Optimization Methods for Civil Engineering

Dr. Rajib Kumar Bhattacharjya
Department of Civil Engineering
Indian Institute of Technology, Guwahati

Lecture - 16
Introduction to Metaheuristic Optimization

Welcome back to the course on Optimization Methods for Civil Engineering. So, today, I will discuss about Metaheuristic Optimization method or basically, I will introduce what is metaheuristic optimization method. So, far we have discussed the classical methods. So, right now you know what is classical optimization technique.

So, you have learned the necessary and sufficient condition for optimality then we have discussed the line search technique ok. So, line search technique that means, for a single variable optimization problem; so, how you can find out the optimal solution of that particular function. Then, we discuss how to solve the multi variable problem.

So, what you are doing? Basically, you are doing couple of lines search. So, you are taking a direction and then, along that direction, you are trying to find out the optimal solution. So, we have discussed few algorithms like the Newton’s method, the steepest descent method and the univariate method as well as the conjugate direction method.

Now, you look at these algorithms. So, the basic assumption when you derive these your algorithm was that the function is a convex function that means there is only one optimal solution. So, therefore, if you apply this algorithm for a nonconvex problem so, having more than one optimal solution so, in that case, what you are getting?

You are getting only the local optimal solution that means you will get a local optimal solution of the problem. So, you may not get the global optimal solution of the problem if you apply these algorithms. So, let us initially look at what is the disadvantage of classical optimization methods or techniques and then, I will discuss about metaheuristic optimization technique which are capable of finding the global optimal solution of a nonconvex problem or a difficult problem ok.

So, let us see the difficulties or you can say disadvantage of classical optimization methods.

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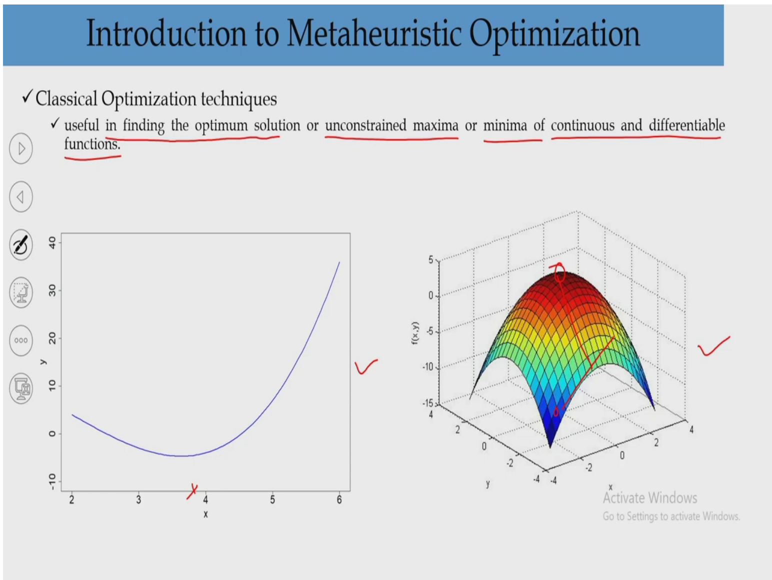

Now as I said the classical optimization techniques are useful in finding optimal solution or unconstrained maxima or minima of a continuous and differentiable function ok. So, the function has to be continuous and differentiable, why? Because, we are using the gradient information. So, therefore, the function has to be continuous as well as differentiable. So, look at the first function.

This is a simple function, we have only one optimal solution somewhere here, this is a convex function, and I can easily solve this problem using classical method. So, you just do a line search, you can apply the golden section search method, you can apply the inter locking method, you can apply the Newton Raphson method or you can apply any line search technique so, single variable optimization technique, you can find out the minimum of this particular function.

Because there is only one minima and you can easily find out the optimal solution of this problem. Similarly, if I take this two-variable function, this is also a convex function ok; this is also a convex function so, you apply any methods like Newton's method or univariate method, conjugate direction method, steepest descent method, you search from any point and finally, you will get the optimal solution of this particular problem.

So, these are simple problem, and I can say this problems are convex problem. So, therefore, if we apply the classical optimization methods so, you will be able to find out the optimal solution of this problems. So, there is no need to apply any other algorithms, because the classical algorithms are capable of solving this problem.

And you know that when we have derived this or when we have discussed about the classical optimization techniques mainly line search as well as after that we have discussed the different methods to get the direction I say that the function has to be a convex function that means, under the assumption that the function is a convex function and we have derived this or we have derived this algorithms ok.

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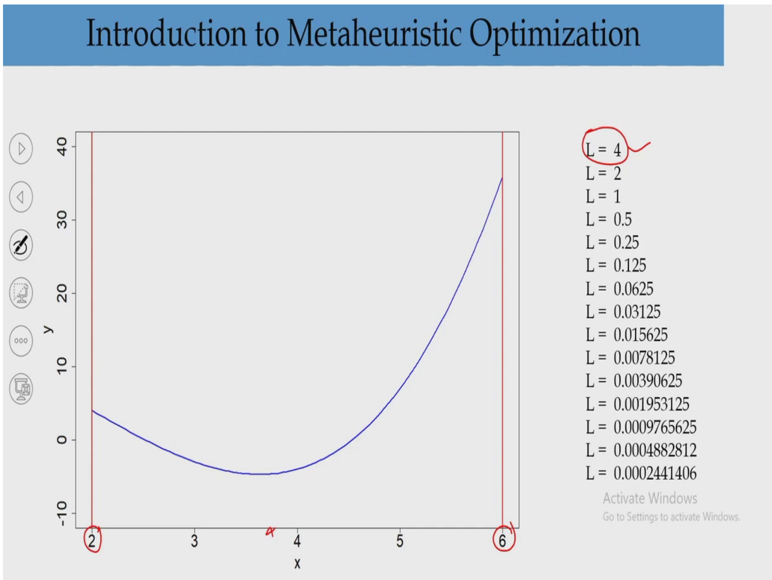

Now, let us see. I would like to show you one example problem. Suppose this is a function and we have only one optimal solution somewhere here; so, we have only one optimal solution somewhere here. Now, if I apply the reason elimination technique ok. So, in this case, I have applied suppose the interval halving method.

So, I have shown you the solution at different iteration and this is the beginning, the initial length of the search space is 4 ok. So, lower bound is 2, upper bound is 6 ok; So, lower bound is 2 and upper bound is 6.

