Introduction to Soft Computing
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Lecture - 20
GA Operator : Crossover techniques

We are discussing, the genetic algorithm operators and we have discussed about encoding and then selection operations. Now we are in a position discuss another very important operation, it is called the crossover operation.

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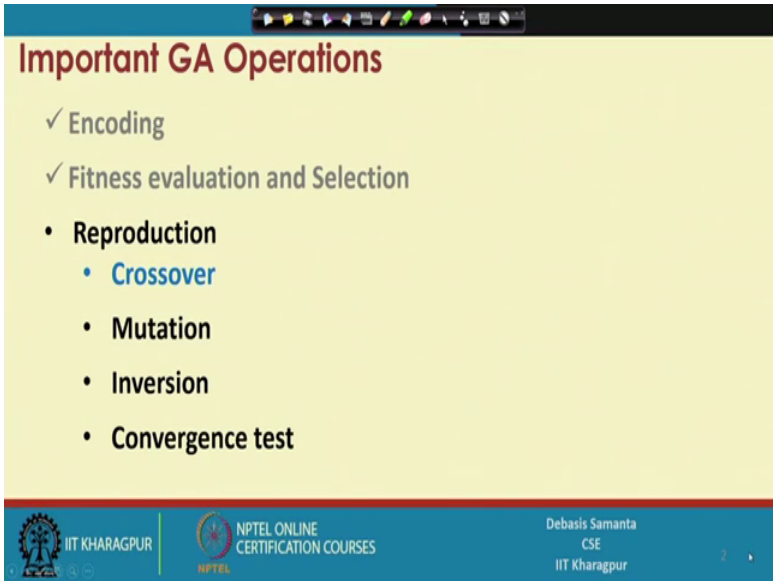

So, crossover operation is basically essential operation in the part of the another task in genetic algorithm is a reproduction.

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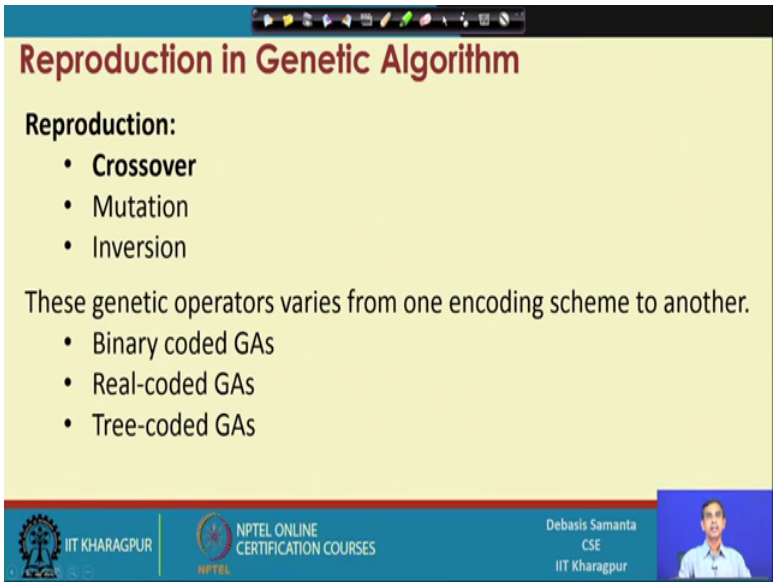

So, reproduction is basically, it consist of in addition the crossover there are some other operations involved mutation inversion which will be discuss in another lectures. So, first we will discuss about the crossover operation and we should, in this context I should mention that, the different encoding scheme. If we follow in genetic algorithm accordingly the different crossover strategies are to be followed.

For example, binary coded GA crossover is not applicable to real coded GA, or the crossover technique that is there for the real coded GA is not applicable to binary coded GA or tree coded GA. So, different the coding encoding scheme is.

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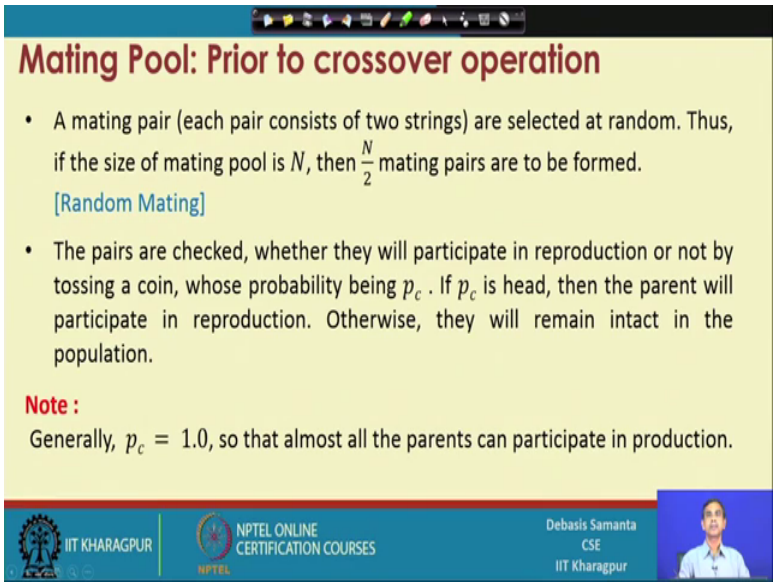

If it is there in the genetic algorithm and according the different crossover techniques are to be followed. Now, so we are discussing about crossover which is basically part of the reproduction and prior to the c production the mating pools are to be created.

So, basic idea about the mating pool creation is that, if we select the Np individual from there the mating pair are to be selected usually it is a random procedure; that means, 2 populations are to be selected at random and then they can be consider is 1 mating pair. So, this is called the random mating.

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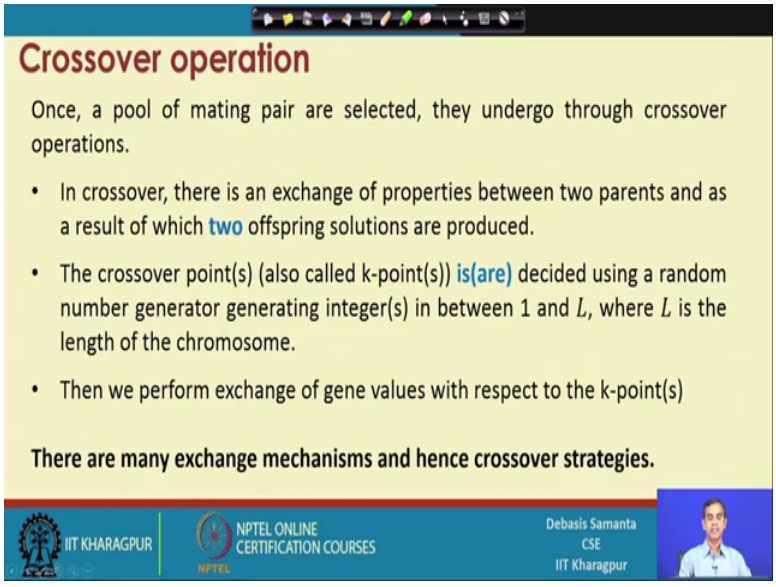

So, random mating once it is there, so it will produce the number of what is called the parents there. So, 1 mating pair this means 2 parents it is, and from the 2 parents we are to produce offspring. So, usually from a mating pair 2 offspring will be produced.

Now, what is the idea of the crossover mating is there. So, we know that each individual is represented by a string, that is whether is we are discussing about say binary coded GA of course, then it is binary string anyway. So, string is basically is the phenotype.

Now, for a phenotype, so there are different values are there and out of these values we have to select some points; that mean, it is called the k point. So, k point is basically as if it is the k point the kinetochore point in case of chromosomes and then based on this k points we have to take the crossover, crossover means is a mutual swapping or interchanging. So, this is the basic idea in the crossover techniques and now let us discuss about crossover techniques in binary coded GA.

