Design of a Location-Aware Library Proactive Information Service System (Postprint)

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Abstract

This study develops a location-aware smart library system designed to provide readers with real-time information services. Recognizing that readers at different locations within the library have varying service requirements—and that different types of readers at the same location also exhibit distinct service expectations—the system must be capable of predicting readers'immediate needs and delivering proactive, differentiated services.

The proposed architecture employs WiFi and GPS positioning technologies to achieve seamless location awareness of readers. It generates differentiated information in real time based on reader role classification for push delivery. Through installation of the APP client, readers can receive location-specific service information throughout the library.

The implementation demonstrates that location services provide an effective approach for libraries to predict users' immediate needs and improve overall user experience.

Full Text

Preamble

Library Active-Information Service System Based on Location Awareness

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Abstract

Objective: To construct a smart library with location awareness capabilities that provides instant information services to readers. **Context:** Readers have varying service requirements at different locations within the library, and different types of readers at the same location also have different service expectations. The system must be able to predict readers' real-time needs and deliver proactive services. **Methods:** We designed a framework for an active information differential service system based on location awareness, employing WiFi and GPS positioning technologies to achieve seamless location tracking of readers, and generating differentiated information for real-time push delivery based on reader role classification. **Results:** By installing the APP client, readers receive different service information at various locations throughout the library. **Conclusions:** Location-based services provide an effective approach for libraries to predict users' immediate needs and improve their experience.

Keywords: Location awareness; WiFi positioning; Differential service

Classification Number: G250

2 Current Status Analysis and Technical Approach

The widespread adoption of mobile internet, smartphones, and GPS technology has driven the development of Location-Based Services (LBS). Location-aware services in libraries represent a crucial component in building modern smart libraries. In recent years, libraries have continuously improved service quality by upgrading hardware and software environments, striving to create modern facilities. Mobile services on smartphones have become a primary avenue for service innovation, with many libraries developing mobile library APPs, establishing public accounts on WeChat, and providing consultation services on social networks such as Renren and Sina Weibo. However, these applications have not integrated location-aware services.

The emergence of LBS concepts has prompted library professionals to explore application models for location-aware services in libraries. Reference [1] analyzes the feasibility and effectiveness of perception services in museum applications based on WiFi indoor systems. Reference [2] investigates mobile library services from the perspective of indoor positioning, offering many instructive service strategies. Reference [3] proposes an ontology-based and location-aware library book recommendation model using WiFi indoor positioning technology, providing insights for personalized book recommendation services with location awareness. In summary, existing research on location-aware information services aims to enable readers to enjoy different information service content in various library areas. For instance, when a reader enters the library lobby, the system could send welcome messages; when they enter a reading room, it could push real-time seat occupancy information. However, if the reader is a faculty member or senior student, they would likely be less interested in seat availability and more interested in information about new books in that reading room. This demonstrates that different types of readers have different service needs.

This paper presents a location-aware library active information differential service system that combines WiFi indoor positioning and GPS technologies. By generating differentiated information through location and role classification tables, the system can predict users' immediate needs through location awareness and implement differential services, thereby improving library service quality and enhancing reader experience to a certain extent.

2.1 Status of Location-Aware Services

[Content merged with section 2 above for logical flow]

4.1 APP Client

Signal Acquisition: Both feature database construction and location awareness require collecting surrounding AP signals from mobile devices. The system encapsulates this functionality in the environmental access module PhyLayer. PhyLayer first obtains mobile device access permissions for WiFi and GPS, then encapsulates the acquired signals (such as AP MAC addresses and signal strength) into designated classes for processing by the data processing layer. The Android development platform provides built-in APIs for WiFi signal acquisition. The key implementation code in this system is as follows:

```
public void GetWifiInfo(WifiInfo[] msg) {
    ……// System network access permission check
    // getSystemService(String) returns service handle by name
    wm = (WifiManager) getSystemService(WIFI_{SERVICE});
    wi = wm.getConnectionInfo();// Returns dynamic information of WiFi connection

    if(wi.getBSSID() == null) // null means not connected
        break;
    // Get network signal strength
    strength = wi.getRssi();
    WifiInfo w=new WifiInfo(wi.getBSSID(), strength);
    msg.add(w);
}while(true);
```

In the above code, the client stores the collected WiFi signal strength RSSI in the structure class WifiInfo and sends it to the server in JSON format.

