A REAL-TIME INFORMATION SERVICE SYSTEM USING WI-FI LOCATION FINDING TECHNOLOGY DURING WATER TRANSPORTATION

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Keywords : Water transportation, Location finding, Information service system, WiFi, GPS

1. INTRODUCTION

The technology of providing place information in real time is known as the concept of ubiquitous computing. This is a method with which real space and virtual space are made to connect. Ubiquitous computing is related to various fields in architectural design and city planning, such as smart housing, smart building, facility location planning, public space planning, sign planning and traceability analysis [1)2)].

Location finding is a fundamental technology for establishing a user's position. Basically, it relies on receiving radio signals and interpreting their relative timing and/or signal strength [3)]. Location finding technology based on WiFi uses access points (APs) of three or more wireless LANs [4)]. Therefore, it is not affected by the number of satellites, which is one of the technical limitations of GPS. Moreover, there are many APs of wireless LANs in a city, and the number is increasing every year [5)]. Thus, this research focuses on the potential for location finding technology using WiFi.

On the other hand, a river place gives a precious taste of nature and open space, and becomes an important hub of a disaster prevention system and sightseeing using shipping services in a city. Therefore, this research aims at developing a system for providing information about the nearby riverside area in real-time during water transportation. The availability of WiFi location finding technology and how passengers can be provided with riverside information in real time are clarified through development and evaluation of a system. It is proposed that this system will be cheaper and offer more personal and social applications than the existing geocoding method.

There is previous researches reporting on the development of WiFi location finding technology and its accuracy verification [6)7)8)9)]. However, an accuracy of location finding by WiFi should differ according to the density or land use of an area in a city. The previous research of the accuracy of location finding according to an area exists about GPS [10)].

2. SYSTEM DEVELOPMENT

2.1. System Configuration

The developed system consists of four subsystems: a WiFi location finding system, a web-based Geographic Information System (GIS), a riverside information database, and a web-based Graphical User Interface (GUI). The WiFi location finding system, the GIS, and the riverside information database are on the distributed host server. The GUI is operated by a web browser on a standard spec client PC or smartphone. Fig. 1 shows the overall view of the developed system.

The WiFi location finding system finds the current position in real time, communicating with WiFi APs. The GIS is provided with the acquired position information (longitude, latitude). PlaceEngine API was used as a WiFi location finding system in this research [11)]. Next, the GIS displays on a map the position information acquired by the WiFi location finding system. Google Maps API was used in this research. The riverside information database is divided and registered into a number of categories. In the database, the information about the riverside past, current situation and future, details of the information (.html), location information (longitude, latitude), photographs (.jpg), and narrations (.mp3) are mutually linked. In the experiment in Section 3, 94 riverside information was registered into six categories (buildings, rivers, bridges, open spaces, stations and events). The GIS extracts the riverside information near a user’s present location from the riverside information database registered beforehand, and displays it. The neighborhood distance which is extracted from the current location is given as a parameter. In the experiment in Section 3, the neighborhood distance was set as 300 m.

2.2. Flow of System Use

The process a user follows when using this GUI system is described below. The following numbers are equivalent to the numbers in Fig. 1.

1. Click “Get Location” button on the GUI of the client PC
2. Get WiFi signal strength
3. Search the WiFi location finding server database

