Enhanced Routing in Disaster Management based on GIS

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ABSTRACT
In emergency routing, core problem is how to reach accident area in minimum time. Traditional distance based routing does not always gives optimal path in time in need. This paper presents an enhanced routing method which is based on Dijkstra's algorithm and Analytical hierarchical processing. Seven impendence factors which cause delay in emergency situations are found and Analytical hierarchical processing is used to compared and analyze these seven factors to give overall weight to each road in network. Then Dijkstra's Algorithm is applied on this weighted road network to give optimal path between source and destination. Optimal path here does not necessarily mean shortest path but a path which takes minimum travel time. Seven impedance factors considered here are, Road length, Road width, Road type, Traffic volume, Mass density, Velocity limit, Junction Delay. As Traffic Volume does not remain constant throughout a day on particular road, dynamic emergency routing is proposed in this paper.

General Terms
Disaster management system, Enhanced routing system, Optimal route based on AHP.

Keywords
GIS, AHP, Emergency routing, Dijkstra's algorithm, Optimal path.

1. INTRODUCTION
India has been traditionally vulnerable to natural disasters on account of its unique geo-climatic conditions. Floods, droughts, cyclones, earthquakes and landslides have been recurrent phenomena. The recent earthquake and bombing in India are hard evidence of the fact that our country needs a better disaster management system. After any disaster happened, providing aid in that area, helping people, or reaching the accident scene in minimum time is most important issue. To find out a path between any two points either shortest path which has minimum distance or optimum path which has minimum travel time is to be selected, but in disaster situations, optimum path will be preferred over shortest path because latter will not guarantee to take minimum time due to lots of factors like traffic volume, road width, mass density etc. Geographical Information System (GIS) can be used for finding this optimal path as well as for representing this valuable spatial information to end-users. Objective of this system is to overcome the pitfalls of existing emergency routing systems and propose a new enhanced routing system which will help users to find out the optimal path from given source to destination considering dynamic traffic volume.

Recent trends towards the development of GIS have promoted researchers to investigate GIS applications for various emergency situations, which mainly involve the integration of GIS with multi criteria decision analysis, and it has attracted significant interest over the past 15 years or so. Emergency routing mainly applies dijkstra's algorithm for finding routes in the network. In Recent years dijkstra's algorithm is modified to give optimal path based on seven impedance factors such as Road Length, Road Width, etc and it was combined with.AHP to give optimal path as explained by Shu Yang et. al.[1]. Shashikiran et. al., explained kruskal's algorithm to generate shortest route between any two nodes based on traffic rate or distance [2]. They described Dynamic Vehicle Navigation System which generates shortest path based on traffic updated given by traffic in-charge but fails to consider other important factors such as road width, mass density etc. Recently, disaster management system was exclusively designed using GIS web services and AJAX (Asynchronous JavaScript and XML) approach so that spatial data can be loaded efficiently into the client browser and loading time can be minimized [3]. Abdul Fattah Chandio et. al. presented the modular structure of route assisting system for path planning [4]. Recently developed GIS-based advanced traveler Information System (ATIS) has a point-and-click graphical user interface which is more user friendly [6].

2. ARCHITECTURE OF SYSTEM
The objectives of Disaster management system are to provide emergency services such as police, fire and medical for the general public in case of emergency situation. The salient features of the system are its detailed database which contains information about all hospitals, police stations, fire stations and streets. Being disaster management system scope of the system is restricted to only up to finding shortest route between user given source and destination. If any disaster or accident occurs in these localities, according to the user's requirement the nearest service will be located on map. It can also provide the shortest route to reach the service provider's location by Dijkstra's algorithm. Search for any emergency services based on the user's locality. The route between any two nodes on the map will be calculated based on many impedance factors. AHP concept is used to calculate the overall priority of each of these factors, then building of a comparison matrix to find which path gives optimal travel time using dijkstra's algorithm. Since out of seven impedance factors, traffic count is dynamic one and overall travel time heavily depends on traffic count on particular road, in order to do realistic decision making, two comparison matrices are built. In the first matrix, traffic has given lowest priority (this matrix can be used when user request for route during morning\evening peak hours when traffic volume on some streets is considerably high). In second matrix, traffic count

has given highest priority (this matrix can be used when user request for route in afternoon/night hours when traffic volume on roads is low). Then priority vector for each road is calculated. Priority of distance is combined with real distance value to give overall weight to each road. Dijkstra's algorithm is applied in weighted road network to give optimal route. Architecture of this improved system is shown in the figure 1.

