IIT Madras

ONLINE DEGREE

Computational Thinking
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Depth First Search (DFS) and Recursive Procedure Call (Part 1)

Professor Madhavan Mukund: So, let us get back to our trains. So, we have looked at things like we saw we can connect you know stations to stations and say where we could reach by direct train and then take new trains, we also connected trains to train saying where you can change and switch to another train.

Professor G.Venkatesh: Another train connecting train.

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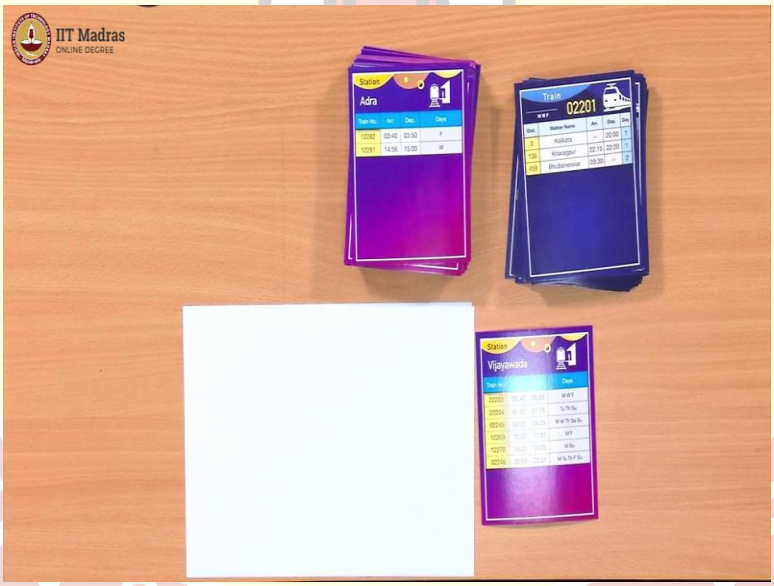

Professor Madhavan Mukund: But I think what we have so far not really looked at very carefully are these days and times.

Professor G. Venkatesh: That we are not done.

Professor Madhavan Mukund: So, supposing we want to pay attention to that, so supposing I want to say I am at a station, we know we can draw this big graph and say where all I could go if I am

willing to wait 24 hours, 48 hours for the next train, but supposing I want to know where I can go today.

Professor G. Venkatesh: Today as in.

Professor Madhavan Mukund: So, as in between say midnight and midnight, so if it is 7'o clock I am starting then before tonight, midnight, if I am 1 am I am starting I have 23 hours, so with all the trains which are available to me.

Professor G. Venkatesh: So, let us say I start on Monday.

Professor Madhavan Mukund: Supposing I start on Monday.

Professor G. Venkatesh: So, what you are asking is if I start on Monday I can start anytime, I can start at any time after.

Professor Madhavan Mukund: Depending on the station the first train on Monday.

Professor G. Venkatesh: 00:05.

Professor Madhavan Mukund: That is correct yes.

Professor G. Venkatesh: So, early morning on Monday you can start.

Professor Madhavan Mukund: And then you can go as far as you want on the train. But you cannot cross.

Professor G. Venkatesh: I can change?

Professor Madhavan Mukund: You can change.

Professor G. Venkatesh: I can get off at a station, take another train

Professor Madhavan Mukund: You can take another train.

Professor G. Venkatesh: But wait, I will have to wait, that take another train like that I can keep doing, I don't have to come back, right.

Professor Madhavan Mukund: You do not have to come back, I just want to know we are all you can.

Professor G. Venkatesh: Where all I can reach by end of tonights

Professor Madhavan Mukund: Yes.

Professor G. Venkatesh: So, till 11:59 pm today Monday, let us do that, I mean how do you do? What is the way to do it?

Professor Madhavan Mukund: Well, we can.

Professor G. Venkatesh: we can pick take a station.

Professor Madhavan Mukund: Pick a station let us say that, pick a station and.

Professor G. Venkatesh: Keep going.

Professor Madhavan Mukund: Start with the first train of the day, I guess on a Monday, first of all let us pick a station. So, here is the station Vijayawada which we have looked at before for other things.

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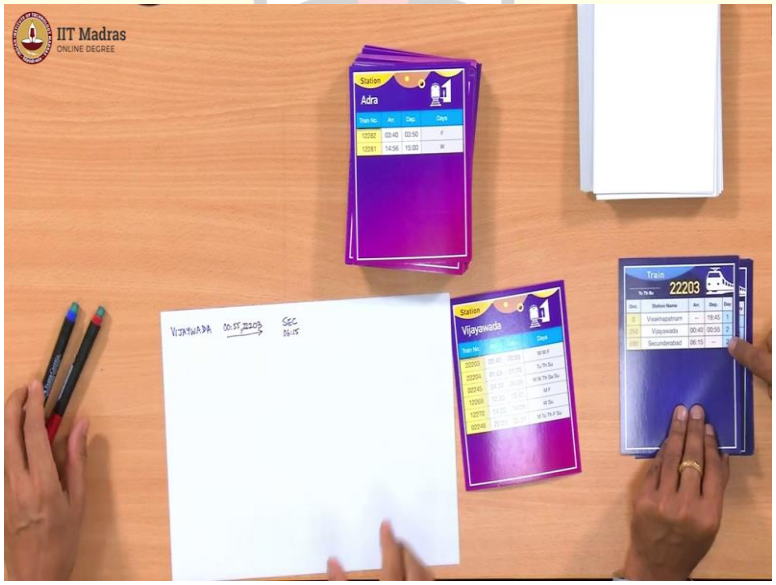