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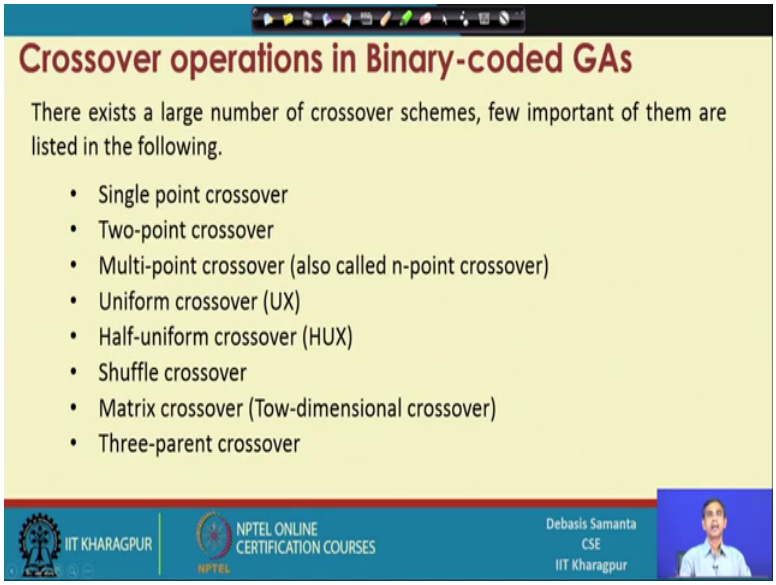

And so for the different crossover techniques, in fact, in binary coded these are the number of crossover techniques are there. So, we have listed around ten crossover techniques we will quickly discuss 1 by 1 with example. So, the first is single point crossover technique.

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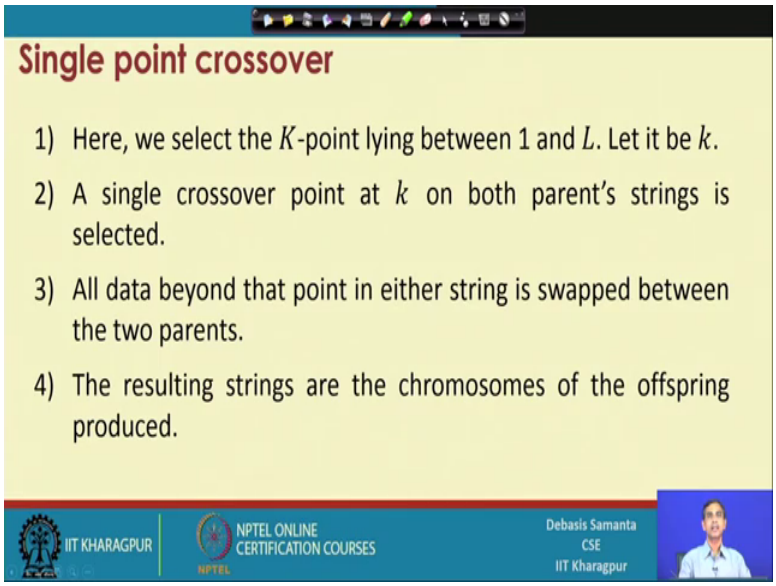

So, in this crossover technique, the idea is that if the length of the chromosomes is L, L means here the number of bits is L together our size of the chromosome is L, then we have to select 1 k point and late it be the k where k is in between 1 and L. So, this basically decides where is the point k it is there on the chromosome, and this is a single point crossover because only 1 point is selected as a kinetochore point, so it is there.

Now, a single crossover point say at k is selected on both parents is there, and then a data beyond the points in either string is swapped between the 2 parents resulting the 2 offspring. So, this is the strategy, the strategy can be better understood if we explain with an example.

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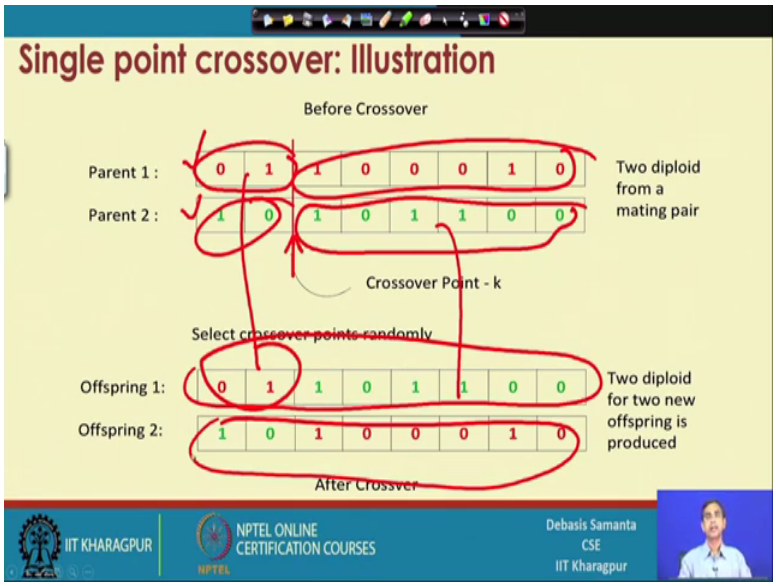

So, here is the example for this so suppose say this is the parent 1, and this is the parent 2, 2 parent's chromosomes are there. And we randomly select 1 crossover point this is the randomly select crossover point k, and once it is selected this crossover point. What we have to do is that, we have to interchange the chromosome parts in their parents to produce the offspring.

For example, so this is the first part of the chromosome in 1 parent, and we take the second from the remaining part of the chromosome from the second parent, and if you take this one then it will produce another offspring. So, these parties from here and these parties from there.

Similarly, for the next offspring we take this part here, and then this part there. So, you produce the another offspring. So, this is the idea about the single point crossover technique, so idea it is like this.

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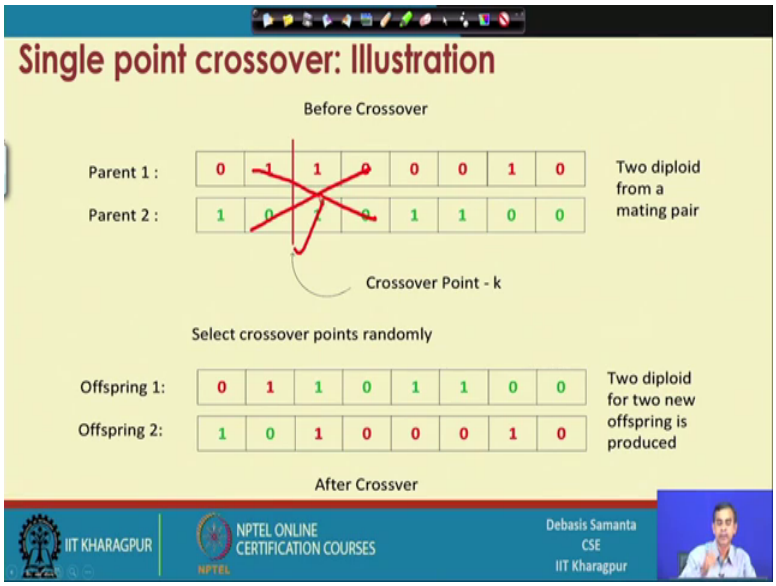

So, these basically these are the 2 crossover, and these are the 2 things are based on this kinetic point it is there this one. So, the idea is like this and it is simple and also gives better result, but if this mechanism have this one limitation all those limitation will be discussed in due time. So, this is the concept of single point crossover technique.

Next we will discuss about 2 point crossover, it is just a modification or improvement over the single point crossover as the name implies instead of k only 1 point they are in the single point crossover.

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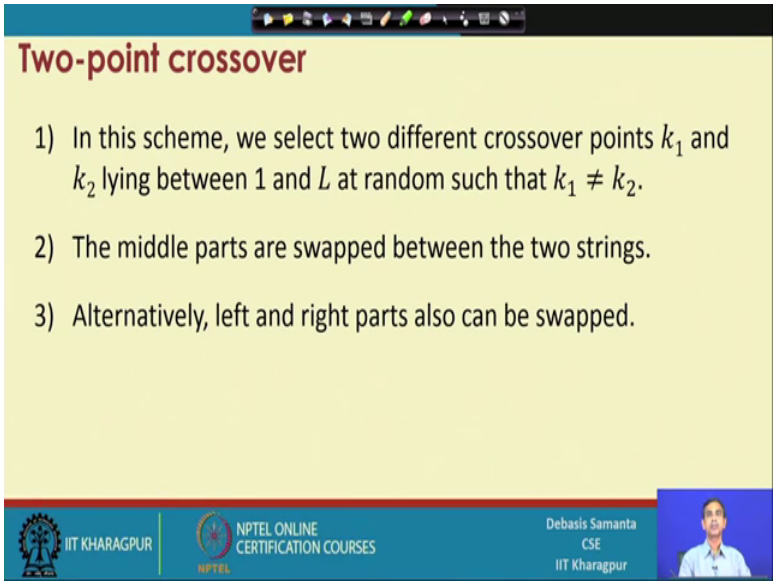

We have to decide the 2 points. So, let these 2 points be k 1 and k 2 in between the chromosome length L. Here, in this strategy the middle parts of the 2 parent's chromosomes are swapped to produce the offspring, so let us see an example.