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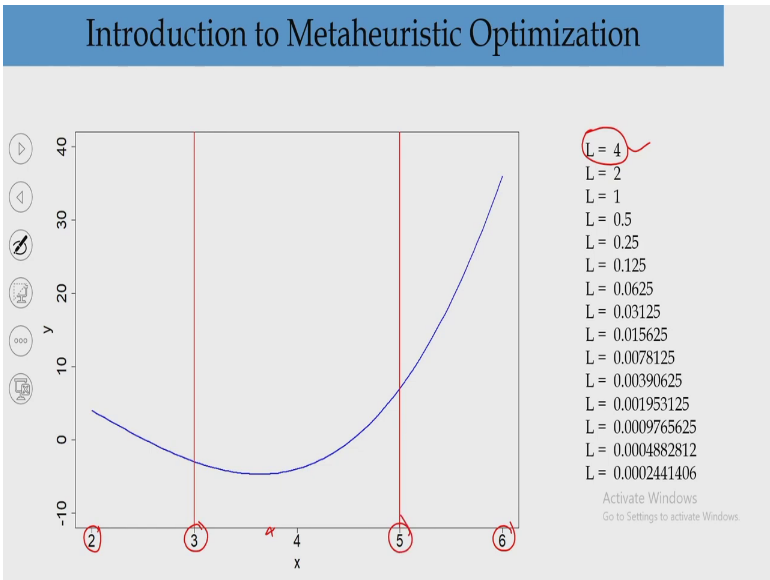

Now, if I apply the interval halving method so, in that case, after one iteration ok, in the second iteration, I am getting the lower bound equal to 3 and upper bound is 5 and the length is equal to 2.

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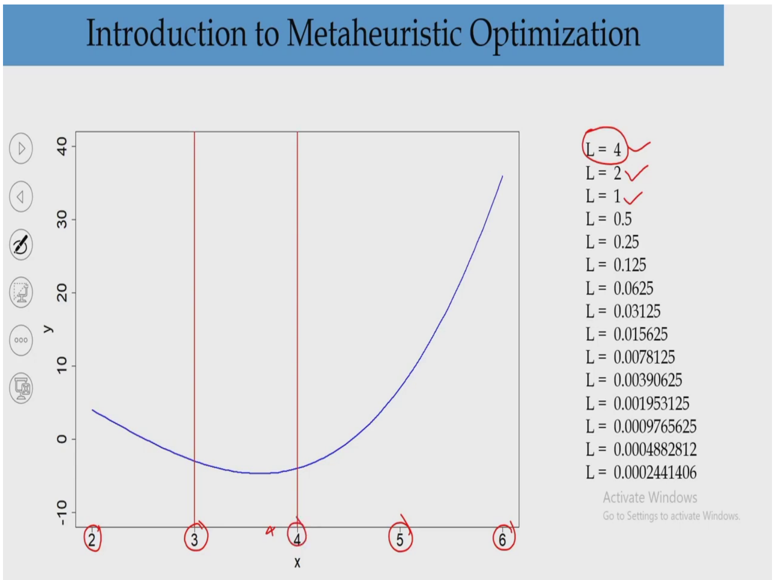

Then in the next iteration, the length I am getting 1, lower bound is 3, upper bound is 4.

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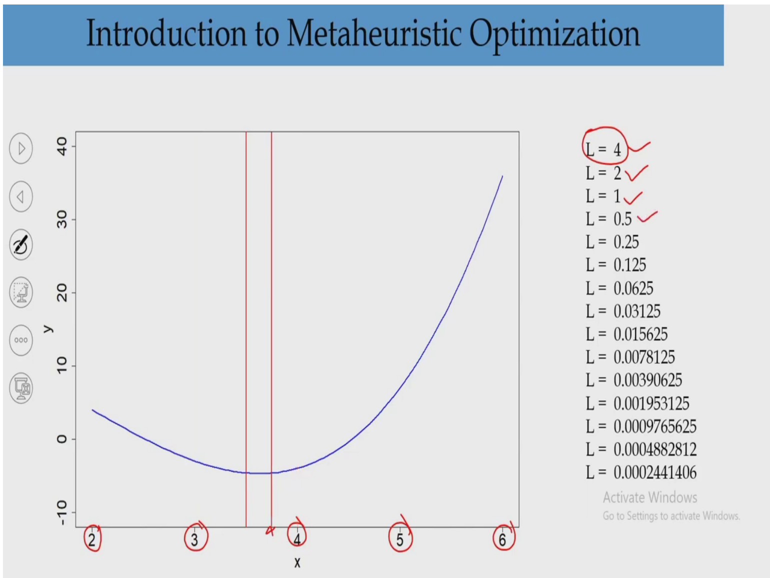

Then, if I continue this iteration so, I am getting length equal to 5 then, 0.25 something like that.

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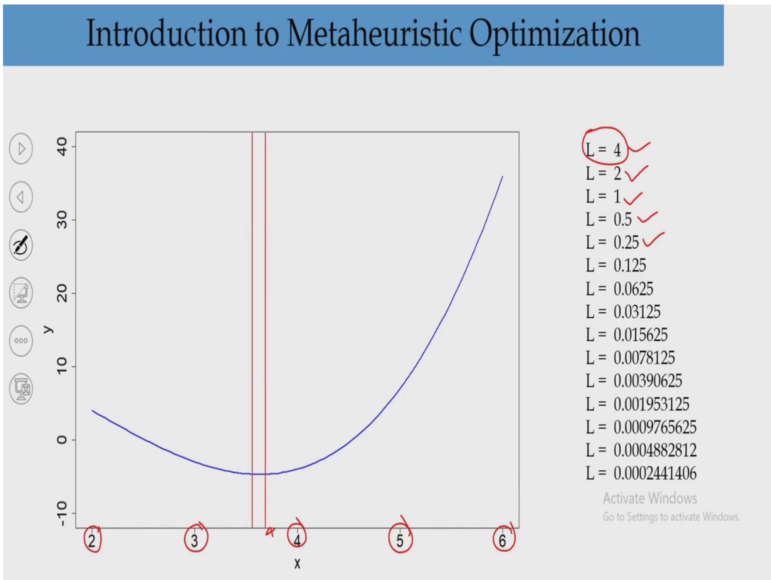

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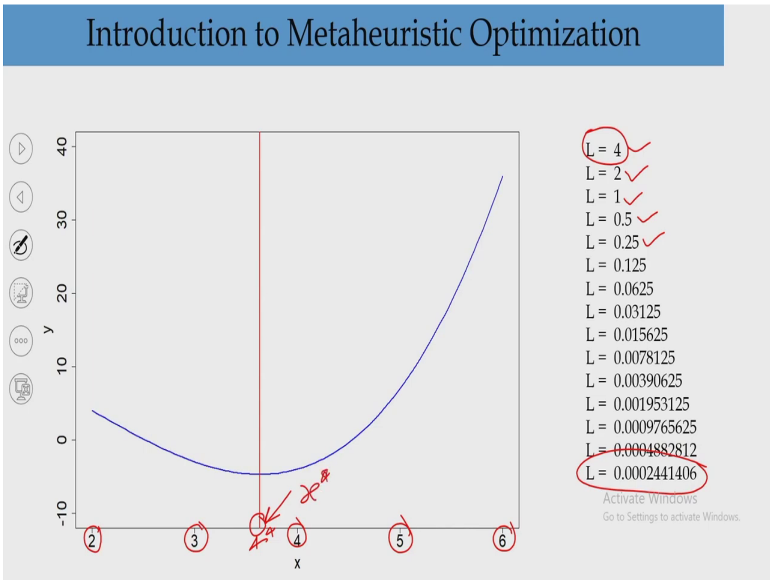

And finally, I am getting a very small length and it is or the value of L is 0.00024414 ok. So, I am getting this particular solution ok. So, this is the optimal solution of this problem, or I can say this is your x star. So, what I am telling here. So, if you have only one optimal solution, if your function is a convex function so, you apply this algorithm ok and you will get the optimal solution of this particular problem.

