**Spatial Informatics**
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**Lecture - 21**
**Spatial Networks - I**

Hello, we will be starting a new topic a one of the very important topic in Spatial Informatics; we will be having couple of lectures on it which is on Spatial Networks, right. So, we discussed a several aspects of a spatial informatics starting from modeling, to indexing and also some of the services etcetera. This spatial networks is usually kept as a separate or separate topic in spatial informatics, because of his some of his typical properties we will see some of the things.

Now, what do we mean by networks, like the, for rather for our several day-to-day applications or what we say sometimes called location based application or envious type of application, this special networks plays an important role. Like I want to find out that from Kharagpur, I want to go to a say particular place in the Kolkata; then what is the, what will be my route, and what are the expected time, etcetera.

So, what it analyzes? It analyzes the network, right. So, as we understand. So, network is a collection of points or junctions. So, to say if we say on the road which are connected by lines, right. So, this is the overall network and this network is prevalent for different type of things like say; computer network or social network, so where it is there. Rather we can also, we also know or we will see also it can be represented as a graph, right.

So, once I can represent as a graph, different graph theoretic or analysis or graph elbows will come into play, it will help us in different analyzing the things. So, with this particular this section of this or this particular topic we will try to see different properties, different features of social networks, how to handle; and also we will try to see that how they differ from our other type of analysis, why you require, why I require a special emphasis on the things right, so that we will try to see, right.

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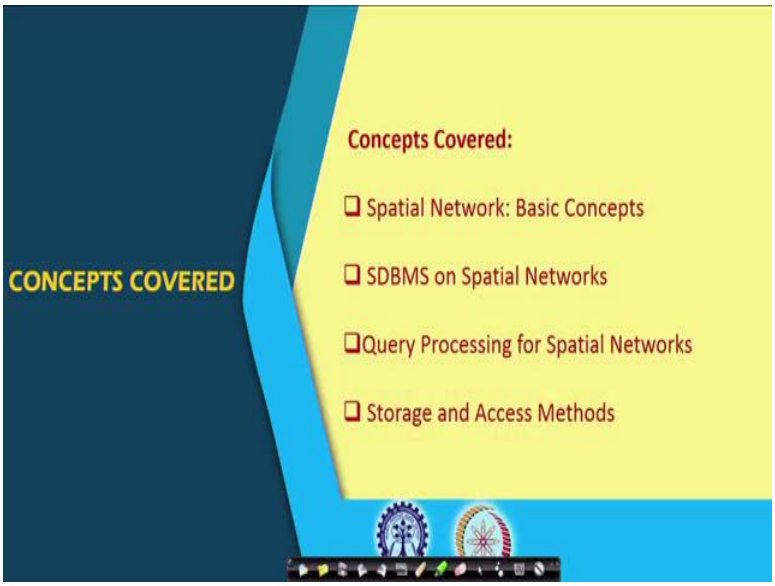


So, these are the broadly some of the things we will try to cover; one is the basic spatial network concepts, and with some examples that some part on the spatial database support, spatial network query processing, and something on try to look on storage access method etcetera that some part on the those things, right.

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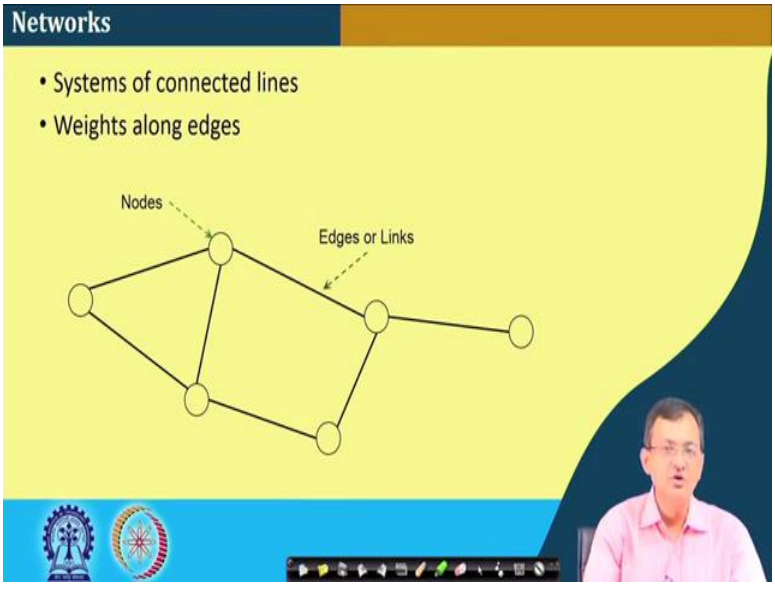


