

A MOBILE INDOOR LOCATION-BASED GIS APPLICATION

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ABSTRACT:

This paper describes the development of a mobile indoor location-based GIS application. A GIS web server was created that delivered building plans and associated indoor data to desktop web clients. The user interface was redesigned for small display mobile web clients. Further work enabled the use of an RFID equipped phone to give precise client indoor location. The GIS web server was built entirely using open source software including MapServer and the PostgreSQL database product with the PostGIS extension. Custom software was developed in PHP. Data was created from CAD building floor plans and Orthophotos. Routes were added and used with Pgdijkstra Routing Module within PostgreSQL. The demonstration system operates in a campus environment with the users viewing interactive maps. A user can change building levels, find offices and services and view routes between selected locations.

1. INTRODUCTION

The British Columbia Institute of Technology (BCIT) is a Polytechnic focusing on applied education. Technical programs range from practical trades through to applied Master's degrees. BCIT offers a Degree or Advanced Diploma in GIS with the emphasis on GIS computer skills. This paper describes a GIS research project which built a GIS web server that delivers map and linked database information to indoor wireless devices, such as mobile phone or Personal digital assistant (PDAs). Location-based applications use the current location of the wireless device when available.

1.1 Indoor GIS

Indoor GIS provides information and mapping applications for one or more buildings using digital data for each building's floor plans together with the building's infrastructure data. A comprehensive indoor GIS data set should include building floor plan detail such as rooms, corridors, stairways, elevators, exits, wiring and network layouts, plumbing, HVAC, room contents, room use, room availability, and information about people such as their usual location, telephone number, e-mail and current location if possible. Example indoor GIS applications which are additional to standard GIS could be to find a person or service, determine a route between indoor locations or trace someone's route, and to notify if equipment moved or people arrived.

1.2 Objective

The objective was to build a GIS web application that serves indoor mobile phones or PDAs based on the current location of the wireless device. Open source and Open GIS were to be used as it is hoped that the application can be made freely available to other University or similar institutions. There were several questions to be resolved. The first question was how to find the

location of a mobile phone or other device within a campus building, and then to send that location to the GIS web server. The second question was which server software should be selected and if the use of custom client software could be avoided. A final question was to examine if applications would be useable given the typical phone display size and phone network performance.

Applications were to be developed for a typical University campus. Users would interact with web pages on their phones while viewing floor plans around their current location, searching and displaying a person's office or classroom, and showing student timetables linked to classroom maps. Previous work (Candy, 2002) had developed some applications for PDAs with a custom location system.

2. BACKGROUND

A major location-based mobile indoor GIS issue is determining the precise indoor location of mobile people and objects at a reasonable cost. Another problem is that most mobile client devices have small display areas and slow network transmission rates.

2.1 Indoor Location

The initial requirements were that the mobile phone or PDA indoor location must be found within a one metre x,y accuracy together with the correct building floor and that the location technology be 'off-the-self' and low cost. The ideal system has users carry a unique id tag on their student or employee card. Long range sensors can continuously detect and precisely locate the tag, and then insert the time stamped tag id and location into the server database. Possible solutions involved Wi-Fi, RF or GPS technology though none met the ideal.

A Wi-Fi based location system has very good potential because a typical University campus has each building covered by at least one Wi-Fi transmitter. Unfortunately, precise location requires the client to be in range of several Wi-Fi transmitters which is unavailable in every room or corridor, especially as a large number of thick walls will block signals. This type of location system needs regular calibration as signal strength varies. The client needs to install special software or carry a battery powered tag that can communicate from the location server (Ekahau, 2007).

Global Positioning System (GPS) is built into some phones and PDAs or is available as an add-on accessory. GPS devices have difficulty determining their location indoors as the signal is typically weak or even unavailable (Getting, 1993). GPS navigation has been used for an outdoor University campus navigation application (Golledge *et al.*, 1998). Assisted GPS technology is installed on some phones and will function indoors even if only a weak GPS signal is available, but may not be accurate enough to determine the exact building floor number (Krasner *et al.*, 1998). Experiments with pseudolite GPS which emulate a satellite-based GPS signal indoors have given centimetre accuracy inside buildings (Kee *et al.*, 2001), but pseudolite systems are expensive if providing coverage for multiple buildings.

