VLSI Physical Design
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Lecture – 13
Placement (Part III)

So, in our last lecture we looked at the simulated annealing technique for placement of the blocks. So, it was a technique which was using some analogy from the process of annealing of glass or metals the way they are crystallized.

Now in this lecture we shall be looking at another method for placement which again takes analogy from another problem of physics namely the property of springs, the elasticity of the springs. Some well known law you must have heard of Hooke's law. So, it is basically based on some property of springs and their equilibrium condition, let us look at that problem.

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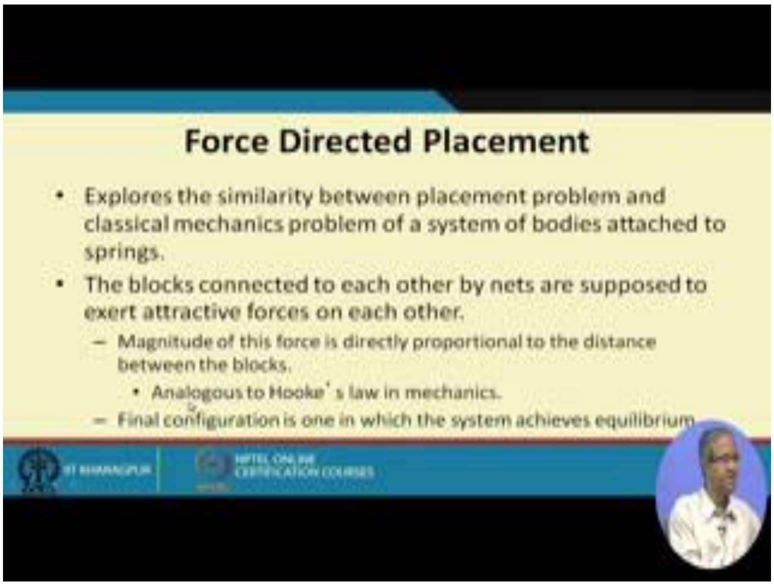

This method is called force directed placement. Now as I had said this method this explores the similarity of analogy between the placement problem and a very classical problem of mechanics which is a system of bodies attached to springs, I shall take an example to illustrate. So, there are a set of bodies which are attached to springs this is the analogy we are drawing here. So, we shall come to it a little later this is a analogy with respect to the placement problem where we say that the blocks that we want to place which are connected to each other by nets they exert attractive forces on each other. Magnitude of the force is directly proportional to the distance between the blocks which is analogous to Hooke's law in mechanics.

Let us try to explain this first. So, we start with Hooke's law. So, what is Hooke's law? So, Hooke's law relates to the property of a spring how stretching or contracting a spring exerts force on a body or a mass which is connected to the spring. So, let see.

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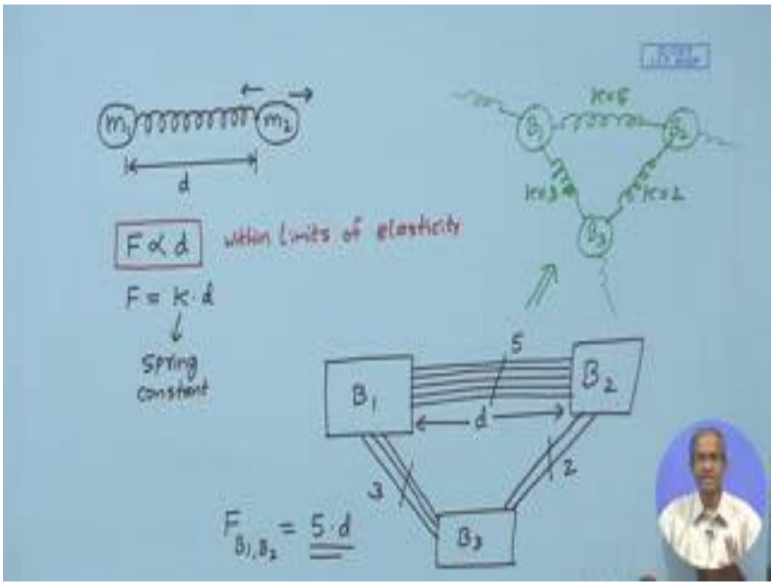

