Artificial Intelligence
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Lecture - 17
Population Based Methods II

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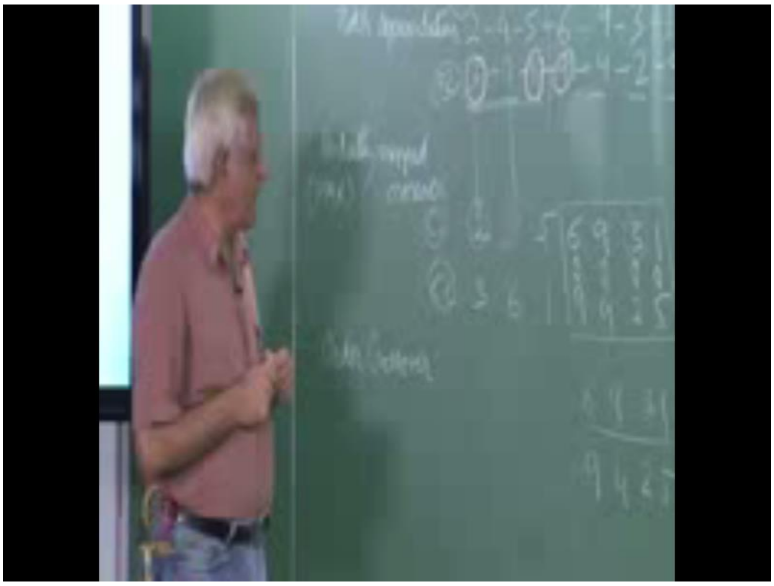

Genetic algorithms and we want to look at GAs for solving TSP. So, as you know the TSP of the travelling salesmen problem the problem where you have to have Hamiltonian cycle b in which you visit every city exactly once and come back to the original cities essentially and 1. So, for example, if you have 9 cities you may have representation which is that you start with 2. And you go to 4 and you go to 5 and you go to 6 and you go to 9 go to 3 1 7 and 8. So, this could be 1 to a and since I am doing JAS. I may want to take 2 to us and try to see how I can generate new to us after that? So let us I another to so let to say this is 3 7 some 2 to as have had mention this problem earlier that how do you now, device cross over operators for the TSP problem? Because you cannot do a single point or multi point cross aver have for the simple reason that supposing have what a do of cross over some point then I 2 a would be 2 4 5 6 4. Now, I able to came back 4 which means I close the loop earlier and so I come do a simple thing like that.

So they at 2 questions we want to look at. One is that given this representation and this representation is called the path representation. Because if all the told represented by path and it is implicit that from the last city in the path you come back the first city. If you means start with 2 4 5 6 9 3 1 7 8 and come back to 2 if I rotated this by certain all would see the same to. So, that the 2 question we want to ask is what the representation to choose and secondly what cross over function to device all for that would the TSP is problemise we said which your very interest many people, because it is got estimated many practical application as will. And people would like to good get good solutions of TSP problem what about the valuation function? As a simple function in this case which given a 2 you can the order commutates cost an you can use valuation function keeping in mind that it is a minimization problem that you want to minimize total cost. So, you have to work out the problem will it is for selection in a care full fraction which I inversely proportional to the cost how is it to solve the problem?

Because a very of a you can find representation and it help use all the problem very quickly essentially. So, let me try out a small game with you. So, the game is that that say you and I playing this game and we have to divided this 9 cities between us. And we get to choose city by city so forget of the cost to a cost nothing to do here this is the different game. And the game is the following they give choose a city and I choose city then you choose a city and I choose a city and so on. The first person to pick up 3 cities exactly which is adder to 15 men’s again so nothing do with that your cost just a do with city labels in the labels are 1 to 9. So, how would you play this game? Let me say I choose you choose something I choose 5 when will be look at my representation so your choose on what 8 I choose 5 you will choose a 1 which will n1 that i to a chosen 8 and 7.

Student: I chosen 5 and 4 you on some of 3 city 15 not 2 cities.

Any 3 cities you pick up any 3 cities.

Student: You cannot choose 7 I would suppose game we cannot 7 will start again you start 4.

I choose 6

Sir: I choose 2, I already chosen 6.

