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Review Paper

Location-aware tour guide systems in museums

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This study develops a location-aware tour guide system that combines wireless networking, established content in digital archives for museums, interior locating technology and geographical information system. A simulated-annealing-based approach back-propagation network (SABPN) algorithm is applied to locate the user, and monitor properties such as the visitor's personal background (e.g., language and age), the content of the visiting materials, and visiting times to provide customized service tour guide system.

Key words: Museum guide system, PDA, WLAN, positioning, neural network.

INTRODUCTION

A museum provides physical surroundings for touring people to acquire knowledge. Countries all over the world are using museums as a core facility to promote culture, art and tourism by widening their collections and services. Exhibitions in museums generally have descriptions beside them in the form of written board or pamphlets. However, these media are inconvenient for visually impaired people, children and older people. Therefore, many museums employ guides to provide vivid descriptions. However, the limited human resources mean that they can only provide group guidance is provided, and are unable to guide each visitor individually. Recent advances in information and networking technology, along with the increase in ownership of wireless network devices, have led museums to begin to construct wireless guidance systems.

Current wireless guidance systems in museum adopt wireless RFID technology to place RFID tags on their collections. A user may detect the specific identification number coded on the collection items through RFID Readers onto his PDA to access or save the guidance information via the wireless network (Kusunoki et al., 2002; Wang et al., 2007). However, this system is expensive. A single RFID reader currently costs over NT$100,000, making it much more expensive than WiFi equipment. Additionally, since the effective reflection distance of the positioning of the tag is short, the sensitivity of the guidance machine to the tag decreases in large crowds.

Wireless networking technology, that is, IEEE 802.1 g, integrates wireless networking technology and established museum content in digital archives format, and easily applies geographic information systems to provide Location-Aware Tour Guide System. Visitors may enter their personal location, background (e.g. language, age), the content of the materials they plan to visit, and visiting timeframe to set up their personal handheld tour guide systems. The guide function for visiting moving line shortens the visitor's visiting line searching time, enable the visitor gains a wide range of appropriate information, thus, increasing the satisfactory level of the museum service.

RELATED WORKS

Guide service medium

Four types of museum tour guide service media are currently available, namely; Expositors, Tape Machines, CD Players, and PDAs, as shown in Table 1 (Chou et al., 2004). According to the table, the PDA has the major benefit of a low variable cost, making it the least expensive format from a long-term point of view, first of all. The content of the collections can easily be integrated to provide inquiry services. Furthermore, in terms of

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Table 1. Medium type.

	Expositors	Tape machines	CD player	PDA
Setup time at the beginning	Long	Short	Short	Short
Costs spent to adapt whenever the display changes	High	Medium	Medium	Low
Long-term expense	High	Low	Low	Low
Content integrity	High	Low	Low	High
Freedom of moving	Low	Low	Low	High
The way to explain	Voice and body language	Sound	Sound	Texts, graphics, sound, and video clips
Available to blind	Yes	Yes	Yes	Yes
Available to deaf	No good	No	No	Yes
Multilingual	No good	Yes	Yes	Yes

interface design, a multimedia format is provided by combining sound, image and text together, and even multi-language services. Therefore, this study uses PDA as the tour guide service media for museums.

LOCATION POSITION TECHNIQUE

Existing systems for location determination include Global Positioning System (GPS) (Patwari et al., 2005), Infrared Ray Positioning System (IRPS) (Want et al., 1992), and Radio Frequency–Based Systems (Bahl and Padmanabhan, 2000). Significantly, GPS is the most frequently adopted location determination system. However, GPS does not work properly in indoor environments or urban areas due to signal blockage and attenuation, which usually decrease the overall positioning accuracy. The IRPS signal cannot pass through walls, ceilings, floors or large objects in a room, since, the emitted signal is commonly reflected by objects. Moreover, a transmitter must be less than 20 feet from any object that it detects, and must not be covered by transparent objects when accepting a tag. Radio-frequency identification (RFBS) generally uses (RFID) tags. The RFID tags reflex distance effectively, shorter and PDA device selectivity also less. Therefore, the RFID technique is still under development, and is fairly expensive. The hardware architectures of these three location determination systems are generally difficult to access. However, the wireless local area network (WLAN) technique is highly popular (Wang et al., 2006; Stella et al., 2007). Therefore, this study adopts WLAN to sense and detect a location. WLAN reduces the cost and risk of hardware construction, and uses existing network resources to determine locations. Therefore, it does not influence original network transportation functions. Several recent studies have reported of location detection methods in a wireless environment. Fox et al. (2003) summarized location tracking systems. Bahl and Padmanabhan (2000) adopted IEEE 801.11b access point signals to locate users. This study concentrates only on works that exploit the properties of the communications medium location determination, without requiring any additional hardware. This study adopts an empirical approach to the problem by considering a WLAN environment using the IEEE 802.11 g standard. The strength of signals received by wireless terminals from multiple access points at different locations in the building is recorded.

