connotation and implementation path of intelligent response services in smart libraries through progressive analysis of contextual awareness and ubiquitous connection.

2. Service Research Orientation of Smart Libraries

Library and information institutions provide typical resource-driven services, establishing connections between people and information/knowledge. Resource assurance capability has always been the mission and professional advantage of these institutions. Digital libraries focus on resource construction, striving to embody resources as “broad, deep, extensive, and large.” Under the new technology ecosystem of “big intelligence, things, and cloud” (big data, artificial intelligence, IoT, cloud computing), the library and information science field has

actively engaged in theoretical discussions and practical explorations to adapt to the new technological environment and open data ecology.

Although smart libraries have not yet formed a unified, comprehensive definition, they are considered the next important developmental stage after digital libraries. Technology-driven transformation is a reality that library and information institutions must face—both an opportunity and a challenge. Specifically, technology serves as the forerunner, promoting continuous reform and development of resources and services. Similar to the rise of digital libraries, early smart libraries primarily originated from technology research, with related technical methods and application practices emerging first. For example, Yan Dong proposed that “Smart Library = Library + IoT + Cloud Computing + Intelligent Devices” [1], representing a typical technical analysis approach. With the development and implementation of new technology combination ecosystems, understanding of smart library connotations has gradually deepened, and interpretations of resource, service, and management intelligence have progressively unfolded.

Wang Shiwei believes that interconnection, efficiency, and convenience are the three major characteristics of smart libraries [2]. Interconnection, as the first characteristic, confirms the fundamental importance of “connection.” Chu Jingli believes that IoT and artificial intelligence technologies are the drivers of smart libraries, with intelligent management and smart services as application goals, proposing six characteristics of smart library services: ubiquitous service locations, virtualized service spaces, intelligent service means, integrated service methods, knowledge-based service content, and satisfactory service experience [3]. Evidently, service is the main aspect of smart library research and practice. Dong Xiaoxia et al. believe that smart libraries are a combination of perception intelligence and digital library service intelligence [4], which can be viewed as empowerment through perception based on digital library construction. The foundation for achieving perception intelligence is the interconnected data collection front-end mainly composed of sensors, and its manifestation is the elevation from document information services to higher-level knowledge services.

Without connection, meaning cannot be generated. Smart libraries do not exist in isolation; they should be viewed within IoT. IoT extends the reach of library and information institutions’ information services in all directions. Smart library service research requires an IoT perspective, recognizing the importance of connections brought by IoT. Rather than delving into IoT technology itself and its specifications, the focus should be on what new connection possibilities IoT brings or what potential connections are broken due to technical reasons and practical issues. This represents a huge management and technical challenge for library and information institutions.

The “intelligence” of smart libraries focuses primarily on the service level, essentially representing the intelligent enhancement of information/knowledge service capabilities. In simple terms, more thoughtful and attentive services. The connotation of service intelligence includes personalization and precision. In-

telligence leads personalization and precision, representing the overall goal of on-demand and adaptable services. Information service research should adhere to the essence of “connection,” involving two actions in the sequence of connection: perception and response. Perception is on the left side of connection, response on the right side. In smart libraries, perception and response form a closed service loop based on connection. Since there has been much existing research and discussion on contextual awareness (the left side of connection), this paper focuses on the service perspective, strengthening intelligent response (the right side of connection), and discussing the service path for achieving intelligent adaptation between quality library resources and service users.

3. Intelligent Response Services of Smart Libraries

3.1 Contextual Awareness Foundation of Smart Library Services

Contextual awareness is the probe for smart library services and the prerequisite for achieving connection foundations. Contextual awareness technology had extensive research even before the rise of IoT. Originating from pervasive computing research, it refers to “computer systems automatically sensing user status, physical environment status, computer system status, and human-computer interaction history to provide corresponding responses” [5]. Early contextual awareness technology research was mostly conducted in small-scale closed experimental environments. With the rapid development of sensor and network technologies and their integration in IoT, the connotation of contextual awareness has continuously enriched, and application fields have expanded from small-scale device interconnection experiments to various industries (such as cities, transportation, communities, libraries, supermarkets, etc.). Li Yingzhi et al. point out that contextual awareness utilizes the interconnected IoT and ubiquitous sensors to convert environmental information into formats understandable by computer systems, enabling rational analysis by algorithms [6]. In fact, IoT 打通了 sensor data collection and network communication data transmission, forming data flows to computer data analysis. The formation of data flows in IoT endows contextual awareness technology with service connotations oriented toward business scenarios.

