

Shortest route finding by ant system algorithm in web geographical information system-based advanced traveller information system

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Abstract: This paper discusses the methodology used in the development of advanced traveller information system (ATIS). This system is designed as a part of web geographical information system (GIS) based advanced public transport systems. Web GIS-based ATIS system includes spatial data for the designed functionalities and provides GIS capabilities to the users through the internet. In addition to these functionalities, a route planning algorithm to plan the shortest route between the selected bus transit points is also designed using ant system algorithm and is integrated with web GIS. This study presents the ant system algorithm adopted for the shortest route finding with the methodology developed for the web GIS-based ATIS system for the study area of the city Chandigarh in India using open source software MapServer as web map server. This study also discusses the three-tier logical architecture used in the methodology for providing GIS capabilities to the user over the internet.

1 Introduction

Road transport is vital to economic development, trade and social integration. Transport demand has been growing rapidly and motor vehicle population has recorded significant growth over the years. This growth of vehicular traffic on roads has been far greater than the growth of the highways; as a result the main arteries are facing capacity saturation. Advanced traveller information systems (ATISs), as an important part of advanced public transport system (APTS), provide information to public transport customers for planning their trips in the form of pre-trip and on-trip information.

These systems providing the information about the planning of shortest route between the desired origin and destination points utilise the latest web-based technologies and reliable path routing algorithms. In this paper, the shortest route finding problem between a set of selected origin and destination points is solved by the method of the inspired heuristics (meta-heuristics) ant colony system (ACS) and the methodology is developed for the integration of this technique in a web-based geographical information system (web GIS) to disseminate the functionalities to the users through the internet as a web GIS-based ATIS.

Ant colony optimisation (ACO) algorithms are part of swarm intelligence, that is, the research field that studies algorithms inspired by the observation of the behaviour of swarms. ACO takes inspiration from the foraging behaviour of some ant species. These ants deposit pheromone on the ground in order to mark some favourable path that should be followed by other members of the colony. ACO exploits a similar mechanism for solving optimisation problems.

References [1, 2] show an experimental setup called 'binary bridge experiment' and investigate experimentally the pheromone laying and following behaviour of real ants. Later an optimisation problem popularly known as the travelling salesman problem is used to illustrate that how the ACO meta-heuristic works [3].

Various researchers utilised the ACO meta-heuristic and modified it with its varied use in solving different optimisation problems, such as in reference [4] investigation of a shortest path network problem is done using an annealed ant system algorithm, in [5] the improved ACS is used for the path routing of urban traffic vehicles, in [6] ACS is used in vehicle routing problem in time window, in [7] a new wireless networking approach to multi-parameter

vehicle navigation systems based on ant algorithm is introduced and in [8] a modified ant colony algorithm for multiple sight-seeing buses route re-planning in emergency is presented.

Another technology used in the development of the web GIS-based ATIS discussed in this paper is web GIS, which is an integration of GIS to the internet. The ability to obtain information through the internet allowed spatial data providers to explore the internet resources for disseminating spatial information. Distribution of geospatial information on the internet is an enforcing factor for information providers [9]. Web GIS-based geographical information systems, which emerged under the internet environment, are characterised by the abilities of storing, analysing, mining and rendering integrate geospatial data from a wide variety of sources, and since it is based on the web, people can manipulate it and obtain visual responses from it simply by using browsers [10]. Web GIS becomes a cheap and easy way of disseminating geospatial data and processing tools over the internet. The web GIS-based information systems developed with open source software (OSS) are very suitable and provide a revolutionary way for system development, especially for organisations of poorer or developing countries that cannot afford proprietary software costs, steep learning curves and complexity to develop their own technology instead of having to purchase it [11, 12].

Information systems having the ability to disseminate geospatial data using web GIS technology were developed by various researchers worldwide. In reference [13], the concept of cost-effective internet-GIS solutions for communes and counties based on OSSs University of Minnesota (UMN) map server for the administration in a county in Germany is described. In [14] the web-based value added data sharing services are implemented and a service-oriented architecture to support the interaction with GIS is proposed. In [15] a web-based GIS system to assist the post-Tsunami recovery process is proposed. In [16] a spatial forest information system based on web service using an OSS approach is proposed. In [17] a study is conducted to examine the applicability of open source web-based GIS for sharing and distributing of data for emergency response operations. In [18] the preliminary results of a geo morphological survey of the Olvera area (Cadiz province, Betic Ranges, Spain) and the use of the GIS, OSS plus database management system for making

available and distributing the landslide data over the web is presented. In [10] the architecture of a ship monitoring system based on web GIS is described. In [19] a comprehensive framework comprising of system architecture, developed methodology and salient features of an ATIS for a metropolitan city of a developing country is presented, and in [20] a web enabled open source GIS-based tourist information system for 'Bhopal', a city of India, using open source GIS software UMN MapServer is developed.

2 Logical architecture of web GIS-based ATIS

The logical architecture depicts the processes and information flow between processes that are needed to meet the functional requirements of the system architecture. In the present study, the logical architecture selected for the proposed web GIS-based ATIS development is a three-tier client server architecture comprising of three layers or tiers: (i) data tier, (ii) application tier and (iii) presentation tier. Data and application tiers reside on the remote server machine, whereas the presentation tier is served on client machines. The data tier is concerned with data preprocessing, storage and management. The application tier involves geospatial and network analysis processing based on the request of the end-user. The presentation tier consists of the end-user application programme and interface that is used by travellers to interact with the system. The selected logical architecture is shown in Fig. 1.

Data tier is responsible for storing and managing data, dealing with data requests from upper tiers. The data may be the spatial data, attribute data, data from structured query language (SQL) database or Environmental Systems Research Institute (ESRI) format files such as .img, .shp or the .map file for UMN MapServer. The data tier serves raster and vector data as per the request or query by the client through map server and web server. The data tier also serves the developed spatial data to MapServer

