Robotics
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Lecture – 37
Robot Motion Planning

So; our aim is to design and develop intelligent and autonomous robot. Now we have seen how to collect the information of the environment with the help of sensors, with the help of cameras.

Now this particular camera could be either the on board camera or the overhead camera. There could be multiple sensors, there could be a combination of sensors as well as camera and we collect information of the environment. Once we have collected the information of the environment; now an intelligent robot should be able to take the decision as the situation demands. So, how to take the decision; how can a robot take decision so, that I am going to discuss.

So, we are going to start with a new topic that is called the topic 8 Robot Motion Planning. So, in motion planning actually what we do is; we try to plan the motion or try to find out the course of action while moving from an initial position to the final position.

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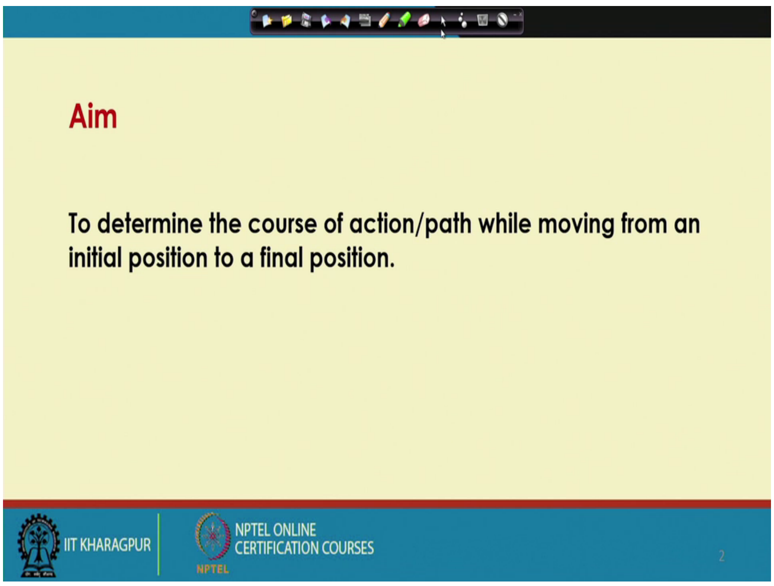

Now let us concentrate let it me consider that this is nothing, but the tip of the manipulator. So, this is the initial position of the robot and the final position is here. So, starting from here so, it is going to reach this particular the final point through a number of intermediate points and might be there could be a few obstacle sort of thing.

So, it will have to avoid collision with the obstacle; so, how to determine the course of action or the path that is the collision free path that is the task of a robot; that means, to perform that particular task, the robot should have a proper motion planner, the path planner ok. Now here I am just going to discuss like how to design and develop a suitable path planner or the motion planner for this particular; the intelligent and autonomous robot.

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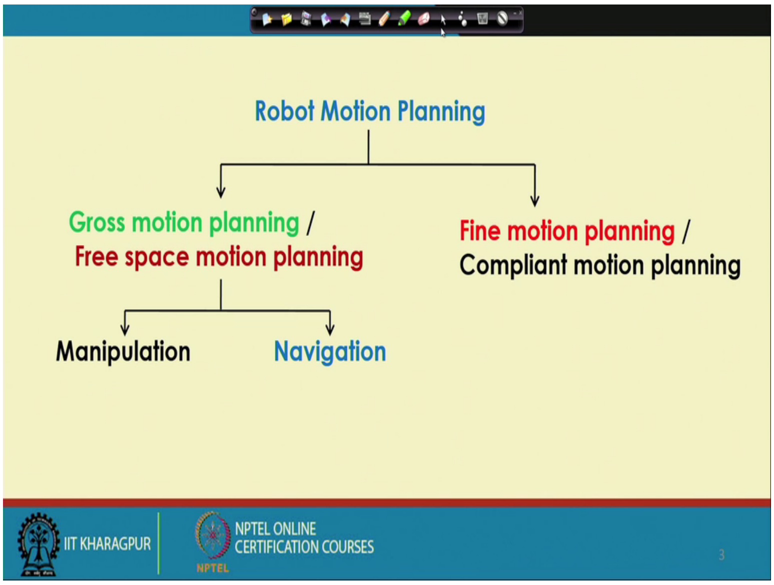

Now, if you see the robot motion planning. So, this robot motion planning are broadly classified into 2 subgroups.