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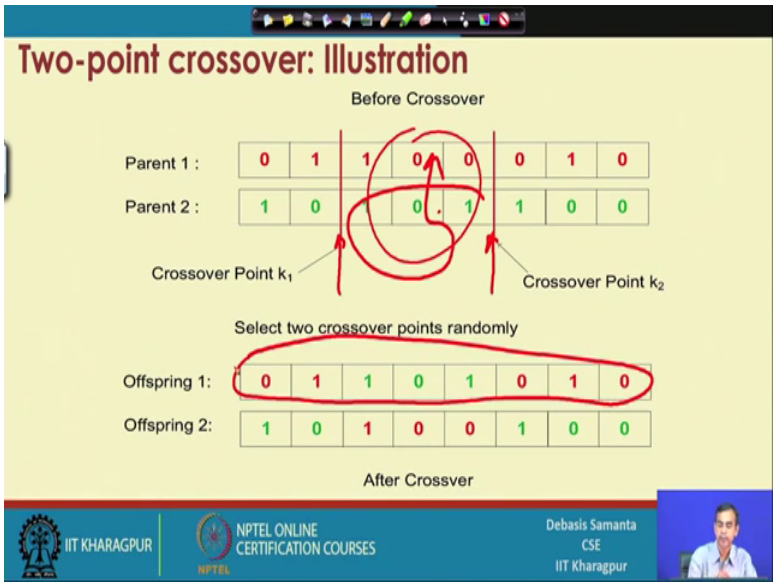

Here is the illustration, so in this example we select 1 k point here, another k k point here. So, it is say k 1 and k 2, and then the offspring will be obtained by swapping the they are middle parts so; that means, here this part is swapped between So, if we take swap means, if this part is go there then it produce this offspring and if we conscious of these part is here right.

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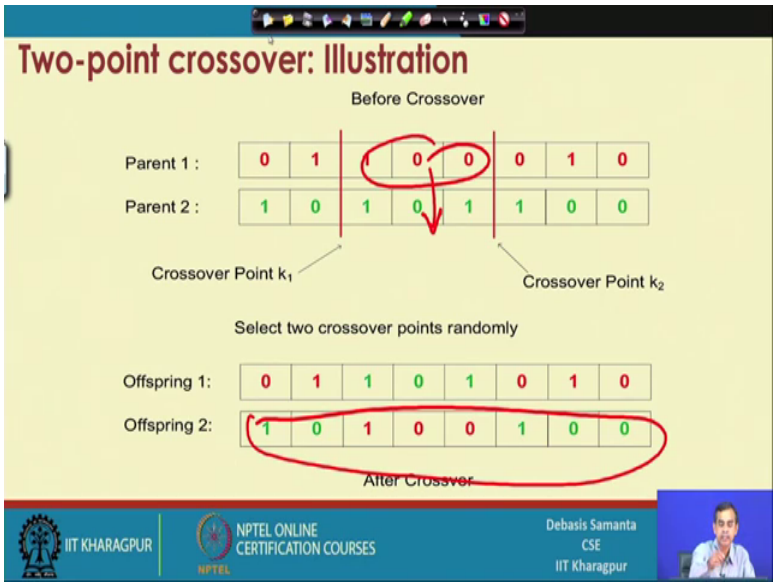

And then it will come this offspring, so this way the 2 offspring can be obtained, the two solutions. In fact, two new solutions are obtained, so this is the, this is why reproduction is carried out in genetic algorithm.

Now, so this is the 2 point crossover technique, and then we will discuss about more general crossover technique is called the multipoint crossover technique. It is more what is called the more points are multipoint means more than 2 points are considered here.

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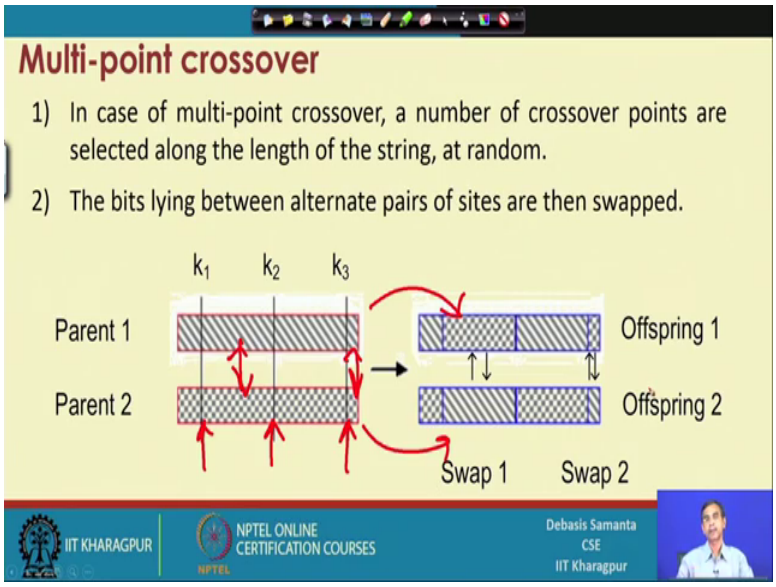

So, idea is like this so in this example we consider the multipoint as a 3. So, we randomly decide 3 k points k 1. k 2 and k 3. And then producing the offspring is based on swapping the alternating part; that means, we can swap this part and this part, and then this part and this part.

So, this way another offspring will be obtained and here another offspring will be obtained which is shown here. So, it is alternative or alternatively we can also consider this part swapping and this part swapping there is another offspring will be also produce. So, it is the strategy whether odd number of parts will be swapped or even number of part will be swapped and accordingly the two different offspring will be created.

So, these are this is the basically generalisation. In fact, it is also 2 point if we consider number of k points only 2, it is also same as single point if the number k point is this 1. So, we can say that multipoint crossover is the generalisation of single point as well as 2 point crossover mechanism. Now, let us discuss the another crossover mechanism, which is which has its own benefit is called the uniform crossover mechanism, it is also abbreviated as ux.

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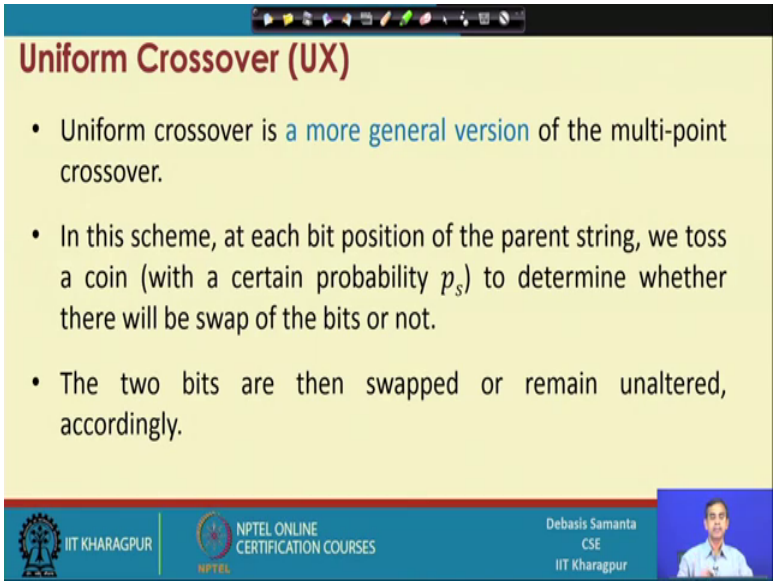

Now, in this mechanism it is basically is a more general version of the multipoint crossover mechanism in fact. Now, in this process in this mechanism, we basically consider the number k points same as the number of bits or number of bits, in the chromosome, in fact, that means, is bit position of the parent string we can consider k

point, but here the thing is that we can make a toss for each bit position, whether they will decide or they will be swap or not.

