IIT Madras

ONLINE DEGREE

Computational Thinking
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Depth First Search (DFS) and Recursive Procedure Call (Part 4)

Professor Madhavan Mukund: So let us get back to our favorite trains. So we did this recursion earlier to find out stations we can reach and trains we can reach. We started a station on a Monday, for instance, where all can we reach on a Monday. And then, we started a train on a Monday and where all can we, which all trains can we connect to up to Tuesday.

But although we were doing things only with one of the, we were interested only in stations or only in trains, we had to go through the trains to go to the station. So we kept going through these two piles.

Professor G. Venkatesh: Stations are connected to trains and train, same way are connected to stations.

Professor Madhavan Mukund: So we were kind of keeping track of these two things. So maybe, it might be nicer to actually split it that way.

Professor G. Venkatesh: Natural, no, it will be? So what does it mean? It means that the train visiting the station means visiting the trains that are going through the station. Visiting the trains means visiting all the stations that are, that the train is going through.

Professor Madhavan Mukund: So I start at the station for instance. So my first task was to find out which all trains can I take in order on a particular day.

Professor G. Venkatesh: So I can say, visit station or visit train?

Professor Madhavan Mukund: Visit train and then for every train, I will say which stations can I visit starting from this time on this day. And then, from those stations, I will say which trains can I visit.

Professor G. Venkatesh: So you are saying that, rather than saying that explore, we had explore train and explore station, now, you have two different procedures.

Professor Madhavan Mukund: Yes. So the trains will explore stations and stations will explore trains. And we will keep track of who is been visited as you move.

Professor G. Venkatesh: So this is not recursion, is it?

Professor Madhavan Mukund: It is a kind of recursion.

Professor G. Venkatesh: Because A is calling B, B is calling A.

Professor Madhavan Mukund: So they are kind of calling each other, so it is a kind of mutual recursion. Yeah. So they are two people.

Professor G. Venkatesh: See this also is recursion; not direct, indirectly. A calls B, B calls A.

Professor Madhavan Mukund: Yeah. So they both have to use each other to proceed.

Professor G. Venkatesh: This is more interesting because I will say, we are making them level equal; the train and the station are coming at the same level.

Professor Madhavan Mukund: And last time also, we were having difficulty, a little difficulty keeping track of this because we were writing these things. So now, I think this might be neater.

Professor G. Venkatesh: So shall we do that? Shall we try exploring the train versus exploring the station? Explore train we will call explore station, explore station we will call explore train.

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Professor Madhavan Mukund: Yeah. Let us try that. So let us start with this. So again, our overall goal is similar. So we start at the station.

Professor G. Venkatesh: We are trying to do a depth first search.

Professor Madhavan Mukund: Yeah, depth first search. We want to find out from this station, which all stations we can reach within 24 hours.

Professor G. Venkatesh: Want to pick a day?

Professor Madhavan Mukund: Let us try a different day, Wednesday. Middle of the week.

Professor G. Venkatesh: So Bhusawal, Wednesday. Bhusawal, Wednesday we start. So we are saying explore Bhusawal. We want to give different explores to when it is explore station; ES we will call it, and ET.

Professor Madhavan Mukund: ET. So from, so we want to explore all trains from Bhusawal on a Wednesday, starting at midnight.

Professor G. Venkatesh: So ES Bhusawal, the procedure ES Bhusawal starting at midnight on Wednesday. What it is supposed to do is it is supposed to look at all the trains.

Professor Madhavan Mukund: That you can reach and then for each of those trains you have to now explore train.

Professor G. Venkatesh: Explore train.

Professor Madhavan Mukund: Yeah, explore train. All right. So first, we will have two visited list. So you will have a visited list.

Professor G. Venkatesh: Visited trains and visited stations, presumably.

Professor Madhavan Mukund: Yeah. So I will write, we call it seen but let us write visited, you know it is easier. And this may or may not, let us see how far we can go with this. So let us start here. So the first.

Professor G. Venkatesh: We have seen Bhusawal, so you can mark Bhusawal. And now, we pick up the first train on a Wednesday which leaves Bhusawal and say, we have to explore that. So 12290. So call explore train. ET, you have to call it. ET at 12290 departure 01:25 on Wednesday. So now, we have to go to that train, 12290. So we get to 12219 and it says Bhusawal 01:25.

Professor Madhavan Mukund: So now, I have to look at the first station I reach on that train after that, Igatpuri.

Professor G. Venkatesh: It is Igatpuri, so I call ES now.

