**Sustainable Materials and Green Buildings**
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**Lecture 30**

**Design Optimization of building**

Okay, so we look into optimization application to energy efficient building design, GA stands from genetic algorithm, its stands for genetic algorithm, right.

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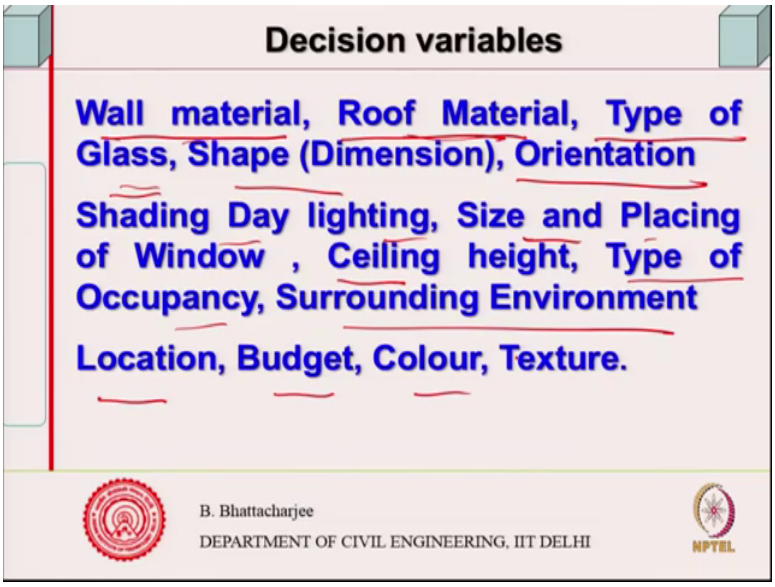


So, as i said in building design the decision variables are I think I was mentioning this you know wall material, roof material, type of glass, shape, orientation this is, this is the decision variables that means you got to know what should be the best orientation this what I was discussing in the last class. And then the combination of the materials in the construction of roof, in the wall and type of glass etc. Shading, day lighting, size and placing of window these are all variables ceiling height, type of occupancy, surrounding environment etc. and obviously location, budget, colour, texture of the expos services these are other decision variable.

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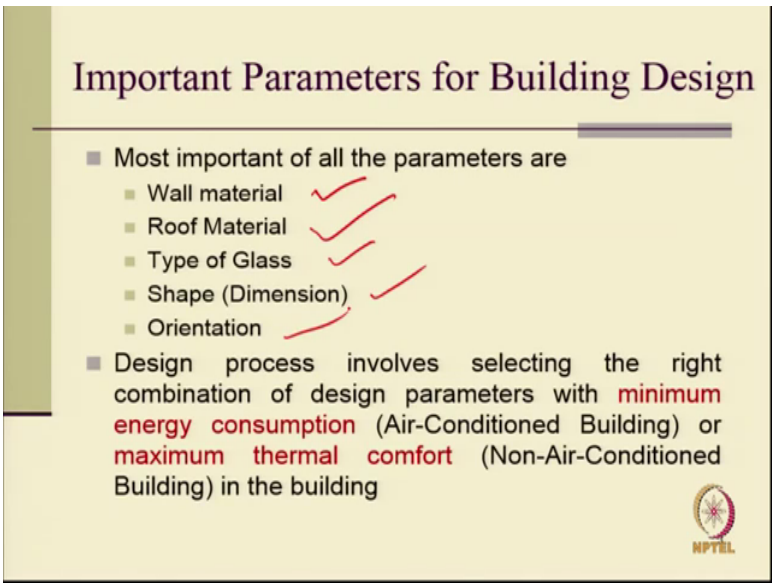


So you know, so therefore important parameters of course for building designing are out of all these Wall material, Roof material, Type of Glass, Shapes and Orientation.

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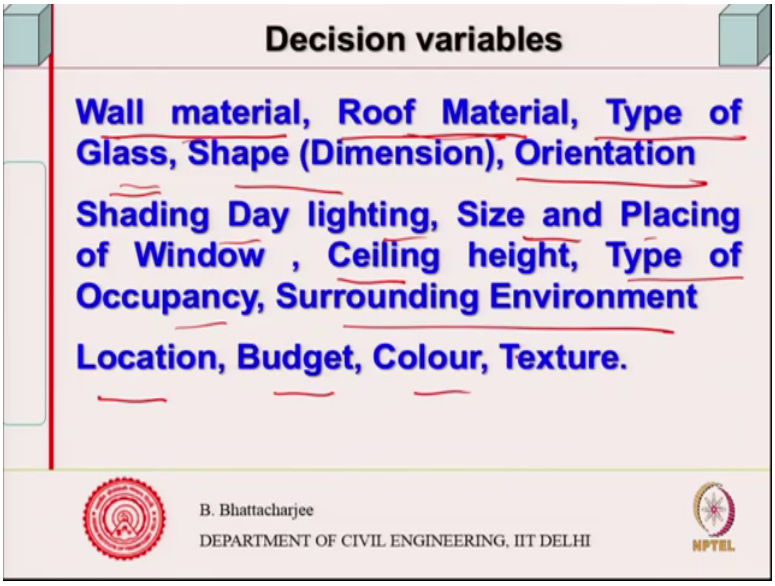


For example, if you look at the previous one back you know the location, budget this you can exclude out for the time being because that would make write more complicated but these are part of the wall system itself, colour of the wall you know colour of the wall, texture if there is any you can one can take.

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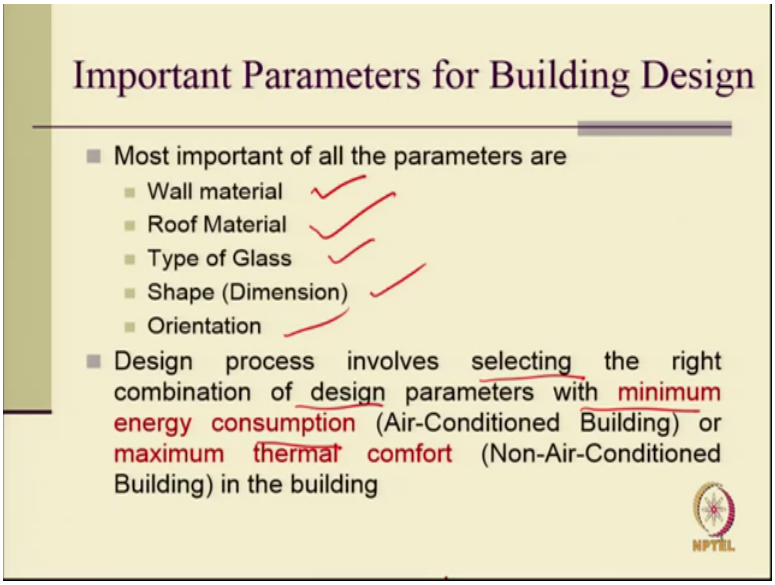


But this example that I am talking about it takes this 5 variables right. So, it involve selecting the right combination of design parameters with minimum energy consumption that is what it is or maximum thermal comfort. You can increase the thermal comfort or minimize the energy, right.

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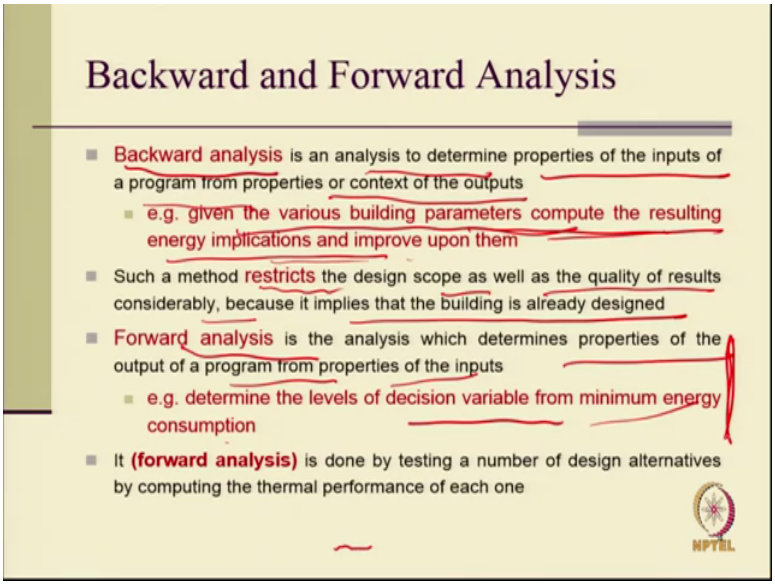


Now, there something called in design process something we called Backward Analysis and something we called Forward Analysis. Now what is Backward Analysis? Backward analysis is the analysis to determine the properties of the inputs of a program from properties from the context of the output. What I mean to say is you know you have already made a design then

you analyse to find out how the decision variables are performing. For example, if you have chosen already chosen a orientation, shape etc-etc.