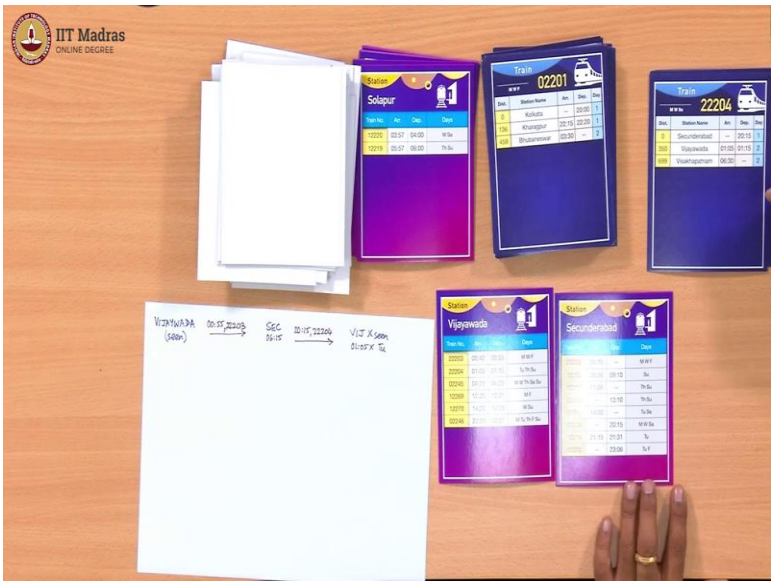

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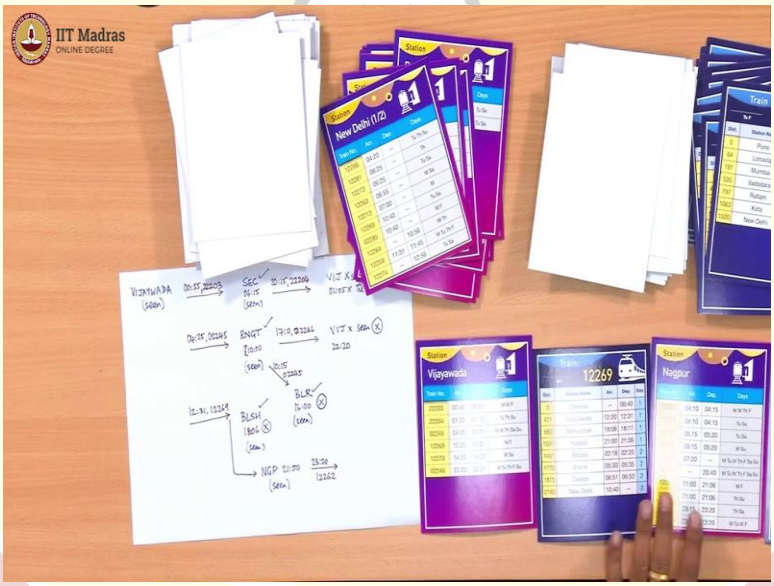

So, you can see that there are trains are listed passing through Vijayawada starting early morning.

Professor G. Venkatesh: It can early morning midnight is to 00:05, first time.

Professor Madhavan Mukund: 10:00pm, but we are on Monday.

Professor G. Venkatesh: It is there Monday is there.

Professor Madhavan Mukund: So, therefore not all these trains are there, so first train is there on Monday, second is not there, third is there, fourth is there, fifth is there and last one is there.

Professor G. Venkatesh: So, we take one train at a time?

Professor Madhavan Mukund: So, then we take the very first train, see where all we can go, then take the next train where all we can go and so on, that could be a logical way to do it.

Professor G. Venkatesh: But we can get off and take change.

Professor Madhavan Mukund: So, then we have to see where all we can go, let us see.

Professor Madhavan Mukund: So, let us start with Vijayawada. So, we have.

Professor G. Venkatesh: Vijayawada the first train is 22203 departing at 00:55,

Professor Madhavan Mukund: Maybe we will note that. So, what is it? 00:55 and the train numbers 22203.

Professor G. Venkatesh: Here it is 22203, so this train is departing 00:55 it going to Secunderabad.

Professor Madhavan Mukund: So, you can only go to one place. So, we reach.

Professor G. Venkatesh: You reach Secunderabad at 06:15, here in the day.

Professor Madhavan Mukund: Same day.

Professor G. Venkatesh: Same day.

Professor Madhavan Mukund: And we reached at 06:15, so now we can decide whether to proceed from Secunderabad.

Professor G. Venkatesh: Monday.

Professor Madhavan Mukund: No, it is leaving on Tuesday from Vishakhapatnam.

Professor G. Venkatesh: It is arriving from there departure, Vishakhapatnam.

Professor Madhavan Mukund: So, at least on Tuesday on Sunday it list on Vishakhapatnam and it passes through Vijayawada just afternoon, so we just made it.

Professor G. Venkatesh: All right very good, the 6 15 minutes on Secunderabad,

Professor Madhavan Mukund: So, now we can.

Professor G. Venkatesh: So, this train we cannot do anything further.

Professor Madhavan Mukund: So, but we can make note.

Professor Madhavan Mukund: We reach Secunderabad we can proceed, now we can decide whether we want to go there.

Professor G. Venkatesh: I want to switch a Secunderabad and continue.

Professor Madhavan Mukund: So, let us just continue and see how far we can go from Secunderabad and then we can come back and look at other trains maybe that would be a better idea.

Professor G. Venkatesh: You keep a lot of tracking you have to keep, but it is okay, let us see.

Professor Madhavan Mukund: No, it just said we are seeing where all we can go on the first train.

Professor G. Venkatesh: Keep going.

Professor Madhavan Mukund: Keep going as far as we can.

Professor G. Venkatesh: As far as we can go.

Professor Madhavan Mukund: And then we will come back and come back to the second train.