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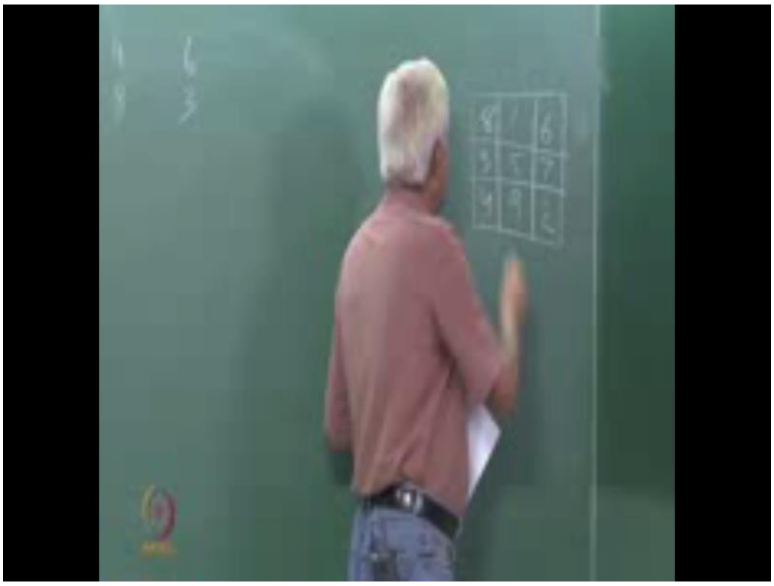

So you choose 4, I choose 6 any choose 5.

Student: no 5 not 5

You set pick 8; you choose 8 then your forcing will choose 3 anyway the point is not to spend the whole class they in this game. But discuss at that I do not know what can of is in your doing but, they can of is in I was doing is shown by this figure. That I created this you recognize this it is a magic who some is 15 and what I was doing? I was playing cross a cost I do not worth came you’re playing something you a doing with. So, what the point of the whole thing is the representation of and helps solve the problem. Especially if in some situation you have knowledge related to some mapping that you can create with representation. So, will look at representation here also, ideally we would like to have a representation in which I can do single point cross over for TSP. But this is not that 1 an there is 1 representation in which we can do single point cross over, but will come to that later. So, let us look at the various cross over that people have tried working with TSP is a GAs and if you just look of the were will find quite of your. Now, while devising cross over 1 thing 1 should keeping mind is at if should be nice if you can device cross over which would allow us to carry forward good feature of 2 hours.

So for example, 2 hour have me features such that some cities thing of cities which away close each other are covered one by one in that order. And that would be nice feature if in carried forward from 1 parent to a child to be nice. So, let us look at some cross over's so 1 cross over which is called partially mapped crossover also call PMX workers follows. That you choose 2 random points this is p 1 and this is p 2 so a choose 2 random points lets a this 1 and this 1. Let me choose 1 here then first you copy whatever is their between those 2 points so you have I would not draw the segment know 6 9 3 1 here and 9 4 2 5. So, this is parent 1, parent 2 this is child 1, child 2 your trying bill. So, first part some part of the solution in this copy in to the child is respective child.

Now, remaining the part solution I really would like to get something from the other parents. So, in partially max map crosser mapping between this city's 6 and 9, 9 and 4, 3 and 2 and 1 and 5 can use this us following. Now, remember this see 1 which is got part of the 2 a from the first parent and you on the next from the other parents. So, you try to copy the less so what are the less? Remaining is 3 7 1 and 6 8 so you try to copy 3 here in to this so this is c 1 in this c 2.

We find to c 1 can we want to get things for this is p 1 and hence p 2. We are try to know copy things in to c 1 from p 2 so we are try to copy 3 with 3 we cannot copy, because 3 already exists in this. So, what this appropriate that follow the point from there so from 3 go to 2 and copy 2 here so we get 2 here. This is the class of this possible operators if you let you a repeat this you are try to copy this 3 here, but you cannot copy 3, because 3 already exists in this child. So, you follow this point a from here and take 2 so you copy to 2 here then you want to copy 7 here from here that is if you copy 7 here 1 you cannot copy so if follow the point at to 5 and you get 5 here. Then 6 you cannot copy, because 6 is here the follow the point got to 9, 9 you cannot copy, because 9 is here follow he point at 4 an 4 can be copy it here. And that is 8 anyways with does not matter. So, this is the partially mapped cross over and I just illustrated to this example and these the algorithms for you to like. So, let me us repeat the example this part of the 2 are is common to the parent. So, this c 1 gets this from p 1 an c 2 gets this from p 2. The remaining part of the 2 which is 2 7 5 4 8 it is got from this process. The right to copy with 3 here, but I cannot copy 3, because 3 is already in might to so a follow the point if from 3 2 this is the mapping that we a talking about partially mapped process.