Now analyse this how good it is and then you change this, change the orientation analyse it back. So you get series of answer that way by backward analysis but the forward analysis would be that you do not start to the plan, you get the plan which would be best for various possible orientation. So backward analysis, so given the various building parameters computes the resulting energy implication and improve up on them.

So, first you have to have all building parameters are to be known and then compute the resulting energy implication and then improve output right improve. So you have to assume first, assume the plan is itself, design itself this is what we do in other designs also some cases. So such method restricts the design scope as well as the quality of the results because it implies at building is already design.

I have already design the building chosen the orientation shape and then analyse to find out how much. And if I am not satisfied with the design I change this, I change the orientation, change the shape and come back to it. So that is the process of backward analysis. Forward analysis which determines the properties of the output of a program from properties of the input. In the sense that determines the levels of decisions variables chooses the orientation from minimum energy consumption.

Now, that is why you need a optimization process because it would first you know you have to optimize the energy consumption and correspondingly which is the best. Which set of orientation, shape their best that you can choose. So this is done by testing of, so what you can do is, you have to have kind of an objective define which will minimize the let us say energy load or maximize the comfort and for that from your chosen orientation, shape etc-etc which is the best it will select.

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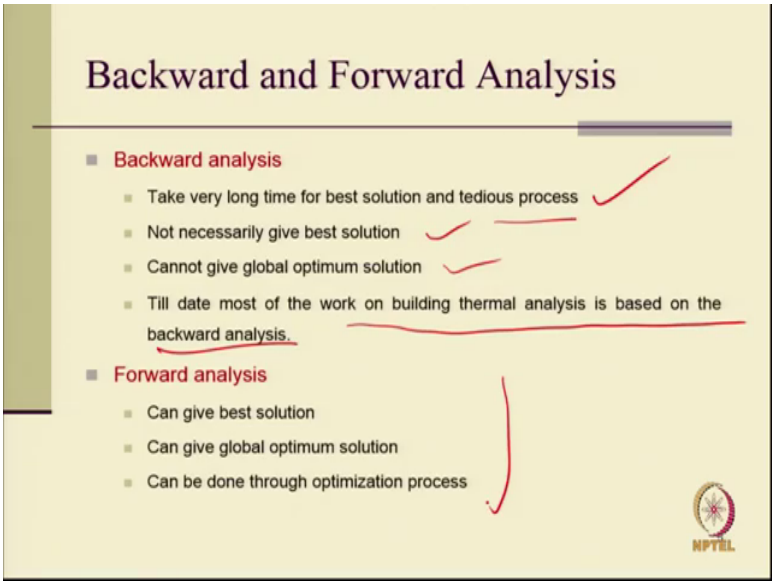


So, forward analysis implies always optimization process. Backward analysis very long you know it is a very long time does not get best solutions tedious process and not necessarily it will not give best solution, cannot give global optimal solution obviously, till date most of the work on building thermal analysis has been based on backward analysis. There are several tools or several guidelines available from long time, what you call, prescriptive guidelines, right.

So if your, there is something called mehonies chart, it was something of this kind. So, you have tables if this is your climatic condition use this that sort of things. So these are all part backward analysis. Forward analysis will give you the best solution and optimum solution therefore it has to be done only through optimization process.That is what the importance of optimization process.

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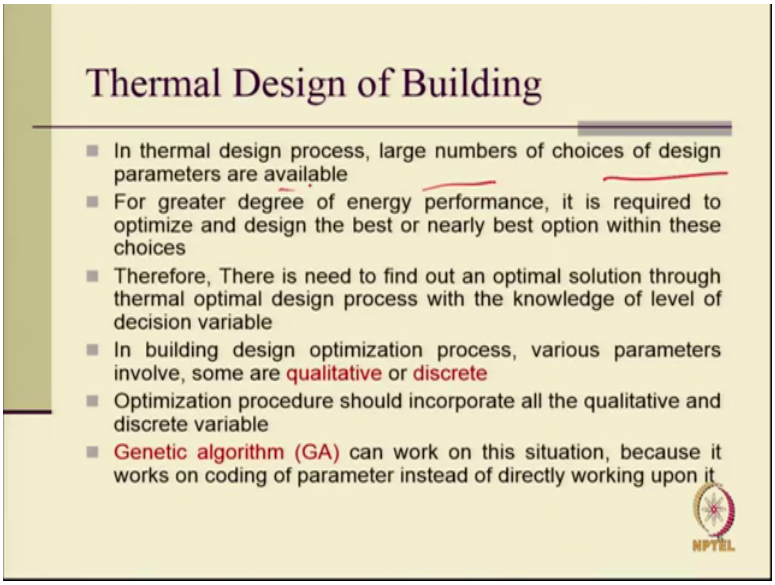


Now thermal design, thermal design process a large number of choices of design parameters that is what we have seen, there is large number of them you know that is what we have seen when we looked at them.

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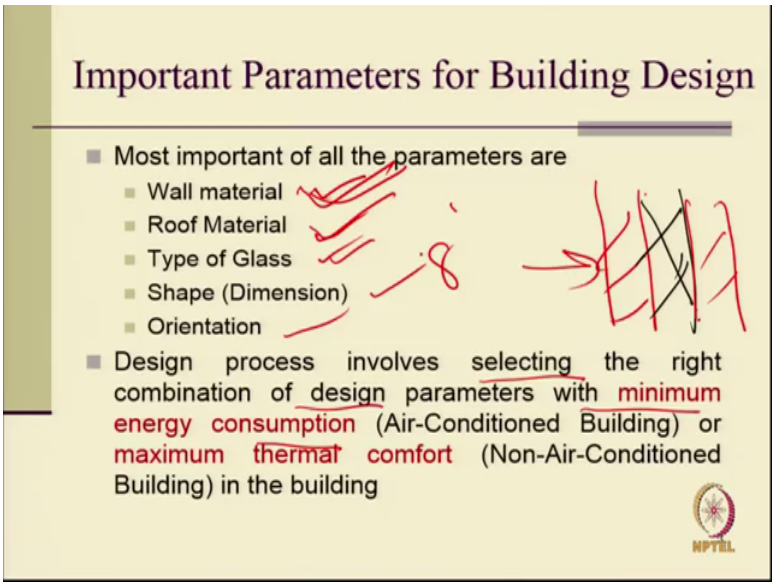


Supposing you consider wall, so wall may have three layer just say for the sake of it simple case three layer. So, one insulation layer you know one insulation layer in between and then again you have the same layer outside so three layers. Now, there can be possibility of varying all the layers right. So, n may have 4 layer wall or 5 layer or n layer wall. So, in that case the number of possibilities are very large. Similarly roof material, type of glasses that is

what we have looked into last class, sometime we are looking at 8 into some 4 or 5. So possibilities are many.

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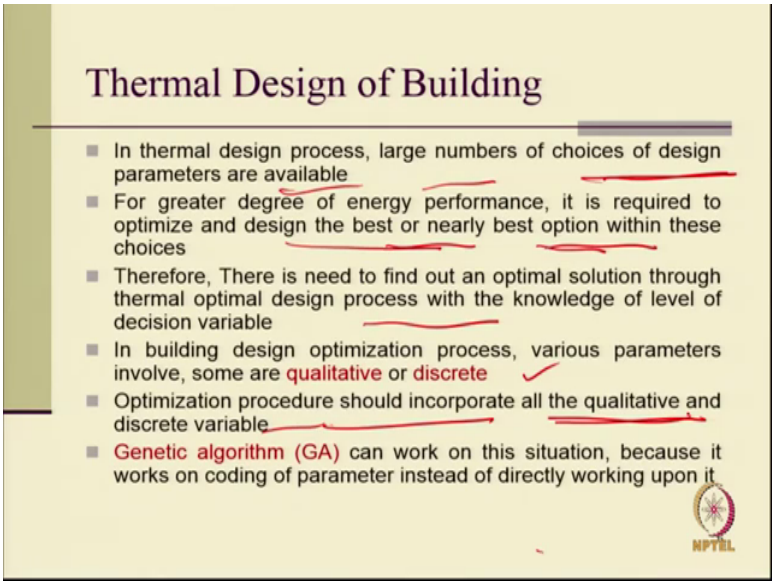


So possibilities are many basically, so large number of choices of designs parameters are available. For greater degree of energy performance it is required to optimize the best or nearly best option with this. Therefore there is a need to find out optimal solution that we have understood now. The building design optimization process, various parameters involve some are qualitative and some are discrete, this what I think I have mentioned earlier also, the some there are qualitative right and they are all discrete.

