Artificial intelligence paper

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The design of the system was the result of a project funded by the Greek Secretariat of Research andTechnology. It will operate in the National Center of Immediate Assistance (KEBAB in Greek), which deals with emergency medical incidents by coordinating and routing ambulances to appropriate hospitals andhealthunits as well as offering medical care to patients during their transport to hospitals. Our research unit was mainly responsible for designing the GIS subsystem, which constitutes the primary focus of this paper.

The paper is an extended version of one presented at Delegate 2000 (Drinkers, Gorillas, Makers, Presents, Siestas, & Disallows, 2000). An operation with substantial importance for the handling of emergency incidents is the routing of an ambulance to an incident site and from there to the closest appropriate hospital. The optimal routes correspond to minimum required transportation times. Finding such routes may prove to be time-consuming in the case of large cities such as Athens with very dense road networks.

However, by exploiting recent advances in the field of data structures, the performance of a shortest-path algorithm in terms of the required computational time can be significantly enhanced. The incorporation of the enhanced shortest-path algorithm thin the GIS will lower our system's response time, thus increasing its inability. This paper is organized as follows. Section 2 briefly presents primary aspects of a Gig's facilities in modeling and analyzing spatial networks. In Section 3 the overall integrated system is described. Section 4 deals with the GIS subsystem and describes its key functions.

Section 5 briefly explains how the performance of a shortest-path algorithm can be enhanced, while Section 6 demonstrates how to incorporate this enhanced algorithm within a commercial GIS such as Raccoon. Finally, Section 7 summarizes the results of the project. . Modeling and analysis of spatial networks GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps (SERIES Web site; Franklin, 1992; Mueller, 1993). Among other things, a GIS facilitates the modeling of spatial networks (e. . Road networks), Other partners in this project were the University of Piraeus, the National Technical University of Athens, the Aristotle University of Thessalonians and the companies ITCH G. Drinkers et al. / Compute. , Environ. And Urban Systems 25 (2001) 267-278 69 offering algorithms to query and analyze them. Spatial networks are modeled with graphs. In the case of road networks, the graph's arcs correspond to street segments whereas the nodes correspond to street segment intersections. Each arc has a weight associated with it, representing the impedance (cost) of traversing it.

In most cases, an arc's impedance is a function of the corresponding street segment's length and traffic volume. A GIS usually provides a number of tools for the analysis of spatial networks. It generally offers tools to find the shortest or minimum impedance route wrought 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. Moreover, street addresses can be converted to map coordinates (address coding). Finally, dynamic segmentation operations offer ways of modeling events (e. G. Pavement quality, speed zones) along routes (SERIES Web site). These capabilities of GIS for analyzing spatial networks enable them to be used as decision support systems for the districting and routing of vehicles (Grassland, Wynn, & Perkins, 1995; Keenan, 1996, 1998). . The overall integrated system Up till now, Kebab's employees were using paper maps and their own 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 yeasts (Eom, Lee, & Kim, 1993), require the integration of a computer-based system with geographic analysis and visualization tools and a telecommunication network. The operation of the integrated system will automate and enhance many of Kebab's services. The system's architecture is depicted in Fig. 1.

It is based on the integration of GIS, GASP and GSM technologies. The GASP and GSM technologies will be used to transmit the exact positions of ambulances to the GIS operating in Kebab's Operations Center. The integration of these technologies enables the management of vehicles such as many trucks, patrol cars and ambulances (Hauberk, 1995). All these applications are parts of the new emerging disciplines of teleprocessing and telecommunication (Laurie, 1999, 2000; Tanzania, 2000). Each ambulance will be equipped with a GASP receiver to determine its exact position based on the signal transmitted by satellites.

In addition, it will have a GSM modem in order to transmit its position to the base station in the Operations Center. This will be achieved through the GSM network. Furthermore, through the GSM network other be equipped with a computer or a 270 Fig. 1 . The overall integrated system. Mobile data terminal to display the route computed by the GIS operating in the Operations Center. Kebab's Operations 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 functions described in Section 4.

The optimal route calculated for a specific ambulance will be transmitted to it. In the Operations Center there will be a computer dedicated tocommunicationwith 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 database management system (DB'S) containing data used by the GIS. Nowadays, most GIS software packages offer a rich set of tools and extensions, enabling the incorporation of GASP data and offering real-time tracking capabilities.

SERIES Archive, for instance, offers an extension called Tracking Analyst that allows direct feed and playback of real-time data within the Archive GISenvironment(SERIES Web site). The system's architecture follows the centralized approach (Laurie, 2000; Tanzania, 2000) whereby a control center (in our case Kebab's Operations Center) coordinates the fleet of mobile vehicles. Data from the vehicles and sensors are sent to this center and, after being evaluated, data and instructions are transmitted to the vehicles. A strong point of this architecture is the easiness with which it is designed. 71 However, the danger of a crash in the control center constitutes a major weakness (Lament, 2000; -rant, 2000). 4. The GIS subsystem The GIS will make use of various data that are either stored in spatial databases and DB'S or transmitted through the GSM network. Spatial data will cover the road network, the locations of hospitals and medical centers, the positions of ambulances, he distribution of incidents occurring in the past, the distribution of population characteristics (e. G. Demographic characteristics or disease spreading), and locations of various landmarks.