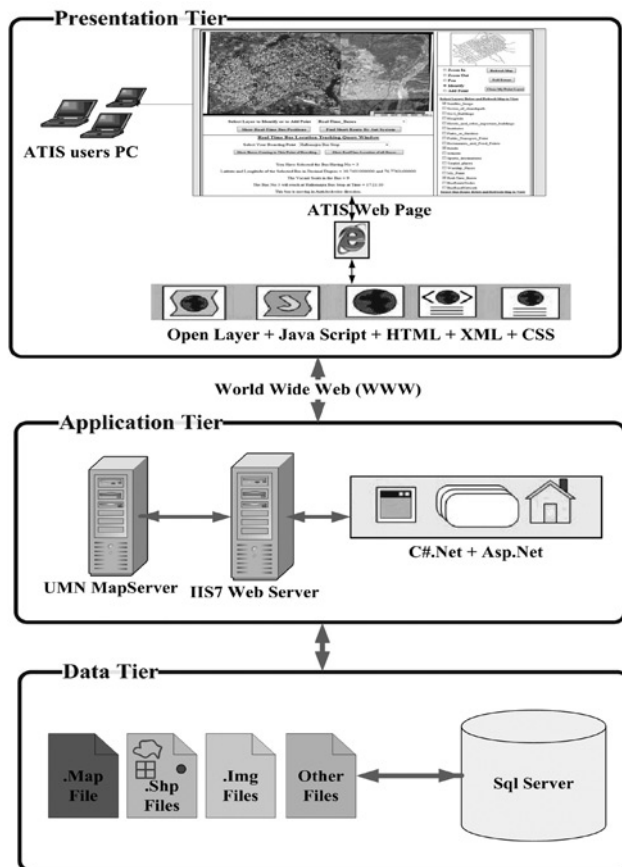


Fig. 1 Logical architecture selected for web GIS-based ATIS

software, which further draws the map image as per the query of the user and map file syntax.

Application tier is composed of a web server (Internet Information Service 7 or IIS7) and a web map server (UMN MapServer). The IIS7 deals with requests from clients encapsulated with hypertext transfer protocol, and the UMN MapServer act as a bridge between the web server and the database, which converts web requests into spatial querying operations and sends querying results back to the web server in map images. These map images generated by the UMN MapServer are served by the web server to the clients through their browser in the presentation tier.

Presentation tier includes various clients from the internet, the users of APTS (travellers) or tourists seeking information from ATIS through their browsers over the internet.

UMN MapServer used as internet map server in the application tier is an OSS and geographic data rendering engine written in C. Beyond browsing GIS data, MapServer allows creating 'geographic image maps', that is, maps that can direct users to content.

MapServer sits inactive on the web server (Internet Information Service 7 or IIS7). When a request is sent to MapServer, it uses information passed through request uniform resource locator and the Mapfile to create an image of the requested map. MapServer is extended and customised through MapScript. MapScript provides a scripting interface for MapServer, for the construction of web and stand-alone applications. MapScript used for the proposed web GIS-based ATIS development was in C# .NET flavour.

3 Ant algorithm for finding shortest routes

In the web page of ATIS system, functionality regarding making the query for the shortest route is designed by using ant system route analysis algorithm.

Real ants are capable of finding the shortest route by their pheromone depending behaviour. The ants lay pheromones on the travelling trails while travelling in search for their food, from their nest to food source. Each ant initially travels on an arbitrary route and later selects the route with high pheromone intensity. Thus, with time, ants start using the high pheromone intensity route, which makes shortest route more desirable and therefore all ants converge to this route.

For development of the shortest route finding between the selected origin and destination nodes of a network, an example network as shown in Fig. 2 was selected. Any two nodes in the example network can be selected as origin and destination, and ant system algorithm can be applied for finding the shortest route between them. The values shown for the links between the various nodes of the network represent the lengths of the links. The process steps of ant system algorithm are explained in the following.

At the start, all links of the network are distributed with an equal amount of pheromone intensity τ_0 and total number of ants equal to

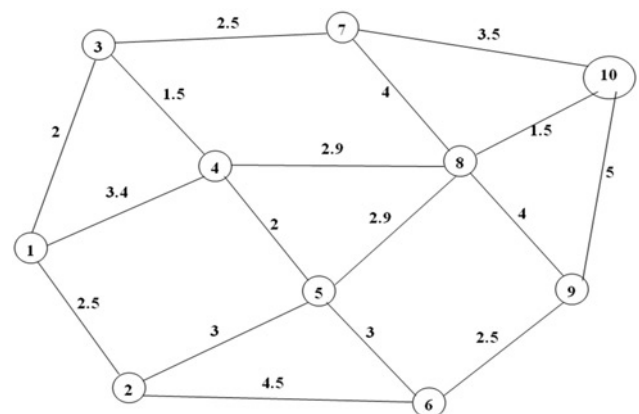


Fig. 2 Example road network used in the development of ant system algorithm for finding shortest route

' m ' are placed on the starting (origin node) node number ' r '. Value of 'global minimum route length' variable ($L_{\text{GlobalMini}}$) is set to a bigger number, such as 1.9999999×10^{10} .

All ants placed at node number r (origin node) can calculate the probability value for their movement to the next valid node s . The probability value depends on the pheromone intensity of the link connecting r to s , and to the inverse of the length of this link.

Probability ($P_{k(r,s)}$) for the k th ant situated at node number r to chose node number s for its movement can be given as

$$p_{k(r,s)} = \begin{cases} \frac{[\tau(r,s)]^\beta \cdot [\eta(r,s)]^\beta}{\sum_{u \in J_k(r)} [\tau(r,u)]^\beta \cdot [\eta(r,u)]^\beta}, & \text{if } s \in J_k(r) \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

where $\tau(r,s)$ is the intensity of pheromone on link (r,s) and will have value τ_0 for the first iteration, $\eta(r,s)$ is the visibility function which is equal to inverse to the length of link (r,s) , that is, $\eta(r,s) = 1/\text{link length}(r,s)$, β is a constant and $J_k(r)$ defines the list of valid node numbers that have valid connected links with node r and are not yet travelled by the k th ant.

Thus, the probability for each ant to move from node r to each valid node ' s ' belonging to $J_k(r)$ can be calculated. Nodes having shorter link length connection with node r will have the bigger probability value and the links which are not connected to node number ' r ' or already travelled by the ant ' k ' will have zero probability.

Total number of ants placed at node number 1 will now be transferred to these three valid nodes according to the probability values,