Qualitative means, north east orientation right, north east orientation the long axis facing north, long axis facing north east, long axis facing north west, so these are all qualitative you cannot quantify them easily although some angles people have tried with some angles but they many of them are qualitative. Shape is qualitative that is what we have looked in the last class and they are discrete, because you do not have continuative from T shape to let us say you know aspect, various aspect ratio of L shape, having rectangular shapes.

Some phases that can be continuity but most of the cases there may not be. So this should incorporate such a procedure, design procedure should incorporate qualitative and discrete variable. So, evolutionary algorithm of a kind of this can work on this situation because it works on coding of the parameter, it does not deal with parameter themselves.

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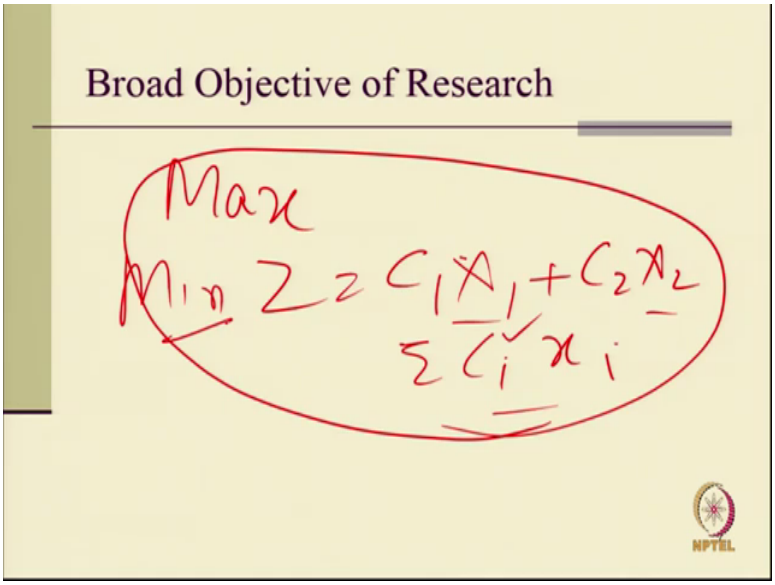


For example, you would have done some optimization yourself in some other classes where you would have objective function maximize z equals I am sure some even if you have not done, does not matter it could be linear problem, could be C1 or C1 X1 plus C2 X2 etc-ect or in other words I can write it at sigma Ci Xi right where this are the or minimize if it is cost coefficient, this could be profit coefficient maximize profit or maximize return or something of that kind and these are linier.

So, this is what we call as objective function maximize this then you might have add sudden constraints which will say that okay you know if it is you cannot have some values of x and y X1, X2 might be restricted. So various constraints, there are production constraints that you have done but I am not interested here in all those. So, therefore there is something called objective function which you maximize or minimize. So, in our case maybe minimize the energy load right. So, that is what you do in an optimization process.

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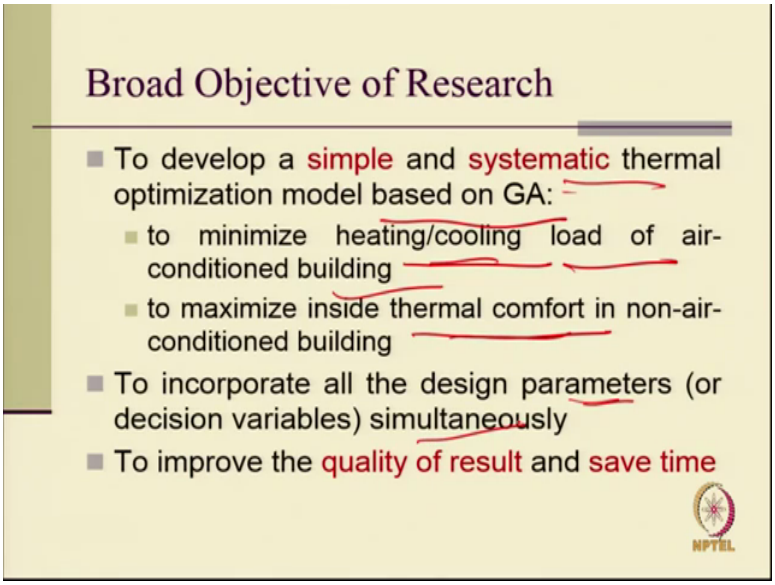


But here my X1, X2 etc are discrete and maybe qualitative. So I can codify this X1, X2 etc if I use them as codes then orientation number 1, orientation number 2, orientation number 3 etc I can codify and my algorithm should work on codified variable. Let us see how we do it.

So, GA base is good one, there are other revolutionary algorithm and modern various kind of algorithm should be available possibly in future also which will work on codified variable. So therefore our objective is to minimize the heating or cooling load of air condition building or maximize the two objectives we can look into. Maximize the thermal comfort in naturally condition building. Then this all the design parameters must be you know taken together, all the decision variables should be taken together simultaneously and must be able to evaluate the objective.

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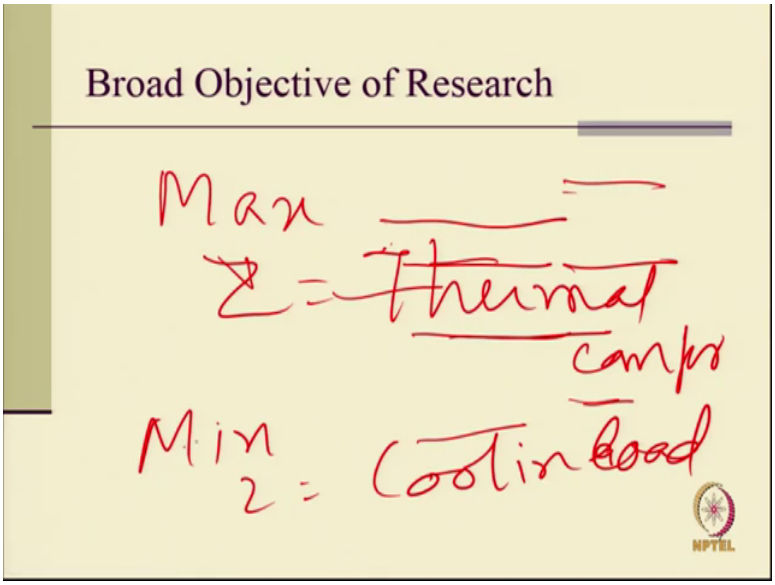


So my objective function here would be some sort of maximization you know maximization of let me I put it Z as or thermal comfort. So I should be able to define thermal comfort in some manner or minimization of cooling load or cooling and heating load some combination which I have shown you earlier. So, if I have to do this i should be able to either explicitly express thermal comfort in some function form there should be some way or cooling load I should be able to express explicitly here we cannot express them explicitly that means I do not have a function which can define orientation x shape y.

What is the cooling load? I cannot find that, I can find it through a procedure of calculation right but otherwise I cannot find it. So all the procedure of calculation we may not discuss here but there are various process like let us say SO method, SA beans method or you know admittance procedure and several other procedures are there through which one can calculate. But I will briefly discuss or give a case study of the situation of optimization here.