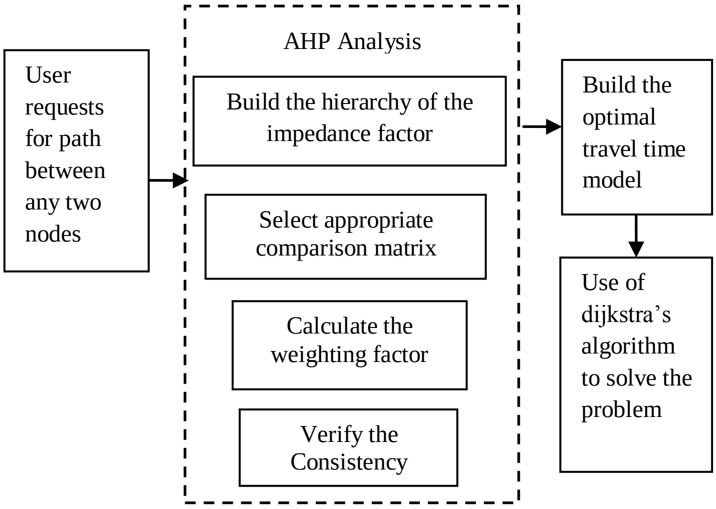

Fig 1: Architecture of Enhanced Routing System

2.1Classical Dijkstra's Algorithm

Dijkstra's algorithm is to solve single source shortest path problem for non negative weighted graph producing shortest path from given source to all nodes in graph. This algorithm has very much importance in routing, networking protocols such as IS-IS and OSPF etc. This algorithm can also be used for finding cost of path from single source to single destination by stopping the algorithm once it reaches to destination vertex.

Let the source node or the node from which shortest path is to be find out, is called as initial node. Distance of any node 'X' is the distance from initial node. Dijkstra's algorithm assumes every node except initial node is at infinity distance and minimizes it in every iteration.

1. Assign distance value zero to initial node and infinity to all other nodes in graph.
2. Set initial node as current node and mark all other node as unvisited.
3. From current node, find distances (from current node) to all of its unvisited neighboring nodes. If this distance is less than their current distance then overwrite this distance with smaller distance.
4. Mark current node as visited. From the set of all neighboring nodes, select node with minimum distance. If this current node is not destination node then set that node as current node and repeat from step number 3.
5. Using the steps given above, shortest path from source node to destination can be easily found out. This simple dijkstra's algorithm is combined with AHP processing to give optimal path between source and destination as explained in next section.

3. SCHEME OF IMPLEMENTATION

3.1Impedance factors selection

In order to evaluate the factors that affects the travel time, there are many techniques. The most efficient one is to evaluate the factor with respect to problem situation. For a particular problem, the set of evaluation criteria may be developed through an examination of the relevant literature, analytical study and opinions. Here some most important factors were reused and through further investigation with some experienced firemen other important impedance factor which delays travel time were also selected. Travel time for particular road depends on all or some of these factors. Which factor is important over another in yielding minimum travel time is purely subjective evaluation. For analyzing these factors and to compute overall priority each factor towards minimum travel time goal, Analytical hierarchical processing is used. The seven factors were selected (as given in Table 1) for further analysis in AHP and the AHP is discussed in detail in the next subsection.

Table 1. List of Impedance factors

Impedance Factors						
Road Length	Road Type	Road Width	Traffic Volume	Mass Density	Velocity limit	Junction Delay

3.2AHP Analysis

The Analytic Hierarchy Process (AHP), introduced by Thomas Saaty (1980), is an effective tool for dealing with complex decision making. Aids decision maker to set priorities and make the best decision by reducing complex decisions to a series of pair wise comparisons, and then synthesizing the results, the AHP helps to capture both subjective and objective aspects of a decision. In addition, the

AHP incorporates a useful technique for checking the consistency of the decision maker's evaluations, thus reducing the bias in the decision making process. The procedure for using the AHP can be summarized as [7]:

3.2.1Model the problem as a hierarchy containing the decision goal, the alternatives for reaching it, and the criteria for evaluating the alternatives.

AHP processing starts with modeling the problem as hierarchy in which overall goal of processing is considered as root and criterion are modeled as branches from that root. Similarly, all impedance factors towards obtaining minimum travel time are considered here in the form of criterions and hierarchy is created as shown in the figure 2.