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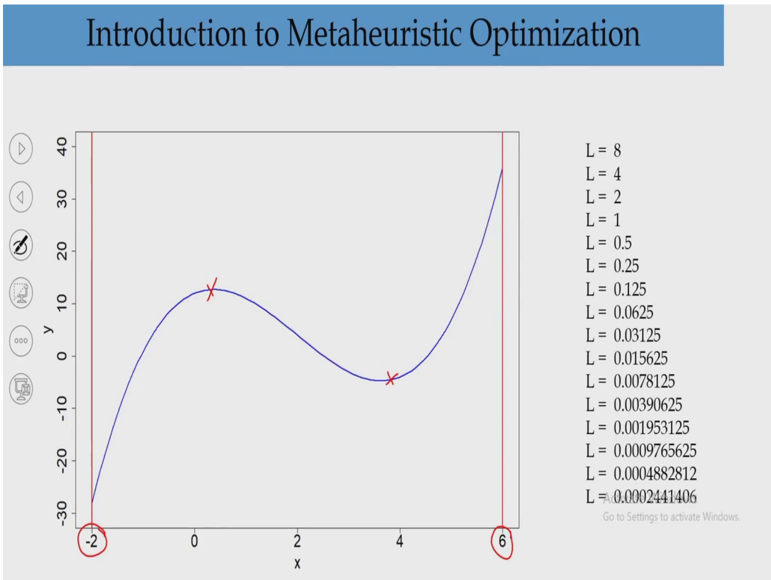

Now, I would like to apply this same interval halving method on this particular function. Now, just see this function has two optimal solution; somewhere here and here or maybe there may be other solution ok. Now, if you apply the interval halving method here, I have taken lower bond equal to minus 2, upper bound equal to plus 6 ok. Now, after the first iteration so, this is the initial solution or you can say the initially lower bound is minus 2 and upper bound is 6 and length is 8 ok.

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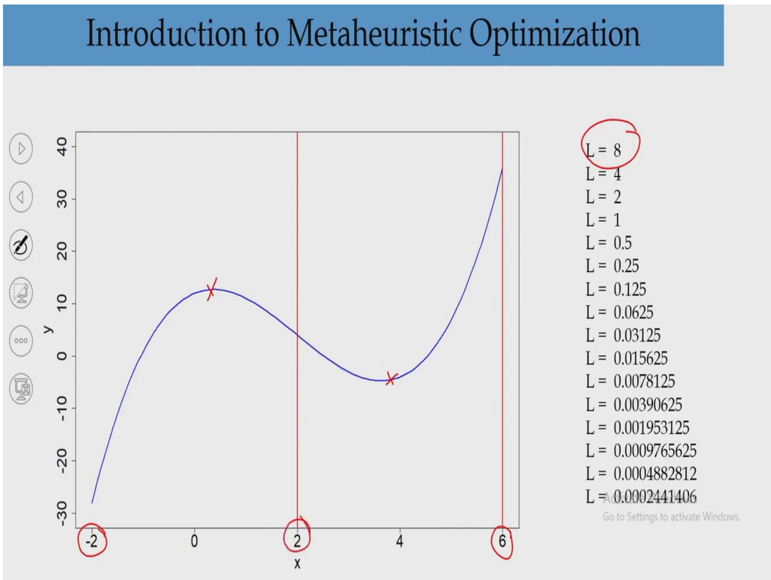

Then, after one iteration so, I am getting 2 and 6 ok.

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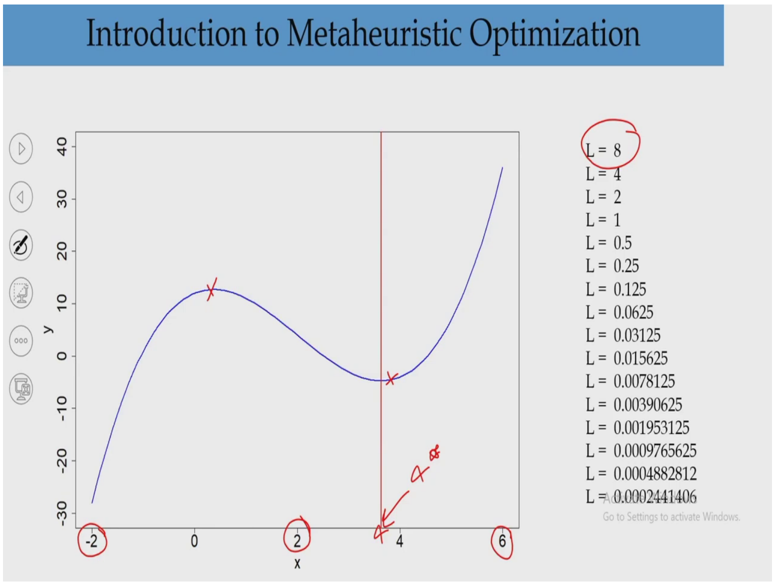

And if I continue this, then finally, I will get the solution somewhere here ok. So, this is the optimal solution of this particular problem. So, this is your x star ok; this is your x star. So, what will happen that if there; if there are more than one optimal solution so, in that case, you will get one of them. So, you can apply, it is not that you cannot apply this algorithm on a nonconvex problem so, you can apply, and you will get one of the local optimal solution.

So, this is a nonconvex function and I have applied the reason elimination technique though it was designed for a convex function, but I can apply this particular algorithm on a nonconvex function and I will get this particular solution.

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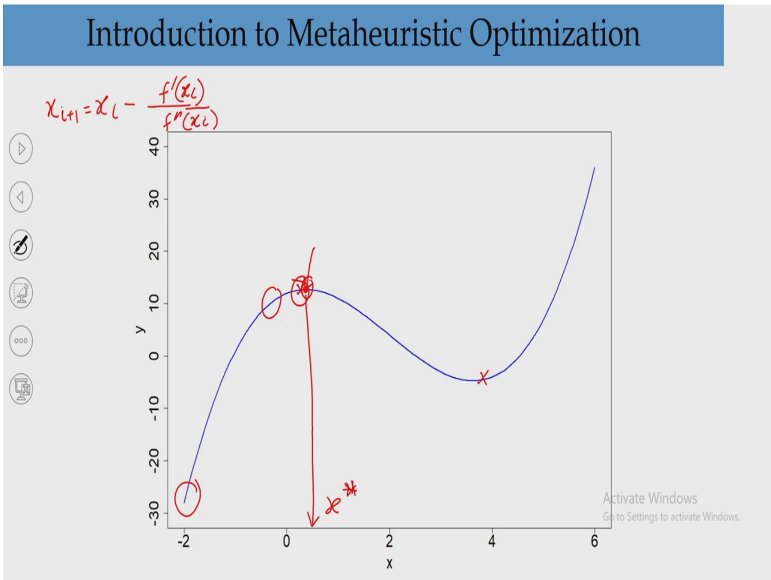

Now, let us apply the Newton Raphson method. So, in case of Newton Raphson method so, what we are doing that we are applying this equation that is x i plus 1 which is equal to x i minus that first derivative at x i divided by second derivative at x i ok to get the optimal solution of this function.

