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# NAVILITE: A LIGHTWEIGHT INDOOR LOCATION-AWARE MOBILE NAVIGATION SERVICE FOR THE HANDICAPPED AND THE ELDERLY

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Faced with the rapidly aging population, shrinking number of caregivers, and the promise of economic returns, the growing demand to provide more service assistance to handicapped persons and the elderly is a challenging task. In Japan, there are about 560,000 people who are in wheelchairs but they are rarely seen in public. One reason is that, they lack the information on the available facilities that cater to their needs once they go out to their destination. Providing these people with information on barrier-free facilities and other related information along their route will help boost their morale, build self-confidence, and self-reliance. In this paper, we describe the development towards a real-time and lightweight location-aware navigation service, called *NaviLite*, with particular focus on people in wheelchairs. We utilized the readily available handheld PHS mobile phone devices to display the location map, obstacles and danger zones within the periphery, and the suggested route to their destinations. We conducted preliminary experiments and discussed its results. *Key words*: wireless mobile computing, location-aware, navigation service, barrier-free facilities

## 1 Introduction

With the rapidly aging population and the shrinking number of caregivers, coupled with some economic returns, there is a growing need to provide more service assistance to handicapped people and the elderly who are still capable of taking care themselves independently.

In a survey conducted by the Health Ministry of Japan, there are about 560,000 people who are in wheelchairs [1]. Although the level of wheelchair users varies, most of these users are still capable of doing their routines without or with minimum assistance. Government agencies and concerned organizations have encouraged communities, public institutions, commercial establishments, amusement parks, etc., to build social infrastructure based on universal design notion for handicapped persons (so-called “barrier free facilities”); such as ramps, elevators, and others. However, in spite of these efforts, people in wheelchairs are rarely seen in public places. One reason that can be attributed to this is that the available information on the availability, location, and details of these barrier free infrastructures are unknown and/or out of reach to wheelchair users.

In this paper, we study the development towards a real-time and lightweight indoor location-aware mobile navigation service, called *NaviLite*, for the handicapped and the elderly. In particular, we take into consideration people in wheelchairs and the use of commodity-off-the shelf hand-held mobile devices (i.e., PHS mobile phones) to construct and test a mobile navigation display featuring different navigational information and guidance.

In the following, Section 2 discusses some related work, while Section 3 explains the base environment. Section 4 describes the system organization, and Section 5 describes the experimental test bed. Section 6 describes some preliminary experiments, and Section 7 cites the concluding remarks and some future works.

## 2 Related Work

There have been various researches in wireless mobile computing technology to support location- and context-aware navigation services in handheld mobile phone devices. To mention a few, [8] proposed a road shape transformation algorithm based on cognitive science to generate deformed maps that will be understandable in a small display and easy to comprehend for route understanding. Whereas [12], introduced a novel location update protocol called state-based location update protocol (SLUP) which significantly minimizes the energy consumption of mobile client by exploiting syntactic information of a user’s movement. On user tracking, [13] proposed using a hybrid neural network for location prediction of mobile users and developed a paging technique based on this prediction location. The above works addresses different issues in their own right to provide support for location- and context-aware navigational service, and these will served as references in pursuing the objective of our study.

This paper, describe the service composition of a small pilot study aimed to provide a navigational aid using low-cost handheld devices for handicapped persons and the elderly, citing people in wheelchairs in particular. The following section briefly describes the three-dimensional (3D) Navi Hyper-kun system which provided motivations and base information in constructing *NaviLite*.

## 3 The 3D Navi Hyper-kun and *NaviLite*

The 3D Navi Hyper-kun system [2] provides a visual simulation model of a building with pre-designed barrier information, path routes, and 3D walkthrough simulation. Furthermore, the system provides display information of the surroundings, available barrier free facilities within the periphery, usage and some details of these barrier free facilities (e.g., sloping walkway or passageway), obstacles and danger zones that must be avoided, suggested route to reach the destination, and other helpful information.