Professor Madhavan Mukund: So Igatpuri, I call ES. Igatpuri and Wednesday at 05:10.

Professor G. Venkatesh: We arrived at 05:10. Strictly speaking, we should say, 05:10.

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Professor Madhavan Mukund: So I have to see what all I can do from Igatpuri at 05:10. So now, I have to go and pick up Igatpuri and see what all trains leave from Igatpuri after 05:10.

Professor G. Venkatesh: This is nicer.

Professor Madhavan Mukund: This is much neater. Because we are keeping track of everything properly.

Professor G. Venkatesh: Everything is systematic.

Professor Madhavan Mukund: So now Igatpuri on a Wednesday at 05:10. So first of all, you have to go past 05:10.

Professor G. Venkatesh: Wednesday at 05:10. This is a separate, 12290.

Professor Madhavan Mukund: So 12262. That is the train we came on, so that is not useful but the next train we should look at. So first I should have put, I should have written on that train actually. 12290.

Professor G. Venkatesh: If we had written it, then we would basically have seen, so we will just proceed. Next will be, after 05:15, the next one is 12262.

Professor Madhavan Mukund: This on a Wednesday.

Professor G. Venkatesh: Yes, 12262. So I will look for 12262.

Professor Madhavan Mukund: That 07:45 is, yeah. So I am writing 12262 as a visited train.

Professor G. Venkatesh: You have visited train and now we have 12262 Igatpuri. We reach Mumbai at 10:30.

Professor Madhavan Mukund: So I come to explore station Mumbai, Wednesday, 10:31. Okay, very good. So now I have to go and.

Professor G. Venkatesh: Since it is last one, I can put it back.

Professor Madhavan Mukund: Yes. That train is not going to go anywhere else. Yeah.

Professor G. Venkatesh: So I will put it back, otherwise, we have too many cards on the table.

Professor Madhavan Mukund: So now, we look for Mumbai, so Mumbai…

Professor G. Venkatesh: In fact, this train is also going to Mumbai, so we have explored Mumbai, we are going to explore Mumbai again but that is at 08:06. Now, we are exploring for 10:35. And we will come back and explore it from 08:06 again.

Professor Madhavan Mukund: So we will have to see now how to do that. Yeah.

Professor G. Venkatesh: So we will be doing it two times.

Professor Madhavan Mukund: It will be in a different branch of this.

Professor G. Venkatesh: It will be in a different branches. It is all right, let it be.

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Professor Madhavan Mukund: 10:31, so you have to look on a Wednesday. So these are all arrivals, so we have go to the next page.

Professor G. Venkatesh: So you we are going to see departures after 10:31 on a Wednesday.

Professor Madhavan Mukund: 17:15.

Professor G. Venkatesh: 12261. So we call explore train.

Professor Madhavan Mukund: 12261 is actually going back I think because it seems to be a pair.

Professor G. Venkatesh: Yeah, we are exploring train 12261.

Professor Madhavan Mukund: Wednesday at 17:15

Professor G. Venkatesh: Look back?

Professor Madhavan Mukund: Yeah, so now you have to back to that train.

Professor G. Venkatesh: This time, we are not doing the other one, we are not saying that remove the pair also. Here is the train. So Mumbai, right?

Professor Madhavan Mukund: Yeah.

Professor G. Venkatesh: 05:15, it comes back to Igatpuri. Igatpuri, is seen. So we have marked it here.

Professor Madhavan Mukund: So, Igatpuri is seen, Mumbai is seen.

Professor G. Venkatesh: So since it is seen; nothing. It comes back. Since it is be, I could continue on this train. So it comes back and this comes back here and I can go to Bhusawal.

Professor Madhavan Mukund: Yeah.

Professor G. Venkatesh: Bhusawal seen. Then it crossed the day. So this is over, right?

Professor Madhavan Mukund: Yeah.

Professor G. Venkatesh: So I am done with 12261 and then, this is not there. Wednesday, Wednesday, Wednesday.

Professor Madhavan Mukund: 12289.

Professor G. Venkatesh: 12289, okay. 12289 Igatpuri.

Professor Madhavan Mukund: At what time was this?

Professor G. Venkatesh: 22:31. No, Mumbai, 20:15.

Professor Madhavan Mukund: But again, this is going back to…

Professor G. Venkatesh: Going to Igatpuri which is seen. Then Bhusawal which we have seen. It has gone to the next day. So this is done. So then we come back to Wednesday. 22:45 02283. So explore train 02283. Okay, here we are. Mumbai 22:45. We go into the next day so finished and come back.

