ARCHITECTURE OF INTEGRATED GIS AND GPS FOR VEHICLE MONITORING

Adela B. Crnišanin*
State University of Novi Pazar, Department of Technical Science, acrnisanin@np.ac.rs
Dejan D. Rančić
University of Niš, Faculty of Electronic Engineering, dejan.rancic@elfak.ni.ac.rs
Petar Ć. Spalević
University of Priština, Faculty of Technical Science, petar.spalevic@pr.ac.rs

***Abstract**: In this paper, system architecture for vehicle monitoring will be presented. The architecture consists of GPS part for collecting information of vehicle position at the moment of observation, spatial database part for storing this information after refining, and in the end , Geographic Information System (GIS) subsystem. Having used GIS, it is possibly to display information on a digital map. The methods of GPS collecting and preparing information will be described in details, especially the method used within a moving object. The spatial database stores information about location (latitude, longitude and elevation) at the time of observation, and some additional desired attributes. GIS provide information to a user by queering and calculating distances to some point and other function.*

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* Corresponding author

1. INTRODUCTION

With the rapid development of economy, there are new requirements for tracking and monitoring of moving objects in real time. Industrial development increases the need for transportation and operational management. Logistics management transporting systems become very important in monitoring vehicles during transport. The development of global positioning technology has made possible positioning of a moving vehicle.

As a wireless communication technology also achieved great progress, it provides a method for remote monitoring and control of a moving object. Many logistics companies, as well as civilian vehicles, are beginning to apply GPS technology to accomplish functions such as positioning, navigation and surveillance.

GPS vehicle tracking system plays a very important role in achieving these goals. It integrates global system for mobile communications (GSM), Global Positioning System (GPS) and geographic information system (GIS) in one system. Such compositions technology allows upgrading system for vehicle monitoring. [1]

The rest of the paper is organized as follows. System architecture and every module are presented in second chapter. Third chapter describe the system component and technologies. In fourth chapter, functioning of the system will be discussed. In the fifth chapter, conclusion with some future research will be given.

2. SYSTEM ARCHITECTURE

In order to present system architecture, some basic functions of software application discussed in this paper need to be presented. This vehicle monitoring system platform is based on GIS and GPS technologies using GSM network and Internet.

This application is applicable to operation of the logistic industry such as vehicle tracking, vehicle management and vehicle dispatch. System network is depicted on Fig. 1.In order to provide vehicle monitoring and management, system is capable to satisfy following functions:

- Display of interactive electronic map. It is possible to pan, zoom, view tips about feature, edit feature, and control multiple layers.
- Vehicle real-time monitoring part (Communication server) receives short messages or message sent via Internet, which consists of vehicle geographic position and working state. This message is then translated into suitable format, and

vehicle information displayed in the electronic map and data in the data grid.

- Query implements query of general information about a vehicle and query of history records satisfying certain conditions.
- Task allocation sends task schedule orders to the specified vehicles, receives response information from vehicles and processes alarm info automatically if an accident happens.
- For history positions of vehicle, selected records from history database meeting specified conditions can appear on map.

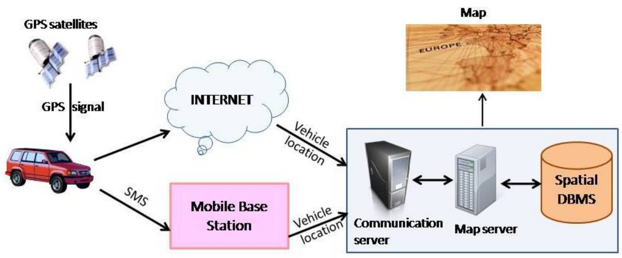

Figure 1. System network for vehicle monitoring

Every vehicle has a part which is installed on the terminal vehicle and which is responsible for receiving GPS satellite positioning signal. This signal contains position which is extracted and then sent to the monitoring center. The monitoring center can receive position information distributed by the vehicles. The monitoring center can control the terminal vehicles. Display, query and control of this information are realized through the monitoring center software.