So, if we look at a networks in general, whether it is our spatial network, whether it is a any network for that matter computer network, whether it is a social network etcetera.

So, what we are having some nodes, or junctions, or intersections, or some point of POI or Point of Interest, and the edge is connecting there, right. It can have one or more edges to become this type of network or connected network.

It can be disconnected also in node separately, then it for our analysis it may not be helpful, right. But it may be helpful in some of the cases, like suppose I want to do analysis that which during a particular flood like situation, which are the villages, which are not accessible by road type of things; if road is my only network there.

Then I want to find out those isolated things which we where we cannot find a path between the things. So, that may be a thing and things like that. So, system of connected lines, right, so what you see and there can be weighted also; that means, weight of the lines right. Like I can say, that is this is a road network, then this particular line is a highway and I give a better weightage in the sense of that may be proportional to the width of the road or traffic capacity of the road, I give some weightage and different type of weightage for the other links also.

So, while finding a path between any two points like this and this, then I need to find out either shortest path, either shortest distance or in some on some other parameter right; even the weight can be with respect to totally different type of things. Like I say, in a city area I, this edges or the links which are connecting this nodes are weight with based of a congestion level, right.

So, if it is congestion level is high, then I have if for my transportation I can say that weight is high in terms of a resistance to the things right. I, if the high weightage I do not want to follow or I can means based on your type of dealing you can have low weightage, high weightage. So, that is the congestion level may be the things, even I can say in some cases like some places like I say, weightage with respect to in terms of a quality of road or in terms of the safety of the road and I can have different type of weightage into the things; immunity is available on the road and type of things know.

So, there can be different parameters spatial non-spatial both which dictates this overall behavior of this network, but nevertheless it is a connected thing; and as we can see it is basically represents a graph.

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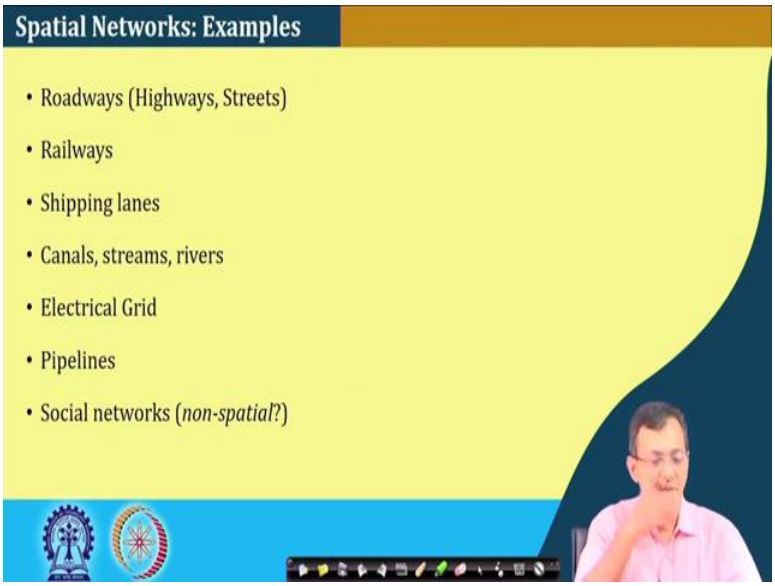


So, there are several example, definitely road and streets and highways etcetera these are one standard example. We can have a railways even we can have waterways, there can be shipping lanes in what we say in marine or transportation, water transportation, so there can be shipping lanes.

