An Information System for the Effective Management of Ambulances

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Abstract
In this paper, we describe a system offering a solution to the problem of ambulance management and emergency incident handling in the prefecture of Attica in Greece. It is based on a Geographic Information System (GIS) coupled with Global Positioning System (GPS) and Global System for Mobile Communication (GSM) technologies. The system's operation is expected to minimize the ambulances' response time. Consequently, there will be a drastic improvement in the way emergency incidents are being handled. This fact will thus significantly affect the quality of health services offered to citizens.

1. Introduction
The efficient management of ambulances in order to achieve fast transportation of patients to the appropriate hospital is a vital aspect of the quality of health services offered to citizens. Accomplishing an effective routing and districting of ambulances will minimize their response time. Therefore, the introduction of computer-based systems can drastically improve the way emergency incidents are being handled.

In this paper, we describe a system offering a solution to the problem of ambulance management and emergency incident handling in the prefecture of Attica in Greece. It is based on a Geographic Information System (GIS) [5,14] coupled with Global Positioning System (GPS) [8] and Global System for Mobile Communication (GSM) [1,4] technologies. The design of the system was the result of a project funded by the Greek Secretariat of Research and Technology. The system will operate in the National Center of Immediate Assistance (its initials are EKAB in Greek) which deals with emergency medical incidents by coordinating and routing ambulances to appropriate hospitals as well as offering medical care to patients during their transport to hospitals.

This paper is organized as follows. Section 2 presents a brief description of a GIS's general functions. Sections 3 and 4 describe basic concepts regarding GPS and GSM technologies respectively. Section 5 presents the basic operations performed by the integrated system which will operate in EKAB's Operation Center. Finally, Section 6 concludes.

2. General functions of a GIS
GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps [5,9]. Among other things, a GIS facilitates the modeling of spatial networks (e.g. road networks)
offering algorithms to query and analyze them. It usually provides tools to find the shortest or minimum impedance route through a network and heuristic procedures to find the most efficient route to a series of locations commonly called the traveling salesman problem. Allocation functions assign portions of the network to a resource supply location and tracing tools provide a means to determine whether one location in a network is connected to another. Distance matrix calculation can be used to calculate distances between sets of origins and destinations whereas location-allocation functions determine site locations and assign demand to sites. Finally, street addresses can be converted to map coordinates (address geocoding). These capabilities of GISs to analyze spatial networks enable them to be used as Decision Support Systems for the districting and routing of vehicles [2,9,10].

3. Introduction to the GPS technology

The Global Positioning System (GPS) is a world radionavigation system funded and controlled by the U.S. Department of Defense. It is used for the determination of the exact positions of various objects located anywhere on the Earth's surface [8,11,15,19,20]. While there are many thousands of civil users of GPS worldwide, the system was designed for and is operated by the U.S. military.

The GPS consists of twenty-four satellites that orbit the Earth in twelve hours, the ground stations and the receivers. The satellites function as reference points that determine an object's position with great accuracy. The GPS receiver, installed on the object, calculates its distance from three different satellites by using the travel time of the signals transmitted from each satellite. Due to atmospheric distortions, errors are introduced into the satellite signals affecting the determination of the objects' positions. However, with various techniques these errors can be effectively dealt with.

Due to the advances in integrated circuits technology, the GPS receivers are small and inexpensive. Therefore, almost every organization can afford to pay for the use of the GPS technology. Nowadays, the GPS is used in vehicles, ships, airplanes, and even laptop computers.

4. Basic concepts of the GSM technology

During the early 1980s, analog cellular telephone systems were experiencing rapid growth in Europe. Each country developed its own system, which was incompatible with everyone else's in equipment and operation [18]. To deal with this undesirable situation, the GSM, a pan-European public mobile system, was developed and standardized by the European Telecommunication Standards Institute in the late 1980s [13,16]. During the 1990s the GSM standard was expanded in every continent.

The primary service supported by the GSM is telephony. Speech is transmitted through the GSM network as a digital stream [1,4,6,12]. An emergency service is also available, where the nearest emergency service provider is notified by dialing three digits (similar to 911). Furthermore, GSM users can send and receive data, at rates up to 9600 bps, to users on the plain telephone service, ISDN, Packet Switched Public Data Networks, and Circuit Switched Public Data Networks [17,18].

In addition, the GSM offers a Short Message Service (SMS), a bi-directional service for short alphanumeric messages. For point-to-point SMS, a message can be sent to another subscriber to the service, and an acknowledgement of receipt is provided to the sender. SMS can also be used in a cell-broadcast mode, for sending messages such as traffic updates [18].

