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Architecture of a GPS-Based Road Management System

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Abstract: Malfunctioning traffic lights, potholes and roads in bad condition are only a few of the innumerable common thoroughfare problems that occasionally contribute to accidents. People tend to ignore reporting those issues as the channels for making a complaint is inconvenient. Accuracy of complaints is also at doubt as it tends to be general eg. Pothole at Ampang Road, in front of a police station. This paper presents the architecture of a Global Positioning System (GPS) based approach for reporting thoroughfare problems via Global System for Mobile Communications (GSM) for road maintenance management environment. To increase accuracy and efficiency, GPS can be used as it enables the tracking and tracing of the three figures of a GPS receiver's coordinates namely longitude, latitude and altitude. Data like location, date and time will be optimized by mapping the site of where the thoroughfare problem exists in a map, with the intention that the relevant authorities could identify the spot and have the problems resolved responsively. The proposed system will serve as a handier and convenient alternative means for road users to send complaints to the relevant authorities, in addition to the existing channels, so that these issues could be addressed in a timely manner.

Key words: Global Positioning System (GPS) · Global System for Mobile Communications (GSM) · Road maintenance · Road management · Thoroughfare

INTRODUCTION

Problems with the road condition can be a nuisance to drivers. In example, malfunctioning traffic lights and potholes are common causes of traffic disarray. In such events, lives are at risk as accidents are bound to happen. Road users could opt for various methods to lodge a report. However, those methods may not point to the exact location of the problem as complaints tend to be general. In contrast, GPS has already become a major outdoor positioning system used for commercial, military and recreational purposes. Besides being used in locating points of interests and navigation, integrating road maps with positioning data obtained from GPS is the most common application of this earth-orbiting-satellite based navigation system. Users can thus view their location on map in real-time by plotting position data acquired from GPS units on maps, whether they are walking, driving, boating or flying. Nevertheless, current GPS technology lacks the function of reporting a problem or situation. Communication can be established between a GPS device and a mobile unit, like GSM in order to offer a more convenient and easy alternative means for users to make complaints on road facilities and public utilities to the appropriate agencies, in addition to the existing channels to make complaints. The combination of GSM and GPS technologies can be used to deliver better road maintenance management as it promises a great potential in the market for mobile telecommunication services [1]. GPS devices can indeed be the most suitable channel to do so, as complaints can be sent in the form of report to the correct agencies, that is, when a problem is spotted virtually. This research aims to develop a prototype that utilizes GPS and GSM as a method to report complaints to relevant authorities, in order to better manage thoroughfare maintenance.

Related Works: These are the general current methods to lodge a report to any authorities: a) calling the authorities or customer service center, b) sending an email, c). sending a Short Message Service (SMS) and d) filling up a complaint form on its website. These methods may be

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inefficient, especially when one is driving or needed an Internet connection. In addition, the exact location of the problem or situation may not be exactly identified as complaints filed could be general. Some road users will choose to ignore, or it has just been long forgotten. This definitely lowers the frequency to show the gravity of a situation and inaccuracy of the problem. As GPS coordinates are used, this method of reporting allows the authorities to identify the exact location of the problem.

GPS, as the major outdoor location-based information capturing approach, has also exploited the use of wireless network to enable the transmission of position data. For instance, GPS unit is widely used in vehicle tracking systems [2-4]. Stationary servers will periodically request position data from the GPS unit placed inside a vehicle. This proposed system is indeed the reverse of this model. Instead of having servers as the requesting end (server-request application), the servers will get an entry only when there is a send command executed in the GPS-GSM unit from the user's end. So it is deduced that such location-based tracking and tracing systems like Radio Frequency Identification (RFID) and GPS applications can indeed be put into an even greater use when they are integrated into wireless or cellular network.

RFID was used by Sriborrirux, Danklang and Indra-Payoong [5] to track bus fleet in Bangkok. Each bus is planted with an active RFID tag. A reader (based station) is installed in each telephone booth by the road side to read the location of the tag, which is when the bus passes the location. The data captured by the based station from the bus RFID tag is sent to a central server via ADSL network. This enables identification of near real-time location of the bus.

Valente *et al*. [6] developed a framework to monitor in real-time dangerous goods transportation. Trucks transporting dangerous goods, in example, flammable liquids and radioactive chemicals are monitored to ensure safety to the driver and also other vehicle users. Real-time monitoring of relevant parameters inside the cargo bay (i.e. temperature, gas concentration, ionizing radiation level) uses wireless sensors in order to detect and prevent dangerous situations from happening due to the nature of the transported load. With that, GPS is used to detect the location of the vehicle at time of reading. These data are sent via General Packet Radio Services (GPRS) to a main station, where it will monitor the mechanics of the trucks.

Ekpenyong,Palmer-Brown and Brimicombe [7], passively used GPS technology to collect characteristics of any 'unknown route' on behalf of the provider. The data collected would be processed by an on-board artificial neural network or transferred back to the provider to combine with data collected from other users. From the collective data, the provider would then decide whether to add that 'unknown route' to the road database. This technology provides the feasibility to identify roads using GPS trajectory data. Using the GPD trajectory data, snap-drift neural network (SDNN) is able to group collected points to reveal travelled road segments.