We can have canal, stream, rivers, different type of water linkages, right. So, this is typically what we say spatial type of things; and even there can be electric grid, right. So, grid I can see that this transmission line may be the edge and the past station can be the nodes, there can be the different type of pipelines, gas pipelines, water pipelines, and type of things. And of course, as we are not wrong it can be a social network also, but whether it is we consider it is a spatial or non-spatial, right.

Now, see road network if we see, there is a this, there is a definitely there are nodes and connections between the nodes and is as a spatial context, right. I say this is Kharagpur, point Kharagpur bus station, if I talking about bus and type of things say; and so there is a coordinate and then there is a coordinate systems to there is a line which follows the road network type of things, right.

So, similarly rail also have stations and connecting linkages, similarly water bodies also having ports or something with the things; electric grids, pipelines has also connections and type of things; whereas the social network may not have that type of things, I may have that everything is there geocoded type of stuffs are there, right.

So, these are different example, scenarios of different type of networks, right. And there can be different type of a properties also right; like suppose I consider a road network, it can be first of all one way or both way or directed or undirected, right. So, if it is one way, it is directed and type of things right; and if it is both way I can I may not have a if it is undirected then I can traffic all things. Not only that, it can be spatial temporal also, like in city region we say that say up to morning 6 O clock, 12 to 6 or 10 to 6 the say segment of the road is undirected, that traffic can go both the way; whereas, 6 to 12 it can be in one direction 12 to say evening 6 it can be other direction right.

So, there are so; that means, with space time means, not only the segment of the road which defines a spatial context, but also the based on the time of the day, the behavior of this network changes, right; traffic cannot go from there this direction or that direction and type of things, right, so this sort of things come into play. So, it plays a important role in that sense, right.

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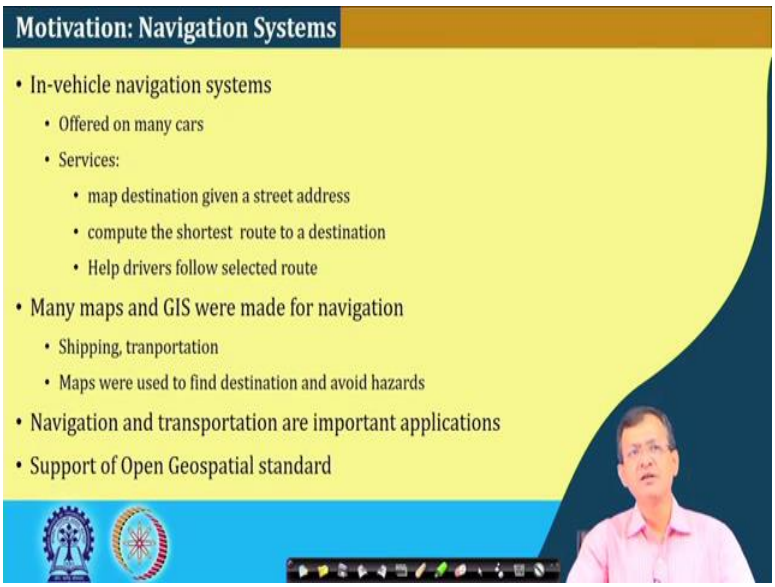


So, there are several example, one major motivation what we could find or what it has a lot of impact of day to day life of us and means people or citizen in general is that navigation systems, right. So, it has a direct impact on the navigation systems, in vehicle navigation system offered on many cars right; this way that navigation system services, map destination given a street address, right.

I give a street address it gives me the direction of the things. We are using different type of cabs and type of things where this sort of things are there, right. Compute the shortest route to a destination; how, what is the shortest route, help driver to follow a selected route. Not only that, it only compute if I find the shortest route or a route prefer route, then the, it helps the driver to follow that route. So, it guides the driver follow the routes.

So, given a destination, now it is easier if the, it is appropriately map to go to the, to that navigate or the automated navigation system installed in your car or vehicle which will help in the things, right. So, now, many further many maps and GIS were made out of navigations right; shipping, transportation, these are out of navigations, right. Maps used for to find destination and avoid hazards and type of things, right.

