Study on GIS based intelligence transportation

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Abstract

Recently a vast amount of geographic information system (GIS) data make road networks around the world as polylines with attributes. In this form, the data are insufficient for applications such as simulation and 3D visualization—tools which will grow in power and demand as sensor data become more pervasive and as governments try to optimize their existing physical infrastructure. With the increased dissemination and computing power of mobile devices, it is now possible to execute distributed artificial intelligence applications for various situations: intelligent routing using algorithms, planning, is tribute optimization of traffic lights. This paper reports on our development of a GIS-based traffic network analysis system, named GIS-based Transport Decision Support System, which provides a graphical analysis platform to transportation planners and researchers for transportation network analysis. The system has the functions of designing traffic networks on digital maps and doing traffic equilibrium analysis, as well as a novel function to integrate local detailed structures of intersections into global networks. The latter is particularly useful for the analysis of large traffic network where the detailed local network structures of some intersections have to be taken into account. The system links great volumes of traffic data and geography information data accumulated for visualization traffic analysis. We added information data on the following: road structure data, zone geography information data and node geography information data. The system also enabled us to extract traffic data by road section and by specific condition.

Keywords: K-means, clustering algorithm, error rate, iteration, reduction, stable

1 Introduction

Traffic simulation describes large numbers of vehicles on a traffic network by taking advantage of the reduced dimensionality typically found on road networks: vehicles follow roads and their motion can be described with few degrees of freedom. Research on techniques for traffic simulation has been carried out since the 1950s; see the survey of Helbing for a good overview of the field. Traffic is an integral component of any virtual environment that attempts to realistically portray the contemporary world, be it a video game, movie, or virtual globe. Traffic is also a global challenge with a direct impact on the economy, energy consumption, and the environment in today's society. Traffic simulation is a key tool to address both the challenges of traffic and its visualization. However, traffic simulation takes place on a complex domain and realistic road networks. The main objective of this work is to create road network representations from polyline data that can be used directly for real-time traffic simulation and visualization in a virtual world.

Traffic simulation presents unique challenges in the acquisition and representation of the underlying simulation domain, namely, the road network. Digital representations of real-world road networks are commonly available, but the level of detail of these data is not immediately usable for many queries related to traffic simulation. Traffic simulations take place on a network of lanes. This network needs to be represented with all its details, including the number of lanes on a road, intersections, merging zones, and ramps.

Optimizing vehicle routes in the context of current road congestions can reduce fuel consumption and transportation time. Maximizing the load of each vehicle in a transport company depending on route, will reduce the amount of trips per goods. Giving the driver information about Point of Interests (POI), such as safe parking spots or resting places, reduces the down time having to search for them manually. Online simulation of trafic can assist existing route guidance systems by predicting problems such as congestion. Accurate predictions require accurate status information about vehicles – the fact that vehicles are distributed over large-scale road infrastructure makes this particularly challenging.

A fundamental problem in transportation network planning and traffic engineering is the evaluation of the impacts of a design plan or some management policy on the distribution of traffic flow on the network, which is solved by the equilibrium network analysis method. The essence of equilibrium network analysis is the consideration of the influence of traffic volumes on travel times, and consequently on route choices of travellers, which then reversely change traffic volumes. There have been developed several software packages in which the equilibrium network analysis algorithms are implemented.

This work entails numerous scientific challenges. First, constructing the intersection, ramp, and road geometries presents numerous special and degenerate cases, typical of geometric computation. Our method is speci-

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fically designed to automatically handle as many of these cases as possible. Second, GIS data of road networks are not intended to be used for simulation. We reformulate these networks in order to extrapolate a network on which simulation can be done. Third, the data as available require filtering in order to be processed; while this is not the main focus of our work, it is a challenge that we have addressed in this paper. Fourth, these networks are large in scale, and so efficient algorithms and implementations are required. Fifth, the scale of the implementation itself is a challenge as this project is a combination of multiple systems, a road network importer, a road network representation, a simulation system, and a visualization system. Finally, there are algorithmic challenges in capturing details such as over-passes and in defining arc roads, which further address the needs of traffic simulation.

The idea in this study is to consider active vehicles in the traffic as agents, which send traffic reports to a centralized server via wireless internet. A centralized server behaves as an agent which collects data from vehicle agents and estimates average traffic flow speed for each road piece on the map. The vehicles are able to retrieve real-time traffic flow speed of a specific set of road pieces when they wish to plan a route between two points. The purpose of the study is to investigate if route planning based on real-time data is more effective and efficient than route planning based on static and statistical traffic data.

