Optimization Methods for Civil Engineering

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Lecture - 17
Genetic Algorithms

Hello student, I would like to welcome again to my course. So, today we will discuss Genetic Algorithm. Already we have discussed the classical method. So, now, you know how to solve a non-linear optimization problem mainly the convex your problem using classical method.

Then we have also discussed what is the difficulties of or difficulty you have faced in solving some of the non-linear problem mainly which are non convex problem and if your problem has more than one optimal solution; that means, you have multiple optimal solution then really it is difficult to solve the problem using classical method.

So, today also I will show you some of the difficulties so that you may face in solving a non convex problem having multiple optimal solution using classical methods. So, initially we will discuss about the difficulties faced while applying classical method and then we will discuss the genetic algorithm.

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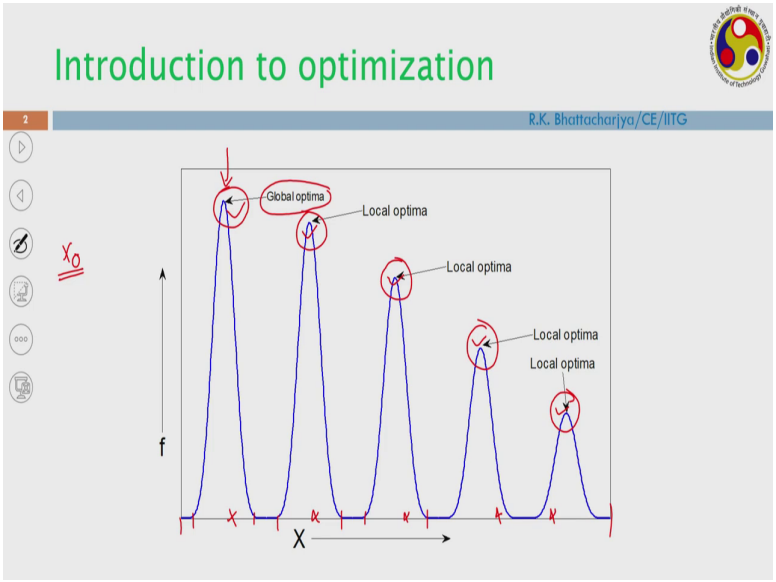

So, I have shown here a function, and if you look at this particular function there are several optimal solution. So, what is optimal solution? The first derivative is zero. So these are all stationary points ok. So these are all stationary points.

And, so you can say that these are all optimal solutions, but one of them is the best solution and we call it global optima, so we call it global optima. So, within the search space, so in this case the search space is coming from here to here. So, within this search space this is the solution and this is the best solution and I can say that this is the global optimal solution of this problem.

Now, the other solution so the first derivative is zero in other solutions also and we call it local optimal solution. Now, let us see if I try to solve this problem using classical method ok.

So, just see this is not an easy problem to be solved using classical method, but you just try to solve this classic this problem using classical method.

Now, as you know that the classical method, so whatever the gradient based method you are applying, so it is starting with a initial solution. So, we call it X naught. So, X naught is the initial solution; that means, the search process is starting from this X naught. Now how to choose this X naught?

Suppose in this case, if you are selecting an x naught somewhere here, suppose if X naught is somewhere here then you will get this optimal solution, if your X naught is somewhere here you will get this optimal solution, u if you somewhere here within this particular range you may get this optimal solution and if your X naught is within this region you may get this optimal solution. And luckily if your X naught is in between this somewhere here, so in that case the global optimal solution of this particular problem.

So therefore, the solution is highly related to what initial solution you have chosen ok. So, if you are if you have luckily chosen a correct initial solution so in that case you may get the global optimal solution of this problem. Otherwise, what you will get? So, if you apply classical method, so you will get a local optimal solution.

So now, what should be the procedure? What you should do basically if you apply classical method? So, what I will do that I will search for optimal solution by changing the initial solution. So, initially you have chosen a random initial solution between upper bound and lower bound between within the search space and then you get an optimal solution.

Now you change the initial solution and just see whether you are getting a different solution or not. So, in this case you are you will be getting a different solution if your initial solution is different range. So, what will happen, that depending upon that what initial solution you have taken so you will get one of this local optimal solution of this problem.

So therefore, if you are lucky and if you have chosen the correct initial solution, so in that case you will get the global optimal solution of this problem. So, therefore, this problem is not easy to solve ok using classical method.

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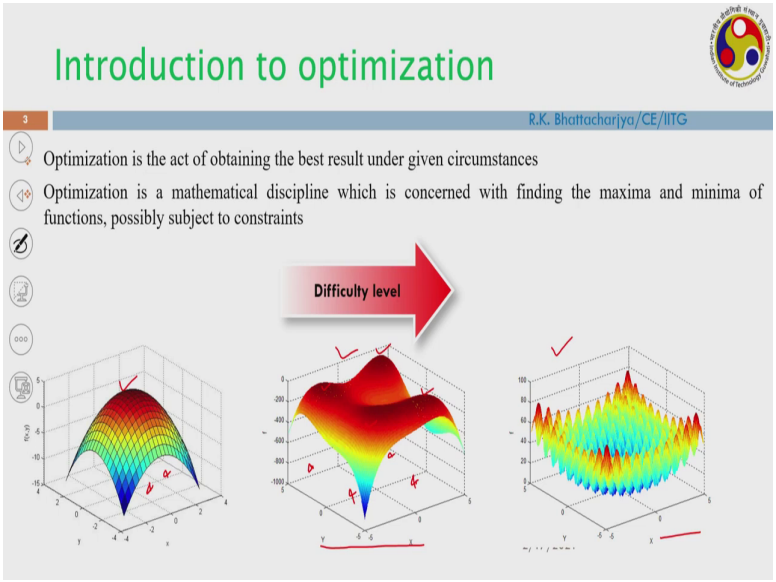

Now, let us see there are I have shown three function here. So, already I have discussed; what is optimization problems. I think you already know that optimization is an act of obtaining the best result under given circumstances and it is a mathematical discipline which is concerned with finding the minima or maxima of a function and possibly subjected to constraint.

So now, let us see this; three function. Suppose the first function, if you see that this is an relatively it is an easy your function if I say or you say or I can say this is a simple function and this is a convex problem, so if you take initial point anywhere in the search space, so you

will get the your optimal solution and there is only one optimal solution here and that is the global optimal solution of this particular problem and this function is a convex function ok.

So, it is a convex function, there is only one optimal solution and that is the global optimal solution of this problem. So, what I suggest that for this particular function so if you apply classical method you will get the; your optimal solution of this problem. So therefore, this particular problem is easy to solve.

So, I am not suggesting that you apply genetic algorithm or any other your types of meta heuristic algorithm for solving this problem. So, simply you apply classical method, because the function is a convex function and you know that for convex function the local optimal optima is also global optima. There is only one optimal solution of this particular function ok.

Now, let us look at the second function. So, second function is relatively difficult function ok. So, the second function is relatively difficult function. So, here you have four optimal solution and, if you are taking some initial solution somewhere here you may get this optimal solution, if you are taking somewhere here you may get this one, if you are taking somewhere here you may get this one or if you are taking somewhere here you may get this solution.

So, for this particular function, so depending upon what initial solution you have chosen, so you will get one of the local one of the local optimal solution. So, you will get one of the local optimal solution and basically it is sensitive to the initial solution.

