IIT Madras

ONLINE DEGREE

Computational Thinking
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Depth First Search (DFS) and Recursive Procedure Call (Part 2)

Professor Madhavan Mukund: Okay, so we have been quite successful at using this recursion to find reachable stations and trains we can take and all that. So one of the other questions we looked at for graphs was this mentoring graph.

Professor G Venkatesh: Mentoring as in…

Professor Madhavan Mukund: We said that one student can help another student

Professor G Venkatesh: If it is between 10 and 20.

Professor Madhavan Mukund: If they have 10 marks between 10 and 20 marks more.

Professor G Venkatesh: Both inclusive yes 10 and 20.

Professor Madhavan Mukund: And we were trying to find these groups, which could work in study groups…

Professor G Venkatesh: Study groups, so I say A can mentor B in maths…

Professor Madhavan Mukund: and then B can mentor C in Physics

Professor Madhavan Mukund: Yeah.

Professor G Venkatesh: And C again A in chemistry.

Professor Madhavan Mukund: Yeah, so these will be cycles…

Professor G Venkatesh: Cycles…

Professor Madhavan Mukund: So, now do you think we could try and use this idea of exploring this graph, so last time we were trying to find these cycles…

Professor G Venkatesh: It says because if you noticed what we did over there, we marked something as seen, so we came back…

Professor Madhavan Mukund: yeah, that is really a cycle.

Professor G Venkatesh: We take a note… a cycle.

Professor Madhavan Mukund: That is a cycle, yeah.

Professor G Venkatesh: If you if you start with a node mark it seen, and then you go around, and you come back to the same node, see a seen node. Actually, made a second.

Professor Madhavan Mukund: Made a second…

Professor G Venkatesh: And we are looking for cycles.

Professor Madhavan Mukund: Yeah. So we can actually use that property maybe.

Professor G Venkatesh: The only problem here I see is that there is a graph natural graph, there was a stations told you which trains to go on to, the trains told you which stations they are getting off at, so the kind of the linkage with a train station, station train gave us a graph.

Professor Madhavan Mukund: So here we have to…

Professor G Venkatesh: Here the graph has to be...

Professor Madhavan Mukund: Yeah, yeah, we love to build this graph.

Professor G Venkatesh: So basically, what we will have to do is we have to note…

Professor Madhavan Mukund: We do not have to make we will see,

Professor G Venkatesh: Okay.

Professor Madhavan Mukund: Probably graph we can make, right?

Professor G Venkatesh: Yeah.

Professor Madhavan Mukund: As we go along.

Professor G Venkatesh: Yeah. But then we will have to keep checking these mentorship things, right? That is what we were.

Professor Madhavan Mukund: It's painful.

Professor G Venkatesh: Yeah. Because everybody will have to keep checking everybody else. Whether you can mentor or not?

Professor Madhavan Mukund: Is a way to make it simpler, this taking of mentorship thing, instead of just searching all the cards that sorted it or something.

Professor G Venkatesh: Yeah, so you know that you can mentor a student and say in one subject, if that student is below, by 10, to 20 marks, but you also know that you cannot come back. Because that lower student cannot mentor the higher student. So once you have gone past a particular student, none of the students beyond that can mentor the earlier students. So if we could arrange the students…

Professor Madhavan Mukund: Then we can kind of, also we can look ahead and see…

Professor G Venkatesh: Look ahead and see…

Professor Madhavan Mukund: Who all are the mentoring case.

Professor Madhavan Mukund: So shall we arrange it? So this is the subset of the card, is it?

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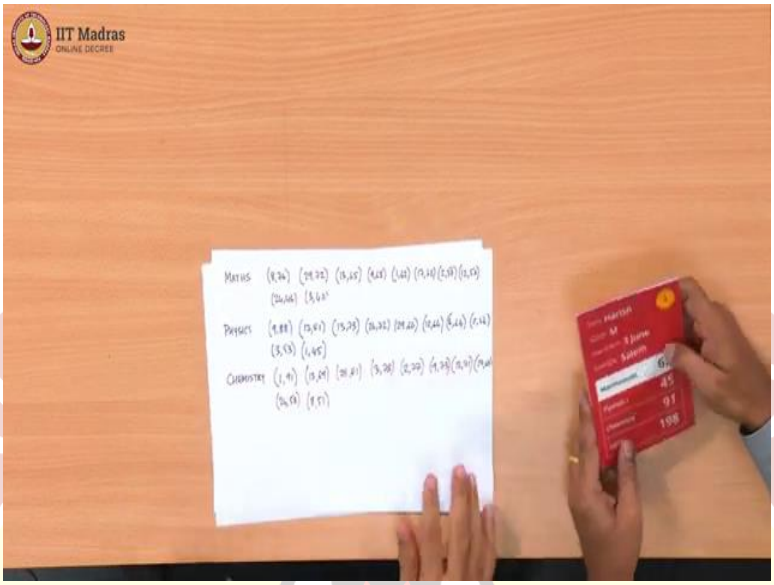

Professor Madhavan Mukund: Yeah, yeah, we take into some 10 cards here out of the 30.