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Professor Madhavan Mukund: And I think this yet one more last train which 12219.

Professor G. Venkatesh: On Wednesday, 12219. But again, it is unlikely to have anything.

Professor Madhavan Mukund: Yeah. Because it is going to leave so late.

Professor G. Venkatesh: 12219, Mumbai, 23:06 goes to Pune 02:05, so gone. Next day. So we explored 12219 and are done with Mumbai.

Professor Madhavan Mukund: We are done with Mumbai. So we were at.

Professor G. Venkatesh: Oh, there are some more from Wednesday. There is one more.

Professor Madhavan Mukund: 12267.

Professor G. Venkatesh: 12267 again we can take. Just for the heck of it I will take out 12267, this is going to Rajkot. But clearly, Ahmedabad is the next stop, it is next day. So we do 12267, get out, and get up. We are down with Mumbai, finally done Mumbai. And where are we now?

Professor Madhavan Mukund: So we were at 12262 train but that was what we were exploring. So from Igatpuri, we had to.

Professor G. Venkatesh: That was the last stop. Put it back because Mumbai was the last stop.

Professor Madhavan Mukund: Okay. Then we have to look at the next train from Igatpuri after 12262 on Wednesday.

Professor G. Venkatesh: Which is 122... Wednesday 12294.

Professor Madhavan Mukund: Yeah. So now, I have to explore that train.

Professor G. Venkatesh: So 12294. So 12294 again, it goes to Mumbai, we have seen Mumbai. So nothing to do.

Professor Madhavan Mukund: What time was that? 12:35

Professor G. Venkatesh: Then Wednesday, 12261 that is train going back.

Professor Madhavan Mukund: Yeah, that we already seen that train.

Professor G. Venkatesh: We have seen 12261, so nothing to do. 12293, not on Wednesday. Then 12289, have we seen?

Professor Madhavan Mukund: 12289 we have seen. Where did we see it? Here. So it was coming back from Mumbai.

Professor G. Venkatesh: So we are done with Igatpuri. So we put Igatpuri back and we return to 12290. We return to 12290. We are here, we were looking at 12290, now we are doing explore Mumbai now. You have to call it again. Unfortunately, we are not wrong, we have seen Mumbai. We have seen Mumbai but we have seen it from.

Professor Madhavan Mukund: We have seen Mumbai only from 10:31 onwards. So we have to look at in between.

Professor G. Venkatesh: So you have to actually keep trying that also.

Professor Madhavan Mukund: So we should probably write it there. So we saw Igatpuri at, from 05:10 onwards; 05:10. And now, we have seen Mumbai from 10:31. And now, we are going to reach Mumbai a little earlier.

Professor G. Venkatesh: And we are seeing Bhusawal from 00:00, write that. So it has seen all of Bhusawal basically. So now we have to go back and see Mumbai from 8.

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Professor Madhavan Mukund: That gap between 8. So now it is 08:15, what time is it?

Professor G. Venkatesh: 08:06; we had arrived at 08:06. So is there anything between 08:06 and 10:31? There is nothing.

Professor Madhavan Mukund: Between 03:55 and 14:40, there are no departures.

Professor G. Venkatesh: Okay. Thank you. So we have nothing; thankfully, nothing to do.

Professor Madhavan Mukund: So now, I can also replace that and say we have actually done it from 08:06.

Professor G. Venkatesh: So we are finished with 12290, it is the last train so we can put it back.

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Professor Madhavan Mukund: So now, we go back to Bhusawal and see the next train which is 12289; it is going the opposite direction.

Professor G. Venkatesh: Here is 12289.

Professor Madhavan Mukund: So we explore the train 12289 on a Wednesday leaving at 2, at what time is the leaving 02:05. So now, I go to Igatpuri again.

Professor Madhavan Mukund: No, it is this way.

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Professor Madhavan Mukund: We are going Nagpur, okay. So I got, now I, it is Nagpur.

Professor G. Venkatesh: It is change of place. 07:20, Nagpur.

Professor Madhavan Mukund: So let me write the train down. So 12289, we have seen and now, we see Nagpur at?

Professor G. Venkatesh: 07:20, we arrive at Nagpur.