Basic spatial data for the road network relate to intersections and the road segments are coded based on intersection type (e. G. Railroad crossing, street intersection) and the type of traffic control device present (e. G. Stop sign, stop light). Road segments form the framework for a number of other geographic features defined using route systems. Street names, for instance, are defined as routes. Along them speed zones ND speed limit signs are recorded as linear and point events, respectively. In addition, lanes are recorded as linear events along these routes.

Since the majority of streets are only two-lane residential streets, only sections with more than two lanes are recorded. Another important aspect is the recording of the locations of hospitals and gas stations. Moreover, address information related to the road network is being stored, facilitating coding operations. Data concerning road traffic will be very useful for the routing of ambulances. These data will be updated by processing traffic statistics and simultaneously taking into inconsideration online data deriving from traffic sensors installed on the road network.

The National Technical University of Athens has installed loop sensors on the road network of Athens, providing essential information on traffic conditions. Traffic data will be stored in a DB'S. Data pertaining to events such as road works or demonstrations that also affect road traffic will be made available from the municipality or the police. Data concerning hospitals, ambulances, and their personnel will also be stored in the DB'S and used by the GIS whenever it is necessary. Information linking conventional loophole numbers with addresses is also stored in a DB'S.

Its importance will become evident in the next section. Some of the primary functions performed by the GIS operating in KEBAB will be the following: 1 . 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, locating all ambulances positioned within a block, all ambulances that are closer to a hospital or some other spot, etc. Different symbols will be used for displaying an ambulance, 272 2. 3. 4. . 6. Pending on its status: an ambulance may be standing by, handling an incident, or tools of the GIS will take into consideration the data concerning the road network, past incident distribution, population distribution, hospital locations, locations of gas stations and traffic conditions and will propose efficient distributions of ambulances. A variety of criteria should be considered in order to perform this operation. For example, areas where many incidents take place should be allocated more ambulances. A densely populated area entails a higher probability of an incident occurring.

Additionally, an area's urban planning affects the way incidents are handled. Areas close to major streets facilitate ambulance access to whereas areas with narrow streets inhibit it. 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. Finding the site of the incident. Based on the address given by the person calling Kebab's Operations Center for help, the GIS can use address coding 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 thus unable to give precise information about the site of the incident. Therefore, the system should include a mechanism for matching a call to an address. The DB'S linking conventional telephone numbers with addresses will facilitate this matching. Things are more complicated if the call is made from a cellular phone, however. In this case, the assistance of the cellular phone providers will be required in order to match a caller's location to the closest address or landmark. Choosing the appropriate ambulance to Andre an emergency incident.

According to ambulance positions, the type and location of the incident and traffic conditions, the GIS finds the ambulance requiring the least time to reach the site of the incident. The choice of ambulance depends on the type of incident because some ambulances are equipped to handle special emergency cases. 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 incident.

Such information will be derived from communication through the GSM network between the ambulance personnel and the personnel in the Operations Center. The GIS can also present the driver with directions corresponding to the routes generated (e. G. Go straight ahead, turn right to Armor Street, etc.). These directions will be transmitted to the ambulance. In a real- time system like ours, the time performance of the routing function is of vital significance. Generation of statistics regarding incidents. The GIS, in cooperation with the DB'S annotating incident records, can significantly assist in the statistical analysis of incidents.

Consequently, important conclusions supporting the ambulance districting can be obtained. 5. The most efficient implementation of Disaster's algorithm An operation with substantial importance for the handling of emergency incidents is the routing of an ambulance to an incident site and from there to the closest appropriate hospital. The optimal routes correspond to minimum required transportation times. Finding such routes may prove to be time-consuming in the case of large cities such as Athens with very dense road networks. A real-time system however, must be able to give a prompt reply to such queries.

Disaster's algorithm is a simple and consequently easily implemented algorithm for finding shortest routes and is the most widely used in GIS software packages. Its performance depends on the data structures (e. G. Heaps or priority queues) used to implement the graph representing the spatial network. By exploiting recent advances in the field of data structures the performance of a significantly enhanced. We assume that we are given a graph with n nodes, m arcs, and integral arc lengths in the range [0,.. C], where C is the largest arc length. This graph represents the road network.

Boris V. Characters, Andrew V. Goldberg and Craig Silversides developed the hot queue data structure (Characters, Goldberg, & Silversides, 1996, 1999) that combines the best features of heaps and multi-level buckets (Denary & Fox, 1979) in a natural way. They proved in theory that if C is very small compared to n, the data structure performs as a multi-level bucket structure. If C is very large, the data structure performs as the heap used in it. For intermediate values of C, the data structure performs better than either the heap or the multi-level jacket structure.