Using GIS and GPS technology, Doriwala and Shah [8] maps various facility provisions around the area of Surat City, Gujerat, India by considering different socio-economic groups. This work was done to determine facility provision in an urban area whereby households with the nearest facility is statistically identified to find the percentage allocation of each groups with identified nearest facility. It was found that higher income households tend to be concentrated near areas accessible to various facilities, as compared to the middle and lower income groups. Also, group of household has a preference to be situated near the vicinity of a healthcare center as compared to other facilities.

In Korea, highway bridges are maintained under the Special Law on Structure Safety in Korea. Inspection must be performed to ensure good structure condition. Research work by Upsani, Shrote and Wani [9] innovated a technological method for inspection, as manual judgment is subjective. Digital image processing technology and robotics was proposed to enhance inspection. However, to locate the visual image grid from and above the bridge is a very complicated procedure. Hence, Differential GPS (DGPS) was used to precisely locate the exact location of the site to be inspected.

Chen and Liu [10] combined GPS, GIS and GSM to present an intelligent vehicle monitoring system. With the integration of these three technologies, the system provides such features as signal return of real-time vehicle positioning and alarm information, sending simple control orders, displaying mobile vehicle position in both graphic and data format and alarm information returning to the control center automatically. On the other hand, Farooq *et al*. [11] proposed a system combining GPS and GSM for enhancing public transportation management services in Pakistan. The system keeps track record of every bus, processes user request about a particular bus location and updates bus location at every bus stop. In both systems, GPS is used as a positioning gadget and GSM is used as a communication link between terminals. The underlying architectures of the entire vehicle tracking systems are all similar – GPS is used to capture the location of the object being tracked and GSM modem is used for mobile connections so that data can be passed.

On a different note, Habenbrock *et al*. [12] used GPS with GSM capabilities to monitor horses during cross-country competition or during training. Recording of critical data, in example, heart rate is useful to assess the horse condition during the exercise. A GPS system integrated with a heart rate recording system with built-in GSM for data transmission were used and tested on horses. Results from this research shows that the degree of accuracy was high and reliable. This proves that physiological data can be recorded even when remotely located, not only in animals but possible extension to patient monitoring.

MATERIAL NAD METHODS

Based on Fig. 1, after retrieving GPS signals from three satellites in the user's vicinity, data which include three-dimensional position, velocity and time information will be calculated by the GPS unit. GPRS communication network is involved in this architecture to act as an intermediary that connects the both ends: the user and the relevant authorities. GSM terminals are thus used at both ends whereby the GSM terminal at sender's side has the duty of processing the location information acquired from the GPS unit and sending it to web server via Short Message Service (SMS); and the other GSM terminal at the authorities' side is responsible for transferring the data to the local computer. Finally, the program embedded in the computer will integrate the position data with the maps.

The development of this system has been divided into four different modules: a) Retrieving GPS data and sending an automatically-generated message, b) Processing of GPS data by SMS server, c) Storing of GPS data into database and d) Plotting of Users' position onto Google Maps.

Retrieving Gps Data and Sending an Automatically-generated Message: Nokia E71 smart phone with Symbian operating system was used as the sender for this system. Considering the A-GPS (Assisted GPS) support and featured Nokia maps embedded in this GSM phone, Nokia E71 has been chosen to do the task of retrieving GPS data and sending this data over the cellular network to the receiving end, which is another phone that is connected to a computer. In this experiment, Sony Ericsson W705 was used as the receiving end. A Python script has been written to retrieve the GPS data and to generate a message automatically (Fig. 4).

Fig. 1: Main system architecture

Fig. 2: Python application

As can be seen in Fig. 3, the user will enter any complains encountered. In this case, 'Potholes'. In Fig. 4, the Python code works by retrieving GPS co-ordinates, which is the user's current location. Once the co-ordinates are retrieved, an automatically generated SMS is sent to the relevant authorities. In Fig. 5, the received SMS shows the sender's latitude, longitude and the complaint entered. The SMS text being sent will have the following predefined format, as specified in the Python script, which is:

Fig. 3: User input request

Fig. 4: Sender's output

Latitude>[space]*%latitude*[space]*Longitude*>[space]*% longitude*[space]*%input*

Processing of GPS Data by SMS Server: At the receiving end, the GSM modem was used to connect to a local machine. SMS server Ozeki was used to process the received SMS and transfer it to the computer.