3. SYSTEM COMPONENTS AND TECHNOLOGIES

System architecture, provided in previous chapter, is made of vehicle terminal, server for GIS map, communication server and also uses Internet and GSM mobile network for exchanging information between vehicle terminal and monitor center.

The earliest interest in geographic information system dates back to 1960. year. GIS technology integrates basic operations with the database, such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by map. [2] Among other things, GIS facilitates the modeling of spatial network (road network), offering algorithms for querying and analysis.

Spatial networks are modeled graphs. In the case of transport networks, arcs correspond to street segments as nodes correspond to the corners. Each arc has a weight, which is the impedance (price) passing that part time (segment). In most cases, the arc impedance is a function of appropriate length of street segments and traffic density.[3]

In this study, for the development of systems for tracking and monitoring of vehicles in real time, and integrating four different high technology: GPS, GIS, GSM and SMS. The most used technologies are described in the following part.

3.1 GIS – QGIS

In this paper, for GIS function implementation, QuantumGIS [4] has been used. QuantumGIS (QGIS) is a powerful and user friendly open Source Geographic Information System that runs on Linux, UNIX, Mac OSX, Windows and Android. QGIS supports vector, raster, and database formats. QGIS is licensed under the GNU Public License.

The QGIS project offers different applications for different use cases. QGIS Desktop (the classic QGIS desktop application offers many GIS functions for data viewing, editing, and analysis). QGIS Browser (a fast and easy data viewer for your local, network and online (WMS) data). QGIS Server (a standard-compliant WMS 1.3 server that can be easily configured using QGIS Desktop project files). At the end, QGIS also has its own Client (web front-end for your web mapping needs based on OpenLayers and GeoExt).

GIS software of the system is developed based on Quantum GIS desktop tool for creating maps and Geoserver, which is a mapping control that has easy and powerful mapping capabilities for applications. With maps, information can be displayed in a format that's easy for everyone to understand.

Maps are more informative than simple charts and graphs, and can be interpreted more quickly and easily than spreadsheets. Fig. 2 shows the main user interface of the Quantum GIS software, which displays the vehicle information in map format. OpenLayer plug-in for Google Street is on the bottom of the layers, followed with the cities represented with points and roads represented with lines, in the north Serbia. These features are necessary for building this vehicle tracking and monitoring and this map will be filled with more data in the future.

GeoServer [5] is an open source server software written in the Java programming language that allows users to share and edit spatial data. Designed for interoperability, publishes data from any major spatial data source using open standards. Since the project is an open community of people, GeoServer is developed, tested and supported by different groups of individuals and organizations from around the world. It is fully compliant with the OpenGIS Consortium's web services specification; Web Map Server (WMS) and Web Feature Server (WFS). GeoServer is available under the GPL 2.0 license.

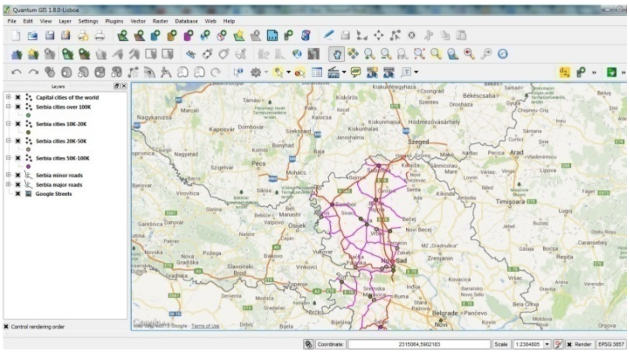

Figure 2. Vehicle road distribution in QGIS map with OpenLayer support

3.2 GIS – Geoserver

GeoServer allows the display of spatial information in the world. The implementation of standard web map services (WMS), GeoServer can generate maps in a variety of output formats.

GeoServer also supports Open Layers for making map generation quick and easy. Spatial queries in GeoServer are possible with the combination of PostgreSQL/PostGIS DBMS. There is a performance comparison between GeoServer and MapServer, another famous open source IMS.[6] OpenLayers is a free library for mapping, which is integrated into GeoServer, to quickly and easily generate a map. GeoServer is built on Geotools-in, open source Java GIS tool.