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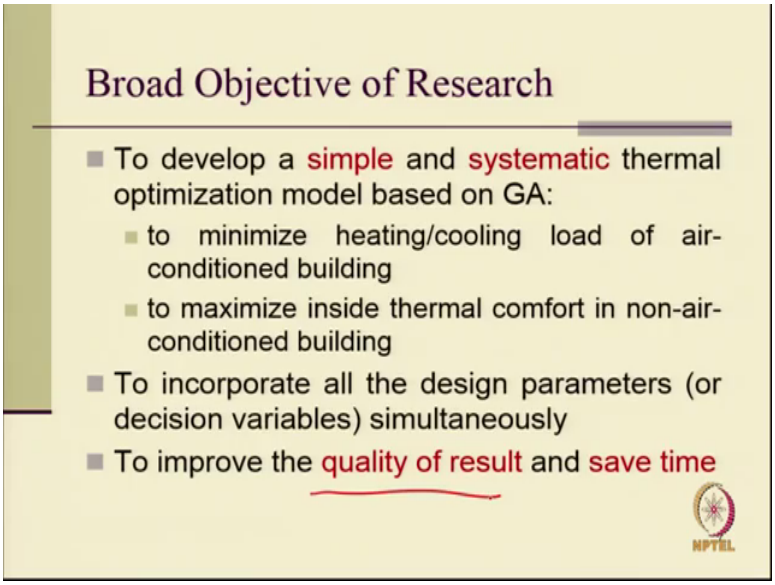


So they improve the gradually it should improve it is a iterative process therefore.

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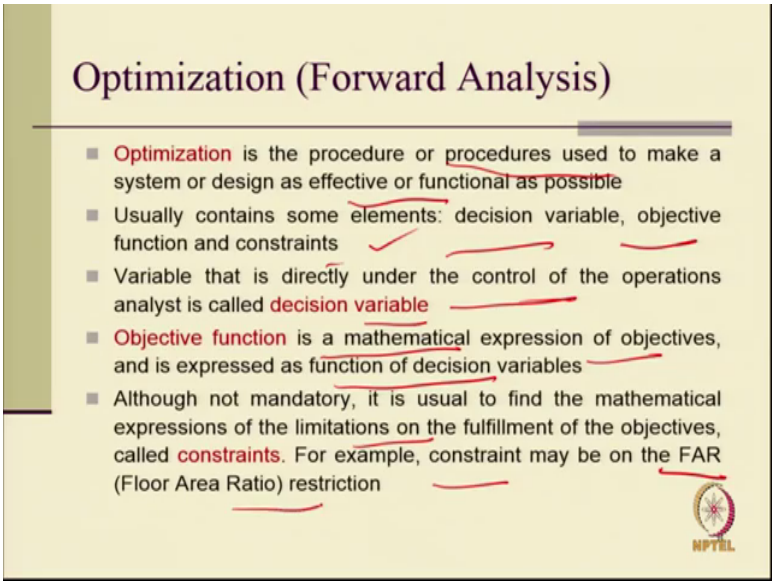


So this optimization procedure make a system design or effective function this are alright. Usually content some elements decision variable, objective functions I have already mentioned. Variables are directly under control and you know they are the decision variable. So, these are objective function in our case is not a mathematical expression as such but in our case it is a kind of a procedure through which you can calculate out the cooling load. Some limitations or constraints you may have.

Now what are the constant in our case? Could be bylaws, building bylaws could be our constraints. So, floor area ratio restriction might be there and this are the this can form kind of constraints which you should be able to build in.

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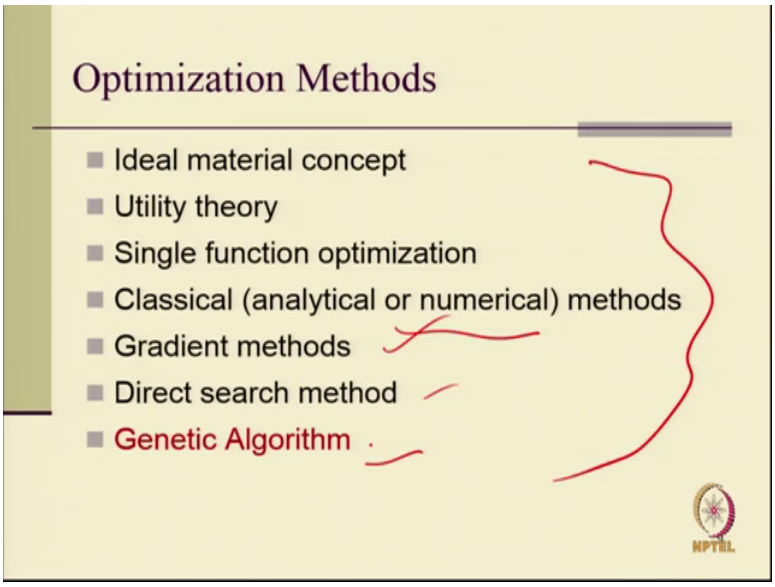


So, you know there are various kind of optimization tools one can use as I said classical methods, gradient methods so this is what suits good this one it is evolutionary algorithm.

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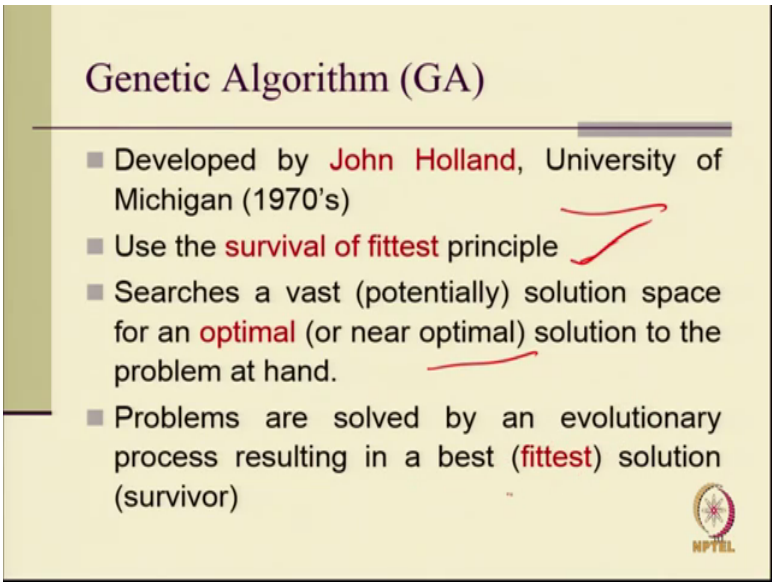


So, let us see okay this is some history of this but i do not think I am really. It is based on survival of fittest principle such as vast potential solution space and then comes to the

optimal or near optimal solution gradually okay. So fittest solution or they are allowed to survive, unfit ones are removed out of this. So, simple example we will show you.

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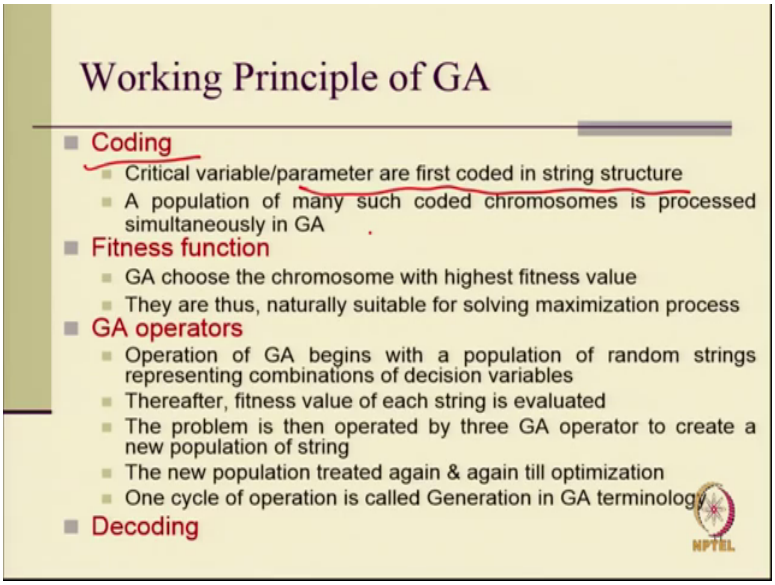


So, first thing is then is coding. So coded, variables are coded then how it is done? Variables are coded. Let us say, I have 8 orientation right, I has 8 orientation let us say, okay now iam trying to find out a blank space. Okay let us say something like this okay-okay some I should be able to utilize the space yeah.