Now, just see. So, this is a nonconvex function ok, this is a nonconvex function and there is a maxima here and there is a minima here ok. Now, if I apply the Newton Raphson method here, suppose I have taken this as a initial point ok so, this as a initial point that is minus 2 as a initial point and if I apply the Newton's method ok. So, in the second iteration, I am getting this point, in the third iteration I am getting this point, fourth iteration I am getting this point so, finally, I am getting this solution ok.

So, this is one x star, or you can say this is a stationary point and this is a maximum point. So, this is one solution of this particular function.

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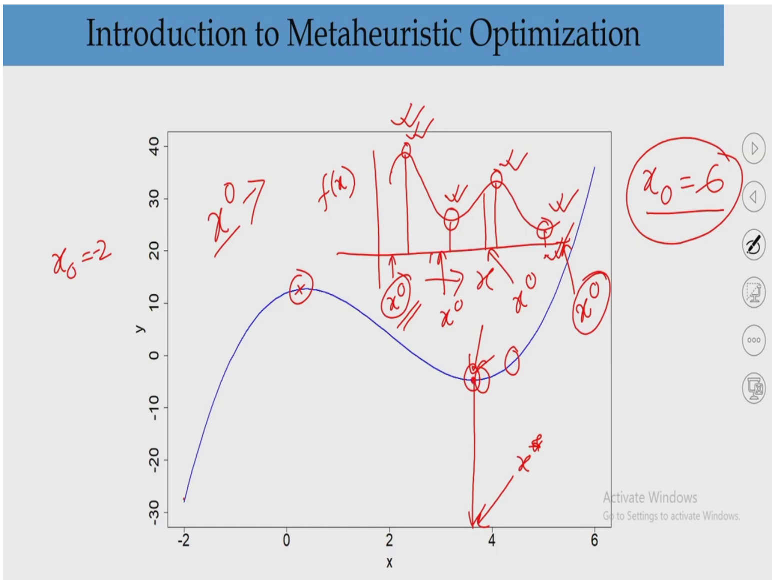

Now, you take plus 6 that x naught equal to 6. So, in the earlier case, I have taken the x naught equal to minus 2. So, from minus 2, I am getting this particular solution, then if I take x naught equal to 6. So, in that case just see in the second iteration, I am getting this solution, third iteration I am getting this solution, fourth iteration I am getting this solution, and this is the solution of this particular function. So, this is another stationary point is not it. So, this is another stationary point.

So, therefore, what will happen? So, if you are taking minus 2 so, you are getting this solution and if you are taking plus 6, you are getting this particular solution. So, therefore, if you apply this algorithms so, you will get one of the solution or you can say you will get the local solution from where actually you are starting. So, therefore, this algorithms are sensitive to initial solution.

Let us take an example problem. So, this is f x and this is x suppose the function is like this. So, we have one solution here and this is a maximum point. We have another solution, this is also a maximum point, this is another point, this is a minimum point, and this is also a minimum point. So, therefore, in this particular function, we have two maxima ok so, this is one maximum point this is another maximum point and there are two minima. So, this is one minimum point and this is another minimum point.

Now, let us use the classical optimization method that means, any single variable optimization technique to find out the maxima and minima of this particular function. Now, if I take this as my initial point x naught, then I will get this particular solution. If I take this particular point as my x naught; so, I will get this particular solution. If I take this particular solution as x naught; so, I may get this solution. And if I take this particular solution as x naught; so, I will get this solution.

So, therefore, what will happen? Depending upon your initial solution, an initial solution you have to define as a user, you have to define the initial solution, this x naught value that user has to define. So, depending upon what initial value you have provided to the algorithm so, you will get one of these optimal solutions.

So, therefore, for a nonconvex problem or if you have more than one optimal solution of a particular function, then this algorithms are highly sensitive to initial points supplied to the algorithm is not it. So, depending upon the initial point, suppose if you are supplying this particular initial point, then you may get the global maximum of this function and if you are giving this particular point as an initial point, then you may get global minimum of this particular function.

So, now in this case, you know actually you have seen this function and you can decide an initial point, but just look about if a problem having 100 variables ok. So, this is not possible to know actually what initial point you should take to get the global optimal solution of the problem ok.

So, therefore, this algorithms are not capable of solving a nonconvex problem or a problem having multiple optimal solutions. So, if you apply this algorithms on such type of problems, in that case, you will get a local optimal solution of the problem.

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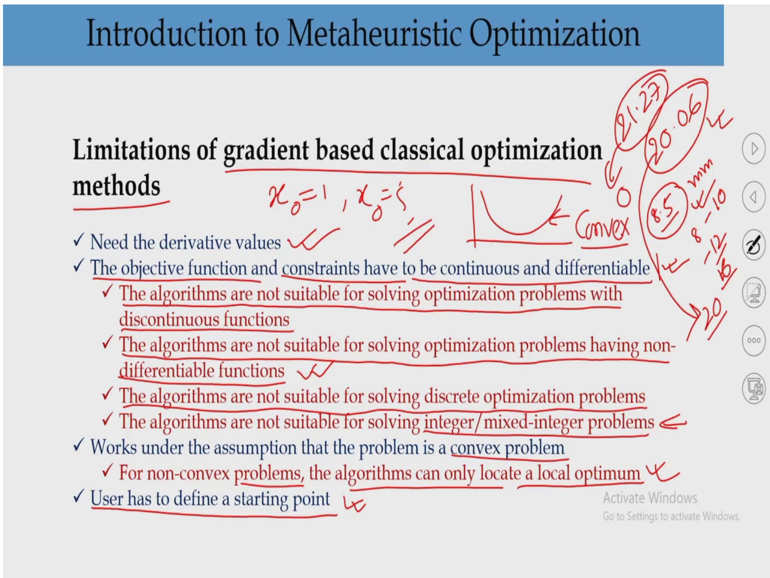

Now, let us look at the limitations of gradient based classical optimization method ok. So, I already discussed that one, but I have listed down the limitations here. So, what you need? You need the derivative values; you need the derivative information is not it. The second one, the objective function and the constraints have to be continuous and differentiable. So, I already said that one.

So, because I would like to apply the gradient based classical optimization technique. So, therefore, the function has to be continuous and differentiable ok. So, this is the need or you can say this is the one assumption or this is the need. So, then what are the limitations? The limitations are the algorithms are not suitable for solving optimization problems with discontinuous function.