Professor G Venkatesh: Some 10 random cards we have taken.

Professor Madhavan Mukund: So arrange it by, for each subject we want to know there is a mentor, so we want to arrange it in decreasing order…

Professor G Venkatesh: decreasing order…

Professor Madhavan Mukund: But we need to make different arrangements. Right?

Professor G Venkatesh: So we saw that right. So we are making three lists.

Professor Madhavan Mukund: Three lists out of this.

Professor G Venkatesh: And we'll keep the index.

Professor Madhavan Mukund: Index and we need the marks also…

Professor G Venkatesh: Marks also…

Professor Madhavan Mukund: Because we do not know how much there, so we will keep a pair they do.

Professor G Venkatesh: I think this is sorted by maths. All right. So this seems to be already sorted by maths.

Professor Madhavan Mukund: Yeah, so let us read Yeah, so let's just write on this thing.

Professor G Venkatesh: So maths list has 8, 74.

Professor Madhavan Mukund: Okay.

Professor G Venkatesh: 29, 72

Professor Madhavan Mukund: Okay.

Professor G Venkatesh: 13. 65

Professor Madhavan Mukund: Okay.

Professor G Venkatesh: 9, 63

Professor Madhavan Mukund: Okay.

Professor G Venkatesh: 1, 62 17, 62, 2, 57 12, 52, 24, 44.

Professor Madhavan Mukund: One second one second.

Professor Madhavan Mukund: 12, 52 Yeah.

Professor G Venkatesh: 24, 44.

Professor Madhavan Mukund: Okay.

Professor G Venkatesh: 3, 42.

Professor Madhavan Mukund: Okay. So there are 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 cards,

Professor G Venkatesh: Okay.

Professor Madhavan Mukund: So now we have to do the same thing with each subject. So we will have to…

Professor G Venkatesh: Do physics, but it is not sorted.

Professor Madhavan Mukund: So we will have to know sort it.

Professor G Venkatesh: So decreasing,

Professor Madhavan Mukund: Yeah decreasing order.

Professor G Venkatesh: Decreasing order okay

Professor Madhavan Mukund: 81 comes above 81, 73, 54 is here, 64 is there, 72 is here. 53 comes above 51. Okay…

Professor G Venkatesh: That is chemistry…

Professor Madhavan Mukund: Oh! That is chemistry let us just check, 88, 81, 73, 72, 66, 64, 54, 64, 54, 53, 45.

Professor G Venkatesh: So we again note down the…

Professor Madhavan Mukund: Yeah, so we will note…

Professor G Venkatesh: The index numbers.

Professor Madhavan Mukund: So we will note it. So, this is now physics marks

Professor G Venkatesh: 9, 88

Professor Madhavan Mukund: Okay.

Professor G Venkatesh: 17, 81.

Professor Madhavan Mukund: Yeah.

Professor G Venkatesh: 13, 73.

Professor Madhavan Mukund: Okay.

Professor G Venkatesh: 24, 72, 29, 66.

Professor Madhavan Mukund: Okay.

Professor G Venkatesh: 12, 64.

Professor Madhavan Mukund: Yeah.

Professor G Venkatesh: 8, 64.

Professor Madhavan Mukund: Yeah.

Professor G Venkatesh: 2, 54, 3, 53, so let us just check okay

Professor Madhavan Mukund: 1, 2, 3, 4, 5, 6, 7, 8, 9, I missed one.

Professor Madhavan Mukund: Just check, 9, 88, 17, 81, 13, 73, 24, 72, 29, 66, 12, 64, 8, 64, 2, 54.

Professor G Venkatesh: Yeah.

Professor Madhavan Mukund: 3, 53.

Professor G Venkatesh: Yeah.

Professor Madhavan Mukund: Well, there is one last one.

Professor G Venkatesh: 1, 45.

Professor Madhavan Mukund: This was the last one? Okay. And then we have to do the same thing for chemistry.

Professor G Venkatesh: Chemistry. So that is sorted. 73, 89, 58, 81, 64, 51, 77, 78, 91 right on top.

Professor Madhavan Mukund: So it is sorted

Professor G Venkatesh: Let us check it out, 91, 89, 81, 78, 77, 73, 67. Okay, as expected 71, 67, 58, alright.

Professor Madhavan Mukund: This is sorted.