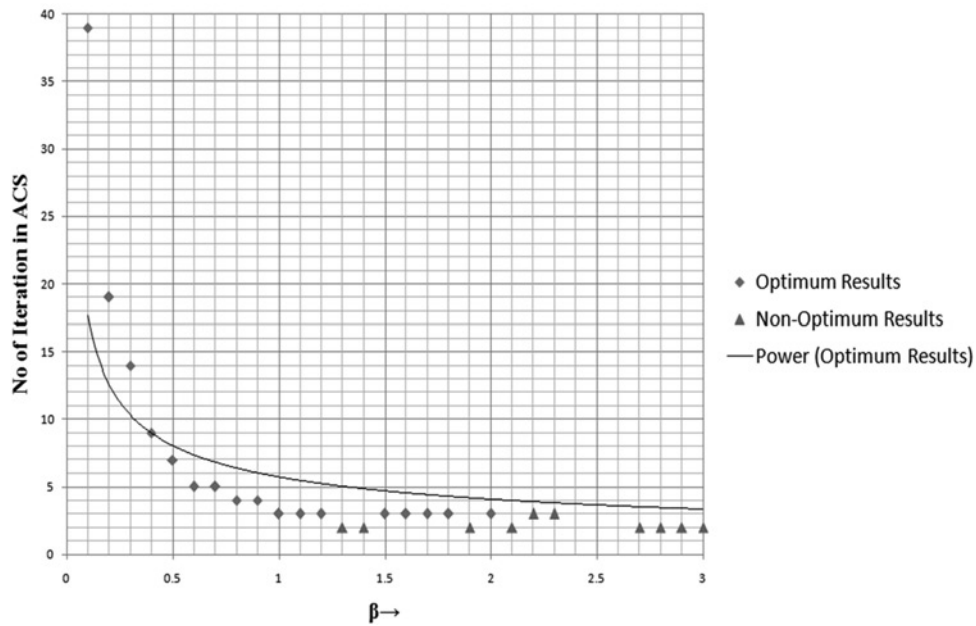


Fig. 3 Number of iterations converged with changing β parameter in ant system algorithm

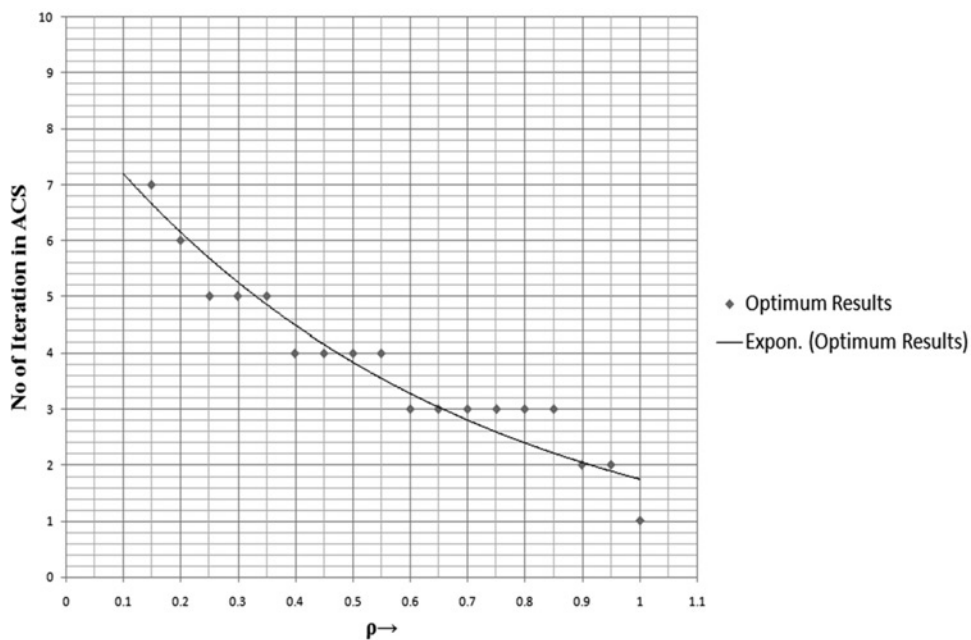


Fig. 4 Number of iterations converged with changing ρ parameter in ant system algorithm

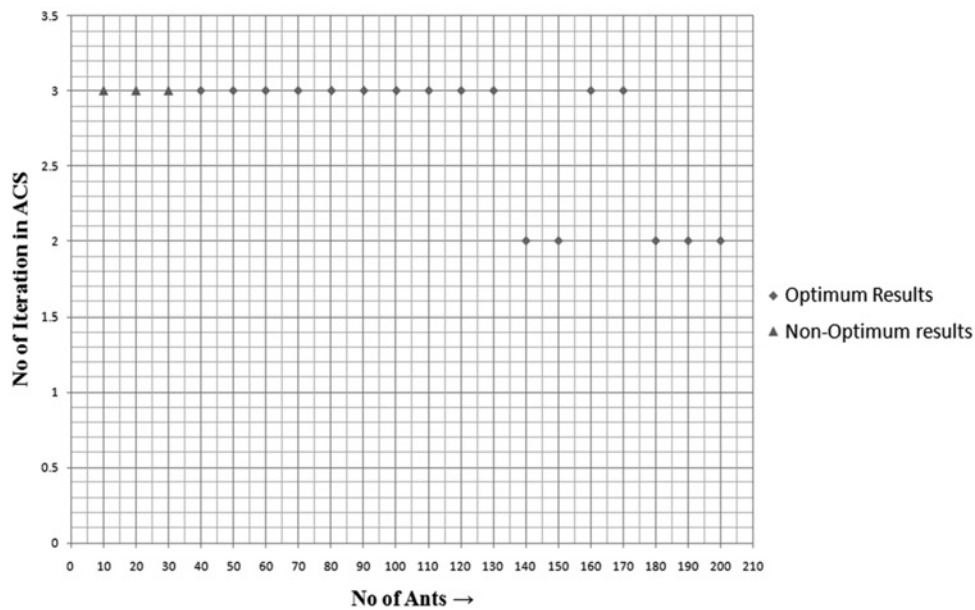


Fig. 5 Number of iterations converged with changing number of ants parameter in ant system algorithm

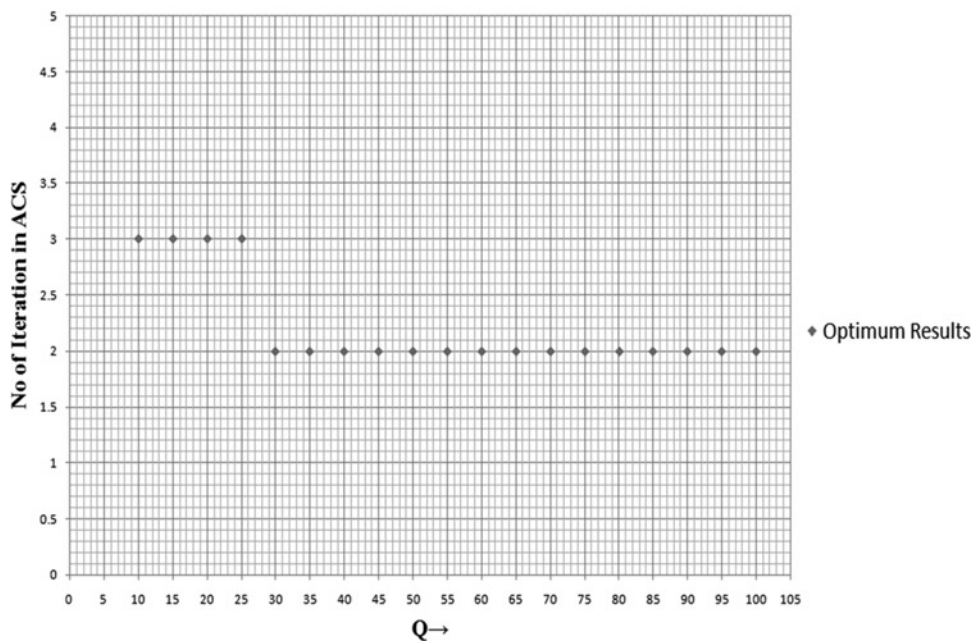


Fig. 6 Number of iterations converged with changing Q parameter in ant system algorithm

and the $J_k(r)$ list for each ant will be updated. Now each ant is at a new node number and has a new $J_k(r)$ list, the process of finding the probabilities and transferring the ants to the new node is iterated.

