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GPS-based real-time location-aware system in outdoor environment

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Abstract

A location-aware system, which is capable to detect a user's whereabout in a region and provide real-time location information in outdoor environment is designed and fabricated, specifically using the GPS (global positioning system) as key technology in view of its stability and high precision in outdoor environment. Experiment is conducted to test this application in campus-based environment. Once GPS receiver detects specific location which is tagged with GPS coordinates, the system provides information relevant to that context and user can operate and react accordingly. Besides, this location-aware system is able to provide user with the route in order to get to a desired place by detecting the direction that the user is moving towards from his/her initial location. The mapping data is transferred via wireless LAN to PDA carried by the user as well as to the back-end system on real-time basis. The test result is analyzed and discussed to validate the effectiveness of using GPS in implementing this system and indicates future works that could be made to improve this prototype to be implemented in other applications, such as theme park, tourist attraction spot or recreational park.

Key Words : global positioning system (GPS), location mapping, location-awareness, wireless LAN

1. Introduction

The emerging technologies in automatic identification by using wireless technologies have spawned a growing interest in location-aware systems. Current research in intelligent environments, pervasive computing, sentient computing, and ubiquitous computing is attempting to fit in the context of human activity with the environment in which the user is interacting with. Location-awareness continues to be integral to a number of research projects in both indoor and outdoor applications[1-3]. Location-awareness differs from localization[4,5] in which localization is the process which assigns location information (position data) to an object while location-awareness is a term used for a device which can interpret the location data obtained from positioning system and provide user with location-dependent information. The information serves the basis for location-awareness and interaction based on "where" resources are in real-time.

The aim of this study is to provide an application system that uses GPS[6,7] as a means of determining user's location and using a wireless LAN as a means of data transport to display data which allows user manipulation and control. Using satellite-based GPS positioning sensing, the system is able to serve as a guidance for users to tour around a location by providing the architectural highlights of buildings and giving direction along the way to reach their desired location. User can know where he is, if he feels lost, and the system is able to provide the name of the area he is in and show his current location on the map.

Generally, a location system can provide two kinds of information which are physical position and semantic (symbolic) location. Often, location-based support system needs semantic location information that carries semantics about the location. Physical locations (i.e.: 35° 8.73' North, 129° 0.42' East) provided by most positioning systems alone are not useful for most users, whereas semantic locations (i.e.: DSU library, football field, bus station) have a certain meaning for users or applications. Physical locations can be considered as a single point in space, whereas semantic locations usually cover areas. The idea of this application is to express the physical location information of user and

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map the physical coordinates to the respective semantic location. The exact position of the user is not of the primary concern in this case, but it must be sufficient enough to identify a user's position in a known set of region. Data networking capabilities of wireless LAN in an outdoor environment have been integrated along with sensors to provide accurate user's location and tracking capabilities, thereby enhancing the value of such networks. Data are transferred from client to server in real-time basis through wireless LAN.

2. System Overview

Following a client/server structural design, our system consists of a front-end client which is operated by a user and back-end server which is controlled by the administrator on a remote site. The overview of our system architecture is shown in Fig. 1. The proposed system design is to use GPS to develop a location support system to locate user's position in a region. Both client and server communicate via wireless LAN to request and transfer positional information.

The final goal of this location support system is to locate user's exact physical position from a symbolic location. Hence, from the region obtained by using

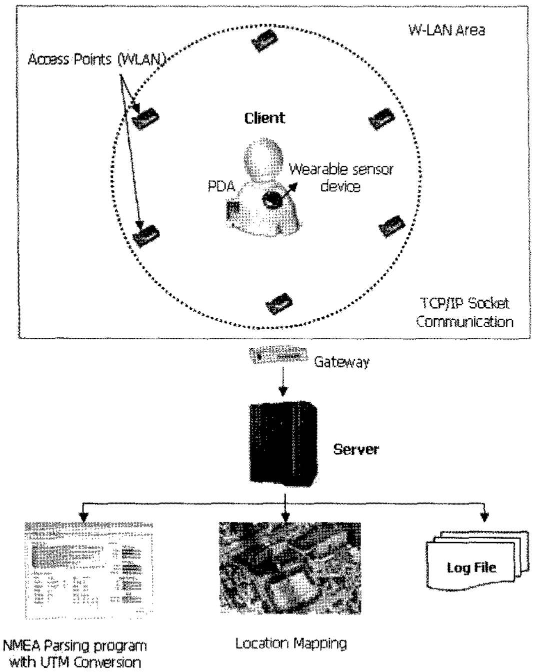

Fig. 1. System architecture.