Professor G. Venkatesh: And then back track come back and see whether there is another one. But then you have to keep track of very aware on this card.

Professor Madhavan Mukund: So, that is why we have written it down. So, we have noted that.

Professor G. Venkatesh: So, we have come back to this card.

Professor Madhavan Mukund: So, we have done one train.

Professor G. Venkatesh: We are processing this train, so it will come back and we can look at this.

Professor Madhavan Mukund: So, we know that, so we know that we are doing the trains in this order, so the next train is going to be the one after that in time.

Professor G. Venkatesh: So, now we have come to Secunderabad, so what do I do now? Go to Secunderabad.

Professor Madhavan Mukund: So, now we have to look up where all we can go from Secunderabad, so we have to look up Secunderabad in this.

Professor G. Venkatesh: And you are at 6 50 in Secunderabad.

Professor Madhavan Mukund: So, we can take only trains after 6 15.

Professor G. Venkatesh: After Secunderabad.

Professor Madhavan Mukund: So, that is Secunderabad, so now.

Professor G. Venkatesh: In fact, this is the first train arrive, so all the trains have arrive.

Professor Madhavan Mukund: So now you can take, but you can take only train which are on Monday.

Professor G. Venkatesh: It is only one.

Professor Madhavan Mukund: Because this is Sunday, Thursday, Thursday, Thursday, Tuesday, so there is only one train.

Professor G. Venkateh: So, there is only one train 22204, leaves at 08:15.

Professor Madhavan Mukund: 08:15 22204, let us see where that goes, I have a suspicion, it is going to go back to Vijayawada, let us see, so.

Professor G. Venkatesh: So 22204, Secunderabad back to Vijayawada.

Professor Madhavan Mukund: In fact, there are two problems.

Professor Madhavan Mukund: It reaches the wrong, so first of all it goes back to Vijayawada, which we have already seen. So, this is, so if we want to if we had these Vijayawada on time this we are already processing Vijayawada, so somehow we should say that this is not good for that reason, because it is already. So, we have to say that this is already.

Professor G.Venkates: Visited.

Professor Madhavan Mukund: so, let us write seen. So, this is already seen. So, then you but it also bad because.

Professor G. Venkatesh: Many case it is not a same day.

Professor Madhavan Mukund: wrong day that is 01:05, this is also wrong.

Professor G. Venkatesh: we gone to the next day.

Professor Madhavan Mukund: So, that Secunderabad was a dead end.

Professor G. Venkatesh: so Secunderabad nothing to do.

Professor Madhavan Mukund: So, there is nothing else after that, this is on Tuesday, only one train from Secunderabad.

Professor G. Venkatesh: This path got me to one city Secunderabad and nothing further I can do.

Professor Madhavan Mukund: So basically, I am at a dead end here.

Professor G. Venkatesh: So, what do I do? I go back.

Professor Madhavan Mukund: So, I will just mark this is back we can put this back, now we go back to Secunderabad, now Secunderabad there was no other train, so we go back to Vijayawada.

Professor G. Venkatesh: I went to Secunderabad, we finished Secunderabad.

Professor Madhavan Mukund: So, there was only one train, this train went nowhere we go back, we look down there is no other train, so we have done with Secundrabad.

Professor G. Venkatesh: We go back Vijayawada.

Professor Madhavan Mukund: So, we can basically say that this is seen that and it is also like finished as nothing more to see in Secunderabad right now.

Professor G. Venkatesh: You could see I mean you could see when you enter the.

Professor Madhavan Mukund: When I enter the station as I seen.

Professor G. Venkatesh: Get out. And I finished with everything in the train when I put a tick mark, I will put a tick mark saying that I am finished with it.

Professor Madhavan Mukund: I am finished with it.

Professor G. Venkatesh: I am not finished Vijayawada.

Professor Madhavan Mukund: Yes

Professor G. Venkatesh: Though I came back to it again. I had to go back

Professor Madhavan Mukund: So, now I go to the I am on Monday, first train I have seen now I am second train is not on Monday, third train is on Monday, so I have to look at.

Professor G. Venkatesh: 02245.

Professor Madhavan Mukund: As which leaves at 04:25.

Professor G. Venkatesh: 02245, so this is Vijayawada 04:25.

Professor Madhavan Mukund: Renigunta.

Professor G. Venkatesh: Renigunta 10:10 not bad, one more city we got, Renigunta is a city town, what is it? It is a town.

Professor Madhavan Mukund: So, Renigunta at… and then Bangalore, that should take us to a lot of places, but we are reaching at 4'o clock. But, so now what should we do? Should we go to Bangalore or you should first check Renigunta and then go or we should go directly.

Professor G. Venkatesh: We will keep track, maybe I think we Renigunta first. So, let us do that, we know that we have something for that row on this card.

Professor Madhavan Mukund: So, we will mark Renigunta as seen in sense not yet completed. So, we will go to Renigunta and see whether there is anything interesting happening at Renigunta. Well, actually at Renigunta there is nothing interesting happening, we can take you back 46 it will probably take me back, let us see.

Professor G. Venkatesh: So, 02246.

Professor Madhavan Mukund: At 16:50, no at 17:00.

Professor G. Venkatesh: 17:00 departure. So, 02246 Renigunta 17:00 departure, goes back to Vijayawada at 22:20.

Professor Madhavan Mukund: So, again in this case Vijayawada still on the same day.

Professor G. Venkatesh: But it is on the same day, which is good, but we are reaching a city which we have already see, so nothing.

Professor Madhavan Mukund: So, there is no need to further explore that because we are already exploring Vijayawada in some sense.

Professor G. Venkatesh: So, we are done with this pathway which is taking to what you were doing is 02245 to Renigunta

Professor Madhavan Mukund: Renigunta and then 02246 to Vijayawada.