### *3.1 The 3D Hyper-Building*

The 3D Hyper-Building is a visual simulation of a virtual building in the 3D Navi Hyper-kun system, providing different building facilities (e.g., rest rooms, tables, chairs, ramps, automatic/manual doors, etc.), equipments (e.g., elevators, escalators, etc.), and obstacles. The building facilities, equipments, and obstacles in the virtual space can be pre-arranged and adjusted so as to simulate an environment that reflects a realistic situation in a building. This flexibility helps to provide wheelchair users a clearer understanding of the surroundings which is important in determining the appropriate route to take.

To speed up the communication processing, we utilized the 2D map image of the first floor of the 3D Hyper-Building in conducting our experiments, as depicted in the client's display panel, Figure 1.

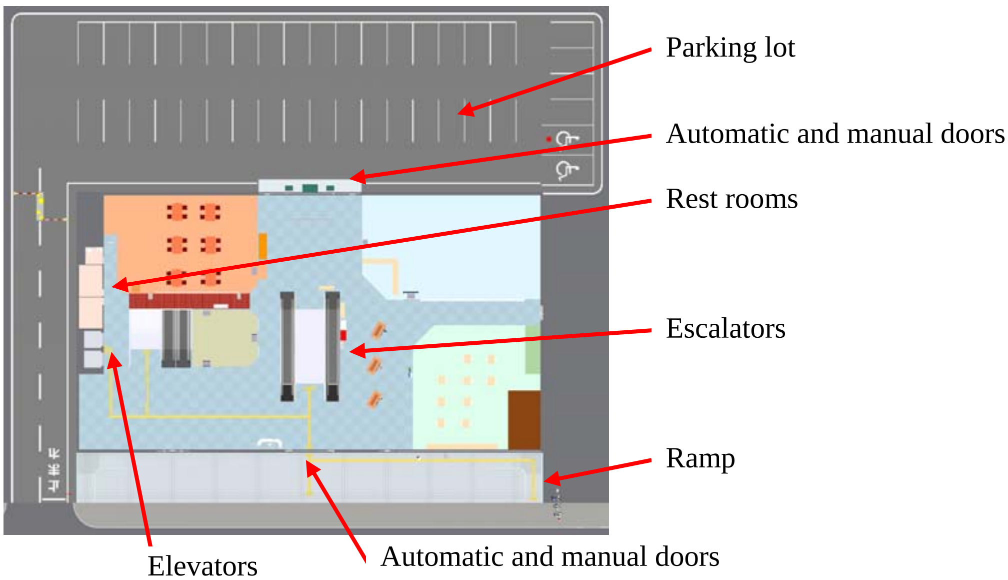


Figure 1 A 2D image of the First Floor in the Hyper-Building

The floor in the hyper-building provides a set of pre-arranged virtual nodes which will serve as reference points to determine the different nodes required to connect and establish the suggested route which wheelchairs users will follow. Each node contains its own ID number, coordinates, information within its vicinity, and some warning information as the case may apply. The nodes are pre-arranged based on the building floor's setup with due consideration to barrier free facilities. Figure 2 shows the numbered nodes in the building floor in which after some calculation these nodes are connected to configure the suggested path.

