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DEVELOPMENT OF GIS TOOL FOR THE SOLUTION OF MAXIMUM FLOW NETWORK USING FORD-FULKERSON ALGORITHM

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ABSTRACT

GIS and network analysis remains exponential fields which are characterized by rapid scientific progress. Network analysis is one of the notable and purposeful research and application areas regarding GIS. The problem of computing a max flow in network analysis is an elementary combinatorial problem with applications in transportation, planning and resource scheduling. Countlessmaximum flow algorithms have been designed over the past decade to improve complexity. Network analysis helps in finding favourable locations for services to be provided. In augmentation, maximum flow problem is calculated by finding a realistic flow through a single source, single sink flow network that is maximum. For this all the augmenting paths are covered linking from source to destination until all paths are covered.The maximum flow network is the simplest problem concerning flow network. This paper discusses maximum flow problem using python programming in GIS environment. Python is a programming language that enables to work rapidly and mergewith the systems more precisely. Enthought canopy provides a python environment that enables easy installation of the scientific packages thus creating a robust environment which one can visualize on. Tool is customized using Arc Toolbox, tool is measured on the road network. In GIS environment results are enumerated.

KEYWORDS:

Ford Fulkerson, augmenting path, tool development, python,GIS(geographical information system)

1. INTRODUCTION:

1.1 GIS and Python

GIS involves geographic which basically is concerned with geography. Geography is a science that studies the land, features and phenomena of the earth. Research on transportation have often shown that they have some form of geographic reference. GIS is a tool that is used to enhance geographic data. Geographic location is the key point that differentiates geographic information from various otherkinds of information.

Python is a multi-paradigm, object oriented, high level language. It's founder Guido Van Rossum first discovered python in the year 1991. It provides a dynamic test system and automatic memory management having a large amount of standard memory. It has the capability of exceptional handling and interfacing with other operating system.When compared with C++ and JAVA its syntax gives programmers the ability to express the concepts in fewer lines of code. The key point of extensible programming is defining functions. Python allows obligatory and optional arguments, keyword arguments, and even arbitrary argument lists.

Python is the scripting language used onarcgis platform. Esri focuses Python in its documentation part and involves Python with the ArcGIS installation.

1.2 Network Flow:

A network flow graph is a directed graph having two distinct vertices the source and the destination vertex. Each edge has an associated capacity which is always finite. Maximum flow problem is the flow from source to the destination. A straightforward solution is to keep finding paths from source to destination where wecan be send as much flow as possible along each path, and update the flow graph afterwards to account for the used space.

1.2.1 Maximum Flow Problem:

Maximum flow problem involves the routing of maximum vehicles from source to destination without violating any capacity constraints.Maximum flow network requires a graph which has to be directed and the paths are assigned some weight. The minimum weight in a single path is considered. Inthe same way all the minimum weights are added to get the maximum flow in a particular graph. Some assumptions are made when max flow in a graph has to be perceivedi.e capacity constraint and flow conservation. Capacity limitation bounds the flow meaning flow through any network cannot exceed the maximum capacity assigned to that arc.Theflow conservation assumes that the total incoming flow on a particular vertex must be equal to the total outgoing flow from that vertex. Thus the overall flow travelling on a vertex apart from source and sink will be zero.

Suppose there is a graph G(E,V)with E denoting number of edges and V denoting number of vertices.Assume that the graph is having start vertex s and end vertex t.Flow traversed in a graph must be maximumstarting from source vertex s and ending at destination vertex t. Now let's consider a path (s,2,5,t) having minimum capacity from all the edges as 8. Hence flow from this path is 8 and no more flow is possible from this path any further.Now let's consider another augmenting path (s,2,3,5,t). The minimum capacity along this path is 2. Therefore, total flow on the sink has become 10. Now let's visit other augmenting paths also. (s,3,5,4,t) is the next path and the minimum flow along this path is 6. (s,3,2,4,t) is another path which is having a minimum flow of 2.(s,3,5,2,4,t) is the last augmenting path having the minimum capacity as 1. So the total flow from s to t becomes equal to 19.

Thus in order to maximize the flow in a network different augmenting path have to be searched and the flow travelling along that path must be the minimum capacity of the edge in that particular path. Thus the procedure has to be iterated again and again until all the augmenting paths have been discovered.