Suppose we have two masses let us call them m 1 and m 2 that are connected by a spring. So, what we can do? Let say the distance between these two bodies is d. So, for a spring you know that if I stretch the spring m 2 if I pull it in this direction release it will again come back here or if I push it in this direction, and if I release it will again come back in the original position. So, so whenever I pull or push a spring or force is exerted which tends to move it back in the other direction, right. So, the force exerted on the spring is proportional to the distance that separates the two ends of the spring this m 1 and m 2. So, you can write F equal to some constant k into d where this constant k is called the spring constant.

So, this depends on the quality of the spring. If it is a very strong spring the value of k will be very large, but if it is very weak spring the value of k will be less. So, this proportionality between f and d this will hold for this spring material within limits of its elasticity. See, if you pull this spring beyond a certain limit then some permanent damage might take place in the material, there can be some permanent deformation now which we say is beyond the limit of elasticity which means if you release it the body m 2 will not come back exactly to its original position, some part of the spring might get damaged permanently. So, that is why we are saying that within limits of elasticity the proportionality of F and d holds.

So, this is for two springs now let us look at the placement problem for we have two blocks let say a block B 1 and a block B 2 let us say there is another block B 3. So, what I; consider is that let say between B 1 and B 2 there are 5 connection wires and nets there are 5 nets which are running between B 2 and B 3 there are 2, between B 1 and B 3 let say there are 3. So, I can draw an analogy. So, what I say is that you see in the placement problem what are you trying to do. The two blocks which are more strongly connected together we try to put them as close together as possible, but if they are not so close strongly connected they maybe put a little for the effort no problem. So, what I am saying is that this problem can I modulate equivalently as three bodies B 1, B 2 and B 3 which are connected by three springs whose spring constants are k equal to 5, k equal to 2 and k equal to 3 because this particular spring is the strongest with the highest value of spring constant it will pull B 1, B 2 closer together.

So, if you leave this system of bodies to move around freely they will finally, settle down into a configuration which is the so called equilibrium condition, the net force on each of the bodies will be 0. There can be other springs also connected. So, I am not showing I am only show showing 3 because if it is only 3 the equilibrium position they will all come to all together, but there are other pulling forces in other directions also.

So, the analogy is like this we have a spring, we have the inter connection lines now the analogy is that Hooke's laws says force will be proportion to the distance, here also the same thing let say this is the distance d between the two blocks B 1 and B 2. So, the attractive forces between B 1 and B 2 will be equal to number of lines this is your k multiplied by the distance exactly like Hooke's law. So, this kind of similarity or analogy you were drawing and using this principle we are faming or formulating this particular method for placing the modules.

So, let us come back to this slide again. So, we are saying that the blocks connected to each other are suppose to exert attractive forces just like as if they are connected by springs as I had said. Magnitude of this force is proportional to the distance this also I have said and when you leave them along to move around freely the final configuration will be the one in which the system achieves equilibrium. So, when I say system achieves equilibrium let us take another example to illustrate this.

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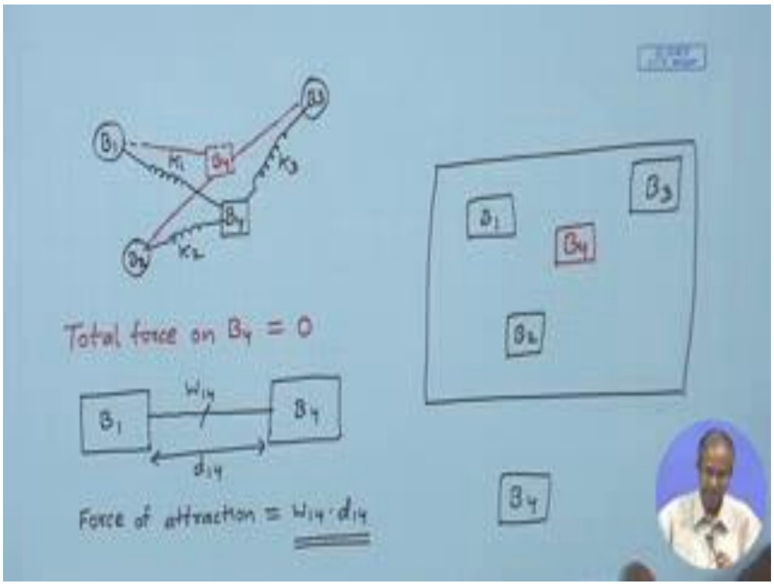