So, the mapping is between these set of cities that you can instead of 3 you can place 2 so and this copy the actually both piece when you do the others city you would do a similar process. So, because I could not copy 3, because already there I go to 2 I am allowed I can copy to 2 here than 7 I can copy directly. Because the does not interfere with anything 1 I cannot copy, because it is here so I got to 5 and copy that. And then 4 6 I cannot copies of 6 I go to 9, but 9 already here of 9 go to 4 9 get 4 here and 8 here. So, let us to the other 1 just complete the example. So, I want to copy 2 here, but I cannot copy 2 I go to 3 and I can am allow to copy with 3 here than 4 I cannot copy here. Because its sales I go to 9 I cannot copy 9 so I go to 6 I can copy 6. Then 5 I cannot copy, because 5 is here I copy 1 here from the mapping then 7 I can copy directly and 8 I can directly. As this process as a given only these 2 children from this to parents. The keep into many device is crossover operators is see that the resultant things at you have are valid to us the and the whole idea is try in device cross over which are valid to us.

Another popular cross over to be slinks is the order cross over. And it works as follows that that like in this crossover you copy first some things 6 9 3 1 9 4 2 5. And for the remaining part you take the slinks in the order in which they appear in the other parent so what do I mean by that? That basically I want all the cities to appear in my 2 out of this, but I want to select them from the second parent now.

But I got 6 9 3 1 from the first parent so in my first parent I already have for this 9 6 3 and 1 this 4 I already got and what this already crossover is that for the remaining cities which I want which is 7 4 2 5 and 8 I simply copy them in the other in which appear in the other parents. So, for example, I can simply an added this in 7 4 2 5 8 how do can this? 7 is here 4 is here 2 is here 5 is here 8 is here. So, in the order in which occurred in the other parent I copy them in to this new child. So, this child is got have the 2 are from its first parent and the remaining 2 are somehow it is got from the other parent with I self good crossover not you should think about this an may be ((refer time: 16:38)). Let us say another representation anything of another representation for the traveling salesman problem. I mean this is the simplest representation the past representation it tells you from which city to go to with city an so an this is that self representation.

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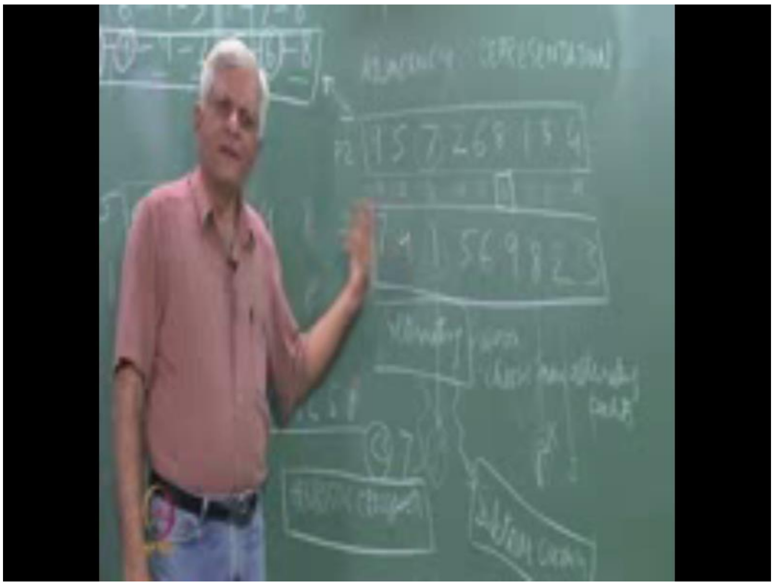

So, there is one representation which is called ordinal representation and another 1 which is called adjacency representation. Let us do the other 1 first and this works as follows that I created representation for this to find something 3 7 1 9 4 2 5 6 8 and it work as follows. That we haven index this is as index in my representation and the value that is a told for each sell in the value that I would go. So, you if i is a index which is one of the value. Then the value that I will tell is the city that I will go to from higher cities. So, if I just look at this to this too is 3 7 1 9 4 2 5 6 8 from 1 I am going to 9. So, I have 9 here then from 2 I am going to 5 I have 5 here. From 3 I am going to 7 here, from 4 I am going to 2, from 5 I am going to 6. From 6 I am going to 8, from 7 I am going to 1, from 8 going to 3 which is the first 1 from 9 I am going to 4. So, this representation is called as adjacency representation this a different representation of a too are ((refer time: 19:33)). So, you got if how we got this representation? So this is the representation of with this 2 only same as this to its us senses the representation is different. This choice I that I am going from 3 to 7 to 1 to 9 to 4 to 2 to 5 to 6 to 8.