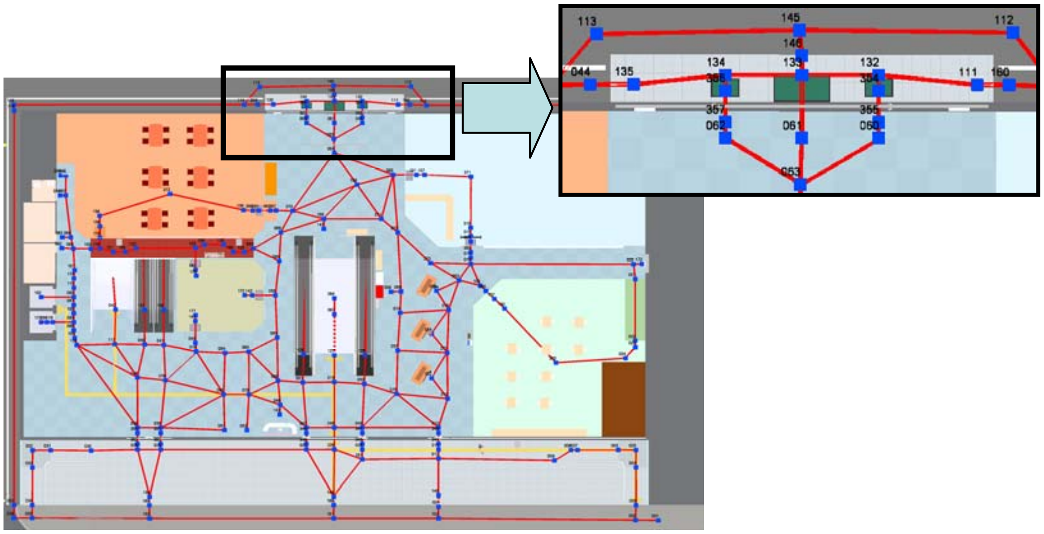


Figure 2 A sample of nodes arrangement in the First Floor of Hyper-Building

### 3.2 Rationale of NaviLite

The development of *NaviLite* stems from the fact that mobile phones, although getting smarter and more features are continuously added, they are also getting more and more expensive. Moreover, the continuous uploading and downloading of data to provide a real-time 3D navigation display service consumes a lot of the mobile phone's battery energy.

These opted us to consider the low-cost and cheaper data transmission rate charge, PHS mobile phones. With the low transmission rate of PHS devices and the goal to provide towards a real-time navigation service, the 2D map format was chosen. With ubiquitous PHS mobile phones, *NaviLite* is envisioned to provide navigational assistance in many ways to wheelchair users, Figure 3.

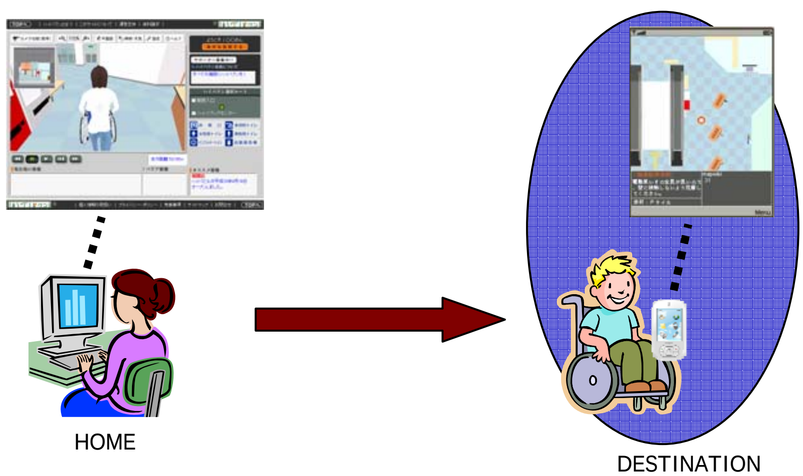


Figure 3 A sample scenario with *NaviLite*

## 4 System Organization

### *4.1 The layered approach*

To speed up communication and data processing, we considered the layered approach in arranging the different objects and information on the floor map, as shown in Figure 4. Layer 3 comprise the MapWiki textual information, while Layer 2 comprise the different nodes for route mapping, and Layer 1 comprise the passage ways, elevators, ramps, and other building facilities on the floor. The combined information is shown at the bottom layer.