Iterating the above process will transfer the ants to the new node numbers, and thus each ant will make a different route. This process is iterated until the following conditions occur:

- All the ants have reached the selected destination node number.
- Some ants have reached the destination node number and the others are dead ants.

Dead ants are those ants that have not reached the destination node number and do not have any valid node number for their transfer in their list $J_k(r)$. These dead ants do not have any further

solution for making their route; therefore, if all the ants other than these dead ants have reached the destination node, then the iteration process can be stopped.

3.1 Link pheromone intensity updating

After each ant has made their route to the destination node, the pheromone intensities on the links of the network are updated.

Table 1 Recommendatory parameters for ant system algorithm

ACS parameters	P	B	Q	Number of ants
value	0.6–0.9	1.5–1.8	30–100	120–150

FID	Shape	Id	Name	Sector
1	Point	2	Sec30/Sec32 Bus Stop	30
2	Point	3	Sec20/Sec33 Bus Stop	20
3	Point	4	Sec21/Sec34 Bus Stop	21
4	Point	5	Sec34/Sec35 Bus Stop	34
5	Point	6	Sec43/Sec44 Bus Stop	43
6	Point	7	Sec 43 Market	43
7	Point	8	Sec42/Sec43 Bus Stop	42
8	Point	9	Sec36/Sec35 Bus Stop	35
9	Point	10	Sec23/Sec36 Bus Stop	23
10	Point	11	Sec24/Sec37 Bus Stop	24
11	Point	12	Rajpur Kalan Bus Stop	0
12	Point	13	Baltana Bus Stop	0
13	Point	14	Sec 47 Market Bus Stop	47
14	Point	15	Sec33/Sec45 Bus Stop	33
15	Point	16	Sec44/Sec45 Bus Stop	44
16	Point	17	Sec 44 Market Bus Stop	44
17	Point	18	Inter State Bus Terminal Sec 43	43
18	Point	19	Sec 42 Market	42
19	Point	20	Sec 37 Market Bus Stop	37
20	Point	21	Sec 38 Market	38
21	Point	22	Sec 39 Market Bus Stop	39
22	Point	23	Sarangpur Barrier Bus Stop	0
23	Point	24	Sector 17 Market	17
24	Point	25	Sec 21 Market Bus Stop	21
25	Point	26	Sec 20 Market Bus Stop	20
26	Point	27	Ram Darbar Colony	0
27	Point	28	Sec 46 Market Bus Stop	46
28	Point	29	Sec 45 Market Bus Stop	45
29	Point	30	Sec42/Sec53 Bus Stop	42
30	Point	31	Sec 40 Market Bus Stop	40
31	Point	32	Sec 41 Market Bus Stop	42

Fig. 7 Node layer attribute table showing node ID, name and sector

The link pheromone intensity can be updated by the following rule

$$\tau_{ij} \leftarrow (1 - \rho) \cdot \tau_{ij} + \sum_{k=1}^m \Delta \tau_{ij}^k \quad (2)$$

where

$$\Delta \tau_{ij}^k = \begin{cases} \frac{Q}{L_k}, & \text{if edge}(i, j) \text{ belongs to the tour of the best ant } k \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

FID	Shape*	Id	Road_Name	LinkLength	Text_Id	LinkCode
50	Polyline	0	Purv_Marg	502.428622	165-166	165166
51	Polyline	0	Chandi_Path	734.495492	250-251	250251
52	Polyline	0	Chandi_Path	644.314663	222-250	222250
53	Polyline	0	Chandi_Path	699.68301	221-222	221222
54	Polyline	0	Purv_Marg	802.836998	166-167	166167
55	Polyline	0	Purv_Marg	697.172101	167-168	167168
56	Polyline	0	Chandi_Path	630.19012	170-221	170221
57	Polyline	0	Udyan_Path	619.694136	242-243	242243
58	Polyline	0	Udyan_Path	744.374492	229-243	229243
59	Polyline	0	NH 21	704.640129	213-280	213280
60	Polyline	0	Udyog_Path	1843.247905	212-238	212238
61	Polyline	0	Udyog_Path	805.968174	236-238	236238
62	Polyline	0	Madhya_Marg	380.354262	128-210	128210
63	Polyline	0	Udyan_Path	618.692627	210-230	210230
64	Polyline	0	Udyan_Path	712.840297	229-230	229230
65	Polyline	0	Madhya_Marg	430.733164	127-210	127210
66	Polyline	0	Madhya_Marg	418.735333	127-215	127215
67	Polyline	0	Madhya_Marg	419.783204	128-209	128209

Fig. 8 Road link attribute data with link code

where ρ is the pheromone evaporation rate having value <1 and $(1 - \rho)$ represents the fraction of pheromone remaining on the link. Q is a constant, having a value more than 1. L_k is the trip length or route length of the best ant k . Setting of parameter β , ρ and Q is discussed later.

Best ant (it may be more than one if they have equal minimum route lengths) is that ant which has travelled by the shortest distance to reach the destination node. The total trip length of this best ant is the shortest in comparison with the other ants and also is less than the value of the 'global minimum route length' ($L_{GlobalMini}$).

As per (2) and (3), the links that are not used in the route of best ant will lose a fraction of their pheromone intensity in evaporation, whereas the links used in the route of best ants will obtain an additional pheromone value equal to Q/L_k .

3.2 Setting value of global minimum route length

Trip length (L_k) for the best ant is compared with the 'global minimum route length' ($L_{GlobalMini}$) and, if found lesser, then the value of the variable ($L_{GlobalMini}$) is set equal to the trip length of the best ant

$$L_{GlobalMini} = \begin{cases} L_k, & \text{if } L_k < L_{GlobalMini} \\ L_{GlobalMini}, & \text{otherwise} \end{cases} \quad (4)$$

3.3 Check for the end condition

The process from the step of 'ant's route generation' is iterated again with this new set of values of link pheromone intensities. The iteration process can be terminated if the following conditions occur:

- All the ants are using a single route to travel from origin node number to the destination node number.
- Or the number of iterations specified has exhausted.