But still, I say that this problem can also be solved using classical method. You just change your initial solution and you may get one of the optimal solution and if you do some random trial, probably you may get all these four optimal solution of this problem. So, you may apply classical method in this particular problem.

However, if you look at the third problem, that is not an easy problem there are several local optimal solutions and one of them is the global optimal solution of this function and you just see, so it is quite difficult to solve this problem using classical optimization technique.

So, in that case so you need some special treatment or you need some specialized algorithm for solving such type of problem ok.

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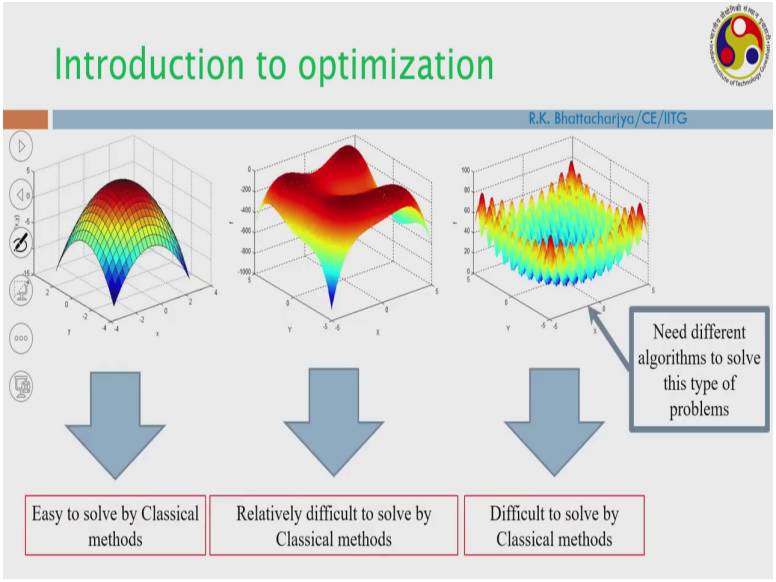

So, if I look at all these three function, as I said the first function is easy to solve by classical method. So you can apply classical method for solving this problem. So, you need not apply the non classical technique for solving this types of problem, but if you go to the second problem; second problem is relatively difficult to solve by classical method, but still you can apply classical method and you will get the your local optimal solution or with some iteration you may get the global optimal solution of this problem.

But, if you look at the third problem; that is difficult to solve using classical methods. So, it is very difficult ok. So you may do lot of iteration. Suppose you are doing lot of iteration by changing the initial solution you may get the global optimal solution, but it is really difficult

to solve using classical method. For such type of problem so you need a different algorithms ok. So, for solving this problem so need different algorithm to solve these type of problem.

So, I will suggest that, if your problem is something like that then you can apply non classical method to solve the problem. So today we will discuss the genetic algorithm. So, you can apply genetic algorithm or otherwise if it is easier so easier to solve suppose first type and second type problem you can apply the classical methods.

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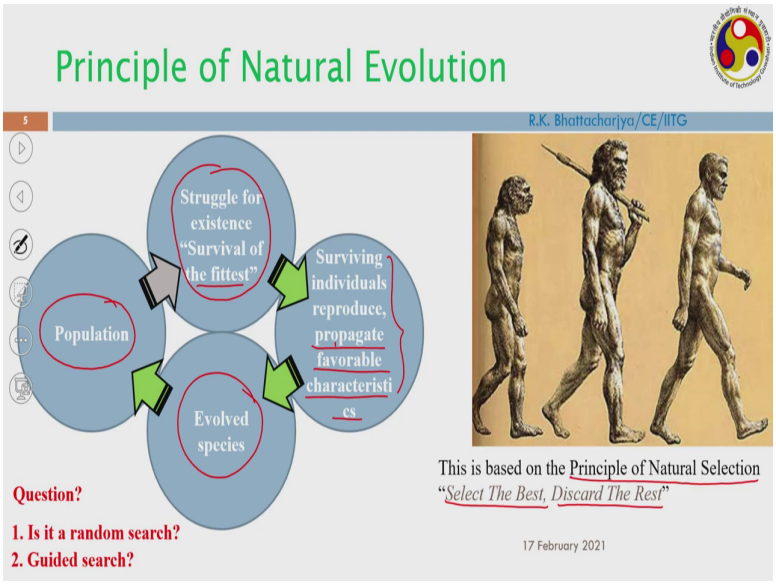

Now, let us discuss genetic algorithm. So, what is genetic algorithm and how it is derived basically, what is the principle, what is the philosophy? So, we will discuss this one. So principle of natural evolution ok. Now, if you look at the population so you just look at the population. So, in nature basically so we are not living as an individual, but we are living as a population ok.

Now, this population is struggling for existence ok so struggling for existence and we call it survival of the fittest. So, what will happen? This population is struggling and the fittest will survive ok. So this is the natural law basically, the fittest will survive and those who are not fit they will be eliminated from this process ok.

Now, those who have survived, this surviving individuals ok surviving individuals reproduce ok. So, they produce their offspring then, they also propagate the favorable characteristics to next generation to their offspring ok. So, what is happening? This surviving individual, they reproduce, they propagate the favorable characteristics so whatever what favorable characteristics they have. I will also explain this thing in some of the slide.

So, the favorable characteristics they propagate and to the to their offspring and this is known as evolved species. So, whatever new species you have basically we call it evolve, because they are slightly different to their your parents ok than their parents. So they are slightly different their parents and it is basically we call it the evolved species ok.

And then this process is continuing in nature and still this process is continuing. So, population, they are struggling for existence, so we call it survival of the fittest; that means, those who are fit they will survive, then surviving individual, they reproduce then propagate favorable characteristics to their next generation ok and this is known as evolve process.

So, now what is the basic principle of natural selection? So, principle is select the best, discard the rest, select the best, discard the rest. That means, the best solution, if I say, if I say from natural point of view the best the fitted solution they will survive and the other those who are weak ok they will be eliminated. So, nature will discard them. So, there are several example, that those who were there may be millions year back. So now, they are not in existence, so they are not there ok.

So, how they have eliminated, because they could not survive in the that struggle for existence ok survival of the fittest. They could not survive and they are right now they are not there. So, that is that has been eliminated by nature.

So, now the basic question is, whatever happening that search process, I can say this is an search process. So, every time you are getting a new solution ok. So how you are getting a new solution? Because, they reproduce and they propagate the favorable characteristic and for and due to that you are getting a new solution and probably you are reaching some optimal solution and they are basically in existence.

So, now the question is that whether it is a random search or it is a guided search? So, whether whatever evolve process, so it you are we are evolving so this evolve process is a random search process or it is a guided search process. Whether it is guiding by some rules or somebody is guiding it ok. So, before that we have to understand what is random search and what is guided search.