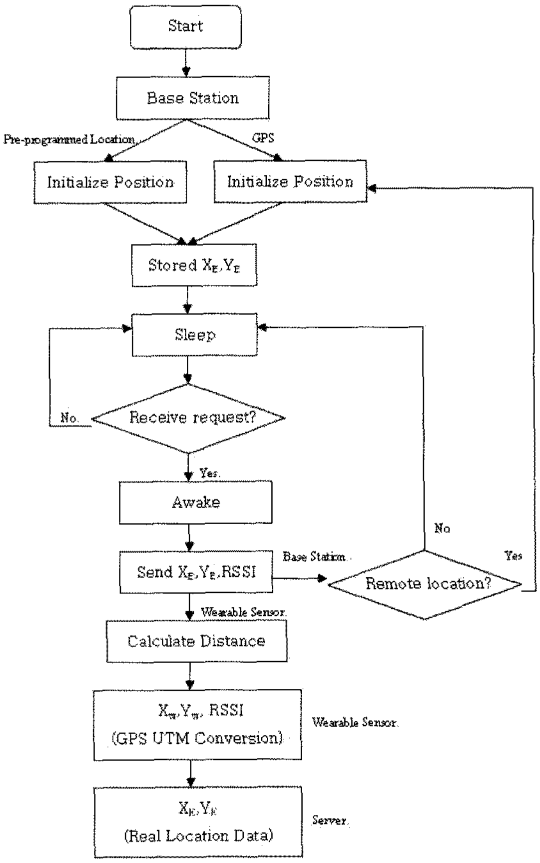

Fig. 2. System flow chart.

GPS, RSSI (received signal strength indication) method is used to further improve the precision on user's trajectory to locate his actual position in that region. The system flow chart of using the combination of both GPS and RSSI is shown in Fig. 2. The system will start by initializing the coordinates of base station either by pre-programmed location (fix location) to the node or by GPS positioning information (remote location). Base station coordinates (X_B,Y_B) are stored in its memory and go into sleep state. Upon receiving of request signal from wearable sensor, base station is awaken and replies by sending its X_B, Y_B, RSSI[8] data to wearable sensor. Wearable sensor checks the replies received and the best node is picked to calculate its position (X_W,Y_W) through GPS UTM (universal transverse mercator) coordinate system's conversion. Positioning data are transmitted over the network to server via IEEE 802.11b connection and real estimated position data (X_E,Y_E) are displayed in the server.

Table 1. Lists of geocentric coordinate system

Datum	Equatorial Radius (meters)	Polar Radius (meters)	Use
NAD83/WGS84	6,378,137	6,356,752.31	Global
GRS 80	6,378,137	6,356,752.31	US
WGS72	6,378,135	6,356,750.50	NASA
Australian 1965	6,378,160	6,356,774.70	Australia
Krasovsky 1940	6,378,245	6,356,863.00	Soviet Union
Clake 1880	6,378,249.10	6,356,514.90	France, Africa
Clarke 1866	6,378,206.40	6,356,583.80	North America
Airy 1830	6,377,563.40	6,356,256.90	Great Britain
Bessel 1841	6,377,397.20	6,356,079.00	Central Europe, Chile, Indonesia
Everest 1830	6,377,276.30	6,356,075.40	South Asia

2.1. GPS Data Collection

Data retrieval is done by connecting GPS receiver with location system in order to get the current location data. The GPS module outputs a set of delimited text string which is known as NMEA 0183 (national marine electronics association)[9] sentence. GPRMC, GPGGA, GPGSA and GPGSV strings which consist of longitude, latitude with time stamp, Dilution of Precision (DOP), speed and course are of vital information in constructing this application. Positional information of an object in the earth's sphere is given in terms of geodetic coordinates consisting of its longitude and latitude in degrees, minutes and seconds. There is a need to convert this geodetic information into a unit which is measurable. Thus, this location support system is responsible not only for data retrieval but also for parsing the read sentences and translating them into a set of coordinates (X, Y) in meter. The conversion of this geodetic data to X, Y coordinates is known as UTM transformation[10]. The mathematical conversion formulas[11] are based on the standard datum parameters in which for this system, UTM-WGS84 (world geodetic system 1984) is adopted. Datum is a model used for calculating the location of the Earth's center. Linking geodetic coordinates to the wrong datum can result in position errors of hundreds of meters. WGS84 is the default datum and is generally used in global. The types of datums and their corresponding parameters of projections are shown in Table 1. This parameters are important in the conversion for the Easting (X) and Northing (Y) coordinates. The algorithms for these conversion are as followed:

Easting Coordinate (X),

$$E' = K_0 \mathrm{v}\left[A + \frac{(1-T+C)A^3}{6} + \frac{(5-18T+T^2+72C-58e'^2)A^5}{120}\right] \quad (1)$$

Northing Coordinates (Y),

$$N' = K_0\left\{M + \mathrm{v}\tan\phi\left[\frac{A^2}{2} + \frac{(5+T-9C+4C^2)A^4}{24} + \frac{(61-58T+T^2+600C-330e'^2)A^6}{720}\right]\right\} \quad (2)$$

$K_0 = 0.9996$, $T = tan^2\phi$, $C = e'^2 cos^2\phi$, $A = cos\phi(\lambda - \lambda_0)$,

$\mathrm{v} = \frac{a}{\sqrt{1-e^2 sin^2\phi}}$, *and*

with

$$M = a\left[\left(1 - \frac{e^2}{4} - \frac{3e^4}{64} - \frac{5e^6}{256} - \ldots\right)\phi - \left(\frac{3e^2}{8} - \frac{3e^4}{32} - \frac{45e^6}{1024} - \ldots\right)sin2\phi + \ldots\right]$$

The conversion equations of X (1) and Y (2) above insured that factorization of polynomials A occurs when these equations were coded. The GPS data parsing program developed for this system on server side are shown in Fig. 3. This NMEA parsing program is able to extract GPS data into a comma-delimited format and thus, speed up the UTM transformation calculations for GPS data collection.

2.2. Mapping Projection

Plotting a curved surface of earth onto a flat surface

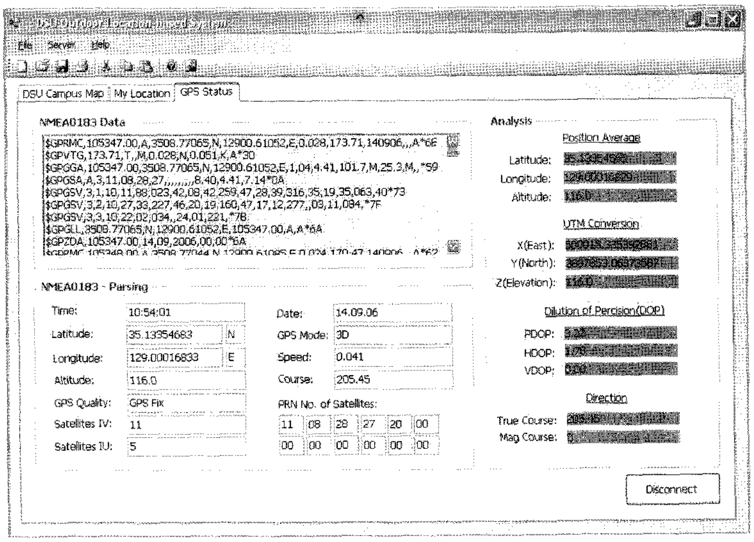

Fig. 3. NMEA parsing program to convert geodetic coordinates into UTM coordinates.

is known as mapping projection[12]. Mapping is done by collecting range of UTM points around the campus. With the X and Y coordinates obtained from applying the WGS84's parameter and geodetic to UTM coordinate conversion algorithm mentioned in previous section, the distance and range of symbolic locations are determined. These UTM coordinates are translated by the system and represented by a location indicator on the map, as shown in Fig. 4, so that the user can actually recognize his location by viewing the map. If the user continues to move with a constant speed, the system is able to predict the direction of the user and direct the user to his desire location.

2.3. Network Communication Protocol

Numbers of network communication protocols exist in the wireless environment, such as Bluetooth[13], RF IEEE802.15.4 and W-LAN IEEE802.11b/g. Among them, W-LAN IEEE802.11b is selected in our architecture as the communication medium due to its high data rate and ease in implementation. It is able to communicate with any device that supports W-LAN. One disadvantage unique to W-LAN is its power consumption issues. The positioning data of the user is further transmitted over the network to both the PDA carried by the user as well as to the server via wireless LAN. This location-aware application is reliant upon the existing wireless network infrastructure in DSU campus to provide semantic location information, which can be used to determine the current location of the wireless device.