Professor G. Venkatesh: 46 back to Vijayawada that's closed, path is close, nothing further to do with 2246 nothing for the Vijayawada so over Vijayawada is over.

Professor Madhavan Mukund: No, Vijayawada, Renigunta is over.

Professor G. Venkatesh: Sorry Renigunta.

Professor Madhavan Mukund: Because we have only one train, so Renigunta is also done now.

Professor G. Venkatesh: Renigunta is also over.

Professor Madhavan Mukund: So, now we proceed.

Professor G. Venkatesh: so, I finished with Renigunta, but I have to come back to this train.

Professor Madhavan Mukund: This train. So, I have to continue on that same train.

Professor G. Venkatesh: So, on each train we are looking at the trains on each train we are looking at the stations and we have to keep track of where we are on the train

Professor Madhavan Mukund: Yes.

Professor G. Venkatesh: And you have to keep track of where we are on the station.

Professor Madhavan Mukund: Which station. So, we have.

Professor G. Venkatesh: keep in track.

Professor Madhavan Mukund: So, the 10:15 now.

Professor G. Venkatesh: But now I have Bangalore.

Professor Madhavan Mukund: So, I take the same train, which I reached at 10:10 now 10:15, I take continue on the 02245.

Professor G. Venkatesh: Continue.

Professor Madhavan Mukund: And I reach Bangalore.

Professor G. Venkatesh: And I reach Bengaluru, at 4’o clock.

Professor Madhavan Mukund: And I reach at 4'o clock the evening.

Professor G. Venkatesh: Now, this is a dead end. So, this train is over.

Professor Madhavan Mukund: This train is over. Now, I have to see what all I can do from Bengaluru at 4pm.

Professor G. Venkatesh: So, I can put the train back? Done of this train.

Professor Madhavan Mukund: Yes. So, now we go back to I am done with this train. Now, we have to look at.

Professor G. Venkatesh: Bengaluru, as we have decided we will continue.

Professor Madhavan Mukund: Yes, we will continue.

Professor G. Venkatesh: So, you are at 4'o clock you are now at Bangalore, I can Monday there is nothing for that to do.

Professor Madhavan Mukund: So, this is also done.

Professor G. Venkatesh: So, Bangalore is over. So, Bengaluru is seen first to enter Bengaluru you had scene, then you finish Bengaluru you could tick mark.

Professor Madhavan Mukund: Now, I go back to Renigunta, but I have already finished Renigunta.

Professor G. Venkatesh: I finished Renigunta.

Professor Madhavan Mukund: So, I go back to the Vijayawada.

Professor G. Venkatesh: Then I do not go back to Renigunta, Renigunta is one of the stations on the train.

Professor Madhavan Mukund: But I reached Bangalore from Renigunta, so I go back on this train to Renigunta and then I go back to Vijayawada, well I do not know whichever way you want to think about it.

Professor G. Venkatesh: Anyways that Renigunta has done.1

Professor Madhavan Mukund: Renigunta has done. But now we have to go back to Vijayawada and now there is a third train.

Professor G. Venkatesh: There is another train, which is this one.

Professor Madhavan Mukund: 12269, which is what time 12:31, 12269.

Professor G. Venkatesh: Some crazy stuff going on here, it looks like we are building some kind of a tree, just like to be, 12269.

Professor Madhavan Mukund: Yes. Balharsah.

Professor G. Venkatesh: This Vijayawada to, this is going somewhere else.

Professor Madhavan Mukund: It is going in the Delhi direction, so it is going to next Balharshah.

Professor G. Venkatesh: So, we have departing 1231 from Vijayawada. And going to Balharshah 1806.

Professor Madhavan Mukund: Now, you could get off.

Professor G. Venkatesh: Which is what we will do, right?

Professor Madhavan Mukund: We will get of to the first place and three that there are place.

Professor G. Venkatesh: Further place you can do Nagpur for example you can go to but delay it for now.

Professor Madhavan Mukund: Yes, let us, go to Balharshah, here it is, now Balharshah 18:06.

Professor G. Venkatesh: We have reached at 18:06.

Professor Madhavan Mukund: On a Monday.

Professor G. Venkatesh: On a Monday, nothing else to do.

Professor Madhavan Mukund: Nothing else to do.

Professor G. Venkatesh: So Balharshah is done.

Professor Madhavan Mukund: Done. So, as we have to see and we close it and it is done.

Professor G. Venkatesh: Balharshah goes, Balharshah is before Bengaluru.

Professor Madhavan Mukund: It is just above Bangalore. So, instead now we could go to Nagpur on the same.

Professor G. Venkatesh: We are now, so we finished Balharshah, we are on this train now.

Professor Madhavan Mukund: Yes.

Professor G. Venkatesh: Now, we are going to Nagpur reach at 21:00, in Nagpur, so let us get the Nagpur card.

Professor Madhavan Mukund: I will write scene for Nagpur.

Professor G. Venkatesh: You have to enter when you enter we should write seen, because we know enter it again, so you want to make sure that you do not here is Nagpur.

Professor Madhavan Mukund: So, we have entered at 21:00.

Professor G. Venkatesh: 21:00, we are here.

Professor Madhavan Mukund: On a Monday.

Professor G. Venkatesh: On a Monday, so there is another… 12262, it leaves at 11:20 chances are did not make anywhere.

Professor Madhavan Mukund: Let us, see what happens.

Professor G. Venkatesh: 12262 at 22:23, 12262 this is another train, you are on this train we got out of Balharshah, we got of this Nagpur, 12262

Professor. G. Venkatesh: Okay…this is another train. We are in this train, we got it for Ballarsha, we got it this one.

Professor. Madhavan Mukund: Nagpur. Now, 12262.