Mo Tong et al. propose a contextual awareness service development method, suggesting that contextual awareness services should include core components such as “sensor data, context, events, scenarios, and services” [7]. Firstly, various sensing devices obtain underlying basic data to form sensor data; secondly, sensor data is abstractly described at the service business layer to form contextual information; thirdly, when contextual information meets business logic trigger conditions, contextual events are generated; next, several contextual information values in contextual events jointly depict the user environment; finally, contextual service execution is achieved.

From an information service perspective, contextual awareness is not the ultimate goal but merely the beginning. It identifies the status and characteristics

of service objects, laying the foundation for subsequent service development. Contextual awareness aims to better respond to user needs, thereby establishing a foundation for quality service content and experience. After contextual awareness, how to achieve intelligent response on top of collected and identified data is key. The next section analyzes intelligent response and its technical connotation, injecting new understanding into smart library services.

3.2 Analysis of Intelligent Response Service Connotation

From the perspective of information service implementation, after contextual awareness, the response phase is entered through ubiquitous connection. Generally speaking, response can be viewed as a combination of feedback and action. In the Modern Chinese Dictionary, response generally refers to expressing agreement or support for a certain call or initiative through words and actions (verb); intelligence generally refers to wisdom and ability (noun), or being processed by high technology and possessing certain human wisdom and abilities (verb).

The term “response” is rarely mentioned in library and information science information service research, and “intelligent response” is even rarer. With contextual awareness as the prerequisite, response at the information service level can be understood as follows: response is directed toward needs. After identifying or receiving user information needs, how to better satisfy these needs and achieve user service satisfaction rises to the issue of response degree and effectiveness, namely the intelligence of response. Whether response is intelligent and its degree of intelligence depends on the matching and satisfaction level of user needs. Intelligence can be measured according to the classic 4R principles of intelligence transmission and services (right information, right time, right user, right cost) [15]. There is no consistent understanding of the explicit definition of intelligent response, and perceptions vary across different professional fields.

In smart library services, intelligent response as a compound term combines “intelligent” and “response,” meaning to think what users think, urgently meet users’ needs, and quickly, efficiently, and flexibly provide required services on demand.

Currently, intelligent response is rarely used as a professional term, with some degree-based descriptions existing in technical engineering and management fields. For example, Intel’s proposed Intelligent Response Technology is a rapid caching technology to improve computer system performance [16]. In smart city emergency management, for instance, AT&T built the public safety communication platform FirstNet [17], utilizing IoT to release public safety assurance capabilities for safer and more efficient intelligent response.

Similar terms to intelligent response include rapid response and dynamic response. These can be considered characteristic descriptions of intelligent response from different dimensions. Rapid response research topics involve supply chain rapid response, intelligence service rapid response, rapid response intel-

ligent diagnosis systems, rapid response design systems, etc. For example, in terms of rapid response capability, Cha Xianjin et al. believe that competitive intelligence consulting service rapid response system capabilities include “perception capability, analysis capability, and information transmission capability” [18]; in supply chain rapid response capability, Zhang Yuchun et al., summarizing domestic and international research, point out that rapid response is mainly reflected in response time and speed, specifically including response time or speed as indicators, internal structure and processes of response time (such as processing cycles, development cycles), and response result evaluation (such as punctuality rate, completion rate) [19].