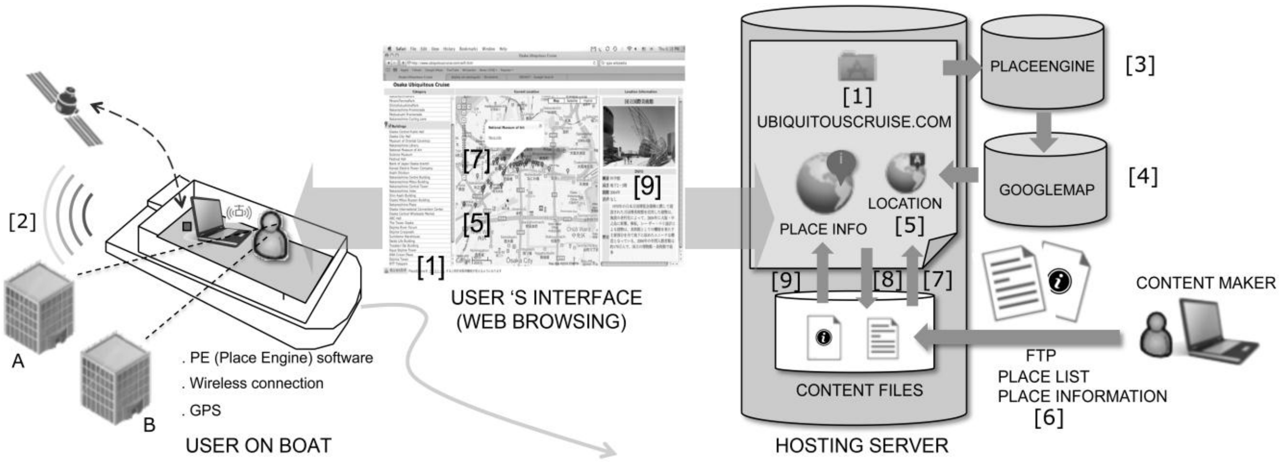

Fig. 1 Overall view of the developed system for location finding and place information.

4. Send the acquired location information (longitude, latitude) by WiFi location finding to the GIS server
5. Display the location as a marker on the GIS
6. Add content which includes distance from the current position to the hosting server
7. Display place information tags on GIS
8. Click a marker according to user's interest
9. Display place information on the right sidebar on GUI

No.2 to 7 are automatically repeated with a certain fixed time interval, while using the system. A time interval is given as a parameter. In the experiment in Section 3, it was set as 10 seconds. Therefore, if the current position moves, position information will be updated by the WiFi location finding system, and the geographic information currently displayed will also be updated automatically.

3. SYSTEM EVALUATION

3.1. Experiment Method

The verification experiment was conducted in the Osaka Nakanoshima area on December 5, 2009. Fig.2 shows photos of the experiment. The weather was fine. The boat carried ten subjects, three staff members and the system. It lasted 53 minutes, and went around Nakanoshima, which was a distance of about 8km. The upper stream of the Okawa river branches at Nakanoshima, and is divided into the Dojima River and the Tosabori River. The experimental boat left Tenmabashi harbor and followed the Tosabori River to the west. At the westernmost end of Nakanoshima, the boat went into the Dojima River and continued to the east. It came out of the Dojima River to the Okawa river, and returned to Tenmabashi harbor around the Kawasaki bridge. As for river width, the Dojima River is 60 to 80 m, the Tosabori River is 40 to 50 m and the Okawa river is 100 to 140 m. The boat was an open-air type without a roof. The current location was acquired by WiFi location finding at intervals of 30 seconds during the water transportation. The current location was also acquired by GPS data logger (DG-100 by GlobalSat Technology Corporation) at intervals of 30 seconds for technological comparison. The average speed of the boat was 8.59 km/h and the highest was 13.2 km/h.

Fig. 2 Experimental photos.

There were ten subjects, of which six were male and four were female. Regarding age, five people were in their 20s, one was in his 30s, three were in their 40s, and one was in her 60s. The subjects browsed riverside information displayed on a notebook PC in real time according to their own interest during the experimentation. Subjects replied to the questionnaire after landing.

3.2. Technology Evaluation

Residual errors by WiFi are clarified according to the area. It is difficult to grasp correctly WiFi APs which influence residual errors. Therefore, the authors classified each area based on land use and PlaceEngine's coverage area as presented on the official site of PlaceEngine [12].