2 Related works

While digital road networks are widely available, the amount of detail varies widely across sources. Data for North America and Europe are freely available from the US Census Bureau’s TIGER/Line database [4] and “crowd-sourced” community projects like OpenStreetMaps [5], but these data sets contain polyline roads with minimal attributes–information about lanes and intersection structure is wholly missing. Commercially available data sets, such as those provided by NAVTEQ [6], often contain some further attributes, such as the lane arrangements at intersections, but they are expensive to obtain, the techniques used are not known, and they do not capture all of the desired detail.

Numerous methods have been proposed for automatic and semiautomatic GIS road extraction from aerial and satellite images. Extensive surveys include [7-9]. These methods are complementary to our work: the GIS network we assume as input could be the product of a satellite image extraction method.

Procedural modelling of cities and roads has been an active area of research interest in computer graphics. For example, recent work in [10,11], among a notable body of investigation, has enabled the generation of detailed, realistic urban layouts, and roads for visualization. Commercial procedural city modelling software is also available. For example, consider the intersection geometry generated by CityEngine. Here, the intersection is modelled as a square connected to neighbouring rectangles with narrow triangles. In our work, we construct the geometry for every lane, not just the roads; the lane connections are C1 continuous, and the geometry defines all the needed parameters for vehicle animation, including orientation and steering angle.

Numerous spatial representations of curves have been developed over the years – see the comprehensive books by Farin [13] and Cohen et al. [14]. However, road networks and traffic behaviour have specific requirements: existing curve representations are not the best suited for modelling road networks to support real-time traffic simulations. For example, the popular NURBS formulation [15], despite of its generality of representations, is costly in space and efficiency. In particular, many splines do not readily admit arc-length parameterizations: those must be obtained using relatively expensive numerical integration techniques for establishing vehicle positions and for describing quantities of vehicles on each lane in traffic simulators. Willemsen et al. [16] describe ribbon networks, specifically discussing the need for “fattened” splines to describe road shapes, and our technique is potentially complimentary to the modelling technique for road networks they present. How-ever, they use the representation of Wang et al. [17], which is only approximately arc length parameterized and requires iterative techniques for evaluation. In contrast, our method only needs a simpler and much cheaper direct evaluation. Van den Berg and Overmars [18] proposed a model of road maps for robot motion planning using connected clothed curves. However, their choice of representation is based solely on the need to generate vehicle motion. For both traffic visualization and simulation, the representation must also be suitable for the generation of road surfaces, which are not necessarily clothed curves. Additionally, clothed curves are expensive to compute–requiring the evaluation of Fresnel integrals–whereas our method relies solely on coordinate frames, sins, and cosines. Nieuwenhuisen et al. [19] use circular arcs, as we do, to represent curves, but these arcs are used to smooth the corners of road maps for motion planning as in [18]. Furthermore, neither of these techniques have been investigated for the case of extracting ribbon-like surfaces, as we do, nor is there an established technique for fitting them to multisegment, no planar polylines.

3 The proposed method

3.1 PRELIMINARIES

The common formulations for traffic simulation are lane-based. These lanes are treated as queues of cars, represented either as discrete agents or by continuous density values. For traffic simulation, lane geometry is irrelevant as long as speed limits and distances are available. However, geometry matters for visualization and for localizing data, such as cell phone or GPS transmissions sent to inform about traffic conditions. These lanes are connected in various ways to form a road network, and cars traverse these connected lanes by crossing intersections and merging between adjacent lanes. The principle requirement for simulation is the creation of this network of lanes. This includes the division of roads into lanes, but also the creation of transient “virtual” lanes within intersections: these virtual lanes exist only during specific states of a traffic signal. The creation of the network of lanes also entails determining the topological relationships be-tween lanes (so that vehicles can change lanes and take on-and off-ramps) and making geometric modifications to the road network to allow the construction of 2D or 3D road geometry.

To efficiently support traffic simulation, there are a number of queries the network needs to be able to answer in a computationally efficient manner. The nature of these queries depends on the simulation technique (i.e., whether the technique is continuum-based or discrete). Additionally, it is desirable that the road network representation abstracts away the details of the queries on the road network to maintain clear separation and software modularity between the traffic simulation and the road network.