Dynamic response is more commonly applied in enterprise economics, environmental science, and automation technology. For example, in enterprise economics, dynamic response mainly emphasizes dynamic adjustment of industrial structure, dynamic handling of trade relations, impact response to industrial competition, dynamic response to consumer demand, etc.; in environmental science, dynamic mainly emphasizes dynamic assessment and adjustment of the interrelationship between energy, land, water resources, and ecological environment.

Different professional fields have different research focuses on response. Rapid response and dynamic response can be considered synonyms of intelligent response, with connotations including response time, speed, process, results, and technical support and dynamic relationships during the response process. These will help the library and information science field conduct diversified expansion of intelligent response service research.

3.3 Intelligent Response Services in Smart Libraries

As mentioned earlier, library and information institutions provide resource-based services. Intelligent response has service as its essential attribute. This section elevates intelligent response from the technical level to the service level and discusses it in the smart library scenario. Intelligent management work related to libraries does not belong to the discussion scope of this paper.

4. Design of Intelligent Response Services for Smart Libraries

4.1 Information Service Perspective of IoT “Perception-Response” Loop

The design of intelligent response services for smart libraries first requires full understanding of IoT space. From an information service perspective, in IoT space, within the tubular space mapping from (real) scenarios to (abstract) contexts, explicitly constructing a “perception-response” loop based on connection helps further conduct in-depth hierarchical design of intelligent response services.

IoT technical architecture is generally divided into three layers: perception layer, network layer, and application layer [20]. These three layers are not suitable for analysis from a human-centered information service perspective, as information services reside in the application layer and cannot be further expanded. This paper focuses on various possible connections in IoT, emphasizing the spatial sense of connections and the perception-response loop within them.

Therefore, IoT is viewed as a large environment of connections, with only basic physical layer and abstract data layer defined. In the three-dimensional connection space of IoT, “people, events, and things” are all within it. The “perception-response” loop from an information service perspective is shown in Figure 1 [Figure 1: see original paper].

In Figure 1 [Figure 1: see original paper], response and perception are arrows in opposite directions. Perception is the foundation of response; response needs to retrieve, analyze, and assemble required intelligence/knowledge from the data pipeline network to prepare for subsequent feedback and action. Perception and response in IoT space constitute two basic components of intelligent information services. Explicitly defining the “perception-response” loop of information services in IoT environments facilitates contextual research in specific real scenarios, which will be combined with smart library scenarios for hierarchical design of intelligent response services below.

4.2 Smart Library Intelligent Response Service Framework

Using the IoT information service “perception-response” loop as the design methodology and combining it with the connotation of smart library intelligent services, this paper proposes a smart library intelligent response service framework. From bottom to top, it includes the contextual awareness layer, contextual modeling layer, contextual computing layer, resource response layer, and intelligent adaptation layer. The outermost ubiquitous network and service terminals wrap the five core layers. The intelligent response service framework is shown in Figure 2 [Figure 2: see original paper].

In the smart library intelligent response service framework, the bottom ubiquitous network aims to emphasize basic connection assurance. Smart libraries must integrate into the multi-dimensional connection space constructed by IoT, maintaining a continuous connection, ready-at-any-time, immediate-response service standby state. The corresponding connotations of the five core layers are explained as follows:

- (1) Contextual Awareness Layer. Contextual awareness is the prerequisite and foundation for smart libraries to achieve intelligent response services, providing technical support for library resource intelligent response. The underlying perception technologies relied upon by smart library intelligent response include sensors, Radio Frequency Identification (RFID), short-range and low-rate wireless communication technology (ZigBee), Bluetooth Low Energy (BLE), Ultra-Wideband (UWB), wireless networks

(WiFi), positioning systems (GPS), long-distance communication network technology (5G), etc. Through the tentacles and connections of contextual awareness technology, user needs, user status, and contextual information are captured quickly, accurately, and comprehensively, providing formalized, machine-readable data support for contextual modeling.