Professor G Venkatesh: So 1, 91, 13, 89, 29, 81, 3, 78, 2, 77, 9, 73,

Professor Madhavan Mukund: one second. Yeah.

Professor G Venkatesh: 12, 71, 17, 67, 24, 58 and 8, 51

Professor Madhavan Mukund: Now, we have 10. Yeah. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

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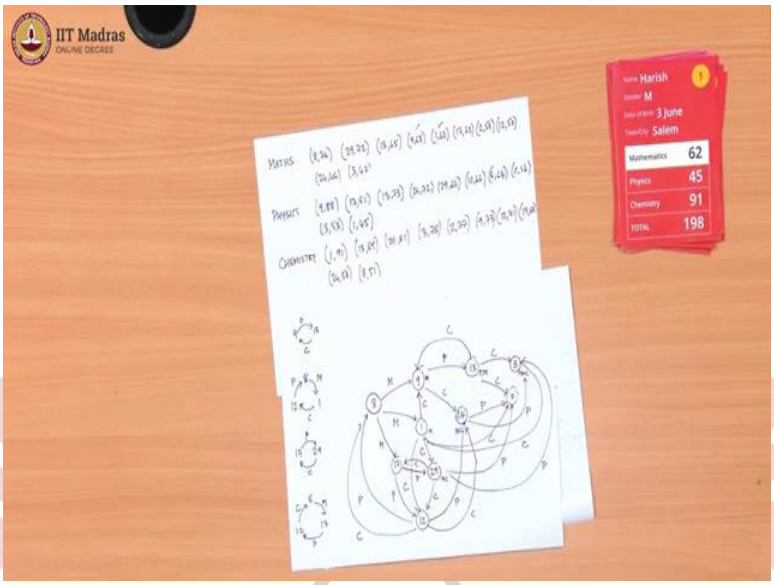

Professor Madhavan Mukund: So now we have this information. So what we want to do is start first by drawing this graph, right?

Professor Madhavan Mukund: So we want to construct this graph out of this information.

Professor G Venkatesh: We will do it as we go along, we will start doing it together.

Professor Madhavan Mukund: Yeah, So let us start doing it for such.

Professor G Venkatesh: So we start with 8, 74

Professor Madhavan Mukund: Yeah why not?

Professor G Venkatesh: So we start with 8, 74.

Professor Madhavan Mukund: So we just want to know a 8, card number 8

Professor G Venkatesh: I will put this thing in increasing order of cards now because easier to index search you know that.

Professor Madhavan Mukund: Correct

Professor G Venkatesh: 1, 3, 2, 9, 8, 24.

Professor Madhavan Mukund: 13 should come up.

Professor G Venkatesh: 13, Okay, so this is it.

Professor Madhavan Mukund: Okay.

Professor G Venkatesh: So find 8.

Professor Madhavan Mukund: Yeah, so no, so we will just start with 8. Right? So we start with card number 8.

Professor G Venkatesh: Card number 8.

Professor Madhavan Mukund: Yeah, so 8 is our first node in our graph…

Professor G Venkatesh: 8 is our first node…

Professor Madhavan Mukund: So now we want to know who all they can mentor in maths.

Professor G Venkatesh: So look at that…

Professor Madhavan Mukund: So anybody between 64 and 54.

Professor G Venkatesh: So go down the list.

Professor Madhavan Mukund: So 65 is too high. So it has to be 63, 62, so this up to 54, so these 4 people…

Professor G Venkatesh: So that is 9.

Professor Madhavan Mukund: So I will just…

Professor G Venkatesh: You draw that.

Professor Madhavan Mukund: So I will draw the arcs. So labeled m right?

Professor G Venkatesh: Yeah, so these are all labelled m marks. So this can mentor in maths number 9, number 1.

Professor Madhavan Mukund: So Strictly speaking, if you are doing DFS right, you should stop at this point and start 9

Professor G Venkatesh: Yes.

Professor Madhavan Mukund: So let us do so.

Professor G Venkatesh: Okay.

Professor Madhavan Mukund: So we will go to 9 and see who can 9 mentor…

Professor G Venkatesh: So you have to keep track that we are here. So this keep track that we are there.

Professor Madhavan Mukund: We are here. Right?

Professor G Venkatesh: And this?

Professor Madhavan Mukund: We should start yeah.

Professor G Venkatesh: So first we start searching 9.

Professor Madhavan Mukund: So 9 should we look at?

Professor G Venkatesh: We should not look at maths because we want to cycle and maths, we do not have any interest in maths yet. So we will go to…

Professor Madhavan Mukund: So, we will mark maths as seen or something?

Professor G Venkatesh: Something marked it. So saying that maths we have seen. So we now want to see only…

Professor Madhavan Mukund: Yeah. So let us put, I will put an M here saying that.