So, these are broadly classified into 2 subgroups; so, these are broadly classified into 2 subgroups. Now, one is one is known as the gross motion planning or the free space motion planning. And another is your the fine motion planning or the compliant motion planning. Now let me let me take one example, let me take one example just to find out the difference between this gross motion planning or the free space motion planning and the fine motion planning.

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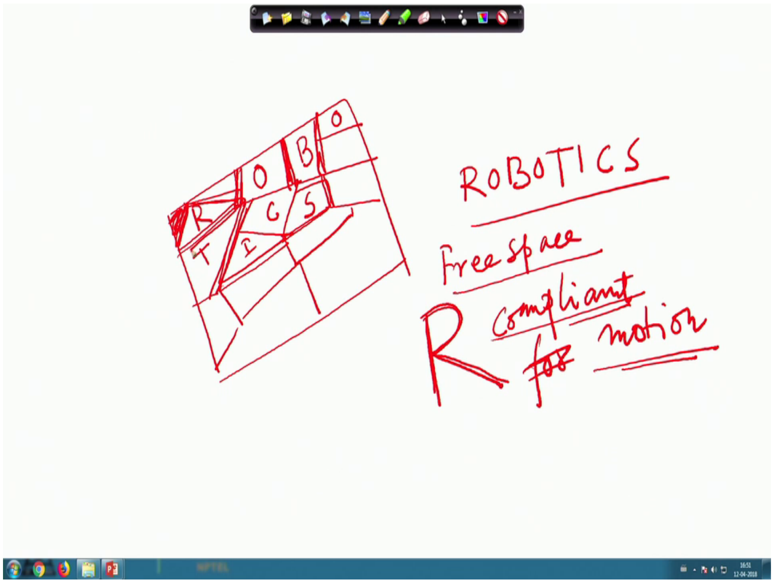

So, let us take one example supposing that say I have got one board something like this. And on this particular board say I will have to write say one word say I am just going to write a word say robot I am just going to write.

Now, this is the black board on which I am just going to write with the help of a marker or a chalk. Now if you just give the same task to a robot to an intelligent robot; that intelligent robot will first try to find out the free space on this particular the board where it can write that particular the word. For example, say the board could be something like this; so, this is here this is not the free zone, so this is not the free zone. So, this is not the free zone ok; so, the board could be something like this.

So, I am just going to show the free zone and your the dark zone sort of thing. So, this is actually the structure; so something is written here and this part is not cleaned of this particular board. So, I cannot write anything on the this part where there something is written. So, how to write the word robot or the robotics? Now if you give this particular task to the robot; the robot will first try to find out where is the free space where I can write down.

So, this particular the word that is the robotics. So, all such your the latest I will have to right. So, first thing it will do is it will try to find out the free space; so, the first thing is it will try to find out the free space. And once it has got that particular free space now it is going to write down the robotics r will be written here. So, R O B O T I C S; so, the robot is going to write down ROBOTICS on the board ok.

Now let me repeat the first thing you will have to find out the free space and once you have got the free space; now you will have to write this particular the word. And this letters you will have to write down and writing this particular letter on the board is not so easy; particularly for the robot.

Because whenever I am writing this particular the letter; so, this particular marker is in touch with the board and there will be compliant motion that is called the compliant motion. So, this particular the marker is in touch with your the compliant motion; marker is in touch with the board there and I will have to put some force; while writing some amount of force is to be put that is called the compliant motion. So, here there are 2 types planning one is called the free space planning, another is called the compliant motion planning.

Now, compliant motion planning is if you want to write down then how to; how to put force, how to manipulate? And while writing; so, I am just gripping. So, that particular marker with the help of my finger then I am doing some sort of manipulation so that I can write down R O and all such things.

So, I have got a planning to write R; I have got a planning, to write O; I have got another planning, to write A; I have got another planning another sequence. And those things starting from our childhood we learn, we learn through a number of iteration through a lot of practice; that is called the compliant motion planning.