- (2) Contextual Modeling Layer. Contextual modeling abstracts the data information obtained by the contextual awareness layer to establish logical models. In smart library intelligent response service contextual modeling, user, task, and resource are three core elements. Specific users (such as research users, teaching users, learning users), tasks (such as academic novelty search, contextual teaching, maker spaces), and content resources (such as academic resources, teaching cases, knowledge bases) all have particular contextual characteristics. Corresponding contextual models can be constructed based on different users, tasks, and resources. In contextual modeling, on one hand, in the horizontal dimension, supporting elements such as time, location, hardware, and software where the contextual model resides must be considered; on the other hand, in the vertical dimension, the dynamic nature of context must be considered. Historical contexts (user activities) that have occurred and future contexts that can be utilized, recommended, and planned for the future are both components of contextual modeling, and they are also core elements that enable contextual awareness to drive intelligent impact.
- (3) Contextual Computing Layer. Contextual computing is the dynamic process of achieving “user-task-resource” matching in smart libraries, primarily realized through formal representation of library resources and service elements, ontology definition, reasoning rules, and machine learning. Specifically, on one hand, contextual computing calculates library resources according to task requirements proposed by users, providing users with library resource utilization windows; on the other hand, contextual computing realizes active, intelligent provision or recommendation of content resources to users, achieving intelligent sensing and deep contextual dialogue services where what users think is what they see and what they obtain is what they want.
- (4) Resource Response Layer. Resource response is the unique response subject of smart libraries, representing the output of contextual modeling and contextual computing, and the process of concretizing and productizing content resource services to form contextual knowledge (products). The resource response in smart library intelligent response essentially uses methods and means in library service scenarios such as open linking, heterogeneous integration, content services, knowledge extraction, knowledge reorganization, and knowledge graphs to conduct contextual knowledge response for library resources, aggregating, integrating, extracting, and visualizing resources needed and valuable for users. Smart library intelligent response services must balance the quality and efficiency of resource

response, emphasizing both the comprehensiveness, accuracy, and novelty of provided resources to guarantee resource response quality, and the timeliness and speed of resource provision and process feedback.

- (5) Intelligent Adaptation Layer. Intelligent adaptation is the service means of docking and satisfying user needs based on formed contextual knowledge (products), and it is also the ultimate implementation of intelligent response services. Intelligent adaptation represents the intelligent enhancement of traditional library document information services (such as in-library services, delivery services) and knowledge services (subject customized services, push services, navigation services). On one hand, intelligent adaptation emphasizes the automation and intelligent enhancement of traditional library and information services; on the other hand, current service means focus on semantic retrieval, precise push, association recommendation, community participation, automatic Q&A, fixed-topic tracking, reminder assistants, and multi-screen interaction, responding to user needs and feeding back user thoughts to achieve intelligent adaptation between users and intelligence/knowledge.

In the smart library intelligent response service framework, “contextual awareness - contextual modeling - contextual computing - resource response - intelligent adaptation” are five core layers. In the implementation process of smart library intelligent response services, these five core layers are progressive relationships, representing the detailed implementation of the IoT information service “perception-response” loop. Notably, the “perception-response” loop is not one-time but cyclical due to the continuous online nature of connections, forming a circular process of mutual perception, model construction, iterative computing, dynamic response, and intelligent services among users, tasks, and resources, ultimately promoting the realization of smart library intelligent response services.

4.3 Implementation Suggestions for Smart Library Intelligent Response Services

The smart library intelligent response service framework brings systematic design thinking, but its implementation and 落地 is a systematic project requiring comprehensive advancement from contextual thinking, contextual technology systems, contextual metadata, and user research perspectives. The following implementation suggestions are provided for reference:

- (1) Establish contextual thinking for intelligent response services. In the current era of information overload, fragmentation, and overly developed networks, how can library and information institutions capture user attention and generate user stickiness and dependence on their services? In smart library scenarios, various service levels and granularities of scenarios need to be identified. Subsequently, service scenarios are abstracted contextually, and technical means are used to perceive, model, and compute service con-

texts, similar to simulating information services. This technically-oriented contextual thinking helps regularize and automate information services, replacing foundational repetitive work to some extent and allowing service personnel to concentrate on more intellectual and creative services.