Professor G Venkatesh: You are carrying M?

Professor Madhavan Mukund: No, I am saying that M here is I have seen maths. I do not have carry.

Professor G Venkatesh: So you have seen that?

Professor Madhavan Mukund: Yeah. So we let us say look at physics,

Professor G Venkatesh: We can say first we will start at physics and then we will go to chemistry in that order.

Professor Madhavan Mukund: So physics, so 88…

Professor G Venkatesh: So physics at 88.

Professor Madhavan Mukund: So we want to look at somebody who is 10 marks below, the first one who is 10 marks below is 13.

Professor G Venkatesh: Okay, so we should just go straight to 13.

Professor Madhavan Mukund: So we will go straight to 13.

Professor G Venkatesh: Right?

Professor Madhavan Mukund: This is DFS, right?

Professor G Venkatesh: Yeah.

Professor Madhavan Mukund: And then here…

Professor G Venkatesh: We have both seen math and physics.

Professor Madhavan Mukund: And physics yeah.

Professor G Venkatesh: Carry both.

Professor Madhavan Mukund: Better.

Professor G Venkatesh: M, P you put.

Professor Madhavan Mukund: So now I have to see chemistry.

Professor G Venkatesh: You have to see only chemistry.

Professor Madhavan Mukund: So this is 13, so 89, so 88 sorry, 79, So 3 is there. That is my next one. Go to card 3,

Professor G Venkatesh: Go to card 3. We are building a graph as we go.

Professor Madhavan Mukund: Now, what should I put here? Because I have seen maths, physics, I have not seen a cycle, but maybe I should drop the maths and say let me look at the physics, chemistry cycle.

Professor G Venkatesh: At this point you have seen maths, physics, chemistry, and you have to see whether this guy can start 78 and whether we can get back to…

Professor Madhavan Mukund: Okay.

Professor G Venkatesh: That is what you have to do.

Professor Madhavan Mukund: Okay,

Professor G Venkatesh: so 3, 78, let us see where we go.

Professor Madhavan Mukund: Chemistry. 3, 78 in chemistry.

Professor G Venkatesh: We have already done it.

Professor Madhavan Mukund: Yeah that is right.

Professor G Venkatesh: So now we…

Professor Madhavan Mukund: So all 3 are…

Professor G Venkatesh: Yeah…

Professor Madhavan Mukund: So everything we seen.

Professor G Venkatesh: Yeah.

Professor Madhavan Mukund: yeah…

Professor G Venkatesh: This is not going to cycle.

Professor Madhavan Mukund: Not going to cycle…

Professor G Venkatesh: So go back…

Professor Madhavan Mukund: Yeah, so go back and see from 13…

Professor G Venkatesh: Go back to 13…

Professor Madhavan Mukund: So 13, we are looking at chemistry, so next one is 2 in chemistry.

Professor Madhavan Mukund: And again, we are finished a bit so it is not, we have not seen a cycle.

Professor G Venkatesh: Unless you come back to 8.

Professor Madhavan Mukund: Yeah.

Professor G Venkatesh: Or nine.

Professor Madhavan Mukund: Yeah…

Professor G Venkatesh: So either 8 or 9 is there?

Professor Madhavan Mukund: Yeah 89, so next is 9. That is within 16 marks.

Professor G Venkatesh: Oh, it is. Alright, very good

Professor Madhavan Mukund: So here we found one cycle right?

Professor G Venkatesh: Again 9, what happened in 9? 9 chemistry?

Professor G Venkatesh::

Professor Madhavan Mukund: Yeah. So, so from 13…

Professor G Venkatesh: Chemistry, brought you back to 9.

Professor Madhavan Mukund: Brought me back to 9 because this is a difference of 16 marks.

Professor G Venkatesh: Oh, we got a cycle.

Professor Madhavan Mukund: So we got to a cycle, Okay.

Professor G Venkatesh: We will note down this cycle.

Professor Madhavan Mukund: We will note down the cycle. Right? So we note on a cycle saying 9.

Professor G Venkatesh: Crazy stuff. We can find all the cycles in this.

Professor Madhavan Mukund: Yeah.

Professor G Venkatesh: Okay, let us try. Let us try a little bit more.

Professor Madhavan Mukund: Let us search a little bit more.

Professor G Venkatesh: Yeah, you are done with 13.

Professor Madhavan Mukund: We are done with 13

Professor G Venkatesh: Now we come back to 9.

Professor Madhavan Mukund: Come back to 9 and we say from 9 instead of, we do not look there. We…

Professor G Venkatesh: We do not have to…

Professor Madhavan Mukund: Because we know that 9 is here. So now we have seen 9…

Professor G Venkatesh: Okay.