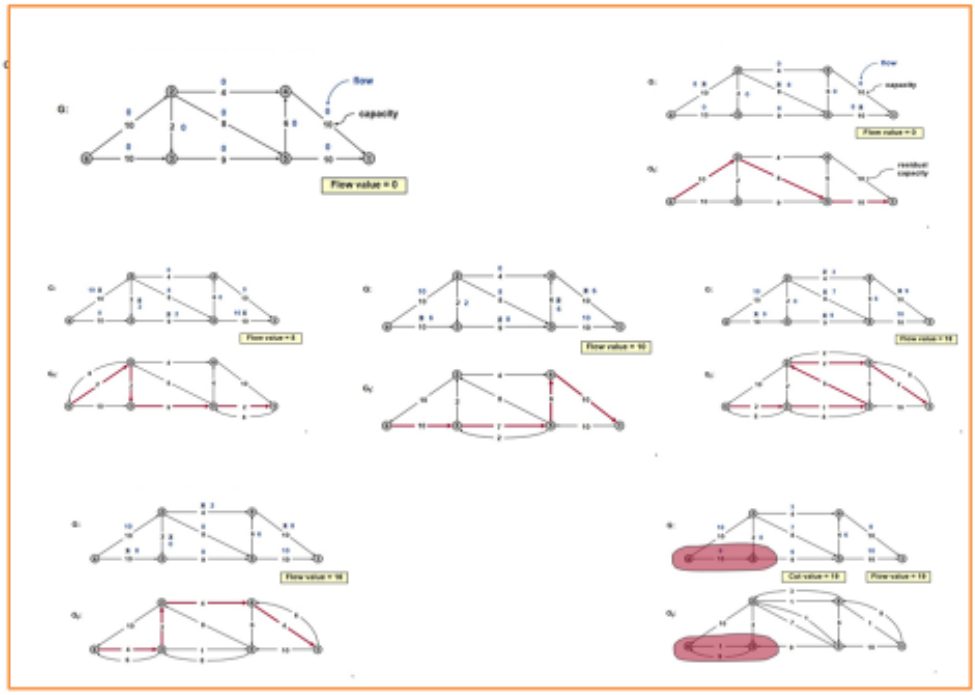


Fig 1.2:Maximum Flow Problem Example

1.3 Ford-Fulkerson Algorithm

Ford Fulkerson Algorithm is an algorithm that reckons the maximum flow in a flow network. The purpose behind the algorithm is that as long as there exists a path between start vertex and the end vertex with the capacity on all the edges we keep sending the flow along one of the paths. We keep on repeating the process till there exists a path from source vertex to the destination vertex.

AUGMENTING PATH-A path constructed by iteratively discovering a path of positive capacity from source to destination and then adding it to the flow is known as augmenting path. Thus showing that the flow is optimal only if and if there exists no augmenting path.

CUTS- A cut in a graph can be defined as the partition of a vertices of a graph into two disjoint sets such that they are joined by atleast an edge between the two sets.

RESIDUAL NETWORK-A standard way to search for forward backward operations that reckons maximum flow. The amount of capacity that can be feasibly added to the entire path. The flow in a network can be increased by finding an augmenting path and sending flow through it.

1.3.1 MATHEMATICAL FORMULATION FOR FORD-FULKERSON ALGORITHM

Let $N=(V,E)$ be a network with $s,t\in V$ being the source and the sink of N respectively.

The **capacity** of an edge denoted byc(u,v). It represents the maximum amount of flow that can pass through an edge.

A **flow** denoted by f(u,v), subject to the following two restraints:

1 Capacity Constraints- The flow of an edge cannot overcome its capacity.

f(u,v)≤c(u,v), for each (u,v)€E(1)

2 Flow Conservation- The sum of the flows entering a node must equal the sum of the flows exiting a node, except for the source and the sink nodes
$\sum_{u:(u,v)\in E} f_{uv}=\sum_{u:(v,u)\in E} f_{vu}$, for each $v\in V\setminus\{s,t\}$(2)

The **value of flow** is defined by |f|=£v(s,v)€E f(s,v), where s is the source of N. It represents the amount of flow passing from the source to the sink.

The **maximum flow problem** is to maximize |f| that is, to route as much flow as possible from s to t.

1.3.2 FORD FULKERSON ALGORITHM-

Step1- Initialize the network flow to zero i.efij=0 for ∀i,j∈ V.

Step2- Create a 'residual network' G R consist of edges having capacity C R which is a cost function for edges in residual network, where
CR = Cij – f ij ,∀i,j∈ V

Step3- Find a path p in the residual network from source to sink i.e s0 to sn. This path is represented by augmenting path.
If s0 = sn , p=0 i.e self-loop not allowed.

Step4- The existence of any path between source and sink in the residual network suggests that there is a path in the original network that can allow extra flow to pass through it.

Step5- Along p find min (Cij – f ij) from all edges belongs to path pr where r= 1, 2,…..n i.e minimum residual capacity of an edge in augmenting path.
So, flow for path p1 is F= min (Cij – f ij).

Step6- Repeat the steps 2-5 until no more paths exist in residual network. With the each iteration flow must be updated such as F = F + min (Cij – f ij).

1.4 RESEARCH OBJECTIVES:

Facts for the present study have been categorised in following two parts:

Principal objectives:
1. Development of GIS tool for the development of maximum flow problem using ford Fulkerson algorithm.
2. Database creation in arcgis in the GIS environment.

Trivial objectives:

1. Discovering the efficient route from source to destination.
2. Analysing the number of vehicles travelling on a particular road.
3. Analysing the area of the road in order to dispatch maximum number of vehicles.

2.0LITERATURE REVIEW:

There are many studies wherein customized tools have been developed using python scripting

language and network analysis available in GIS and these customized tools have been very useful in these studies. An overview of such studies is discussed in this section.

ArcGIS geoprocessing structure includes a writing environment, and Python is the writing language included in ArcGIS. NetworkX is a package in python for the design,handling, and learning of the construction, dynamics, and functions of elaboratenetworks. Its goal is to create the graphs, digraphs and multigraphs with Python. Networkx provides many graph algorithms for network structure and analysis measure. The additional power of using networkx within Python is the fact that Python is a fast prototyping, fast teaching and easy to teach general purpose programming language.

Nijagunappa et.al (2007) have solved three kind of network analysis problem like Network Tracing, Path analysis, Tour analysis using Arc View Network analyst extension module considering Dehradun as their study area.

Kelvin M.Curtin have solved network analysis problem like finding a route between point locations, determining the service area for a facility, finding the closest facility across the network and creating an origin-destination matrix.

Tae EunChoe,MunWai Lee and NielsHaering proposed a new traffic analysis framework by integrating camera calibration information and GIS data ,traffic lane information is extracted thus improving detection speed and reduce false alarms.

Hari Shankar, Gangesh Mani, Kamal Pandeyused Tabu Search Algorithm for the study , finding optimal solution of Multi-Depot Capacitated Vehicle Routing Problem with Time Window(MDCVRPTW). This algorithm uses three types of movements to obtain multi route adjacent solutions:the relocation, interchange and crossover movements.