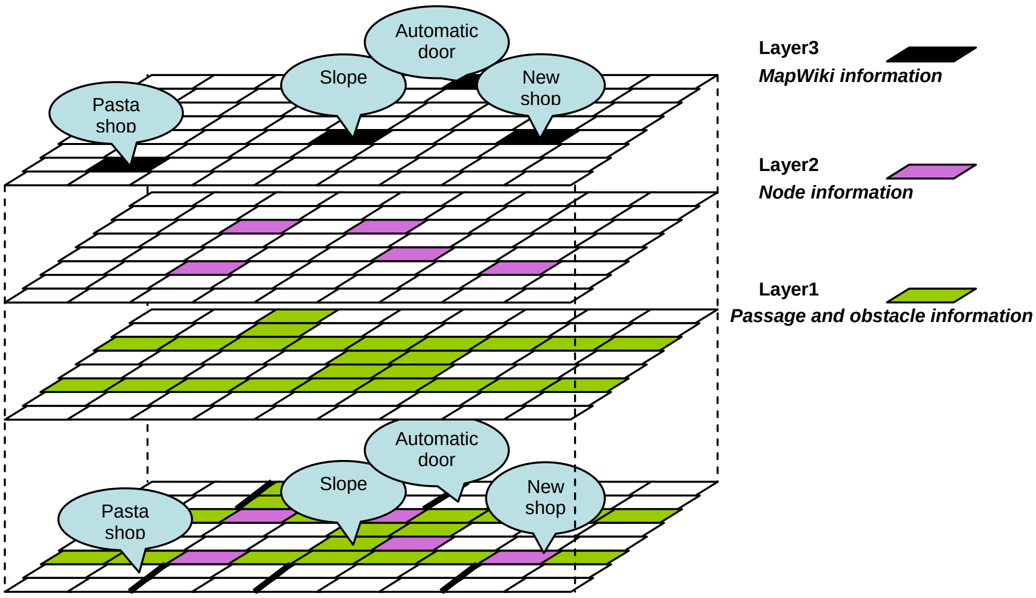


Figure 4 The data layered architecture.

### *4.2 Communication system organization*

Figure 5 illustrates the client-server transaction in realizing the navigation display service. The route search server is remotely located and maintains the 3D Hyper-Building simulation model, the routing information to the destination with respect to the client's current location, and information data for Mapwiki. The vicinity node server on the other hand, maintains the information of the building floor, i.e, barrier-free facilities, obstacles, etc.

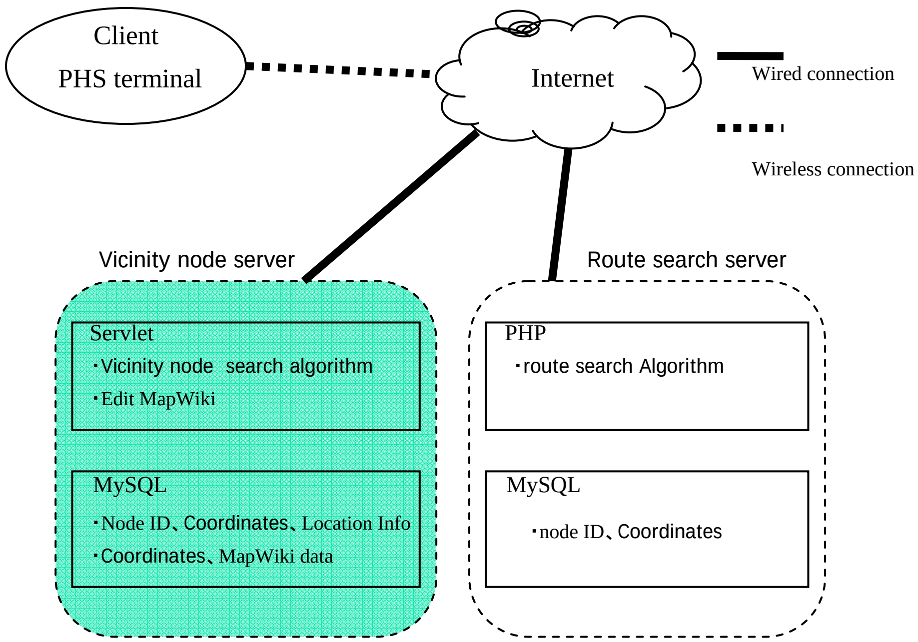


Figure 5 The *NaviLite* communication system organization

## 5 Experimental Test Bed

### *5.1 The client device*

The PHS or Personal Handy phone System is a simplified type of mobile phones (available in Japan) with a transmission rate of 32kbps. To date, efforts by PHS provider Willcom Inc. are underway to provide wireless telecom services in the 2.5-gigahertz frequency band in the near future. With the current enhanced functions and cheaper call charges, the number of PHS users has increased recently and is staging a major comeback in the challenging mobile phone market. Because PHS mobile phones offer cheaper packet transmission rates and call charges (relative to cellular phones), we have chosen it for this study.