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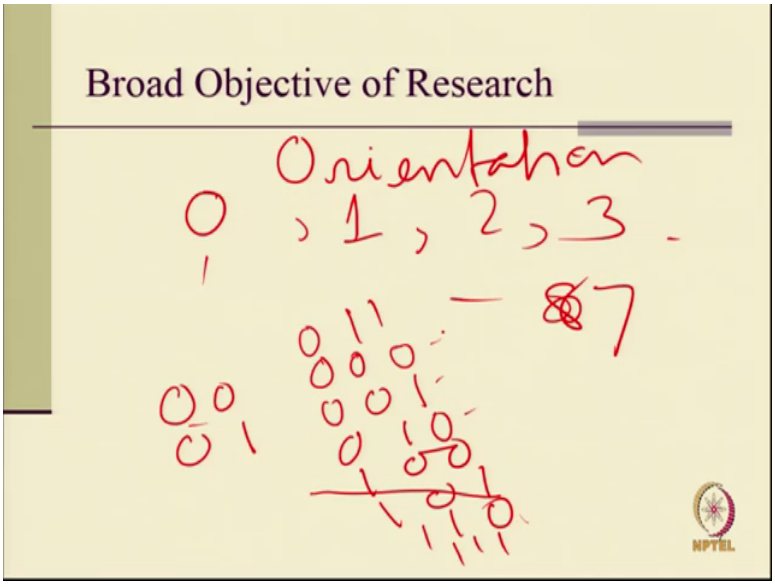


So 8 orientation let us say, so I call orientation 0, 1, 2, 3 orientation let us say to 8. One of the simplest way of doing the coding is in binary. So this I can code it as since there are 8 such

you know 7 sorry up to 7, so 8 such one in binary 2 digits 00 then 01, 2 numbers I can represent by 2 digits. If I represent it by 3 numbers 000, 001, 010, 100 right, 101, 110 and 111. So, you can see 1, 2, 3, 4, 10 I have miss something maybe 101 I have done and then 110 then there must be one more 0 yeah 000, 011 this is what.

So, you will have if it is 3 digits, binary digits you can use code 8 variable. If it is 4 then 16 cases you know so I have taken 16 orientation instead then I could have coded them in 4 digit binary right, 4 digit binary okay. So this is what is done. So first thing is coding, first one is coding.

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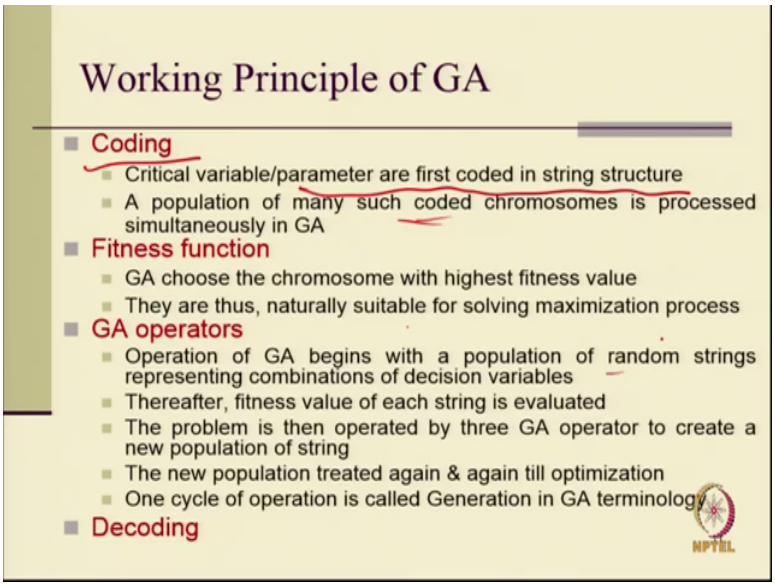


So I code and that is why took 8 orientation, 8 shapes etc deliberately. So, that I can code each one of them through three digits. So, decision variables their levels are actually coded in binary form right, coded in binary form. okay. So that is the first thing, then I have something called fitness function which is a objective function, then they are operation. What I do? I take a random population to start with, right random population to start with that means okay, now how do I combine this variable?

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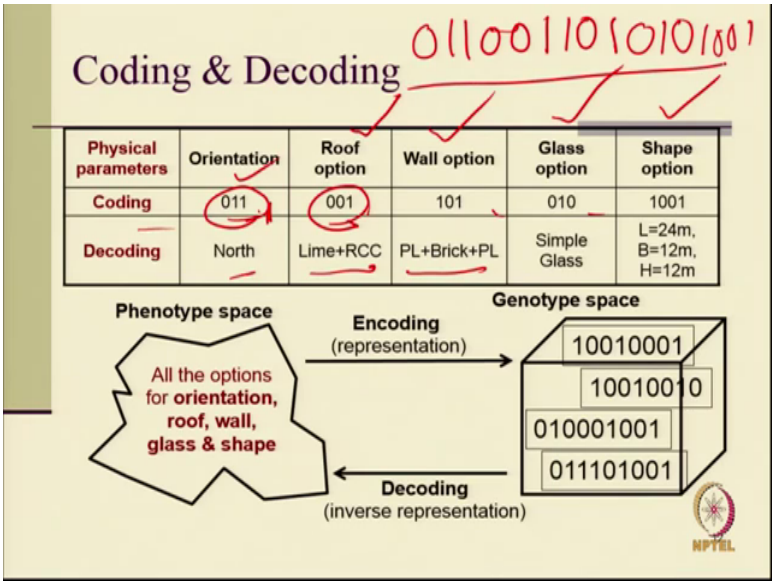


Now, supposing I have got orientation. Let us say, I have just taking straight way now, so orientation is 011, roof orientation is coded because I will have let us say 8, each one are taken I am taking 8 cases of orientation, 8 roof orientation roof option, 8 wall options, 8 glass options, 8 shape options right. So let us say this is my north correspond to 011, it is coded as 011. So each orientation is coded as a binary number, 3 digit binary number right lime plus RCC this is coded as 001.

So each wall you know roof option is coded as in this manner. Now, all these are written in a sequence in the sense that so this particular case I will write it as 011, 001, 101, 010 and this was 16 actually let us say so this will be one individual choice, I can put them in one single sequence to combine all the variable together, this gives me one single case.

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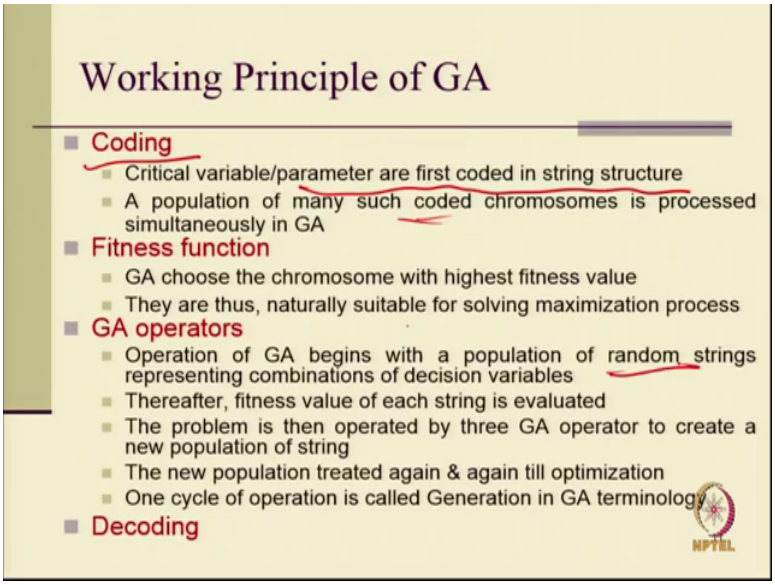


So what I got to do is, I will assume you know a population that mean several such cases which I will generate random manner.