- (2) Strengthen the construction of contextual awareness technology systems. With the rapid development and application of IoT, RFID, and other technologies, the technical means for achieving smart library intelligent construction and intelligent response services will become increasingly advanced and diversified. For different smart library intelligent response contexts, appropriate contextual awareness technologies should be selected for combination and matching, focusing on the core links and layers of the smart library intelligent response service framework—“contextual awareness - contextual modeling - contextual computing - resource response - intelligent services”—to achieve optimal technology utilization and effectiveness while technologies continue evolving, choosing systems that suit actual conditions (the latest technology is not necessarily the best), are effective, and have scalability.
- (3) Strengthen specialized and integrated research on contextual metadata. IoT brings hard connections of everything interlinked. In smart library scenarios, the data obtained through contextual awareness and the metadata accompanying this data are important foundational factual basis for subsequent contextual modeling, contextual computing, resource response, and intelligent adaptation. Specialized contextual metadata helps clarify relationships among various elements in context, further enhancing semantic association and enrichment. To strengthen the integration between the physical IoT and the virtual World Wide Web, W3C has initiated standard formulation for the Web of Things (WoT), which includes metadata description standards for contextual elements [21]. In smart libraries, conducting integrated research on contextual metadata schemes by referencing existing resource metadata standards, technical metadata standards, and management metadata standards is highly necessary, helping achieve contextual reorganization of resources in connections and providing direction and basis for service intelligence.
- (4) Strengthen user research for intelligent response services. Providing intelligent response services for users is the main goal and value embodiment of smart libraries. Several aspects should be noted: First, strengthen user cultivation and user stickiness research to enhance smart library attention and user numbers; second, conduct user need identification, task opinion collection, intelligent Q&A, personalized recommendation, etc., to improve user satisfaction with smart library services; third, handle user privacy properly—contextual awareness will inevitably collect various user information, and library and information institutions should emphasize user privacy and information security protection, cautiously handling and using user data to eliminate user concerns.

5. Conclusion and Thoughts

In the three-dimensional connection space of IoT, smart libraries have no physical boundaries; they are beside everyone who needs them. Information services extend pervasively through the ubiquitous connection network constructed by IoT, like personal butlers or friends, always guarding users' side and attending to their knowledge acquisition and information needs. This description represents the beautiful vision of smart library intelligent response services, corresponding to the promising future currently promised by intelligent assistants and robots.

Future smart library services are intangible and ubiquitous. In the library and information science field, the battleground for information services is no longer suitable for the future, and one-way embedded processes cannot fully meet service needs. The future requires multi-directional interaction integrated into connection networks, where library and information institutions and users merge into one, both being network nodes constructed by IoT. In IoT's "perception-response" loop, intelligent services require various forms and means for connection potential activation: connect anytime, anywhere, and on demand. In short, connections bring infinite possibilities.

Additionally, a certain level of calmness and vigilance should be maintained regarding the generalization of IoT contextual awareness technology. Library and information institutions should actively consider new concepts and ideas that technology brings to services, but also emphasize the reality of technology application 落地. For library and information institutions, whether contextual awareness applications have realistic connection foundations and whether IoT hardware device perception functions can be 落地 require careful consideration. For example, the most typical RFID application controversy in libraries—the technology itself can indeed bring some intelligent enhancement, but the balance between input cost and benefit still needs to be weighed.

Whether user-facing terminal APPs and service systems can collect, capture, and continuously obtain user behavior data is also an important practical test. Without stable regular connections and continuous data aggregation, the foundation of contextual awareness is not solid, and the perception and computation of scenario-to-context abstraction cannot be realized, making the "perception-response" loop unable to operate. Small-scale or closed contextual awareness experiments have positive exploratory value, but from an information service design and implementation perspective, realistic conditions and implementation factors must be considered. Do not fear new things and changes, think rationally and argue reasonably, and progressively promote the 落地 of smart library concepts. Smart library intelligent services need to strengthen two important means—perception and response—in connections, and their realization is not far away.

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Fan Wei: Proposed the paper framework and revised the paper.

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