The PHS mobile device has a built-in Java platform, Jblend. Figure 4 show the PHS mobile phone used in the experiments and Table 1 summarized its features.

Figure 6 The Willcom PHS mobile phone

Table 1 The PHS mobile device.

| | W-Zero3 [es] (WS007SH) |
|---|---|
| OS | Windows Mobile 5.0 for PocketPC |
| CPU | Intel PXA270 416MHz |
| Memory | Flash128MB |

### *5.2 Client-Server transaction*

As mentioned, this navigation system adapts the client-server paradigm. The client initiates the transaction by sending its location coordinates to the vicinity node server which will in turn provide the number of the virtual node nearest to the client, as well as the related information within the vicinity. When the client requests the route from its current location to destination, the client sends the number of the nearest virtual node and the destination's virtual node number to the route search server. After some configuration processing, the route search server sends the route information to the client.

The client-server communication is conducted over the PHS network. While the availability of wireless LAN (Wi-Fi and the evolving Wi-Max) for network access in public places and establishments are increasingly becoming popular; the hotspots needs to be installed, maintained, and requires financial investment. This issue is another consideration for employing the PHS network.

### *5.3 User's location information and tracking*

To acquire one's position outdoor, GPS is widely used. Whereas, to acquire one's position indoor and tracking its location, some alternatives are widely available; such as through access points in wireless LAN [4, 5] which are envisioned to provide ubiquitous network access in commercial establishments and public places. Wi-Fi tracking is already available in the market but it is costly. The use of RFID [6] has also gained popular interests among researchers and developers. Other methods [7] include the Bluetooth function in some hand-held mobile devices, and the sensor networks.

While the above positioning and tracking methods exhibit excellent functions, the installation and equipment costs are our concern. The availability of PHS mobile phones as commodity-of-the shelf devices and its capability to communicate indoors which does not require add-on devices and special set-ups, are our priorities in realizing a cost-effective means of providing the navigational service.

In this paper, we focus on the development of display information service on the PHS mobile device and assumed that a tracking procedure is already in place. Say, a number of RFID tags are sparsely placed in key spots such as in ramps, doors, hallways, and others, which will provide the user its location coordinates.

### *5.4 Display usability consideration*

In designing the navigation display service, it is important that the user neither feel stress nor get puzzled, must be able to access different information, and use the device functions easily [10, 14]. For wheelchair users, we consider the following criteria in providing the usability of the service.

- Intuitive interface: The user should be able to acquire and easily comprehend different information displayed on the screen.

- Distinctiveness: The instructions should be provided to the user using standard custom design functions, i.e., by clicking *Exit* button, etc., for the user to easily familiarize with the usage.
- User-friendly: The instructions should be plain and simple. To activate the display, this can be done by pushing a specific key on the PHS mobile phone which will display the menu options and available functions easily. The usage can be understood by highlighting textual information and providing *Help* options on the display.

In our experiments, we consider the following basic information that must be displayed on the PHS, which are peculiar and important to wheelchair users.

- Surrounding's information: This pertains on the floor information in the building (e.g., the 3D hyper building) including the floor plan and other facilities. While other navigation system displays only general floor information, more specific information is needed for wheelchair users which can be used for other purposes, e.g., detour route, etc.
- Obstacle and danger information: This includes some detailed information on existing obstacles along the route on the building floor, e.g., the type of door (sliding or swing type), garbage boxes, danger zones (stairs, closed doors, etc.), entrance to elevators, etc.
- Route to destination: This pertains to the suggested route that the wheelchair user has to follow to reach the destination. As wheelchairs could be manually or electrically operated, the route may differ as well.