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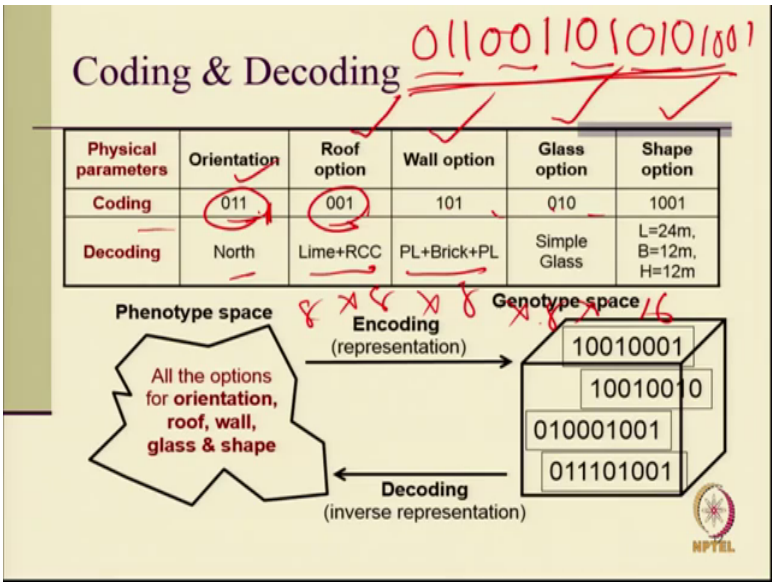


So I have to have, in this particular cases I have seen, I will have 3, 36, 39, (3, 1, 2, 3, 4) 4 into 3 is 12 plus 4, 16. So I have a 16 digit binary number which represent a case. Now how many total cases will there in this case? 8 into 8 into 8 into 8 into 16 so that many number of cases are possible out of which I select randomly some number which is based also on the principles and then do the GA operation on them. So that is what I do.

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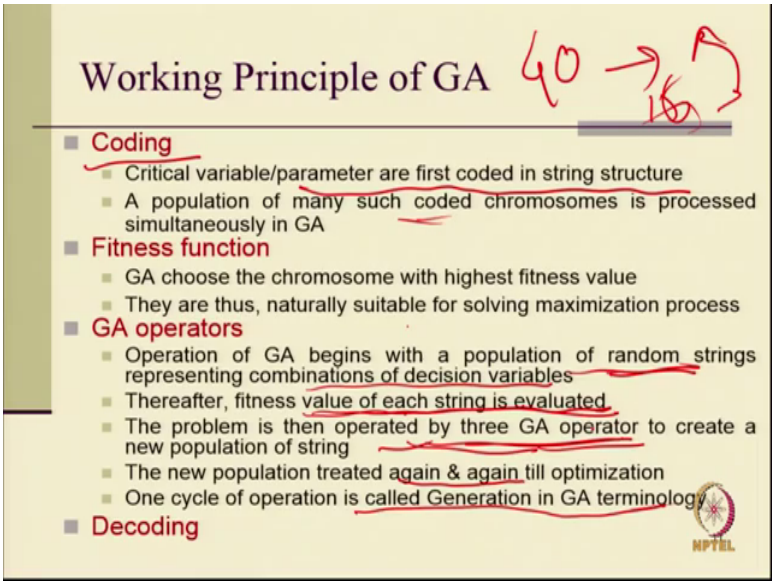


So, GA begins with the population of random strings representing combination of decision variable. So a string represents combination of decision variable right. Thereafter fitness value of each string is evaluated. Now with this case I can evaluate the fitness value through anyone of my procedure. From example, if I have a procedure for calculating the cooling load then for this case, this particular case I can calculate out the cooling load I am not explaining how to calculate out the cooling load but as I said there are you know there are ways solution procedures through which you can actually determine the cooling load for the given string.

So fitness value of each string is evaluated, 40 of them if I have taken to start with, 40 population of 40 then I have evaluate all of them then you operate GA operated and create a new population, that means what I do? I remove those who are not fit and keep only those are fit. Now, that would obviously reduce down if I started with 40 to reduce down to something some number let us say 20, 18 or 15 or whatever it is depending upon on how we have selected the initial 15 or 16.

Now this 16 has to be again made into 40, this is by what is called at crossover new population is generated out of this I will just explain this again. So new population or new strings are created out of this 16 again I bring back 40, I make that 40 new one and this 40 again I evaluate and this process continues till I get the you know no improvements in my results.

So, let us see how it is, new population is created again till optimize and one cycle of operation is called a GA operation you know in GA terminology and once you find out the

best then you can decode it to find out what was your solution. Because the coding you know, sequence you know, so you can come back right. So this is how it is.

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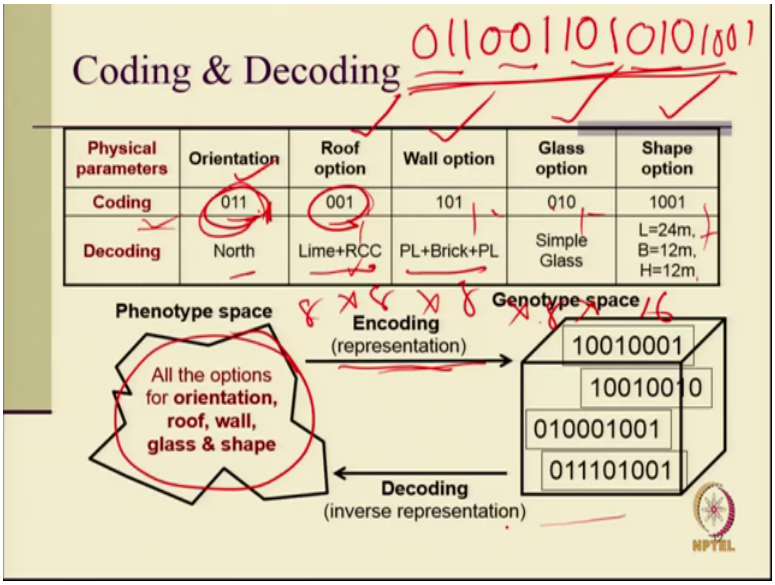


For example, say coding if orientation is 011 then this is decode simple glass and so on, shape option was l24 or12 etc. So, first is encoding all options orientation, roof, wall this are done encoding. So, you make them into sort of string right and then decoding is the last one.

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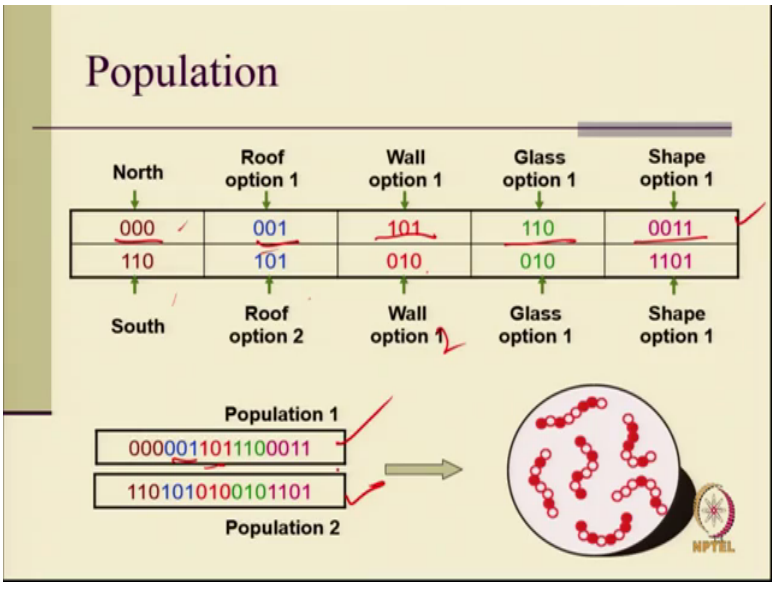


So how you do go about it? Let us say, this is roof of option 1 is this, roof option 2 is this, this is north, south I have defining it you know coding them already done the coding that way. Wall option 1, wall option 1 that could be wall option 2 or something like this, glass option 1,

glass option 2 and so on so shape option and so on. So what it does if I have this then the population will be 0, 001 you know the blue represents roof option, wall option 101 and glass option 110 and shape option 0011.

So, this is the first one, this is the second one you know the individual, in the individual 2 in the population if you have 40 or such things so two of them right two of them. So there would be pair, they would we work in pairs. So there would be 20 pairs let us say to start with right and what we do is.

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We select the best and keep this out and how you I do that?