So, swapping will result a new what is called the offspring. So, the idea it is that we have to consider for each bit position, and then take a toss, toss means whether 1 or 0, toss a coin like. And then with a it is basically assume certain probability, if it is a 50% probability that, in case of 50% you just half of the time you swap them.

And if the probabilities 1; that means, here the ps value that we have mentioned, here if ps is the probability of swapping if it is 1, then you swap whatever the things it is there. Now, we can discuss this thing with an example, so that you can understand it.

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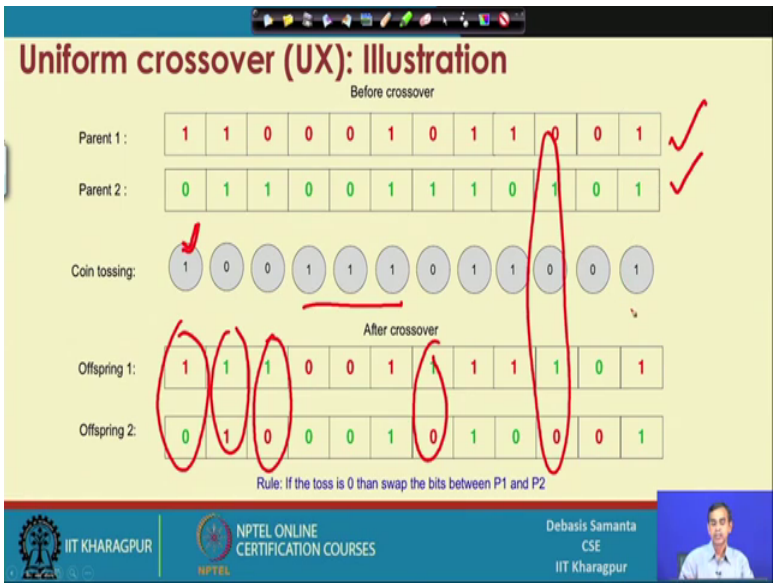

Now, here is the idea about let us see these are the 2 parent chromosome p 1 and p 2 right and. So, for the first bit position we toss, a we toss a coin and the if the toss gives the result 1. So, here the possibly if the strategy is that, if toss if the coin tosses a 0, then we should swap between the parent p 1 and p 2 and if it is 1 then we should not swap.

For example here in this case the toss is 1. So, in the then they will not be swap so they will remain same as it is there in the parents on the other hand it is 0. So, we swap it is, so it is this swap and it is 0 also we swap. So, it is swap means it gives the new values and then they are 1 1. So, no change 0 1 it is also swapped from 0 to 1 and then it is also 0 0, it is also swapped it is like this and. So, it is there, so this one, so this way you can

see from this mechanism. If this is the input parents scheme and this operation is allowed on these 2 parents scheme, and then it provides 2 offspring as the different, what is called the chromosome pattern or different string.

So, this way 2 offspring can be obtained from the parent chromosomes using the uniform crossover technique, next we will discuss another technique it is called the half uniform crossover so the idea it is like this.

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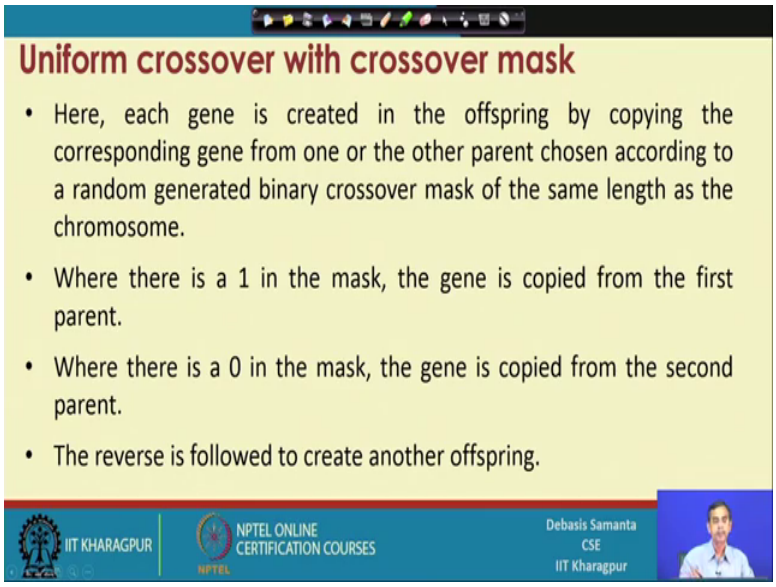

So before going to half uniform crossover we want to discuss 1 little modification of the uniform crossover this is called the uniform crossover with crossover masks. So, there basically we have to toss a coin for every bit position, which is sometimes little bit computational expensive because tossing a coin require some computational effort.

Otherwise, we can consider 1 mask, this mask is a basically random what is called the bit patterns, sometimes 1 any third chromosome, third population, third individual can be consider also as a masks because it contents 1 and 0 in random pattern.

So, now whatever with the masks it is selected, now in the mask if there is a there is 1 then the gene is copied from the first parent. If there is a 0 in the mask then gene is copied from the second parent otherwise.

So, this way it will give 1 offspring and if you follow the reverse protocol then it will follow the another offspring Now, let us illustrate the concept with an example about this uniform crossover with crossover marks here.

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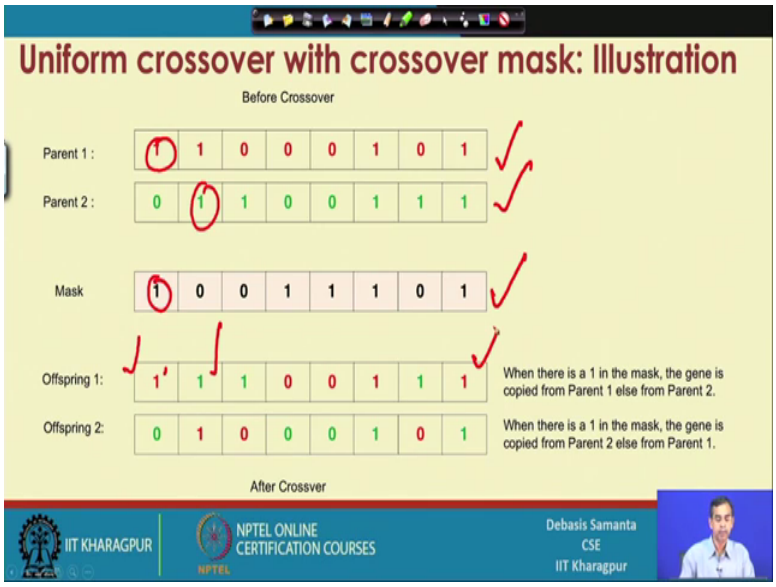

So, this is basically the 2 parents and this is the mask that we have followed. So, mask means it is a random bit pattern with 0s and 1s.

Now, the policies that when there is 1 in the mask then the gene is copied from parent 1 parent 1 else from the parent 2. So, if this is the policy by which this offspring is created. So, here the mask is 1, so we will copy the bit pattern from parent 1 to this 1, and if it is 0 then we will copy the bit pattern from this 1. So, this way this pattern will be obtained

Now, if we will follow the reverse pattern; that means, when there is 1 in the mask the gene is copied from the parent 2 else from parent 1 then. So, this offspring will be created from the 2 parent, based on this crossover mask. Now if we consider the different mask from the same parent. In fact, we produce another offspring, so changing the mask also from the same parent can be used to generate more than 1 offspring, more than a large number of offspring from the same parent itself. So, this is the 1 advantage of this idea it is.

So, this is the uniform crossover with crossover marks. Now, we will discuss about other improve methodology, it is called the half uniform crossover sometimes it is called the HUX.