And free space motion planning; the purpose of free space motion planning is to find out the feasible and the infeasible zone. For example, say this is an infeasible zone, but this part is a feasible zone where I can write down one letter. So, the purpose of free space planning is to determine the feasible space an infeasible space, but the purpose of compliant motion planning is to write that particular the letter.

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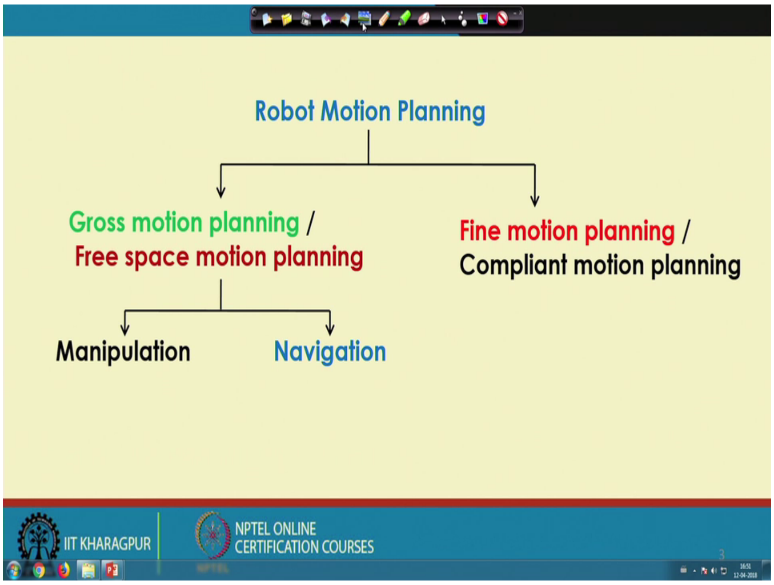

So, this is actually your, this is actually a bit difficult so this compliant motion planning or this particular fine motion planning is bit difficult. And this gross motion planning or the free space motion planning is easy I should say and here in this particular course; so, I will be concentrating only on this particular; the gross motion planning or the free space motion planning. But I will not be discussing the fine motion planning or the compliant motion planning because this has been kept actually beyond the scope of this particular course. So, I will be concentrating on this particular the gross motion planning or the free space motion planning.

Now, this gross motion planning or the free space motion planning can be once again subdivided into 2 parts one is called the manipulation problem, another is called the navigation problem. The moment actually I am just going to take the help of one serial manipulator, just to write something on the board that is called the manipulation task or the moment I am just writing something on this particular board ok.

So, that is nothing, but the manipulation task and the moment that moving robot or the mobile robot is actually working that is nothing, but is your the navigation task. In fact, we are planning to a give some practical examples of this manipulation and navigation in this particular course, might be at the latter part.

So, we are going to concentrate on this particular manipulation and navigation; that means, if I just want to put it in another way; that a serial manipulator or a parallel manipulator solves the manipulation problem. On the other hand, a mobile robot it could be a wheel robot or a multi legged robot or a tracked vehicle tackles the; the navigation problem. And let us see how to how to proceed further with different types of the motion.

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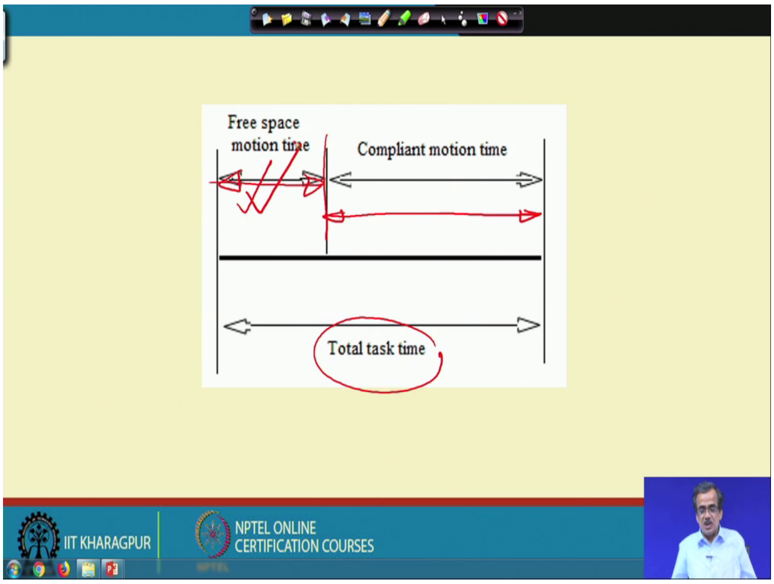