Table 2 The three response time limits and the corresponding reactions of the user [15].

| Response time | User reaction |
|---|---|
| 0.1 second | Is about the limit for having the user feel that the system is reacting instantaneously, meaning that no special feedback is necessary except to display the result. |
| 1.0 second | Is about the limit for the user's flow of thought to stay uninterrupted, even though the user will notice the delay. |
| 10 seconds | Is about the limit for keeping the user's attention focused on the dialogue. |

## 6 Preliminary Experiments

### *6.1 Experiment 1: Vicinity information*

As the wheelchair user moves in the area, it sends its location coordinates to the nearest virtual node, which will in turn send back the relevant information within the vicinity (Layer 1) as displayed on the screen, Figure 7.

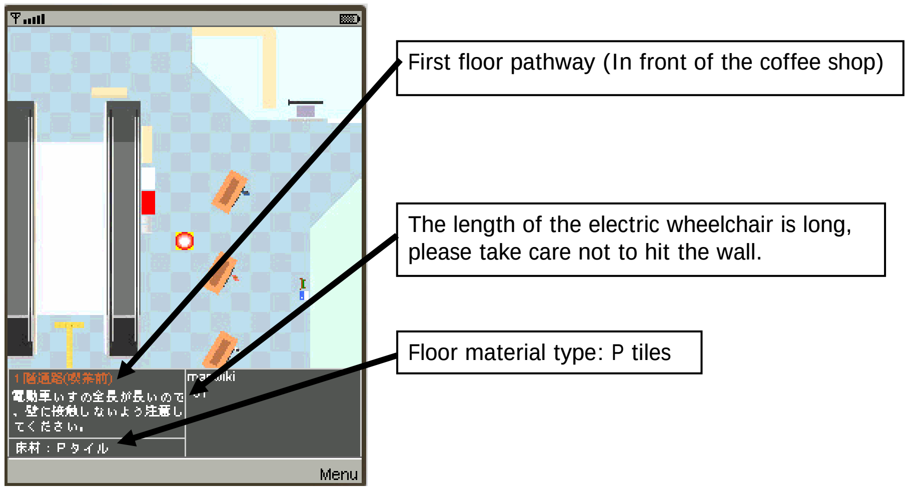


Figure 7 Display of vicinity's textual information

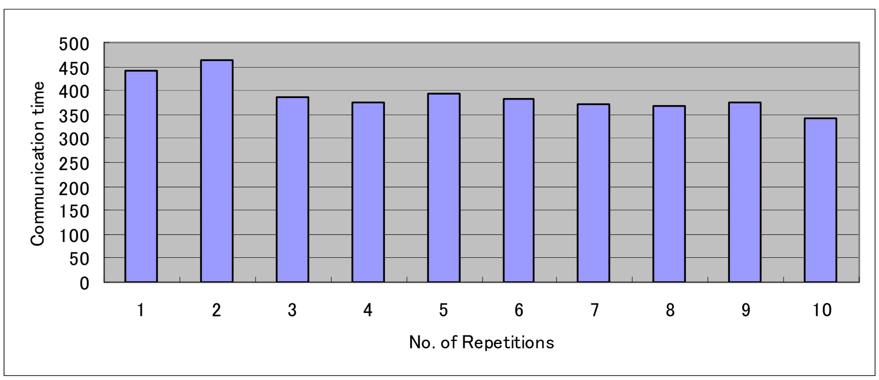


Figure 8 Processing time to display vicinity textual information

We measured the communication time required from when the client sends its location coordinates to the vicinity node server until the relevant information is displayed on the screen. From Figure 8, the communication time required is 389.8 milliseconds on the average which falls within the 1.0 second response time limit, Figure 4 [15].

### *6.2 Experiment 2: Route search*

The client acquires the number of the virtual node nearest to its location from the vicinity node server. This experiment is to measure the time from when the client send the nearest virtual node number and destination node number to the route search server. The virtual node numbers are used by the route search server to configure and map the appropriate route, and send the route information to the client and displayed on the screen (Layer 2). The route to destination is displayed as blue line on the screen, as shown in Figure 9.