Professor Madhavan Mukund: So explore Nagpur on a Wednesday at 07:20. So let us pull out Nagpur. Nagpur should be just after Mumbai I think. It should have been somewhere there, maybe it got mixed up. Yeah. Okay. So what does Nagpur say?
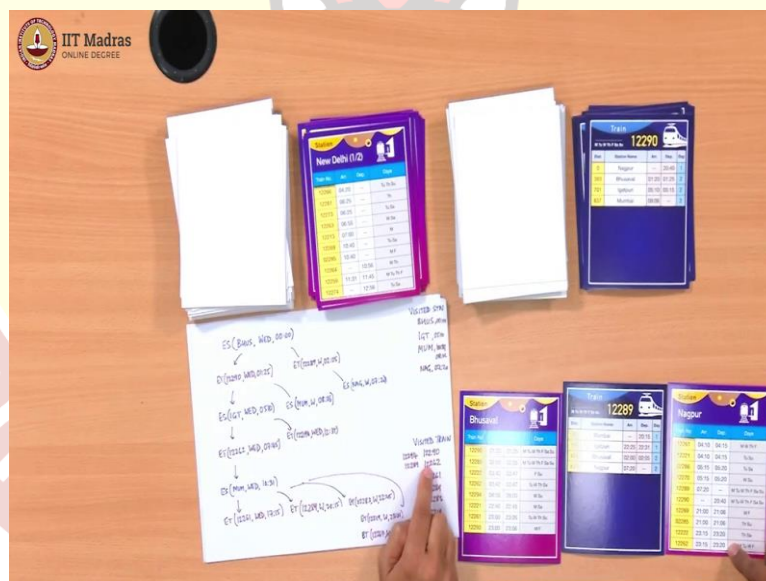
Professor G. Venkatesh: 07:20. On a Wednesday, so there is on Wednesday one train only actually; no there is one more. Anyway. So there is 12290, have you seen.

Professor Madhavan Mukund: Yeah. 12290, we have seen because that is going to go back to Bhusawal this next stop.

Professor G. Venkatesh: So it is nothing to do?

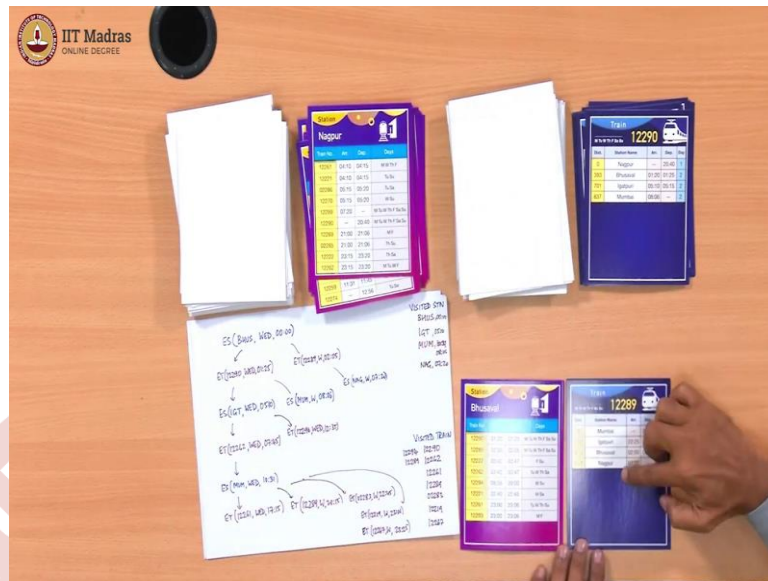Professor Madhavan Mukund: Yeah.

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Professor G. Venkatesh: And then Wednesday, 12262 at 11:20. Nothing much, we are likely to do here.

Professor Madhavan Mukund: And that also, we have seen actually.

Professor G. Venkatesh: You have seen that also. So Nagpur is done. Keep it back?
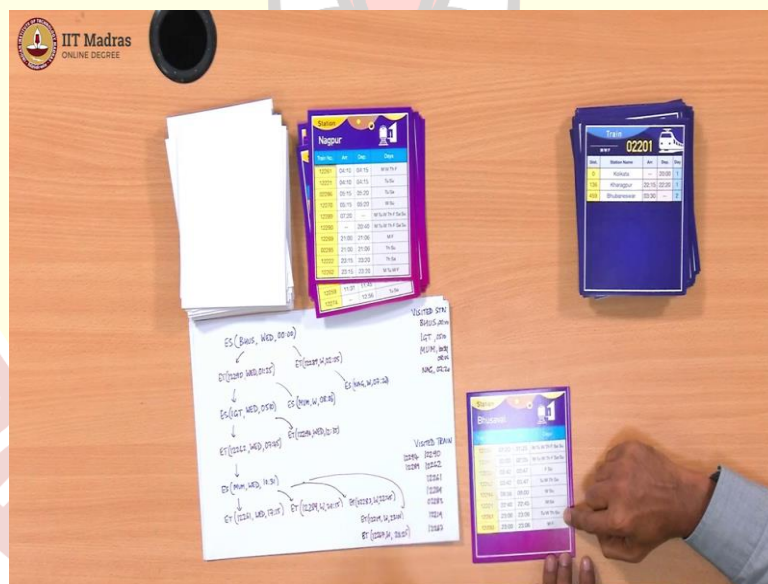
Professor Madhavan Mukund: Yeah, that is fine.