Navigation and transportation are two important applications of the things and also looking at that a as it is as this requires a different networks to be talking to each other. So, there is another thing which is coming up with that open geospatial standards for that, right. So, that I can quickly interoperate between the things, like I can take the road network put into my navigation system and find out the things if the road network is not there; unless that is in particular standard I cannot take that. I may not even take the road network, if you recollect we talked about services, spatial services where we connect to the things in terms of services, a service driven type of things.

So, there are different motivation for like this where we can have different, then navigation is one of the major what we say application, what we see into the day to day life.

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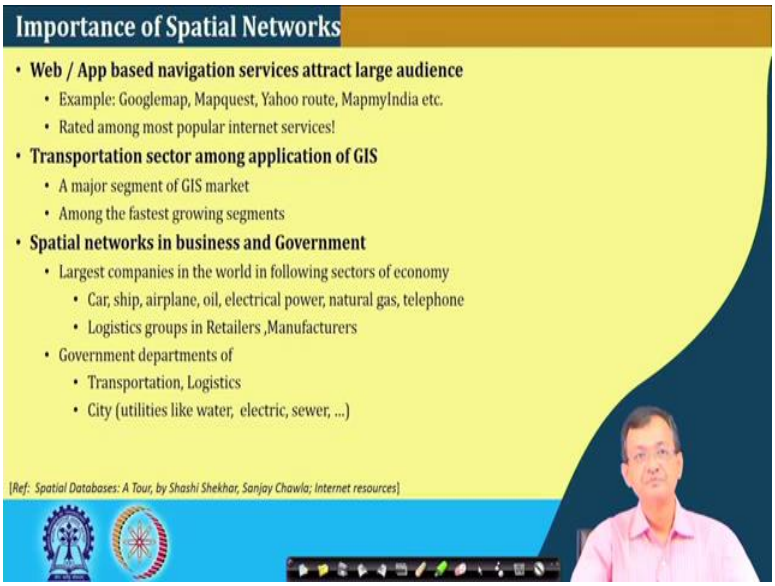


So, importance of spatial networks is nothing too much elaborate; one is that web or web based app or a web based navigation services is one of the things what we have seen. Not only that, that web or app based type of things transportation sector among the application of GIS there a lot of things has been going on the transportation sector, where large scale application of spatial networks is there.

Spatial networks are being widely used in both business and government applications right. Large companies in the world is following sectors of the economy like; car, ship, air traffic, oil, etcetera which are using this type of a thing; different logistic groups like retailers, manufacturers this logistic groups are using these networks in a large scale, right.

And of course, government department like transportation, logistics; city utilities like, water, electrics, sewerage electric government that sewerage movement and type of things are where we are using this network conceptually in a large scale, right. So, if we look at that applicability of the networks is pretty high right, where things are like this ok.

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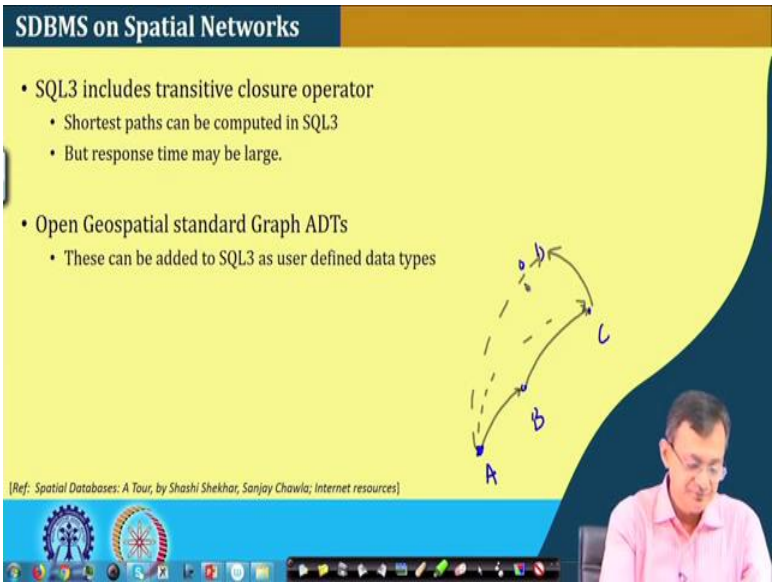


So, if we look at that spatial database management system on spatial networks and how they will be stored etcetera. So, SQL 3 include transitive closure operator like that is important like, I say that I can reach A to B by one of B to C and transitive closure will allow me that I can reach from A to C right. I say that I have different multimode transportal system; transport system I want to go from here to Kolkata a particular place in Kolkata, say in airport Kolkata. Airport in a my minimum time or shortest path may not my constraint, I my constraint is that within a time limit I want to have a minimal cost travel.