There are many custom RF indoor location ideas. The Cricket Location-Support System uses beacons to send RF and ultrasound information to 'listeners'. The listeners, which are built into mobile devices, can compute their location from the beacons (Priyantha *et al.*, 2001). The listener can be connected into a mobile device using a compact flash interface. RADAR is an RF-based system that determines a device location using signal strength information gathered at multiple receiver locations (Bahl and Padmanabhan, 2000). Both of the above RF-type systems use custom base stations and require the client to carry additional hardware.

Bluetooth can also be used to fix location as any Bluetooth device should be able to connect to any other nearby Bluetooth device (Haartsen *et al.*, 1997). Bluetooth beacons are needed in all areas of a building and the client needs custom software to scan for the beacons and estimate location (Cheung *et al.*, 2006) Work on location estimation algorithms (Gwon *et al.*, 2004) suggests that Bluetooth can provide more accurate location than Wi-Fi and can complement Wi-Fi for even more precise measurement.

RFID systems consist of a RFID reader that sends out a radio frequency wave to the 'Tag'. The 'Tag' broadcasts back its stored data to the reader. RFID enabled phones are now available where the phone can read a passive tag and then take some action such as load a web page. Tags can be passive or active, but powered active tags have a longer range (Finkenzeller, 1999). The ideal RFID indoor location system has the user carry a 'long range' passive RFID tag while the buildings have RFID sensors at very frequent intervals

2.2 Mobile Clients

Current mobile clients have a web browser and a wireless internet connection. Typical clients can be classified into mobile phones, smartphones (Blackberry or similar phones) and PDA's. All these devices have small display areas which require simple icons and often more than one screen to make some queries. In general, each class of device has a different

screen area. All devices have web browser software but each browser has different capabilities. Some phones do not have HTML browsers and these cannot be supported by the graphical interactive map application. Phones require an indoor phone signal which may be subject to dropped connections. PDAs rely on an indoor wireless internet connection such as 802.11g.

3. DESIGN

One major requirement was to provide indoor maps and routes to multiple small client devices with different operating systems without installing any client software. This was resolved by using server side scripts interacting with client HTML browsers and to use an RFID location system when available (figure 1).

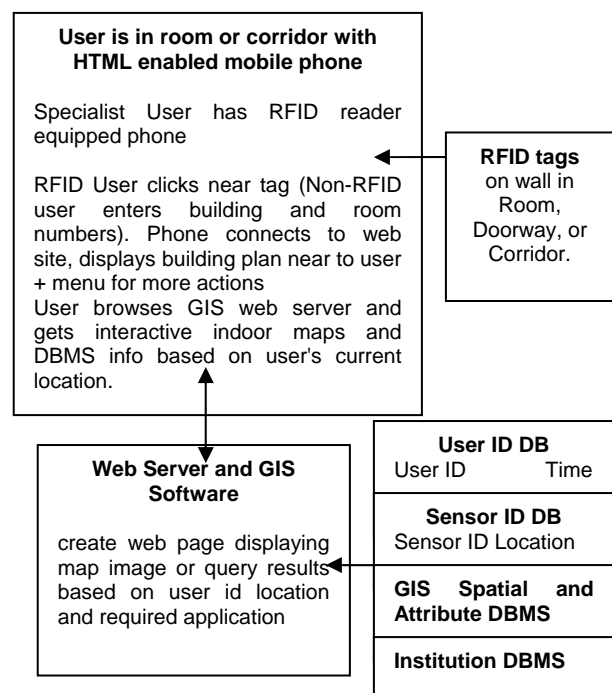


Figure 1. Design Overview

3.1 Server Software

The software is entirely open source to be consistent with the goal of making the application freely available. The web server is Apache with the Linux Fedora operating system. The GIS server side is fully programmable and supports "lightweight" clients. The GIS server is provided by MapServer using data stored in the PostGIS / PostgreSQL DBMS. The PostGIS software enables topological operations with spatial data within the DBMS. A Dijkstra Routing Module (Pasche, 2006) installed in the PostgreSQL DBMS will generate a list of line segments for the shortest route between two line end points. The line segments can be stored in a temporary table and drawn over any currently displayed GIS data layers. The PHP server scripts get requests from the clients, interact with MapServer and the DBMS and generate new HTML pages containing map images or database query results. The server scripts were developed and tested with a PC browser, then modified for various mobile clients that have smaller displays and a more limited user interface.

