Location-Based Botany Guide: A Prototype of Web-Based Tracking and Guiding

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Abstract. Wireless positioning technologies make it possible to keep track of mobile devices, and Web technologies make Web applications highly interactive. The combination of them gives rise to location-based Web applications, which generate and deliver Web content tailored to user locations. Location-based Web applications are able to utilize the enormous resources on the Web and allow users to use different location-based services without installing specific software. The paper presents a prototype of Web-based tracking and guiding - the Location-Based Botany Guide, which is a Web-based multimedia guiding system used in botanical gardens for biology students and visitors. The system adopts a general architecture for Web-based tracking and guiding, which consists of the Location Server, the Content Server, the Botanical Guiding Web Server and the clients. Personalization technology is applied to provide the users with personalized recommendations and presentations.

Keywords: location-based services, Web, location-based Web applications, guiding, personalization, botany.

1 Introduction

Development of positioning technologies and wireless networks has given rise to location-based services, which provide users with services that are tailored to their locations. Tremendous research has been conducted on location-based services over the years [1,2,3]. For example, CyberGuide [4], GUIDE [5], MobiDENK [6], Hippie [7], CRUMPET [8] and PEACH [9] for tourism services; ActiveCampus [10] deployed on the campus of University of California, San Diego; Safe & Sound [11] used to monitor children's locations. Most existent location-based applications are either standalone programs running on mobile devices or applications working in client-server mode. The majority lack generality. Different applications require different software to be installed on the user's mobile device. There is a great need for a general solution.

At present the World Wide Web is the platform for communication, research, business and many other things. Vast information and resources exist on the

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Web. Integrating location-awareness with the World Wide Web not only allows users to utilize the vast resources on the Web but also enable them to use various location-based applications and services without installing extra software. There are some researches on the integration of location-awareness with the Web. GPSWeb [12] introduces the concept of location-based browsing and aims to provide GPS support for Web browsers. LAWS [13] is a location-aware system built on top of HTTP with a modified Web browser. Web-Enhanced GPS [14] demonstrates the possibilities of creating location-based services on mobile devices using existing data on the Web and the position information from a GPS receiver. HP Labs Cooltown project [15] builds a software model, the Web presence manager, to support the integration of the physical world and the Web. Simon et al. [16] present an application framework that leverages geospatial content on the Web on mobile phones and PDAs.

The Location-Based Botany Guide is a prototype of Web-based tracking and guiding to be used in the Botanical Garden of Freiburg in Germany. Different from the previous work in both architecture and application field, it demonstrates how a Web-based tracking and guiding system works and how it is implemented. Botanical gardens are places where people often visit. The conventional ways of providing botanical information include guided tours by a botanist or explanations on specific web sites. Guided tours by a botanist can provide detailed and scientific information but are rather expensive. Information on the web sites is usually free of charge, but not tailored to the users. The Location-Based Botany Guide solves the problem well by tracking the users and providing them with location-based, personalized, scientific and cohesive multimedia information about the nearby plants. It can be used as a learning system for biology students as well as an electronic guide for visitors. Personalization is applied to enhance the guiding and learning process.

The paper is organized as follows. Section 2 first describes the functions and features of the Location-Based Botany Guide. Section 3 presents the general architecture of the system. The implementation of the location-based and personalized services is presented in Section 4. Privacy issues are discussed in Section 5. Section 6 concludes the paper and presents the directions for the future work.

2 The Location-Based Botany Guide

The Location-Based Botany Guide is a prototypical application of Web-based tracking and guiding that we are developing for the Botanical Garden of Freiburg, Germany. When the users walk in the botanical garden, the system provides them with personalized, scientific and cohesive multimedia presentations about the nearby plants according to their locations, context and characteristics. The botanical garden is covered with wireless LAN. The users must be equipped with a laptop, tablet PC or handheld that is Wi-Fi-enabled and optionally GPS-enabled. Before a user uses the system, he or she must log in. After authenticating the user, the system sets up an initial user and context model of him or her and updates the model continuously during the whole course until the user logs out.

The system can be used as a location-based learning system for biology students as well as an electronic botany guide for visitors.

Let us take an example: a student goes to the botanical garden. She opens the Web browser, types in the Web address of the Location-Based Botany Guide, logs in and begins to study with the system. The system provides the map mode and the guide mode. In the map mode, she gets a dynamic interactive online map of the garden with the botanical information embedded. While walking in the garden, her real-time location is displayed on the map. In the guide mode, the system keeps track of her and presents the personalized multimedia learning material of the nearby plants in her Web browser automatically.