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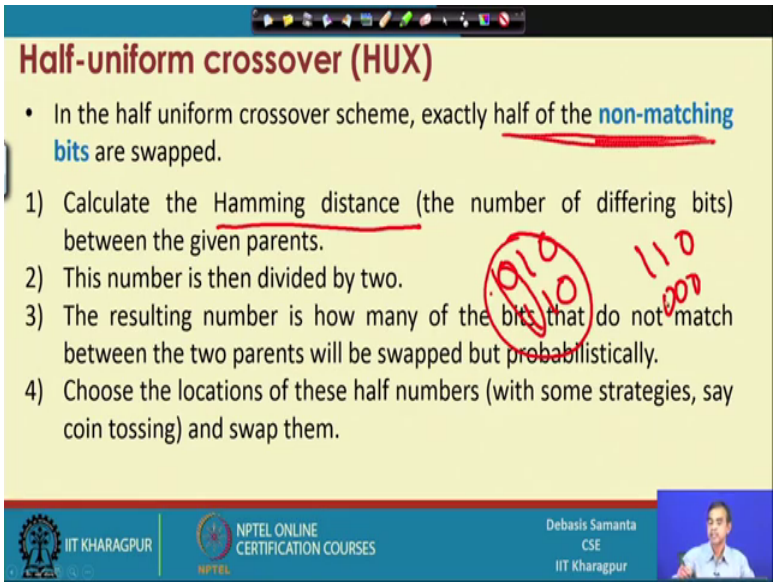

Now, in this half uniform crossover scheme, if the idea is exactly the half of the nonmatching bits are swapped now again here the 2 calculations are required. So, you have to first calculate half the half of the nonmatching bits. So, this is required a calculation here, but this calculation can be done very easily, if we use the concept of hamming distance.

So, if the 2 bits things are given then the hamming distance is basically in the 2 bit patterns. how many bit patterns are different in each of them. So, it basically number of differing bit patterns gives the hamming distance.

For example if this is 0 1 0 and 0 1, so it is 0. Then in this case we can see only bit pattern is different. So, hamming distance between the 2 is only 1, on the other hand 1 1 0 and 0 0 0 here we can see the 2 bit patterns are difference. So, hamming distance between these 2 strings are 2. So, this way the hamming distance gives us how many number of bits are differ in the 2 2 chromosomes.

Then half of them the number will be obtained just simply divided this hamming distance by 2. So, this 1 if the hamming distance is 6, and then the half of this will be 3

and if it is a 5, then it will be 2 like this one. So, these are the things it is there, then the idea is that whatever the half of the nonmatching bit patterns are to be swapped and they can be swapped, either in a random fashion by tossing a coin or just using any positive here.

So, here the resulting number is how many of the bits that do not match between the 2 parents and they will be swapped probabilistically, here is a concept is called the probabilistically; that means, again we can toss a coin like. So, you can causes toss a coin and then if the toss gives 1 then, this bit pattern will be swapped and if it is not then 0. So, probability in this case 50% then so it is half of the things will be swap like. So, now let us see let us explain this half uniform crossover with an example.

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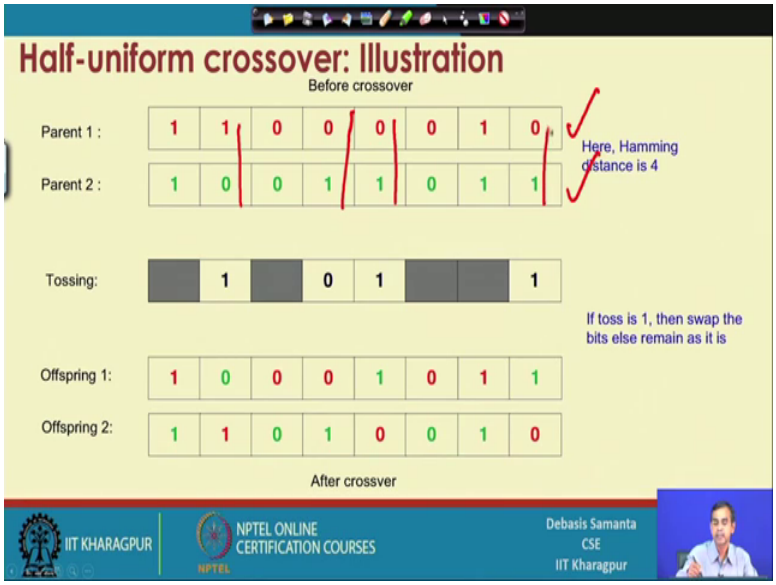

And here I just mention the example here. So, these are the 2 input chromosomes at the parents and we see in these 2 parents, the hamming distance is 4, here is basically this is the 1 different. So, different bit pattern is this 1 and this is the different, this is different and this is different. So, 4 bits patterns are different therefore, hamming distance is 4.

Now, so for the different bit pattern we have to have a toss. So, toss is here say 1, so if it is 1 then the swap the bit pattern else it remains 0.

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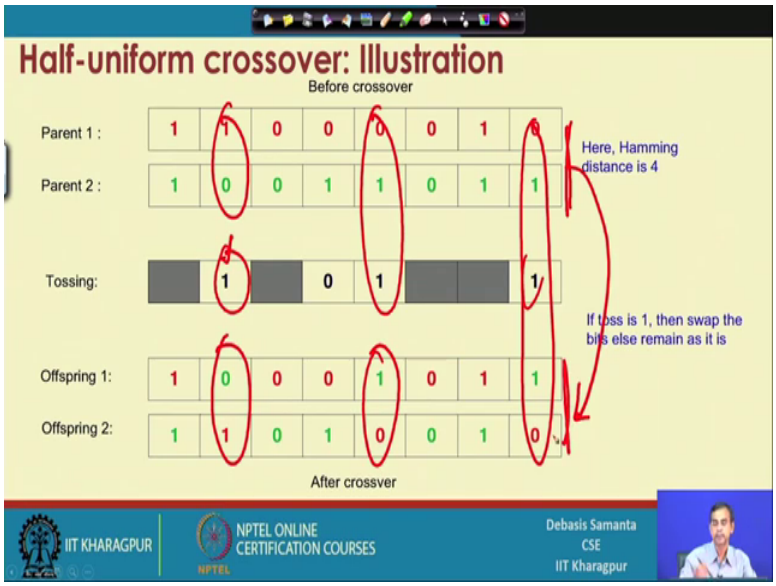

So, if we swap it then we can obtain, so here 1 and then swapping these 2 gives this 1 similarly here 1. So, it is swapping these 2 it will give this 1, and here is also 1 swapping these 2 it will gives 1. So, this way from these 2 parents we can get 2 offspring.

Now, again if we follow that different technique here for example, if toss is 0 then swap then another 2 different other 2 different offspring will be created. So, whatever the strategy whether toss 1 or 0 you can follow any 1, and then obtain the new offspring this way. So, this is the idea about the half uniform crossover techniques. Now, we will discuss a now another little bit complex crossover technique it is called the supple crossover technique.

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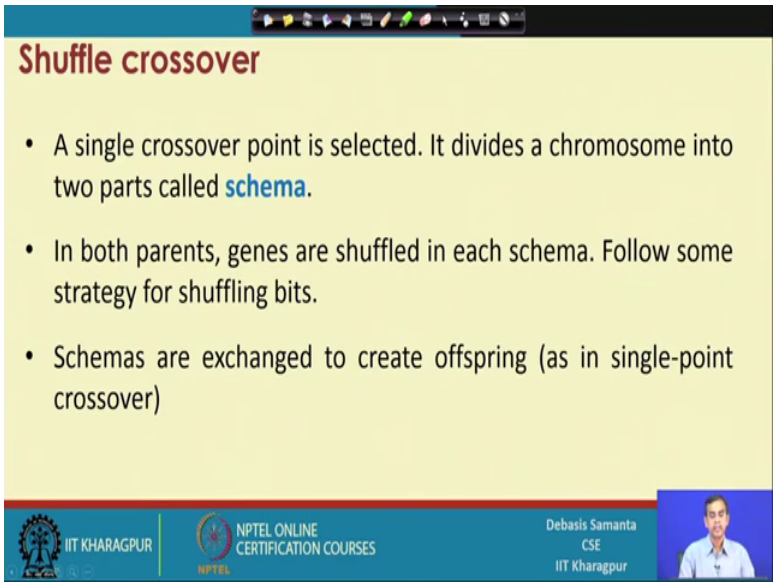

Now, it is basically a single crossover look like. So, a single crossover point is first selected in this technique and then it divides the entire chromosome into 2 parts, they are called the schema and in both parents genes are first shuffled in each schema following some sampling strategy. Then then as it is in the single point crossover the schema are exchanged to create offspring. Now, so here better we can explain this concept with an example.