With each method, the location finding value (longitude, latitude) of 110 points was acquired through the water transportation. GPS logging data indicated location finding was almost the same as the actual location. One of the reasons was that the sky exposure ratio was high in the Nakanoshima area. Therefore, GPS logging data was used as a most probable value for evaluating the value of WiFi location finding. Based on the location finding value acquired at the same time by using two systems of WiFi and GPS, the residual error D was computed by using Hubeny's formula for distance calculation (1).

$$
\begin{aligned}
D &= \sqrt{(M * \Delta P)^2 + (N \times \cos(P) * \Delta R)^2} \\
M &= a * (1-e^2) / \sqrt{(1-e^2 \sin^2(P))^3} \\
N &= a / \sqrt{1-e^2 \sin^2(P)} \\
f &= 1/299.152813 \\
F &= 1/f \\
e &= \sqrt{2F-1}/F \\
a &= 6377397.155(m)
\end{aligned}
\qquad (1)
$$

D: Residual error between 2 points which are location finding values of the same place by GPS and WiFi (m), P: Average latitude between 2 points which are location finding values of the same place by GPS and WiFi, ΔP: Latitude difference between 2 points which are location finding values of the same place by GPS and WiFi, ΔR: Longitude difference between 2 points which are location finding values of the same place by GPS and WiFi, M: Meridian radius of curvature, N: Prime vertical radius of curvature

Although a residual error of 0 m is desirable, it is actually difficult to achieve. Therefore, the range of acceptable residual error was considered. Firstly, 12 logged points (No.37, 75, 82, 83, 90, 93-96, 104, 105 and 107) for which the residual error was not less than 1000 m were eliminated beforehand. As a result, the whole logged points are 98. If the estimated current position is within the range displayed on the map of a GIS, the user can understand the current position based on one's experience or the surrounding context. Even if a large residual error occurs, there is the possibility that the next location finding carried out after 30 seconds will acquire a more exact estimated current position. Therefore, in this research, the acceptable residual error was set to 100 m. A value of not less than 100 m was treated as an abnormal value. As a result, 52 (53.1%) of the 98 logged points had a normal value and 46 (46.9%) had an abnormal value. The average residual error of the whole 98 logged points was 192.9 m. The average residual error of 52 points with the normal values was 28.4 m.

Fig.3 shows the distance between WiFi and GPS logged points which are also pointed out on the Nakanoshima Map. Residual errors are analyzed according to the situation of the land use which affects WiFi location finding (Table 1).

The Nakanoshima central area is also a high-density area of APs [12]. In this area (No.8-24 and 60-80 without No.75. 37 points), the abnormal value rate of incidence is 24.3%, and

Table 1 Experimental result according to the land use

	No.3-30	No. 31-59	No. 60-80	No. 81-90	No.1, 2, 91-110	Total
Acquired points	28	29	21	10	22	110
Eliminated points	0	1	1	3	7	12
Normal value points	24	9	15	0	4	52
Abnormal value points (rate)	4 (14.3%)	19 (67.9%)	5 (25.0%)	7 (100%)	11 (73.3%)	46 (46.9%)
Max. of error (m)	483.3	604.2	450	931.3	871	931.3
Min. of error (m)	0	6.7	0	177.2	2.5	0
Average error (m)	48.0	192.2	73.9	596.9	421.9	192.9
Average error of normal values (m)	14.4	61.5	31.3	N/A	27.0	28.4

Table 2 Comparison of the Central area, another area and GPS

	Central area (No.8-24, 60-80)	Anothe r area	Total	High-rise area by GPS[12]	Low-rise area by GPS[12]
Acquired points	38	72	110	N/A	N/A
Eliminated points	1	11	12	N/A	N/A
Normal value points	28	24	52	141	62
Abnormal value points (rate)	9 (24.3%)	37 (60.7%)	46 (46.9%)	N/A	N/A
Max. of error (m)	483.3	931.3	931.3	193.8	105.5
Min. of error (m)	0	2.5	0	1.5	1.4
Average error (m)	70.8	266.9	192.9	N/A	N/A
Average error of normal values (m)	21.8	36.1	28.4	40.4	18.2

the average residual error with the normal value is 21.8 m (Table 2). These are lower values as compared with another area and a total average of the experiment.