Now this particular, it shows this sketch shows actually if this is the total time for planning; now the free space motion planning takes only a small part, small duration. On the other hand the compliant motion planning takes the larger duration and the total time is nothing, but is your the total time for the motion planning or total task time. So, the total task time if I divide the free space motion time is much smaller compared to your the compliant motion time, but as I told I am just going to concentrate in this course only on the free space motion planning.

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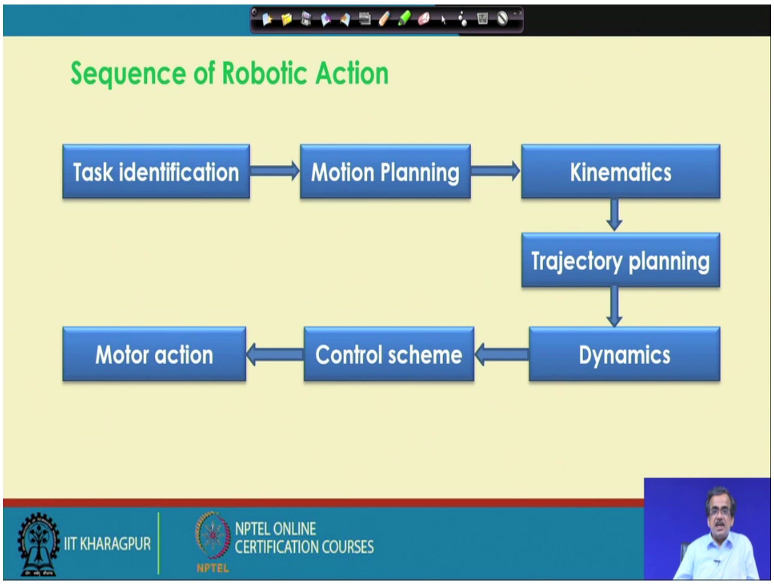

Now, this shows actually the sequence of robotic action and you will see that all such things all such modules, I have already discussed and now I am discussing motion planning. So, if I complete this discussion on motion planning you will see that all such modules of robotics have been touched. For example, say if I just want to solve one robotic one task with the help of a robot; the first thing is your the task identification.

So, you will have to identify the task; the task which is going to be tackled or solved with the help of a robot. Then we go for the motion planning which I am discussing now and once that particular; the motion the plan of action or the course of action has been planned, we go for the kinematic analysis that I have already done; already discussed.

Then we go for the trajectory planning before the dynamics. So, dynamics also I have discussed; the control scheme also I have discussed because you will have to realize that particular the torque with the help of a motor with a suitable controller. And once those things are ready; now, we are in a position to generate that particular the motion.

And this is actually in short the all the necessary modules of robotics; and as I told that in this course I am just going to touch the fundamentals of all the modules ok. So, let us try to concentrate more on this particular the motion planning now.