THE DIGITAL GUIDE SYSTEM TYPE

Current digital guidance systems can be classified as follows (Lin, 2006):

(1) Systems that store the audio-video data in the guidance media. Visitors are expected to use these systems on their own. The iPAQ Exhibition Explorer in Modern Art Museum in San Francisco belongs to this type.
(II) Systems that store guidance audio-video data in a server. The content information is accessed from a data bank through the guidance media, which senses the matching code of the collection and requests the appropriate information to be transferred to it. Systems of this type include the electronic MUSS program, the Personal Digital Museum Assistant in Japan, the Wireless Museum PDA Tour Guide System in the Tate Modern Art Gallery in London and the National Palace Museum Tour Guide System in Taipei belong to this kind of system.
(III) Systems of this type are similar to those in type 2, except that the audience can obtain information using the internet at the exhibition site (through OR via) wireless transmission in a broadband Access Point (AP). Such systems include the wireless tour guide system in Explorer Exhibition in San Francisco, palmtop digital tour guide system in Gaty Museum in L.A. and the wireless tour guide system in the History Museum.

POSITIONING TECHNIQUE

This study adopts a novel simulated-annealing-based approach back-propagation network (SABPN), which is

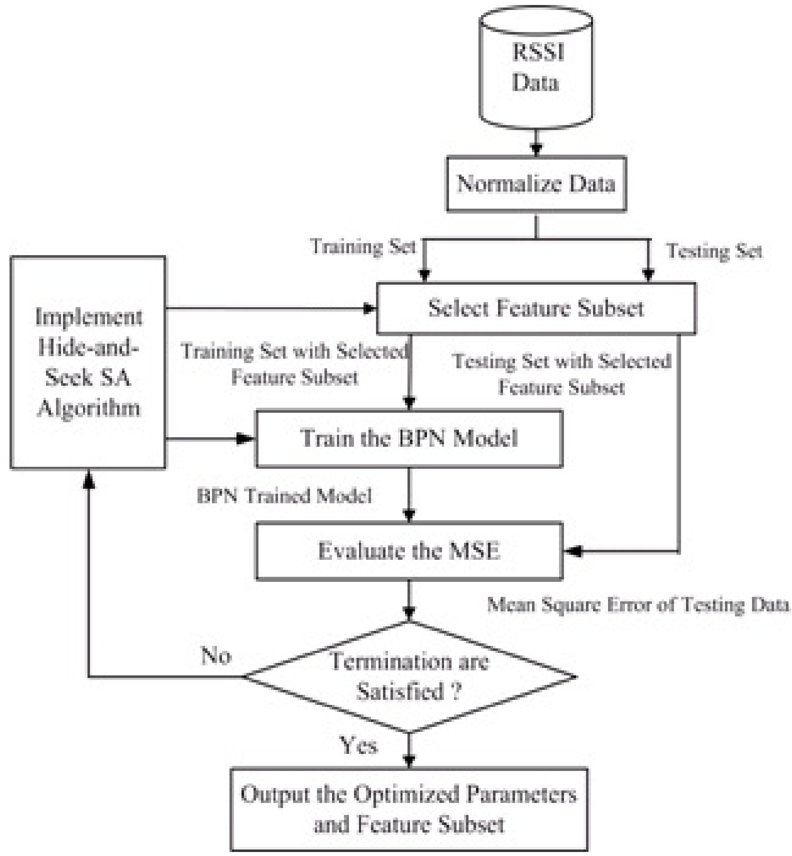

Figure 1. System architecture of the proposed SABPN.

proposed by Tsai et al. (2009), for obtaining the optimal parameter settings for back-propagation network (BPN) and selecting the beneficial subset of features to have a higher classification accuracy rate. The SABPN achieve a small mean square error for the location determination problem and add a variable for determining the number of learning cycle of BPN. Figure 1 presents the framework for combining an SA with a BPN. The proposed SABPN optimizes the parameter settings of BPN architectures and selects the beneficial subset of features simultaneously. The objective is to minimize the mean square error of test data.

This study proposes WLAM infrastructure, since, WLANs have better scalability and lower installation and maintenance costs than ad hoc solutions, enabling them to be easily used to survey location systems using their own infrastructure and components (Ivan and Branka, 2005; Scott and Hazas, 2003).