2.1 Botanical Domain

The system is an application in the field of botany. Therefore, the contents are organized and presented based on the botanical domain, which is categorized

Fig. 1. Part of the botanical taxonomy of angiosperm

Fig. 2. Plantation of angiosperm in the Botanical Garden of Freiburg

to the botanical taxonomy. Fig. 1 shows part of the botanical taxonomy of angiosperm stored in our database. We use the following botanical taxonomical levels: system, group, class, order, family, subfamily, genus and species. Although the plantation in the botanical garden is according to the botanical taxonomy, it has a different geographic hierarchy. As shown in Fig. 2, the tree structure on the map is the plantation of the system of angiosperm, according to its evolution. The circles on the tree structure are orders, in which are planted individuals. Based on the plantation, we use the plantation levels of garden, system, order and individual for location-based content queries.

2.2 Interactive Map

An interactive map is always necessary for a guiding system, which shows where the user is and what is around and guides the user through the tour. The Location-Based Botany Guide is no exception, which provides an online interactive map of the botanical garden with the botanical information embedded and the user's real-time location marked. The map and the embedded botanical information are dynamically generated from the Content Server via Simple Object Access Protocol (SOAP), and the information is grouped into layers so that the users can choose which layers to display. Using GPS and Wi-Fi fingerprinting, the system is able to locate and track the user and mark his or her real-time location on the map continuously. The system is also able to display the plant that the user searches for and guide him or her to that plant.

The interactive map is implemented with OpenLayers technology [17], which is an open source map viewing library written in pure JavaScript and can display map tiles and markers loaded from any source. OpenLayers implements a JavaScript API that we can use to put a dynamic map in web pages easily and build rich Web-based geographic applications.

Fig. 3. Guide mode of the Location-Based Botany Guide

2.3 Botany Guide

The botany guide is the most important function of the system. Fig. 3 shows a snapshot of the guide mode. The user can choose between *locate mode* and *track mode*. In track mode, the system keeps track of the user and presents the botanical information about the nearby plants promptly and automatically while the user is walking around in the botanical garden. In locate mode, the system determines the current location of the user and presents the botanical information after the user issues the *locate* command. In both track and locate mode, the system first performs location-dependent content queries to retrieve the plants in the vicinity and recommends a short list of related plants based on the user characteristics and the context. After the user chooses what to learn from the list, the system composes a personalized presentation of the chosen plant and delivers it to the user. The user can choose the query type from planar point query, window query, nearest neighbour(s) query or composite query. He or she can choose the notification mode (update the page automatically or give a hint). The information can be presented in one page, in multiple pages, or as slideshow. The botanical information presented includes the botanical description of the plant, additional multimedia information, hyperlinks to its taxonomical parents and ancestors, hyperlinks to its taxonomical children or planted individuals, scientific self-tests, and personal recommendations.

3 Architecture

The architecture of the Location-Based Botany Guide is a general-purpose solution for Web-based tracking and guiding. Web-based tracking and guiding integrates location-awareness even context-awareness with Web applications and realizes tracking and guiding on the Web. The clients are standard Web browsers and the server is a standard Web server capable of generating location-based Web content in real time.

The process of Web-based tracking and guiding can be divided to four parts: location-aware Web system, location determination, location-dependent content query and personalized presentation. A location-aware Web system is the underlying infrastructure for Web-based tracking and guiding. It allows the transmission of location information from the Web browser to the Web server (since most positioning devices, such as GPS, are on the user side) and enables the automatic update of Web pages in the Web browser. Location determination is one of the most important prerequisites and ingredients for any location-based application. With knowledge of user locations, the Web server performs location-dependent content queries to retrieve the relevant content. After receiving the location-dependent content, the Web server generates the personalized presentation and delivers the presentation to the user. [18]

Based on the process of Web-based tracking and guiding, the architecture of the Location-Based Botany Guide is composed of the Botanical Guiding Web Server, the Location Server, the Content Server, and the clients, as Fig. 4 illustrates. The Botanical Guiding Web Server, the Location Server and the Content Server constitute the server side of the system. The Botanical Guiding Web Server interacts with the clients, while the Location Server and the Content Server serve the Botanical Guiding Web Server.