This representation says that you tell me any city and I tell you where to go from that city. So, if you tell me city 3 where you going from 3, so look at this index 3 you say going to 7 where you going from 6 you going from 6 to 8. So, if you see a 6 to 8, so these a different is a called adjacency. Now, every not every premonition is a legal adjacency representation so let me given example. Supposing I want to represent something like this you go to 2 from 1 and you go to 1 from 2 and so on. Now, obviously, formation of number 1 to 9 I have shown you formation the I do not care what is the rest I am saying the this is not a valid told. Because from 1 you going 2 according to this is the index from 1 you going 2 from 2 you a going to 1 so already done know in this cycle so it cannot to be part of a. So, not so is my poser to you in the past representation every formation in the value to a in adjacency representation is not every formation in the value to so is an in conscience here I am losing out on some 2 hours here.

So, if will member that in the past representation if I what a located this representation by cycle of any length. For example, I would start with 4 2 5 6 8 3 7 1 9 then I would get same to our back which is the different formation, but the same 2 hours essentially where is every 2 are has a unique representation in the adjacency representation. Whereas, to be may in 9 city to a you a start from any other 9 cities and that would be still the same to ((refer time: 28:17)). Now, given the adjacency representation so again of will it as this is the index can you thing of a crossover. Given 2, 2 as adjacency representation can you know exploit this fact that you know that from this city 1 parent is going to 1. So, let us to the other 1 in the other 1 you going from 1 to 7 from 2, 4 from 3 to 1 from 4 to 5 from 5 to 6 from 6 to 9 from 7 to 8 from 8 to 2 and from 9 to 3 S. I have this to 2 us in the in the first to this is p 1 and this p 2 the different adjacency representation work and of a customer of at any think of.

Especially if you want to ensure that one of the child is at least a better child better than the parents look as a 1 once simple crossover operator it is called alternating crossover. And we basically says that all alternating cities you pick the parent from the you pick the next city from the different parent alternating parents. So, choose from known parents so that construct 1 2 so you choose let us say the first so you a constructing lets a c 3 another child we choose the first 1 from p 1. So, this say you are going to 7 from 1, we a going to 7 then from 7 where are we going to go 1 city says go to 1. And other city says go to 8 essentially from 7. So, here we cannot choose 1, because if at know you can choose 1 in other problem we choose know you cannot choose 1. If you go for 1 to 7 and from 7 to 1 in you already in cycles so you cannot choose 1. So, at this point you only to choose 1, but you are not to allow choose 1, because it is form a cycle you can either choose other parent or you can make an random choice so people if I both of something.

So, the basic idea in alternating crossover is to try and choose as you construct that the parent from alternate all the next city from the alternating parent. And if you cannot then you to result to some 10 of random process any things next so either you can u use 8 here or you can choose random process. So, let us say we choose 8 here and than we say for the next 1 from 8 you go to 3 choose from the other 1 you put 3 here. And then from 3 choose from the first parent you 1 go to 1 so you go to 7 you 1 go to 7 so you choose something random. So, you can see that neither of them can come here, because if you go to choose 1 here then you saying form 1 go to 7, from 7 go to 8 from 8 go to 3 and from 3 go to 1. So, that is so cycle that you do not want to form and for the single reason you we any way you cannot go to 7 from 2 cities so you can put 7 there so you would put 7 random value here. You can the exchange this idea in say the alternating you can say subtour crossover.

So, thus as be selected subtour to here in both these example you can say choose a subtour from 1 parent then choose a next subtour from the next parent an then choose remaining from the first and so on. Also, in say of the alternating cities you can alternate subtour crossover you can exchange in this idea. But the most in testing 1 here is called Heuristic crossover, so let me write it here. And what the heuristic crossover says is at you first random a choose some city so let us say you started city 6 or city 1 lets a city 6 in another matter. Then for deciding as to way to go from that city you look at the 2 toward if your chosen 6. For example, as a starting point 1 parent says go to 8 the other parent says go to 9 from 6 the heuristic crossover says that take the short a of the 2 adjust so 1 says go from 6 to 8 1 goes other says go to 6 to 9. This one says the choose the shorter of the 2 in this essentially. So, depending on what the values are we will choose the 8 or 9 in then construct the 2 of a from 8 other 9 in a similar. At every stage we try to choose where to go from that city based on the distance to the next city and that is easy to do with this I, because you are now easing in this fashion essentially. Try to do that heuristic crossover with this and should be quite difficult is an essentially. Because this as the index representation it tells you exactly that if you 1 go from 6 from city 5 what are 2 parents in? Here you would at scan the whole thing in say 5 from 5 go to 6 and then 5 from 5 go to 6 in this also.