Professor. G. Venkatesh: We will put it on top of this only.

Professor. Madhavan Mukund: And it crosses, because next is Bhusaval, but it is too late. Unfortunately, so we cannot get that.

Professor. G. Venkatesh: We could have reached Busaval if it was.

Professor. Madhavan Mukund: We will start.

Professor. G. Venkatesh: So, because it cross the

Professor. Madhavan Mukund: So, I would not even write it down because we do want the wrongly think that we reach Bhusaval.

Professor. G. Venkatesh: So, 12262 we could not go here.

Professor. Madhavan Mukund: Yes.

Professor. G. Venkatesh: So, 12262 is done. So, Nagpur come back Nagpur is done. So, Nagpur tick mark. So, we go back to Vijayawada and come back to this train, 12262.

Professor. Madhavan Mukund: Yeah, but there is nothing happen to this I think.

Professor. G. Venkatesh: Okay. And this train, Bhopal is on the next day.

Professor. Madhavan Mukund: Yeah, so we are done with this train.

Professor. Madhavan Mukund: Yeah.

Professor. G. Venkatesh: So, I put the train back, 12269 and we come back to Vijayawada.

Professor. Madhavan Mukund: Yes. So, what is this going on now, what are we doing? Is this done, this seems to be some very systematic way of searching?

Professor. Madhavan Mukund: Yeah.

Professor. G. Venkatesh: Is not it?

Professor. Madhavan Mukund: Correct. So, we are kind of searching one level, then searching from that level, under level, searching one more level and making sure that we do not come back and search something the second time.

Professor. G. Venkatesh: this kind of search?

Professor. Madhavan Mukund: So, this, we are going deeper and deeper into this how far we are going. So, we are going one level further, two levels further, three level further. So, we can say we are going in depth. So, instead of so we could have gone sideways, you could have looked at everything that we could reach in one one station away and halt trains, instead we are took each train, went as far as it goes, so this is depth first search.

Professor. G. Venkatesh: Depth first search.

Professor. Madhavan Mukund: So, we go deeper rather than going sideways.

Professor. G. Venkatesh: DFS.

Professor. Madhavan Mukund: DFS.

Professor. G. Venkatesh: Depth First Search.

Professor. Madhavan Mukund: So, there is one large train, I think we are not going to get us anywhere because it is..

Professor. Madhavan Mukund: Yeah, it is leaves so late, the fourth one.

Professor. G. Venkatesh: Let us try it. 02246.

Professor. Madhavan Mukund: So, this leaves at 22:31, 02246 unlikely, but you could, I think we said other is again this Renigunta train I think.

Professor. G. Venkatesh: So, this is the one. That 22:31 and reach Vijaynagaram at 04:30.

Professor. Madhavan Mukund: So, here we, can we say we have explore everything from Vijayawada?

Professor. G. Venkatesh: Starting on a Monday, Yes.

Professor. Madhavan Mukund: I will try on Monday. So, we can start on Monday.

Professor. G. Venkatesh: If you start on a Monday at anytime…

Professor. G. Venkatesh: Anytime.

Professor. Madhavan Mukund: Anytime, then we can potentially reach one day station, Secunderabad…

Professor. G. Venkatesh: Secunderabad.

Professor. Madhavan Mukund: Renigunta.

Professor. G. Venkatesh: Renigunta, Bhalarsha, Bangalore and Nagpur.

Professor. Madhavan Mukund: These are the stations you can reach.

Professor. G. Venkatesh: You can reach in one day. 1, 2, 3, 4, 5 stations you had reach in one day.

Professor. Madhavan Mukund: Interesting.

Professor. G. Venkatesh: Yeah. So, let us reflect it. So, this you are saying is a depth first search, DFS.

Professor. Madhavan Mukund: Yes.

Professor. G. Venkatesh: How does it works? I mean, you start with a station first and then?

Professor. Madhavan Mukund: Then you take one direction leaving out of that station in any outgoing.

Professor. G. Venkatesh: Any outgoing.

Professor. Madhavan Mukund: Any outgoing. And then you go to that station.

Professor. G. Venkatesh: Go to a station.

Professor. Madhavan Mukund: And then you repeat the same thing there.

Professor. G. Venkatesh: You repeat the same thing…

Professor. Madhavan Mukund: Keep in track of the fact that you have come from here.

Professor. G. Venkatesh: It is something major. Again you will start at the station and do whatever you are doing.

Professor. Madhavan Mukund: Yeah. You will do the same thing. So, we came to Secunderabad, we looked at all the trains in Secunderabad on Monday. Only thing is we have to make sure that you are leaving only after the time that you arrived, otherwise you are doing,...

Professor. G. Venkatesh: Keep track of that as a parameter or something.

Professor. Madhavan Mukund: So, we have staring time, so for Vijayawada starting time is Monday midnight.

Professor. G. Venkatesh: Midnight.

Professor. Madhavan Mukund: Now, Secunderabad, it is now Monday 06:15.

Professor. G. Venkatesh: 06:15.

Professor. Madhavan Mukund: Then look at all trains on Monday 06:15 and onwards.

Professor. G. Venkatesh: So, …

Professor. Madhavan Mukund: And you pick the first one.

Professor. G. Venkatesh: Suppose I had a say this is like a procedure, I mean you can write a procedure.

Professor. Madhavan Mukund: Yes.

Professor. G. Venkatesh: Looks like, see if I have procedure which says…

Professor. Madhavan Mukund: Explore.

Professor. G. Venkatesh: Explore. Just write it down, what does it look like, Explore and with explore we give it an argument which is station.