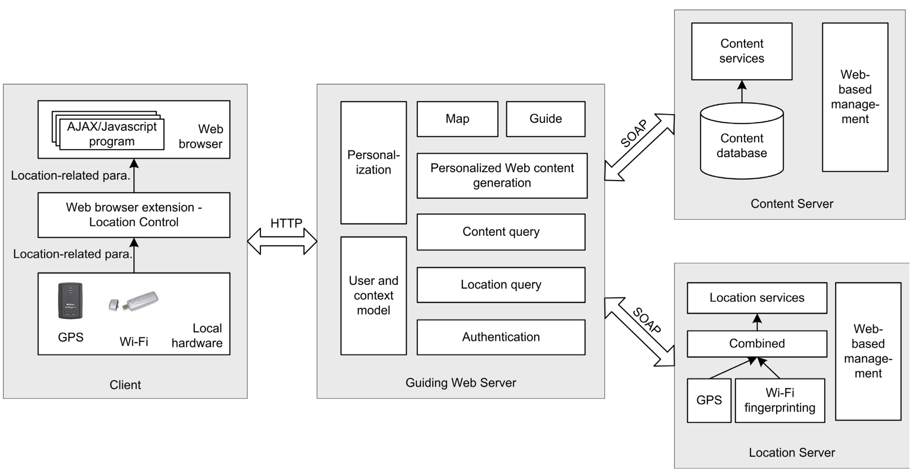

Fig. 4. Architecture of the Location-Based Botany Guide

3.1 Client

The client of the system is standard Web browsers. Since positioning devices are usually installed on the user side, the location-related parameters, such as GPS coordinate and Wi-Fi fingerprint, must be retrieved from the local hardware by the Web browser and transmitted to the Web server. This feature will be supported by standard Web browsers in the near future [19]. Currently we rely on a Web browser extension, called the Location Control, to retrieve the location-related parameters from the local positioning hardware. An Asynchronous JavaScript and XML (AJAX) program running within the Web browser invokes the Location Control, collects the GPS data and Wi-Fi data, then transmits them to the Web server so that the Web server can keep track of the client. The location-based Web content generated by the Web server is delivered and displayed in the Web browser automatically through the AJAX program. The Location Control is general purpose and can be used by any location-based Web applications using the same framework.

3.2 Botanical Guiding Web Server

The Botanical Guiding Web Server is a standard Web server hosting the tracking and guiding system. It authenticates the users, performs location queries to the Location Server for user locations, performs content queries to the Content Server, generates location-based Web content, implements the interactive map and the botany guide. The Botanical Guiding Web Server builds and updates the user and context model for every user and hence realizes personalization. When receiving a *locate* or *track* request from a client, the Botanical Guiding Web Server first extracts the location-related parameters from the client request, queries the Location Server about the current location of the user, then queries the Content Server about the location-dependent content, afterwards generates personalized Web content and delivers it back to the client.

3.3 Location Server

The Location Server runs the location determination algorithms and provides location services via SOAP. This way it is independent from any particular application and can be used by other applications. It receives location queries with location-related parameters and replies with the coordinates. GPS and Wi-Fi fingerprinting are combined to provide an improved and more stable positioning service. Management of the Location Server is via Web pages, which includes configuration of positioning algorithms, calibration of Wi-Fi fingerprinting, management of the radio map. There are two reasons that we implement location determination on the dedicated Location Server. One is that the client should be general-purpose and lightweight since it is a Web browser with an extension, the other is that mobile devices are not suitable for complex algorithms due to limited computing and battery capabilities. Therefore, our solution is that the client only collects the location-related parameters from the local hardware and leaves the location determination algorithm to the dedicated Location Server. Any location-aware Web system adopting such an architecture can share the same Web browser extension.

3.4 Content Server

With knowledge of user locations, the Botanical Guiding Web Server performs location-dependent content queries to the Content Server to retrieve the relevant content. The Content Server stores the multimedia content in a MySQL database and provides the content services via SOAP as well, which makes the database structure transparent and independent. It receives both location-dependent and non-location-dependent content queries, performs appropriate spatial or non-spatial search in the database, and replies with the relevant content. Management of the Content Server is Web-based. Organization of the content in the database takes into account both botanical and spatial features. The database is organized according to the botanical taxonomy. The records in the database are bound to a geographic location (i.e. a point) or a geographic area (i.e. a polygon) in order for location-awareness. The database is indexed on the geographic attribute to improve search efficiency.