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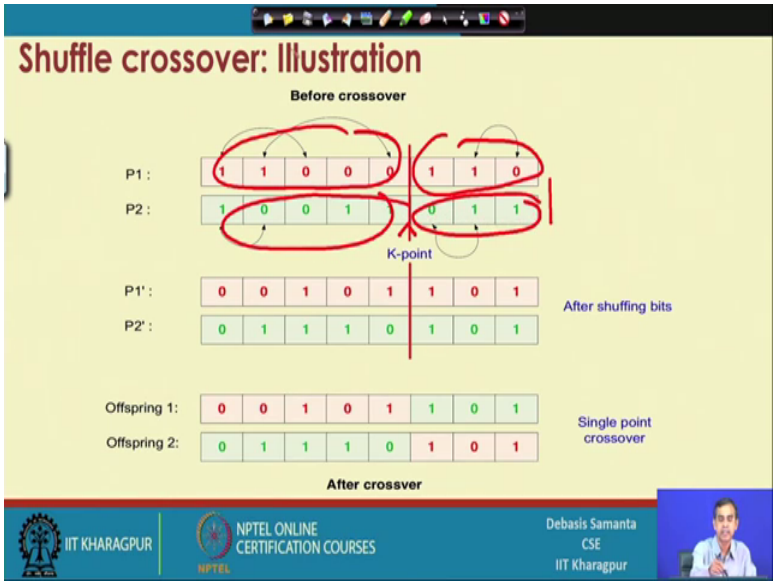

Now, let us observer this example here, so these are the 2 parents p 1 and a single point is selected let this single point is this 1 the k point and then this is the 1 schema in 1 chromosome and this is the another schema in 1 chromosome. So, the 2 schema in 2 chromosomes are selected in this case.

Now, in each schema we have to follow a shuffling, following some strategy maybe that first and third will be shuffled, and then second and fifth will be shuffled, in the first schema then here the last and first then next 1 will be selected and then first. So, these are shuffling, so these are the basically 1 shuffling mechanisms that we have followed.

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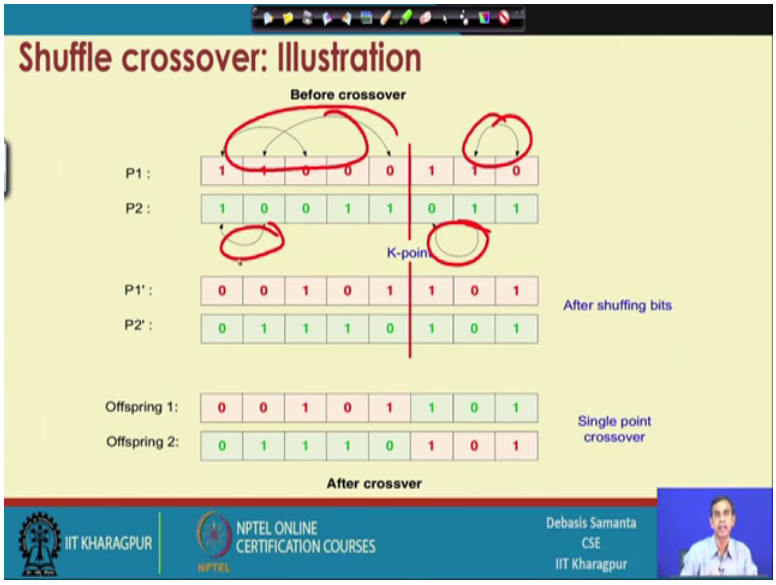

And sometimes a may random sampling can also be considered. So, shuffling mechanism what will do so they will interchange this 1? So, for example, from this shuffling mechanism, we obtain this 1 and for this this chromosome also we obtain this 1.

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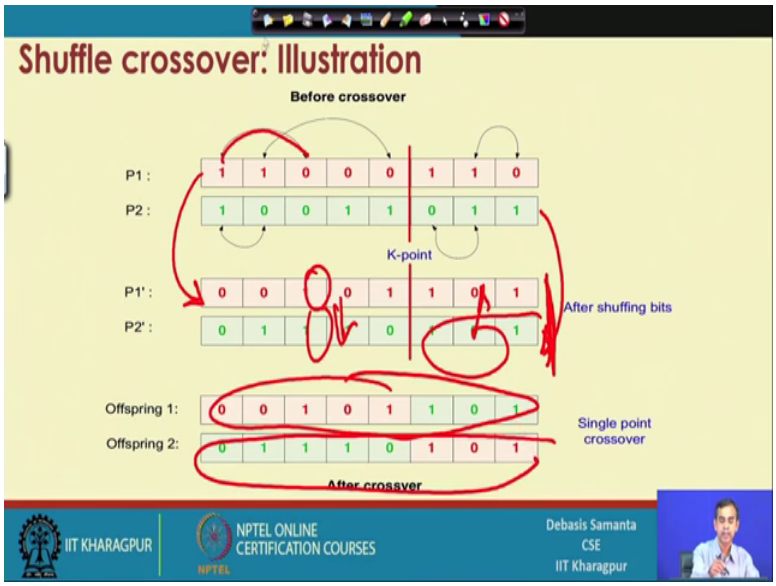

So, shuffling little bit results you the two different chromosomes in the parents. So, it is basically intermediate stage of the crossover mechanism once it is then then we can follow the simple single point crossover thereafter, so it is basically if we follow the single point say. So, this part will be swapped this part, and then this part and this part will be swapped this 1. So, it will give this 1 is the 1 chromosome and this another is the another chromosome.

So, finally, this is the parent chromosome and it will produce the offspring chromosome and we can understand that shuffling how it better compared to the or how this chromosome. So, for the variation in the offspring is concerned is comparable to the other crossover mechanism like say uniform crossover or the single point crossover like this one. So, this is a shuffling crossover it has little bit computational demand, but it is more variation in the offspring is possible.

So, if we note need more variation in the offspring then we should think for this kind of crossover mechanism, and then the another crossover mechanism it is called the matrix crossover, usually this crossover is preferable when the size of the chromosome is too large.

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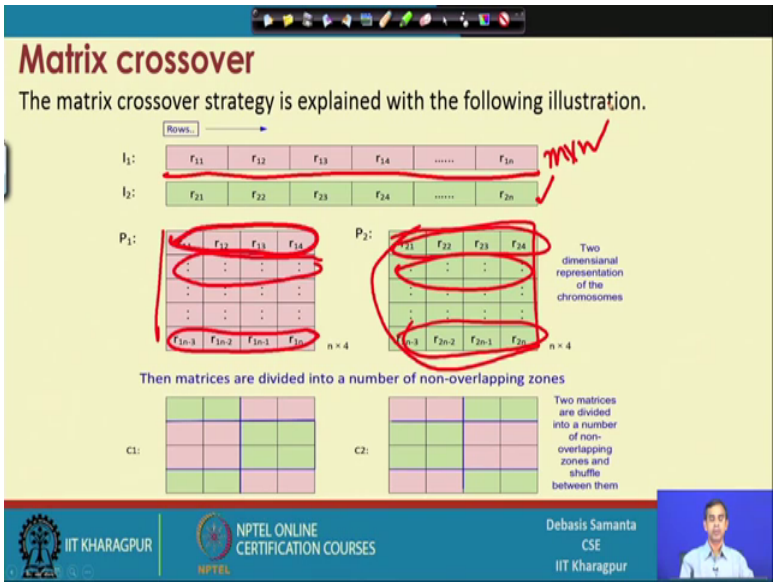

Now, if the size of the chromosome is too large then we can represent 1 chromosome in the form of a matrix. So, how a chromosome can be represented in the form of matrix is shown here, say suppose this is the entire what is called the chromosome for a parent and then we can make into a equal number of pieces.

So, for example, here 4 genes into 1 piece and then next 4 into 1 gene and then they can be placed in the metrics like. So, the first 4 in the first row, then second 4 genes in the second row and then this way so this 1. So, it is called the row major ordering of the chromosome.