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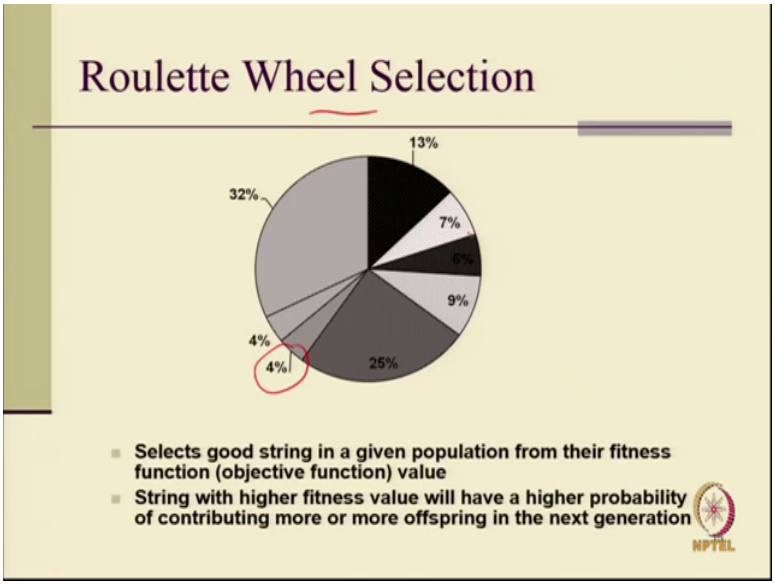


We use, supposing I have evaluated all 40 of them, one of the simplest way is to do by what is called a Roulette Wheel Selection, random selection. So what you do is you see, you find out the fitness values and fitness values which are only 4 percent fit, some might be 7 percent fit, some must be 32 percent fit this will come clear.

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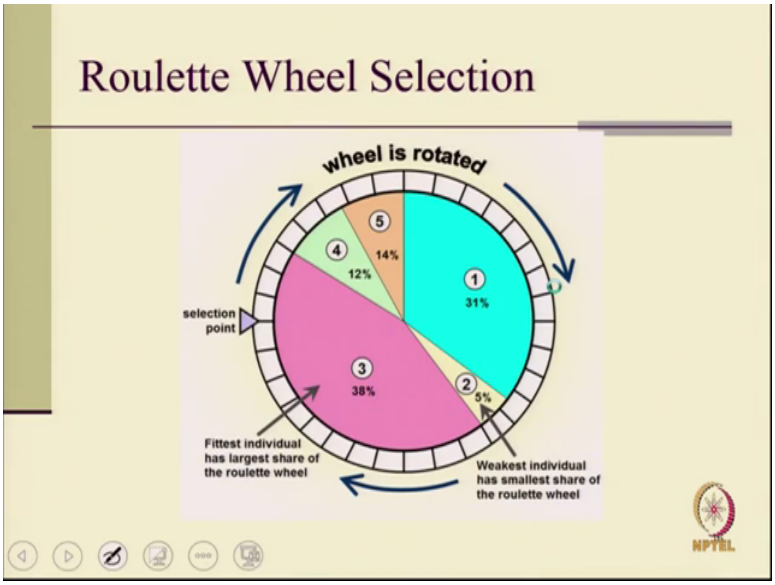


Okay this will become layer, so an example I will come back.

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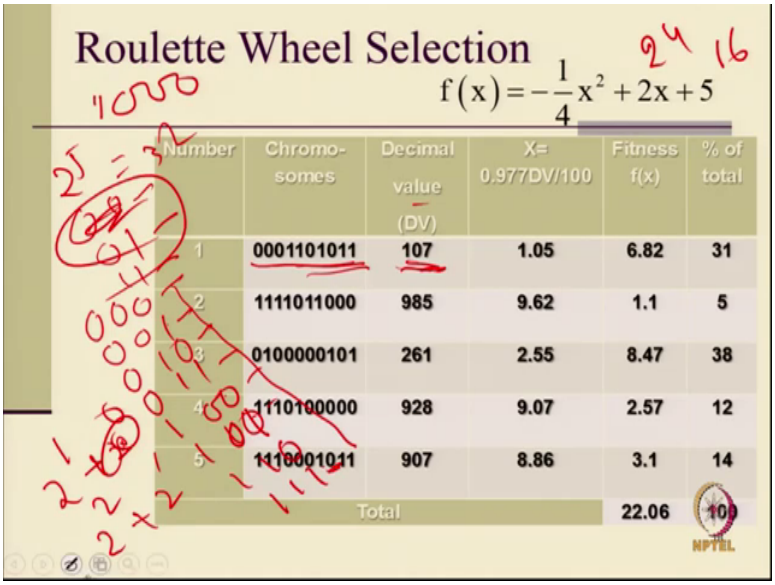


First is, so you know the simplest way of selection actually. For example, if this is the example if i take this is my fitness function f x is equal to minus 4 x square 2x plus 5 and I use this are called chromosomes each string and its decimal value and representing it by 6 plus 10 digit number. So the decimal value of this one would be you know how much is the decimal value? Because we know 001 is 2, so decimal will how it is calculated binary decimal values 0001 then 11 then 000, 001, 010 then 011, 100, 110, 101 first then 110 and then 111.

So, you can see that this number is how much? This 0, this is 1, this is 2, this is 3, this is 4, this is 5, this is 6, 7, 8 you know so you can basically how do you represents? If it is number of digit sorry this is 2 digits only, if it is 2 digits only it will be 2 to the power 1 plus 2 to the power 0. If it is three digits 2 to the power 2 plus 2 to the power 1 how many of them would be there? 1, 2, 3, 4, 5, 6,7, 8, 2 to the power you know this is, this one is 00, 00 is not there, two digits sorry, it will be 2 to the power 3, so 2 to the power 3.

So supposing I am denoting by 2 to the power you know this would be how much? In binary, I want to convert this one into regular number that our decimal value, it will be a three digit decimal value supposing I have thousand you know this, if I have 2 to the power 4 that is 16, 2 to the power 5 is 32, 2 to the power 6.

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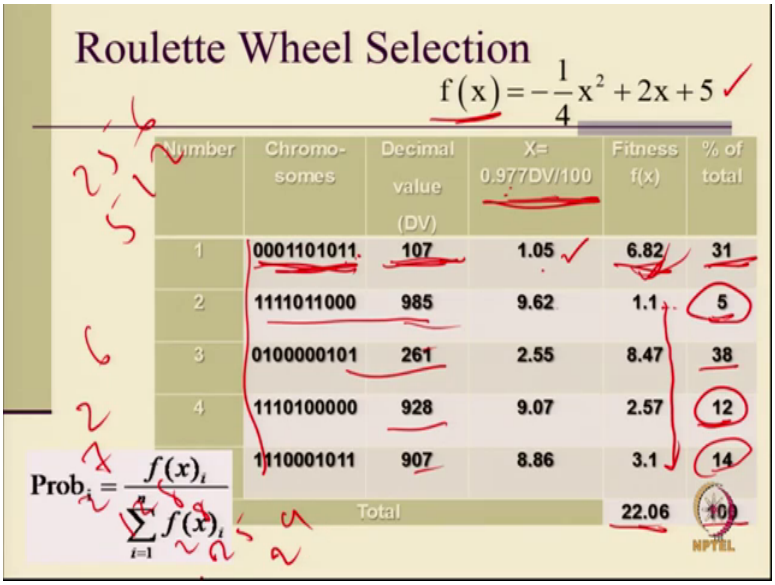


2 to the power is 6, 64 and 2 to the power 7, 128, 2 to the power 8, 256 and 2 to the power of 9, 256 into to 512 and 2 to the power 10 that is why there thousand you know there is three digit values I will represent by 10 digits. So this is just of an example.

Now, if you take this value how much this value would be? Because this should be 2 to the power 0 into 1 plus 2 to the power 1 into 1 plus you know like so if you have add this up you actually convert this binary into digital you will get 107. Similarly, if you convert this you will get 985, 260 and so on so forth. Now I will anyway we can look into this again if required. Now, x is equals to we are taking x value defining x you know this is my objective function or fitness function, x is defining in 0.977 decimal value divided by 100.

Just arbitrarily I am saying this is function of x which is defined like this, the decimal value divided by 100. So this is my x value, the fitness value is calculated according to this function is you know 6.82 and in this manner I can calculate the fitness value for each of this cases. Because usually 107 multiplied by 1977 divided by 100, 105, 985 multiplied by 0.977 divided by 100 is 962 and so on. So, if I sum them up this is 22.06, this is 31 percent of you know this would be okay if I this total I call it 100 and this is if you see this you know if I divide this 682 by 22.6 I get 31, 1.1 divided by 26 I get 5 and so on so forth right.

So I can arrange them in ascending order 1.15 percent 2.57 then 12 percent and next one is 3.14 you know then 6.8231 and this is 14 percent. So I can you know I can find out probability of finding.