So, that I from here IIT campus to Kharagpur railway station I take a taxi, or bus if available all right, from a station to Howrah station I take a train; from Howrah station to the airport I take again a bus or taxi and type of things, right. Now, there may be lot of other, there may be lot of options the number of trains, number of busses, number of taxi services, etcetera and so, I need to have say A B; so, A B C D, 4 type of things are there, right.

I have A node A B C D and my transport one maybe this, one this, one this, right. So, the transitive closure allow that with these I am trying to optimize in everything say. So, A to B, B to then; A to B, B to C then I can have a path this is there; if A to B, B to C, and C to D is there then this path is possible. So, this type of things are possible things right and then again open geospatial, open GIS standard for abstract data type is another

important; that how do I store this data, how do I model this data that requires some standardization. Otherwise I may not be able to read others data right like, for that matter I say that my rail network, or rail related information, rail networks are stored in a with our Indian rail repository, right.

And say bus or if it is with the either transport or the state transport department right; and maybe the taxi related data may be with some other things right like, maybe taxi union and type of things, so that networks are there. So, I need to collect these things and or I need to query on those things to find out the things. So and there should be a standardization of the things, right. So, that is important. So, this is; so, how this spatial database management system will work is, one important aspects we need to look into.

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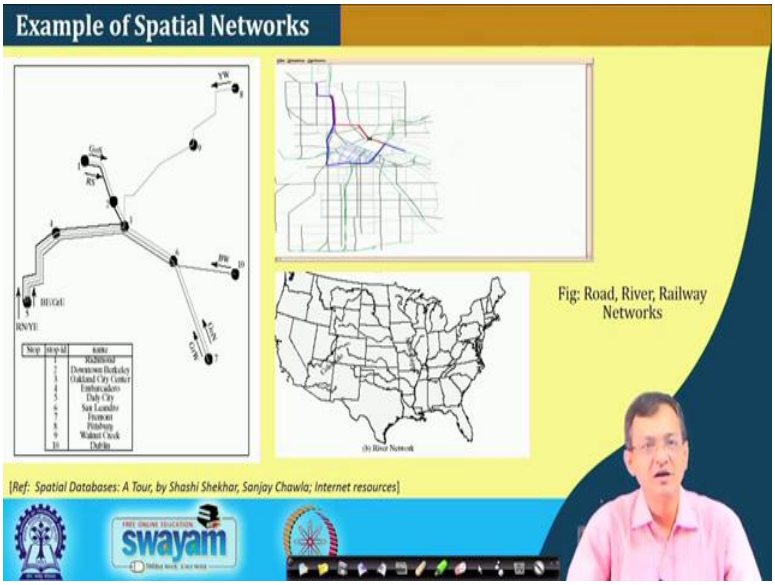


So, this is different sort of networks which are there right; one is road, one is a river, one is railway and different type of networks, right. So, based on that what are the roads networks are there, like here that bus stop, different stop IDs and different this bus is moving and type of things said like that. So, there are as we know that buses have routes etcetera, similarly road, rail networks and so these are the things.

Now, if I want to query on the one thing, one thing; if it is a multi-modal, then I need to query on the all the things, right with maintained by three different organization or three different depositories we need to look into the ethics.