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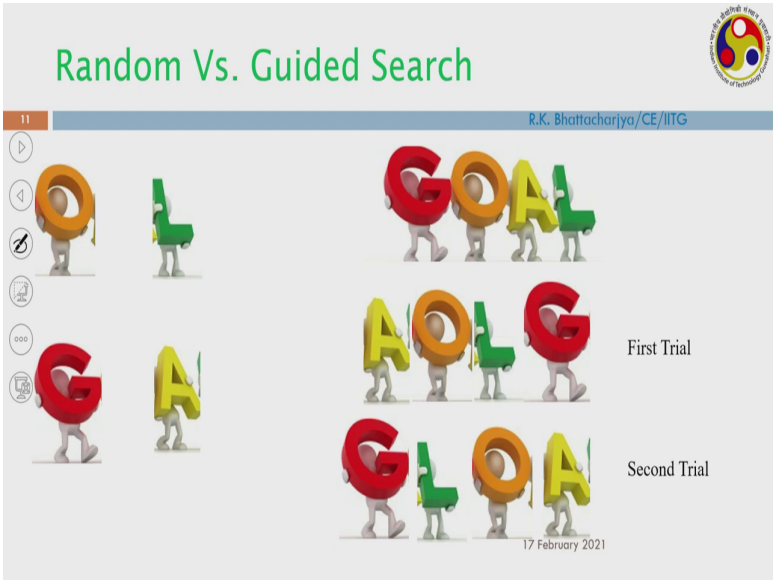

So, in the next slide I will explain; what is random search and what is guided search.

Now, just take an example of this building blocks ok. So now, you have this is a very simple problem. So, I would with this I would like to explain what is random search and what is guided search. So now, I have four letters, I have four letters and this is O L G A. So these four letters I have. Now, I am asking you that you create the word goal using this letter. So, that is not that difficult.

So what you can you can arrange this letter, that G O A L; GOAL you can basically arrange this letter in that order and you can write the word goal. So, this is not a difficult problem.

Now, if I put some difficulty in this particular problem, so what difficulty? That I will put a blindfold on your eyes ok. So I will put a blindfold and then what will happen you will not be able to see. Now, I am asking you that you try to create the word goal using these four letters ok. And, what I will do? I will reshuffle it, I will reshuffle it, I will put in a put on a table and then with that blindfold you just try to make that word goal using this four letter.

So now, only what help I can do basically or what I can tell you that once you are showing arranging the letter then I can say that whether you got the solution or you are not getting the solution. So, if you got the solution I will say, yes ok, this is the solution. You could arrange the letter in that sequence and you are getting the solution. So I will say yes or otherwise what I will do I will say no, so you are not getting the solution. So, this is the only information I will tell I will give you that yes or no ok.

Now, you try to do that ok. So, what will happen what will happen? So, your objective function is this; objective function is that you try to create this particular word that is the objective and then first trial is A O L G.

So, this is the first trial, you have arranged something like that. So, then what I will say? I will say that this is not the solution, so I will say no. Now, what you will do? Basically, then you will again rearrange those thing, rearrange this four your letter and you will give another trial.

And, suppose this is the second trial. So, second trial you are getting G L O A, that is that is also not the solution. So then what I will say, I will say no basically. Now you see how much iteration you main you may need or you may required to get the optimal solution of this problem. So, you are not sure basically. So it may take your few 100 or some iteration you may need to get this the solution; that means, that G O A L.

Now, this is purely random search ok. So because, suppose the there is no interlinking between first trial and second trial this is purely a random process. So, you are you are rearranging this your that your letter and there is no interrelation between first trial and second trial or second trial and third trial, so this is a purely random process. I hope this is clear to you. What is random process?

Now second is; I am giving you some more information ok. So, apart from yes or no I will also tell that whether you are partially correct or not basically. Suppose, if I say that in the second trial the first letter is correct; that means, you got the first letter ok.

So, G O A L you should get, but you got the first letter; that means, first letter is correct that you got G. So this is the additional information I am giving to you ok so; that means, the first letter is correct. Then what will happen? Then what will happen that you are basically, you will fixing that one ok first letter, you will fix then you will try to rearrange the rest three.

Then suppose, next time I am telling the fourth one is correct ok, then you will fix the fourth one and then basically I am saying the third one is correct. So, something like that so in that case what will happen in that case you just see the difference between first method and second method, in random search there was no information about your partial your correctness of this particulars your solution, but in the second you are getting some additional information.

So, in the second method, so you will get your solution probably in a lesser iteration. So, this search is guided search; that means, somebody has guiding this search ok. So therefore, you are getting your solution in a lesser time. I hope this is clear to you. So, we have discussed mainly what is random search and what is guided search.

Now, question is that, so what is the natural evolution process? So, whether it is a random search process or it is a guided search process, so it is not a random search process. Because the there is there is a interlinking between the trial, between the events ok. So therefore, this is not a random search, this is a guided search ok. So, how it is who is guiding basically. So, that I would like to explain in a in the next slide.

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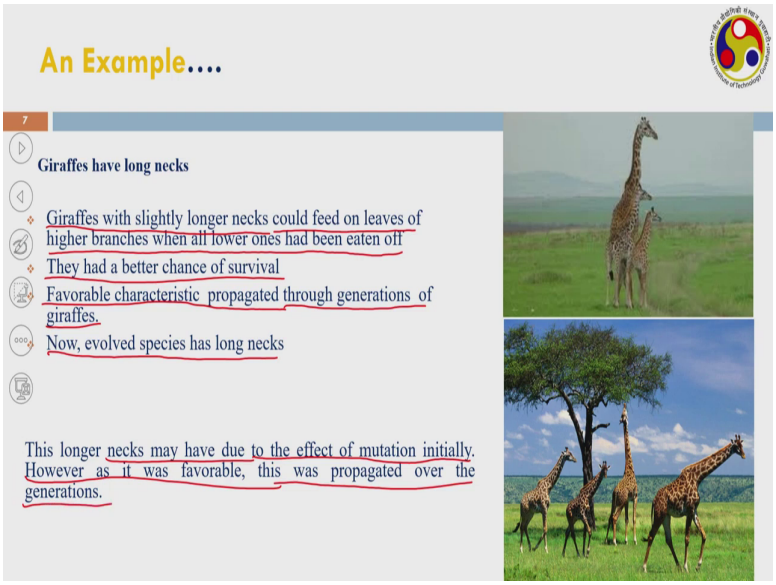

Let us see another example problem ok. So, another example, so if you look at giraffe ok. So, I think all of you have seen that one. So, if you look at now giraffe has longer neck, leg is

neck is longer, but millions or millions of year back basically they have shorter neck ok, so some studies saying that they had actually shorter neck actually.

Now, what happened at that time, the giraffe so giraffe with slightly longer neck could feed on leaves of the higher branches when all the lower leaves had been eaten off ok. So, when there was no leaf on the ground so the giraffe with slightly longer neck they are in a advantageous position and they could take the leaf from the higher branches ok.

And, that had a better chance of survival. So therefore, what has happened, that those giraffes having slightly longer neck so they had a better chance of survival, because when there are no leaves on the ground, they can take the leaves from the higher branches ok. So they had a better chance of survival.

Now, if you look at this is a favorable characteristics ok of that particular giraffe. So, some giraffe they have longer neck and this characteristics, what is there in their gene basically. So, that is basically you can say that is a favorable characteristics. Now what is happening? These favorable characteristics propagating to their offspring.

So, favorable characteristics propagated through generation of giraffe ok. So, that has been propagated and now they evolve to a new species and which has basically longer necks ok so they evolve these species has longer neck. So, this is basically you can say, now what is happening, so whatever giraffe.

So, shorten one the giraffe with shorter neck they could not survive because that was not a favorable your characteristics, but what is favorable characteristics here? The favorable characteristics is the longer one, giraffe with longer neck and they could survive and other could not survive and therefore, this a this evolved to a new species and those now whatever we are getting basically, this giraffes are having longer neck ok. How they are getting longer neck?