Feature Database Construction: The feature database is fundamental to feature-based positioning methods. By collecting data from the area to be positioned, a feature database is established for matching with real-time data to achieve positioning. Referencing the methods in literature [7,10], this system collects all signals at each sampling point 50 times and stores them in the database, finally calculating their average value Avg and fluctuation weight Range. Manual collection and processing is labor-intensive and tedious. The system designs a dedicated SignalGetActivity interface module in the APP for automatic collection. The processing flow is shown in [Figure 3: see original paper]: input location identifier, X coordinate, and Y coordinate, collect WiFi signals 50 times at certain intervals, and send all data in JSON format to the server.

The server parses the JSON data sent by the client and stores it in a collection table. shows the raw information collected by the mobile client at the same location. The AP name field records the AP' s MAC address, while Pos-name, Pos-X, and Pos-Y fields record the description of the collection point, which is entered by the mobile client during data collection. The feature database management module calculates the average of the 50 sampling values for each AP signal at each point and stores the calculated values in a database table as shown in . The Avg-RSSI field stores a list of AP identifiers, average signal strength, and fluctuation weight Range. This list-based storage mainly considers that the number of APs may change dynamically, facilitating expansion.

Real-time Location Service Information: The location information service in the APP client needs to implement three functions: running as a background service on the mobile device, sending surrounding location feature information to the server at regular frequencies, and displaying information pushed from the server on the mobile device through background notifications. Android provides the Service component to implement background running functionality, similar to services on Windows. The key code for the background service module is as follows:

```
public class CumtLibService extends Service {
    @Override
    public void onCreate() {
        // ...
    }
    @Override
    public int onStartCommand(Intent intent, int flags, int startId) {
        new WifiGetThread().start();// Start information collection thread
        return START_{STICKY};// Ensure automatic restart after service termination
    }
}
```

In the above code, the APP service starts a WifiGetThread() thread that primarily collects surrounding WiFi information at a certain frequency. The key code for this module is as follows:

```
Public class WifiGetThread extends Thread{
    @Override
    public void run(){
        do{
            try{
                Thread.sleep(2000);
                WifiInfo[] msg = new WifiInfo ();
                GetWifiInfo(msg);// Call WiFi signal acquisition function
                GPSInfo gps=GetGPSInfo();// Call GPS information acquisition function
                PushInfoServlet(JsonLocInfo (msg, gps)); // Call information sending module
            }catch (InterruptedException e){
                e.printStackTrace();
```

```
            }
        }while (true);
    }
}
```

WifiGetThread continuously performs signal acquisition through a while loop and uses the Thread.Sleep function to set the collection frequency. Too high a frequency would occupy excessive mobile hardware resources and WiFi signal channels, while too low a frequency would affect information timeliness. Considering that WiFi and GPS signal acquisition has certain delays, the system sets a sampling frequency of 2 seconds as appropriate.

Through signal acquisition, the system passes the generated GetWifiInfo and GPSInfo to the information sending module PushInfoServlet. This module pulls information from the server using the GET method, sending location information and reader ID as parameters to the server, and displays the returned data in the notification bar. The core code is as follows:

```
Public viod PushInfoServlet(JsonLocInfo) {
    // Server-side location calculation module address
    String url = "http://localhost /LocationServlet/";
    // Send request to server using GET method
    JsonLocInfo.Push("uid", UID);// Add reader ID
    AsyncHttpClient.get(url, JsonLocInfo, new AsyncHttpResponseHandler() {
        @Override
        public void onSuccess(int statusCode, Header[] headers, byte[] responseBody) {
            try {
                JSONObject noticemsg = new JSONObject(new String(responseBody, "utf-8"));
                int state = noticemsg.getInt("state");
                // Determine if information service is available
                if (state == "success") {
                    Notification(noticemsg);   // Call message notification display module
                }
            } catch (Exception e) {
                e.printStackTrace();
            }
        }
    });
}
```

4.2 Server-side Design

Location Calculation: The server receives JSON location data from the client and performs location calculation. The processing flow is shown in [Figure 4: see original paper]. Each time GPS information is stored in the database table, while WiFi information is only stored after successful matching because unsuccessful matching indicates invalid WiFi information that can be discarded directly. The GPS location push interface (shaded part in [Figure 4: see original paper]) is integrated for future system expansion.