Let say I have three bodies, let us call them blocks B 1, B 2 and let say B 3 is here - so I am assuming that these three B 1, B 2, B 3 we represent blocks which are already placed on a floor plan let us a full custom design where we have placed B 1 here, we have placed B 3 here, we have placed B 2 here. Now what we are now contemplating a fourth block B 4 we are trying to find out a good location to place it ok.

So, this B 4 I am denoting by a body B 4 I am showing it in a rectangle which as if is connected by springs to these three already placed blocks B 1, B 2, B 3. So, their connectivity can be k 1, k 2, k 3 right. Now, what I am saying that in this condition I release B 4, so let B 4 move around and reach a final position which will be its equilibrium position. Let say suppose the final position of B 4 is this, if you release B 4 the final position B 4 with this. So, B 1 will connected this, this will be connected this. So, in the final position the total force exerted on the block B 4 will be equal to 0 this is the definition of equilibrium, right.

So, when you have this equilibrium we say that we have found out the best position to place block B 4. This is the basic concept behind force directed placement right. So, so in general if you just again look at it whatever I have said that if there are two blocks like this let us say B 1 and B 4 in general. So, you have the inter connections the weight will be let say w 14. So, how many lines connecting this; distance between these blocks let say d 14. So, the force of attraction between these two blocks B 1 and B 4 will be w 14 multiplied by d 14 just exactly like Hooke's law whatever it says it will be proportional to the distance w 14 will be constant, right.

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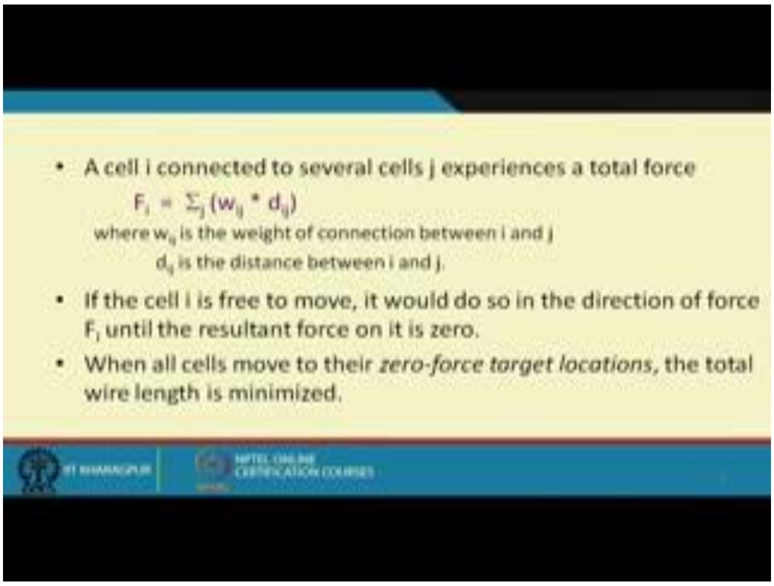

So then a cell connected to several other cells will experience a force, well I will be explaining this expression let me work out a simple scenario first will be easier to appreciate.

