Intelligent GIS-Based Road Accident Analysis and Real-Time Monitoring Automated System using WiMAX/GPRS

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Abstract

It has been a big concern for many people and government to reduce the amount of road accident specially in Malaysia since it could be a big threat to this country. Malaysian government has spent millions of money in order to reduce the number of accident occurrence through several modes of campaign. Unfortunately, from years to years the number keeps increasing. The lack of a comprehensive accident recording and analysis system in Malaysia can be effective in these kinds of problems. By making use of IRAS (Intelligent Road Accident System), the police would be control and manage whole accident events as a real-time monitoring system. This system exploits WiMAX and GPRS communications to connect to the server for transfer the specific data to the data center. This system can be used for a comprehensive intelligent GIS-based solution for accident analysis and management. The system is developed based on object and aspect oriented software design such as .NET technology.

Keyword: GIS, Accident, WiMAX, GPRS, LBS, Monitoring

1. Introduction

Road traffic accident is complicated to analyze as it crosses the boundaries of engineering, geography, and human behavior. Therefore, there is a need for a more systematic approach, which can automatically detect statistically significant spatial accident clusters and offering repeatable results. To implement traffic accident countermeasures effectively and efficiently, it is important to identify accident-prone locations and to analyze accident patterns so that the most appropriate measures can be taken for each specific location.

2. Research Motivation

The research undertaken intends to find a completed solution to covering all aspects in managing and monitoring accident data. The system is based on GIS and telecommunications infrastructures technologies. In this case, IRAS (Intelligent Road Accident System) is used to get the better results from accident data, which includes the most effective and useful queries, reports, charts and advanced graphical user interface. The work evaluates for performance of a GIS-based solution in order to integrate infrastructure communication systems such as WiMAX and GPRS to develop a multiplatform middle-ware for real-time monitoring, automated services. The development is based on aspect and object oriented software design. In addition, the other objective is to be established a dataware house for the real-time smart decision support system for automated services and analysis. Also, this system offers Location Based Services (LBS) for Clients' cell phone, PDAs, smart phones and laptops.

3. System Architecture

3.1. Enabling Telegeoinformatics

Telegeoinformatics is enabled through advanced in such fields as geopositioning, mobile computing, and wireless networking. There are different architectures possible for Telegeoinformatics, but one that is expected to be widely used is based on a distributed mobile computing environment where clients are location aware, that is capable of determining their location in real-time, and interconnected to intermediary servers via WiMAX/GPRS or even wired networks.
Telegeoinformatics can be based on different architectures to meet different requirements of applications, where clients and servers are connected via wireless networks. The middleware is used for performing many computations and activities and linking the different components of Telegeoinformatics. One of the key responsibilities of the middleware is ensuring interoperability among heterogeneous data, software, and functions. Figure 1 shows an ideal middleware for Telegeoinformatics.

3.2. Interoperability of Telegeoinformatics

In order to make Telegeoinformatics interoperable, the middleware must be based on special mechanism and protocols. Insomuch as geospatial data and geoprocessing are central to Telegeoinformatics, providing geospatial interoperability, eg., in Location-Based Services (LBSs) led by the Open GIS Consortium (OGC), should be one of the objectives of the middleware (OpenLS, 2001).