4 Location-Based and Personalized Services

4.1 User and Context Modeling

Personalization is of significant value to location-based applications. It tailors the content to the users based on their locations, knowledge, interests and so on. Personalization constitutes an iterative process of user and context modeling and adaptive content presentation. Personalization is based on the user and context model, which is the collection of information that characterizes the user and the contextual situation in which he or she is. [20,21]

Stereotype. The Location-Based Botany Guide requires the user to log in with a username. After authentication, the system sets up the initial user and context model based on the registration information of the user and determines his or her stereotype accordingly. Three stereotypes exist in the system: teachers, biology students, and visitors. Different stereotypes require different contents.

User knowledge. User knowledge modeling enables the system to adapt the learning activity to the user's knowledge level. The user knowledge model in the Location-Based Botany Guide is based on the botanical taxonomy and models the user's knowledge of every taxonomical entity independently via qualitative values (novice, intermediate and advanced). An example of user knowledge model is {(Magnoliales, intermediate), (Magnoliaceae, intermediate), (Ranunculales, novice)}. Before the system presents the content for a plant, it first checks the user knowledge level and presents the content accordingly. The system determines the user knowledge by botanical self-tests predefined by the teachers.

Change of the knowledge level of a plant will lead to the change of the knowledge level of its botanical parents and children (a process of knowledge propagation).

User interests. User interest modeling allows the system to provide the information that the user is interested in. Similar to the user knowledge model, the user interest model is based on the botanical taxonomy too and models the user's interest in every taxonomical entity independently via qualitative values (low, intermediate and high). For example, {(Magnoliales, intermediate), (Magnoliaceae, intermediate), (Ranunculales, low)}. The user interest model is empty initially, and gets updated through the interaction between the user and the system. The interest level of a plant will be increased if the user chooses to read it. The longer the user stays at the plant, the higher the interest level can be. If the user is interested in a plant, he or she may be interested in its botanical parents and botanical children (called interest propagation).

Preferences, device and season. The user can specify the multimedia types that he or she prefers, the notification mode when a new presentation is available (auto start or give a hint), and the presentation mode (all in one page, multi-pages, or slideshow). Different portable devices have different operating systems, screen sizes, software and capabilities, which makes the user experiences quite different. The system is able to adapt the presentation to the device. Since there are many combinations of features of portable devices, the system maps the combinations of features to a few stereotypes and presents the information according to the stereotype. The system also adapts the presentation to the season as the plants are seasonal.

4.2 Location Determination

Many systems have tackled the problem of location determination over the years, such as GPS, Wi-Fi, GSM and RFID. GPS is currently the predominant mechanism for outdoor positioning. With its modernization it aims to provide signal redundancy and improve positioning accuracy, signal availability and system integrity [22]. GALILEO, the European satellite navigation system supposed to be in operation by 2013, will provide a highly accurate, guaranteed global positioning service under civilian control, and promises real-time positioning down to less than a meter [23]. For indoors, Wi-Fi positioning is a promising approach, which makes use of 802.11 signal for location determination and is able to achieve the accuracy of a few meters [24,25]. Different positioning approaches can be combined for improved accuracy and performance.

One of our design principles is to make use of available and cheap devices. Current GPS has difficulties providing accurate locations under pool signal conditions and takes up to a few minutes for the first position fix. Therefore, both GPS and Wi-Fi fingerprinting positioning are adopted in our system. According to the number of satellites in view and Horizontal Dilution of Precision (HDOP), we can decide to use GPS, Wi-Fi fingerprinting, or a combination of them, as illustrated in Fig. 5.