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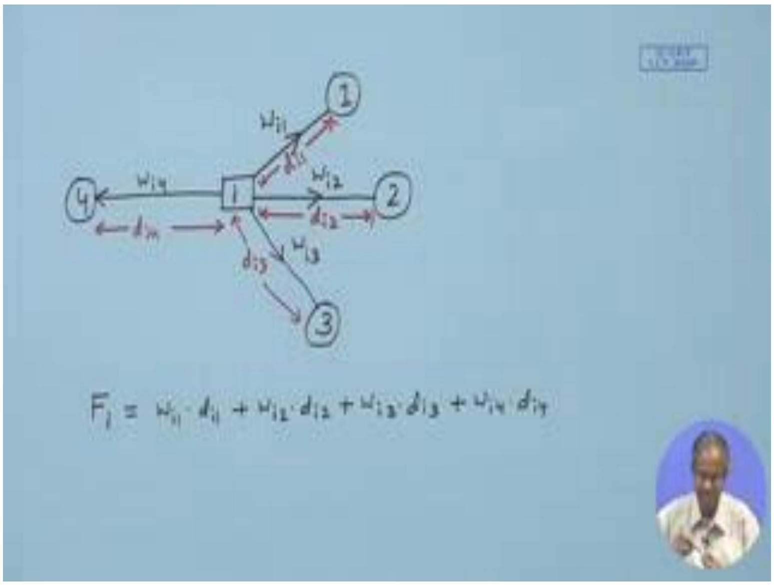

Let say I have a scenario like this for I have a block ‘i’ which I want to place there are already four blocks which are already placed let say 1, 2, 3 and 4 . So, each of these blocks is generating some attractive forces. So, 1 is trying to attract i toward itself, 2 is trying to attract i towards itself, 3 is trying to attract i toward itself and 4 is trying to attract i towards itself. Now it depends on the let us say, let us call this weights w i1, w i 2, w i3 and w i4. So, the total force that will be exerted on the block F i will be denoted by w i1 into d i1 where d i1 is the distance this is d i1, d i1.

Similarly, this will be d i2, this will be d i3 and this will be d i4. So, the total force exerted on I will be w i2 d i2 plus w i3 d i3 and w i4 d i4. Now what you want to do is that you will have to solve some equations and find out the location for i for which this force will become 0, because some of them will be pulling in the right direction, some blocks will be pulling in the left direction. So, there will be a sign in that plus and minus. The sum total has to be 0 both in the x direction and also in the y direction, right. So, this exactly what I have shown here is mentioned in the slide in a general form where a cell is attracted by other j number of cells. So, it will be summation over j w ij d ij this will be total forces where w ij is the number of connections between i and j that is the weight of the connection and d ij will denote the distance.

Now what I have just mentioned - if the cell i is allow to move freely, so it will be moving towards the direction of the dominant force and in its final position which is sometime called the 0 force target location the resultant force F i will be become zero. So, if we allow the cell I to move freely it will automatically come and rest in its final so called 0 force target location. So, our objective is to find out the coordinate of the 0 force target location so that we can decide which is the best location to place that block.

So, in this way if you carry out an iteration one by one we replace the cells. So, when all the cells move to their 0 force locations, the total wire length is expected to be minimized this is what we are trying to do because the two blocks which has maximum number of wires between them will be having maximum force so they are expected to come closer, together this is the basic idea.

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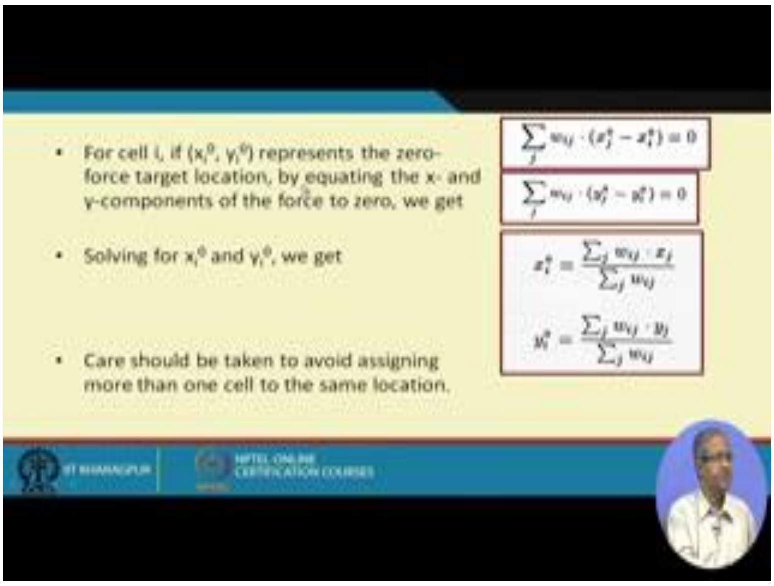