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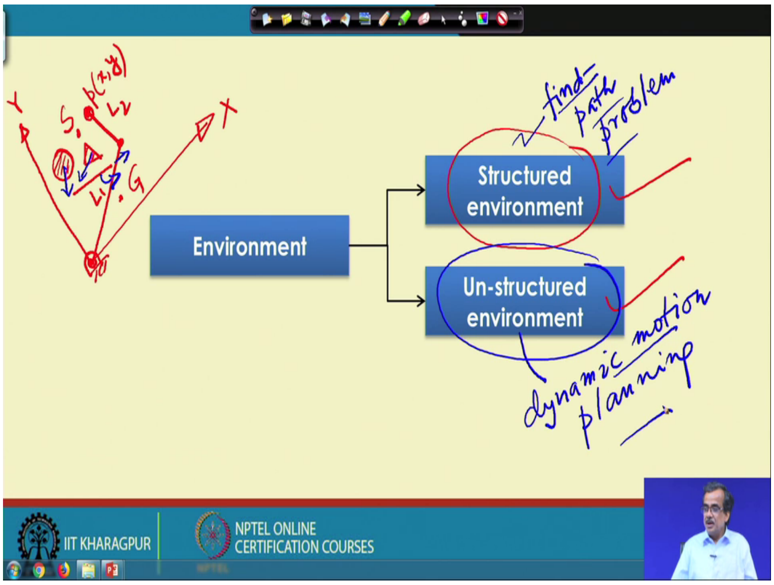

Now, if you see the environment; the environment could be either a structured environment there is the known environment or it could be unstructured. Now if the complete information of the environment is known beforehand that is called the structured environment.

For example, say I am just going to solve a motion planning problem like this where the environment is known. Let me take a very simple example supposing that say I have got say X and Y in Cartesian coordinate system and I have got a robot. Say if the robot having say 2 degrees of freedom very simple.

So, this is L 1 this is L 2 ok; so, this is the length of the first link length of the second link and this is the tip of the manipulator whose coordinate is X and Y. Supposing that I am just going to give a task that you start from here that is point S and you reach the goal that is point G ok. Now the tip of the manipulator is going to start from here and it is going to reach the goal.

And supposing that I am just going to put one condition or the constraint that the tip of the manipulator should not collide with any of the obstacle; supposing that I have got one triangular obstacle, I have got one circular obstacle, I have got one line obstacle and these are all 2 D stationary or the fixed obstacle.

Now here the environment is known; this is a structured environment. So, we know this particular the static obstacles, we know their location and I know my problem that the tip of the manipulator should start from here and it will reach this particular the goal ok. And this type of environment is known as the structured environment.

Now, if I just modify little bit for example, say if I add if I just consider that these obstacles are moving. For example, say this obstacle is moving in this particular direction with some speed. So, this is moving in this particular direction with some speed so, this is moving in this particular direction or say this particular direction with some speed ok.

Now the problem becomes difficult and the position of the obstacles are going to vary with time and that particular problem will become a problem of motion planning in the presence of moving obstacle. So, the path planning or the motion planning in the presence of the structured environment that is called the find path problem; that is called the find path problem.

And the motion planning in the presence of unstructured environment; so, this is known as your dynamic motion planning problem; dynamic motion planning problem or the motion planning among dynamic obstacle or dynamic environment. So, I am just going to discuss like how to tackle the problem that is your the find path problem and your this type of dynamic motion planning problem. And I am just going to discuss the working principle of a few tools.

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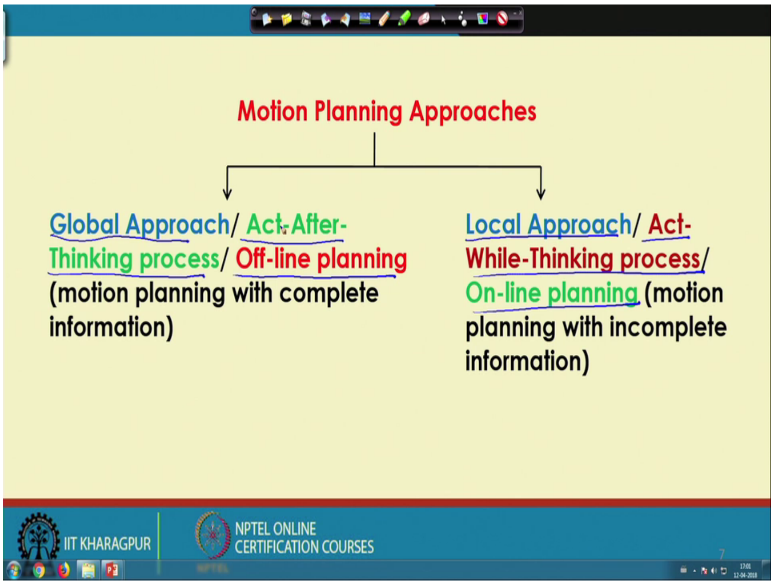

The tools for motion planning and with the help of some example I am just going to explain. Now, here the motion planning approaches if you see those are broadly classified into 2 subgroups. Now, one is called actually the global approach or this is also known as act after thinking process or this is known as the offline planning.