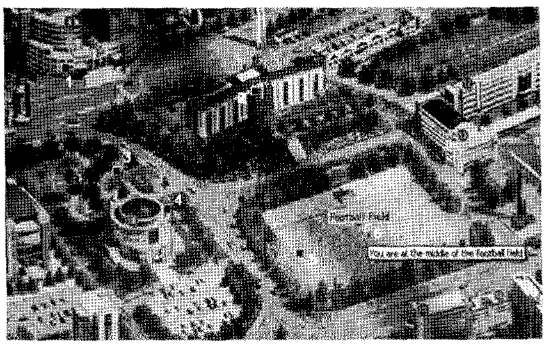

Fig. 4. Mapping symbolic locations to UTM coordinates.

2.4. Log File

The system includes a log file, as shown in Fig. 5, which stores the information concerning the places that the user has visited. Once the location status indicator

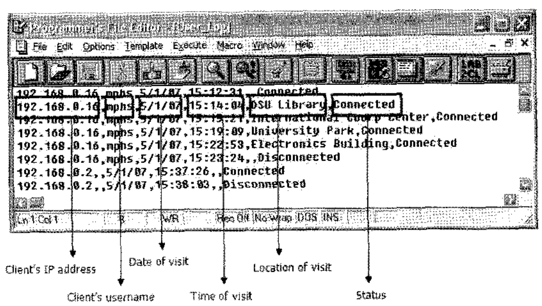

Fig. 5. Log file.

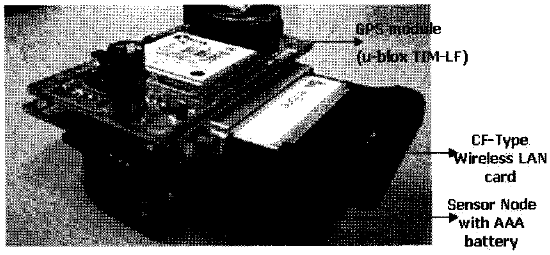

Fig. 6. GPS device carried by user along the experiment.

at a place on the map is invoked, activities log including client's IP, time and date are recorded and stored in the server. The data is separated by client's IP address. Thus, the system is able to differentiate the identity of each user in the case of multi-users circumstances. The log file is created in a text file format which can be imported to a datasheet for analysis purposes. The activity history of a user and the popularity of a place can be analyzed by viewing how many times the user visits a particular place in the same day. This feature can be further enhanced to be stored in a database.

3. Experimental Setup and Results

In order to calibrate the effectiveness of this real-time location-aware system, an experiment with real world scenarios at DSU campus[14] is deployed to study the performance and suitability of GPS in location-aware system. For client devices, a PDA (Personal Digital Assistant) with 802.11 wireless capabilities and a GPS receiver of u-blox TIM-LF (ANTARIS, Switzerland)[15] module along with Compact Flash type Wireless LAN card, as shown in Fig. 6, are carried by the user throughout the entire experiment. This GPS module is able to achieve the accuracy of 2.5 m. User walks around the

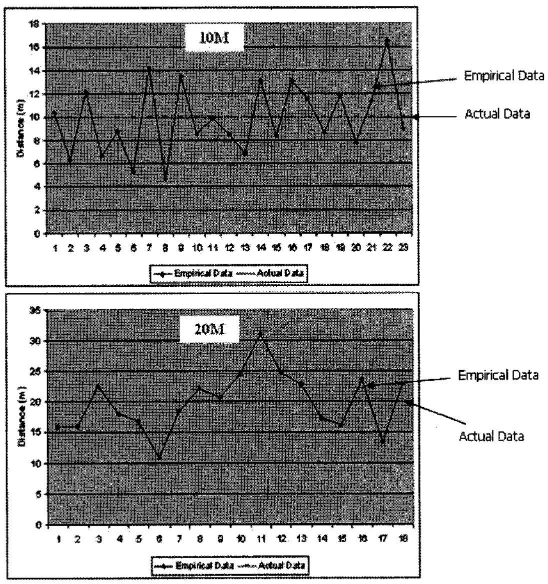

Fig. 7. GPS accuracy test result.