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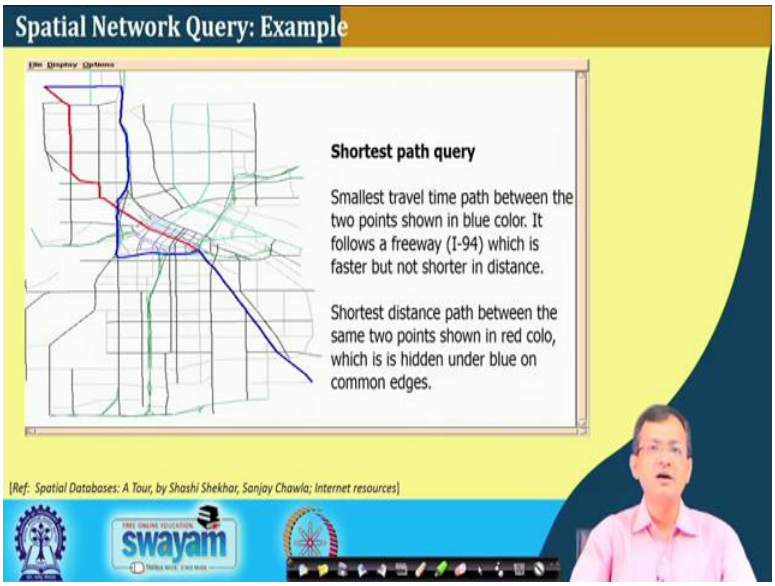


Now if we look at the query, one of the most widely used query is the shortest path, right. Travel; smallest travel time path between the two points between like, is the true color, it is somewhere in the US road network, so that is using the freeway.

Shortest distance between the two points shown in red color, there is a typo which is hidden under the blue color in the common edges and type of things. So, I can have shortest path in terms of shortest time, shortest distance or you can have different type of parameters; like my path will be shortest distance wise. However, it should always moving through something like a national highway or type of things, right.

Maximum it should be moving through national highway, I can say minimal maybe distance shortest; but there should be congestion level will be minimal. So, there are different aspects like waiting the edges in different way and can find out the different shortest path queries. So, this is one of the important query in case of a spatial networks.

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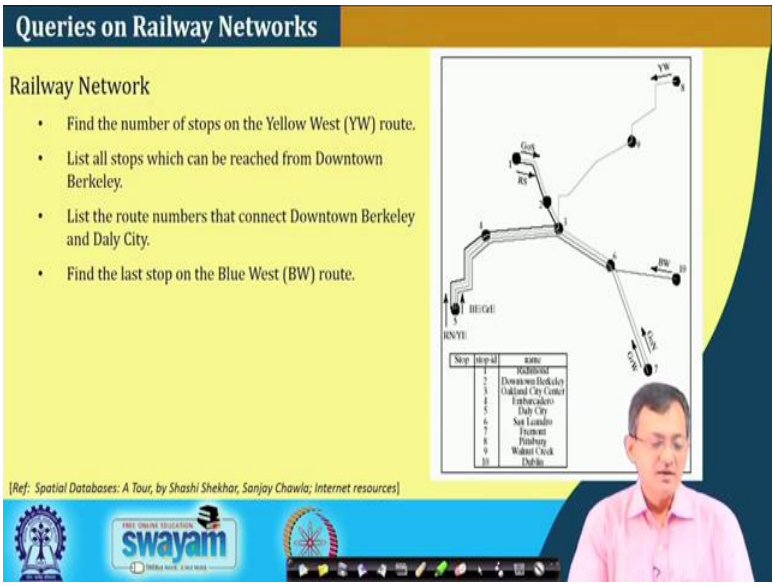


Say like a for rail network like queries like, find the number of stops in a particular route, find all stop that can be reached from A to station B, find the route numbers connects a particular station and a particular city and type of things, find the last stop on that particular route network; like this is this can be different type of queries which may be used.

Now, this is working on the spatial network X ray aspect of the thing right, so this sort of queries are handles. Now given a road route a rail network like with, if it is appropriately represent in a graph form, then I can answer this queries in a much better way, right. So, and if you see these are our generic queries.