3.2 GIS DATA FILTERING

We filter the GIS data we use to remove the most commonly occurring errors. These changes are not meant to change the underlying geometry or topology of the network, only to correct sloppy data creation. The first filter removes points that are coincident, where is a distance argument that is kept on the order of feet. This is done prior to the splitting and joining algorithms, while the remaining filters are applied afterward. The second filter removes collinear points within roads. The third filter ensures that no point added to a road causes it to turn too sharply or double back on itself. This filter calculates the offset, as in Figure 1, that would be required for a circle of minimum turning radius to be inscribed within the polyline segments. If this offset is greater than half the length of either segment, the node is not added. This ensures that when a point is added to the road, the road still satisfies the kinematic constraints of a typical car. Further filtering includes ensuring that one way roads are defined in the correct direction and that roads have been assigned the correct classification.

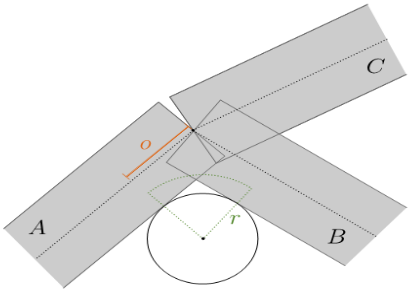

FIGURE 1 A simple intersection with three roads

3.3 THE PROPOSED COMPONENTS

We have implemented the Traffic Map Editor (TME), as a traffic simulator in Java in which infrastructures can be edited easily by using the mouse, and different levels of road usage can be simulated. A large number of fixed and dynamic traffic light controllers have already been tested in the simulator and the resulting average waiting times of cars have been plotted and compared. We will speak about dynamic traffic lights system as the adaptability component of the solution.

1) Application Architecture: Traffic Map Editor (TME) has been divided in several main components that describe the features that come together with the application. The architecture allows developers to not only build on top of TME but also allows them to enrich core features by adding new (or even replace) plug-ins. To the core of the application have been attached several important components as: db, editor, exporter, importer, network view, visualizer, simulation statistic or TmeEventServer.

2) Traffic Data: Traffic data that is aimed to be shared between agents is the speed of the vehicles moving along road segments and average speed of unique road segments. Vehicle agents request traffic data from the server agent by sending a list of road identifiers. Server agent's response to these requests contains the calculated average flow speed of the requested road segments. The reports that vehicle agents send to the server agent contain the momentary movement speed of the vehicle and the unique id of the road segment on which the vehicle is moving. These reports also contain the reporting time and the exact coordinates of the vehicle at that moment. These reports are received by the server agent and the average flow speeds of road segments are calculated.

In our development of GIS-TDSS for traffic road network mapping applications, objectives on geographic processing providing operations for processing or transforming data in a manner determined by user specified data. Through the system, we are able to integrate with other new traffic analysis model, this including road information, data management, and traffic model execution and management. Figure 2 shows the structure of our development of GIS-TDSS system.

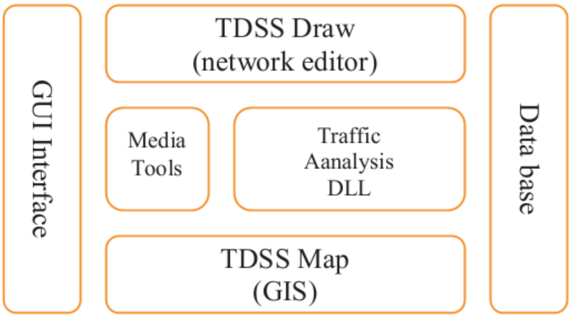

FIGURE 2 Structure of GIS-TDSS system

Similar to other GIS software, geographic information in our development is organized into 6 groups as follows: GUI system, database system, TDSS Map, TDSS Draw, media information tool and traffic network analysis algorithm DLL (Dynamic link library) files. GUI is the basic function group in a graphic interface built using Microsoft GDI (Graphics Device Interface). TDSS Map is the core module for processing digital map.

TDSS Draw is the module for network drawing and editing. The media tools module provides tools for storing various kind of regional multimedia information, e.g., traffic video at important intersections. The traffic network analysis algorithm DLL is the dynamic link library of network analysis programs. GIS-TDSS uses conventional layer models for storing and editing information. The topological relation between a global network and a local network is described in the data table for the local network data, detailed structure of this is described in the following section.

3.4 DATA STRUCTURE

The characteristics of the geospatial data set are changing. First and foremost, in order to meet users demands effectively, the capacity for the real-time collection, synthesis and access must exist; data import and export is essential. The data should be seamless, without artificial boundaries, and linked to attributes table that has become critical to many applications, for example, traffic flow management, road of disaster, and flood and earthquake traffic.