And we have got another that is called the local approach act while thinking process or the online planning. Now if the environment is known; if the structured environment we have then we can go for some sort of global planning, global approach or offline planning ok.

But supposing that I have got some sort of the moving obstacles in the environment; the environment is dynamic. So, here; so this environment is your un structured environment; so we will have to go for the local approach or act while thinking process or online planning.

Now let us try to explain the principle of this particular both global approach and the local approach. Now let us start with; so this particular your the motion planning scheme.

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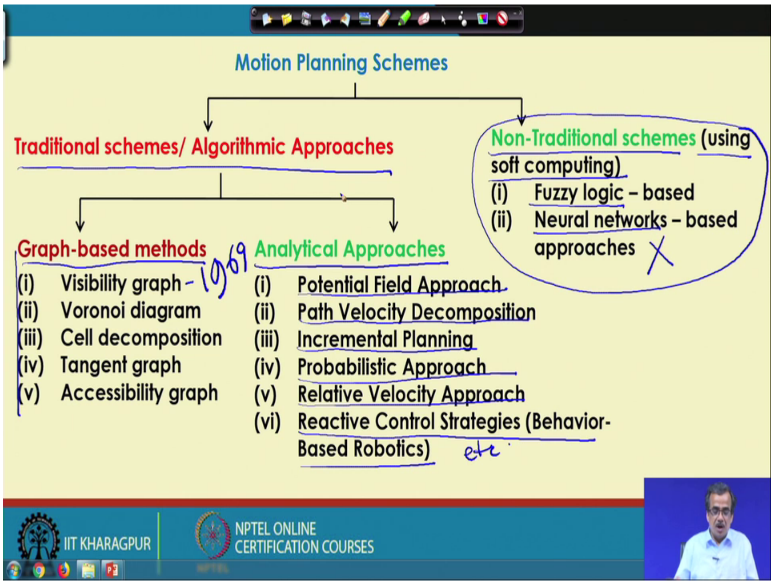

Now, if you see the motion planning schemes; these are broadly classified are into 2 groups one is called the traditional schemes or the algorithmic approaches. And we have got the non traditional schemes using the principle of the soft computing.

Now here actually the traditional schemes are known also known as algorithmic approaches, these are once again classified into 2 sub groups. One is called the graph based techniques and we have got the analytical approaches. Now if you see if we compare this graph based methods and the analytical approaches; the graph based method actually it was proposed first. For example, the visibility graph that was proposed first in the year 1969 by Nilsson, then we have got the Voronoi diagram, cell decomposition, tangent graph, accessibility graph; so, these are all graph based methods.

On the other hand actually we have got some analytical approaches. For example, say we have got the potential field method, we have got the path velocity decomposition, then we have got the incremental planning, probabilistic approach, then comes relative velocity approach, then reactive control scheme or behaviour based robotics etcetera ok.

So, we have got a large number of approaches, large number of methods to solve this particular the motion planning problem. Now on the non traditional side in fact, we have got a few approaches like the motion planning approaches using the principle of fuzzy reasoning tool, using the principle of your the neural networks, using the principle of the combined neuro-fuzzy system and so on.

Now those things actually is beyond the scope of this particular course. So, this will not be taught in this particular course; so, here actually I am just going to concentrate only on the traditional schemes or the algorithmic approaches. And both the graph based techniques as well as the analytical approaches we are going to discuss and we will see that how to solve that particular the find path problem and dynamic motion planning problem.