If the end condition is fulfilled, then the route selected by the maximum number of ants, or all ants, will be the shortest route between the selected origin and destination nodes.

3.4 C# coding for ant system algorithm

The ant system algorithm used for the shortest route finding was coded in the C# (C Sharp) programming language and integrated with the ATIS web page functionalities. This code was developed initially for the example network and later was generalised for any size of the network.

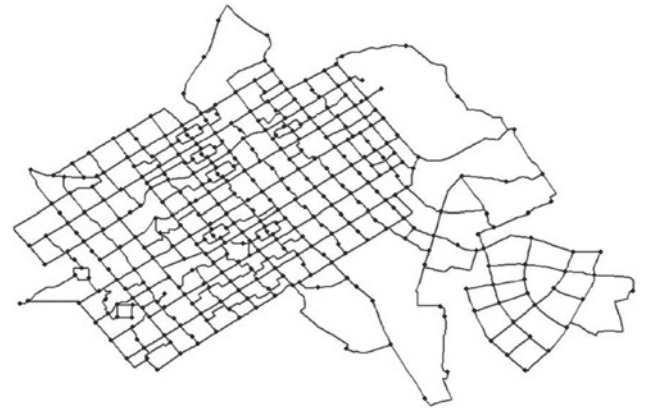


Fig. 9 Link-node topology in the digitised layers

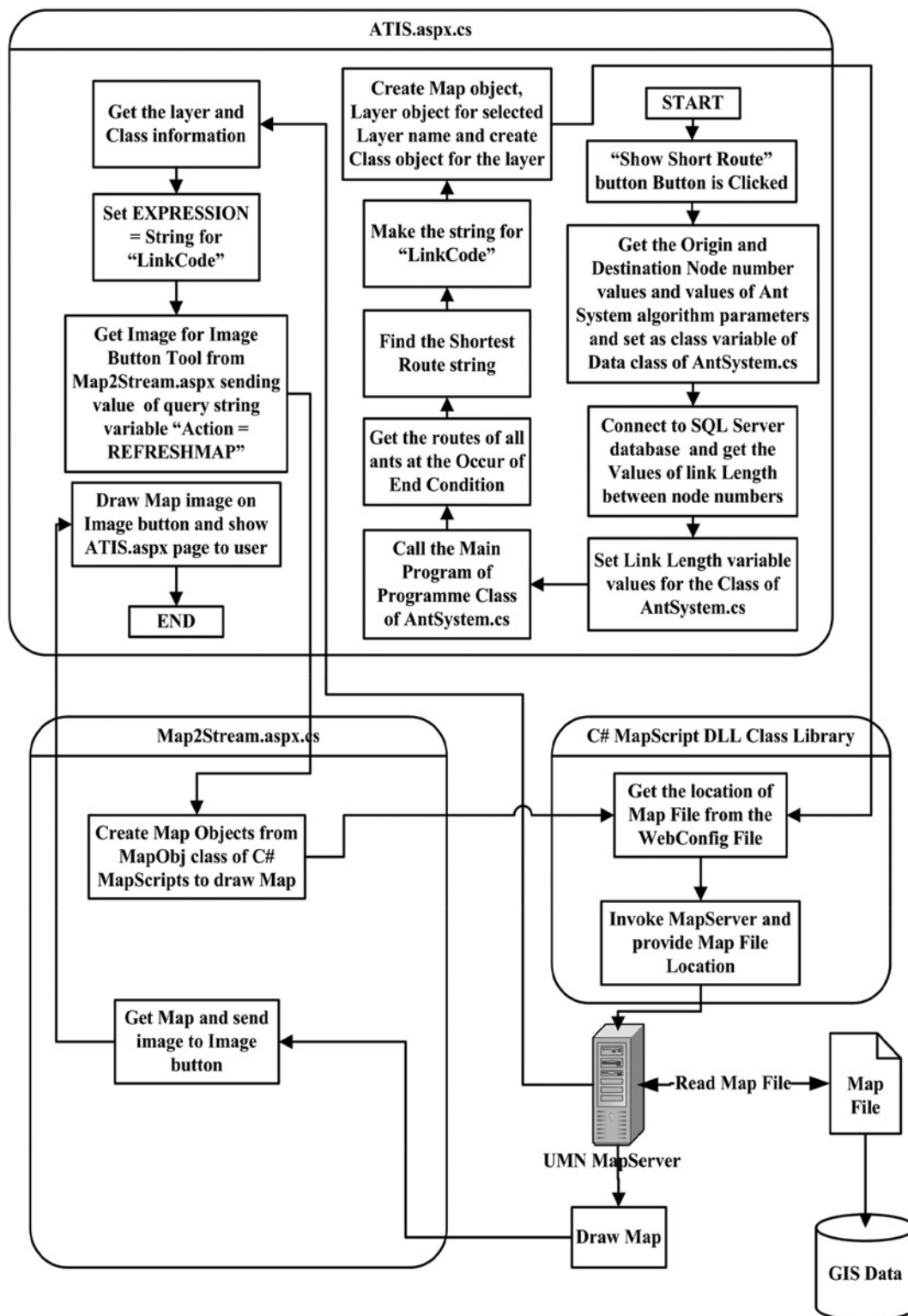


Fig. 10 Flowchart for finding shortest path by ant system algorithm in ATIS web page

3.5 Parameter settings for ant system algorithm

The probability function explained in (1) and pheromone update rules in (2) and (3) have various parameter values in the equations. The optimal values for these parameters β , Q , ρ and m (number of ants) were found out in order for the whole process of ant system algorithm to work optimally.

The values for these parameters can affect the convergence of the solution; therefore variation in the number of iterations required for

the solution is plotted for different values of these parameters. The values of parameters that give solutions in minimum iterations are set as recommendatory values of parameters for the ant system algorithm.

Optimal solution for shortest route in the example network was found for the various values of parameter β , and the number of iterations required for the solution was also recorded. It was found that the convergence speed of the process of searching shortest route is affected by the algorithm parameters. It was observed that the



Fig. 11 Shortest route designed by ant system algorithm shown on the map image in ATIS web page

convergence speed of shortest route finding was higher, whereas the β , Q , ρ and ant number were set bigger, and it was lower while the values were set as smaller. In some cases, the results were converged at a wrong path or could not be converged at any path at all and non-optimal results were obtained. The results are shown in Figs. 3–6.