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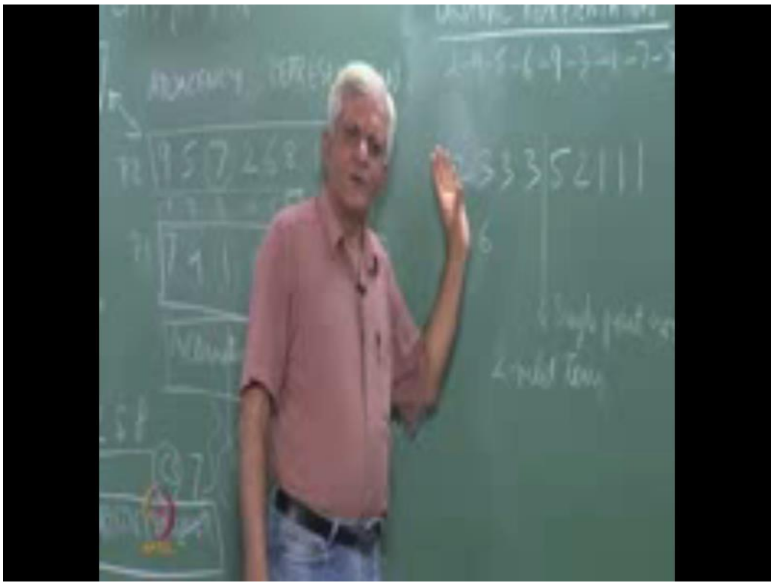

So, the last one that you on look at is called ordinal representation and it work as follows. The let us take the first 2 an you just copy here 2 4 5 6 9 3 in the ordinary representation what you do? You just listen carefully to this process you look at position, so think of this index this is 1 2 and so on as both. So, this is the first city in a 2 a second city is a third city is a 4 city is and so on. You have to a reference in this and is so less assume as the reference index simply this which is the already in this cities name. So the first city in you 2 is 2 and that is second and the reference index so you right 2 here. But your know this from here reference here new reference is the reference without the city 2 the next city in your 2 are is 4 and its reference is 1 2 3 so you right 3 here and we remove that from there. The next city here 2 are 5 and its indexes 3 here we right 3 here again and remove this from here. And next cities 6 and its indexes 1 2 3 its again 3 next cities 9 so remove 6 from here 1 2 3 4 5, 5 here we remove that the next 3 which is 2 here. And we remove this and 1 which is 1 an then remove 1 then 7 which is 1 we remover 7 and 8 at this representation of the 2 are is calling ordinary representation.

So, just repeat what we are doing here is that we have a reference index which is dynamic which is only the index which have the new cities the remaining cities. Essentially we have all 1 to 9 so 2 is in position to here so with 8 then we remove to then 4 comes to position 3 then we remove 4 from their 5 comes in position 3 remove 5 and so on 1 we get this 2. As an exercise I will ask to construct the to a ordinary representation for the second 2 a as well all lets to it know so 3 is in position 3 when we remove 3 we get 7 which will be an position 6 and so on. So new I live it is an exercise we to do. The interesting thing and this is the exercise it I want to try would is at 1 to represent 2 2 us using an ordinary representation then you just to a single point crossover. And you get 2 valued 2 us so why do you like this single point crossover? We like it simply, because it is very easy to implement that is once you have a representation the already do is cut of this thing at 1 place and put together the cut race and new haven 1 new 2. But if you try to imaging words happing here is at with is few different schemes of representation they allow you different says of crossover.

And for example, this adjacency representation which is 1 of the most popular it allows it you some form of heuristic knowledge we says that from a given city you can makes some in form choices to where to go next city. So, even if you 1 not able to fill in the parent from 1 of the 2 base on this whether it is alternating crossover or subtour crossover or heuristic crossover if you are not able to filling from another parent. You can say heuristically choose the closer city which is the allowed and try to bill shorter 2 to us in the you are the ultimate go list bill shorter to us where this presentation does not allow any such at all this presentation the earn allow that. But it at is allows it do a simple crossover of essentially and remember that is crossover as to be done in every cycle for in every of parents at a choose essentially.