3.0STUDY AREA:

Dehradun city has been taken as the study area for the present study. Dehradun located in the northern part of India is the capital city of Uttarakhand and lies between 30°31′80″ E latitude to 78°02′90″N longitude.Dehradun is enclosed by India's two massive rivers-Yamuna lyingon the west and Ganges on the east. The city is prominient for its vivid landscape and for its clement climate.Fig shows the geographical extent of study area for the network analysis.

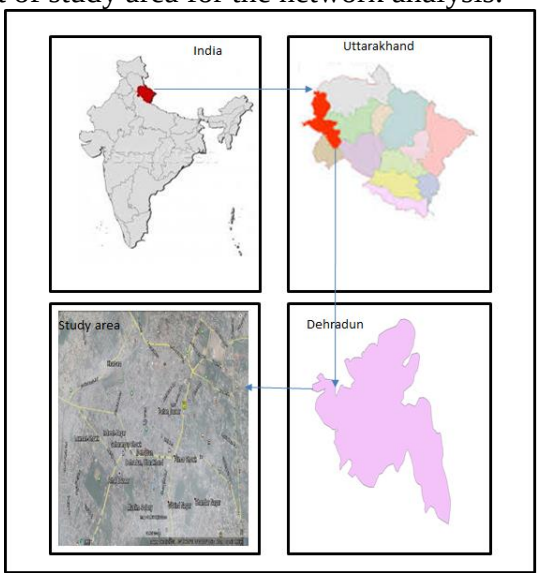


Fig 3.1: Study Area

3.1 GEOGRAPHY:Dehradun lies at an elevation of about 450m above the sea-level.
Dehradun is a major academic and research center and a famous summer recede. The weather of Dehradun seems to be pleasing round the year the geography of Dehradun reveals april to july to be the exemplory time for visiting Dehradun.

3.2 CLIMATE:Climate of Dehradun district is generally temperatei.e neither too hot nor too cold thus experiencing a moderate climate. It deviates from tropical to severe cold relayingon the altitude of the area.Dehradun district being steep, variations in temperature are considerable depending on the elevation.

3.3 RAINFALL:Dehradun is described as the 'Rainy City of India' due to continous and everlasting rainfalls most of it occuring in monsoon. Dehradun is said to be India's wettest State capitalwith 2,865 mm of rainfall. Much of the annual rainfall is experienced during the months from june to September with july and august being the rainiest.

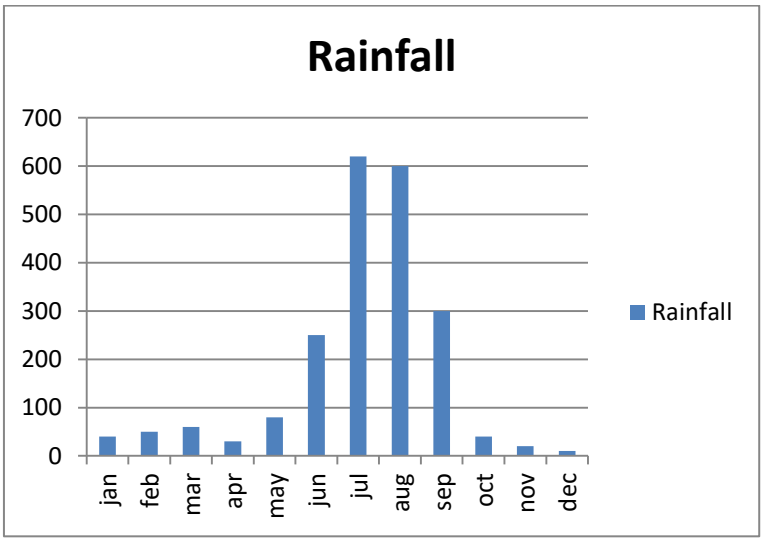


Fig 3.3: Mean Rainfall in Dehradun

3.4 TEMPERATURE: Dehradun enjoys an amiable climate. In summers temperature ranges between 36°C to 16.7°C. Winter temperature vary between 23.4°C and 5.2°C.

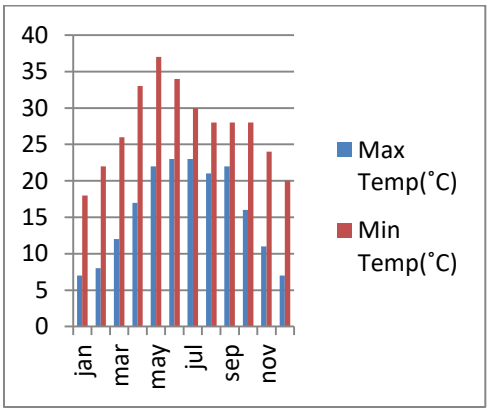


Fig 3.4: Max and Min Temperature of Dehradun

3.5ROAD NETWORK-

India being on second rank in terms of road network comprising a total length of about 4,689,842 kilometers. Transportation network forms the backbone of economic development in the country. Qualitatively india's road network is a blend of contemporary highways and precise, gravelled roads and are being enhanced. Indian economy relies on road network. Road network has been considered analytic towards the evolution of the country, social amalgamation and its security requirements. The major provocation in road network lies in the constructive planning, design, construction and maintainance for transportation of people and goods.