As shown in Fig. 3, the number of iterations is recorded with every increment of 0.1 of parameter β from its value (0.2–3). It can be seen that the convergent speed of the shortest path searching process is monotonically increasing with the changing value of β . When value of β is <1 , the iterations used in finding the solution are bigger in number. Although, if the β value is more than 1, then the solution convergent speed is higher and it takes few iterations to compute the shortest path. There are many non-optimal results achieved, undesirably, when β is bigger than 2. The convergent speed here becomes too high when the results are converged at a non-optimal path.

The number of iterations used to find the shortest path result with varied value of parameter ρ is shown in Fig. 4, the recorded number of iterations with every increment of 0.05 of parameter ρ varied from 0.15 to 1. It can be seen that the number of iterations is influenced a little bit by changing the value of parameter ρ . The convergent speed of the process to find shortest route is higher when a bigger value of the parameter ρ is selected.

With the observations and findings mentioned above, a well set group of the algorithm parameters is important for the shortest

route finding results. The rate of convergence of the ant system algorithm was found and a set of recommendatory values for the above parameters are recommended, as mentioned, in Table 1.

4 Development of web GIS-based ATIS

ATIS functionalities are disseminated through the internet to satisfy the public transport user's queries. These queries can be made over a variety of data that may be the feature attribute data, bus route information, bus queue shelters location etc. In addition, the queries can be made to the vector layers, such as the road layer in showing the shortest route in GIS environment or showing the point feature as per the users query. To develop the system that satisfies the possible designed queries, it was necessary to collect the required data that will be served to the users in response to their queries. The area of 'Chandigarh City in India' was selected as the study area for the development of web GIS-based ATIS. The data and databases developed for the bus routes, road network, point features and other related information of Chandigarh were used in development of web-based APTS system.

4.1 Spatial data development for data tier

Data tier serves the data as per the queries made by the users through the presentation tier and the subsequent invoked system code in application tier. Databases and spatial data were developed including associated attributes for the various spatial layers.

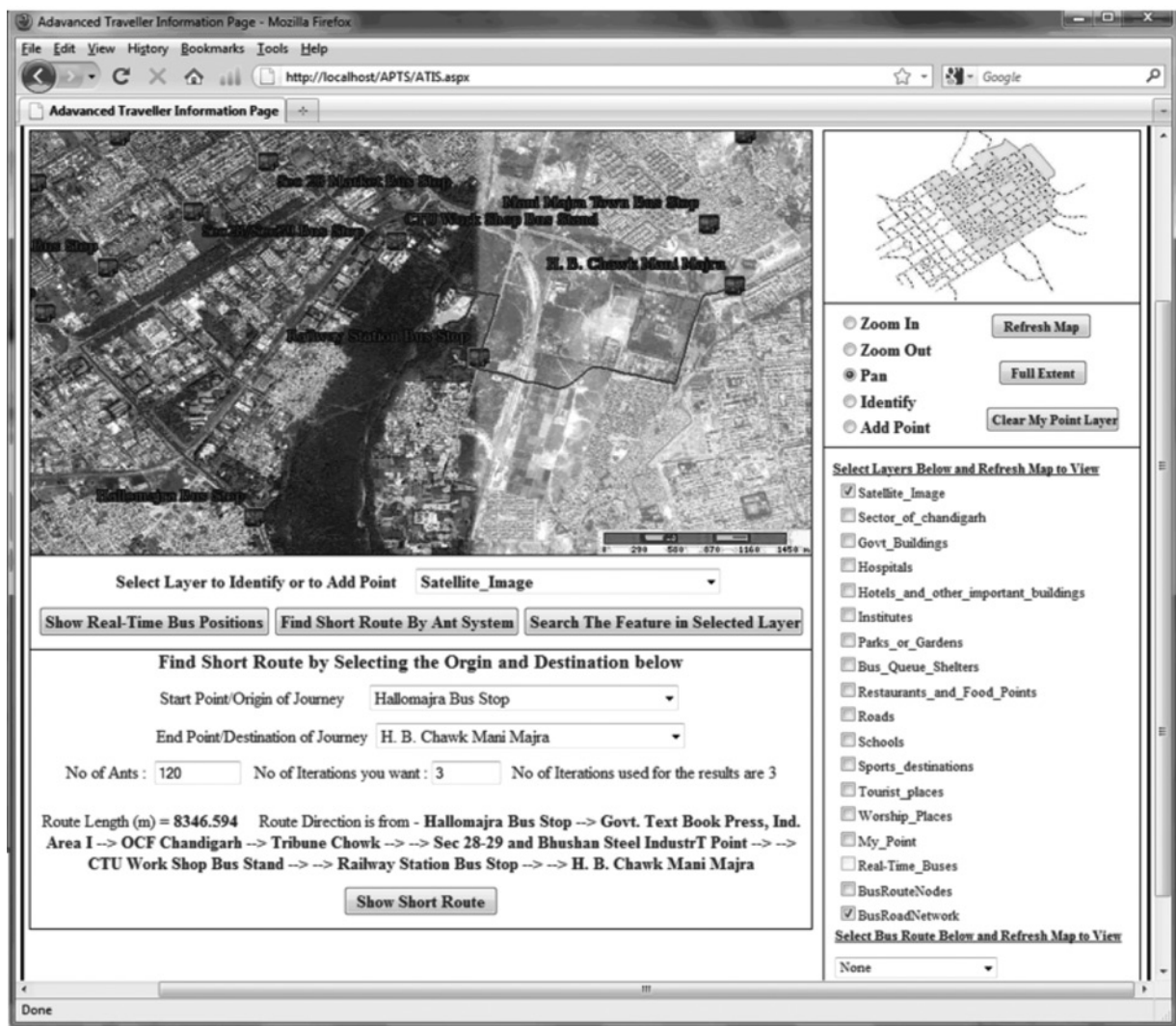


Fig. 12 Non-optimal short route designed by the ant system algorithm when insufficient numbers of iteration are entered in ATIS web page

Geo-referenced raster image of the study area and other vector layers for roads, point features, transfer points (bus queue shelter) and link-node topology layers were developed in the ESRI file format using Arc GIS 9.3 and ERDAS IMAGINE 8.5 software. Database containing the data tables related to the network link-node attribute information, such as link lengths data of the road network of the study area further used in the ant system algorithm for shortest route finding, was developed in the Microsoft SQL Server 2005.

4.2 Link-node topology

Roads of the study area Chandigarh and nearby areas such as Mohali, Zareekpur, Panchkula, Dhanas, Kuda Lahora and Sarangpur etc. were selected for the digitisation process in development of vector layers for links and node of the road network. These spatial vector layers are also used in analysis provided by the route algorithms, that is, ant system algorithm, therefore a node-link topology was adopted while digitising the road links. Node-link topology used in the process defines the nodes and links.