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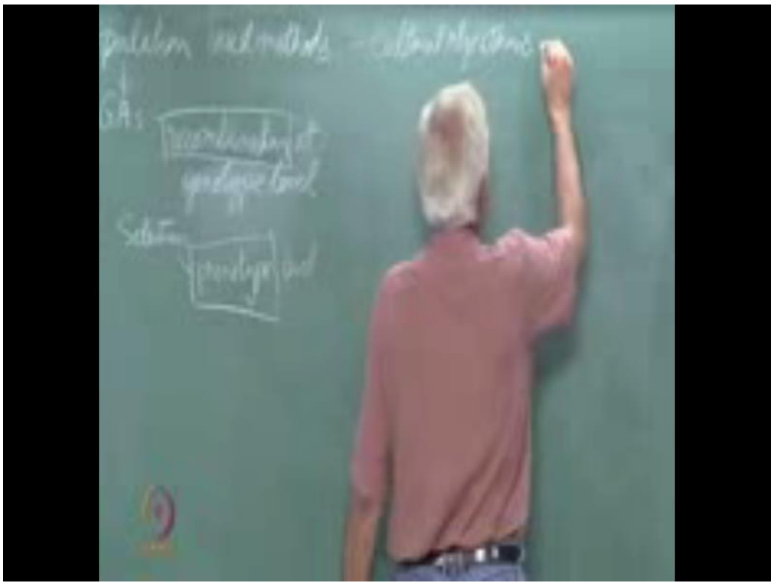

So continue in our study of population based methods. We look at nature again to get inspiration from different way that the members of the population interact with each other. So, member, that we a said, that call genetic algorithms some it action in genetic level which is the process of recombination at genotype level. So, recombination happen as a genotype level where as selection ((refer time; 37:28)) happens of the phenotype level. So, the such is happening at a micro level the mixing of gens from 2 different parents to come off with new candidates. And those candidates fainting without in some real the women training to serve I have essentially. Now, there is the another clause of methods which some people call as cultural algorithms, because they involve high level interaction between the agency at what you my say is a cultural level.

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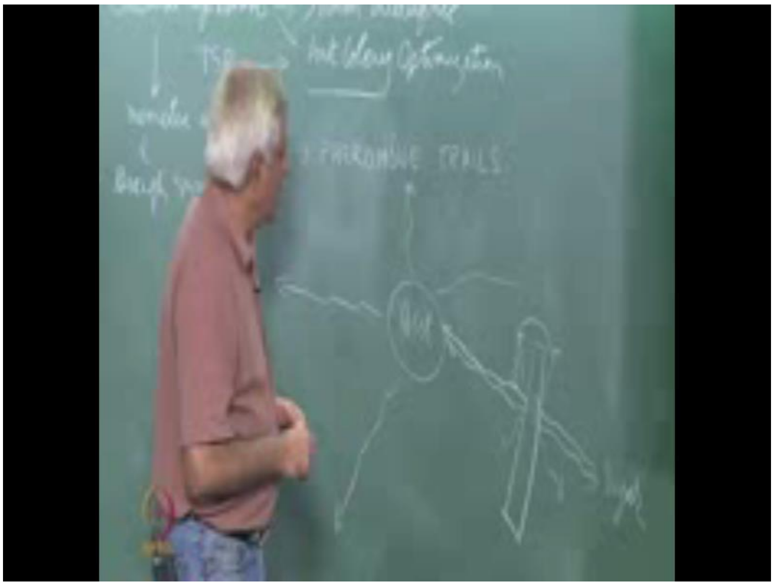

And there are various names by which these algorithms go so 1 is all swarm intelligence and it is in quite popular as optimization method in the recent pass. Even choose a term ant colony of optimization and we will look at continue looking at the TSP problem for ant colony optimization. So, you must the familiar with ant colony this ant colony was a terms which was use by ((refer time; 39:06)) in one of this book ((refer time; 39:07)) the very shows that an individual ant cannot be a very effective feature in some sense. But I colony of fans all society of fans is very successful in that task what is the main task at ant such trying do? There the building nest that were there is the we and sitting out they an there is worker and who job is so go out to in the world for verge in food and get some food bag essentially. Now, in terms of that am interact with each other to a process of symbol essentially and this kind of interaction called mimetic is that 2 symbols 2 signs ant symbol essentially. And is very common in the animal world for animals for feature to use symbol for examples you know animal used to mark territory essentially dogs another predators used to mark territory.

But these ants are using it know kind of cooperative fashion and they want to used. They want to convey were they having being to the less of the ant community and they do this by a process of pheromone trails. So, pheromone is a chemical sentences which an ant drops wherever it goes essentially. So, you can a imagine situation in the real world where the ants are answer exploring some piece an dropping pheromone on the way back essentially. Now, how to the use is pheromone? Either drop was themselves always somebody else is that have a tendency to go in a direction which as pheromone trails essentially. So, it is like marking out pass for each other and following the pass essentially. So you can imaging the situation where there is an ant nest and that is if 4 hypothetical ants go of in 4 different direction in such of a food. And let us say this is founds some sugar here some 4 it is found essentially 1 some food as the end of the trail essentially. So, let us a why in this happens after some time some more ants come out and them what to the do? So initially 4 ant spent out there after sometime 4 so let us a 4 more just for the sake of the argument 4 more ants come out then they likely to follow the trails. Some goes this way some goes this way some goes this way some go that.