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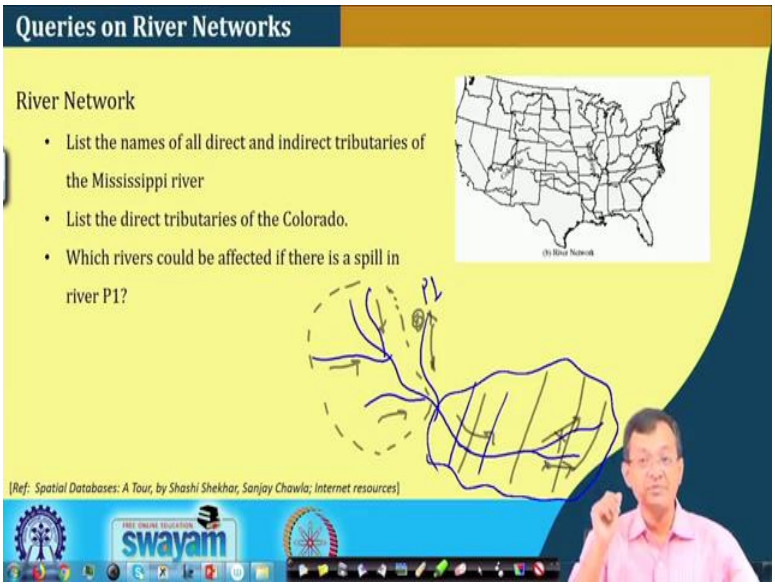


Similarly if I have a river network or road means what we say waterways or water network for that matter, list the names of all districts and indirect tributaries of the Mississippi river.

So, all district and indirect tributaries of Mississippi river, list the district direct tributaries of Colorado river, right. So, I can have a type of things which river could be affected there is spill in river P 1, right. So, a particular river say, if which river will be affected if a particular river P 1 is there. That is a interesting feature when we talk about the road net river, network and type of things there. If you see, if we look at the river network it is like this right o let us look at a different way like there are different tributary, sub tributaries which are there and the river is flowing like this.

There can be some branching somewhere, like the particularly the flow is this directions. Now what I am telling, if there is a spill suppose this is river P 1; now if there is a some spilling out here, then it is unlikely that this portion will be affected, right. The rest of the things will be affected, but this is the things will not be affected. So, if there a thing the, which are likely to be affected is rest of the things; like if there is another tributary, sub tributaries like this, this will be affected.

Now, because the direction of the flow is inherent for this type of textile, there is river will not flow in the reverse order, alright. So, if I; if there is a spilled in one then I can

say that this portion is likely to be affected, right. This portion is sorry, is likely to be affected by the thing right. So, I need to take corrective action, etcetera right.

Now, now if it is not spill even, if I say that a particular movement a from this direction to this direction a particular movement of a particular ship is there or particular a traveling through water one; if I am transporting something, then I need to take care that whether that particular ship has that enough, means way to travel to the things right.

So, those are the things which are typically for a river network.

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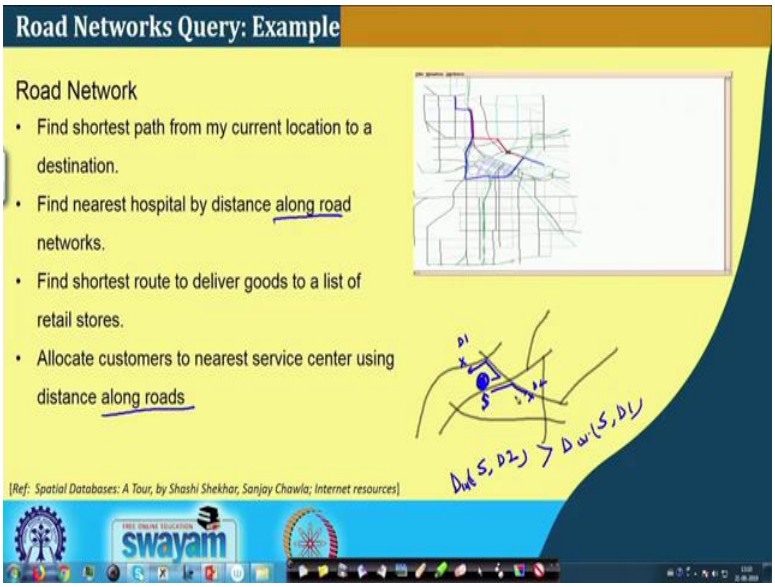


Now, if we look at a road network query this like the popular query like find the shortest path from the current location to a destination, right; from a shortest path from the current location or to a particular destination which we use for our navigation purpose in our everyday whenever we are traveling somewhere and type of things.