3.6 TRANSPORTATION:
Transport mode corresponding to the present study is as follows:

Road: Road network of Dehradun is very well preserved network. Road transport in Dehradun encompasses buses cars and bikes. National Highway (NH-72) 200km long passes through Dehradun. For short journeys from neighbouring cities one can take a car. Buses are also a convenient mode of road transport for travelling within Dehradun.
4.0MATERIALS AND METHODS:
4.1 MATERIALS
SOFTWARE USED:

Table 4.1.1: Software Required

S.NO	SOFTWARE	USE
1.	ESRI ArcGIS 10.1	Used for creation of database.
2.	Enthought Canopy	Used for Programming.
3.	GDAL/OGR	Used for linking of python script with database.
4.	Field Data	Used for data collecting and analysing for traffic on roads.
5.	Sattelite Data	Used for capturing pictures from google earth.

SATTELITE DATA:

Table 4.1.2: Specifications Of Satellite

S.NO	NAME OF SATTELITE	RESOLUTION
1.	IKONOS	0.82m
2.	QUICKBIRD	0.65m
3.	SKYSAT	0.9m

4.2 METHODS:

Maximum Flow Tool:
Procedure adopted for developing maximum flow tool in the form of flow chart is described further-

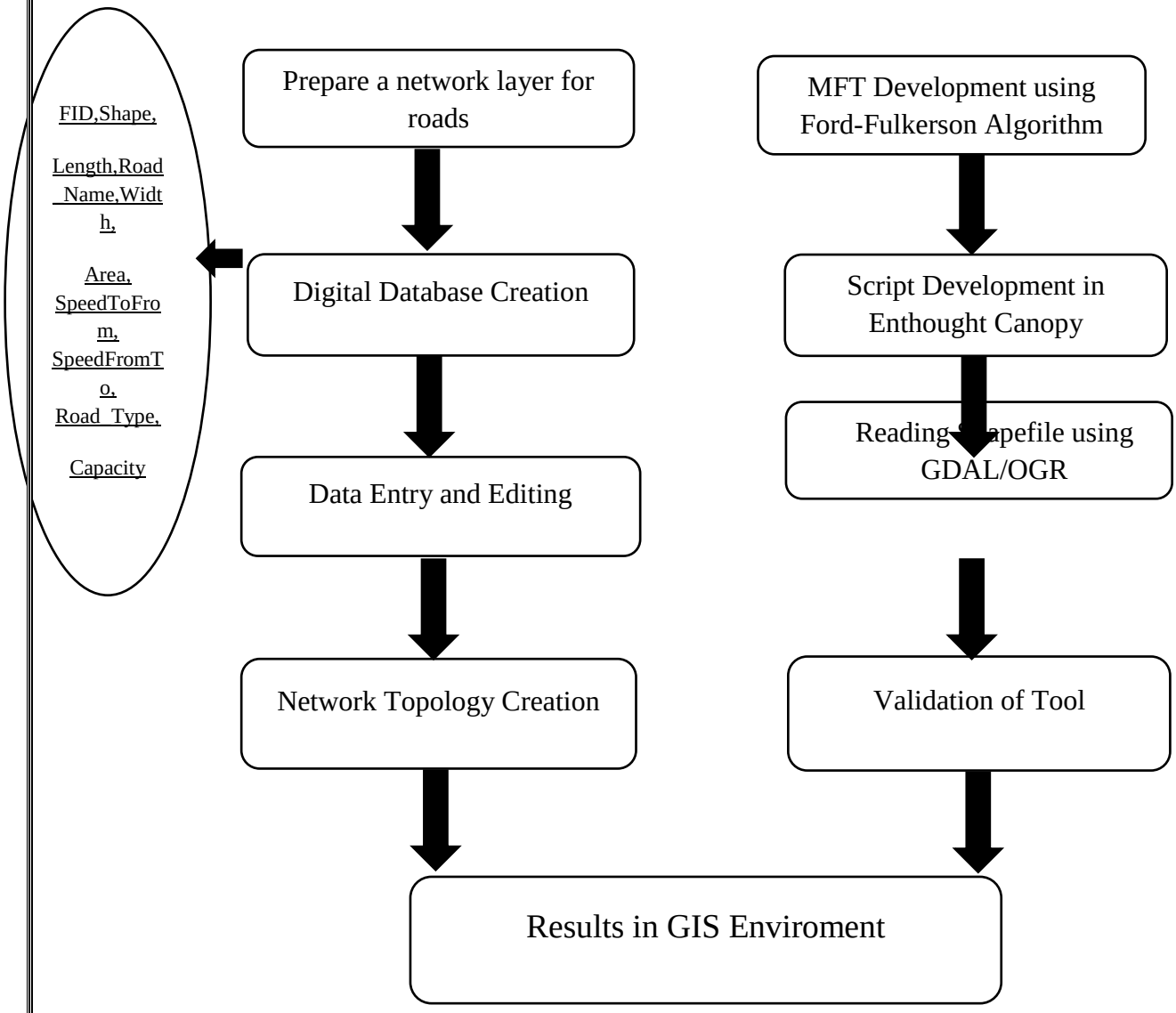


Fig 4.2: Methodological Flowchart

Digital Database Creation:-

For working with the max flow tool in GIS environment a road network is required to be created. To accomplish this purpose digital database using Datum WGS_1984 and projection UTM has been created. Attribute required to perform the tool correctly is shown in table 4.2.
Mathematical formula used for calculating the capacity is

Capacity=Area of Road/Area of Vehicles.
Area of Road=Length of road* Width of road
Area of Vehicles=(l+(2*a))*(w+(2*b)) *3

where a is the spacing in lengthi.e a is assumed to be 0.5
b is the spacing in widthi.e b is assumed to be 0.5
multiplying by 3 because we have considered 3types of vehicles i.e car ,bus and bike.