This longer neck may have due to the effect of mutation initially. So, initially because of mutation some giraffe may had a longer neck; however, as it was a favorable and this was

propagated over the generation over the generation and this is basically evolve so you are evolving in a new species.

So, I would like to give you another example. Suppose, we are living at an altitude of around 200 feet to 300 feet and, if you compare the temperature pressure and oxygen level with an altitude of 1000 feet or 1500 feet something like that, so there is a huge difference oxygen level will be lower at an higher altitude.

Now, question is that, so if you are putting a suppose if you are shifting 100 people from this altitude to a higher level altitude, so what may happen the some may not be able to survive at that at that atmosphere.

Because, less oxygen, temperature is different, pressure is different. So, some your some of that population may not be able to survive at that, but there will be some your some individual who will be able to survive at that oxygen level. Because, and that is a basically favorable characteristics for them.

So, now what will happen in the next generation this favorable character characteristics will be propagated to their offspring and then this is basically evolve as a new species. Now these species basically they can survive with lesser oxygen ok. So we call it adaptation.

So, we can adapt to a new environment ok and that is basically propagated to true generation and then basically after few generation so they will be able to survive with lesser oxygen ok at that higher altitude.

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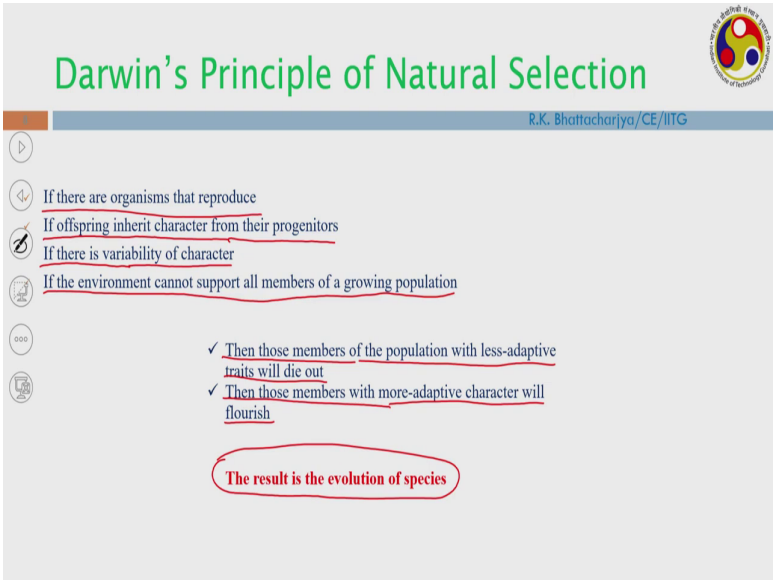

Now, what Darwin's Principle of Natural Selection. So, the principle said, if there are organism that are that reproduce ok. So, if there are organism that reproduce. If offspring inherit character from their progenitor ok. So, they are whatever characteristics they have they are getting or inherited from their parents.

If there is variability of character. So, whatever the character of its population or its individual of the population and there is a variability of the character and if the environment cannot support all the member of the growing population. Then what will happen? Those members of the population with less adaptive trait will die out.

So what I am telling, that when you are not adopting or are to that change the environment, then what will happen? They will die out ok. Then those members with more adaptive character will flourish ok.

So, what will happen, as I said, that once we are shifting some people to at higher altitude, so as I said that those who will be able to adapt with the new environment, so they will survive and other will be eliminated from the process then those member of the population with less adaptive trait will die out and those member with more adaptive character will flourish and this results in evolution of spaces.

So, now what we are doing basically? So, we are trying to implement this principle of nature artificially in finding the optimal solution of an optimization problem; mainly for non-linear optimization problem. So, we trying to apply the principle of your natural selection artificially for solving an optimization problem ok.

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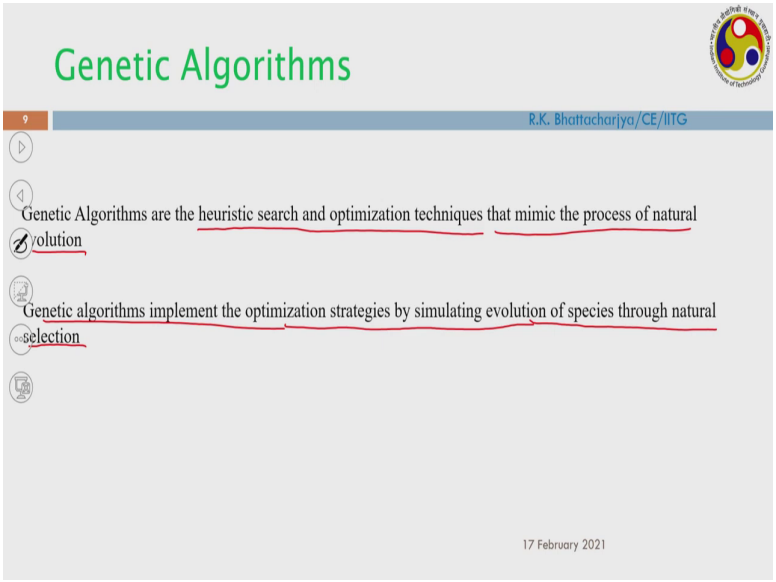

Now, what is genetic algorithm? The genetic algorithms are the heuristic search and optimization technique that mimic the process of natural evolution ok the process of natural evolution. So, this is basically, so what we are trying to do here we are trying to mimic the process of natural evolution.

So, genetic algorithms implement the optimization strategies by simulating evolution of species through natural selection ok. So, we are trying to apply the law what is basically what nature is following artificially and then we are trying to solve the optimization problem.

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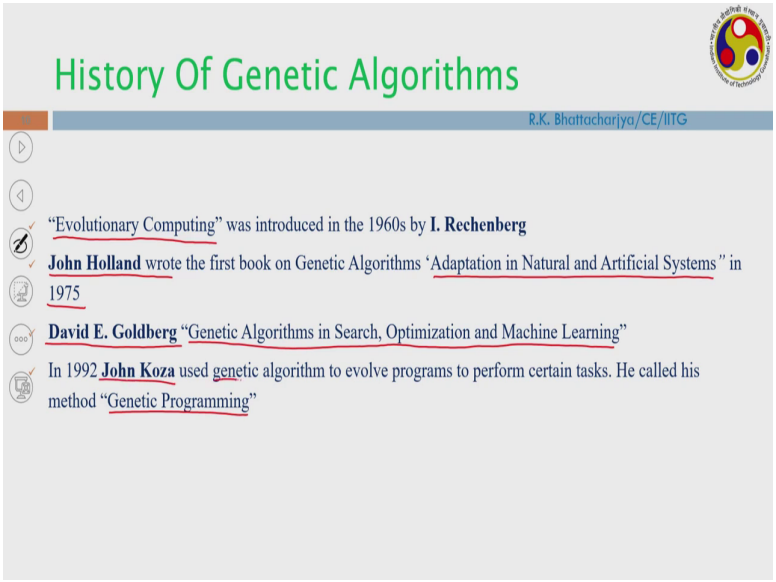

Now, History of Genetic Algorithm. So, Evolutionary Computing was introduced by introduced by I. Rechenberg in 1960. So, around 60s this principle or around 60s people have discussed about evolutionary computing, but at that time it was not very popular so people did not accept that one as an optimization method ok.

So, it was just discuss. Some people have tried to solve some simple optimization problem using this concept, but at that time it was not very popular. Even if today also, some people are telling that genetic algorithm or other meta heuristic optimization method they are not really an optimization technique.