Find nearest hospital by distance along the road networks, this is important right; nearest hospital which is all the thing right. Find shortest to deliver goods to a list of retail stores. So, this is a again you can say that a optimization problem, right I have n number of a retail stores of a particular things, like I have a particular things and I have particular retail store, n number of retail stores.

Now, say I have a food chain right, I produce the major thing one and I in the city I distribute. Now what should be my path, so that there are different course things taking

the shortest possible time I want to distribute and also there is a demand base, right. So, even I go to a particular retail store in the third position or fourth position, but the demand is pretty high. So, otherwise there will be, it will be starving right, customers are there it is not able to there.

So, there can be different constant for handling my movement's right. So, allocate customer to nearest service center using distance along the road right. So, if I want to allocate customer based on the things to the nearest service center, using the distance along the road right. So, one interesting thing what we can see, there are some statement coming up right here along the road right here also along roads, right.

So, what why we are emphasizing this, say I have a road network like this, some right; and I have a say source point here, and I have some say destination points one is say I have a road network here also. So, this source I have a source which is this point, it is there alright and I have some which is connected here to the road and I have some destinations like, one maybe here a retail store right, one may be here.

Now, this may be D 1, destination 1, D 2 and this is say S source right. Now see though D 1 is nearer to source, but along the road if I want to find out, this is the way you can go; whereas, D 2 Euclidean distance maybe more than D 1. So, if S is D 2 if I want to find out the Euclidean distance D normally, it is more than distance of S, D 1, right Euclidean distance mode; however, going by road this is nearer, right.

So, here when we were considering this network, network has a different behavior on the whole thing, right. So, that is why we are mentioning that moving along the road right; that is why the study of the things is there. Now if you recollect, there about normal spatial thing my this distance was the nearness.

Now the definition of nearness is changing right, if I have to go roundabout way by big wall and come here which is otherwise my Euclidean distance is 100 meters; but I might need to travel say 500 meters to reach that point right. Like boundary wall here and the other side of the wall and you are 10 meters away; but you have to go to the exit gate and then come back to this particular thing, right. So, these need to be followed by the thing.

So, what we say that the nearness definition when we talk about this spatial networks is different; then the how way; how we defined it in our normal things. So, now, if I want

to say, even if I have my storage things are there; now if I want to store like if you recollect that our indexing like Z or space filling curve, so to say Z and edge. Now if there are nearby, then the definition then they are things are I want to store in the same area; but here my nearness definition is that by distance wise, nearness things are there right, because this physically or Euclidean wise distance wise nearness may not matter right, when we look at the road network.

Secondly, I the whole way of representation, I may not be representation how it is distributed right; it is all my defining by the edge. Say I have a little far distance of the things, then I give edge weight accordingly right, it cannot if the representation, the visual representation may not always reflect actually how the physically things are on the ground right it gives us. Because for the analysis I require a, I need to analyze this graph right, which can be a road, rail things or a multiple type of things.

So, I need to make a meta graph and try to do that whichever is the super impose graph and then find out that what which has the shortest distance. That is why if we see that, dealing these things, handling this type of spatial networks is typically different than how we handle our normal networks aim sorry, normal spatial database is all spatial queries like type of things, right.

So, that is why we will gradually see in our subsequent lectures also, that how will; how this type of networks are analyzed in a different way. So, for if we look at today's discussion, so what we trying to today we have studied in new topic on spatial network and what we try to see that how this different scenarios how things are networks. Why these are important, why important, why different type of applications which are like one of the popular application we have seen that shortest path which is a predominant application for different type of things.

Not only that we try to also look at that how that can be represented and analyzed, right. So, like one is that putting them as a standard graph problem right, as a graph representation. So, my all graph related stuff or graph related algorithms, graph related storage mechanisms will come into play, alright. So, with this let us conclude today. We will continue our discussion on spatial networks in subsequent couple of lectures and we will try to see the different aspects of the spatial networks.

Thank you.