Table 4.2: List of Attributes used in Max Flow Tool

S.NO	Attribute Field	Data Type	S.NO	Attribute Field	Data Type
1.	FID	Long Integer	6.	Area	Double
2.	Shape	Text	7.	Speedtofrom	Long Integer
3.	Length	Double	8.	Speedfromto	Long Integer
4.	Road_name	Text	9.	Road_type	Text
5.	Width	Double	10.	Capacity	Long Integer

4.3 Network Topology:
Network topology is created to spatially connect the features. In the present study topology has been created for MFT development and network analysis. Topology is created inside the feature dataset in the source layers that are participating in network analysis. Topology rules are defined such as:
There must not be any overlapping between line features.

4.4Tool Validation: Validation of tool includes deciding the parameters. Parameters for the present problem aredecided as input dataset and feature class and the output layers. The max flow problem requires a capacity field which is added in database. After adding all the parameters to the script, validation process is completed.

5.0RESULTS AND CONCLUSION:

5.1 Maximum Flow Problem: The results obtained after the execution of the tool are discussed in this section. As discussed earlier, the tool is tested for on a road network for which an example layer has been digitized in ArcMap. Results with for Ford-Fulkerson algorithm and with changing source and sink are shown further.

5.2 Database For MFT: Network database designed for testing of tool is shown in fig . Here we have taken a small database but it can be large, according to the requirement. Table shows the database table prepared for the computation of Max Flow.

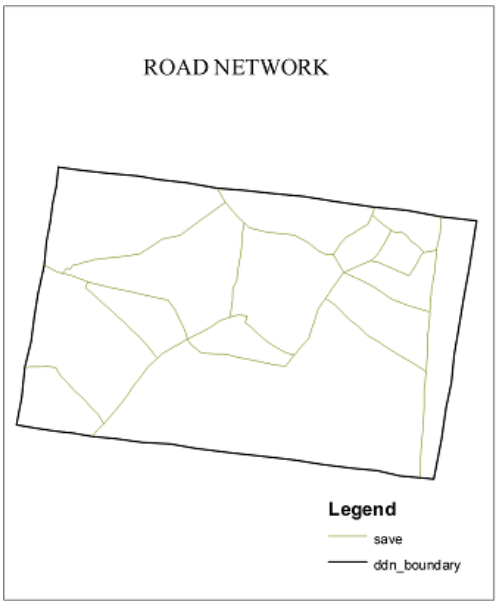


Fig 5.2: Road Network ForMFT

Table5.2 : Database Table For MFT

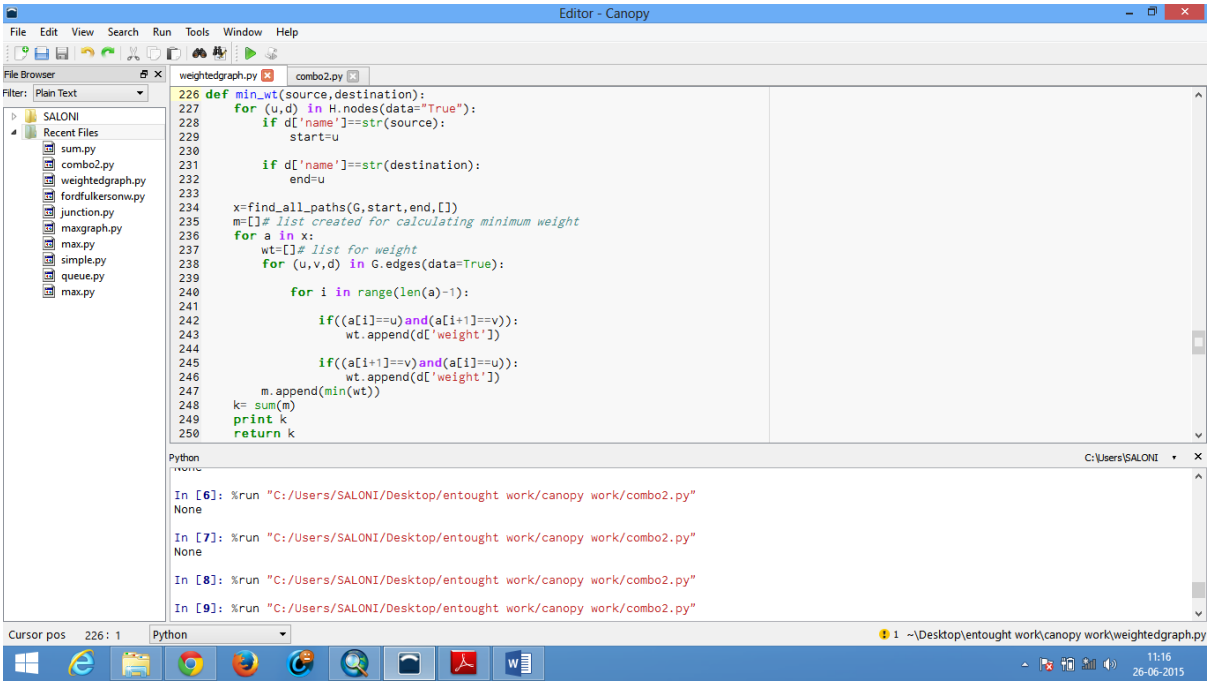
	FID	Shape *	FID_New_ro	length	road_name	width	area	speedtofro	speedfromt	road_type	capacity	timetofrom	timefromto
	0	Polyline	3	1143.139942	arhant bazar	11.72	13397.600117	50	45	minor road	78	23	25
	1	Polyline	12	2173.713439	E-canal road	14.15	30758.045165	60	50	major road	180	36	43
	2	Polyline	11	878.73248	guru road	11.7	10281.170019	50	45	minor road	60	18	20
	3	Polyline	3	1143.139942	arhant bazar	11.72	13397.600117	50	45	minor road	78	23	25
	4	Polyline	4	2361.008217	NH-72	17.23	40680.171574	70	60	highway	238	34	39
	5	Polyline	13	1198.927281	tilak road	7.68	9207.761515	50	45	minor road	54	24	27
	6	Polyline	14	702.711447	raja road	9.72	6830.355269	50	45	minor road	40	14	16
	7	Polyline	4	2361.008217	NH-72	17.23	40680.171574	70	60	highway	238	34	39
	8	Polyline	10	1043.3852	amrit kaur road	6.81	7105.453209	50	45	minor road	42	21	23
	9	Polyline	2	883.04355	malviya road	17.28	15258.992546	50	45	minor road	89	18	20
	10	Polyline	1	1437.529116	bindal marg	10.42	14979.053393	50	45	minor road	88	29	32
	11	Polyline	1	1437.529116	bindal marg	10.42	14979.053393	50	45	minor road	88	29	32
	12	Polyline	4	2361.008217	NH-72	17.23	40680.171574	70	60	highway	238	34	39
	13	Polyline	6	788.540096	crossroad	13.38	10550.666482	50	45	minor road	62	16	18
	14	Polyline	1	1437.529116	bindal marg	10.42	14979.053393	50	45	minor road	88	29	32
	15	Polyline	4	2361.008217	NH-72	17.23	40680.171574	70	60	highway	238	34	39
	16	Polyline	5	1352.063332	chakroata road	20.66	27933.628432	50	45	minor road	163	27	30
	17	Polyline	9	570.483652	pant road	15.44	8808.26759	50	45	minor road	52	11	13
	18	Polyline	8	657.243444	new survey road	16.11	10588.191878	50	45	minor road	62	13	15
	19	Polyline	12	2173.713439	E-canal road	14.15	30758.045165	60	50	major road	180	36	43
	20	Polyline	4	2361.008217	NH-72	17.23	40680.171574	70	60	highway	238	34	39
	21	Polyline	8	657.243444	new survey road	16.11	10588.191878	50	45	minor road	62	13	15
	22	Polyline	13	1198.927281	tilak road	7.68	9207.761515	50	45	minor road	54	24	27
	23	Polyline	5	1352.063332	chakroata road	20.66	27933.628432	50	45	minor road	163	27	30
	24	Polyline	12	2173.713439	E-canal road	14.15	30758.045165	60	50	major road	180	36	43
	25	Polyline	7	542.26667	rajpur road	20.64	11192.384068	50	45	minor road	65	11	12
	26	Polyline	8	657.243444	new survey road	16.11	10588.191878	50	45	minor road	62	13	15
	27	Polyline	7	542.26667	rajpur road	20.64	11192.384068	50	45	minor road	65	11	12
	28	Polyline	0	1530.383079	govind garh	16.17	24746.294393	50	45	minor road	145	31	34
	29	Polyline	5	1352.063332	chakroata road	20.66	27933.628432	50	45	minor road	163	27	30
	30	Polyline	5	1352.063332	chakroata road	20.66	27933.628432	50	45	minor road	163	27	30