The access points (APs) are D-Link, and the mobile terminal is a Personal Digital Assistant computer running Windows CE. The network operates in the 2.4 GHz license-free (ISM) band with a data rate of 54 Mbps. Four channels, 1, 6, 7 and 11, were used. The signal strength of these beacon packets was used as the Received Signal Strength Information (RSSI). The locations of coordinates for measuring signal strength were chosen and stored on a personal digital assistant. A WLAN based on the 802.11 g standard was located on the ground floor of a building. The ground floor had 9 access points (APs). The ground floor had an area of 35.6 × 24.4 = 872.2 m^2 and had three classrooms, two bathrooms and two storage rooms. Nine Vigor 2600VG APs were installed on the floor. Figure 2 shows the locations of the APs. The nine access points operated on channels 1, 6, 7 and 11 to prevent overlap.

Among the 6600 examples collected, based on the 4:1 ratio (Sheila and Stefan, 2006), this study randomly selects 5280 examples as training examples and 1320 as test examples. Several neural networks were trained using different configurations and learning algorithms. In all cases, the output layer had two neurons corresponding to the *X* and *Y* coordinates to estimate.

Experimental results are summarized with the observed accuracy. Average absolute error was calculated for each test as follows:

$$e = \frac{1}{p}\sum_{i=1}^{p}\sqrt{(Xt_i - Xo_i)^2 + (Yt_i - Yo_i)^2} \ ,$$

where Xt_i and Yt_i are correct (target) coordinates, Xo_i and Yo_i are the *X* and *Y* coordinates obtained by the neural

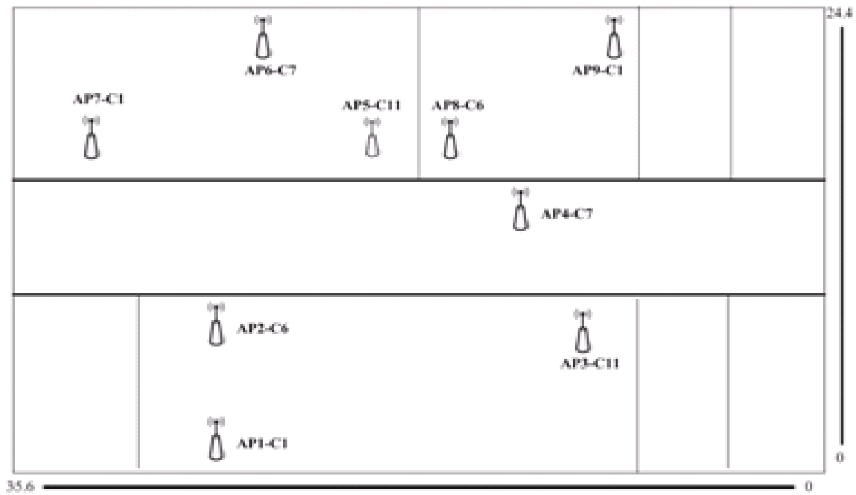

Figure 2. The ground floor layout with positions of the access points.

Table 2. Probability distribution of the error estimated.

Under 0.5 m	0.5 ~ 1 m	1 ~ 1.5 m	1.5 ~ 2 m	Upper 2 m
		(%)		
55.98	82.27	89.39	92.87	7.13

network, respectively, and P is the number of tests or training patterns. Based on room size and antique of the museum used as this site study, the target was set at a maximum error of two meters to deliver location-aware information, just as a tour guide delivers information to tourists. To locate people in the museum, a 2-m maximum error was considered adequate–a person can be reached visually within this range.

After running a few experiments with several combinations of parameter settings, the terminal search iteration, C_{iter} of the SABPN, was set to 500 to identify the optimal BPN parameter settings (learning rate, momentum term, learning cycle and number of hidden neurons) and feature selection for the network architecture. The learning rate was 0–0.45, whereas the momentum term was 0.4–0.9. The BPN used 1 hidden layer and the sigmoid transfer function. The learning cycle was set at 500–5000. The number of neurons in hidden layer was 2–22. The number of neurons in the input layer and output layer was 9 (9 signals) and 2 (predicting X and Y coordinates), respectively.

Table 2 shows the SABPN system about 92% of samples fall within two meters. Further analysis indicates that the SABPN technique achieves an accuracy of 82% samples falling within one meter. The accuracy rate of SABPN technique was 56% within 0.5 meters. Moreover, as the positioning system data was continuously updated, these errors would soon be corrected and renewed when they move out of range. Consequently, applying SABPN technique improves the precision of location determination.