Now, this ant which is found this piece of food what was it do? Very unselfishly it brings bag to the nest essentially so once it is found this food it just follow its own trail back and goes back to the next and deposits a food. But in the process if as tendency the trail it as deposited more pheromone on the way back. So, this amount of pheromone on this trail because more essentially. Now, if you assume that that ant has a tendency to move al1 pheromone trail in the more pheromone there is in a kale the more the antive likely to following. So, the next ant which comes out is more like to choose this selection then in your base directions and follow that kale. And notice that once more and more ants go along with trail more and more pheromone will be deposited along the way and the kale becomes strong and stronger. And eventually after period of time you will find that this entered ant colony is sub tour travelling food and back essentially.

Hence it is a common pheromone you must have absorb in the real world essentially. Not only that if you go to put an optical in the pass of these ants if you own experiment then off course we cannot follow the trail. So, this part the cannot full so they will start diverting in different direction. But eventually some of them will come back to this trail or some of them may find different pass of the trail some make come back to the trail. And in the thing is that the ant switch come back to this trail will do it faster essentially. So, they will is establish of pheromone trail faster than an ant with goals of wonders of in count pack. And this fact that ants which happen to do things faster they live the trails earlier. And more ants follow on that trail can be seen as process of optimization, because they are so the fine in the shorter paths shortest paths of found first. Assuming the they enough number of ants in this environment shortest pass will be found first and they will be followed first in so on about. In that sense you will see that ants for you open fine go to task to the to the source to the source of food an back to the essentially.

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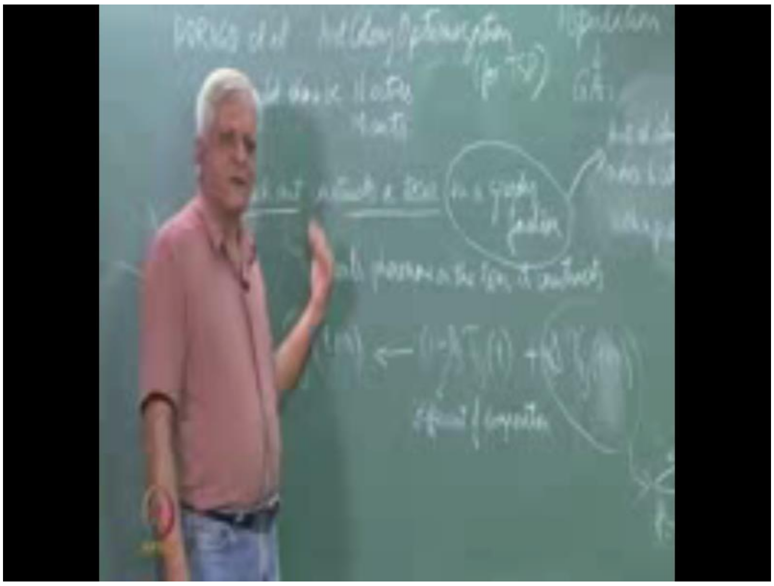

Now, there was is group of miss chest that by DORIGO at an who device is all go set up all will comes call an colony optimization. And we look at it with an example of the TSP problem. And the way that is algorithms works is follows that let they we N cities and let they we M ants. And we assume that is ants kind of distributed randomly across these cities. The basic process that we will follow is at each ant constructs a tour in a greedy fashion. Each ant constructs to a Grady fashion and this will take N time steps because the to a will have to have N cities. And each ant also deposits pheromone we just use at the pheromone again on the tour it constructs. So, you can imagine that all these M ants are there trying to find so all that travelling salesmen problem try to fine the shortest tour. Each an constructs a tour in a Grady fashion and deposits certain want of pheromone on the tour it is created. So, the way will be look at tour is that we will look at the amount of pheromone at the end of N time units after each ants constructs a tour.

So, we will use T i j to stand for the pheromone on the link from the higher city to this j i city. So, this is city i this is city j an than off course there is the other thing essentially so how much pheromone is on this? You will do not by T i j and we will update it at every N time units. So, if you know the tau pherom1 on time t you can compute the pheromone at time T plus N after each. And this will be updated as some of the whole pheromone that was let from earlier times plus new pheromone which has been deposited by ants in the last 2. And the whole pheromone that will deposit in earlier times as the tendency you operate. So, we will assume that some of it will you operate so whatever the value was at time T it we get you operate by some value which is 1 minus let us a lambda where lambda we will calls as a coefficient of you operation. So, lambda tells you how fast the pheromone you operates. If lambda is high if it is close to 1 then you can see that none of the whole will remain if lambda is low.