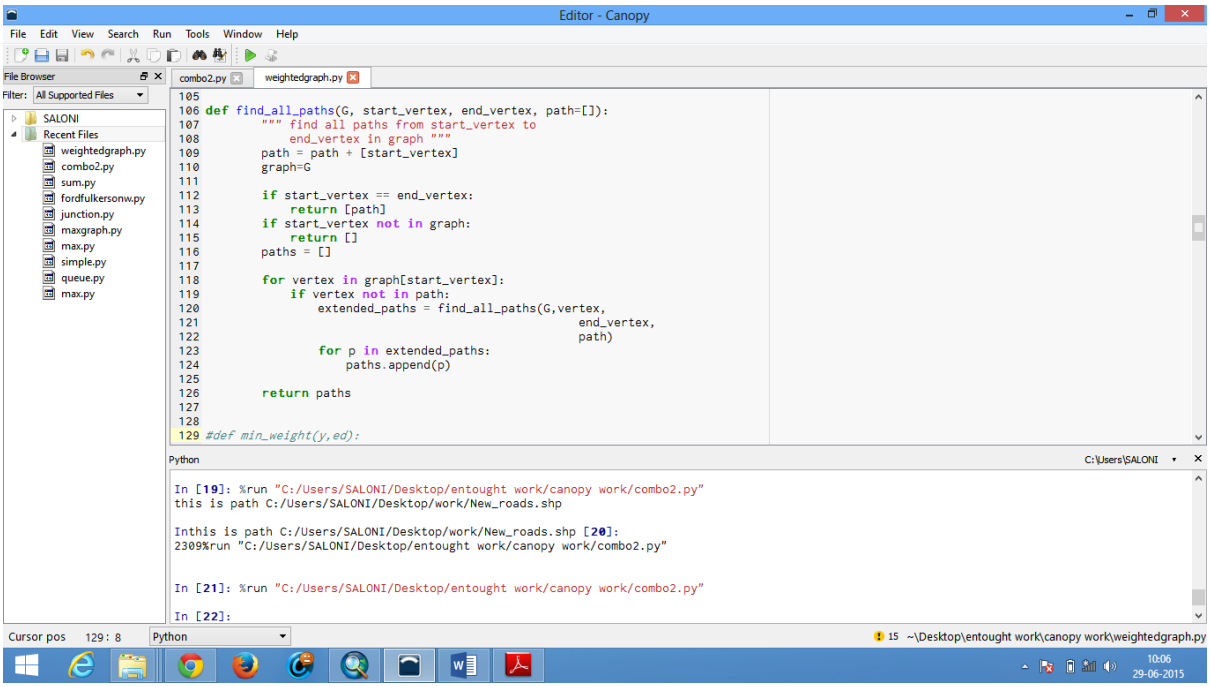
Here, the FID is the integer field representing the number of fields. The Shape field indicates the shape of all the roads i.e polyline. Length field contains the length of the roads. Road_name field stores the name of all the roads. Width field contains the width of all the roads. Area gives the area of the roads. SpeedToFrom and SpeedFromTo field contains the speed with which vehicles travel

.Road_Type indicates the type of road whether it is a minor road, major road or highway.Capacity field shows the number of vehicles that a particular road can accommodate.