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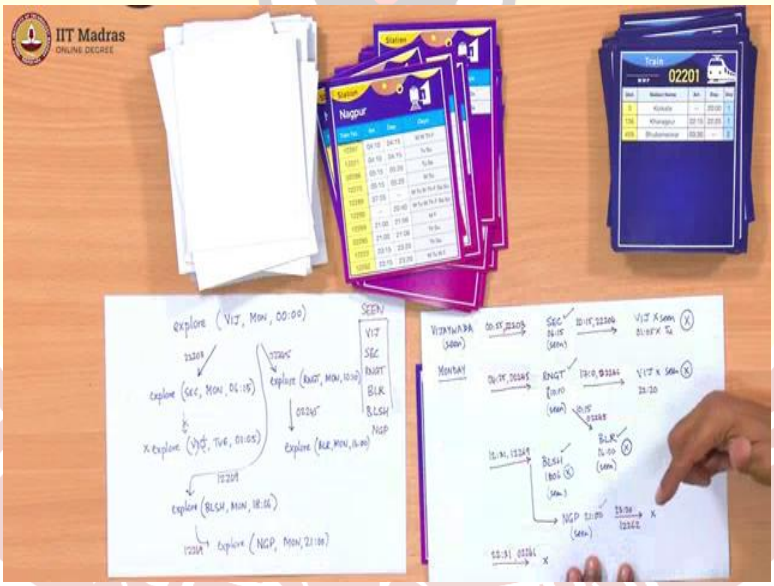

Professor. Madhavan Mukund: Yeah.

Professor. G. Venkatesh: And we give an argument as time. So, initially you are starting with explore Vijayawada.

Professor. Madhavan Mukund: You say explore Vijayawada.

Professor. G. Venkatesh: From 00:00.

Professor. Madhavan Mukund: Yeah, so, you, this is what you are initially saying, explore Vijayawada. So, Monday.

Professor. G. Venkatesh: For Monday, you have to say that also. Explore Vijayawada, Monday.

Professor. Madhavan Mukund: So, we can think of that as together is one parameter, date and time but we will put it at least 2 also.

Professor. G. Venkatesh: Okay. Now, this explore Vijayawada, Monday, 00:00.

Professor. Madhavan Mukund: So, what happens is that we take this first train whichever it was 22203.

Professor. G. Venkatesh: and then we have 22230 gave us this…

Professor. Madhavan Mukund: That give us Secunderabad. So, if you look at this, if you look at this thing,…

Professor. G. Venkatesh: It gave us Secunderabad.

Professor. Madhavan Mukund: So, that gave us, so now we say that I was…

Professor. G. Venkatesh: We want to explore…

Professor. Madhavan Mukund: So, Secunderabad.

Professor. G. Venkatesh: Same procedure calling.

Professor. Madhavan Mukund: Yes. The procedure is calling itself in a way that it is calling itself with some information which is new.

Professor. G. Venkatesh: It is crazy, we never had a procedure which is cause this ever. So, this procedure…

Professor. G. Venkatesh: So, this explore is not again…

Professor. Madhavan Mukund: Called a max or something which will normally finish and then give you an answer.

Professor. G. Venkatesh: So, it is like some you said a contractor or sub-contractor. Yeah, so now this are like a contractor has given it a, here the contractor is giving to itself.

Professor. G. Venkatesh: Yeah, So he suspended its job in some sense.

Professor. Madhavan Mukund: So, he was trying to explore from Vijayawada, he said okay I will hold it and put it on hold. Mean while let me go and…

Professor. G. Venkatesh: explore something else.

Professor. Madhavan Mukund: Explore something else..

Professor. G. Venkatesh: and come back to…

Professor. Madhavan Mukund: And then finish that and I will come back and finish this job.

Professor. G. Venkatesh: I see.

Professor. Madhavan Mukund: Because I need this to find that. So, I do this.

Professor. G. Venkatesh: Okay.

Professor. Madhavan Mukund: and then this it turns out

Professor. G. Venkatesh: The procedure is calling itself.

Professor. Madhavan Mukund: yeah.

Professor. G. Venkatesh: the name for a procedure that calls itself?

Professor. Madhavan Mukund: I think we can it is it is called recursion. Recursion meaning recurring, it is something which is happening again and again so, it is calling itself.

Professor. G. Venkatesh: Recursive.

Professor. Madhavan Mukund: So, it is a recursive procedure.

Professor. G. Venkatesh: Recursive procedure.

Professor. Madhavan Mukund: It uses itself, it uses another version of the same problem to solve the problem.

Professor. G. Venkatesh: Okay.

Professor. Madhavan Mukund: So,…

Professor. G. Venkatesh: So, explore on Monday.

Professor. Madhavan Mukund: So, let us put it more precisely, so in this calls this.

Professor. G. Venkatesh: Now this crazy thing is that I will call explore, calls explore, calls explore, calls explore, calls explore, it calls like that. But you make sure that,…

Professor. Madhavan Mukund: So, there must be a point where it will be able to…

Professor. G. Venkatesh: Call a procedure, that may come back. you have being called yourself…

Professor. Madhavan Mukund: So, they might be coming as a, it must be its ending point.

Professor. G. Venkatesh: Yeah, that we are not allowing, each time the city is different.

Professor. Madhavan Mukund: City is different and the time is also moving ahead.

Professor. G. Venkatesh: So, that is where..

Professor. Madhavan Mukund: we are going to run out of time. So, the time is going to stop us from moving beyond a certain point

Professor. G. Venkatesh: Making an infield, going on and on. And even city also. We are saying something,

Professor. Madhavan Mukund: we will never be able to reach the same…

Professor. G. Venkatesh: If you reinvert to Vijayawada like we are doing going to and you go Secunderabad, it is going to call explore again.

Professor. Madhavan Mukund: Yeah.

Professor. G. Venkatesh: It will call explore again, right?