Current mature location matching algorithms mainly include: Probabilistic algorithms: using Bayesian estimation theory with different likelihood functions (e.g., kernel function-based likelihood functions) to calculate the posterior probability of the target location, taking the location with maximum posterior probability as the final position; Deterministic algorithms [10]: selecting the centroid of several points with the smallest distance to the currently collected information in the feature fingerprint database as the target location estimate.

Deterministic algorithms have low complexity and fast computation speed. This paper is also based on this method, and its location positioning function is described as follows:

```
Input parameters: Message data APs(Mac, RSSI) array
Output parameters: Location data Loc(X, Y)
Begin
    For Each APi in APs
        Select Loci
        IF RSSIi in (APi.RSSI+ , RSSIi+ );
        N=Count(Loci);
        IF Loci Selected
            Ei=1/n;
        Else
            Ei=0;
        End If;
    End For;
    Return Loci Where max(Ei);
```

In the function, is obtained by averaging the fluctuation weight Range of all collection points for each AP during feature database construction. The formula is as follows:

$$\epsilon = \frac{\sum range}{count(ap)}$$

For the RSSI value of each incoming AP, the system searches the fingerprint database for location points satisfying the range [RSSI- , RSSI+]. If n points belong to this interval, each is assigned a weight of 1/n, while all other points are assigned weight 0. After processing all APs using the above procedure, the point with the maximum weight is selected as the estimated location. When multiple points have the same weight, the one with the smallest signal strength distance is chosen.

Information Classification: After successful location matching, the server needs to generate push information. Based on daily library service functions, this system categorizes push information into 6 types, as shown in :

TABLE:4 Push Information Classification - Introduction information: Based on location, push information about reading room introductions, facilities, and current library occupancy - Book information: Based on reading room location, push the latest book recommendations - Consultation information: Based on location, proactively provide online consultation services - Friend information: Identify nearby readers with the same major to form a virtual research room - News information: Latest library activities and news - Other information: Other relevant information

Each category in has different content at different locations, and multiple types of information may coexist at the same location. For example, a reading room can have introduction information, book recommendation information, and friend information, with introduction information having the highest priority to ensure it is pushed first. To accurately distinguish the service functions of each physical space in the library, the system defines the types of service information contained in each location as shown in .

TABLE:5 Information Categories by Location - Book reading room: Book recommendations, friend recommendations, consultation services, introduction information - Research room: Friend recommendations, consultation services - Electronic reading room: Consultation services, news information, introduction information - Journal reading room: News information, introduction information - Various service departments: Consultation services, news information, other information, introduction information - Library entrance: Introduction information - Bookstore: Book recommendations, other information, news information

Reader Role Setting: Different types of readers have different service expectations. For example, junior students may be interested in various library activities or news, while faculty and graduate students may prefer information about new books and databases. Based on this, we believe that readers with similar types have similar service expectations. Following this principle, this system divides readers into 5 role categories, with each role containing reader types and service information categories as shown in . Reader types are based on those included in the library' s OPAC system.

TABLE:6 Reader Role Information Configuration - Faculty, lab staff, graduate students: Book recommendations, introduction information - Undergraduate students, second-degree students: News information, book recommendations, consultation services, introduction information - Academic readers (PhD, Master' s): Friend recommendations, book recommendations, introduction information - Foreign readers (foreign teachers, international students): Consultation services, news information, introduction information - Off-campus readers, adult education, others: Consultation services, introduction information

Reader Role Acquisition: Reader type corresponds to reader role. The OPAC reader information includes reader type. To determine the reader' s role, users must register using their OPAC account ID, which is sent to the server along with location information in JSON format during location requests. The server uses the received ID as a parameter to call the OPAC Web service interface for obtaining reader information. This interface returns an XML data package containing reader type, which the server uses to match the role configuration table and determine the reader' s role. The processing flow is shown in [Figure 5: see original paper]. When a reader is not registered or the ID is incorrect, the system classifies them as "off-campus reader." For convenience, the client saves the account information entered by the reader as private data in mobile storage, which is read on subsequent runs so readers don' t need to re-enter their credentials.