So, they are telling that classical method are only the optimization method. So, genetic algorithm or other meta heuristic optimization methods are not really an optimization technique, but the other groups are saying the problem which are not your treatable, so which

you cannot solve using classical method that you can solve using genetic algorithm or other meta heuristic optimization technique.

So, now many people have accepted this algorithm, but in 1960s so people did not accept that as an optimization technique and in 1975, so Professor John Holland, so he was professor in the University of Michigan and he wrote the first book on genetic algorithm, that is; Adaptation in Natural and Artificial System.

So, that is the first book on genetic algorithm written by Professor Holland and at that time also this algorithm was not very popular. People did not accept it as an optimization technique ok for or optimization or powerful optimization techniques. People did not accept that genetic algorithm as a powerful optimization technique.

Then; David Goldberg, so he was the he was a student of Professor Holland. So, Phd student of Professor Holland and he did lot of work on genetic algorithm and he eventually he wrote a book in 1989; that name of the book is, Genetic Algorithm in Search, Optimization and Machine Learning ok. So, it was I think one of the most popular book at that time.

And then, he tried to use genetic algorithm in solving different complex non-linear optimization problem; and finally, he could establish that genetic algorithm as a powerful optimization technique ok.

So, and after Goldberg, many people have used genetic algorithm in solving complex optimization problem and there was another type of genetic algorithm, we call it genetic programming. This is not an optimization method, but they use the principle of your natural evolution. So, in 1992 John Koza used genetic algorithm and to evolve program to perform certain task and he call that method as genetic programming ok.

So, this is how genetic algorithm has evolved and after that many people have used genetic algorithm and now I think it is one of the popular methods in for solving non-linear your non convex your problem, optimization problem; non-linear non convex optimization problem.

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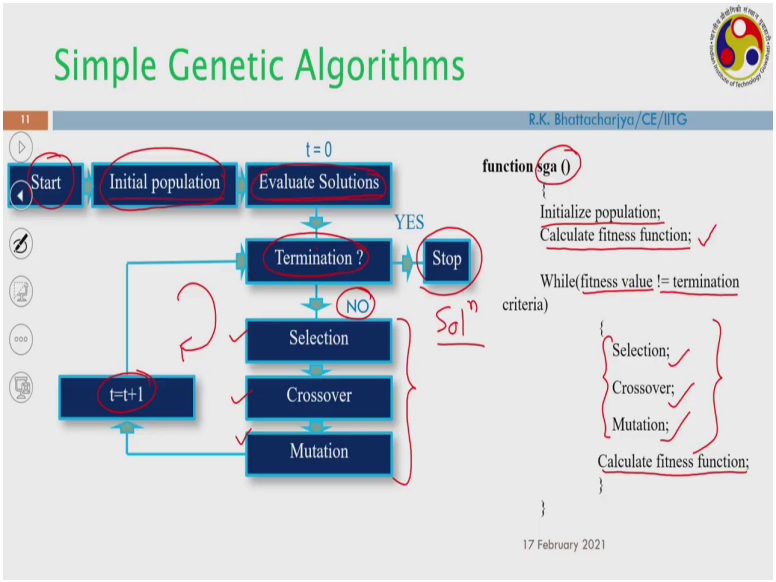

Now, let us discuss the simple genetic algorithm ok. So, first I will discuss this one and then I also I have also given the pseudo code for implementing the simple genetic algorithm. So, here this algorithm anyway. So you are starting this algorithm and then generate initial population. So what you are doing? You are geneting you are generating a not a single solution, but a population.

Population is nothing but set of solution. So, if you look at the basic difference of this algorithm; genetic algorithm with the classical method. So, most of the classical method, what we do basically? We start our algorithm from a single initial solution, but here, the difference is we are not starting from a single solution, but we are starting from a set of solution and we call it population.

So, in nature we call it population and therefore, we call it population. And now we are initiating the population, we call it initial population. Now, next is the evaluate the solution. So, evaluate the member of the population. So, suppose your population is 10 or population size is 15; that means, it is a set of 15 solutions.

Now you evaluate this solution. What is evaluation means? You are trying to put a number which will show whether that solution is a better solution or inferior solution. So, you are trying to quantify that one using a number and we call it evaluate solution.

So, I will discuss about how you can assign a fitness value to this particular solution and we call it evaluate solution. And, after evaluation what you will do you will check for termination criteria; that means, this loop cannot go on and on and on because you have to stop this loop.

In case of natural evolution that loop is continuing, now this process is still continuing, but in our case I have to get a solution. So I cannot continue means suppose to mean suppose I cannot continue that one so I have to terminate this algorithm. So therefore, some termination criteria you have to put here.

Now what should be the termination criteria? So, I will discuss in details in some of in some of the classes, but termination criteria one criteria may be the number of iteration, we call it generation ok. So, in this case we call it generation, but it is nothing but the iteration.

So now, this iteration can be a termination criteria that I would like to iterate for 100 iteration ok. So, I would like to continue 100 iteration or 500 iteration or 50 iteration or something like that. That can be a termination criteria ok.

Apart from iteration, there may be some other termination criteria that you have a population of solution and there is a best solution in that particular population, best solution ok. You have 50 solution and out of 51 is the best solution.

Now, this best solution is not changing for some generation ok. Suppose it is not changing for 10 generation or it is not changing for 50 generation, something like that, so that I can put actually. That if it is not changing for some generation; that means, you have reached the or you got the optimal solution and that is why you are not getting any improved solution for last 10 generation or 50 generation.

So, in that case what I can do, I can declare that I already got the optimal solution and therefore, I would like to terminate this iteration. So, that may be a another criteria to do that. So, I will discuss about this thing.

So, we are putting some termination criteria, if it is satisfied then you will stop and you will declare that you got the solution, but if it is not, the termination criteria is not satisfied, so in that case, what you will do basically; no in that case you will go through these three operators ok and we call it these three genetic operators.

That is, selection, crossover and mutation. That, whatever solution it will pass through these three operators and then these three operator, what is the function of these three operator? So, these three operator will generate some new solution ok.

So, I will discuss how this operator can generate new solutions. So they will generate new solution or we can we can say new generation they will generate and once they are getting new generation, so this is the you are getting a new generation and that is t equal to t plus 1 new generation and then this termination criteria will satisfy, you will check and then this iteration will continue ok.

So, this iteration will continue till this is not satisfied and once the termination criteria is satisfied, so you will get your solution ok. So, you would get your solution; optimal solution ok.

So, this is the simple genetic algorithm. So, I can implement using some programming language. So I can use any programming language that also we will discuss. And, now this is

the pseudo code ok. So, the function is s g a simple genetic algorithm. So, this function is starting with initial population and then you calculate the fitness function ok, something you assign a fitness value and that will basically show how fit that particular solution is. So, you calculate your fitness function and then this loop will continue while loop.

So, while fitness value is basically not meeting the termination criteria and then you are this solution will go through this selection operator, crossover operator, mutation and you will calculate the fitness function again and then this loop will continue ok. So, this is the pseudo code.

So, it is the algorithm is not very difficult, this is a very simple algorithm, concept is very simple, but it is one of the powerful algorithms for solving your non-linear non convex problem ok. So, basically you are going through selection crossover and mutation operator.

So these three operators; so we will discuss this three operator, but the basic idea is that you are creating some new solution from the earlier solution. So, from one generation to another next generation, so you are creating some new solution.