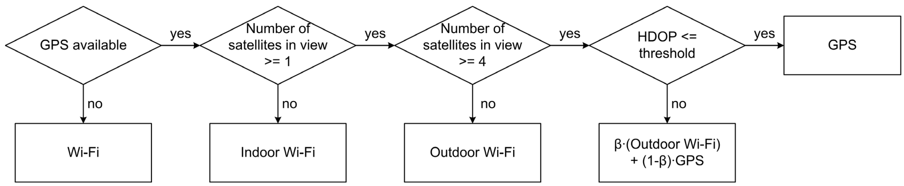

Fig. 5. Combine GPS and Wi-Fi fingerprinting for location determination

As Wi-Fi signal strength oscillates randomly and users can not jump big distances, a history-based Wi-Fi fingerprinting algorithm is used in our system, which makes use of a series of consecutive signal strength instead of only the current one for location determination. According to the Euclidean distance of signal strength, the k most likely estimations of the unknown location, called the "k nearest neighbors", can be determined. Repeat this step periodically, an h-depth history of "k nearest neighbors" will be formed. Calculate the shortest path from the first column to the last column in the h-depth history vector, the end node on the shortest path is the current estimated location. In the indoor area, the layout and interior structure of the building is applied which is proved to be able to reduce logical errors such as wrong estimations of rooms or wrong estimations of floors. Even if the cubical spatial distance between two locations on two different floors may be short, the path between them is long since they can only be connected via staircases or lifts. Using the path distance instead of the cubical spatial distance as the physical distance, the history-based algorithm can reduce the wrong estimations of rooms and floors effectively. [26]

4.3 Content Query and Recommendations

The system supports three basic types of location-dependent content queries: planar point query, window query and nearest neighbours query. With planar point queries [27], the system queries whether the user is in the garden or in a certain plantation subarea. With window queries [28], using the user's current location as the center and a specified distance as the radius, the system returns all the plants or subareas that are within or intersect with the circle window. With nearest neighbours queries [28], the system returns the nearest plants or subareas to the user.

Plants in botanical gardens are planted in a systematic and hierarchical way. Therefore, the query should be performed in a systematic way too. We adopt a combination of planar point query and window query (illustrated in Fig. 6) to find the most relevant information. The system first performs a planar point query to determine whether the user enters a new subarea or stays in the same subarea. If the user enters a new subarea, the system gives him or her a hint that he or she is entering a new subarea and presents the introductory information about the new subarea. If the user stays in the same subarea, the system performs

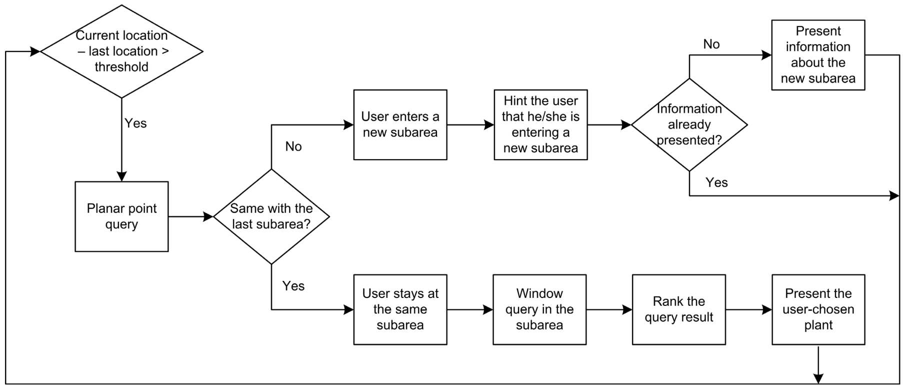

Fig. 6. Location-dependent content query

window query within the subarea and makes ranked recommendations of nearby plants (or subareas) based on the user and context model.

Plants in botanical gardens are usually planted densely. It is often impossible to distinguish individual plants with the currently available and cheap positioning devices. Therefore, the system makes a short list of recommendations based on the query result and the user and context model, from which the user can choose. The plants on the list have a picture of the current season to help the user choose the plant that he or she is interested in or looking at. In addition, the system marks the recommended plants on a properly zoomed map for visual navigation. The recommendation will be ranked according to the user and context model, in order that the most relevant plants appear first. The process of ranking is as follows [21]:

1. Remove irrelevant plants. Each plant goes through the user and context model and only the matched plants pass through. The plants must match the stereotype of the user, the knowledge level of the user, the interest level, the preferences and the season.
2. Rank relevant plants. The plants are ranked according to the following attributes (the order of the attributes reflects their importance for ranking):
   (a) the interest level of the user to the plant. The plant with a higher interest level goes first.
   (b) the knowledge level of the user to the plant. The plant with a lower knowledge level goes first.
   (c) the distance between the user and the plant.

4.4 Personalized Presentation

Recommendations are a list of plants, from which the user chooses which one to see. After the user has chosen a plant, the system retrieves the multimedia content about the plant from the Content Server, composes them to a cohesive presentation and delivers it to the user. The content selection is based on:

– The stereotype of the user.
– The knowledge level of the user. If the user is a novice, the introductory information will be selected; if intermediate, the intermediate information will be selected; if advanced, the advanced information will be selected.
– The interest level of the user. If the interest level is low, only the very brief information will be selected; if intermediate, more detailed information be selected; if high, full explanation will be selected.
– Preferences, device and season.