The GIS-TDSS system project file consists of a workspaces file, multiple geometric files, multiple relational data tables and multiple attribute data tables. The map file is a direct access, variable-record-length file in which each record describes a shape with a list of its vertices. In the index file, each record contains the offset of the corresponding main file record from the beginning of the main file. The data table contains feature attributes with one record per feature. The one-to-one relationship between geometry and attributes is based on record number. Attribute records in the data file must be in the same order as records in the main file. Figure 3 shows the data file structure of GIS-TDSS system and data file flow.

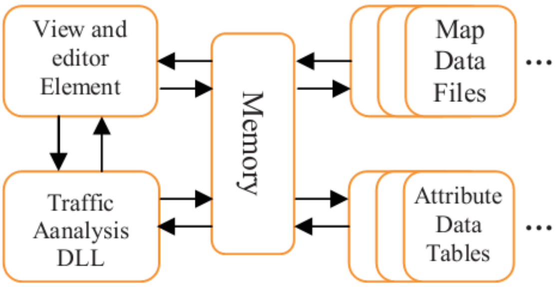

FIGURE 3 Data file structure of GIS-TDSS system

We propose new concepts for the GIS-DSS system: seamless operation of a detailed local network into a global network. As mentioned in the Introduction section, the integration of a detailed local network for an intersection into a global network is necessary to improve traffic analysis accuracy without involving too large a computational burden.

In the general structure of GIS (9), spatial data can be divided into three groups: 1) geometric data – data for describing space characteristics of spatial data, also known as location data, positioning data; 2) attribute data – data for describing attributes of spatial data such as type, grade, name, status, and so on; 3) relational data – data for describing topological relationship between spatial data. These three data groups are stored in separate tables in conventional GIS. In this study, the geometric data and relational data are placed in a unified data management table. In the following an example is given to illustrate our method.

The module for implementing the above data modification in the GIS-TDSS is shown in Figure 4.

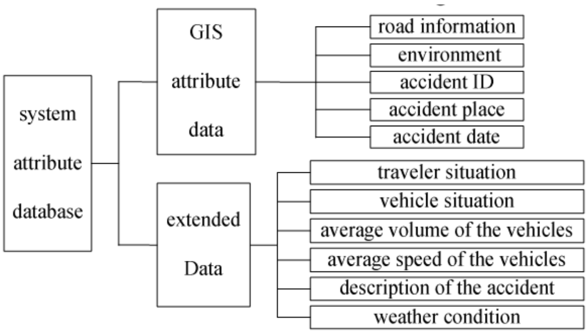

FIGURE 4 Attribute data organization chart of the traffic

The layer manager extracts data from data file in accordance with the requirements of the system, forms a graphic layer with the data of the geometric table, and then loads the required layer attribute data, and loads them into memory to output the required layer. The data manager controls the definition and value assignment of the structure and metadata in the layer-refining table, defines the geometric shapes in network, extracts data, etc.

3.5 DATA PROCESSING

Geographic entities are organized by layers in spatial database, mainly including point, line, and area entity. Geographic entities of map are called graphic element which are display as Feature object. Each geographic entity has its own attribute and is stored in attribute list in the form of one record. Entities with similar attributes or functions are stored in the same layer when needed in practical application. Each layer corresponds with one attribute list, to realize operation and inquiry of attributes of graphic element.

Actually, in the traffic information management and promulgating system based on GIS, the spatial database which storing and managing various spatial information and attribute data of graphic element is a map file of MapInfo in the system, including spatial database of non-related data structure with spatial information and attribute database with related data structure. The files or updated ones can be downloaded when running the GIS viewer. Spatial data mainly include point, line, area entity such as urban road network, urban terrain, traffic facility map, administrative regionalization, road transect and vertical section. Spatial data on the road map are collected and input by electronic map or engineering drawing of AutoCAD format. Then the data are edited and processed by MapInfo. At last, basic layers are integrated by Geoset Manager, in order to link and operate.

4 Experiments

Traffic attribute data in GIS attribute list are applied to inquire and analyse basic information about road traffic by users, not including parameters of traffic flow and all the information of traffic accidents, while they are stored in extended database and defined according to data list field. Entity attribute list of traffic flow and accident is formed by part of extended data list field. Traffic reference point data are from writing and electronic data related to traffic police department, which are processed by manual inputting, scanning, and format changing and so on. At last, the data are inputted into SQL Server 2000 database. The data collected from section detector through the analysis and decision-making module processing, the necessary flow, with an average speed of traffic flow parameters and other important information are archived, stored in SQL Server2000 database, which provide basic data for the future transport planning and road design and transportation research.