5. Basic operations of the integrated system
Up till now EKAB's employees were based on paper maps and their experience in order to achieve the effective routing and districting of ambulances. However, these two functions which constitute significant areas in the field of Decision Support Systems [3] require computer-based systems. The operation of a GIS in EKAB will automate and enhance many of its services.

The GIS will make use of various data that is either stored in spatial databases and Database Management Systems (DBMSs) or transmitted through the GSM network. Spatial data will concern the road network, the locations of hospitals and medical centers, the position of ambulances, the distribution of incidents occurring in the past and the distribution of population characteristics (e.g. demographic characteristics or disease spreading). Data concerning road traffic will be very useful for the routing of ambulances. This data will be updated according to an algorithm that processes traffic statistics and simultaneously takes into consideration on-line data deriving from traffic sensors installed on the road network. Data pertaining to events such as road works or demonstrations that also affects road traffic will be made available from the municipality or the police. Furthermore, data concerning hospitals, ambulances, and their personnel will be stored in DBMSs and used by the GIS whenever it is necessary.

Some of the primary functions performed by the GIS operating in EKAB will be the following:

- Depiction on a map of ambulance positions and hospital locations. Useful queries that will be performed include the display of information about an ambulance or a hospital chosen from the map, the finding of all ambulances positioned within a block, the finding of all ambulances that are closer to a hospital or some other spot, etc.

- Ambulance districting. The analysis tools of the GIS will take into consideration the data concerning the road network, past incident distribution, hospital locations and traffic and will propose efficient distributions of ambulances. For example, areas where many incidents take place should be allocated with an increased number of ambulances. If the administrator of the GIS chooses to distribute ambulances according to his/her own criteria the depiction on the map of all the available information and the interaction with the GIS will be of significant assistance.

- Choosing the appropriate ambulance to handle an emergency incident. According to ambulance positions, the location of the incident and road traffic the GIS finds the ambulance requiring the least time to reach the site of the incident.

- Finding the site of the incident. Based on the address given by the person calling EKAB's Operation Center for help, the GIS can use address geocoding functions to find the incident's coordinates on the map. However, in many cases the person calling for help may be at a loss for words and unable thus to give precise information about the site of the incident. Therefore, the system should include a mechanism matching a call to an address.

- Routing an ambulance to the incident site and from there to the closest appropriate hospital. The GIS will be used to find the optimal routes corresponding to minimum required transportation time. The distance as well as traffic data will be taken into account. The appropriate hospital will furthermore depend on the type of the incident. The GIS can also present driving directions corresponding to the generated routes (e.g. go straight ahead, turn right to Ermou Street, etc.). Moreover, the generation of alternative less optimal routes is possible as well.

- Generation of statistics regarding incidents and their depiction on the map. The GIS in cooperation with the DBMS containing incident records can significantly assist in the statistical analysis of incidents. Consequently, important conclusions supporting the districting of ambulances can be reached.
The GPS and GSM technologies will be used to transmit the exact positions of ambulances to the GIS operating in EKAB's Operation Center. The integration of these technologies enables the management of vehicles such as company trucks, patrol cars and ambulances [7].

The GPS consists of a set of twenty-four satellites that enable the determination of a vehicle's position. Each ambulance will be equipped with a GPS receiver, which requires the signal transmitted by three satellites in order to determine its exact position. In addition, it will have a GSM modem in order to transmit its position to the base station in the Operation Center. The transmission will be achieved through the GSM network. Furthermore, through the GSM network other useful data as well as voice can be transmitted. Each ambulance may also be equipped with a computer or a mobile data terminal used to display the route computed by the GIS operating in the Operation Center.

EKAB's Operation Center will exchange data with the ambulances through the GSM network. It will receive the ambulance positions and will use the GIS to perform the aforementioned functions. The calculated optimal routes for a specific ambulance will be transmitted to it. In the Operation Center there will be a computer dedicated to the communication with the ambulances and another one for the operation of the GIS. In addition, there will be one or more computers for the operation of the DBMSs containing data used by the GIS.

6. Conclusion

In this paper, we describe a system offering a solution to the problem of ambulance management and emergency incident handling in the prefecture of Attica in Greece. It is based on the integration of GIS, GPS and GSM technologies. The design of the system was the result of a project funded by the Greek Secretariat of Research and Technology. The system will operate in the National Center of Immediate Assistance (its initials are EKAB in Greek).

The described system will improve the services provided to citizens by EKAB. Due to the effective management of ambulances, the required time to transport patients to hospitals will be significantly reduced. The benefits deriving from systems operating in other countries and performing a subset of our system's functions were impressive.

7. References