Professor Madhavan Mukund: In physics. So we look at 9 in chemistry now. We could find a maths, chemistry physics cycle…

Professor G Venkatesh: Okay, okay. Okay.

Professor G Venkatesh: So we have seen maths.

Professor Madhavan Mukund: Yeah.

Professor G Venkatesh: We did not look at physics.

Professor Madhavan Mukund: Yeah. So now I am going to.

Professor G Venkatesh: Now we will come back to 9 and look at chemistry.

Professor Madhavan Mukund: Yeah. So now we look at chemistry edges out of 9. So chemistry…

Professor G Venkatesh: This is enough?

Professor Madhavan Mukund: Looks like.

Professor Madhavan Mukund: So 73, so we have to go to 63 so this, this 67 here so 24 and 8.

Professor G Venkatesh: 24 and 8.

Professor Madhavan Mukund: Okay, so 24 is here. It is a new thing.

Professor G Venkatesh: That is enough I think.

Professor Madhavan Mukund: That is enough. So now we have at 24 we have seen maths…

Professor G Venkatesh:: So I do not have these cards.

Professor Madhavan Mukund: Yeah, I think the card we do not need anymore.

Professor G Venkatesh:: I just captured it. Alright? Super.

Professor Madhavan Mukund: So 24 is caught, we have reached with maths and chemistry, so we need to look at physics edges from 24. So we go to 24 here, look for physics edges, so 72, so 62. So that is 2 which is a new node, so we are going to stop. Actually we have a 2 here, so I should just do this.

Professor G Venkatesh: Okay,

Professor Madhavan Mukund: so this is physics, and 72, so we can go up to 52. So one more edge 3. So this also there, but there is no cycle,

Professor G Venkatesh:: There is no cycle. So…

Professor Madhavan Mukund: So…

Professor G Venkatesh:: 24 is done.

Professor Madhavan Mukund: 24 is done. So this was from 9. Right so we are looking at 9 chemistry.

Professor G Venkatesh:: 9 we did physics, 9 we did Chemistry.

Professor Madhavan Mukund: Yeah. So 9…

Professor G Venkatesh:: So…

Professor Madhavan Mukund: No, no we did 9 we have one more I thing. So 73, so we can go down up to 53.

Professor G Venkatesh:: Yeah.

Professor Madhavan Mukund: 58 no, this is 51, so I cannot come back here. Okay, so 9 is done.

Professor G Venkatesh:: 9 is done. 9 both physics and chemistry are done. We cannot do maths because maths is over. So they are finished with 9. So we go back to 8.

Professor Madhavan Mukund: And now we look at 8 is next.

Professor G Venkatesh:: 8 is next…

Professor Madhavan Mukund: Which is 1, so I will put 1 here. So now 1 way again start with physics so I will mark a maths here. So 1 is right down, 1 cannot mentor anybody in physics, so that is dead. Then we can do 1 chemistry. So 1's chemistry is high. So in chemistry, 1 can mentor 29…

Professor G Venkatesh:: 21 to 29.

Professor Madhavan Mukund: 29. So 29.

Professor G Venkatesh: We many possibilities chemistry.

Professor Madhavan Mukund: So now we go back, now we want to look at 29 for physics.

Professor G Venkatesh: We have finished maths, we have finished chemistry, only physics is left.

Professor Madhavan Mukund: Yeah, so 29 physics has 66 marks so 56 onward, so 2 is a possibility.

Professor G Venkatesh: 56 onwards till 46. We have 2 possibilities here.

Professor Madhavan Mukund: So two and but that is another node so he stopped there and 3, so they can all mentor 3 and 2.

Professor G Venkatesh: Again other node so stop there.

Professor Madhavan Mukund: Yeah. So 29 is done.

Professor G Venkatesh: 29 is done. Okay.

Professor Madhavan Mukund: So we started at 1, we had 29

Professor G Venkatesh: You are done at 29 chemistry, you are not done 29 physics. Okay physics we are done, chemistry we are done. But you can come back here, 29 and instead of maths, this is chemistry, right?

Professor Madhavan Mukund: Yeah. Correct.

Professor G Venkatesh: You did not mark it.

Professor Madhavan Mukund: So we have a look at physics only.

Professor G Venkatesh: I come back to M, come back to 1.

Professor Madhavan Mukund: Yeah and look at the next chemistry…

Professor G Venkatesh: Physics…

Professor Madhavan Mukund: Next chemistry.

Professor G Venkatesh: Next chemistry is still there.

Professor Madhavan Mukund: Yeah, so 91, 81, 78 so we can go up to 71. So there are a lot of people, these five guys are there. So 3 is there. So that is also now a long…

Professor G Venkatesh: But you can continue there.