So, now, if your function is discontinuous ok, it is not a continuous function; so, you will not be able to apply this algorithm. So, this is one limitation. The second limitation is the algorithms are not suitable for solving optimization problem having non-differentiable function ok. So, if your function is non-differentiable, it is continuous function, but non-differentiable so, in that case, you will not be able to apply this algorithms.

Now, I would like to tell one point here, there may be a function ok, it is differentiable, but question is that how you are calculating derivative? So, you have to calculate derivative using numerical methods many time. So, you need to calculate the derivative you using numerical method.

So, I discuss about that one, how you can calculate the derivative using numerical methods. So, now in that case, what will happen? So, many time, you will face some problem in calculating the derivative of the function ok. So, therefore, these algorithms are not suitable for solving optimization problem having non-differentiable function even if sometime its differentiable, but it is very difficult to calculate the derivative.

So, it may take lot of time to calculate the derivative also. So, in that case also, these algorithms are not suitable ok. Then, the third one is the algorithms are not suitable for solving discrete optimization problem ok. So, discrete problem so, I can say that if your problem is discrete in nature ok so, in that case, this algorithms are not your suitable because that function is not a continuous function.

So, similarly, if you have integer problem or mixed integer problem so, many times what happen? Suppose I can give an example of integer problem suppose you would like to design a particular your beam or column ok and I would like to design the reinforcement, I would like to minimize the reinforce requirements so, ok.

So, reinforce is suppose you are giving in terms of diameter of the bar. Now, this diameter of the bar so, suppose you are getting 8.5 so, 8.5 will not be available, 8.5 mm bar suppose your optimal solution is 8.5 mm bar you need to use in that particular beam or column.

Now, 8.5 is not available ok in the market because either you will get 8 mm or you may get 10 mm or you may get 12 mm, then 16 mm, then 20 mm like that so, 8.5 is not available. Similarly, suppose you are getting 20.06 so, that is also not available so, I then either you have to use 20 or 25 or your 18 or 16 ok. So, therefore, these problems are your integer type problem. So, either you can use 20 or 16 or 12 something like that. Now, in that case, these algorithms are not suitable ok.

So, if you are apply this algorithms, then you will get a value suppose something like that as I said in this case 8.5 or 20.06 or 21.27 so, this is not available in the market. So, therefore, you will not be able to use this particular value. So, in that case, these algorithms are not suitable for solving integer problem or mixed integer problem. So, here, there may be integer variable along with the continuous variable ok.

Then, the other limitation is are the work under assumptions that the problem is a convex problem. So, I have already explained that one that when we derive this algorithms ok. So, in that case, we said that the function is a convex function, we have only one optimal solution, if the function is a convex function ok so, convex function. And we have already discussed what is convex function and what is nonconvex functions ok.

So, this algorithms work under the assumption that the problem is a convex problem. So, entire problem is a convex problem. For nonconvex problems, the algorithm can only locate a local optimum ok. So, if your problem as I said you can apply, you can apply this algorithms on a nonconvex problem, but in that case, you will get a local optimal solution. So, you can apply provided the function is a continuous function and function is differentiable ok.

So, in that case, you can apply, and you will get a local optimal solution of the problem. Now, question is that how to get the global optimal solution. You can try, you can use this algorithms to get the global optimal solution of the problem, but what you have to do? You have to sense your initial points. Suppose you are starting with x naught equal to initial 1, maybe after that x naught equal to 5.

So, for different x naught ok so, you can try and just see whether you are getting a better optimal solution of the problem. So, you can apply on a nonconvex problem, but in that case, you will get the local optimal your solution of the problem or a local optimal solution you will get.

Now, user has to define a starting point. So, this is you can say another limitation because I do not know in case of a nonconvex problem, if you have more than one optimal solution of a particular problem and I would like to find out the global optimal solution of the problem so, in that case, I really do not know what starting point I should take so, but user has to define a starting point here and you can say suppose if I use a suitable starting point.

So, whatever starting point you have given, luckily that starting point is near the global optimal solution of the problem or you can say on that particular region where global optimum solution is there. So, in that case, you will get the global optimal solution of the problem. So, user has to define a starting point and you can say this is another limitation of classical optimization technique ok.

So, why I am telling about this limitation? Because this metaheuristic optimization methods are developed to overcome this limitations ok. So, when we will discuss about metaheuristic optimization methods ok or technique so, these algorithms are actually develop or design to overcome this limitations of the classical optimization methods. I hope this is clear to you.

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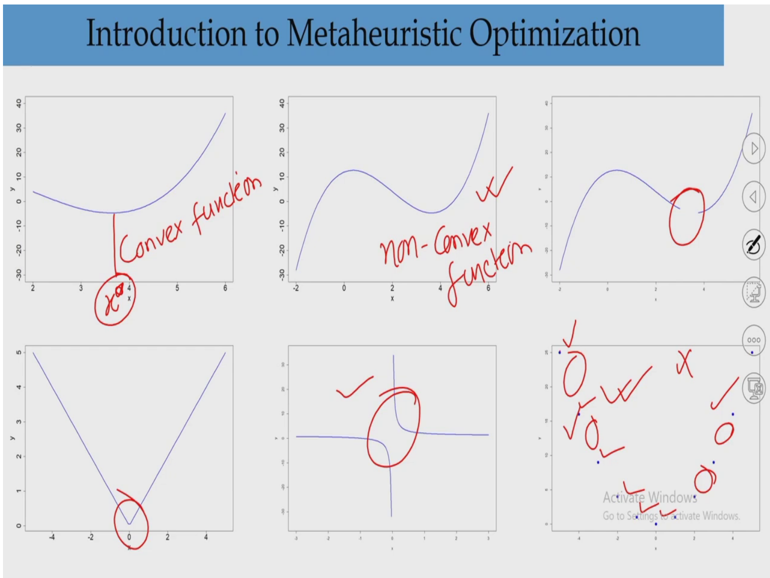

Now, I have shown you some functions here. So, I can apply the first function is a convex function is not it? Convex function ok. So, I can apply the classical optimization technique and I can obtain the global as well as local optimal solution of this problem and this is a local optimal solution as well as the global optimal solution of the problem because this is a convex function.

Now, this is a nonconvex function is not it, this is a nonconvex function. So, in this case also, I can apply the classical optimization technique because the function is differentiable and the function is continuous so, I can apply the classical optimization technique.

But I will get one of the solution. If you have multiple optimal solutions, then in that case, you will get one of that if you apply the gradient based classical optimization technique. So, you can apply here, but depending upon what initial solution you have provided so, you will get one of the optimal solution of the problem.

Now, this is a discontinuous function, the third function so, I will not be able to apply the classical optimization technique, the function is not continuous ok. Then, similarly, this particular function is non-differentiable at this particular point. So, therefore, I will not be able to apply the classical optimization technique and similarly, here also this is discontinuous function, this is also a non-continuous function.