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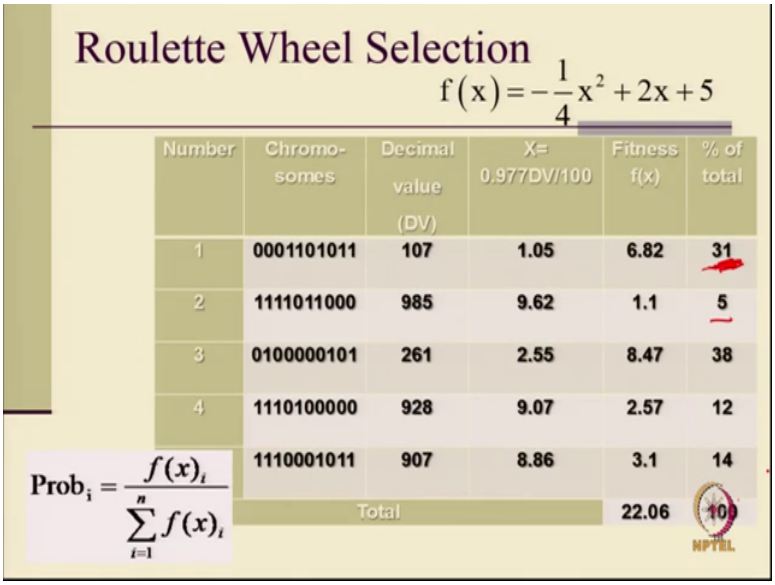


I can find out probability of finding so this basically nothing but relative frequency in percentage you know this is relative frequency in percentage, 31 percent of the this is 31 percent fit. 31 you know in the fitness if you look at it 31 percent is this. So how do you find out probability? Probability is basically (31) you know it 0.31 probability of finding you know probability of this is 0.31, probability of this one is 0.05 and so on so forth. So, this probabilities I can find out and i can generate now random numbers.

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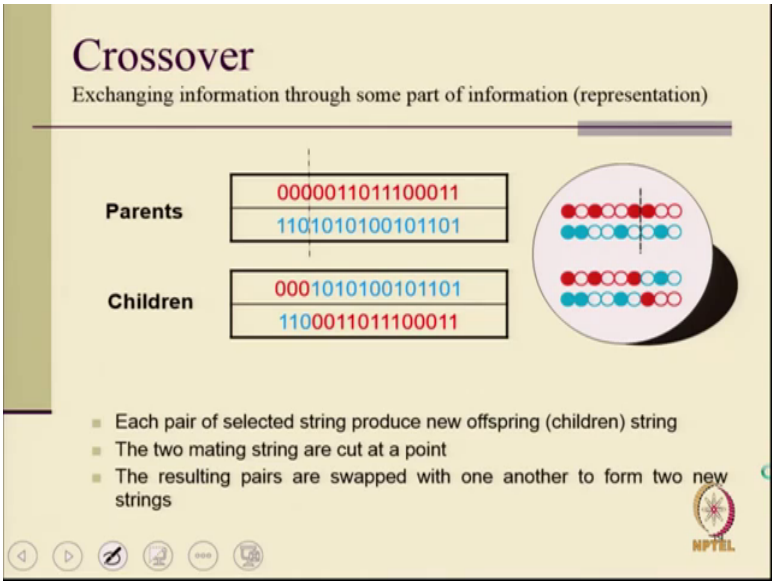


So for example I generate random numbers.

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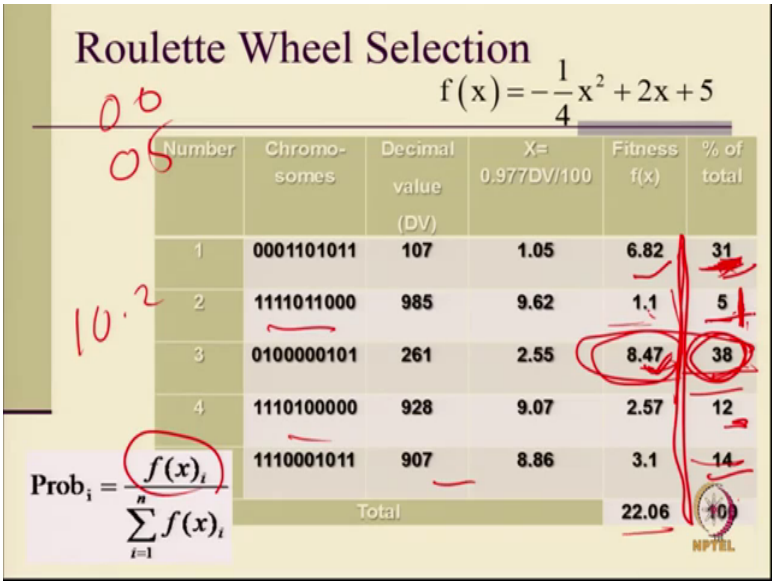


If I generate random numbers, if it is between 0 to 5 right the lowest one is 0 to 5 then I repeat this. If it is between 5 to 17 you know cumulative 5 to 17 then I will choose random two digit random number I can generate. So, if the number is between 00 to 05 I will repeat this if it is 5 to 17 that means 06 to 17, 5125 plus 12 is 17 I will repeat this number right because I got to generate more population and if it is the next one is you know 17 plus 14.

So between this then I will generate this number and if it is beyond that then I will generate enough to 31 and last one we 38. So I actually generate this is the largest value of the fitness and this have got a chance of being selected 38 percent. The one which has got the largest values of fitness because I am summing them up and dividing by the cumulative value, total value. So, this will be repeating itself 38 percent of the time, this will be repeating itself 31 percent of time and the one which is small the fitness value is small so what I am doing? I am summing up all the fitness value.

The largest fitness value, this will have this percentage, highest. Supposing sum total was 22.6 and let us say this was something was 10.1 or something right out of this. So 10.1 divided by 22 that would mean that 50 percent more than the 50 percent chance I will select that. So, whichever has got the highest value here it has got the maximum chance of the being selected. So, because I will generating random numbers. Now I select them accordingly. So, this will have 38 percent chance of being selected.

So, probability of selection is define by this fxi values divided by sigma fxi. This will have 31 percent probability of selection, this will have 14 percent probability, this is only 5 percent of

selection which means that when I complete the population back again I will have majority of this number which gives me highest fitness for this function.

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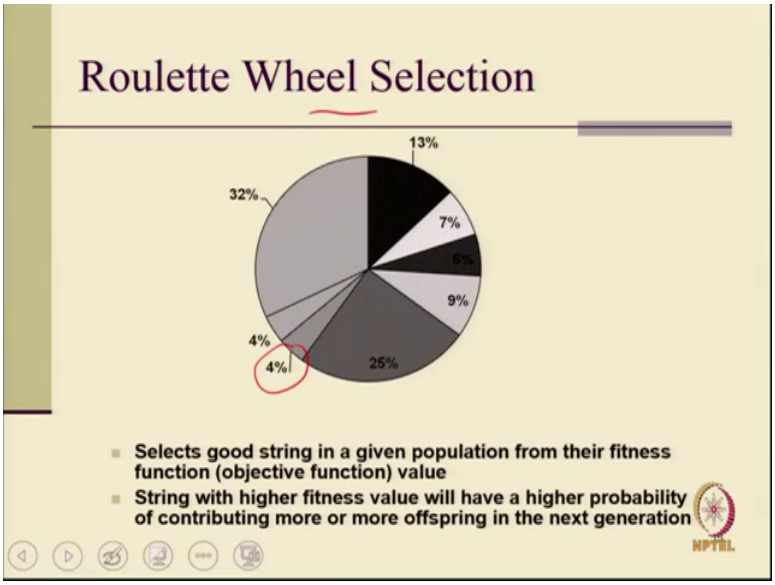


So, same thing we can repeat for our building case also. So, the fitness value which was 32 percent chance of being selected that I can write in a pie diagram like these, 32 percent something 13 percent etc and generate random number between 0 to 100 right or depending upon the how many variables you have taken 0 to 100 is good enough. So because it 2 percent, only 32 percent I am talking in percentages.

So, the fitness value corresponding to this you will have the highest transfer being selected right and the one this will have less chances of being selected .So once you have selected, created a new population of the same number that you have started then we will do something more. So, we will just wait for a minute and answer some of the question and then comeback.