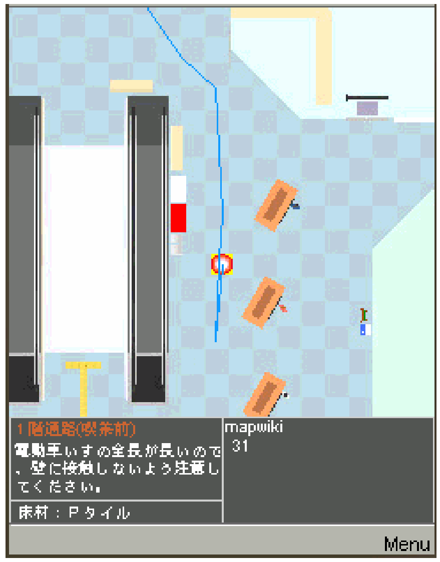


Figure 9 The route as displayed on the client screen..

The client location coordinates is sent to the vicinity node server.

現在位置座標(560,545)

The vicinity node server replies its node-ID to the client.

現在位置ID:57

The client sends the IDs of vicinity node server, destination node and user, to route search server.

現在位置ID:57
目的地ID:133
ユーザ情報:1

The route search server replies to the client the list of nodes to traverse towards the destination node.

経路間ノード:(558,542),(560,516),(556,445),(537,428),
(508,386),(482,348),(481,331),(482,311),
(482,285)

As shown in Figure 10, the communication time is about 1142.7 milliseconds, on the average.

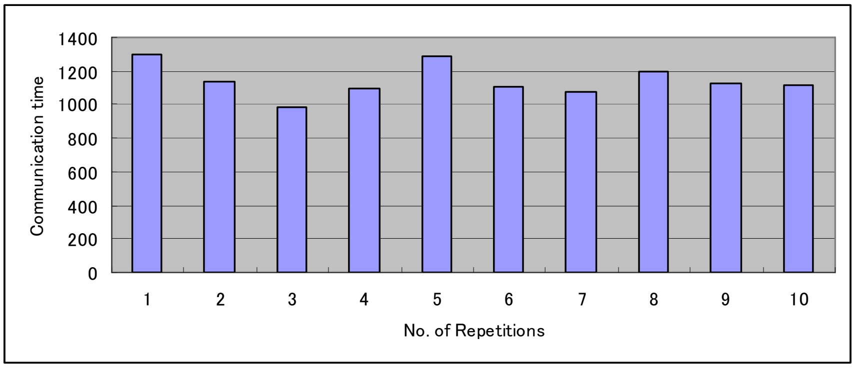


Figure 10 Communication time required for the route search

### *6.3 Experiment 3: Location-aware information*

To realize the sharing of information among users, especially among wheelchair users, we adopted the idea of MapWiki [16] like function so users can freely enter new and/or edit existing textual information through their mobile phones (Layer 3). We developed the MapWiki-like function and measured the time from sending newly edited information until it is displayed on the mobile phone screen.

The client's location coordinates is sent to vicinity node server:

現在位置座標(120,145)

The vicinity node server sends the related information to the client:

1/30までアスファルトの舗装工事中みたいです

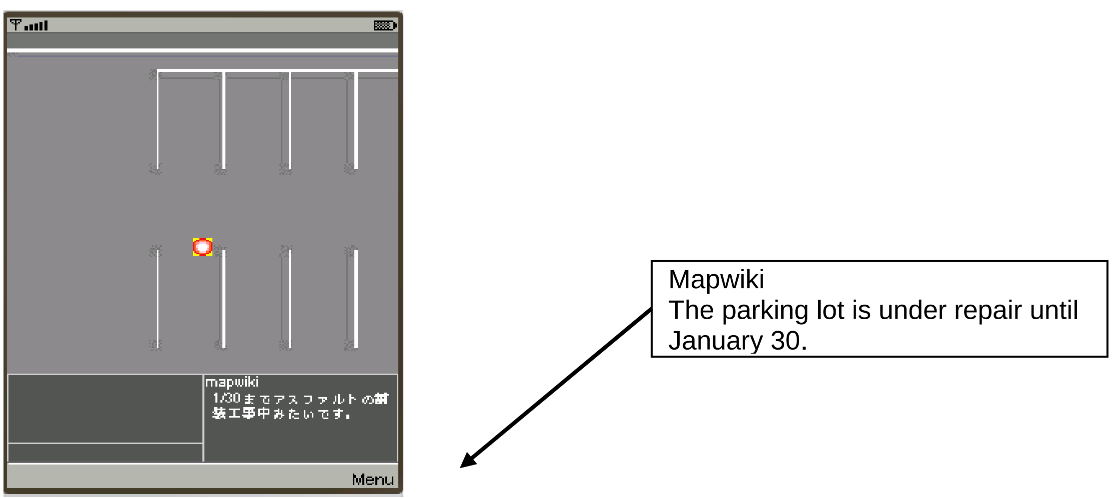


Figure 11 Display of Mapwiki textual information

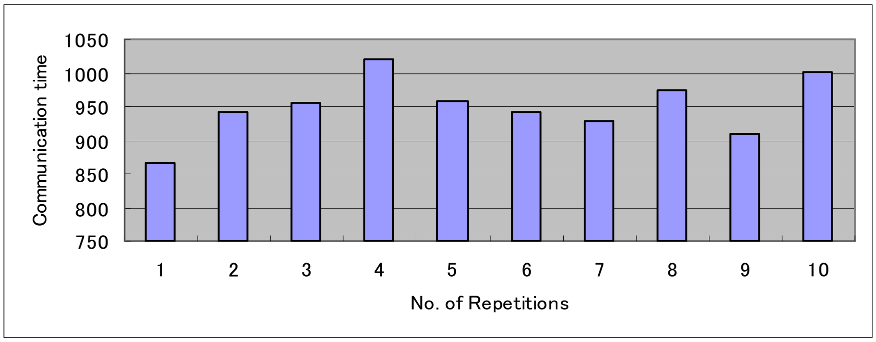


Figure 12 Processing time to process and display Mapwiki textual information

The graph in Figure 12 illustrates the time measured from when the textual information was entered on the mobile phone, then to the server for storage, and back to the mobile phone for display. Due to the limited space on the mobile phone display, the number of characters and/or letters that can be entered is limited. The measurement was repeated 10 times and the average is about 962 milliseconds, which is within the "1.0 second time limit" [15].

## 7 Concluding Remarks

We described a small pilot study towards a real-time and lightweight mobile navigation service. In this paper, although we considered people in wheelchairs as our particular subjects, the study in general is also applicable to other handicapped persons and the elderly.

The time required to display the vicinity node information (Experiment 1) was 389.8 milliseconds, on the average. Likewise, the time required to store and display the location-aware information (Experiment 3) was 962 milliseconds, on the average. These two experiment results fell below the "1.0 second response time limit required for the user's flow of thought to stay uninterrupted, even though the user will notice the delay" [15], implying its validity.

Whereas, the time required to process and display the suggested route information (Experiment 2) was about 1142.7 milliseconds, on the average. This response time limit exceeded the 1.0 time limit, and falls within the "10 seconds response time, which is about the limit for keeping the user's attention focused on the dialogue" [15], and users will feel this processing time delay.

In the present set-up, the configuration and mapping of virtual nodes to provide route information are processed at the remote route search server which incurs a large processing overhead. In the future, we plan to replicate the virtual nodes information to the local server for fast access. Likewise, future work includes the development of a location-aware mobile service management scheme to reduce the overall communication cost for servicing location and service management operations. Furthermore, for accessibility and usability as well as successful adaptation, we plan to unleash the full capabilities and features of the PHS mobile devices to implement a comprehensive navigational aid service in the ubiquitous society.

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