Storing of GPS Data into Database: SMS server will store the GPS data and related information into local database at authorities' side. MySQL is used to store the messages sent by the GPS-embedded smart phone. Xampp, a cross-platform web server, is chosen as one of the main development tools not only because of its support for

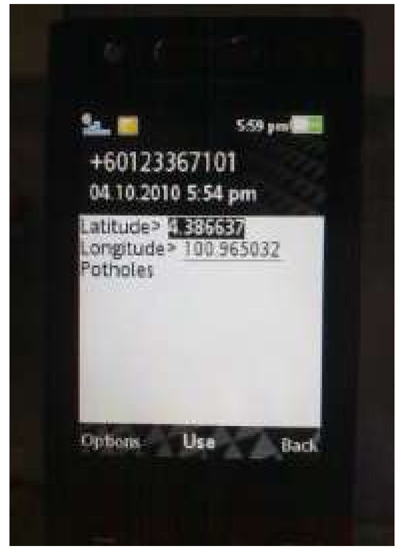

Fig. 5: Receiver's output

Fig. 6: Output at the relevant authorities' end

creating and manipulating database in MySQL, but also of its Apache HTTP server and interpreter for PHP scripts, which will be written to display the database information and plot users' position onto Google Maps in later phase.

Plotting of Users' Positions onto Google Maps: GMap EZ framework is used to plot users' positions onto Google Maps. Basically this development phase consists of two sub parts:

Retrieve Database Data and Display on Webpage: A PHP script has been written to build connection to the database and retrieve the data in the database, which stores all the incoming SMS texts from the senders. By extracting the SMS text sent by the user, it is able to display in a table form on the webpage. The *explode* function is used to split the message into different components, so that each can be assigned to the designated variables in the PHP script. By this the values of latitude, longitude and problem of each sender can be displayed in a clear and distinguishing manner as in Fig. 6. A tracking feature is built to trace the progress of the work. For instance, when the road *problem a*, *id b, latitude x and longitude y* has been solved, the authorities can change the status of this entry by clicking the button "Change". The value of this field in the database will be changed to "Done" after a user clicks the button.

Display Users' Position onto Google Maps: Google Maps is embedded in the PHP webpage to enable easy search and mapping for the relevant authorities. As in Fig 6, a "Go!" button is created for each entry so that different map will be generated when different location is chosen. The PHP script is written in such logic that the latitude and longitude values will determine the output of the map, what the end users will see.

Benefits: This system can indeed benefit the relevant authorities in several ways:

Road Problem Tracking: The proposed system acts as a tracking system, in example, for the Department of Public Works. It is an easier avenue for people to lodge complaints. Authorities can keep a log of complaints and trace the work status of each task regarding road problem. The status of a work can be changed and database will be updated after a particular problem has been fixed. All entries are sorted by date and time, so that old problems are put at a higher priority.

Higher Accuracy: The position data will help the relevant authorities to find the location of a particular road problem with a higher accuracy level. For instance, a user using SMS or Internet to file a complaint would probably input a street name as the location of the road problem to be fixed. First, the particular street might be a long lane, thus making it difficult for the authorities to look for the exact location of the problem. Second, there might be two or more streets in the country bearing the same name. This proposed system eases them by providing them the exact location of the problem, namely longitude and latitude. GPS Reporting System is to take GPS accuracy seriously as the data is of high importance. Authors Mohamad, Mohd Alil and Ismail [13] have performed two types of tests to study the availability, reliability and accuracy of GPS data in Malaysia. Both static positioning and mobile positioning tests have been conducted and it is proven that GPS receiver has position accuracy of 2.5m (50% out of 17280 GPS data) and 5m (90% out of 17280 GPS data) in Kuala Lumpur area. This result contribute to a new refinement in the interpretation of GPS data in the proposed GPS Reporting System: a GPS data with a latitude and longitude of 2.9211862 and 101.777972 possibly means that a pothole is within the range 5 meters from the position (2.9211862, 101.777972).

Higher Efficiency: This system offers a more convenient alternative means for users to make complaints regarding thoroughfare issues to the relevant authorities. Users, while using a GPS navigation device on road, can send a report to them upon seeing a road problem on the spot. This increases the chances of making complaints to the party, because tendency to forget and to ignore the problem becomes higher as time passes. These thoroughfare issues can be addressed efficiently and responsively with this proposed system.

Prioritization of Action: If a road problem is reported more often, collective data will show the density of an area and the gravity of the situation. This will give an indication to the relevant authorities the severity of the problem being reported. Hence, the authorities will disperse resources based on problem that requires immediate attention.

CONCLUSION

With GPS real-time tracking and tracing capabilities, location can be captured and sent to the authorities through GSM network for identifying the sites where thoroughfare problems exist. This proposed system acts as a relatively convenient channel for drivers to send complaints with the intention that issues regarding public infrastructure could be addressed promptly and thus greater welfare will be achieved eventually. Future works suggest using a commercialized GPS device, which has touch screen feature, to easily make a report. With mobile phones, it can also image capturing capability, where users will be able to take a photo of the road problem and the image will be sent automatically to the receiving end. Also, by using sensors, we can detect the road condition and the GPS device can automatically send the report to the relevant authorities. Besides, the scope of the project can also be extended to other parties such as hospitals and police, to have wider coverage to create a civic-minded community.

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