Similarly, for the second chromosome we can have another matrix in the row major positioning. So, this is the first row second row and the last row continues 4 elements also. So, it basically if we consider m cross n like this one; that means, if in each row m number of genes and their n if the total size of the chromosome is m cross n this way. So, a chromosome of size m into n can be converted into a matrix of m rows and n column that we have discussed here.

Now, 1 representing a linear chromosome into the form of a 2 dimensional representation of the matrix then we can follow the matrix crossover, it is just like a swapping crossover like or it is just like a sapling what is the idea is that we have to make few block in each chromosomes. So, I consider that this is the 1 block, this is the another block.

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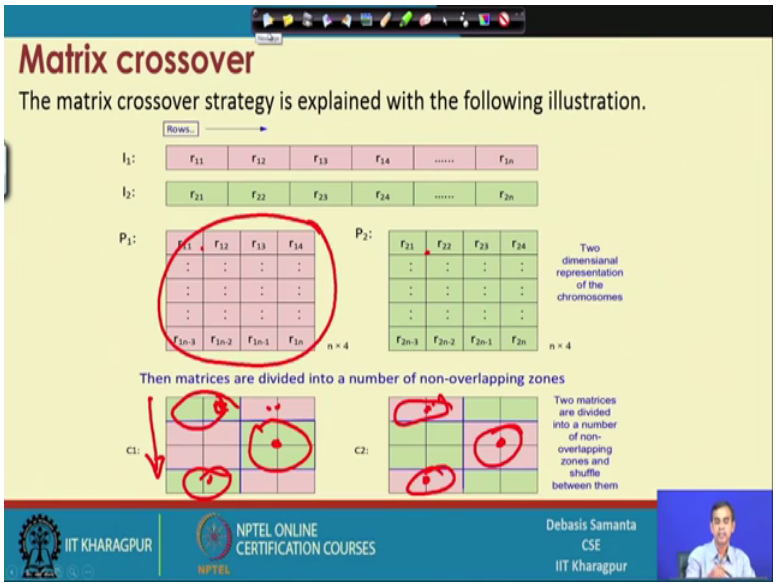

And this is the another block this is another block this is another block this is another block so; that means, entire chromosome is divided by six different blocks the same blocking is also followed here then we will swapped. So, this block will be swapped with this block, so here from this it will go there from this it will go there.

Similarly, this is the another block it will be swapped right from in between there. So, for example, it is not swapped here, so we swapped only this block is swapped with this 1 and this block is swapped with this 1 and this block is swapped with this 1 right.

So, if we can swap alternatively some blocks and then it basically gives, so this is the original what is called the chromosome and here is the this is the child chromosome or offspring chromosome, and you can say that in the child chromosome some parts these are the parts from the another parent similarly in this chromosome also these are the parts from the another parent and this is from the this 1.

So, this way the variations or the new chromosomes can be obtained using this matrix crossover mechanism. So, we have discussed about the different crossover technique and there is a 1 another crossover technique it is called 3 parent crossover technique, the 3 parent crossover means, whatever the crossover technique that we have discussed they consider only 2 parents, but here is the 3 parents and the crossover technique is like.

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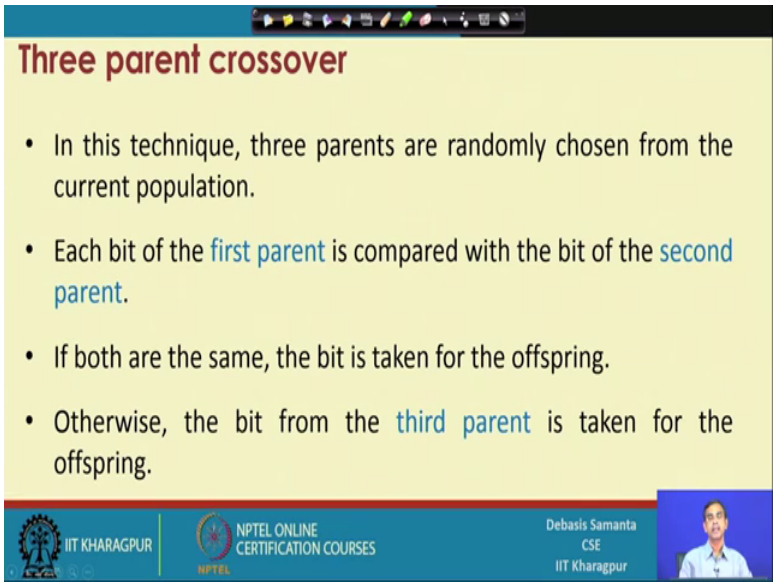

In this technique as you saw the 3 parents are chosen at random from the mating pool. Then each bit of the first parent is compared with the bit of the second parent, if both the bits are same then the bit is taken for the offspring otherwise the bit from the third parent is taken for the offspring.

So, this way 1 offspring will be obtain now again another offspring can be obtained if both are the same in the third step then we can take the any 1 from the offspring and this 1. Now, let us see how this chromosome can be we can illustrate this kind of technique here.

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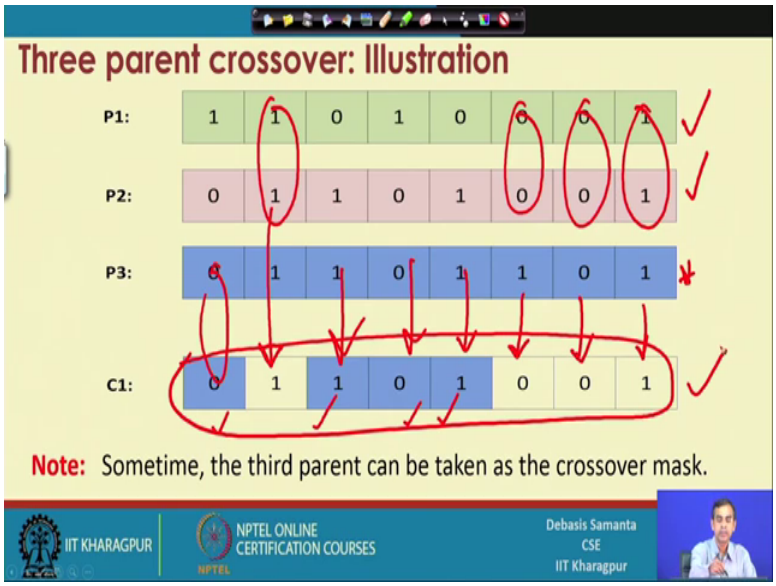

So, this is an example here, in this example you see this is the 1 parent and another parent is there, and then third parent if this 1 the third parent. So, as the strategy set if the bit position are same then we copy it into their for example, here the 2 bit position same, so it is copied into here.

And similarly we see here also the bit position are same. So, it is copied here and here also bit position same it is copied, here there also bit position are same it is copied here. So, we have copied directly from the 2 parents if we see that the 2 parents contain the same bit positions.

Now, for the remaining bits in the offspring we can select from the parent; that means, this is selected from this 1, this is from here this is from here this is from here and so on. So, this way this new offspring will be created, so you can see we can see here that. So, 3 parents can be involved in to produce 1 offspring and it is a mechanism like this 1.

So, this is the idea about the 3 parent crossover technique, and we have discussed about many crossover techniques, it is right time to discuss exactly who what are the.

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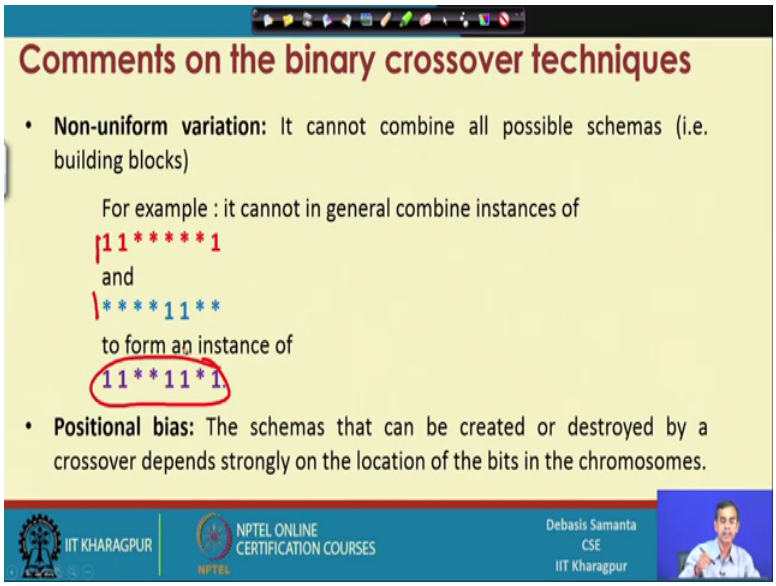

Why the different crossover techniques and what are the points are there to be considered in order to decide a better crossover technique, binary crossover techniques.