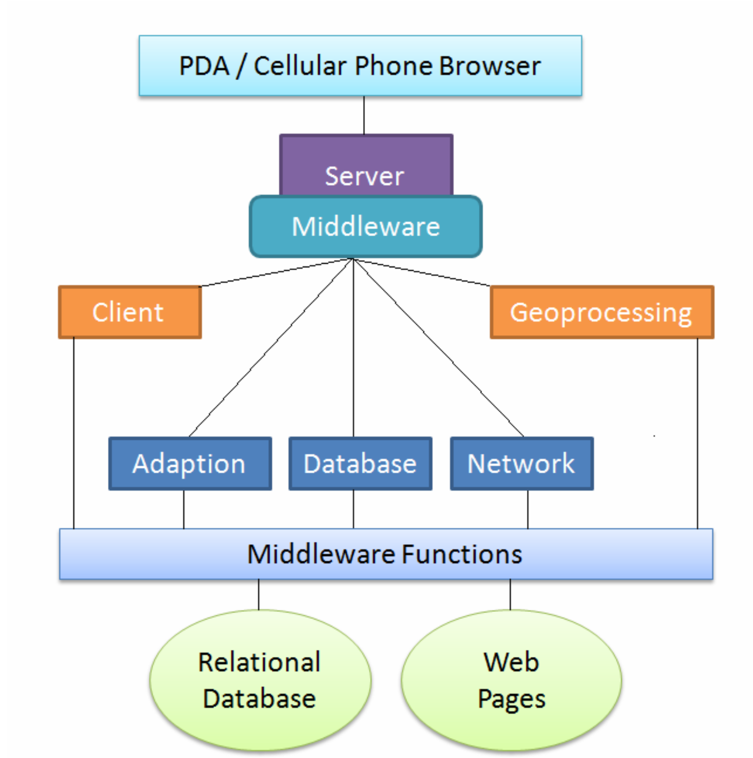

Figure 1: Telegeoinformatics Architecture

3.3. Strategies and Adaptation

One adaptation strategy in Telegeoinformatics is to adapt to the client machine the user would use to access the system. There are several client variations: PDA, Desktop PC, laptop, cell phone. Differences include storage capacity, processing power and user interface. Telegeoinformatics should have knowledge about these client's limitations with respect to the output interface and adjust its output information presentation to the capabilities available. Heineman (1999) has analyzed and evaluated various adaptation techniques for software components. On such technique is active interface. This technique acts on port requests between software components, which is where method request are received. Another technique is Automatic Path Creation (APC), which is a data format, and routing technique that allows multi data format adaptation and adapts to current network conditions (Zao and Katz, 2002). Adaptation is not the modification of components by system designers; this is considered component evolution. Adaptation should be accomplished automatically by the system with little user intervention. In addition, adaptation should be considered a design capable of adapting to users with respect to the user's needs (Stephanidis, 2001).

3.4. Terminal-Centric Positioning

The Terminal-Centric methods rely on the positioning software installed in the mobile terminal. The method, which is used in this research, is Network Assisted GPS (A-GPS); this method can also be used in the network-centric mode, according to Andersson (2001). A-GPS uses an assisting network of GPS receivers that can provide information enabling a significant reduction of the time-to-first-fix (TTFF) from 20-45 s, to 1-8 s, so the receiver does not need to wait until the broadcast navigation message is read. It only needs to acquire the signal to compute its position almost instantly. For the timing information to be available through the network, the network and GPS would have to be synchronized to the same time reference. According to Andersson (2001) the assistance data is normally broadcast every hour, and thus it has a very little impact on the network's operability.

3.5. Network-Centric and Hybrid Positioning

Cell Global Identity with Timing Advance (CGI-TA) is one of the network-centric and hybrid positioning methods, which is used in this research. CGI uses the cell ID to locate the user within the cell, where the cell is defined as a coverage area of a base station (the tower nearest to the user). It is an inexpensive method, compatible with the existing devices, with the accuracy limited to the size of the cell, which may range from 10-500 m indoor micro cell to an outdoor macro cell reaching several kilometers (Andersson, 2002). CGI is often supplemented by the Timing Advance (TA) information that provides the time between the start of the radio frame and the data burst. This enables the adjustment of a mobile set's transmit time to correctly align the time, at which its signal arrives at the base (Snap Track, 2002).

4. Network-Based Service

The deployment of wireless-based LBSs relies on a common standards-based network infrastructure. The telecom market is currently experiencing a transition in the delivery of services from proprietary and network closed implementations to an open, IP-based service environment. The positioning service will be an important component in this open, IP-based service environment. The building of positioning information with LBSs, personalization, security, and messaging will be key for any operator when offering service packaging to the clients. The LBSs request/response flow is generally carried out within a wireless carrier network that includes mobile phone, the wireless network, the positioning server, gateway servers, geospatial server and the LBS application. The mobile phone provides a keypad for query and either a numeric or graphical interface for display. The positioning server, usually embedded in the wireless carrier's infrastructure, calculates the position of the device using one or more positioning approaches. The various wireless location measurement technologies fall into two broad categories: network-based and handset-based solutions (Campbell, 2001). Network-based solutions rely on base station radios to triangulate the position of a roaming mobile device, either with received radio signals or with transmitted synchronization pulses. The advantage of this approach is that it enables every user to access LBS without the need to upgrade the handset. Handset-based solution are systems that incorporate the measuring and processing of the location information within the handset. GPS is the principal technology and has been further enhanced by the development of A-GPS, which allows faster and more accurate service (Moeglein, 2001).