Professor Madhavan Mukund: Yeah and now I continue because I am not reaching it after 3 hops. Yeah, I can now come to chemistry here and I can ask whether 3 can do anything in physics.

Professor G Venkatesh: Physics.

Professor Madhavan Mukund: 3 cannot do anything with physics.

Professor G Venkatesh: Okay.

Professor Madhavan Mukund: So we are done.

Professor G Venkatesh: So we are done. So, come back,

Professor Madhavan Mukund: Come back. So now…

Professor G Venkatesh: Come back to 1

Professor Madhavan Mukund: Come back to 1 and now we look for…

Professor G Venkatesh: Next in chemistry

Professor Madhavan Mukund: 2 so now we come…

Professor G Venkatesh: Here again, there is possibility to proceed beyond 2.

Professor Madhavan Mukund: This is again chemistry,

Professor G Venkatesh: So 2 in physics.

Professor Madhavan Mukund: So 2 in physics again…

Professor G Venkatesh: 54.

Professor Madhavan Mukund: 54 nothing can be done.

Professor G Venkatesh: So 2 is closed.

Professor Madhavan Mukund: So 2 is closed, so we come back to 73, 9. So now we have from here, we have a side edge, an edge going backwards and chemistry.

Professor G Venkatesh: Okay.

Professor Madhavan Mukund: But from 9 we have already seen all the physics edges.

Professor G Venkatesh: We have seen all the physics edges.

Professor Madhavan Mukund: And then we come to….

Professor G Venkatesh: So we come back to 1…

Professor Madhavan Mukund: And the last one is 12. So this is a new node, which we have not seen before. So we have a chemistry edge to 12. Now we have to look at physics ages from 12, 12 is 71 so 61 so 12 can go to 24 and to 8.

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Professor G Venkatesh: Can 71 fill just about 24 and 8.

Professor Madhavan Mukund: So I can come here…

Professor G Venkatesh: 24 is here.

Professor Madhavan Mukund: Yeah just let me draw it in blue just to make it so this is a physics edge and 8…

Professor G Venkatesh: So maths, chemistry, physics. No look.

Professor Madhavan Mukund: Yeah, but here we have a physics edge to 8.

Professor G Venkatesh: 8 is a here no look…

Professor Madhavan Mukund: No, no 8 is where we started

Professor G Venkatesh: Okay we came back.

Professor Madhavan Mukund: Yeah.

Professor G Venkatesh: Excellent. Wow. Oh, that is nice. Oh, maths 8 to 1 maths,

Professor Madhavan Mukund: 1 to 12…

Professor G Venkatesh: 1 to 12 chemistry and 12 to 8 physics.

Professor Madhavan Mukund: Yes.
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Professor G Venkatesh: Really good.

Professor Madhavan Mukund: So 8...

Professor G Venkatesh: This depth first search is a….

Professor Madhavan Mukund: Oh, yeah.

Professor G Venkatesh: Yeah.

Professor Madhavan Mukund: Right. So 1 to 12 chemistry, 12 to 8 physics.

Professor G Venkatesh: Nice. Yeah. But the thing will make sure that we get everything.

Professor Madhavan Mukund: Yeah.

Professor G Venkatesh: It will search for everything it is just systematically…

Professor Madhavan Mukund: Yeah, it is looking for every possible thing and then wherever we see a cycle will spot it. So like we can continue doing this if we wanted.

Professor G Venkatesh: So we will draw 17 and so on.

Professor Madhavan Mukund: So the next one would have been 17 here which is new I think.

Professor G Venkatesh: Then we would have to look at 17 maths.

Professor Madhavan Mukund: Yeah 17 via maths, so then, of course, we will have to go back to 8 and look at physics and chemistry also. So there will be a whole new set of things, but from 17 if we look at physics, then 81 so it has up to 61, 71 to 61 so they are these three guys 29...

Professor G Venkatesh: 12 and 8.

Professor Madhavan Mukund: So this is to physics. But we have not seen…

Professor G Venkatesh: Chemistry

Professor Madhavan Mukund: Chemistry edges from 29 are there, we should look at 29 chemistry edges.

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Professor G Venkatesh: So from 71 to 60, 71 to 61, so all of these guys 71 to 61.

Professor Madhavan Mukund: Okay, so 12 is 1, so this is a chemistry edge.

Professor G Venkatesh: And then 67…

Professor Madhavan Mukund: So it is right here, there is a small cycling here, so 17 itself…

Professor G Venkatesh: 17 to 29 to 17.

Professor Madhavan Mukund: Yeah 17 to 29 on physics and back on chemistry. Okay.

Professor G Venkatesh: That is it. 71 to 61.

Professor Madhavan Mukund: 29, 71 to 61 only 2 yeah.

Professor G Venkatesh: So we are done with 29 chemistry we have explored.