It is much more than the map generator. GeoServer also supports Web Feature Service (WFS) standard, which allows sharing and editing the data used to generate the map. Others may turn their data into their websites and applications, freeing up your data and allows greater transparency.

3.3 GIS – OpenLayer

OpenLayers [7] technology is also used in this application. It is a JavaScript library for displaying dynamic map data in any web page without server side dependencies. This web page views the mapping services published by Geoserver using the OpenLayers web mapping library. The OpenLayer is open source, making it flexible and capable across standards as well as proprietary application programming interfaces (APIs). It allows to use any of the tile sets provided by Google, OpenStreet Map, Microsoft and Yahoo, all within the same programming API.

3.4 GPS

Global Positioning System (GPS) is a space global navigation satellite system. In this paper, information that GPS offer are crucial. It provides reliable positioning, navigation and time services on a continuous basis in all weather, day and night, anywhere on or near the Earth. GPS consists of three parts: between 24 and 32 satellites that orbit the Earth, the four cells for the control and monitoring of the Earth, and the GPS receivers owned by users. GPS satellites broadcast signals from space that are used by the GPS receiver and a three-dimensional position (latitude, longitude, and altitude) plus the time. In this study, for the development of systems for tracking and monitoring of vehicles in real time, and integrating four different high technology: GPS, GIS, GSM and SMS.

Global Positioning System (GPS) technology has created a revolution in surveying and mapping around the world. It is a technology that offers great potential to GIS, where data collection has proven to be the most limiting factor to successful implementation and use. GPS was established by the U.S. Defense Department to transmit signals that can be used to generate highly precise location data. Use of the technology requires operation of specially developed GPS receivers and accompanying software. The receivers capture the signals transmitted by the satellites to calculate and record the data digitally. Specially designed software is then employed to calculate position data from the signals.

Numerous types of receivers are now available in the marketplace making use of multiple approaches to the signal capture and generation of position data. The individual approaches provide various levels of accuracy under differing conditions and at differing costs. In general, with each approach, the receiver locates and "locks onto" multiple (generally 4 to 6 or more) satellites and records the signal from each of the satellites digitally.[8]

The satellites transmit multiple coded signals that are interpreted in various ways among the approaches. The data thus recorded are analyzed by software that compares the various satellite signals and pre-recorded control parameter data to generate latitude, longitude, and elevation data.

The GPS consists of a specially designed receiver, an antenna, a data recording or logging device, and possibly other devices for recording additional data observed at the location. Operation also requires a computer for processing the data. Interface devices are necessary to upload data to a PC or other processor. Since the system is ultimately operated by the military and can potentially be used by an enemy, security is a key consideration. The signals are continuously modified and can be encrypted to provide security in times of threat. The reality of that risk is probably quite minimal in today's international environment. The growth of a very large industry around the technology further ensures its continued availability.

There are other satellite navigation systems: Galileo is a European Union Global Positioning System, Glonass is a Russian and BeiDou (or COMPASS) is the Chinese system.

3.5 GSM and SMS

SMS (Short Message Services) is an important technology that has made a serious impact on our everyday life. It enabled ubiquitous communication channel to be extended for feature rich value added services. SMS technology has helped tracking vehicles, criminals and also has the potential to become a channel for launching cyber attack. It has the potential to be a channel for launching DoS attack and triggering malware. It has also helped law enforcement agencies to track adversaries.

3.6 Spatial database - PostGIS

In early GIS implementations, spatial data and related attribute information were stored separately. The attribute information was in a database (or flat file), while the spatial information was in a separate, proprietary, GIS file structure. For example, municipalities often would store property line information in a GIS file and ownership information in a database. Spatial databases were born when people started to treat spatial information as first class database objects.[9]

Spatial database stores spatial object and manipulate that spatial object just like other objects in database. Spatial data describes either location or shape (house, river, parks, lakes), and in abstract view, these entities are represented as points, lines and polygons.