Spatial data are the basic loaders to indicate, query, analyse space and construct road network. Since the range of urban road network is large, traffic information is refreshed at any time. The spatial data of different traffic information in road network are on adjusting, which need to maintain and refresh spatial data frequently, in order to ensure integrity, accuracy, and validity of spatial data. Attribute data are stored in a list in the form of database, usually extended database. There are many alternatives here and relation database is often chosen, such as SQL Server, Oracle, Sybase, Access, dBase, Paradox, and so on. Generally, SQL Server and Oracle are used to develop large-scale database, Access and dBase are used to develop medium and small-scale database. The attribute and spatial data are linked by data index mechanism in GIS. Graphs and characters can be checked quickly with each other too. Data index mechanism is a method associating spatial objects with attribute data.

1) When we query spatial information from the attribute information, in the first the corresponding database records should be found in the attribute data file, such as the number N record. You can find the Nth pointer in the cross-index file, the pointer is pointing to a map of an object which is the spatial objects correspond with the database records.

2) When we query attribute information from the spatial information, if you have found a space object from the map, the system read out its spatial information and the corresponding database record number from the spatial data file, according to a database record number, the attribute information of the map object could be query in the attribute database. History data records of traffic information are stored in extended database, which should also be connected with processing module of extended detectors. Besides, there should be index linking attribute data of graphic elements. Related database can be realized on this point.

Suppose that we are interested in the traffic flow crossing a special intersection indicated in the map. For this the detailed network for the intersection is integrated into the global city road network. Due to space restriction, the detailed data for the parameters of the network are omitted here.

Step 1: The Conventional equilibrium analysis result of the common transport network, and the part surrounded by the dotted line. We can find out the traffic volume of the four links (two-way) connected to node intersection.

Step 2: The node intersection is set to be a common intersection (local detailed network), so that new twelve links at the intersection can be inserted into data table and the start point or the end point of four links connected to the node intersection can be revised.

Step 3: A further calculation on the new network obtained in Step 2 is taken to get the new equilibrium analysis results. The traffic volume change on links connected to node happened.

For detailed analysis of the intersection denoted as node Intersection in the network, Intersection is expanded as a local detailed network with twelve new links. It can be seen that some of the traffic volumes have turned onto other links due to the delay impact of the intersection.

Two alternative evaluation procedures were used in testing the accuracy of the road traffic noise prediction model developed in this study. First, grouped data were collected from 85 locations near road segments where sound propagation was not interrupted by barriers. Second, an additional set of grouped data were collected from 148 reception points within housing estates in Beijing, where the noise environment was believed to be much closer to real conditions. Results of these two data collection procedures are presented in Figures 5 and 6.

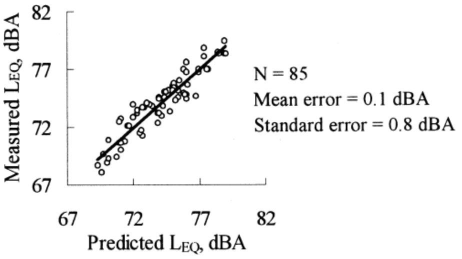

FIGURE 5 Evaluation of accuracy of model by field data

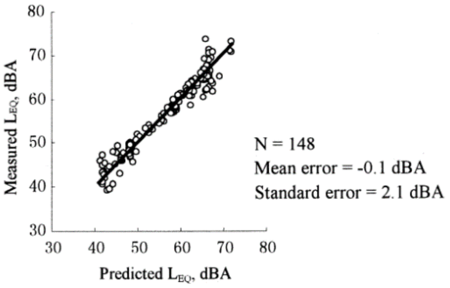

FIGURE 6 Evaluation of accuracy of model.

Evaluation of the modelled results indicates that noise prediction is more accurate at locations closer to the road carriage way where the environment of sound propagation is less complex. The model has an accuracy of 0.8

dBA for traffic noise prediction at locations nearer the road, and was accurate to 2.1 dBA for locations within the housing estate. Further, there were no systematic errors in the prediction results observed for either set of conditions. The accuracy in predictive results of the adjusted model for China is comparable to those of the FHWA model, whose predictive accuracy is 2.0 dBA.

5 Conclusions

We have presented a method for transforming GIS data into a topological and geometric representation suitable for use in traffic simulation. Our geometric representation of roads is visually smooth, including at ramps and intersections. Our method preserves the topological relationships of the GIS road network. We have shown examples of GIS data that have been processed by our method and composed with satellite images. These figures illustrate features of the road networks generated by our method, such as intersection handling and highway ramps, as well as the extensive scale of models that our method can process within a matter of few seconds.

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