So, let us make a simple calculation. So, a force you know even if you are a mechanic a force will be having its x component and y component in a two dimension plane. So, we are separately equating the x components and y components of the force to 0 and trying to solve for the coordinate. So, for the cell i let us assume that x i 0 and y i 0 will represents the 0 force target location. So, then the total force exerted on cell i in this final location in the x direction will be w ij, x j 0 minus x i 0, this j is all other blocks and i is the for j this 0 is not required actually. So, you need 0 only for i for i because the I mentioned that all the other blocks are already there in the 0, 0 force target location that is why I am showing 0 here, but right in these equation we are more interested in xi 0.

So, distance between the two blocks in the x direction will be x j minus x i multiplied by weight.

Similarly, in the y direction distance between the two blocks will be y j minus y i 0 multiplied by weight. So, if you equate these two separately to 0s; that means, the net force along the x direction along the y direction will be 0 if you solve it you get the value of x i j this x i 0 I am writing instead, this y i 0 I am writing y j, y j 0. So, the final location is given by x and y values by expressions like this. So, if I know the coordinates of all other blocks and their weights of connections. So, we can calculate the value of the 0 force target location, but of course, we should check explicitly that there is no overlap when we are generating the target coordinate because you may be generating such target coordinate which is already occupied. So, you will have to put the block in some nearby location, fine.

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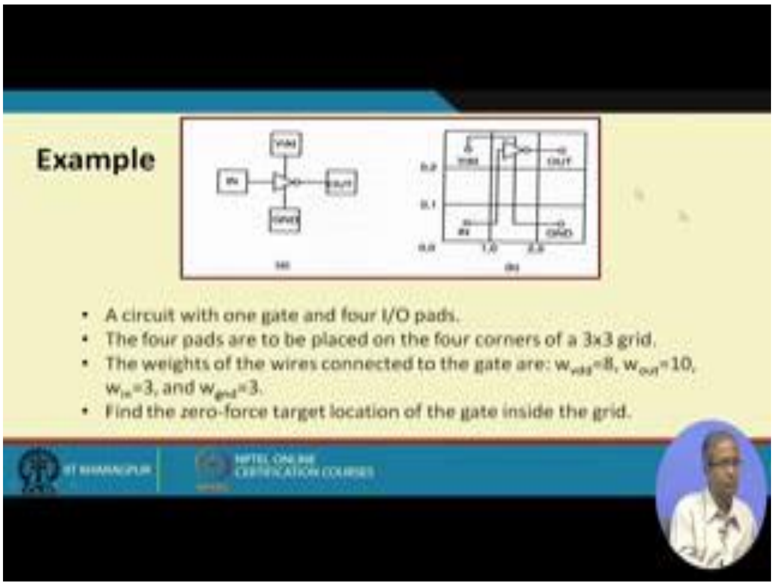

So, let us look a small example to illustrate. So, the problem is shown in the diagram on the left you ignore the diagram on the right temporally because this represents the final solution, but we shall arriving at this. You see in this example I have shown four input output pads indicating in out vdd and ground and one gate right. So, I am assuming for simplicity that I have a three by three grid like structure a very small sub problem for illustration where the four pads are already pre placed in 0074he four corner rectangles, vdd is here out is here ground is here and in is here. Now our problem is to find out the best location to place this in invert at this gate. So, there are 1 2 3 4 5 locations available. So, out of this 5 locations which is the best location to place this gate. So, whatever is available here is that the weights of the wires are given.