Therefore, I will not be able to apply the classical optimization technique ok and this one is you have discrete search phase ok. So, solution can be here, solution can be here, solution can be here, solution can be here, solution can be here so, this is not a continuous function.

So, you will not be able to apply the classical optimization technique or gradient based classical optimization technique for solving or for finding the optimal solution of this particular function or particular problem because this is discrete in nature ok. So, either you will get you should get this solution, or you should get this solution or you should get this solution, there is no solution here ok. So, in between there is no solution. So, therefore, you will not be able to apply the gradient base classical optimization.

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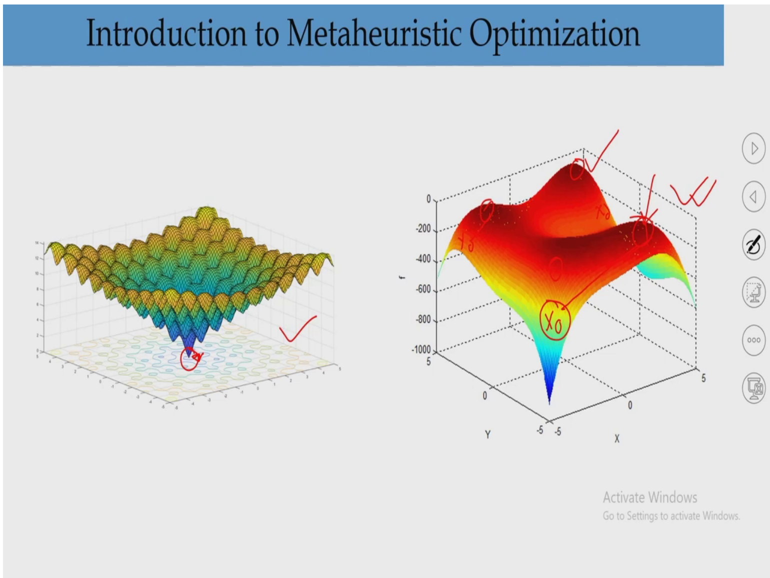

Similarly, you look at this particular function. So, let me look at, let me discuss about this second function. So, here you just see there are four optimal solution of this particular problem ok. Now, this is a continuous function, and this is also differentiable, but only problem is this is not a convex function ok. We have more than one optimal solution.

Now, I can apply the classical optimization technique because the function is differentiable and continuous ok. Now, if you take x naught somewhere here so, maybe you are going in this direction and in this direction so, you may get this particular point. Now, if you are taking x naught somewhere here, then you may get this point, x naught somewhere here you may get this particular point.

So, therefore, depending upon what x naught you have chosen so, you will get one of the optimal solution ok. So, you may not get the global optimal solution, but you will get one optimal solution. Now, you look at this particular function so, there are innumerable, there are lot of local optimal solution and one of them is the global optimal solution. So, you have only one global optimal solution so, somewhere here and others are local optimal solutions ok.

Now, if you apply the classical optimization methods here so, you will get one of the local optimal solution. So, what you have to do? You have to change your initial point and luckily if you are giving initial point somewhere here so, you may get the global optimal solution of the problem. So, therefore, this particular function is therefore, it is not that easy to get the global optimal solution of this particular function using classical optimization method.

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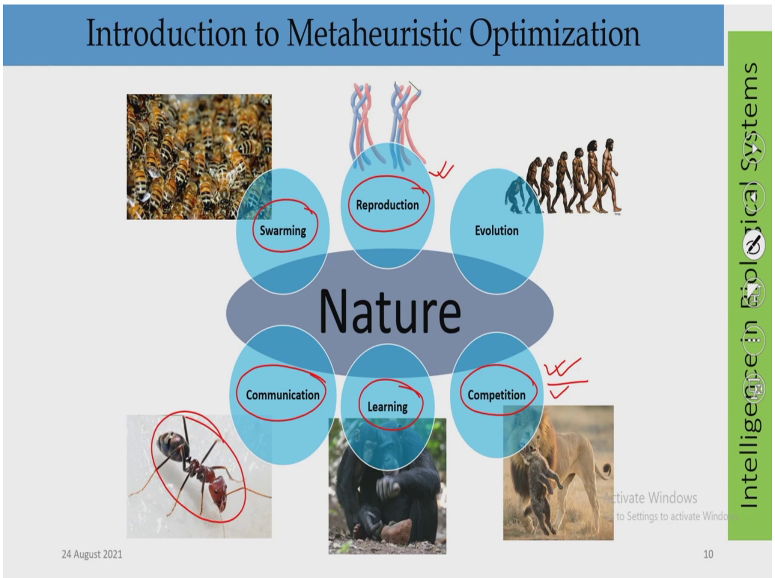

Now, you know what is the disadvantage of classical optimization methods so, let us look at the metaheuristic optimization. Now, metaheuristic optimizations methods are derived from different phenomenon's happening in natures. So, if you look at the nature so, intelligence in biological system. Now, let us start from this particular your circle computation.

So, what is happening? In nature, there is a competition, or we can say that we are struggling for survival. So, within the spaces or across the spaces is not it. So, there is a competition and competition is for the resources, for the survival. So, therefore, everyone will not be able to survive in nature and you can say the fittest will survive.

Those who are fit, those who are strong, those who are intelligent, they will survive so, other people will not be able to survive because of competition is not it. So, because of competition. So, this is one phenomenon which is happening in nature ok. Then, another is learning. So, we are learning not only the human beings, even the animals, even the ants so, they are learning with the experience ok with experience they are learning.

So, they are learning and you can say this is a trial and error-based learning method ok so, they are learning. Then, they are also communicating. So, there is a very good mechanism to communicate each other ok. So, they are communicating with the your other individual of that particular species so, there is a good communication method.

Then swarming. Swarming is, so, they are actually working in group ok. So, they are not working in individual means suppose they are not working individually ok. So, they are working in group, and you can say the swarming. Suppose they are when they are searching food, they are not going alone.

So, they are going in a group and they have a very good methodology to search the food and basically, it is a well-organized, it is not arbitrarily they are moving from here and there and in search of food. So, they are moving in group or swarming. And reproduction, reproduction means they produce offspring.

Now, when they produce offspring, some of the offspring may be better than their parents ok. So, that means, the offspring may be better than parents or they may have the means better capability for survival. So, that is another your factor or that is another factor what is happening in nature ok so, these are.

So, now, what we are doing basically? If you look at these natural processes or if you look at the phenomenon what is happening in nature or intelligence in biological your system, now people are trying to look at this phenomenon and if you are looking at it, everything is optimized.

Suppose when this ant, they are searching for food so, as I said in my first class also so, they have a very good communication technique, they are communicating each other, and they have a methodology to move in a shortest route basically ok. So, therefore, they are not moving arbitrarily. So, they have actually optimized the process so that they can reach, or they can take the food using a shortest distance ok.

Similarly, if you look at the other phenomenon what is happening in nature, they are also using, or their processor also optimize process. So, by looking at this your natural processes so, many researcher, they have proposed the optimization methods so, we call it metaheuristic optimization method. So, I will explain why it is metaheuristic optimization ok. So, they have given different metaheuristic optimization method for solving optimization problem.