Differential Information Generation: The system locates the current push information category list through both the reader' s location and role, then generates differentiated service information. The processing flow is shown in [Figure 6: see original paper]: input location information S to match with the location information classification table and generate the push information category list A for the current location; simultaneously, match the reader role with the role information classification table to generate the push information category list B for this role; take the intersection of A and B to generate the final category list C; finally, retrieve information belonging to category list C at location S from the push information list as the push information. Through the processing flow in [Figure 6: see original paper], different roles in the same area and the same role in different locations will receive different information.

Information Expiration Time: The frequency of information push directly affects reader experience. For example, welcome messages in the library lobby can be sent every day upon entry, but sending reading room introduction information after each positioning would be inappropriate. To enable appropriate push frequencies for each piece of information based on location, this system sets an expiration time T for each configured push message. Before sending each message, the system checks the message log table and only pushes the message if the time interval between the last sending of the same message to that reader and the current time exceeds the configured expiration time T.

4.3 Service Quality Improvement Strategies

Readers receive push information from various APPs daily. For library active information services to stand out among numerous messages, content must be improved through multiple channels based on user interests. Information push strategies designed by various service systems may often be uninteresting to readers. To address this, our system includes a service feedback function where readers can rate received service information. The rating scale is divided into 5 levels by information type: 5 points, 4 points, 3 points, 2 points, and 1 point. The server stores user-submitted ratings in an information rating table and periodically adjusts the priority of information types based on these ratings.

5 System Application and Evaluation

Based on the architecture shown in [Figure 2: see original paper], we developed the main functions of the platform, which includes three parts: server-side, APP client, and application management interface. The server runs as a background service, providing business processing for the APP and management interface. Figure 7: see original paper shows the prompt information after the system receives push information, and Figure 7: see original paper shows the introduction information about the natural science reading room when opening a message, which includes the information rating function for readers.

Testing was conducted by running the APP client with different reader types at multiple locations in the library to evaluate the accuracy of system information push. Statistical results from 10 test groups are shown in . The number of messages received in the circulation hall and reading rooms is basically the same as the test count, while information loss occurs in research rooms and the novelty search department. Analysis reveals that this is mainly because the circulation hall and reading rooms have large spaces (radius > 10 meters), so positioning calculation errors can basically be covered by the sampling points within the corresponding space. However, research rooms and the novelty search department have small spaces, and positioning calculation errors sometimes exceed the space radius, resulting in failed information push.

TABLE:7 Statistics of Received Messages from Testing - Circulation Hall: Welcome information: 10, Consultation information: 10 - Natural Science Reading Room: Introduction information: 9, Book information: 9 - Social Science Reading Room: Introduction information: 8, Welcome information: 10, News information: 10, Consultation information: 10 - Research Room: Welcome information: 9, Introduction information: 10, Book information: 10, Friend information: 3, Consultation service: 6 - Novelty Search Department: Introduction information: 9, Book information: 9, Friend information: 5 - Bookstore: Introduction information: 8, Welcome information: 10, Consultation service: 10 - Library Entrance: Introduction information: 7

[Figure 8: see original paper] shows the rating records from reader feedback statistics in the management interface. It can be observed that introduction and book recommendation information receive relatively high ratings, while consultation and news information receive relatively low ratings. This conclusion can also be drawn from : the library hall and reading rooms contain introduction and book recommendation information with high positioning calculation success rates. Additionally, readers are more interested in book recommendation information than other types, resulting in higher satisfaction.

Location-aware services have begun to be applied in large shopping malls, museums, and other service fields, representing an important component for building smart libraries in the future. Many library and information science researchers in China have started exploring this field, though mature practical applications remain limited. This paper designs an active service system framework based on location awareness from an application perspective, elaborates on the main functional implementations, achieves seamless location awareness of readers through indoor WiFi and GPS positioning technologies, and generates personalized differential information through reader role information classification tables. The system has been deployed in the China University of Mining and Technology Library, enhancing user experience and receiving unanimous recognition from various reader groups. Its limitation lies in the need for finer classification granularity and further consideration of individual needs. Utilizing data mining algorithms to discover users' personalized needs will be a future research direction.

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Author Contributions

Deng Zhiwen: Designed the system framework, programming, drafted and revised the paper;
Du Pingping: Proposed the research ideas, designed the research content;
Mu Yafeng: System data collection, application testing.

Conflict of Interest Statement

All authors declare no conflict of interest.

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