Points on the vector layer are defined as 'node' as per the following:

- Any 'bus queue shelter' identified on the image is considered as a node.

- Points of road links crossing are considered as nodes.
- Any dead end of the road link is considered as a node.
- Node is assigned with a node number starting from 1.
- Bus shelter node has a name (bus queue shelter name) along with the node number assigned to it in their attribute table.
- Node number assigned to the node is a unique number and each node has a different node number.

Road link lengths on the vector layer are defined as 'links' as per the following:

- All the roads will be digitised as polylines and part of the road between the two above defined nodes is known as link.
- Each link has a link code number in their attribute table.
- Link code number comprises the digits of the two node numbers between which that link is placed, with smaller node number at the start. For example, if a link is digitised between node number 267 and node number 135, then the link code number is 135 267.

Digitisation of these two layers is done in the ArcMap of ArcGIS 9.3 software. Link code number and node number entered in the attribute tables (as shown in Figs. 7 and 8) of these layers are later used in the development of network analysis functionality using ant system algorithm.

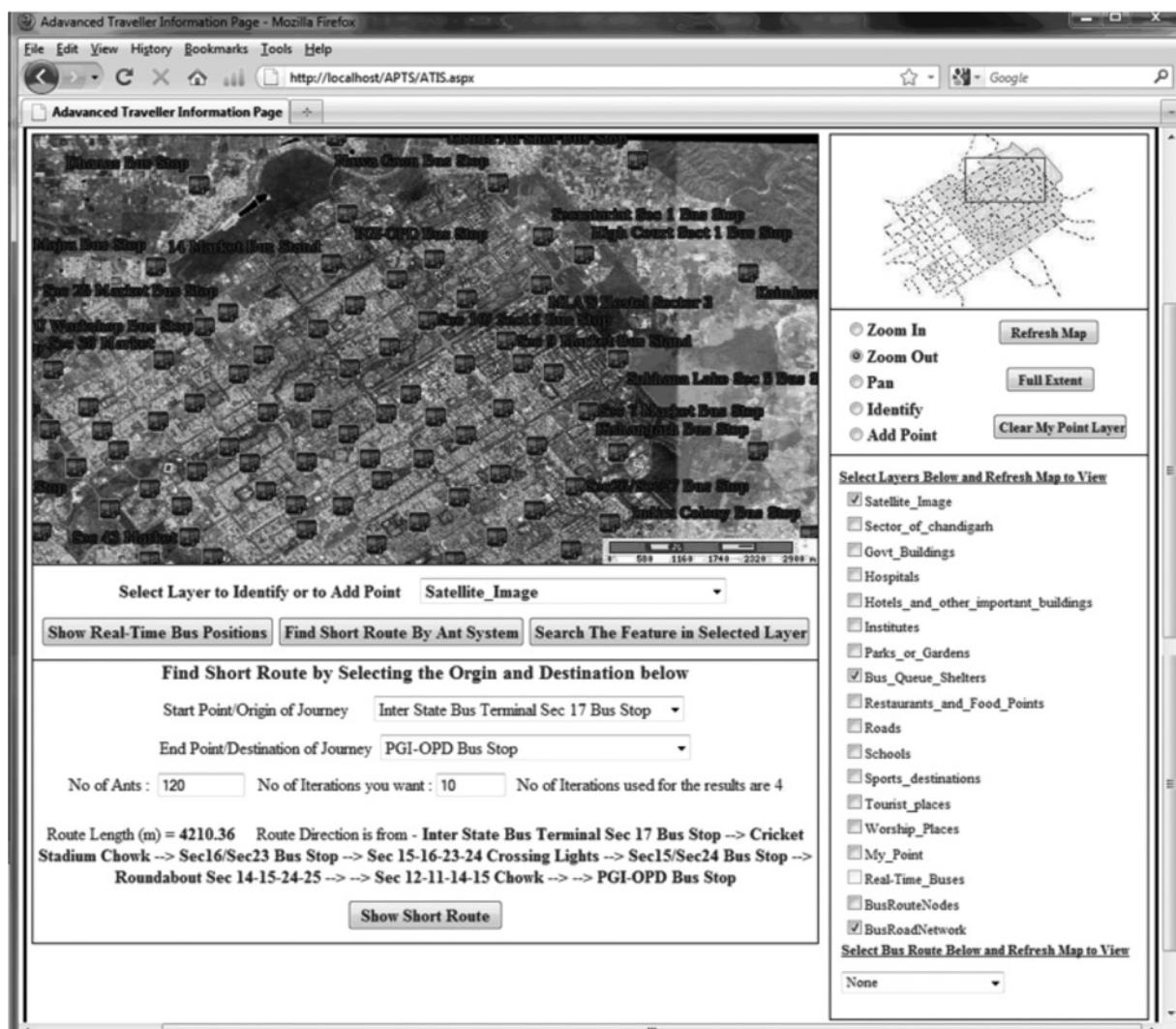


Fig. 13 Ant system showing shortest route between inter state bus terminus and Post Graduate Institute out patient department

Fig. 9 shows the digitised node-link topology showing 600 links between 372 nodes in the road network of the study area.

4.3 Finding shortest routes by ant system in ATIS web page

Shortest routes between the selected bus queues shelters of Chandigarh city can be found by the designed functionality provided in the ATIS web page. The ant system code written in C# language and attached in a class is called for a solution, when users request for the shortest route calculation through web-based graphical user interface of ATIS web page, and the results are passed to the MapServer by C# map scripts. The MapServer then creates a map showing the shortest route between these two selected origin and destination points in ATIS web page.

Ant system algorithm returns the resulting shortest route in a string which shows the direction from origin node to destination node by providing the values of node in between as for example shown below:

'23-->28-->89-->231-->11-->12-->27-->223-->13-->88-->45'.

This string is then converted by the # code in a string that can be inserted in the class 'EXPRESSION' of the road layer to tell the MapServer to show the links having link numbers (refer to link-node topology above) from the above results string. This converted string for 'EXPRESSION' looks like the following if converted from the above shown example string:

'([LinkCode]=2328) or ([LinkCode]=2889) or ([LinkCode]=89231) or ([LinkCode]=11231) or ([LinkCode]=1112) or ([LinkCode]=1227) or ([LinkCode]=27223) or ([LinkCode]=13223) or ([LinkCode]=1388) or ([LinkCode]=4588))'.