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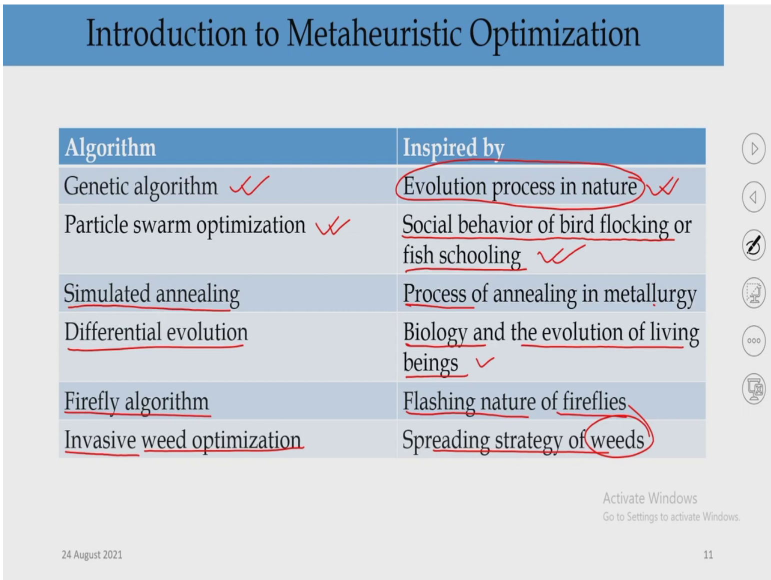

Now, some of the metaheuristic optimization algorithms are genetic algorithm ok. So, inspired by the evolution process in nature so, this algorithm. So, people are looking at the evolution process and whether this evolution process is a random process or a guided process. So, it is not a random process and based on that, this algorithms has been you derived or it has been proposed and it is working fine in finding the optimal solution of the problem ok.

Similarly, there are some other algorithms. So, this one is particle swarm optimization and this is based on social behavior of bird flocking or fish schooling ok. So, what is the social behavior based on the social behavior of bird flocking or fish schooling ok. So, how they are searching food.

Then, similarly, the simulated annealing, this is inspired by the process of annealing in metallurgy ok so, process of annealing in metallurgy. So, based on that, this simulated annealing algorithm has been developed. Then, difference in evolution, this is based on biology and the evolution of living beings ok. So, based on that so, it has been developed. Then, firefly algorithm. So, this is inspired by the flashing nature of fireflies ok so, flushing nature of firefly. So, I will also discuss about this algorithm.

Then. there is another algorithm which is inspired by the spreading strategy of weeds ok. So, if you look at a paddy field or a cultivated field is basically captured by the weed, this is unwanted. So, this is based on the spreading strategy of weed so, which are unwanted as you know so, we call it invasive weed optimization. So, it is inspired by how weed is occupying the entire fields or it is an we call it invasive weed optimization ok.

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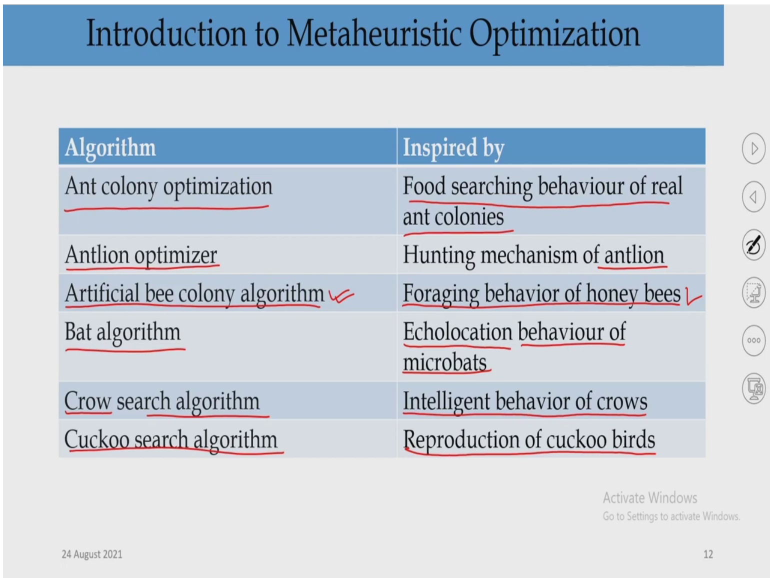

Algorithm	Inspired by
Ant colony optimization	Food searching behaviour of real ant colonies
Antlion optimizer	Hunting mechanism of antlion
Artificial bee colony algorithm	Foraging behavior of honey bees
Bat algorithm	Echolocation behaviour of microbats
Crow search algorithm	Intelligent behavior of crows
Cuckoo search algorithm	Reproduction of cuckoo birds

Now, ant colony optimization. In the first-class introduction also, I said about that one. So, ant colony optimization so, it is inspired by food searching behavior of real and colonies ok.

So, how they are searching food ok. So, based on that, this algorithm has been developed so, inspired by the food searching behavior of real ant. Antlion optimizer; so, hunting mechanism of antlion ok. So, this is inspired by the hunting mechanism of antlion.

Then, artificial bee colony algorithm. So, foraging behavior of honeybees ok. So, how they are collecting the honey in a honeybees ok. So, based on that or inspired by that mechanism, this algorithm has been proposed or it has been developed artificial bee colony algorithm.

Then, bat algorithm that is inspired by echolocation behaviour of microbats ok. So, this is another algorithm. Then, crow search algorithm. So, this is inspired by the intelligent behavior of crows ok. So, this is another metaheuristic optimization algorithm. Then, cuckoo search algorithm so, this is inspired by the reproduction of cuckoo birds ok.

So, this is some of the metaheuristic algorithms. So, these algorithms are inspired by the different phenomenon what is happening in nature and if you look at these algorithms so, they are not actually using the gradient information so, that also I will explain, they are not using gradient information and they are only using the function fellow, but this algorithms are inspired by the different phenomenon, different activities happening in nature ok.

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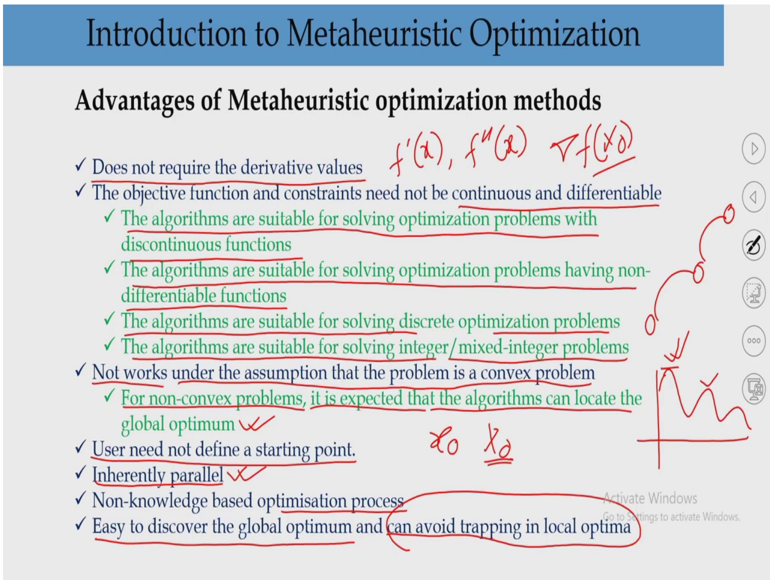

Now, let me discuss what are the advantage of metaheuristic optimization method. So, the first advantage is does not required the derivative value ok. So, we do not use the derivative value either first derivative or second derivative so, I do not need that one ok. So, I need not calculate the derivative value ok. So, this is you can say this is the main advantage of metaheuristic optimization method. So, I do not need the derivative information.