SYSTEM IMPLEMENTATION

System framework

The location-aware museum's tour guide system consists of four components, the client (PDA), the location position agent, the context-aware agent and the content server.

(I) The client collects the power signature information, and transmitted it to the location position agent. Additionally, the client acts as a terminal to display the received messages.
(II) The location position agent estimates the position of the PDA. Location detection is achieved by combining the strengths of 802.11b/g wireless access signals. Neural networks are used to estimate position from RSSI signature information received from the access points. The location position agent stores results in the content server.
(III) The context-aware agent will send data to the appropriate recipients.
(IV) The content server stores the messages and location information of the PDA. The exhibition is shown in multimedia format. The images are mostly stored in *.png or *.jpg. Text files are stored in the BIG5 format. Audio files are in *.wav or *.mp3 format. Audio-video combination is in the *.wma, *.wmv or *.avi format. All these images, texts and audio-video files are stored using flash in a content server.

Sample scenario

A *scenario* is presented to illustrate the use of the location-aware museums tour guide system. Figure 3 shows how the components of the system's architecture interact for this scenario. As the visitor enters the

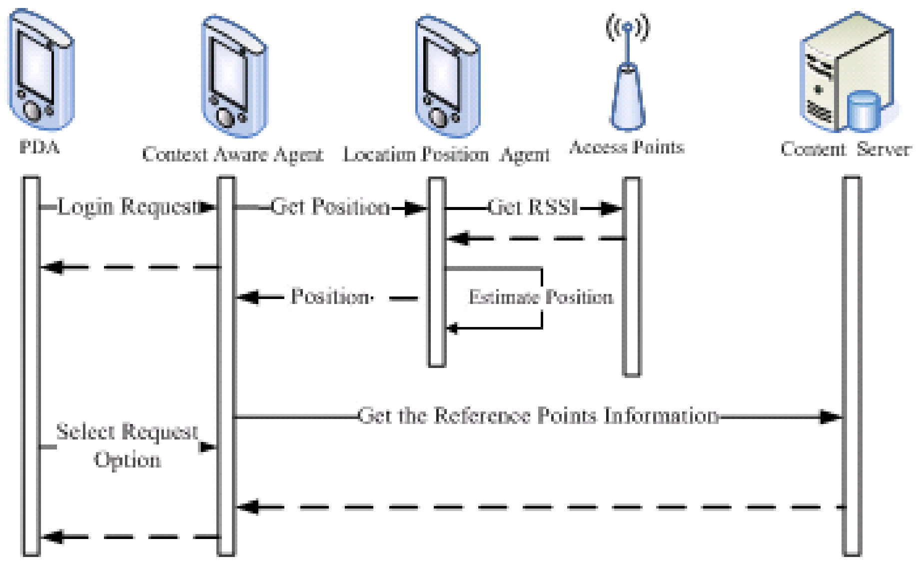

Figure 3. Sequence diagram of Museums tour guide system.

museum, he could lease a PDA from the service desk. A visitor who has been to the museum before, inputs his ID and the password to enter the system (Figure 4) Visitors can not only edit personal data, but can also choose the tour guide mode, e.g., preset, alternative or self-assigned. The preset tour guide follows the system preset guiding route; the alternative guide follows the themes of the exhibition and the personalized tour guide follows an itinerary set by the visitor (Figure 5).

Systems presentation

The location position agent can sense the strengths of the signals from all the access points to which the devices can be linked after the tour guiding mode is selected. If the visitor changes the location, then these signals function as input numbers. They are then calculated along with the weighted trained BPN to produce the X and Y coordinates. The context-aware agent then matches the coordinates to the location on the map, which is then shown on the visitor's PDA. Figure 6 presents an example of this situation, where the red frame line indicates the floor plan of a particular floor in a museum; the black dot indicates the location of the exhibiting material, and green flag shows the path taken by the visitor.

When the visitor selects a particular collection in the exhibition, the context aware agent transmits the information on its surrounding exhibiting materials to the visitor's PDA. The size of the exhibited collection changes based on the distance between the visitor and the exhibition material and becoming larger as they get closer (Figure 7). The system describes the exhibition in detail as the visitor clicks on its image (Figure 8).

CONCLUSION

This study establishes a prototype tour guide system for the National Palace Museum of Taiwan, based on a context-aware framework where visitors in different contexts can obtain information customized to their needs. Location is undoubtedly important to understand the context of mobile users. Location becomes a useful indexing datum from which to infer the overall context used by a system to provide services and information to mobile user. Moreover, mobile users constantly adjust their contexts, especially their locations. The location-detection system senses the location of a visitor traveling around the museum; indicates the location to the visitor through the PDA, then uploads the pre-defined information in real time to the device based on the location.