5. Multi Criteria Decision Making (MCDM)

The MCDM tool, which is embedded in server-side application, indicates AHP (Analytical Hierarchy Process) method, which can be used for decision making in GIS-based solution using input numeric values by the user. This tool is based on pairwise comparison method that developed by Tomas Saaty in 1970 in context of MADM (which is refer to attributes) method. It represents a theoretically founded approach to computing weights that are representing the relative importance of criteria. In this technique, weights are not assigning directly, but represent a “best fit” set of weights derived from the eigenvector of square reciprocal matrix. The objective of the AHP is to ensure that evaluation of weighting is consisted or not.

The AHP relies on three fundamental assumptions:

i. Preferences for different alternatives depend on separate criteria, which can be reasoned about independently and given numerical scores.

ii. The score for a given criteria can be calculated from sub-criteria. That is, the criteria can be arranged in a hierarchy and the score at each level of hierarchy can be calculated as a weighted sum of the lower level scores.

iii. Suitable scores can be calculated from only pairwise comparisons.

AHP is a mathematical decision making technique that allows consideration of both qualitative and quantitative aspects of decisions. It reduces complex decisions to a series of one-on-one comparisons, and then synthesizes the results. Compared to other techniques like ranking and rating, the AHP uses the human ability to compare single properties of alternatives, it not only helps decision makers choose the best alternative, but also provides a clear rational for the choice.

6. Methodology

The develop system consist of the main module that operate as a real-time monitoring system. The system started with a field data collection which perform as client. All data which are related to accident, can be categorizes into spatial data and non-spatial data which are merged into one database. The merged data is transferred to the dataware house via internet by using WiMAX/GPRS. Dataware house will then be established with two different reference of data includes Road Networks (map data) and Datacenter (description data). The main system uses integrated data from the dataware house and analyzes on them to achieve various types of statistical reports, these reports can be customized and improved with different elements by interaction through the designed GUI.

The main system will be able to recycle the outcome of the primary analyses into the system and pass the statistical reports to MCDM unit (Multi Criteria Decision Making). Under the module, AHP (Analytical Hierarchy Process) technique is used for decisions making process. The results will then be used in the next module, which is SDM (Smart Decision Maker). In this module, reports can be compared together, make the best decision for diagnosis, and define the proposed solution related to current situation. SDM unit has potential to modeling suggested solution based on GIS interface. Figure 2 shows the process and relations between main system and the other parts to provide the proposed solution.

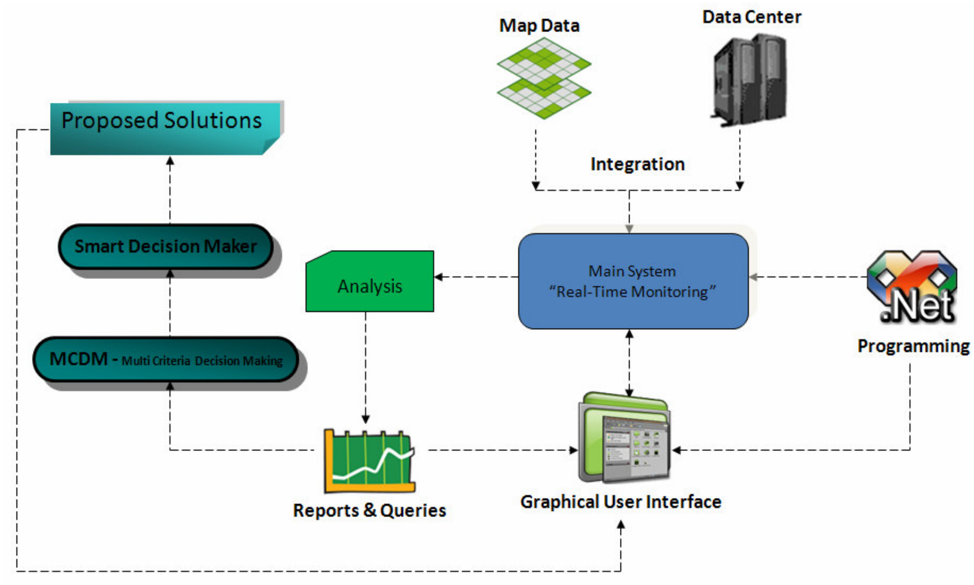

Figure 2: The relationship between main system and MCDM and SDM modules

There are two types of clients that should be defined to the system, Police and end users (citizens). After each accident, the clients (citizens) can provide necessary information to the main system by using their Mobile Phone (SMS) or using their PDA (WiMAX/GPRS). The main system automatically will search and announce the nearest police vehicle via internet around the accident location and suggest the best path to get to the accident location based on the traffics information, time and distance. In this case, police officers using PDA via internet directly to the main system will key all accident information in and then the system will automatically send data to the dataware house and update the database. Also at the same time, system will be able to inform other involved organizations and companies such as medical emergency services, insurance and car service companies. Figure 3 shows the relationship between main system and clients.