Professor Madhavan Mukund: Yeah…

Professor G Venkatesh: So…

Professor Madhavan Mukund: From 17 we were looking at physics. So 17…

Professor G Venkatesh: So 17 with chemistry you have to try.

Professor Madhavan Mukund: No, no 17, 29 no there is 2 more 12. So 12 is again a physics edge here. Okay. So from 12, we have not done chemistry, but 12, 71 to 24 is there on chemistry and 12, 71…

Professor G Venkatesh: 24 and 8 both of the…

Professor Madhavan Mukund: 24 and 8. So 24…

Professor G Venkatesh: You have seen 24.

Professor Madhavan Mukund: Okay. But look at this, we have got another cycle coming back with another study cycle involving 8, it looks like.
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Professor G Venkatesh: Which is 8, 17, 12…

Professor Madhavan Mukund: Yeah. So we have 8, goes on maths to 17, goes on physics to 12 and comes back on chemistry to 8. So 12 and 8 can pair up with either 1 or with 17.

Professor G Venkatesh: Nice, you can go on like this. I mean, we do not have to finish it. But I think the general idea is very nice. Now we are trying to call it, it is a procedure, right? There is a recursive procedure. What are we doing? I mean, what is the procedure?

Professor Madhavan Mukund: So we are at the top, we are doing this depth first search on the nodes…

Professor G Venkatesh: It is called a DFS,

Professor Madhavan Mukund: DFS, and we are also…

Professor G Venkatesh: But the graph is not there, finding the graph.

Professor Madhavan Mukund: It is finding the graph as we go along…

Professor G Venkatesh: And…

Professor Madhavan Mukund: And it is also finding every time we see a cycle, instead of just saying I have stopped. I also read of…

Professor G Venkatesh: If we are carrying the, also of the DFS, we are carrying the things we have seen.

Professor Madhavan Mukund: Yeah, so we have to actually keep track of that path to this current node.

Professor G Venkatesh: So should we write it? I will just try writing it, so what does it look like? We are calling DFS, it is called a DFS simply.

Professor Madhavan Mukund: Yes.

Professor G Venkatesh: So we call DFS with a node, with a card index right? a card ID.

Professor Madhavan Mukund: Yeah. So when we come in we are keeping track of two things right, we are keeping track of which, so we are never looking at paths which are more than three long first of all.

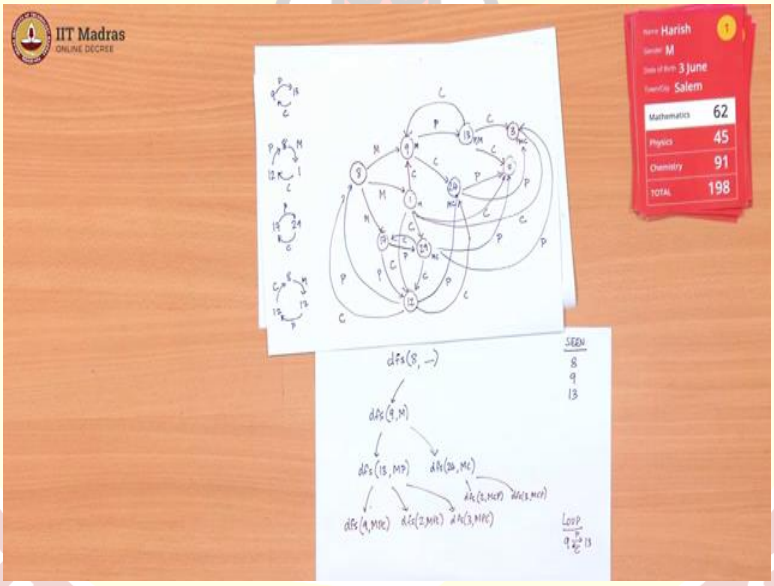
Professor G Venkatesh: That because we are keeping, if you pass the MPC, MPMC…

Professor Madhavan Mukund: Yeah,

Professor G Venkatesh: You can return.

Professor Madhavan Mukund:Yeah. So we are keeping track of the last two nodes, we have seen…

Professor G Venkatesh: Last two…(Refer Slide 22:43)



Professor Madhavan Mukund: And the last two subject subjects you see. So we can sort of think of it as so one way of thinking of it…

Professor G Venkatesh: Why do we need to keep track of the nodes because the marked as seen.

Professor Madhavan Mukund: Yeah. Well seen.

Professor G Venkatesh: We have marked it as seen, because we will go back to the node.

Professor Madhavan Mukund: Yeah.

Professor G Venkatesh: So if you keep a scene like we did earlier.

Professor Madhavan Mukund: Yeah.

Professor G Venkatesh: And put the node numbers.