3.2 Client Software

No additional client software is required but only clients with a HTML browser are supported. A client will start a browser and go to the server entry script. The script attempts to detect the client browser family and client display area using the Wireless Universal Resource File (WURFL). Newer client devices require special handling. Clients are divided into non-pointing (most phones) and pointing (PDA or PC). Non-pointing devices receive only HTML with all map or search controls fixed as hyperlinks back to the server. Pointing devices receive HTML and JavaScript, allowing the user to interact with the map. Smaller display clients may see a sequence of pages compared to a larger display device.

3.3 Indoor location Determination

This application required a practical low-cost method for accurate indoor location but this is not available. A compromise was to use an RFID tag sensor system which meets the need for accuracy but not for low cost. A RFID system might have the user carry an RFID tag (for example, a tag on the back of a student or employee card) while the building doorways and walls have RFID sensors at close intervals. However, due to the current cost of purchasing, installing and connecting a very large number of RFID readers, the test system has the user carry the sensor and the walls and doors have the RFID tags

The Nokia 5140 RFID phone was selected for tests though the hardware cost means that it will only be used by specialists such as building security employees. The RFID tags are very low cost thin plastic with sticky backs and simply placed on corridor walls or on the outside of a room door. The RFID phone user just places the phone close to tag to get a location map as a tag read event will trigger the phone to retrieve a web page. Other non-RFID enabled mobile users can just enter the nearest room number (the campus has all rooms named systematically so, for example, a room named sw3 2089 is room 089 on the 2nd floor in building sw3), or the user can select the building, floor and corridor from lists.

3.4 Spatial Data

The data is in the UTM coordinate system, zone 10, NAD 1983. The positional accuracy is close to one metre. The exterior data was digitized from an Orthophoto of the campus region. The test buildings were obtained as CAD files for each building floor and converted to the required map projection. The spatial data was created as shapefiles and then converted into SQL scripts for DBMS insertion. All campus buildings, roads and parking areas were added together with detailed building floor plans for the available buildings. A campus route network data set was created as building corridor centre lines linked to room centre points and exterior pathways. Route nodes had to be carefully numbered so that overlapping floor areas would be considered separate route sections except where intersection occurs at stairways or elevators. An institution database provides class and student timetables and classroom building/room locations. The phone book database provides people and services information and building/room locations.

4. TEST RESULTS

The system was tested within the BCIT campus test building using a HTML phone, RFID tag reader HTML phone, HTML 'Smart Phone', Windows Mobile PDA and PC. The initial web page is formatted for the particular client device.

4.1 Applications

The client begins interaction by entering the server web address. The server delivers a web page appropriate for the client device type. Small screen devices receive text menus with maps appearing once a choice or input has been made. Larger screen devices receive an initial campus map. All map interfaces provide controls to navigate up and down floor plans, and to find/locate people and services. There are also the usual map zoom, pan and full extent controls. All map views show the current client location if known. Symbols and colour are used to indicate if the location is above or below the current floor level displayed.

The search form is used to find people or services by name and to find routes between two locations. All searches return a list hyperlinked to the campus map view zoomed in around the search result target and client location. A route start location defaults to the current location if known and the route end location defaults to the last found person or service (figure 2).