Well, these number are just for illustration purposes, do not think that why we did you weight is 8 and ground it is 3, these are nothing just some numbers. So, let us say w vdd this weight, this weight or this line is 8 and w and out is 10, w and in is 3 and ground is also 3. So, our objective is to find out these 0 force target location of this gate right let see. So, this is our three by three grid we are assuming that 0 0 indicates this cell this is 10, 20, this is 01, 11, 21, 02 and 22 that is the convention.

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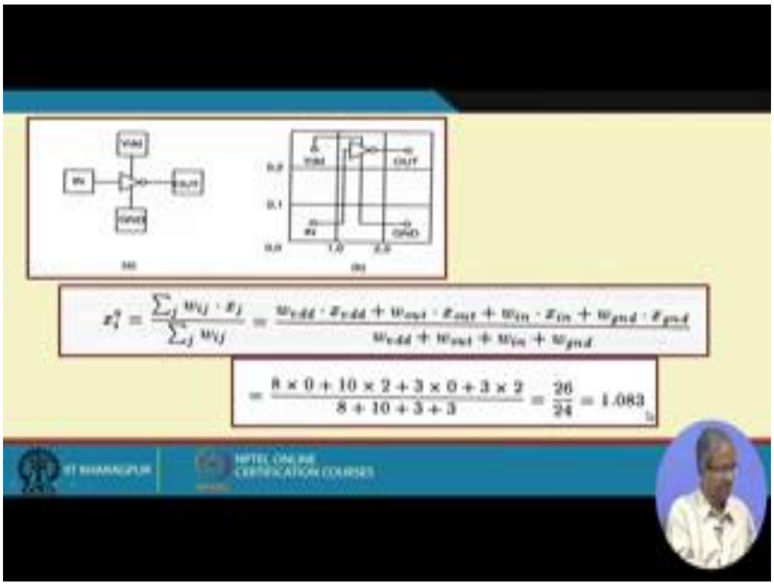

So, just we are following that equation which we derived just sometime back. Let us first calculate the 0 force x coordinate according to the equation we derived. So, w ij values are already known 8, 10, 3 and 3. So, the numerator w ij into x j will be there are four j's vdd, out, in and ground. So, w vdd, x vdd plus w out x out, w in x in and w ground x ground, in the denominator just be sum of the weights. So, you put the values the weights are 8, 10, 3 and 3 – w vdd is 8 and x vdd for vdd what is the x coordinate? 0, it is 02; for out weight is 10, the x coordinate is 2 - 10 into 2; for x in the x coordinate is again 0 - 3 into 0; for ground x coordinate is again 2 – 20, 3 into 2.

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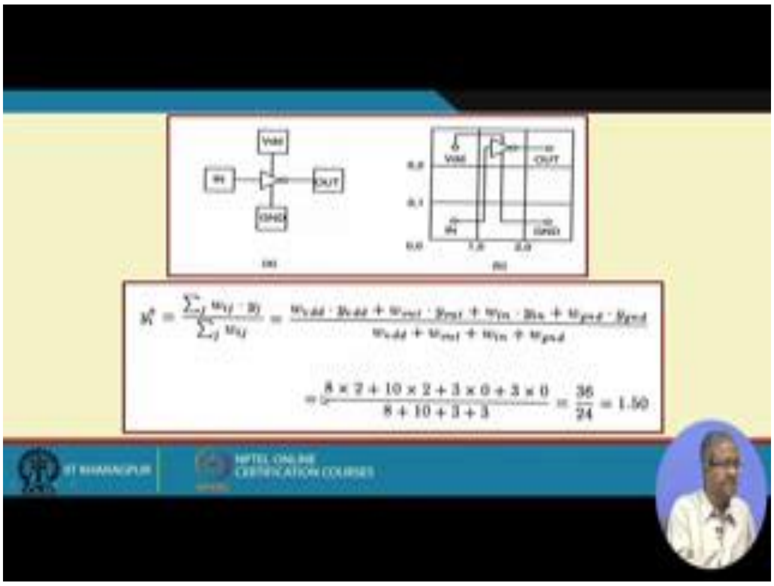

So, if you calculate it comes to 26 by 24 is 1.83. Similarly if you calculate the 0 force I mean y coordinate using this equation it will be similar. So, the equation will be like this y vdd, y out etcetera. So, this y vdd 8 into for vdd y coordinate is 2 - 0 comma 2, y out is also 2, but in and ground the y coordinate is 0. So, it is 0 and 0. So, this comes to 16 and 20 – 36 and this is 24. So, you get 1.5.