In the previous research of location finding by GPS in Osaka which is the similar location as this research [10], the residual error was 1.5 m to 193.8 m and the average residual error was 40.4 m in high-rise building area. The residual error was 1.4 m to 105.5 m and the average residual error was 18.2 m in low-rise building area (Table 2). The residual error of location finding by WiFi in the Nakanoshima central area which is a high-rise building area is 21.8 m, and is lower than the residual error by GPS. In a high-rise building area, while reception of GPS worsens and the accuracy of location finding falls, WiFi does not have the influence.

3.3. Usability Evaluation

The evaluation of the proposed system which cannot be grasped only by Technology Evaluation are clarified. A subject evaluates overall impression of the system, each item of the system, and ranking of the most poorly rated items of the system and experiment by a questionnaire.

As the whole system for showing nearby riverside information in real time during the water transportation developed in this research, 80% of subjects evaluated it as positive.

Fig. 4 shows subject's grades for each item of the system and the experiment in a range from 0 to 100 percent. Location accuracy was the item that received the least

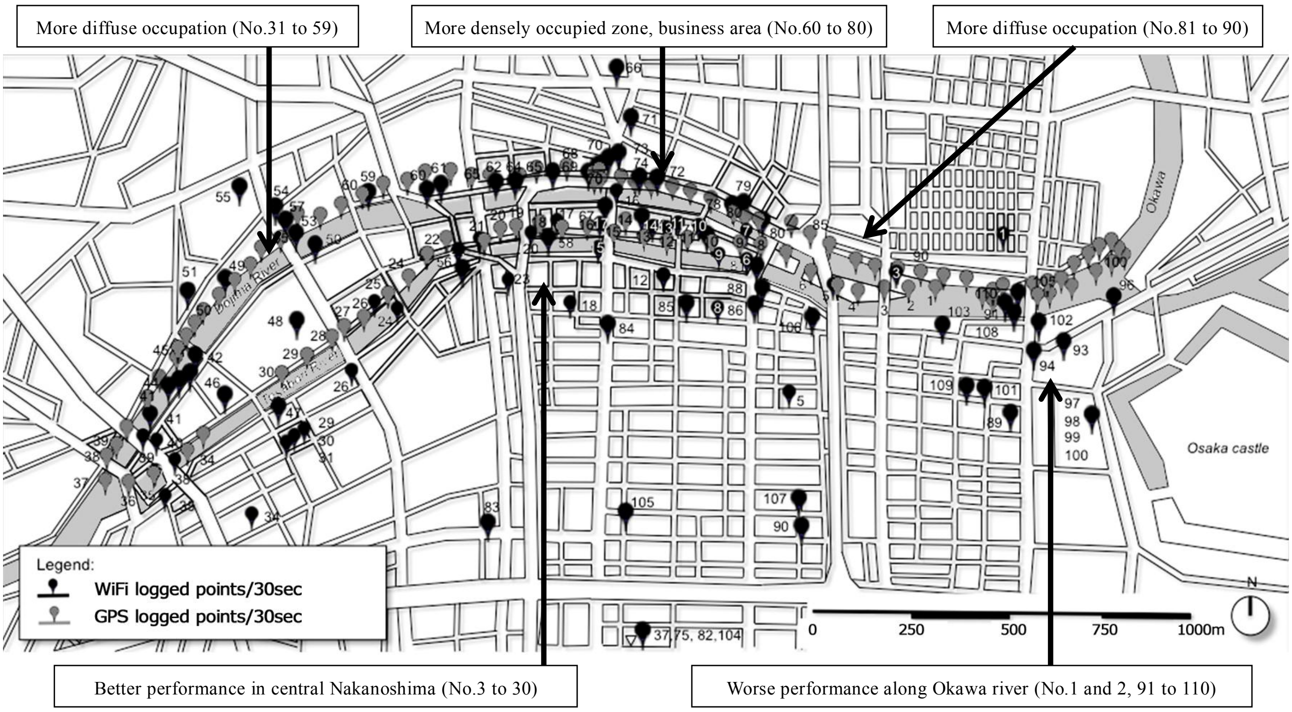

Fig. 3 Distance between WiFi and GPS logged points (Above: Map of Nakanoshima with WiFi (black) and GPS (gray) estimated points.