The first idea is that non-uniform variation is preferable non-uniform means it is not like that whatever the pattern there in the parent should be followed there. So, better if we can intermix the pattern there. So, for example, it is here if this is the 1 parent if the parent then, so it is basically better 1 instance will be like this 1 as a more variability is there.

So, crossover technique should be such a technique, such that it should provide more variability in the offspring chromosome another is a positional bias, positional bias means.

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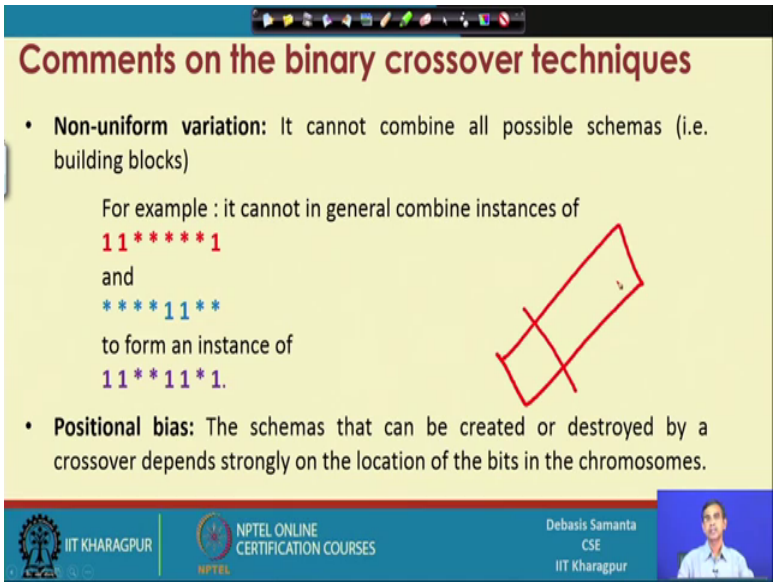

If this is the 1 chromosome, so sometimes whatever the mechanism we follow either their n point will cannot be interfered; that means, n point will be copied always there. So, it is called the positional bias n point positional bias like. So, this came, so the crossover techniques should be that the positional bias can be avoided. Now, there is another also called n point bias it is also once at a positional bias.

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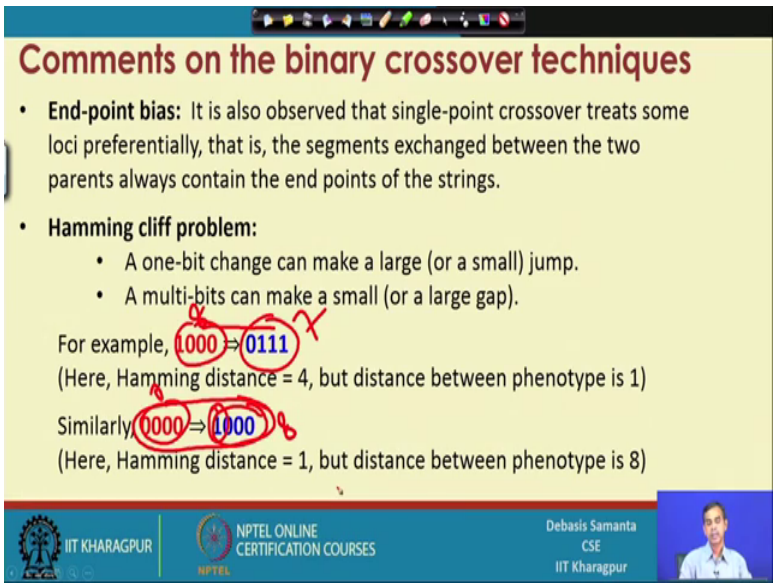

For example single point crossover always has certain n point bias always, because it is always n point is to be copied into this 1. Another is that some crossover technique may suffer from 1 problem and this is called the hamming cliff problem.

So, hamming cliff basically if we change a small, it may not give a better changes. On the other hand if we change again a large, then it can give a very small change for example, here if we see. So, some chromosome is there parent chromosome and it is converted to this one. So, what you can say that there is a large number of change changes in bits, now large number of changes in bits whether gives a better population from the wide diversity.

Now, for example here, so these are binary suppose binary and this is the equivalent is 8 and this is the 7, I mean decimal equivalent, this means that changing a lot number of patterns or bits basically produces the number changing from 8 to 7 is a very few differences there.

On the other hand is another example here, if the 0 0 and there is a only small changes, this is the small changes. So, small changes can produce a huge difference for example, it has 0 and this is 8, so the 1 bit changes also can gives a huge changes.

Now, whenever we have to do this crossover basically our objective to explore the better what is called the solution better solution in the context that. So, we have a solution 1 and then the next solution should be near amount that solution or very far from that solution it is need to be decided. So, if we see that 1 solution is far from the latest solution that we have explored then it may be good sometimes it may not be good.

So, hamming cliff problem is the 1 problem, which basically needs to be considered how much deviations that we want to have in our solution. So, these are the points that we have to consider. So, far the chromosome our crossover operation is concerned.

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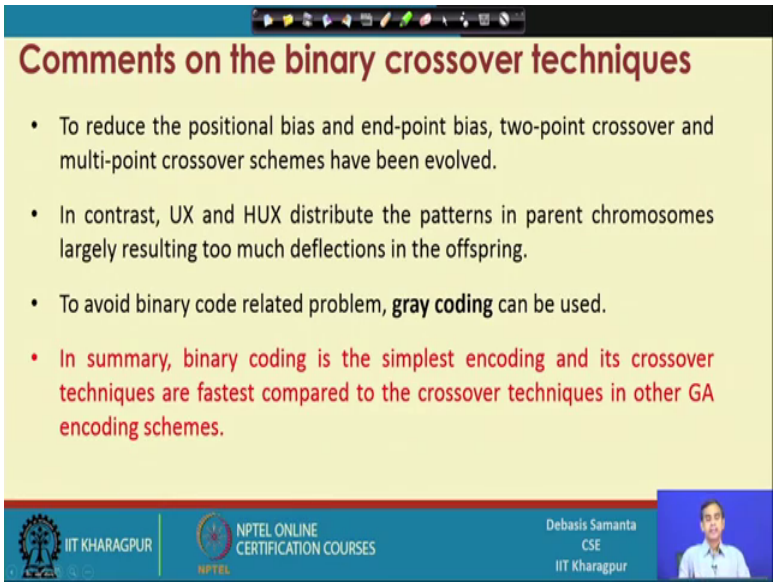

And there are many other ideas also, so we have discussed the different crossover techniques in the context of binary coded GA. So, sometimes other than binary coding people follow gray coding, it is the another concept which call basically also helpful to solve many of the problem that we have discussed; that means, position bias n point bias or hamming cliff problem all these 1.

Now, this is the last thing that we want to mention in the context of binary coded GA crossover technique. So, binary coding is comparable to any other coding technique. In fact, because whatever the crossover technique, crossover is the most what is called the costliest operation in case of GA algorithm

So, we should consider that crossover techniques should be in such a way that it is gives the faster result, because GA algorithm run execution takes maximum time in the process of reproduction; that means, a crossover operation. So, whatever the techniques are there it is observed that the binary coded GA, which follows the binary crossover techniques are the fastest technique.

So, that is why the many programmer they follow the GA encoding scheme, for the GA encoding scheme the binary encoding scheme and then implementation or programming of the different crossover operation also straightforward ok.

So, this is how much I want to mention about the crossover techniques related to the binary coded GA, and as I told you the different crossover techniques are to be followed in case of different coding is followed. So, next we will discuss the crossover techniques related to real coded GA.

Thank you for today.