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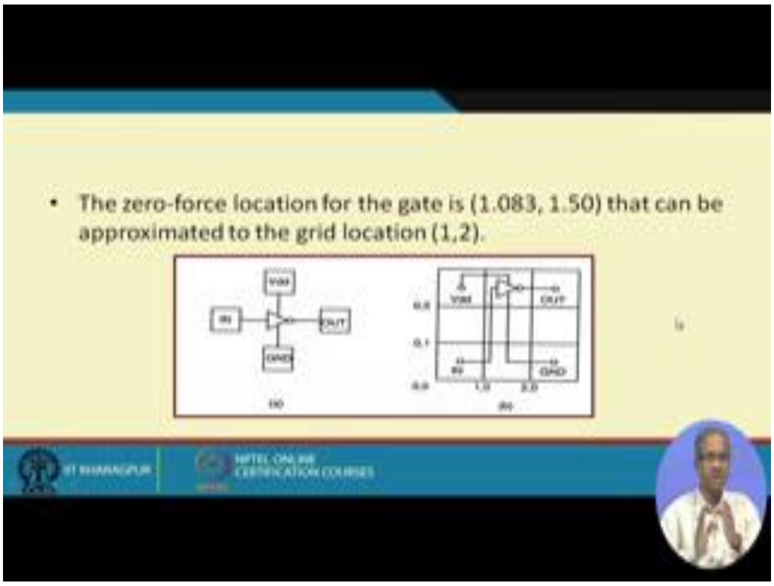

So, the 0 force location has been calculated as 1.083 and 1.5 and if you do a round of it comes to 1 comma 2 nearest integer values. So, 1 comma 2 will be this cell. So, the final solution is shown. So, for this particular problem this gate has to be placed in this location within the grid.

So, this is the basic idea behind that the force directed placement you can say where the sub problem that we had looked at right now is that some other j number of blocks are already placed, I am trying to place a new block i so what should be the coordinate of i such that the total force that is exerted on i by the external j blocks will be 0, both in the x direction and also in the y direction.

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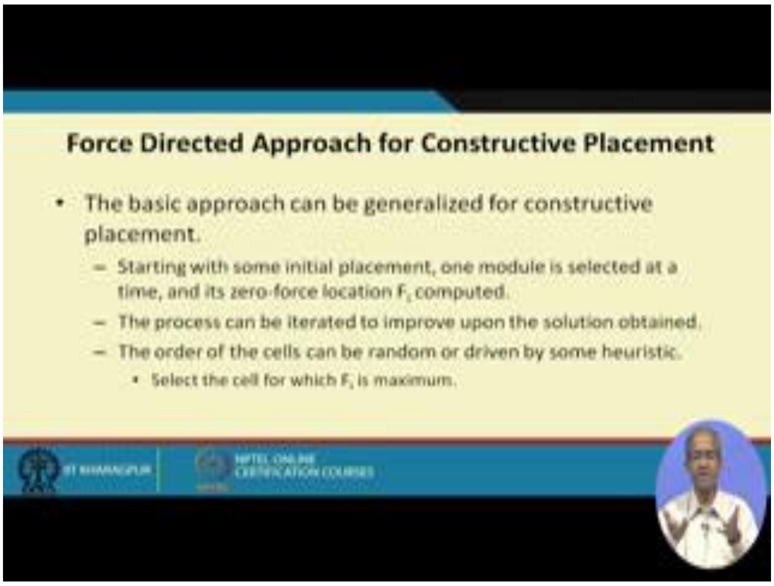

Now, so we have looked at the sub problem for placing one block only assuming the other j blocks are placed. Now this approach can be used for constructive placement. Constructive placement means I have let say, I have 100 blocks I want to place all of them constructive means I am placing them one by one in some sequence. So, slowly I am constructing the placement, constructive means something which grows in size as it proceeds.