The objective function and constraint need not be continuous and differentiable. So, the one of the limitation of classical optimization methods are one of the limitations is that the function should be continuous and differentiable, but in case of metaheuristic optimization method so, this restriction is not there.

So, function can be a discontinuous function, discrete function, non-differentiable function so, you can solve the optimization problem having discontinuous function, non-differentiable function and you can also solve the discrete problem, integer problem, mixed integer problem.

So, therefore, the algorithms are suitable for solving optimization problem with discontinuous function. Algorithms are suitable for solving optimization problem having non-differentiable function. The algorithms are suitable for solving discrete optimization problem. The algorithms are also suitable for solving integer and mixed integer problem ok.

So, another advantage is not works under the assumption that the problem is a convex problem. So, I can apply this algorithm for nonconvex function rather I will say that if your problem is a nonconvex problem. So, I also discussed this thing earlier that suppose how to select an algorithm. So, now, you have different algorithms ok. Now, you have classical algorithm now, you have metaheuristic optimization methods now, for your problem which one you will select?

So, what I will say that if your problem is a convex problem, you go for classical optimization technique because they are very good algorithm for solving a convex problem. So, if your problem is a convex problem, if you know that if your problem is a convex problem, you apply the classical optimization method.

Now, if your problem is a nonconvex problem, then you apply this metaheuristic optimization problem. So, I will suggest that you apply metaheuristic optimization problem. So, therefore, for nonconvex problem, it is expected that the algorithm can locate the global optimum ok. So, it can locate the global optimum. So, in case of metaheuristic optimization problem that probability is very high that you will get the global optimal solution of the problem.

So, it will not, it will basically avoid the local optimal solution. Then, user need not define a starting point. So, I need not define a starting point like classical method, I have to define what is x naught ok. So, x naught I have to define and from there, your search process will start, but in this case, I need not define the starting point ok.

Then, it is inherently parallel that means, if I want to apply parallel your computation ok. So, I can do inherently parallel, but the classical algorithms are sequential that means, from you are going from one point to another, then you are going to another point, but here, this is inherently parallel ok.

Non-knowledgeable based optimization. So, here, I do not want to actually without knowing the nature of the function actually, you can apply this algorithm so, non-knowledge-based optimization process. So, without knowing that suppose in case of classical methods; so, you should know actually what problem you are trying to solve it ok otherwise, you may not get the optimal solution.

But in this case, I do not need the knowledge on the problem ok. So, without knowing about much about the objective function and constraint so, I can apply this because I am not calculating the derivative, or it can be applied on a non-continuous your function also it. So, it can be applied on a non-continuous, non-differentiable function also.

So, non-knowledge base optimization easy to discover the global optimum. As I said it is expected that the problem will give you the global optimal solution of the problem, easy to discover the global optimum and can avoid trapping in local optima. So, I can avoid the local optimal solution that mean suppose if your function is something like that, I would like to find out the global minima so, I may get this particular.

And similarly, if I need to find out the global maxima that also I may get. So, I can easily avoid the other local optimal solutions ok. So, these are advantage of the metaheuristic optimization methods. So, I would like to tell that metaheuristic optimization methods are problem independent method ok. So, it is not depend on what type of problem actually you are trying to solve. So, it is independent of the problem.

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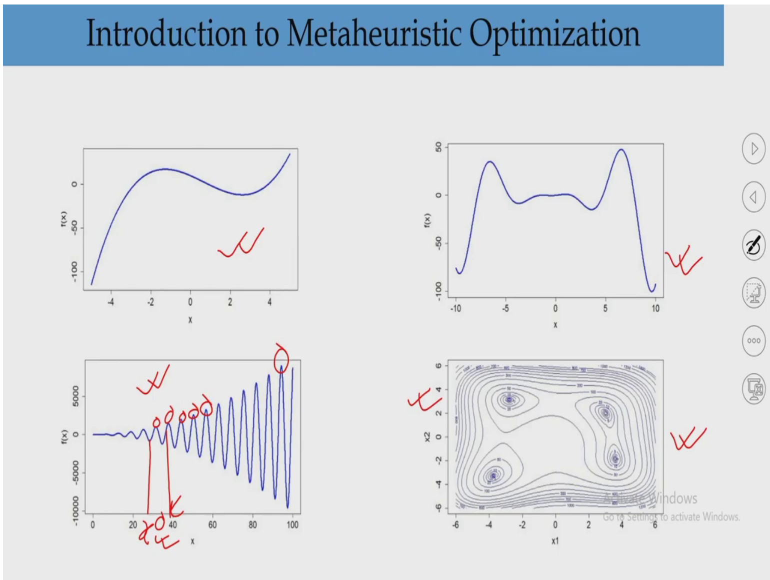

Now, as I said now, I can apply the metaheuristic optimization method for finding the global maximum solution, global maximum or global minimum. So, I can apply here also, I can apply here also, now you look at this is a very difficult problem if you apply the classical optimization method.

Because, so, if you are putting this particular point as your x naught so, you will get this solution. If you are putting this one, then you will get this solution. If you are putting somewhere here, you may get this solution, this solution, this solution. So, therefore, depending upon what x naught you are using, you will get 1 of the local optimal solutions.

But if you apply the metaheuristic optimization methods so, you may get the global optimal solution in a single run ok. Similarly, I can also apply the metaheuristic optimization methods here. So, this is all about the introduction to metaheuristic optimization methods.

So, today I have introduced you what is metaheuristic optimization methods, I also discuss the disadvantages of classical optimization methods ok. So, in many problems, if your problem is not continuous, non-differentiable, you will not be able to apply classical methods. Similarly, if your problem is a integer problem or a discrete problem so, you will not be able to apply classical method.

So, to overcome those things so, this metaheuristic optimization methods can be used and this method can give you the global optimal solution of the problem or your search process will not trap in a local optimal point. So, I can avoid the local optimal solution and I can get the global optimal solution of the problem.

So, in the next class, I will discuss genetic algorithm. So, this is one of the metaheuristic optimization algorithms very powerful in finding the global optimal solution of the problem. So, I will discuss this algorithms in the next class.

Thank you.