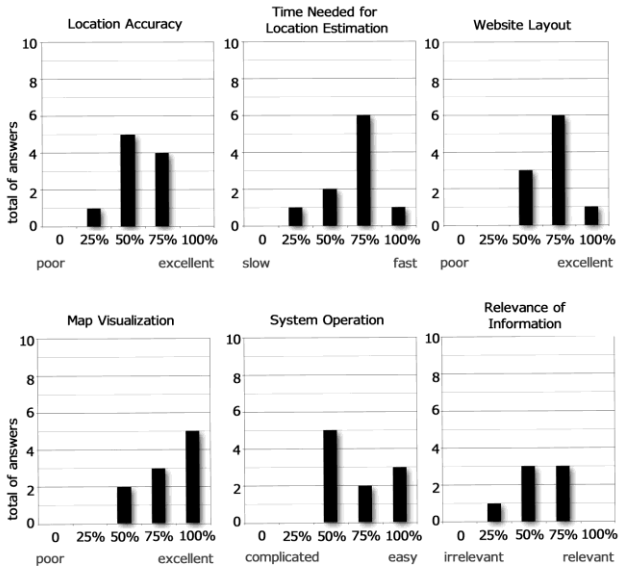

Fig.4 Grading evaluation for each item of the system

positive evaluation, but considerably more than expected after compiling the technical data. The zoom properties of Google Maps may have led participants to expect better accuracy in many of the failure points. Although the location accuracy was the item that received the best mean evaluation, none of the items had a completely negative rating.

Moreover, each subject was asked to rate 12 factors about the developed system and the water transportation. The subjects ranked the problematical items sequentially from No.1 to No.12 through the experiment. Each ranking was scored so that the No.1 was one point, and No.12 was twelve points. That is, a low score meant a low evaluation. Table 3 shows the result. The lowest item in sum total score was location accuracy. Next was time needed for location finding. It is clear from the usability evaluation that improving the WiFi location finding service is an important issue. Moreover, the item which most subjects indicated as the worst (No.1) was glare of sunlight reflected from the display. This means that it is hard to see the display while outdoors, as has been reported by previous research [13].

Finally, the subjects of the developed system are listed below. These pointed-out subjects serve as data that may be

Table 3 Ranking of the most poorly rated items of the system and experiment

	Item	Ranking 1	2	3	4	5	6	7	8	9	10	11	12	Total
System	Location Accuracy	3	4	3										20
System	Time Needed for Location Finding	1	1	2	4	1	1							36
System	Webpage Refresh	1		1	3	4		1						43
System	Map Visualization					1	1	1	1	4	1	1		83
System	Webpage Design		2		1		1		3	2	1			66
System	Information Display					2	2	1	2	1	2			74
System	Amount of Contents		1	2		1	2	2	2					55
External	Glare of sunlight reflected from the display	4	2					2			1		1	44
External	Boat Layout					1		1	1	1	2	3	1	94
External	Weather Factor				1		2	1	1	1	2	2		88
External	Sea Sickness			1				1			1	5	2	99
Others		1		1	1									8

useful for future system improvement.