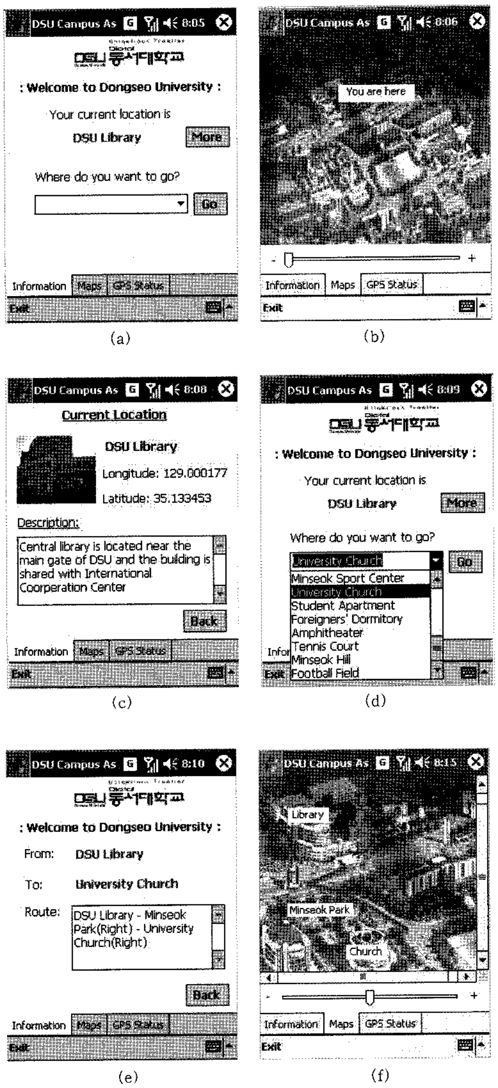

Fig. 8. Various menu on client PDA; (a) start-up main menu, (b) user's current location on "Map" module, (c) detail information on user's current location is shown, (d) locations list for user selection, (e) routes for user to get to the destination, (f) visual representation of routing on the map.

campus with an average speed of 1.25 m/s. The mapping of user's position is monitored at the back-end server as well.

The accuracy tests of the GPS module obtained through the experiment are shown in Fig. 7. In 10 m of distance, the error rate given is around ±3.2 m whereas in 20 m of distance, the error rate of ±4.5 m is obtained.

The experiment results on the client side (PDA) are presented in Fig. 8. When the application is executed, it detects user's current location and displays the symbolic information of the current location in the main page under 'Information' module (Fig. 8(a)). User's location on the campus map, represented by a greet dot, is shown under the 'Map' module (Fig. 8(b)). A click on the "MORE" button brings user to a page with detailed information on his/her current location as shown in Fig. 8(c). User can define the desired destination he/she wishes to go from a list of locations provided (Fig. 8(d)) and a hit on the "GO" button retrieves the information from the server and the route from user's current location to selected destination is displayed in both text form under "Information" module as well as on the map under "Map" module, as shown in Fig. 8(e) and Fig. 8(f) respectively. The "Map" page also has a zoom feature which allows user to have a clearer view of the buildings' locations on the map.

With this information, it is able to guide user along the way, prompting him/her at every intersection and showing current location. The initially hidden location

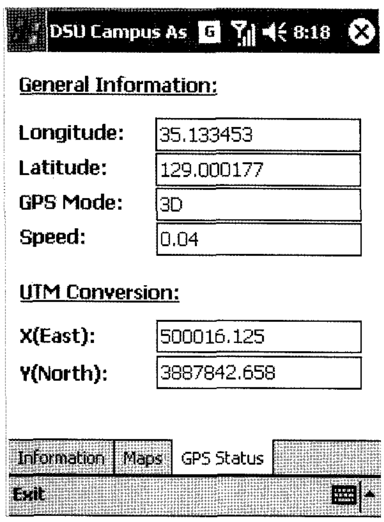

Fig. 9. Position information provided by GPS.

indicator on the map shows up when user moves within the specified range of coordinates. The "GPS Status" module shown in Fig. 9 shows the position information of user provided by GPS for user to view his/her current physical position. Experiment results show that the application reacts accordingly upon user's request and the position of the user can be displayed in real-time on both client and server side as expected.

4. Conclusions

In this paper, the prototype of constructing a real-time outdoor location-aware system by using GPS is presented. For visitors that visit a place for the first time, it may be difficult for them to find their way to the right place. This location-aware system is able to provide user with a pleasant campus tour with continuous updated visual representation of his/her current location on the map. Though this paper uses already known GPS location determination method, it proposes a method to support location-aware services by means of region location sensing in a real-time fashion across Wireless LAN requiring no extra integration with other systems by utilizing GPS. The prototype of this campus-based experiment can be used as a proof-to-concept implementation of the proposed technique. Future work will be focusing on providing a more thorough and comprehensive evaluation of the proposed architecture by integrating RSSI with GPS to enhance its accuracy on user's trajectory.

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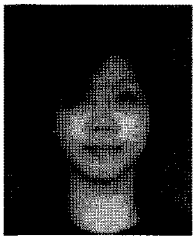

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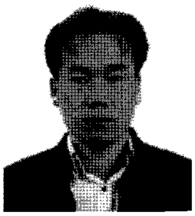

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