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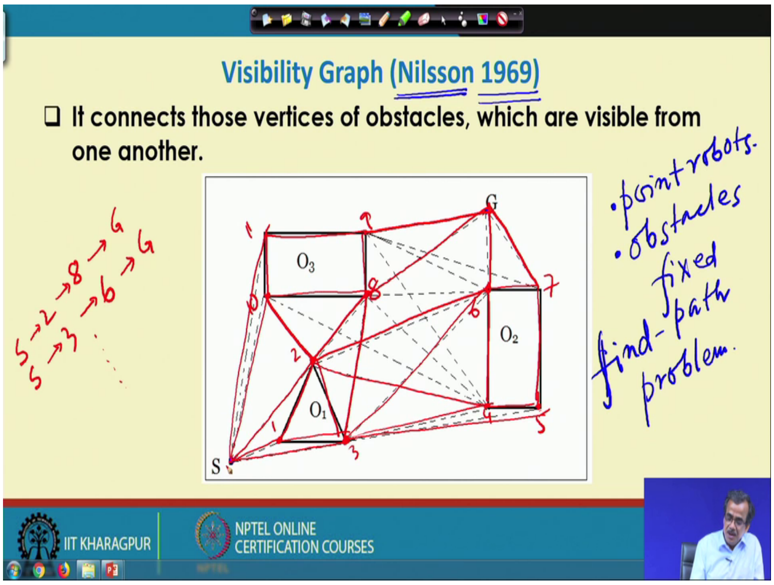

Now here so, we are going to start with say one the graph base technique which is known as the visibility graph. And this particular visibility graph as I told; so, this is the first approach which was proposed in the year 1969 by Nilsson and here the principle is very simple; now for simplicity we are considering that the robots are point robot.

So, we are just going to consider the point robots and we are going to consider that the obstacles are; obstacles are stationary that is the fixed obstacle. Now the problem scenario is very simple and this type of problem is known as the find path problem. So, this is known as the find path problem; that means, starting from an initial position. So, it will have to reach the goal by avoiding collision with this particular the static obstacle.

Now, let us try to see; so, this is the starting point for this particular point robot and for simplicity we are going to consider the point robot and this is the goal. And here we have got some obstacles like your; we have got the obstacle like. So, this is obstacle 1 here we have got say obstacle 2 and these are all 2D obstacle, stationary obstacle ok; so this is your another obstacle. Now according to this particular method; so, we will start from here now if there is no such obstacle; so very easily you can correct this S and G by straight line.

And that will be the best path or the optimal path that will be the collision free and time optimal path could be because there is no such obstacle. But due to the presence of this particular obstacle; so the robot we will have to find out a feasible path.

So, that it is not going to collide with this particular the obstacle; the rule is very simple. The rule is as follows it connects those vertices of obstacle which are visible from one another. Now let me start from here and let me try to look towards the goal. So, I starting from here if I look towards goal; so, this particular vertex is visible, this is also visible, this is also visible. So, you draw one line here, you draw another line here, you draw another line here.

Now, you come back here now from here you look into this. So, this particular vertex is visible, this vertex is visible this is also visible. So, the visible vertex you connect by the straight line visible vertex you connect by the straight line and similarly from here; so this particular vertex is also visible.

But this is not visible, this may not be visible this is also not visible. Now from here; so, this particular vertex is visible so this vertex is also visible. Similarly from here so this is also visible this is also visible, but this is not visible this is also not visible, this is also not visible.

Now from here; so, the goal is visible, then from here; so this is visible. So, from here; so this is visible from here this is visible ok. Now, so another thing is from here; so this is also visible and this is also visible. Now if I just do the numbering say it is 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and this is G. So, I can write down the different feasible paths.

For example, one path could be starting from S; you go to 2 you go to 2, then 2 to 8; 2 to 8, then 8 to G 8 to G. Another path could be that start from S then you go to 3. So, you come here then you go to 6, go to 6 and then you go to G.

Similarly, there could be many other possible combination possible sequence ok. Now out of all the possible sequences you can find out the time optimal path the time, these are all collision free path. And if you want to find out collision free at the same time optimal path, we will have to take the help of some optimization tool.

But Nilsson did not use any such optimization tool he could give all such feasible paths. And then he concluded that starting from S to reach this particular goal, there are many such feasible collision free paths. And out of all the feasible paths; the robot we will have to choose one; this is actually the principle of the visibility graph.

Thank you.