As illustrated in Fig. 7, based on the user and context model and the predefined templates, the selected contents are composed to an internal multimedia document tree [29], which contains the medium elements to be presented and describes the spatial and temporal relationships between them and how they will be presented. The multimedia document tree can be transformed to different formats such as HTML or Flash based on the user's device and preferences, hence makes it possible to dynamically author the personalized multimedia presentation in different formats and for different devices. [21]

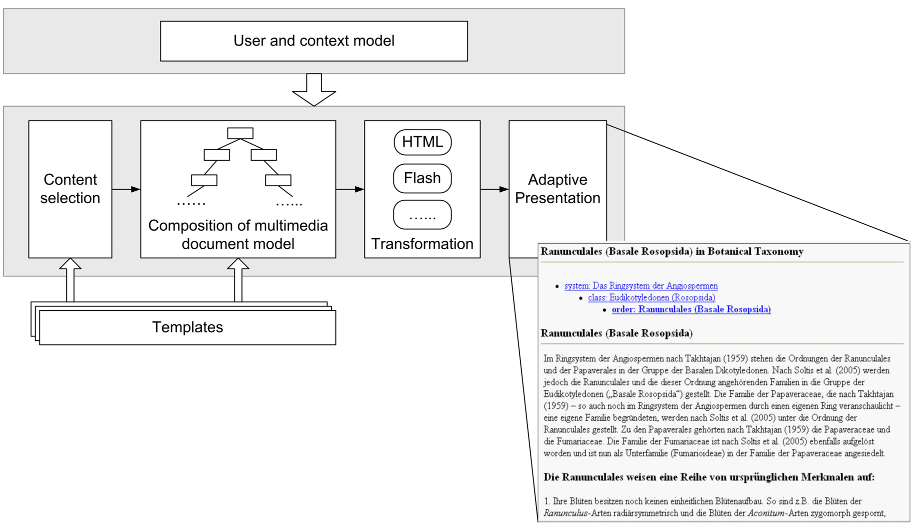

Fig. 7. Personalized presentation

5 Privacy and Security

Privacy is always a concern for location-based services, since user locations are disclosed which can be used to reason user activities and interests. The privacy principles adopted in the Location-Based Botany Guide are to minimize information disclosure while benefiting from the service and to leave the users in control of their information revelation. In our system the positioning devices are on the user side. The user decides when to start and when to stop tracking. Only after the user issues a *locate* or *track* command, the location-related parameters will be collected and sent to the server. This puts the users in control of location revelation and allows them to trade privacy for utility on a case-by-case basis. User information contained in the user and context model is stored on the Botanical Guiding Web server temporarily for the current session. As soon as the user logs out, his or her information will be deleted immediately, and stored as cookies on his or her own mobile device. A user can use the system with a pseudoname instead of his or her real identity. Thus there is no direct link between the stored data and the real user identity, the privacy is hence enhanced.

The system uses wireless LAN for the data communication between the clients and the servers, which is protected by VPN. The Botanical Guiding Web Server and the clients authenticate to each other through secure HTTP. The users must log in before using the system and the system authenticates itself by providing a valid certificate. The Web browser extension (i.e. the Location Control) is a program running locally on the mobile device and is able to access local resources. A malicious one may result in severe privacy disclosure, information loss and other damages. Therefore, the extension should be signed to make sure it is not tampered with by third parties.

6 Conclusions and Future Work

We have presented a Web-based and personalized guiding system in botanical gardens, which provides location-dependent and personalized botanical content to students or visitors in the garden. The system demonstrates the possibility of integrating location-awareness with the World Wide Web to create Web-based tracking and guiding systems. The system consists of the Location Server, the Content Server, the Botanical Guiding Web Server and the clients which are standard Web browsers extended with the Location Control. The system allows users to use location-based applications without specific software and to utilize the vast resources on the Web. The architecture and design of the system provides a general framework for similar applications.

Currently the system is a local application used in botanical gardens. In the future, we will make a more general framework for applications in other fields, which may be local area applications or wide area applications. There are vast information and resources on the Web. Utilizing the information on the Web will free us from the tedious process of creating the content database. How to perform location-dependent Web search and how to retrieve location-dependent Web content will be part of our next research. Personalized recommendation and presentation based on user and context model still need to be improved. Evaluation of the system and evaluation of how the users like the system will be conducted in the near future.

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