1. Making a more interactive interface
2. Improving WiFi location finding accuracy
3. Addressing limitations on internet accessibility outdoors
4. Addressing practical problems concerning the reading and hearing of contents outdoors

4. CONCLUSION

This research presents a system which displays nearby riverside information relating to the past, current and future situations of riverside places in real time during water transportation. In order to estimate the current position information, WiFi location finding technology was focused on and a verification experiment was conducted. The contributions of this research are as follows:

- The developed system is a web application with high flexibility, consisting of a WiFi location finding system, a GIS, a riverside information database, GUI, etc. Therefore, if the Internet is accessible, a normal notebook PC or smart phone can also be used. Users can browse and share riverside information which includes buildings, rivers, bridges, open spaces, stations and events with images or movies during the water transportation interactively. The proposed system was evaluated positively by the subjects.
- As a result of technological evaluation, the average residual error of the whole 98 logged points was 192.91 m. On the other hand, when the focus was only on the central district in Nakanoshima, where APs exists most, the average residual error showed 21.8 m. This is lower value as compared with another area, a total average of the experiment, and GPS in a high-rise building area.
- In the usability evaluation, 80% of examinees evaluated the whole system as positive. On the other hand, when 12 factors about the developed system and the water transportation were rated, the evaluation of location finding accuracy and glare of sunlight reflected from the display was low.

WiFi location finding technology is still a new technology which has considerable potential, but further improvement is required for practical application of the system as future works. It is difficult to grasp where APs are at the time of system use in a city. Therefore, a visualized database of wireless LAN APs needs to be created. Moreover, it is necessary to show the WiFi location finding accuracy.

ACKNOWLEDGEMENTS

A portion of this research was done with the assistance of subject number 211049 of the 2009 Support Project of Regional Activities for Understanding of Science (Japan Science and Technology Agency (JST)). The author would like to thank Keihan Osaka Suijo Bus and subjects for the cooperation in the experiment.

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水上輸送を対象としたWiFi位置推定技術による
リアルタイム情報提供システム

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キーワード：水上輸送，位置推定，情報提供システム，WiFi，GPS

近年、ユビキタスコンピューティングは、場所と情報とを結びつける概念および技術として、建築設計や都市計画分野と関係が見られる。一方、河川分野では、都市空間において水・緑・オープンスペースを提供すると共に、防災や観光分野での水上輸送が重要視されつつある。そこで本研究は、水上輸送時に沿川情報をリアルタイムに提供するシステムについて考察することを目的とする。舟の現在位置を取得するためにWiFi位置推定技術の可能性を探究した。

研究の方法として、まず、情報提供システムを位置推定技術、GIS技術、web技術等を要素技術として開発する。次に、大阪市の大川、堂島川、土佐堀川で囲まれる中之島を対象とした情報提供システムをプロトタイプとして構築する。そして、実際の水上輸送実験を実施して、地域別のWiFi位置推定技術検証とユーザビリティ評価を実施する。

本研究で得られた成果を示す。

1）開発した情報提供システムは、舟の現在位置を把握するためのWiFi位置推定システム、現在位置周辺の情報を地図上に表示するwebGIS、川沿いの情報を蓄積するデータベース、GUIから成る。これらはweb技術を基礎としており、インターネット接続が可能な標準仕様のPCやスマートフォンで利用可能な汎用性の高いシステムである。ユーザは建物、河川、橋梁、オープンスペース、駅、イベントなどの沿川の情報を画像や映像と共に閲覧することが可能である。

2）技術検証の結果、WiFi 位置推定技術により取得された現在位置と最確値との平均残差は中之島全体において192.9mとなった。一方、WiFiアクセスポイントが集中する中之島都心地区に限れば、平均残差は21.8mとなった。これは水上輸送時に川沿いの情報を提供する目的やGPS精度との比較において許容可能である。

3）ユーザビリティ評価の結果、80%の被験者がシステム全体に対して肯定的な評価をしている。さらに、現在位置の取得やGUI設計などの個別項目についても高い評価が得られた。一方、開発したシステムと実験に関する12項目を順位付けした際には、位置推定の精度やディスプレイのグレアの項目が低い評価となった。

以上より、開発したシステムは一定の評価を得られたといえる。一方で、WiFi位置推定システムにより得られる位置推定情報の精度をユーザが把握できないことなどの課題も明らかになった。今後の課題としたい。

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