By creating the layer object and class object for the road network vector layer shape file, by MapServer C# map scripts the 'EXPRESSION' set in the map file for the layer is changed to

'EXPRESSION = '([LinkCode]=2328) or ([LinkCode]=2889) or ([LinkCode]=89231) or ([LinkCode]=11231) or ([LinkCode]=1112) or ([LinkCode]=1227) or ([LinkCode]=27223) or ([LinkCode]=13223) or ([LinkCode]=1388) or ([LinkCode]=4588))'.

The MapServer is requested to generate a new map with the above 'EXPRESSION' value for the layer. This new map, drawn by MapServer, is then sent back to the ATIS web page. Thus the shortest route between the selected origin and destination point created by ant system algorithm analysis can be shown to the user on the spatial map in ATIS web page. Flowchart of the above process is shown in Fig. 10.

Number of ants and maximum number of iterations allowed in the ant system algorithm are the parameters of ant system algorithm and should be selected in such a way that ant system results for finding the shortest route can be converted to the optimum shortest route. Fig. 11 shows that the ant system algorithm has used four iterations out of five allowed iterations to find the shortest route. If the maximum allowed iterations are restricted to the three (as

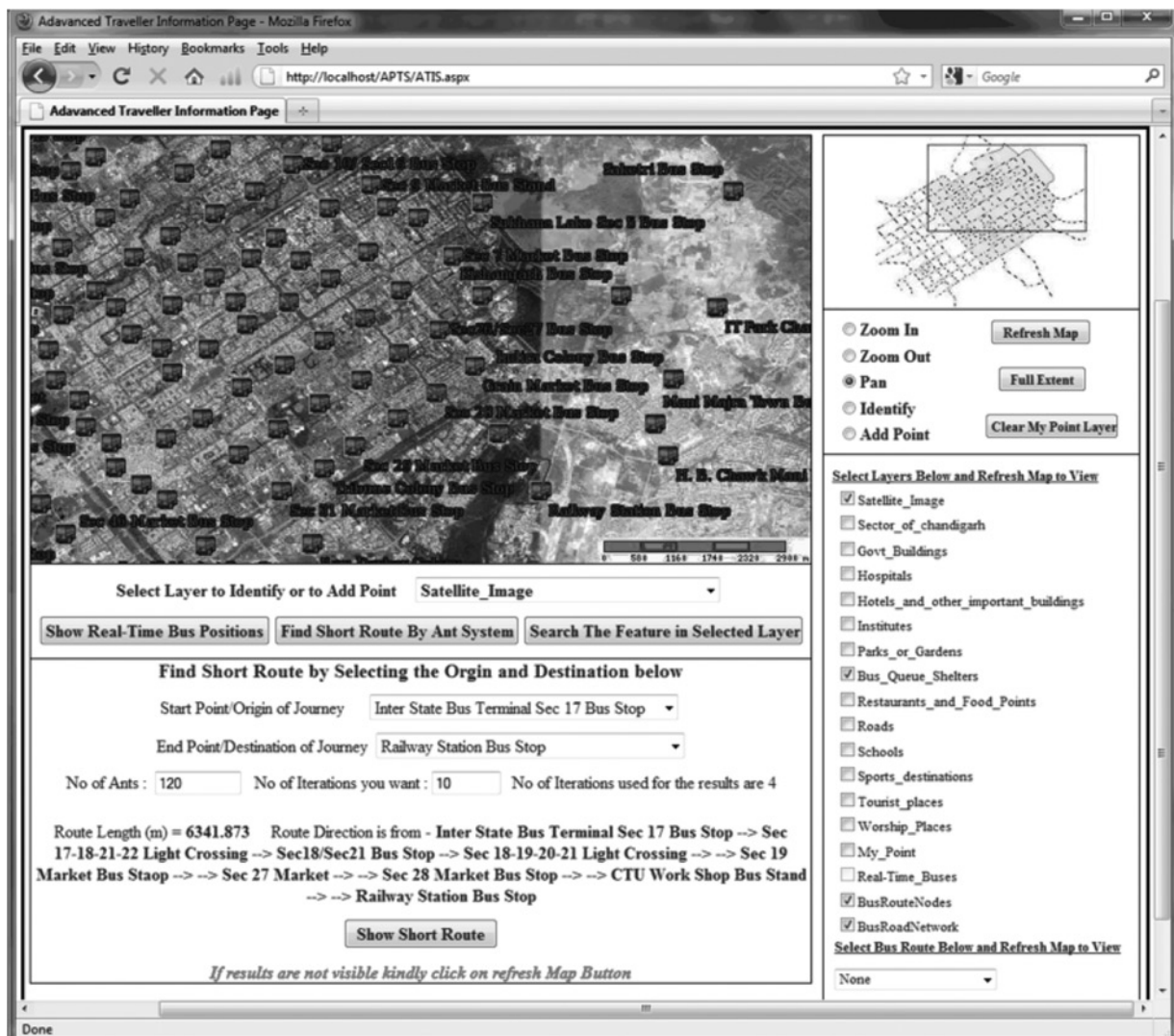


Fig. 14 Ant systems showing shortest route between inter state bus terminus and railway station

selected in Fig. 12), then ant system algorithm will design a route that will not be the shortest one as shown in Fig. 12.

Figs. 13 and 14 show the shortest route calculated by the designed system using ant system algorithm between selected bus queue shelters.

5 Conclusions

1. This paper work presents a methodology of providing better public transport information system using internet-based technologies, especially for the developing countries like India, where internet usage has grown in manifold, but its application in disseminating the travel related information for public transport system is way behind the developed countries.
2. Implementing a complete web-based ATIS for a city is a costly affair and opposite to the developed countries, the developing countries have financial constraints. The developed methodology demonstrates the working of designed functionalities for travellers seeking information related to pre-trip/on-trip shortest routes by using the OSS MapServer and represents an economical design of the system.
3. In the development methodology, a three-tier logical architecture for the system is selected that comprises the presentation tier, application tier and data tier. This logical architecture selected based on three-tier system design found suitable for providing GIS capabilities to the user over the internet.

4. Web-based GIS functionality of the ATIS system is developed using the C # (C Sharp) map scripts of the MapServer in ASP. NET environment, and it was found that the map scripts developed for the MapServer integration are efficiently compatible in the developing environment of ASP.NET web pages of the ATIS system.

5. Ant system algorithm is found to be suitable for finding the shortest route in the network of a city. The developed C# (C sharp) programming logics for the shortest route finding using ant system algorithm, and their integration with the ATIS system of study area of Chandigarh city to show the result in web GIS environment, are found to be efficient and well compatible with the design based on the MapServer.

6. The complete web GIS-based APTS was applied on the system over the intranet using MapServer version 3.0 as internet map server and IIS 7 as web server at IIT Roorkee, which validates the methodology used in the designing functionalities of the system.

6 References

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