So, the constructive placement is very simple it start with some initial placement you select, well initially initial placement is null nothing is there. So, you select one module at a time, computes its 0 force location and try to place it there. Well of course, there are some heuristics using which you can iterate to improve upon the solution obtained. Now the order in which you take these cells for placement it can be either random or driven by some heuristics like for example, mean at every stage you have been you consider all the remaining cells.

Like for example, out of the 100 I have already placed 40 cells 60 are remaining. So, I calculate for each of the remaining 60 cells for which the value of F i is coming to be maximum. So, if I have come up with the tentative placement. So, for the tentative placement which is coming to the maximum. So, you select the cell for which F i is maximum and try to generate a new location for they calculate. Of course, here I am assuming that I am starting with some kind of a random placement not placing them one by one. So, I am randomly placing the 100 cells on the floor, but one by one I am considering them for optimization trying to find out the 0 force location.

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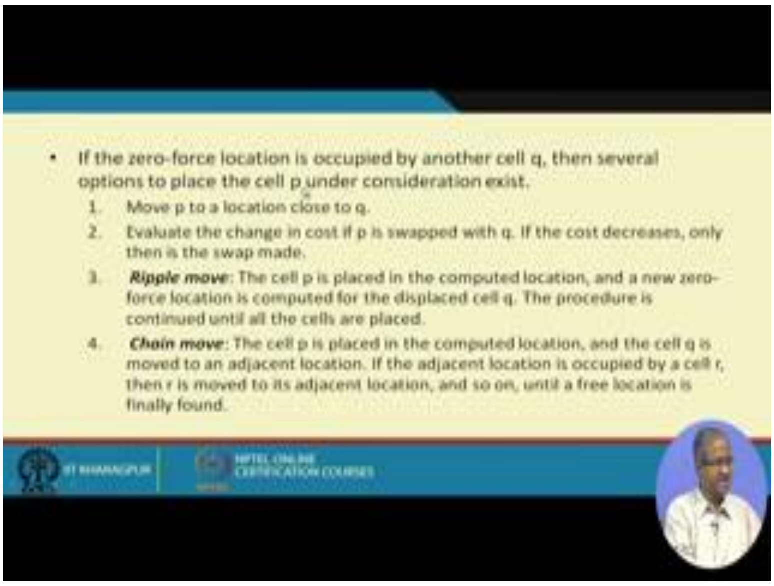

So, there are a number of heuristics which have been proposed that when you calculate the 0 force location of a block or a cell. So, if you find that the 0 force location is already occupied by another cell q, then the cell under consideration let say p you have several options for this. You move p, well you cannot put p into q because p is already occupied you move p to a location which is close to q either right, left, top, bottom, somewhere there.

Number two is you evaluate that what if we exchange or swap p and q. So, if you exchange p and q and see that the cost is decreasing then you can just accept the swap. Ripple move means we do some kind of a rippling or chain reaction, like you place the cell p in the location that has been computed which is occupied by q and for q with the new location of p you compute the new 0 force location for q you place q in that location, if you see that location is also occupied by another cell r you find this 0 location for r in this way you repeat till all the cells at the end are getting placed.

And finally, a chain move is you do not re-compute the 0 force location every time like an ripple move, but you move the cell p in the computed location and the cell q which is occupying that location earlier you move it to an adjacent location. If the adjacent location is also occupied by some other cell r, you move r to the adjacent location and so on like you are shifting all the cells basically until a free location is finally found.

So, we have seen the force directed scheduling and constructive placement case where using means analogy from springs the way forces are exerted by springs on a body we can also find out the best location to place the blocks. Now there has been a number of such placement tools which use this kind of heuristic based on force directive placement to actually find out the location for the different blocks.

So, with this we come to the end of this lecture number 13.

Thank you.