Professor Madhavan Mukund: Okay, so let us do that. We will put a…

Professor G Venkatesh: And you carry in that recursion, when you are doing the recursion, you carry the MPC string, let us say.

Professor Madhavan Mukund: Okay.

Professor G Venkatesh: You carry 3 letters. 1 you can carry can, carry empty, empty. This initially it will carry with empty.

Professor Madhavan Mukund: Yeah, so I start DFS at 8…

Professor G Venkatesh: With empty

Professor Madhavan Mukund: With nothing. I just put it blank. Okay. So now 8 called 9

Professor G Venkatesh: 8, called 9. DFS 9 with M.

Professor Madhavan Mukund: Having seen M, so now I can only do pm. So then 9 called 13 with P

Professor G Venkatesh: So now you have both M and P in it. So DFS called 13 with M and P and then

Professor Madhavan Mukund: 13 called 2 and then we stopped…

Professor G Venkatesh: 13 was for 9 actually and then it formed a loop.

Professor Madhavan Mukund: Okay so…

Professor G Venkatesh: It is also the put C we have to enter C.

Professor Madhavan Mukund: Yeah…

Professor G Venkatesh: You saw 8 you put up 8.

Professor Madhavan Mukund: Yeah, so 8, I should have put here 8 and 9 then 13.

Professor G Venkatesh: So it called DFS when it called DFS 8,

Professor Madhavan Mukund: 8 is seen.

Professor G Venkatesh: So that is a loop.

Professor Madhavan Mukund: 8 or 9, 9, 9. Sorry. Yeah. So it called 9 with MPC…

Professor G Venkatesh: MPC .

Professor Madhavan Mukund: And since 9 is seen, we saw a loop. So we will go back, like suppose we can go back and figure out…

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Professor Madhavan Mukund: Yeah…

Professor G Venkatesh: What is on that loop? And then it also, so at this point, we so maybe we should also maybe…

Professor Madhavan Mukund: Make lists, list of loops.

Professor G Venkatesh: Yeah. Yeah. So we could have gone back and seen that that was a physics edge and this was a chemistry edge, so this. Yeah. So we could record this. Now we go back to 13, and it is always 2 and 3. But there because they were different and we have run out of anytime we reach a node…

Professor Madhavan Mukund: Which is…

Professor G Venkatesh: Which all three letters are there….

Professor Madhavan Mukund: Nothing to do…

Professor Madhavan Mukund: We cannot proceed. So we will just stop.

Professor G Venkatesh: Right?
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Professor Madhavan Mukund: Came back 13.

Professor G Venkatesh: 13

Professor Madhavan Mukund: Nothing to do, came back to 9.

Professor G Venkatesh: 9, so now 9, we were looking to see if there any more physics edges and…

Professor Madhavan Mukund: Physics, nothing to do.

Professor G Venkatesh: Nothing was there.

Professor Madhavan Mukund: Physics over to next.

Professor G Venkatesh: So now we got chemistry. Right, so then we said 24…

Professor Madhavan Mukund: So we called 9…

Professor G Venkatesh: From 9 we call 24 with M and C and then from 24, we called with M and C and now we can only call with P and we ended up again at 2.

Professor Madhavan Mukund: So again it is all MPC is seen.

Professor G Venkatesh: Yeah.

Professor Madhavan Mukund: No loop. Yeah.

Professor G Venkatesh: And

Professor Madhavan Mukund: So like this, we are creating, again, you are getting a tree.

Professor G Venkatesh: Yeah,

Professor Madhavan Mukund: The spanning tree of this graph.

Professor G Venkatesh: Yeah.

Professor Madhavan Mukund: It is a very complicated graph. Tree looks much easier to understand.

Professor G Venkatesh: Yeah.

Professor Madhavan Mukund: And then we go back, and so on. And every time we see a loop we spread it out. So this our tree.

Professor G Venkatesh: So technically, this, because we are keeping the sequence this 3 with MPC is different from the 3 with MPC. But yeah, so again, but I think the key thing the interesting thing here is that this there was no natural graph.

Professor Madhavan Mukund: Yes, we were building the graph…

Professor G Venkatesh: Building the graph as we get along and in fact actually you do not need to build…

Professor Madhavan Mukund: Yeah, and to build the graph, we actually do it efficiently we use this sorted list so that we could quickly find out who the neighbors are. Because it is kind of implicit the graph is not actually part of our… Yeah, so it is not that like the trains as you said, the trains and the stations they list the neighbors directly. Here we have to figure out the neighbors by looking at the marks thing and then instead of going back each time and looking up say otherwise, every time we look up, pick up a card, we have to go through all the cards and find out who all 10 marks away or 20 bucks. So once and for all if we arrange it in sorted order, we can find that out by quickly looking up this.