Geographic Information Systems (GIS) as Spatial Decision Support Systems (SDSS)

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ABSTRACT

Recent advances in Operations Research (OR) and Information Technology (IT) have made it possible to integrate Operations Research techniques and Geographic Information Systems (GIS). This integration can be used for the development of Spatial Decision Support Systems (SDSS).There is an increasing need for incorporation of routing techniques into a Decision Support System (DSS) for making effective business decision making in transportation. GIS can be used to analyze the routes. Route analysis helps us to generate the most efficient route (best route / shortest route) that the vehicle should take between the company and it supply chain link. Alternative routes can also be generated and analyzed. Alternative routes help in rerouting of the supplies in case of problems (either man –made or natural) on one route. Travel speed is used as a proxy, to traffic data to calculate the time taken to reach from origin to destination by the shortest/best route. In this paper a spatial decision support system is developed for route generation.

Introduction

Operations Research (OR) has identified a wide range of useful modeling techniques. However a number of difficulties exist in the practical application of these mathematical modeling techniques. These include problems of data assembly and data storage. Real world problems frequently have a richer set of objectives and constraints than are typically found in mathematical formulations. Some of these problems have been addressed by the incorporation of modeling techniques in decision support systems.

One of the new types of information technology of interest is Geographic Information Systems (GIS). These systems provide relatively complex database and interface features designed to facilitate the handling of all types of geographic data. GIS can be combined with OR models to build Spatial Decision Support Systems (SDSS).

In this paper a spatial decision support system is developed for route generation. In order to achieve realistic results, the volume of traffic data has to be real time. In this paper travel speed is used as a proxy to traffic data. User selects the travel speed and the system calculates the time to reach from origin to destination by the shortest/ best path.

Geographic information systems (GIS)

GIS's ability to assimilate the concepts and algorithms from many disciplines such as cartography, geography, surveying, statistics and computational mathematics makes it a versatile tool for handling geo-referenced data. GIS establishes one-to-one relationship between spatial and non-spatial data and thereby performs an integrated analysis. The spatial data could be in the form of charts, aerial photographs, maps, satellite images, GPS observations. The attribute data (non-spatial data) could be in the form of numbers, symbols from say census data, demographic data, customer data, supplier or vendor depots details, company's godowns. Information about spatial features is stored under the GIS in the form of:

1. Points (No dimension),
2. Lines (One dimension) and
3. Area/Polygon (Two dimensions)

GIS has the ability to keep spatial and non-spatial information in different layers. Thus the information can be processed according to any combination of layers. This facilitates various spatial operations like overlay, union, intersection and clipping of maps with corresponding operations performed on the linked database. The output of such analysis can be depicted in the form of 2D and 3D maps, graphs, statistical tables. From a decision makers perspective GIS is defined as *"a managerial decision making tool for decision making, involving a spatial dimension as one of the variable among a set of variables considered for decision making[1]"*

Spatial Decision Support Systems (SDSS)

GIS software is highly suitable for developing SDSS's. GIS software provides interface for spatial information. GIS also provides database support for effective storage of spatial data. Further, GIS software provides a link between the interface and database to allow user easily query spatial data. The focus of an SDSS, as of a DSS generally, is to provide specific support for the problem to be solved. Thus in case of routing problem, this may require to display the road network, district boundaries, the best route, alternatives to best route, government and non-government utilities like banks, hospitals, post offices, police stations, petrol bunks, restaurants ,customer places, sales depots, retail outlets, suppliers godowns, etc.

Road Network in Karnataka, India

Karnataka is situated approximately between the latitudes 11.5° and 18.5° North and the longitudes 74° and 78.5° East. Karnataka the eighth largest state in the country has a total

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[1] GIS Definition derived during the courses of research on "Business Graphics – A New Approach to Decision Making", Vinod N. Sambrani

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geographical area of about 1, 91,791 square kilometers, accounting for over 5.8 percent of the total area of the country.

Table- 1.1
Road Network in Karnataka State,India

SL	Road Type	Length
1	National Highway	3,973 Kilometers
2	State Highways	17,222 Kilometers
3	Major District Roads	30,975 Kilometers
4	Other District Roads	1,634 Kilometers
5	Village, Irrigation, Forest Roads	88,154 Kilometers

Source: Karnataka road Development Corporation limited /Road policy

Dharwad district, the study area has the following road length:

Table- 1.2
Road Network in Dharwad District of Karnataka State

Thaluka	NH	SH	MDR	Total Length
Dharwad	30	189	126	345
Hubli	80	41	120	241
Kalghatgi	33	59	74	166
Kundhagola	0	37	106	143
Navalgund	46	94	128	268
Dharwad District	189	420	554	**1163 Kilometers**