5.3 Tool Development: Tool development concerned with writing the scripts in python environment. It includes designing, developing and debugging of the code. In the script writing there are different modules.

In the script writing there are different modules. min_wt(source,destination) function is designed in which we have to pass source and destination. The find_all_paths(G,start,end,[]) function returns all the paths discovered from start vertex to end vertex. Variable u stores the coordinates of a vertex. G is the variable which stores the road network. wt stores all the weight. Sum function returns the addition of the minimum weight/capacity of the network.

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105
106 def find_all_paths(G, start_vertex, end_vertex, path=[]):
107 """ find all paths from start_vertex to
108 end_vertex in graph """
109 path = path + [start_vertex]
110 graph=G
111
112 if start_vertex == end_vertex:
113 return [path]
114 if start_vertex not in graph:
115 return []
116 paths = []
117
118 for vertex in graph[start_vertex]:
119 if vertex not in path:
120 extended_paths = find_all_paths(G,vertex,
121 end_vertex,
122 path)
123 for p in extended_paths:
124 paths.append(p)
125
126 return paths
127
128
129 #def min_weight(y,ed):
Python
C:\Users\SALONI
In [19]: %run "C:/Users/SALONI/Desktop/entought work/canopy work/combo2.py"
this is path C:/Users/SALONI/Desktop/work/New_roads.shp
Inthis is path C:/Users/SALONI/Desktop/work/New_roads.shp [20]:
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In [21]: %run "C:/Users/SALONI/Desktop/entought work/canopy work/combo2.py"
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15 ~\Desktop\entought work\canopy work\weightedgraph.py
10:06
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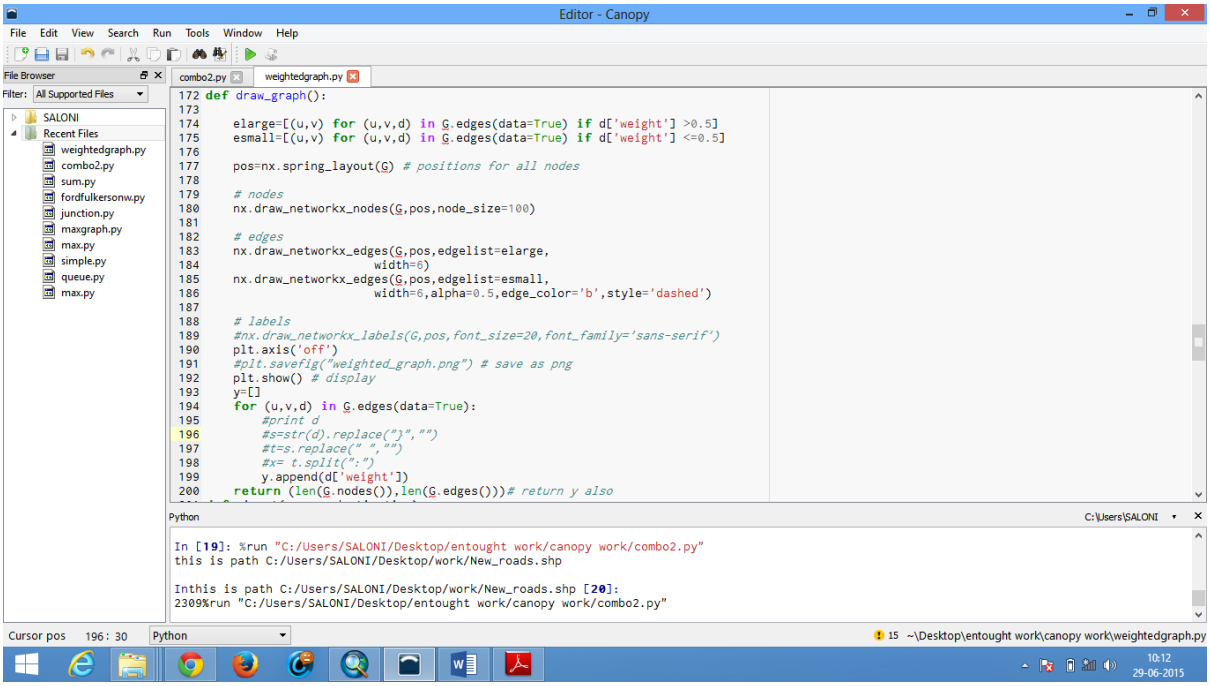
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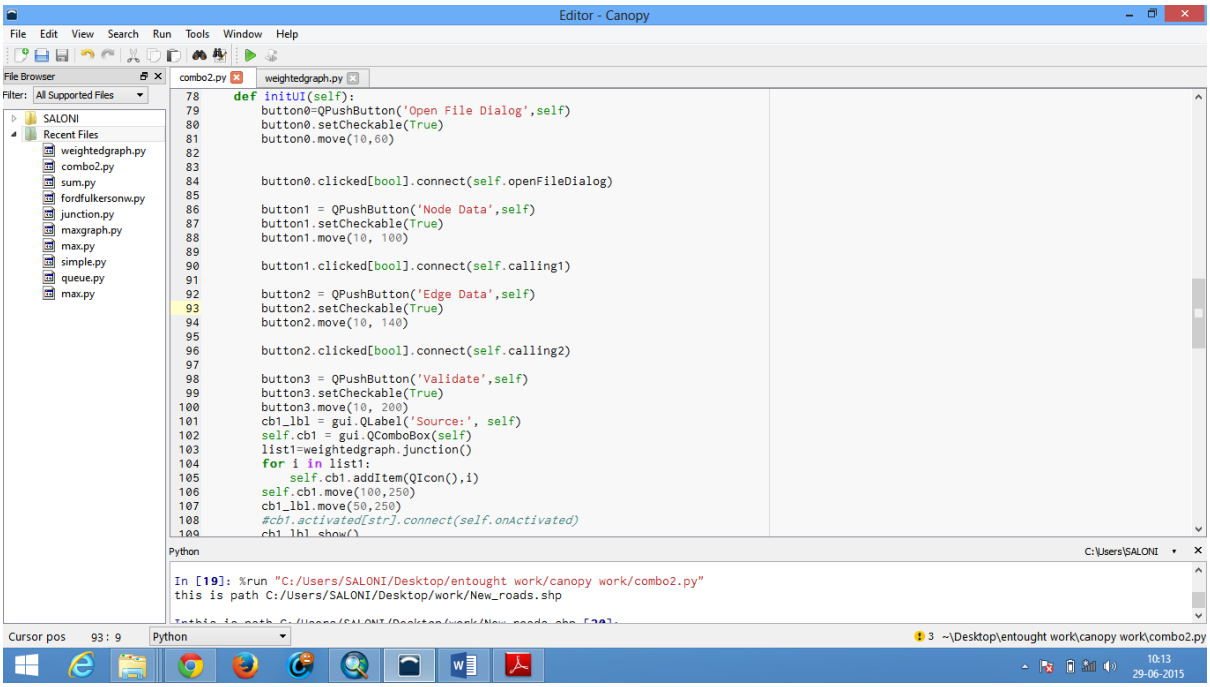
fordfulkersonw.py
junction.py
maxgraph.py
max.py
simple.py
queue.py
max.py
combo2.py
weightedgraph.py
172 def draw_graph():
173
174 elarge=[(u,v) for (u,v,d) in G.edges(data=True) if d['weight'] >0.5]
175 esmall=[(u,v) for (u,v,d) in G.edges(data=True) if d['weight'] <=0.5]
176
177 pos=nx.spring_layout(G) # positions for all nodes
178
179 # nodes
180 nx.draw_networkx_nodes(G,pos,node_size=100)
181
182 # edges
183 nx.draw_networkx_edges(G,pos,edgelist=elarge,
184 width=6)
185 nx.draw_networkx_edges(G,pos,edgelist=esmall,
186 width=6,alpha=0.5,edge_color='b',style='dashed')
187
188 # labels
189 #nx.draw_networkx_labels(G,pos,font_size=20,font_family='sans-serif')
190 plt.axis('off')
191 #plt.savefig("weighted_graph.png") # save as png
192 plt.show() # display
193 y=[]
194 for (u,v,d) in G.edges(data=True):
195 #print d
196 #s=str(d).replace("}","")
197 #t=s.replace(" ","")
198 #x= t.split(":")
199 y.append(d['weight'])
200 return (len(G.nodes()),len(G.edges()))# return y also
Python
C:\Users\SALONI
In [19]: %run "C:/Users/SALONI/Desktop/entought work/canopy work/combo2.py"
this is path C:/Users/SALONI/Desktop/work/New_roads.shp
Inthis is path C:/Users/SALONI/Desktop/work/New_roads.shp [20]:
2309%run "C:/Users/SALONI/Desktop/entought work/canopy work/combo2.py"
Cursor pos 196 : 30
Python
15 ~\Desktop\entought work\canopy work\weightedgraph.py
10:12
29-06-2015