Then you can see that some of 2 whole will remain plus the new pheromone that is deposits and that we will call as tau i j n let a say. We can say the incremental amount is delta tau i j at time t plus n let us say. So, this is the incremental amount of pherom1 that and so deposited in the last cycle and this is for tremens of the whole pherom1 essentially an how much is this amount? This is basically the sum fall i is equal to 1 to n for each of the ants the amount of pheromone deposited while in the k let use k here were using i n j here deposited by the k ant essentially. So, the total pherom1 deposited in the last cycle is the sum of the pheromone to deposited by all the ants and for each ants this term delta tau i j k would be either 0 or little be sum value it to be 0 if that and does not have this i j h in h 2 an it to non zero if it is it has i at in this 2.

So that 2 cases a 0 if ant does not tours edge i j otherwise it is a value it is denoted by q divided by l k were q is sum constant that we use control this own computation. And l k is a cost of tour found by is ant kin the k ant essentially. So, the important thing here the way the this dapples from the real world situation is at the amount of tour amount of pheromone that an deposits on an edge is inversely proportional to length of the tour. It is found which means that the ant switch fine shorter to us will end of the deposits more pheromone on those i j is and I am switch a found long to us will at the deposited in less pheromone. So, again we want reinforce the idea that an sit of fine shorter to us they will encourage other and so follow that real essentially and that why I will do deposit more pheromone essentially. So, this is how pheromone is updated at the end of every cycle now that lives is part of the Grady to a construction how does and actually constructed to is basically simple stochastic process in which an ant and looks at a set of cities at it can move to and moves to it in a holistic fashion.

So, let us assume that ant at a city i moves to city j with a probability little bit like what we did in the simulated ((refer time; 53:01)) which is the proportional to the following. The amount of pheromone on that edge that it is considering raise to sum power alpha multiply it by a factor which is called eta i j is to power beta, so again alpha and beta to constant, if you control the influence of these 2 factors. So, there 2 factors tau i j is a want of pherom1 on that which an eta i j is called visibility. Basically it is inversely proportion to cost of that edge. So, in other words if that the adjust very if the if the city j is very close to city i and this eta factor will shoot up. Because this is inversely proportion to cost and then the ants so this factors says that the ant is likely to choose a city which is close to the city i at which it is.

This factor says the ants likely to follow that to good go to that city on which the pheromone trails is higher. And then they a control by these 2 parameters divided by sum of all a city that it can go to so T i h is to alpha eta i h is to beta were h is the set of allowed city and what you mean by allowed cities? Cities which will not close a loop in is remember the, that ask at we a try to find is complete tour the ants a so as at ask of constructing a complete tour in a Grady fashion. So, it goes of city to city and at any point it only considers those cities as prospective destinations which will not close to ((refer time; 55:24)). So, essentially what this ants it doing is sitting at this location i and it is got is we a assuming a completely connecting graph here the it as we do in the TSP so it can move to any other city.

But we will only choose those cities which first of all it has not already tour, because you do not wonder close the loop again so it cannot go to city which it has already tour essentially. So, these only set of allowed cities and from the allowed cities we chooses is to move to 1 of them call j probabilistically. And the probability is proportion 2 thing; one is how strong is pheromone trail on that h. And secondly how close that new city is to the current city, because eventually you want to find shortest pass. In shortest pass is always be need of it adjust which are short adjust essentially so this is the ant colony optimization algorithm.

You have the set up ants each ant construct a tour then base on the 2 it is constructed each ant deposits a certain amount of pheromone on every edge that it has moved on and that the end of this whole process, we update the amount of pheromone on every edge in the graph. So, edges on which ants will travel will have pheromone edges on which ants will travel to fine short to us will have more pheromone. And they will influence more ants to follow, because of this factor on those adjust. So, in the end ideally like in this situation if all the ants of moving along like 1 caravan. In the TS also 1 would expect all the ants would be travelling 1 optimal to essentially. And it would be a go to exercise for you to influent this an colony optimization and see how man, how the ants out up converts to the shortest to at least for small problems you can we seen quite easily. So, will stop here and in the next class we will move away from this optimization. And we go back to state space such and try to see deterministic algorithms for fine in shortest pass essentially.