Many DBMS offer spatial functionalities, some are: ESRI ArcSDE, Oracle Spaial, IBM DB2 Spatial Extender Informix Spatial DataBlade , MS SQL Server (with ESRI SDE), Geomedia on MS Access, PostGIS / PostgreSQL. In this paper, PostGIS[10] for PostgreSQL has been used. PostGIS is a spatial extension for PostgreSQL DBMS and aims to be an "OpenGIS Simple Features for SQL" compliant spatial database. PostGIS spatially enables PostgreSQL by adding spatial objects, functions, and indexing. It is free software and an important component in open and free GIS and important building block for all future open source spatial projects.

Generally, spatial databases are able to treat spatial data like anything else in database (transactions, backups, integrity checks, less data redundancy, fundamental organization and operations handled by the DB, multi-user support, security/access control, locking).

Using SQL expressions, spatial querying is able to determine spatial relationship (distance, adjacency, containment) and also to perform spatial operations (area, length, intersection, union, buffer).

4. FUNCTIONING OF THE SYSTEM

GIS has been increasingly used to support AVL (Automatic vehicle location) and IVHS (Intelligent Vehicle Highway System) applications.[11] In this case, the GIS maintains a base map of the street system and necessary reference features on which the vehicle location is displayed or along which routing or other spatial analysis functions are performed.

The GPS is used to provide the real-time location of the vehicle to be displayed or routed with this base. In this use, the vehicle to be located has a GPS receiver mounted and continuously operating. This is a real-time data collection and management effort requiring very sophisticated system. Also, GPS is also used to create the base file of the street network to be used in this application.

The design and implementation of the prototype show that it is feasible to develop a system such as the one described in this paper using open source GIS software. However, the problem of join descriptive data using a CSV file with a geographic data in QGIS was discovered. Excel encodes this CSV file using ANSI (American National Standard Institute) character set.

In QGIS, text features from outside QGIS cannot be pasted to a layer within QGIS. As a result, there is a language error for the join descriptive data. We suggest one of the solutions for this problem by using PostgreSQL/PostGIS capabilities. First, it is neccessary to convert an ANSI CSV file to a UTF-8 CSV file by using Notepad or EditPlus. UTF-8 is appropriate for writing code for cross-platform software. Second, an Unicode CSV file is imported into PostgreSQL/PostGIS. Then, descriptive data in the CSV file can be joined with a geographic data by using the joins tab in PostgreSQL/PostGIS.

Technically, this vehicle monitoring system comprises two virtually connected parts: vehicle-mounted subsystem (GPS), monitoring and communication subsystem. Functioning of each is described in following parts.

4.1 Vehicle GPS terminal subsystem

Vehicle GPS subsystem functions are to communicate with the monitoring centre by sending information such as vehicle position and vehicle status. Main functions of the vehicle GPS subsystem are:

Sending positioning information: GPS receiver will do positioning in real-time and send the positioning information, using SMS, to the monitoring center.
Data display: display real-time position of the vehicle, such as the longitude, latitude, speed and heading direction.
Receiving dispatch instructions: receive dispatch instructions sent from the monitoring center, and display or give out voice on the display element.
Alarm: in case of emergencies, the driver will initiate the alarm device, and the monitoring center will display information about the vehicle conditions, position of accident and the vehicle and personnel.

4.2 Monitoring center subsystem

The main functions of monitoring center subsystem are about processing, displaying and managing the vehicle position and alarm information received. According to these functions, it mainly consists of GPS and alarm information receiving subsystem, GIS subsystem, information management subsystem and data maintenance subsystem.

According to this multiple subsystems, monitoring center provide all information about moving vehicle. All these information are available in spatial database.

5. CONCLUSION

Solution presented in this paper is simple and have low implementation cost. Sytems that connects GPS and GIS technologies for vehicle monitoring system has a great future in the transportation industry. Using open source GIS; Quantum GIS, PostgresSQL/PostGIS and GeoServer are feasible to develop an application of GIS. Further research will be focused on spatial database optimization for better querying spatial object and features.

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