6.0CONCLUSIONS AND RECOMMENDATIONS:

Network analysis is the amalgamation of methods enlisted by developers and administrators to study the attributes of network, inclusive of connectivity and capacity. Network analysis is most remarkable part of GIS. Network development is mainly concerned to the minimization of the cost in the network that may be characterisedin terms of maximum flow. In the current application we have to solve the maximization problem for a road network in GIS environment. Maximum flow problem can be solved with distinctiveapproacheswhich is priorly suggested. But in this study we have used mainly one algorithmi.e Ford Fulkerson Algorithm to evolve tool for the solution of maximum flow problem.

For the testing and calibration of maximum flow tool, a network database for road network has been prepared in ArcGIS. In the study Maximum Flow Tool using Ford Fulkerson Algorithm gives results by spanning possible path in the network. The outputs comes out by using FFA has been accessed in GIS environment which clearly satisfy assumptions and conditions proposed by this algorithm. The spanning process achievedfor FFA gives some dangling node in GIS environment in the present study with no effect on maximum value returned as the results. The implementation of FFA would be very useful for a completely directed network in the study.

In the present study, road network analysis has been performed using network analyst tool in ArcGIS 10.1. Network analyst tool is very useful which would help in finding maximum flow by adding minimum capacity of every path. This analysis would be useful in case of routing maximum number of vehicles from start and end vertex.Route for a facility or to a location can be found on the basis of capacity. The most important thing for any analysis on network is attributes which are given in the database and in network dataset creation. Because priority on the basis of which the route are generated depends on these attributes.

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