Source: Public Works Departments Roads in Karnataka

Methodology

The activities undertaken for the study are shown in the figure 1.1
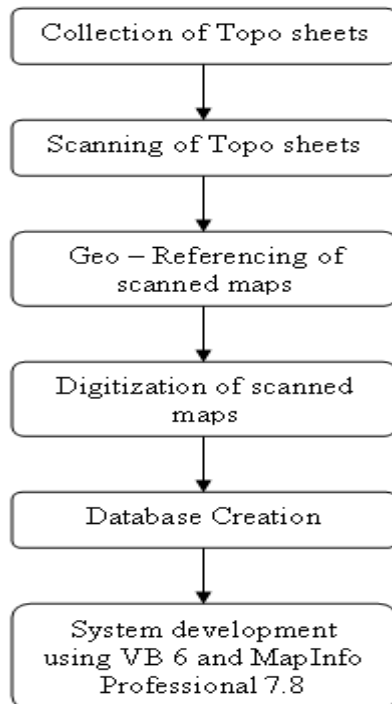

Figure 1.1: Flow Chart

Some of the important steps involved in the work plan are:

Geo-referencing

Scanned maps don't usually contain information as to where the area represented on the map fits on the surface of the earth thus the image needs to be aligned or geo-referenced. Geo-referencing is the process of establishing the relationship between an image (row, column) coordinate system, called image space, and a map (x, y) coordinate system, called map spaces. The image needs to be registered to a set of coordinates that are in map space. The parameters necessary to register can be determined in two ways,

1. By extracting them from the information that accompany the image, or
2. By using a geo referencing tool like GPS to transform the image co-ordinates.

Depending on the means of collection, images can exhibit a variety of spectral and geometric distortions. Image processing technique like rectifying and rubber sheeting can be used to correct many types of distortions.

Digitizing

Digitizing is the tracing of information from analog format, such as paper map, to digital format, so that it can be stored and displayed with a computer. Paper maps are scanned to capture it as a raster image. Using the digitizing tools available in the GIS software or AutoCad software, raster image is digitized into digital format.

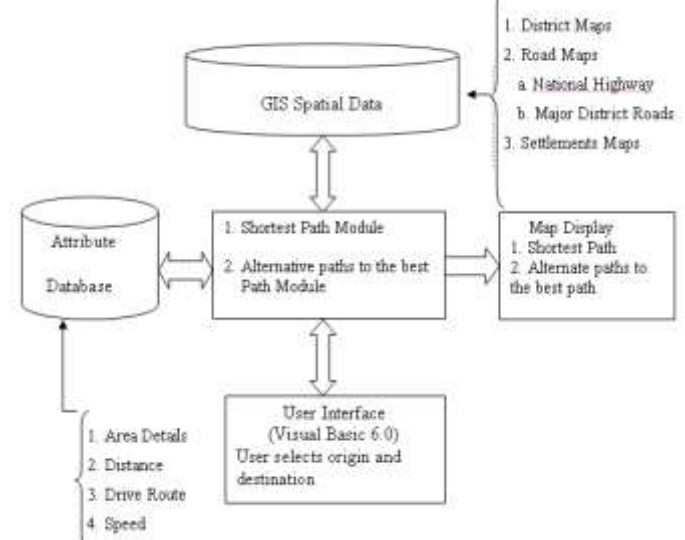**Spatial decision support system framework**

Figure 1.2: SDSS Model for Route Generation

Source: Model developed during the courses of research on "Business Graphics – A New Approach to Decision Making", Vinod N. Sambrani

System Development

The SDSS is developed using Visual Basic 6 as the front end tool. All the spatial and attribute data is stored in MapInfo Professional version 7.8, which acts as the back-end tool. Shortest path and Alternate path module has been developed using the routing algorithm developed by Dijkstra. Each of the components involved in the system development are discussed below:

Visual Basic 6.0 as a Front – End Tool

With Visual Basic, the program is written by assembling the objects that will be used for screen display and interacting with the user, adjusting the properties of those objects, determining which event should be responded to, thinking through the variables needed for holding data and for passing information from one part of the program to another, and writing the command lines that will run when events are activated. At each stage of development, any aspect of the program may be added or changed.

MapInfo Professional 7.8 – Backend Tool

Among several GIS systems, MapInfo is commonly used. Factors such as lower hardware requirements, easy to learn and master, high quality and low cost makes MapInfo become a

popular system. MapInfo Professional provides data visualization, including step-by-step thematic mapping and three linked view of data that is Maps, Graphs and Tables. MapInfo Professional supports raster map registration and imports a variety of standard raster formats and vector formats. MapInfo can also generate HTML image maps that can be included in web pages.