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Professor G. Venkatesh: And this is the last train, so this is also done. And then, come back to Bhusawal.

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Professor Madhavan Mukund: Bhusawal, and look at now the fourth train, 12262. But 12262, we have seen.

Professor G. Venkatesh: We have seen 12262?

Professor Madhavan Mukund: So that is done. Keep going down, 9 o'clock is 12294; that also we have seen. So there is nothing new here.

Professor G. Venkatesh: 12221?

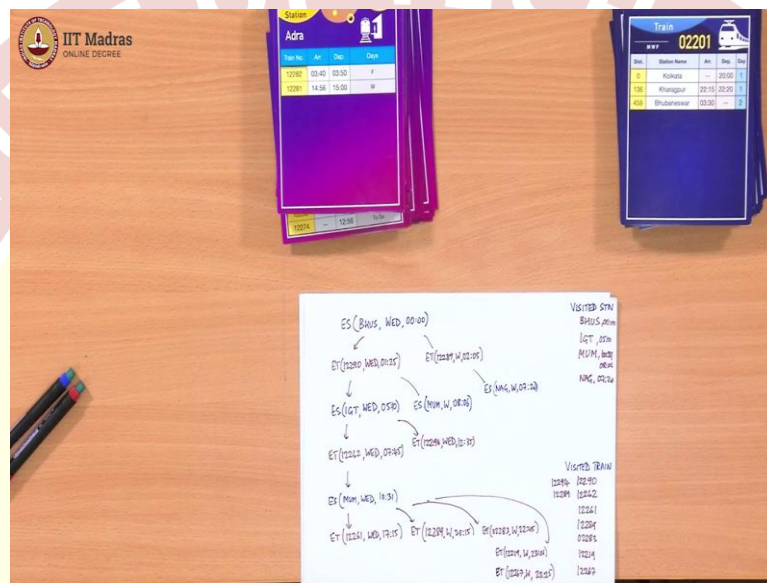Professor Madhavan Mukund: 12221 is there on a Wednesday?

Professor G. Venkatesh: No.

Professor Madhavan Mukund: 12261; that also, we have seen.

Professor G. Venkatesh: So we are done.

Professor Madhavan Mukund: That is it.

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Professor G. Venkatesh: We are back Bhusawal. So this is the tree. This is our depth first search tree.

Professor Madhavan Mukund: Yes. And in which we have alternately gone between trains and station.

Professor G. Venkatesh: Much cleaner, much cleaner. ES and ET, we did. ES, ET; ES, ET and what did we found? From Bhusawal, if you leave on Wednesday, in the midnight, which are the places you can see. You can go to Igatpuri, you can go to Mumbai, Nagpur; that is all. But you can see these many trains.

Professor Madhavan Mukund: These many trains you can see. So it is all both, in some sense, we can, on the way, you also pick up the train information. One thing we also said is now you have to be a little bit more careful about the visited station because we visited, then we visited earlier then there is a segment of that station, which we have to see again. So we had to keep track of the time from which we have seen it.

It might have come up even in the earlier example but we did not actually find these two routes reaching the station at two different times.

Professor G. Venkatesh: So I think the interesting thing about this is this mutual recursion. Sometimes it is much nicer to ride the trains.

Professor Madhavan Mukund: Yeah. So the station is helping the train and the…

Professor G. Venkatesh: Train is helping the station.

Professor Madhavan Mukund: And that is how the information is organized, so it makes sense. The neighbors of the trains are the stations and the neighbors of the stations are the trains. This is what we said earlier also. And that makes sense then to look at the neighbors directly rather than go through the neighbor to the neighbor. That is what we were doing earlier. So that is that is a good thing.