Professor. Madhavan Mukund: It will call explore again, but it will already know that this is a bad call because there are two reasons, one is which it is again Vijayawada and the other thing is now it is calling it on Tuesday which we do not want because we have skipped.

Professor. G. Venkatesh: But you will go inside the call and then you will figure out and then come out of the call.

Professor. Madhavan Mukund: Then we will say that this does not work. So, we will sort of cancel this out somehow.

Professor. G. Venkatesh: See inside when you are looking for explore, you will say it is Tuesday so sorry. Inside this explore itself we can check this.

Professor. Madhavan Mukund: Yeah. They will call so anyway so this will this call will basically not call, not connect the call and then we checked that in Bangalore, there is no other, I mean, Secunderabad…

Professor. G. Venkatesh: the fault is checking second, when you exploring Secunderabad, check that. So, some way you have to have noted that Vijayawada is there, right?

Professor. Madhavan Mukund: Correct. We wrote seen. So, assume that there is a….

Professor. G. Venkatesh: So, in some sense you will have to be passing either somewhere here or looking up somewhere

Professor. Madhavan Mukund: In list of everything which is being seen.

Professor. G. Venkatesh: So, this guy, everybody has access to that.

Professor. Madhavan Mukund: Yeah.

Professor. G. Venkatesh: So, we can assume that there is a table here which is seen and in that you are putting Dictionary.

Professor. Madhavan Mukund: Let us call it a dictionary. So, initially I insert Vijayawada there. Then when I come here and insert Secunderabad there. So, when Secunderabad is exploring it first checks whether the city you want to explore is seen or not. So, if it is seen…

Professor. G. Venkatesh: Seen and exploring.

Professor. Madhavan Mukund: So, if it is in the dictionary, Vijayawada is there, then you want to make a call.

Professor. G. Venkatesh: what to make a call.

Professor. Madhavan Mukund: So, that will also you avoid.

Professor. G. Venkatesh: So, this will, The two ways, one is time and other is

Professor. Madhavan Mukund: Because there are only some, there are lot of station but only that many. We cannot do infinitely and there is only, time is also going to run out.

Professor. G. Venkatesh: This is cool I mean, this is interesting because it is a very simple way of thinking a lot thing, because we normally do this many times in order to do something, you say go somewhere and do the same thing there. If you want to search for something in the many rooms I want to search let us say, I can search. So, firstly I can say I can have a search in this room or I can go to a next room and start searching.

Professor. Madhavan Mukund: Yes.

Professor. G. Venkatesh: So, what do I say? I say that with searching, the next room we will start searching is what is the procedure I can have a search in that room or I can go to the next room and search.

Professor. Madhavan Mukund: Yeah.

Professor. G. Venkatesh: So, it is the same actually.

Professor. Madhavan Mukund: Yes.

Professor. G. Venkatesh: So, searching basically is li saying search here and then continue to search in the next room, call search again in the next room, something like that.

Professor. Madhavan Mukund: And do not come back to the same room and start..

Professor. G. Venkatesh: Start again.

Professor. Madhavan Mukund: Do not start again. Do not repeat the thing again which you are going to.

Professor. G. Venkatesh: Which you are going to continue..

Professor. Madhavan Mukund: Which you are going back to continue the search from a different room but do not go back and restart…

Professor. G. Venkatesh: Restart. Alright so let us try and see about these three looks like, this recur is called some kind of cautery.

Professor. Madhavan Mukund: Yeah.

Professor. G. Venkatesh: So, now for this called some kind of cautery.

Professor. Madhavan Mukund: Yeah. So, now this Secunderabad is done and then it returns back there.

Professor. G. Venkatesh: It return back here.

Professor. Madhavan Mukund: So, now this, so now this calls a second one which is explored.

Professor. G. Venkatesh: But still now we have come back with this procedure call. We were inside the explore Vijayawada….

Professor. Madhavan Mukund: That is called explore the Secunderabad…

Professor. G. Venkatesh: Which came to dead end.

Professor. Madhavan Mukund: Which came to dead end and then Secunderabad itself it finished.

Professor. G. Venkatesh: So, it finished it returned, it came back to explore and now explore Vijayawada is continuing.

Professor. Madhavan Mukund: Yes. And now it is going to call it with its Renigunta.

Professor. G. Venkatesh: With Renigunta.

Professor. Madhavan Mukund: Explore Renigunta on Monday at 15:00, no 10:10

Professor. G. Venkatesh: 10:10. So, then as soon as you enter you will mark Renigunta as seen.

Professor. Madhavan Mukund: So, now you will put Renigunta here.

Professor. G. Venkatesh: Put Renigunta there and now it could…

Professor. Madhavan Mukund: And then it turns out that the only thing you can do from here is you can this to go back to Vijayawada which is seen.

Professor. G. Venkatesh: Get off and take another train.

Professor. Madhavan Mukund: Yeah.

Professor. G. Venkatesh: This train and go back to Vijayawada, then that Vijayawada is seen, so that path is closed. So, this path becomes closed.

Professor. Madhavan Mukund: So, this path becomes closed.

Professor. G. Venkatesh: So, this path becomes closed.

Professor. Madhavan Mukund: So, this was what train now? 02245. So, now

Professor. G. Venkatesh: You come back again, this is called.

Professor. Madhavan Mukund: So, Renigunta is now done.

Professor. G. Venkatesh: Not done, we have to continue on that same train, 2245 and you go to Bangalore. So, now you explore Bangalore. Explore Bangalore.

Professor. Madhavan Mukund: You are arriving at Bangalore at 4, 1600 on Monday. So, we have to first mark it as…

Professor. G. Venkatesh: First mark Bangalore as seen.

Professor. Madhavan Mukund: Right.