Routing Algorithm

In a shortest path calculation from an origin to a destination the route with the lowest overall impedance is selected. Impedance can be defined in terms of distance, travel time, speed, or generalized cost. One of the best algorithms to find the shortest path is the Dijkstra[2] Algorithm, which determines the shortest distance from a specified vertex to a final vertex. The algorithm searches all possible paths. But it builds the path one segment at a time. Starting from an origin it identifies the node that is nearest to it and which has not already been identified on the shortest path. After each node has been identified to be on the shortest path, it is removed from search possibilities. The algorithm proceeds until the shortest path to all nodes has been determined. In this application, the shortest path is by distance.

There are many situations in which it is necessary to generate alternatives to the shortest or best path. In pre-trip planning, for example drivers often want to be provided with one path for their outbound trip and an alternative path for their return. Another example could be a user often wants to be provided with several alternative paths that they can use to avoid particular facilities. Alternate paths allows a user to prefer a particular path because of light traffic, few stops, etc. or avert using a particular path because of frequent delays , high toll, etc. In view of the above statements it is important to find the alternatives to the best path from a given origin and destination. Each alternate route between an origin and a destination is generated, using the same method employed to obtain the initial least- distance route (i.e., by applying the Dijkstra algorithm), after first discouraging re-use of most street segments used by the least distance route and all previously generated alternate routes. The method for discouraging re-use is to artificially inflate the costs (distance) associated with using those previously-used street segments[3]

Tools Available in the SDSS

Table- 1.3

Tool Name	Symbol	Description
Select Tool		Select tool is used to select objects/records in a Map, Layout or Browser window. Also acts as the default pointer/ cursor tool.
Pan (Grabber)		Grabber tool helps to reposition a map or layout within its window.
Zoom Out		Zoom-out tool helps to get a wider area view of a map or layout.

[2]Dijkstra's algorithm is of use when working with directional graphs. It constructs the shortest path between a starting-node and a goal-node. It is assumed that every link between two nodes has a certain cost or distance, and this algorithm finds the path between the two given nodes with the lowest cost or distance.

[3] Alternate Route Generation – Ronald L. Blewitt Pub. No. US 2002/0143464 AI 3rd October 2002.

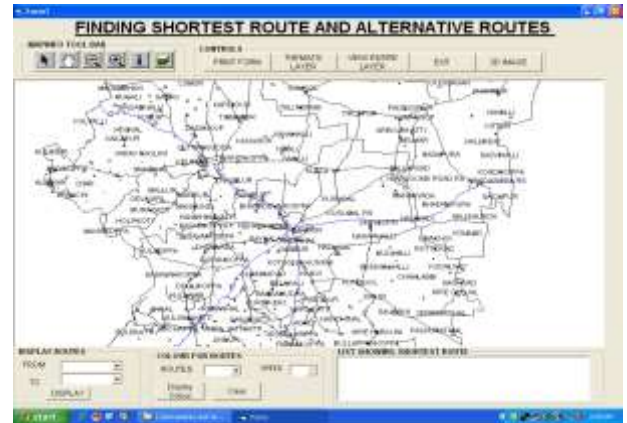|		
Zoom In		Helps get a closer area view of a map or layout.
Information Tool		Information tool helps to view the tabular data that is associated with a map object
Layer Control		Helps to accesses the layer control dialog box to specify how various tables in a map window are layered and displayed

Figure 1.3: Snapshot of the SDSS for Route Generation

Working with the SDSS
1. Run the SDSS application.
2. Select the 'From' (i.e. the Origin) and 'To' (i.e. the Destination) places from the combo boxes available under the label 'Display Routes'.
3. Click on the 'Display' button to zoom in the selected area.
4. Select route1 form the combo box labeled 'Route' and click on the "Display Colour' button to display the first route.
5. Similarly select route 2 form the combo box labeled 'Route' and click on the "Display Colour' button to display the second route.
6. Continue the same procedure till all the routes are generated.
7. The shortest/ best path between the origin and destination along with the alternative routes are generated in different colours.
8. Click on the combo box labeled 'Speed' to choose the speed of travel. Select the speed to calculate the time to travel between the origin and destination by the shortest / best path.

Conclusion

Spatial Decision Support Systems will be an important area of OR applications. GIS is of interest because it allows decision maker incorporate a spatial dimension in their decision making. The system developed allows user to have prior information about the road network, the shortest path and the alternative paths between an origin and a destination along with other details. Based on the average travel speed the travel time is also known. Thus the traveler can plan his travel better.

Attribute data like the demographic, census data, government and nongovernmental utilities data like hospitals, banks, post offices, restaurants etc. can be integrated into the system. With this kind of information transportation service providers both public and private can make analysis about cost, pricing and profitability of running their buses on different routes. Manager's can take effective decisions regarding their logistics. These kinds of systems help decision makers in effective management of their supply chain. The value addition

comes through the use of GIS, along with other attribute data, which is used in decision making.

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