The guidance system can then be designed as a geographic information system (GIS), which analyzes data and provides information based on geographic location. Since the layout of the museum does not change frequently, the floor space is partitioned into identical grids, and the learning algorithm is executed at each grid point. The strengths of the signal from various accessible APs are recorded at each grid point, and act as the signature at that grid point. Since the strengths of the signals change due to different environmental conditions, the distribution of the signal strengths is measured from each accessible AP. These signatures at the grid points are recorded and can be used as the reference for location detection, along with the geographic information system established for the museum.

Analytical results clearly demonstrate that the locations in an indoor environment can be determined using the signal strengths of IEEE 802.11 g access points as input samples for training neural networks. The accuracy of

Figure 4. System appearance.

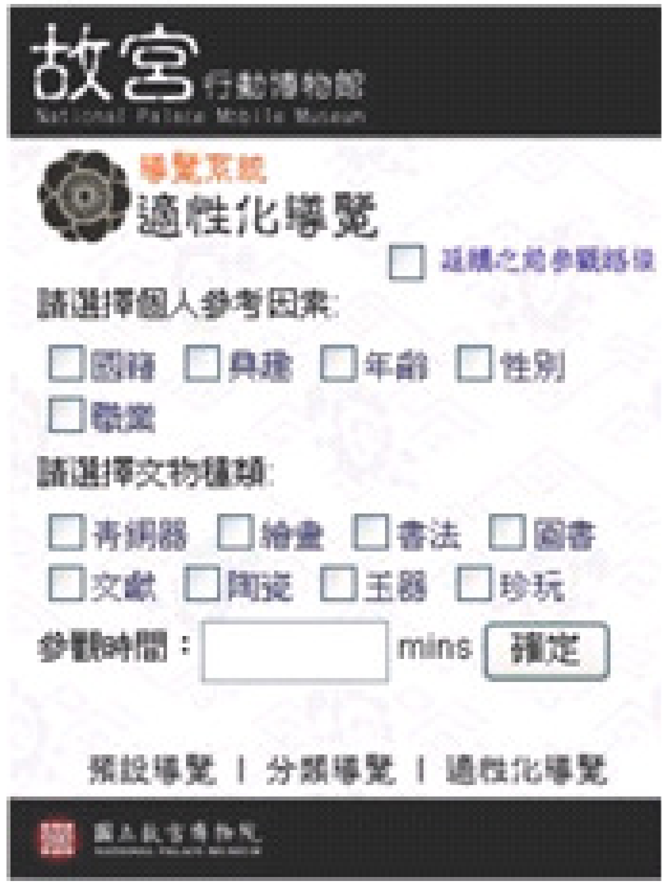

Figure 5. The adaptability turns guide system.

Figure 6. Wireless positioning.

Figure 7. Exhibit the article change.

Figure 8. Content of exhibition guides.

location determination depends on the learning algorithm and the number of labeled examples. A reasonable number of labeled samples can yield very good results, with an average absolute distance error less than 1.1 m. Based on the room size and antique of the museums utilized as our site study, this study set a maximum error of two meters as the target for delivering location-aware information, such as tour guides, to the tourist. A 2-m maximum error is considered as reasonable for locating people within the museums, since a person can be reached visually within this range. Compared with past museum tour guide systems, Zimmermann and Lorenz (2008) designed a tour guide system with an RFID reader embedded in an ear phone. When the reader senses an RFID tag within an antique within its read range, it means the user is standing in front of the antique, using the audio tour guide system. Ghiani et al. (2009) used an RFID PDA system with the same positioning method as that in Zimmermann and Lorenz (2008). This RFID PDA system is compatible with many tour guide devices, user information and history records of cultural relic visiting.

The proposed system adopts the IEEE 802.11 g standard and the SABPN technique, achieving accurate prediction of user position and lower implementation costs than the two RFID systems described above. IEEE 802.11 and SABPN continually receive RSSI signals and to instantly refresh the user's position. In addition, since Smart Phones and PDAs are often capable of Wi-Fi transmission, visitors can use their own mobile devices as museum tour guides. In practice, this is more convenient than renting a PDA system from the museum. Additionally, the tour guiding material could be classified to satisfy the requirements of different groups, increasing the fun in learning. Users' behaviour could be further analyzed based on the established effective membership data bank in the tour guide system in order to serve the target users more precisely, and thus, improve the operation performance of museums.

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