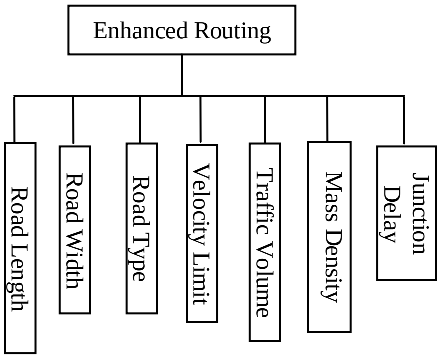

Fig 2: The hierarchy of enhanced routing

3.2.2Establish priorities among the elements of the hierarchy by making a series of judgments based on pair wise comparisons of the elements.

In AHP method, for obtaining priority vector of all criterions, Pair wise comparison is performed. Pair wise comparison is done in order to compare the importance of one criterion on another (Refer Table 2.). Scales are defined to quantitatively evaluate the importance of one criterion over another.

Table 2. Scales in pair wise comparisons

Intensity of Importance	Verbal Judgment of Preference
1	Equally Importance
3	Moderate Importance
5	Strong Importance
7	Extreme Importance
9	Extremely More Importance
2,4,6,8	Intermediate values between Adjacent Scale Values

If the elements of the pair wise comparison matrix are shown with c_{ij}, which indicates the importance of i^{th} criterion over j^{th}, then c_{ji} could be calculated as $1/c_{ij}$. Giving importance ratios for each pair of alternatives, a matrix of pair wise comparison ratios is obtained.

3.2.3Synthesize these judgments to yield a set of overall priorities for the hierarchy.

Priorities of each factor is calculated by first calculating normalized comparison matrix by geometric mean method given as,

$$r_i = \prod_{j=1}^{n}(a_{ij})^{\frac{1}{n}} \quad (1)$$

Then priorities are calculated as

$$w_i = \frac{r_i}{\sum_j r_j} \quad (2)$$

Where a_{ij} (i,j=1…n) are the comparison values in the pair wise comparison matrix and n is number of alternatives.

3.2.4Check the consistency of the judgments.

Consistence comparison matrix holds the condition $a_{ij} * a_{jk} = a_{ik}$ where a_{ij} is the ijth element of the matrix. Consistency Ratio is a measure to check consistency of comparison matrix which is calculated as follows,

$$\text{C.R} = \frac{\text{C.I}}{\text{R.I}} \quad (3)$$

$$C.I = (\lambda_{max} - n)/(n-1) \quad (4)$$

In this $\lambda_{max}$is maximum eigen value of comparison matrix, n is number of criterion and R.I is Random Index (Refer Table 3)

If C.R. < 0.1 then consistency is acceptable otherwise comparison matrix should be modified again until it reaches consistency criterion.

Table 3. Random Index for n = 1…7

n	1	2	3	4	5	6	7
R.I.	0.00	0.00	0.58	0.90	1.12	1.24	1.32

Priority vector of n criterion indicates the priority of each criterion toward final goal that is obtaining enhanced routing. Greater priority value indicated that a particular criterion is having greater contribution in achieving final goal [8].

3.3Integration of AHP with Dijkstra's algorithm

This can be done by combining priority value of Road length factor with its real value to give modified distances in between two nodes. On particular road traffic volume varies throughout a day resulting variation of priorities. Two types of comparison matrix and their respective priority vectors can constructed for high traffic and low traffic for some streets which are more vulnerable to traffic. Depending on time at which user request for route high or low PV is selected.

3.4Apply enhanced dijkstra's algorithm

Dijkstra's algorithm is applied on street network with modified road length to get optimal path.

4.EXPERIMENTAL ANALYSIS

For testing this system under real time GIS usage experiments are carried out to ensure algorithm works properly.

4.1Input

Study area: City of Somerville, in Middlesex County, Massachusetts, United States, located just north of Boston [9]. Data collected is in ESRI shape files of streets, hospitals, police stations etc from different sources. For implementing this system street network of 87 streets is taken.

4.2AHP Processing

Comparison matrices are made for every street in the network. Priorities of one impedance factor over all other factors are decided. As traffic on particular road does not remain constant throughout a day, two comparison matrices are made for some streets whose average daily traffic is more than usual. These two matrices are different in the way priorities are given in different traffic conditions. Now if user requests for a route in peak hours then comparison matrix for high traffic (HTCM) will be used and vice versa.

Priorities in HTCM are assigned in a way to give lower priority to traffic for obtaining final goal i.e. minimal travel time. An example of such street is given in table 4. The priority vector obtained for this HTCM clearly indicates that street with high traffic gets lower priority value to traffic volume and as a consequence of it; Road Length gets relative higher priority value (Refer table 5).