Professor. G. Venkatesh: Now you start exploring Bangalore which is what we try to do when we looked at Bangalore, we found that there are no trains in Bangalore.

Professor. Madhavan Mukund: so, then again Bangalore is over.

Professor. G. Venkatesh: Bangalore is over, this is nothing further to do in Bangalore. It is completes. It came back to Renigunta, noting further to do in Renigunta, came back to Vijayawada, and that is it. Now, we have done other train, now we get to this next train. Then in Vijayawada you have one more train.

Professor. Madhavan Mukund: Yeah, so I will although we do it third, I will write from here so that it goes out, so this is the third train that we do.

Professor. G. Venkatesh: Okay.

Professor. Madhavan Mukund: So, this 12…

Professor. G. Venkatesh: 12269.

Professor. Madhavan Mukund: then it took me to Bhalarsha.

Professor. G. Venkatesh: It took me to Bhalarsha. So, which means I explore Bhalarsha.

Professor. Madhavan Mukund: Yeah, so I have to explore Bhalarsha, so I mark Bhalarsha as visited.

Professor. G. Venkatesh: I mark Bhalarsha as seen and then I do an explore Bhalarsha, 1806 on Monday. Now this call explore Bhalarsha, did not yield anything, is going further to do. So, it came back again.

Professor. Madhavan Mukund: So, actually I continue with same train, so we do the same thing for Renigunta, then we will just continue Bangalore edge on the same train. So, …

Professor. G. Venkatesh: You moving further toward Bhalarsha so, I came back, continue on the same train. And then I explore Nagpur.

Professor. Madhavan Mukund: At 21:00.

Professor. G. Venkatesh: 2100, again Nagpur goes into the seen bucket. So, I can just read out all these…

Professor. Madhavan Mukund: we know everything exactly. yes.

Professor. G. Venkatesh: Okay. So that all I have to do. Will read this out and I am done.

Professor. Madhavan Mukund: But just tell this in order in which we saw them, that is important.

Professor. G. Venkatesh: Right. So, I went to Nagpur,…

Professor. Madhavan Mukund: then I saw nothing more it can be done…

Professor. G. Venkatesh: I think now it could be done in Nagpur.

Professor. Madhavan Mukund: Yeah.

Professor. G. Venkatesh: So, I came back from Nagpur.

Professor. Madhavan Mukund: So, I see Bhalarsha is done.

Professor. G. Venkatesh: I go back to Vijayawada,

Professor. Madhavan Mukund: then I found this one more train but this one more train does not take me anywhere, so there is a kind of fourth possibility but it does not…

Professor. G. Venkatesh: Does not heal anything.

Professor. Madhavan Mukund: Does heal anything. Then I am done. And I finished with Vijayawada.

Professor. G. Venkatesh: So, finally I explore Vijayawada

Professor. Madhavan Mukund: Vijayawada is also done.

Professor. G. Venkatesh: So, this thing, this thing you have done here, this is like a tree. So, this tree so recursion, we are calling explore so, there is a multiple explore calls are there,..

Professor. Madhavan Mukund: Hmm.

Professor. G. Venkatesh: But it is not a tree, right? So, it is a tree because the desired mode does not come in again because you have marked it seen that is why it is not coming again. It is a tree. And so, we are saying it is recursion, so it is kind of a way of doing depth first search. So, you are saying when we do depth first search, we are actually creating…

Professor. Madhavan Mukund: This tree.

Professor. G. Venkatesh: tree or graph?

Professor. Madhavan Mukund: With this extra information as to what you already seen in this.

Professor. G. Venkatesh: So, this is graph, graph of stations. Station's graph is basically that one station, another station if you again go via train, there is a harp, there is a edge from this station to that station.

Professor. Madhavan Mukund: Yes.

Professor. G. Venkatesh: So, we made a big graph. By doing depth first search and this graph starting at Vijayawada, what are created basically is some kind of a tress.

Professor. Madhavan Mukund: Yes.

Professor. G. Venkatesh: Tree of the edges of the graph.

Professor. Madhavan Mukund: Yes.

Professor. G. Venkatesh: I see, which itself may be interesting, this tree?

Professor. Madhavan Mukund: Yeah, because we can see here in this tree, first of all it tells us the ordering in which we visit these thing.

Professor. G. Venkatesh: I put one day, if I said instead of one day, if I said two days, that allowed you two days,…

Professor. Madhavan Mukund: then you would

Professor. G. Venkatesh: Then you would have gone further, right?

Professor. Madhavan Mukund: Yes.

Professor. G. Venkatesh: You could have extended.

Professor. Madhavan Mukund: So, some of these trains for instance, you could have made a connection on the second day where you will in Vijayawada you could have left on Tuesday.

Professor. G. Venkatesh: So, I could have make the long, bigger tress, but we still be a tree.

Professor. Madhavan Mukund: You still be a tree.

Professor. G. Venkatesh: because I have not allowed you to come back to the same station, because I have not get a seen, so I will get a bigger tree and it take 3 days I will get a bigger tree and if 4 days, 5 days, 6, 7 days, I would have used everything, does not it? only if everybody can reach everybody else, we do not know, but potentially with the tree itself, this is tree, now it cover the entire graph.

Professor. Madhavan Mukund: Yeah.

Professor. G. Venkatesh: The whole graph it can reach, probability that given enough days, but we had additional information now because we are days, we are time there, export also. It is interesting. So, many things we introduced, we introduced the motion of depth first search, then this idea that a function or procedure can call itself.

Professor. Madhavan Mukund: Yes. Keeping track of this extra information in the side.

Professor. G. Venkatesh: Seen, so we do not go or repeat every going to the loop of some. This is a funny kind of movement we are calling it. So, keeping track of seen and what it generates is some kind of a tree. Some kind of recursion tree. Nice.