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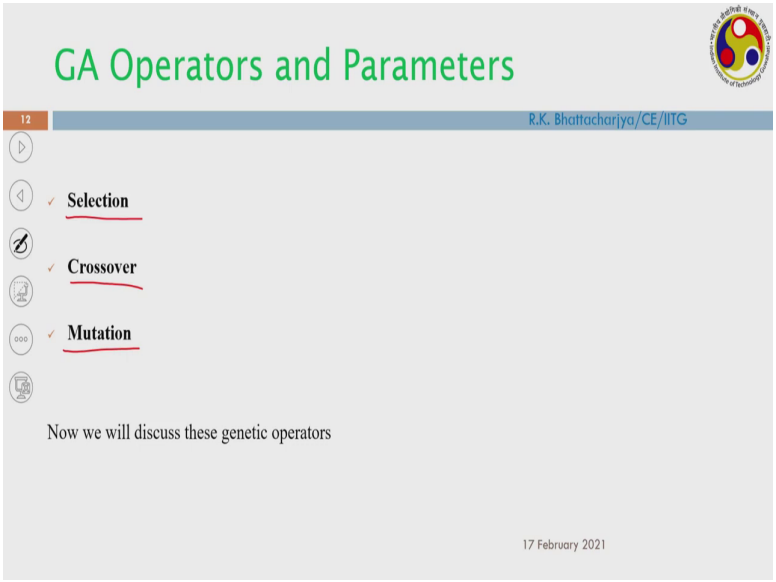

Now, let us discuss this operator. So, as I said, there are three operators here; selection, crossover and mutation. Selection, crossover and mutation. So, now, we will discuss this genetic operator one by one and I will also discuss what is the function of these three operators. So, what they do basically, so that will be discussed and how to implement that operator, so that also will be discussed.

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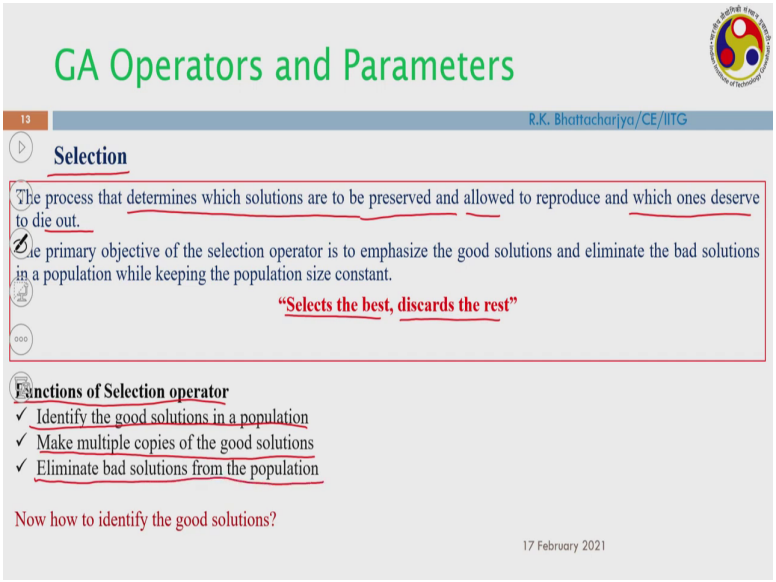

The first operator is, selection operator ok. The process that determine which solution are to be preserved and allowed to reproduce and which one deserve to die out. So, what is the function? That the this is a process. So, selection operator is a process that determines which solution that determines which solutions are to be preserved ok.

So, which one you will preserve and allow to reproduce; that means you will allow this solution to reproduce and which one deserve to die out. So, basically we will try to implement the survival of fittest using this particular operator.

The primary objective of the selection operator is to emphasize the good solutions and eliminate the bad solution in a population while keeping the population size constant ok.

Suppose, you have a population size of 10 solution ok. So, in a population or 100 solution in a population, so what is this operator will do?

This operator will try to create multiple copies of the better solution and then it will try to eliminate the worst solution or inferior solution and then it will also try to maintain the same population size it will maintain the same population size. You have 100 solution and after implementing this operator you should have 100 solutions ok.

So, the basic idea is that, the select the best discard the rest. So, it will select the best solution, better solution and it will discard the worse or inferior solution. Now, what is the function of this particular operator? So, the function of this particular operator. The function is identify the good solution in a population. So, this operator will identify the good solution in the population.

Then the second function is make multiple copies make multiple copies of the good solution. So, this operator will create multiple copies ok of the good solution. And the third one is eliminate bad solution from the population ok. So therefore, these are the three main function of this particular operator, selection operator.

So, it will identify the good solution in a population, it will make multiple copies of the good solution and it will eliminate bad solutions from the population. Now, how to identify the good solution ok. So, how to identify the good solution.

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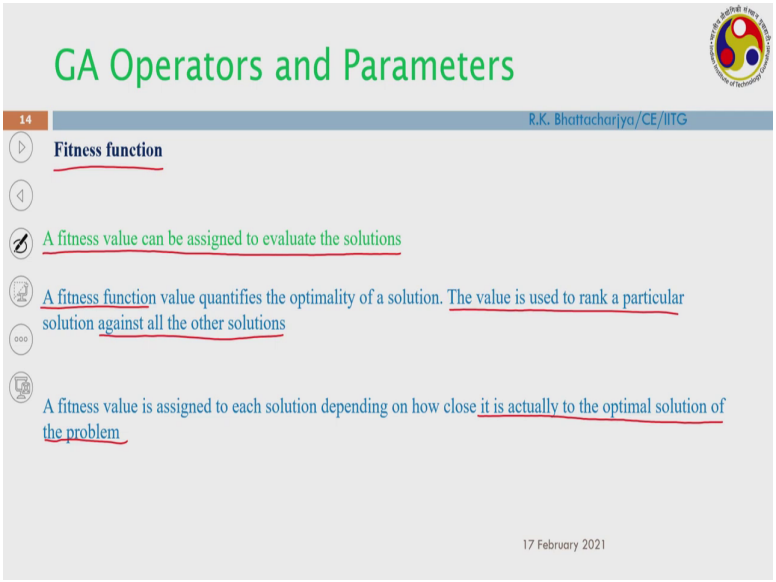

So, we can identify the good solution using fitness function. So, using fitness function. Now, what is fitness function? A fitness value can be assigned to evaluate the solution. So, what I can do, each solution I can assign a fitness value. So by looking at that value you can tell whether the solution is the better solution, inferior solution, the best solution or something like that by looking at that value.

A fitness function value quantifies the optimality of a solution. So, we are trying to quantify the solution. The value is used to rank a particular solution against all other solution. So using that value I can rank that particular solution against all other solution. So, I can do that using fitness function.

If, a fitness value is assigned to each solution depending on how close it is actually to the optimal solution of the problem ok. So, optimal solution of the problem, so I can do that

using the fitness value ok. So, I have to assign a fitness value to the solution of that population.