In case of low traffic street, priority value of Road Length is smaller than Traffic Volume. When priority values of each Road length is combined with the actual distance, high traffic streets gets higher weight than low traffic streets. Dijkstra's algorithm includes streets with minimum weight for calculating optimal path from given source to destination.

Table 4. Comparison Matrix for High Traffic (HTCM)

	length	width	type	vel limit	traffic volume	mass	junction
	1	**2**	**3**	**4**	**5**	**6**	**7**
Length 1	1.00	4.00	8.00	4.00	4.00	2.00	2.00
Width 2	0.25	1.00	2.00	1.00	1.00	0.50	0.50
type 3	0.13	0.50	1.00	0.50	0.50	0.25	0.25
vel limit 4	0.25	1.00	2.00	1.00	1.00	0.50	0.50
traffic volume 5	0.25	1.00	2.00	1.00	1.00	0.50	0.50
mass density 6	0.50	2.00	4.00	2.00	2.00	1.00	1.00
junction delay 7	0.50	2.00	4.00	2.00	2.00	1.00	1.00

Table 5. Priority Vector for High Traffic

Length	Width	Type	Velocity limit	Traffic Vol	Mass Density	Junct Delay
0.35	0.09	0.04	0.09	0.09	0.17	0.17

4.3Apply enhanced Dijkstra's algorithm

Figure 4 shows network of 87 streets. Simple dijkstra's gives shortest path as shown in the figure 4.

Figure 5 shows, when enhanced dijkstra's algorithm applied on same network to find route between same source to destination, it alters the route as shown in the figure 4.

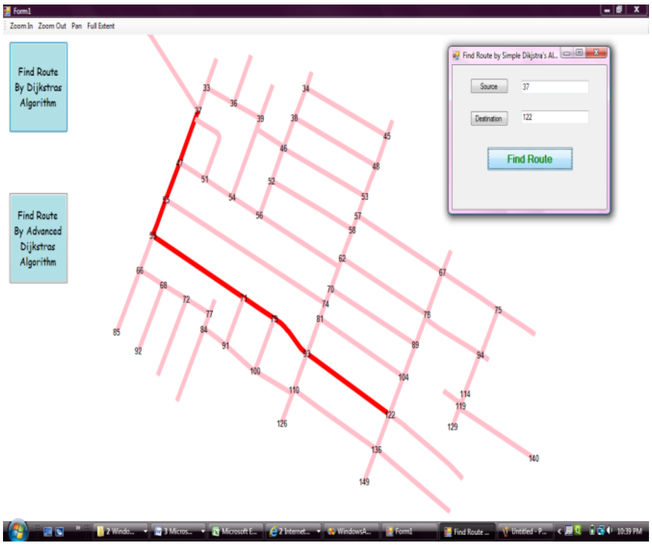

Fig 4: Shortest path by Simple Dijkstra's algorithm

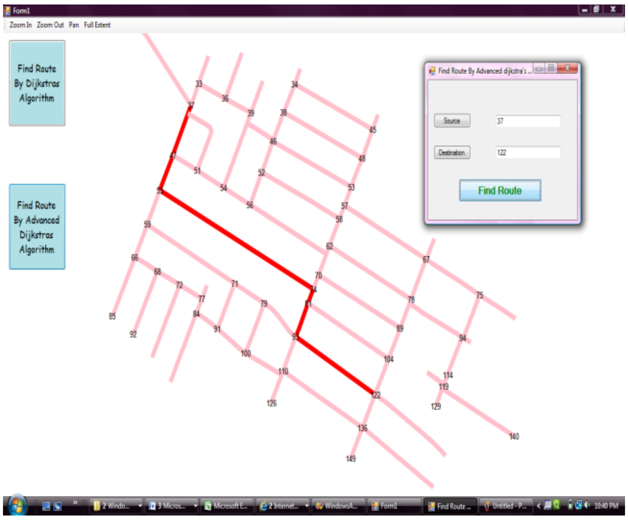

Fig 5: Optimal path by Enhanced Dijkstra's algorithm

5. CONCLUSION

In emergency situations finding a path which takes minimum travel times is critical. There are many factors which influences travel time in real time. Considering priorities of each of these factors in contribution to minimum travel time path, optimal path can be obtained. Analytical hierarchical processing can be used to prioritize these factors and to decide which factor play great role in yielding optimal path. Considering different priorities for traffic volume at different time a day, a more realistic path can be obtained. Future work will focus on capturing real time traffic conditions periodically to achieve more reliable routing system which can be used in any emergency situations.

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