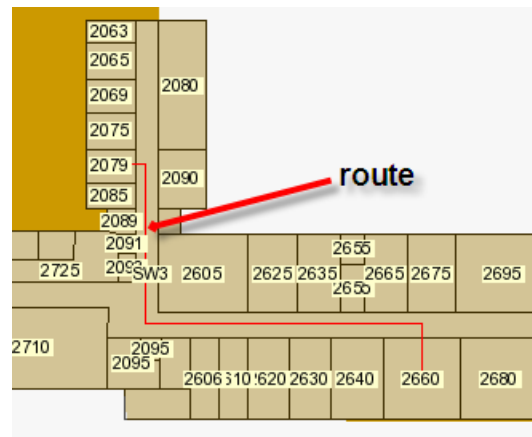


Figure 2. A simple route result

The route locations can be entered or overwritten with the user's text input. Routes can be found with a 'no stairs' option. Other search options include student timetables and room usage.

4.2 Small HTML phone

An HTML phone with a small display (e.g. 120x100) will be sent a text menu when first connecting to the server. The user can pick options to show a map, find a person or location or route between two locations. The map display area will default to the region around the result. The web page controls are text characters instead of image icons as icons use up too much display area (figure 3). Each text character is hyperlinked to execute a server script with various parameters. The 'my' location map requires the user to select a building and enter a room number.



Figure 3. HTML phone display with text for map controls

The small phone screen makes it difficult for the user to see the campus map unless 'zoomed' to a large scale. A user who wants to view a route across the campus will be required to keep panning across the map. Voice output from a route query would probably be a more useful result.

4.3 RFID phone

A Nokia HTML phone with an RFID tag reader acts in much the same way as a small display HTML phone except that the "my" location is found from an tag read event. The user has to 'touch' the tags with the back of the phone (figure 4). The phone then goes to the GIS web server and gets a building map of the area around the tag.



Figure 4. Using the RFID phone

The passive RFID tags are simply stick-on plastic and placed on doors or walls. The RFID phone is an expensive device and only applicable to specific user groups, such as building maintenance employees. RFID phone users have a unique user id and the id and tag events are also stored in the server database. A 'trace' RFID user map can be generated for a particular time interval. This map might be used by management staff to track the movements of specialist RFID phone users, such as campus security personnel, who may be required to visit a sequence of tags during their work.

4.4 Smart phone and PDA

Most smartphones have around a 320x240 pixel resolution and 16-million-color output. There is some kind of pointing device

but the phone may not have a touch screen. Most of these phones are designed for one-handed operation. The Nokia E62 phone as shown in figure 5 is fairly typical in that there is a central joystick pointing device that lets the user navigate around a web page and then click on an active icon.



Figure 5. Smartphone display

The phone has no Wi-Fi capability so all web access is over the mobile phone connection. The user interface is much improved over the user interface of the basic HTML phone due to the pointing device and better screen resolution. Floor plans are easier to see and the screen area allows more of a route to be displayed.

The PDA user experience is very similar to that of using a personal computer web browser. Newer PDAs use a VGA (640x480) display and standard web pages are viewable with some scrolling. Figure 5 shows a PDA displaying part of a larger web page with two query forms and an interactive map.



Figure 5. PDA display

The map icons have associated JavaScript actions as Java applets are not supported by the PDA Windows mobile internet

explorer web browser. The PDA uses Wi-Fi for a fast and free web indoor connection.

5. CONCLUSIONS AND FURTHER WORK

The main issue for most campus mobile phone users is the cost of accessing graphical web pages on their phone. A current typical Canadian mobile data rate is \$25 per month for only 3MB of web page viewing or \$100 per month for 100MB with an additional \$3 per MB. A secondary issue is the relatively slow wireless data load times. It is also unrealistic that campus user would have an RFID enabled phone to use in location-based applications.

The ideal solution will not require the client to use special hardware or install any software or pay any significant amount to use the phone web connection. This solution may well be possible as it appears that in the future all mobile phones will have built-in Wi-Fi for web browsing when in range of a network connection. This is very applicable to a campus environment where Wi-Fi is already present throughout campus buildings and the connection is fast and free but secure. Wi-Fi might also be used for user location if the need to carry powered Wi-Fi tags can be avoided. Phone displays are growing in size and quality which will improve the user experience. Wi-Fi location services will be investigated in future work together with examining voice output or even video from route queries.

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