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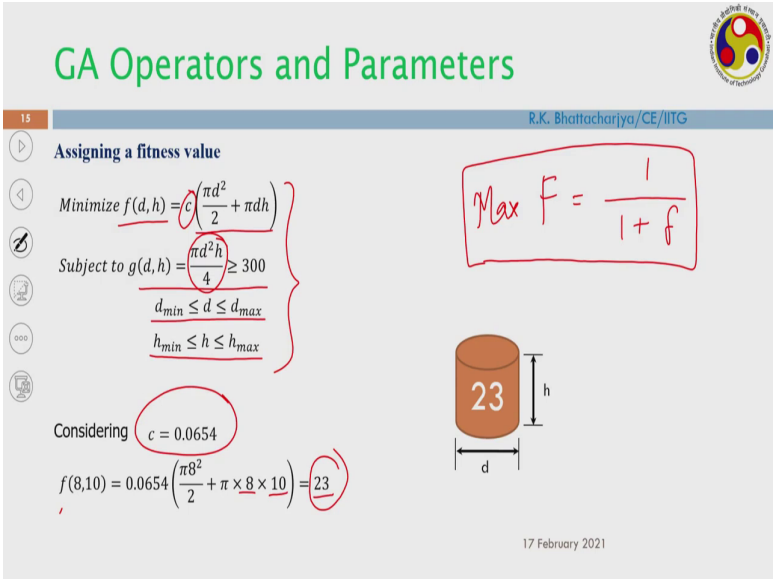

Now, let us take an example problem and then I think the concept will be cleared to you. I have chosen a simple problem here. This is the objective function minimize f which is a function of d and h. So, d is basically the diameter of this can and h is the height of the can. So, what is the objective of this problem? Objective of this problem is, we would like to find out the dimension of this can which will basically minimize the cost ok so minimize the cost.

Now, what is the cost here? Cost is, cost of the material, so material cost. That means, surface area of this is pi d square by 2 plus pi d h ok. So, this is the surface area of this particular can and multiplying with c. So, c will convert it to cos basically, and this is the surface area you

are getting multiplied by c will convert to cost ok. So, I would like to minimize the cost, I would like to design this can or finding the optimal dimension of this can.

And, and basically we would like to minimize this one. And there are some constraint; the constraint is that the volume should be greater than 300 ok. So, volume should be greater than 300, d and h you have to chosen in such a way that the volume is greater than 300 and there is a upper limit and lower limit of d and there is a upper limit and lower limit of h. So, h and d should be between upper limit and lower limit.

So, for example, if I have chosen, suppose if I say, that diameter is 8 and 10 is the height of this can and then I am getting 23 for c equal to 0.0564. So, for that this value of c, so I am getting the value equal to 23. So, this is this will give you the cost of this particular can.

Now, question is that, so in this particular problem so what we are doing here? We are trying to minimize the cost. We are trying to minimize the cost and therefore, that if the objective function value is lesser, that means that is the better solution ok. So, in this case the objective function value is lesser means that is the better solution. So, and it is more suppose, now it is 23. Now if I was another solution suppose another d and h I am getting 24, so then 23 is the better solution because cost is less.

Now, if you have so I can also just because I will just the concept is something that the these value is lesser means the solution is better, but if you have any difficulties in that concept, I can also convert to capital F and in that case I can maximize this. So, capital F I can write 1 by 1 plus small f ok.

So I can do that. So, in that case, if capital F is more; that means, the solution is better. If capital F is lesser then solution is inferior. But, I am not using it right now, but you can use this one also ok. I can convert a minimization problem to maximization problem using this. But what I am doing here, I am trying to see this value and if that value objective function value is lesser; that means, that is a better solution and if it is more; that means, that is an inferior solution.

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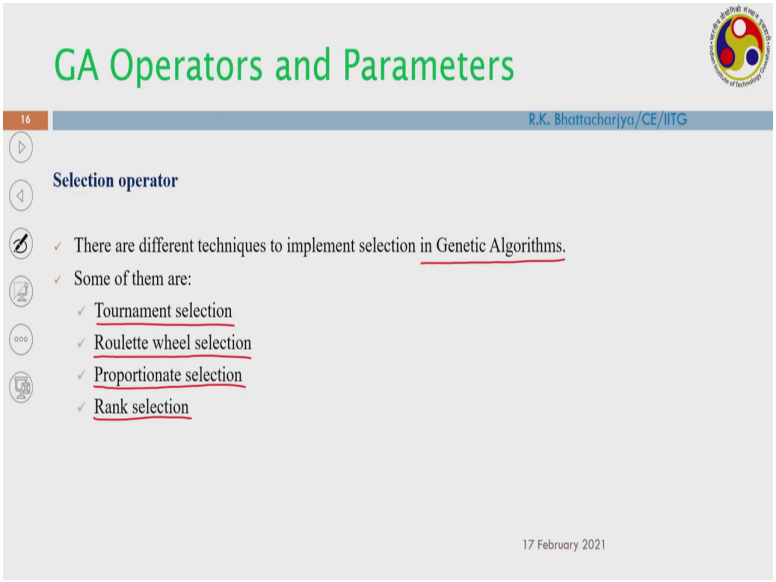

So, what selection operator will do and how we are implementing this selection operator ok. There are different techniques to implement selection in genetic algorithm. So, I have different algorithm for that, different techniques for that. So, some of them are tournament selection. Tournament selection; one is roulette wheel selection, then proportionate selection and rank selection ok.

So, we will discuss one by one. So, I can implement one of them basically or there are some other your selection operator also or you can have your own selection operator, but you just remember that; what is the function of selection operator that you have to identify the better solution.

So, this is one function and then you have to make multiple copies of the better individual and then you have to eliminate the inferior solution. So, that is the function of selection operator.

So, with this function you can apply or you can have different technique, but objective is to eliminate the inferior solution, getting multiple copies of the better solution that you have to implement ok.

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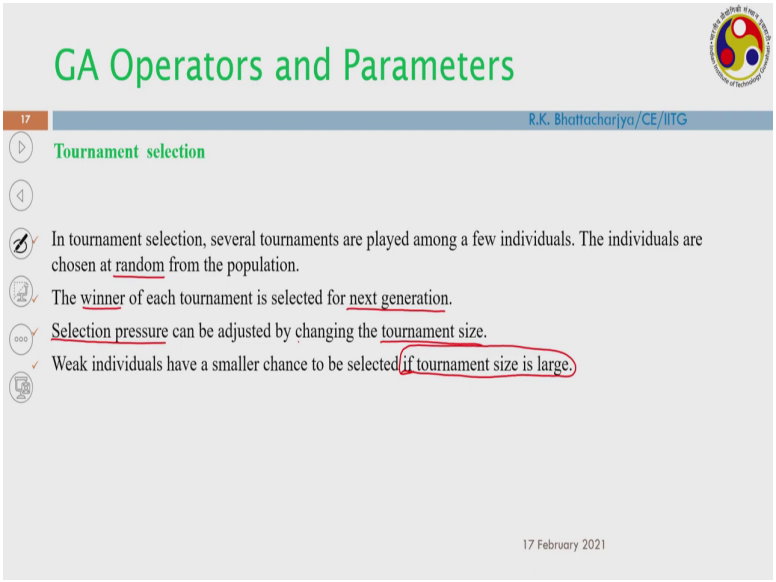

So, I will discuss one by one. So, let us discuss the tournament selection. What is tournament selection? So, in tournament selection, several tournaments are played among few individuals ok.

The individuals are chosen at random from the population. So, it is with random randomly chosen ok. The winner of each tournament is selected for the next generation. The winner will go to the next generation ok. So, this is the tournament selection and selection pressure can be adjusted by changing the tournament size.