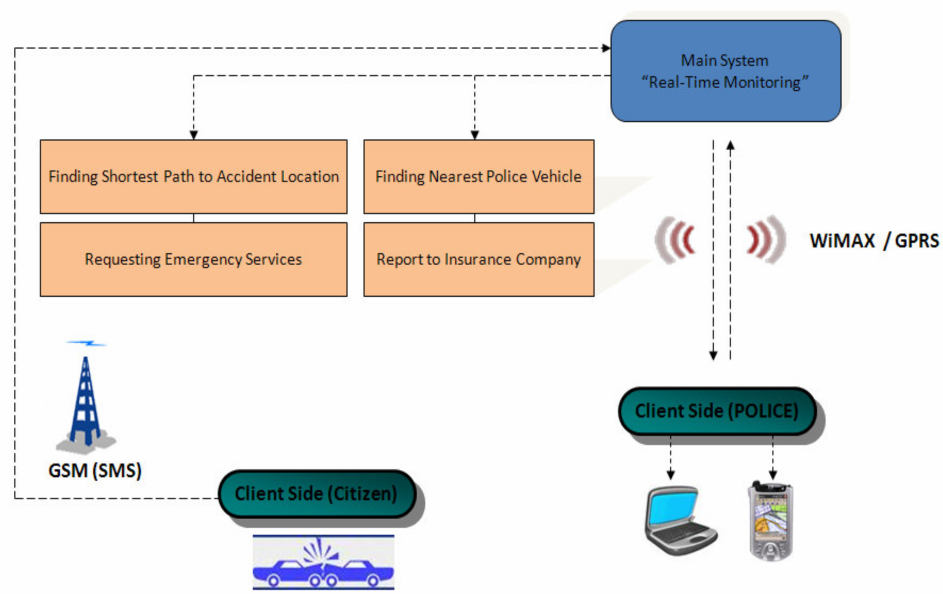

Figure 3: The relationship between main system and clients

7. Results and Discussion

The system being developed manage to support online communication through the GSM/GPRS/WiMAX services. User who wants to use this system must have a few equipments on his/her car which call On-Board Unit (OBU). These equipments consist of GPS and wireless communication devices. The main system also consists of Auto Alarming System (AAS) to inform the system for any accident events throughout the city. In this case, when an accident occurs, the location of the accident sends to the main system by client (citizen) using GPS devices installed on the vehicle, this task is done by calling OBU which, automatically or manually send the accident position to the server via internet using WiMAX or GPRS. From the signal received, the system will find the nearest police vehicle according to the accident coordinate system and sends the primary information to client (police officer) in their PDAs via internet. Then, accident data will be send to data center and store on the system and dataware house. This system can send online data to road accident database using PDA or Smartphone by police officers in real time access. In addition, Smart Decision Making (SDM), Multi Criteria Decision Making (MCDM) and Automatically Proposed solution system (APSS) units can be applied professionally and analytically for making the particular reports and queries in a proper manner.

8. Conclusion

The research outcome is a comprehensive system to cover accident management and analysis, smart automated service for accident locations, accident and service diagnosis, reducing the number of accidents, increasing the level of road safety and fast delivery services such as insurance companies and emergency services. For further works, the system should also include the ability to inform clients about the risk zones in all over the city using LBS services, based on the main system reports, queries and real time traffic monitoring. The system classifies and categorizes the road networks into four zones, so when a vehicle enter to each zone, the system will automatically send the risk message to alert the accident risk on that particular zone or location of the city. In addition, the system shall offer some services for clients such as air download client version (for PDAs or Smartphone) of application for using these LBS services. All LBS data, which will be shown on client phone, are generated by the main system with real time updates via internet, so the clients have real time information about the traffic conditions and accident risk zones around them.

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