So, I can actually the I can adjust the selection pressure. So I will discuss this thing in details what is selection pressure. And then, weak individuals have a smaller chance to be selected if tournament size is large. Tournament size is large means there will be more selection pressure ok. So, tournament size is large in that case, so I will explain when I will this when I discuss with an example problem. So, this is the tournament.

So, idea is that so you just select randomly, from the population you select few individuals it may be it should be more than two, the minimum three you have to select and then you can select three four five something like that, but if you are increasing your number selection pressure will increase.

So, I will also discuss what will happen if selection pressure is increased ok. Suppose then, what we will do basically, I am picking few individuals and ask them to play tournament ok. So, maybe it is a boxing tournament or something like that. So, what you are doing, this individual will play now ok, and at the end of the game one will be winner ok and this winner will go to the next generation. So this is a very simple concept to implement selection operator. The winner one will go to the next generation. Then what I will do? I will have a different tournament.

So next time, I will select another group and they will also go for the tournament and winner one will be selected. So that way, they will all the member of this population will play a tournament and the winner of that tournament will go to the next generation. So, this is the idea of tournament selection.

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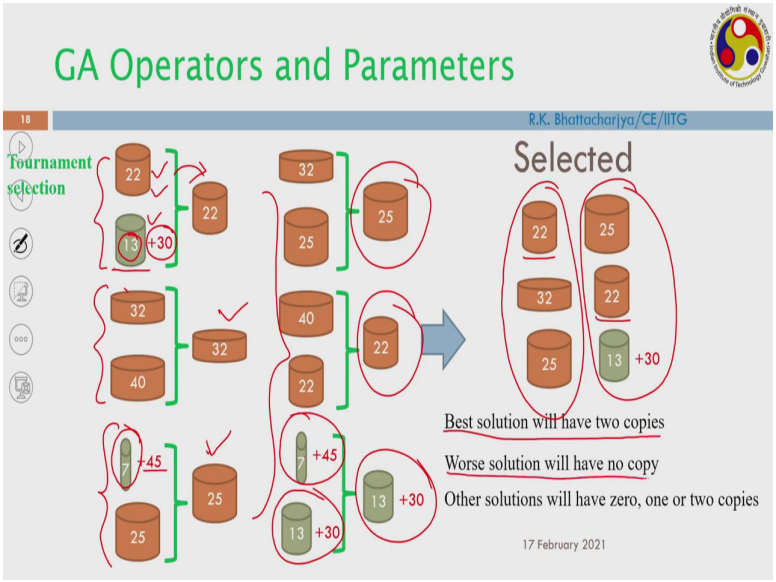

Now, let us take this example problem. Suppose, I have I am just explaining like. So, I have total six solution ok. So, this is first set, this is second set and this is third set. So, I have six solution.

So, what I am doing here? These six solution, so I am putting in a box. So, just the I am explaining the algorithm. So, what I am doing I am putting in a box and from that box randomly I am picking two solution

So, when you are picking these two solution, the first trial, the 22 and 13 is coming ok. 22 and 13 is coming. So now, they will play tournament then the stronger one will win the tournament and they will go to he will go to the next generation.

Now, in this case what is happening, that this is 22 and this is 13, but though it is 13 this is actually violating the constraints. So, if you recall the problem, so what we have discussed, the problem is minimization of cost, but at the same time the volume of the can should be 300 ok. Now it is not 300, so it is somewhat 270 and therefore, there is a violation of 30.

So, this is an infeasible solution and I do not want to select this solution and therefore, I am putting this violation here, though cost is 13, but solution is infeasible and that cannot be selected so I am putting the violation.

So now, if they are playing tournament, 22 is the better solution and 22 will be selected. So, I mean in the next trial 32 and 40 is coming and out of 32 is the better solution, so 32 will win the tournament and in the third trial 7 is coming with 25, but 7 is an in is an infeasible solution, the infeasibility the violation value is 45 and therefore, 25 will be selected.

Now, what I am doing here, so we have total six solution and out of six so how many if I select two individual for a tournament; that means, my tournament size is two, so in that case what will happen, I can play three tournaments. Is not it because my total solution is six, so three tournaments means three winner. So, I am getting three winner and these three winner will go to the next generation.

Now, what is the another purpose of selection operator? As I said, that the size of population size should be constant. That means, so I have six solution and after the tournament I should get six solution again, but now in the first set of tournaments so what I am getting? I am getting three solution. So therefore, what you have to do? We have to play the tournament again ok. So, we will ask them to play the tournament again and this time also I am selecting randomly.

So, now what is happening; 32 is playing with 25 and 25 is the winner and then 40 is playing with 22, so in that case 22 is the win winner and here both are infeasible and 7 is playing with 13 and in this case, this is basically little bit the violation is your less here and therefore 13 will win the tournament.

Now, from this tournament so from the second tournament also second round of tournament I am getting another three solution. So, in the first round I am getting three solution, in the second round I am getting three solutions and therefore I am getting total six solution ok. So, this six solution I am getting; this is three solution I am getting from the first round and this three solution I am getting from the second round.

Now, you look at this solution ok. So, 22 is the best solution in the population. So, 22, what is happening? Because, he is the best solution, so whenever he is playing the tournament in the first round or in the second round so he is the winner. So, 22 will have minimum two copies ok.

Now, what is the worse solution? So, worse solution is 7 ok 7 with a violation of 45, that is the worse solution. So, he will not be able to win the tournament in both the time so he will have zero copies, is not it.

So, the worse solution in the first round also he was not winner in the second round also he cannot be an winner. So, therefore, he will not have any copies; that means, the worse solution will not have any copies. So, you can see here, but the other solution depending upon who is playing with whom, so they may have one copies or two copies ok.

So, therefore finally I can conclude this thing. The best solution will have two copies; the worse solution will have no copy. So he will not have any copy. And the other solution will have zero one or two copies ok. So, they will be between they may have zero copies, they may have one copies or they may have two copies ok.

Now, if you look at what I am doing here, my tournament size is two in this case ok and therefore, I am playing this tournament that two rounds ok; first round I am getting three solution and second round I am getting another three solution, is not it. Now, if my tournament size is three, then what will happen? So that means, I am taking three solutions and I am asking them to go for tournament and out of three, one will be the winner.

So, therefore, in the first round how many solutions you will get? You will get two solution, because tournament size is three. Now, so you in first round the three is playing, first three is playing and then second three is playing.

So, you are getting two solution. Then what you have to so to get six solution, how many round you have to play? You have to play three round, because every round you are getting two winner, the second round you are getting two, third round you are getting two and all together you are getting total six solution.

Now, if you look at the best solution, the 22, what will happen? You will win the tournament in the first round itself, second round itself, third round itself. So you will have three copies is not it. So, you will have three copies worse solution anyway. So, you will not be able to win the tournament, so you will have zero copies and other may between zero and three copies, depending upon who is playing with whom basically.

So, now this is called selection pressure. So, what is happening, if you are increasing your tournament size from two to three; that means, best solution will have three copies. Now, if you are selecting suppose tournament size of four, then the best solution will have four copies, something like that.

So, now basically, so if you are increasing your tournament size then the best solution will have multiple copies. So, we do not won that. Some that is also not good for the search process I will also discuss when I will discuss the other operators then you will appreciate.

So, we are not basically two or three is fine tournament size, but we are not using tournament size of four five something like that, because the it will the your population will be saturated with the best solution, so that we do not won ok. So, and we will avoid that one ok. Then let us stop here. So, we will continue our discussion on genetic operators tomorrow.

Thank you.