Robotics
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Lecture – 45
Summary (Contd.)

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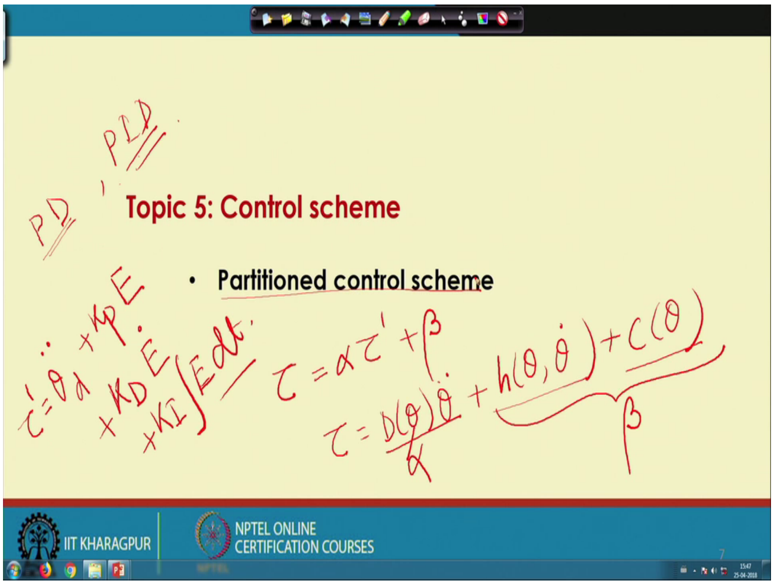

Now, then we concentrated on the control scheme; that means, once you have determine the expression for the joint torque, then how to achieve that? How can the motor supply that type of that amount of torque in a particular the cycle time? And each of this particular motor, generally we use DC motor is actually equipped with one controller; say PD controller or PID controller or PI controller. And with the help of that; so, this particular motor will be able to generate; so the required torque.

Now, in partitioned control scheme actually what we do is the total torque tau that is divided into 2 parts alpha tau prime plus beta. Now this alpha is nothing, but your D theta that is the inertia terms and this B is nothing, but is actually if I just write down the expression for the torque that is a D theta, theta double dot plus your h theta theta dot plus your C theta. So, this is nothing, but the expression for the joint torque.

So, this is the inertia term, correlation centrifugal term and this is the gravity term. So, beta is actually take care of this correlation centrifugal and your the gravity terms. So, this is nothing, but beta and D theta is nothing, but alpha then how to determine this particular tau prime? To determine the tau prime actually a what we do is; either we take the help of PD controller that is Proportional Derivative controller or we take the help of PID controller that is Proportional Integral and Derivative controller.

Now, supposing that I am using PD controller; so tau prime will be theta d; double dot that is the desired acceleration plus K P, that is the gain value for the proportional gain multiplied by error plus your K D that is the derivative gain multiplied by is your E dot. And if I use PID controller; so, I will have to add K I that is the integral gain multiplied by integration E dt; E is nothing, but the error and E dot is the rate of error ok. So, using this particular principle and using the partition control scheme and using the closed loop control system so the motor will be able to generate that particular the desired torque; so, these things I have discussed in much more details.

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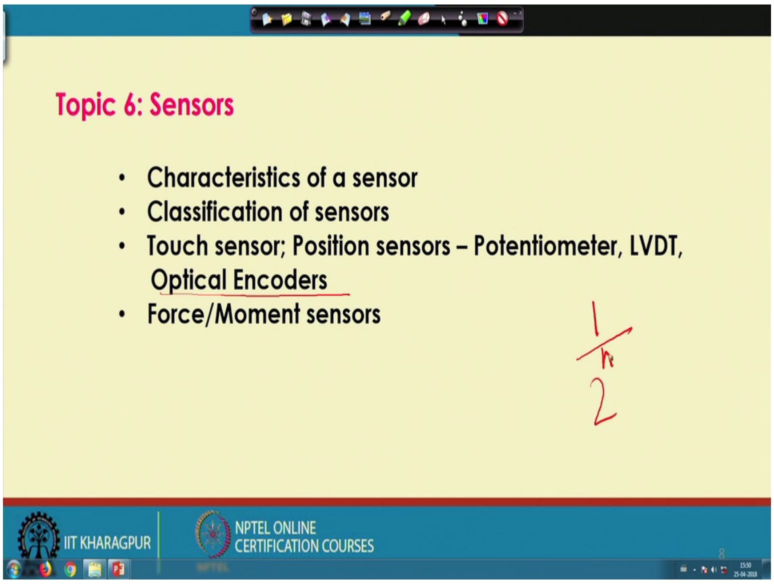

Now, comes your if you want to make the robot intelligent; we will have to take the help of some sensors because we human being we use a large number of sensors like eyes, ears, nose, skin and all such things. Sometimes we collect information with the help of multiple sensors and there will be multi sensor data fusion also.

Here also in robotics we will have to use the different types of sensors and if you want to purchase a sensor so we will have to prepare the specification; so, we will have to mention what is the resolution of a sensor, what is the repeatability of a sensor, what is the range of a sensor and so on. Then comes your; we discussed the different types of sensors we generally used in robots for example, we have got internal sensors, we have got external sensors.

Internal sensors are generally used to operate the drive units and external sensors are generally used to collect information of the environment; we have got some sort of your a touch sensor, we have got noncontact sensors ok; in fact, we have got different types of sensors. Now we discussed in detail the principle of touch sensor like limit switch that different types of position sensor like potentiometer; how does it work.

Then LVDT; that is a Linear Variable Differential Transformer and it can measure the linear displacement and for measuring the rotary displacement; we will have to use RVDT; that is RVDT is a Rotary Variable Differential Transformer. We can use some sort of optical encoders; now optical encoders could be either the absolute optical encoder or there could be incremental optical encoder. Absolute optical encoder is more accurate, more costly because there we use large number of your the photo detectors and here the resolution which we get is nothing, but 1 in 2 raised to the power n; n is nothing, but the number of concentric rings.

And then comes your the force or the moment sensor; now these force or moment sensors are generally used to find out what should be the component of the force, the component of the moment. Supposing that one robot is doing some sort of manipulation task that is say it is doing some sort of peak and place type of operation and while doing this peaking and place type of operation; so, the gripper is going to grip, it is going to carry it and place it somewhere.

So, the robotic joints are subjected to some amount of force, moments, torques and to determine that so we can take the help of so this type of force or the moment sensor. The working principle of this force and moment sensors I have discussed in much more details.

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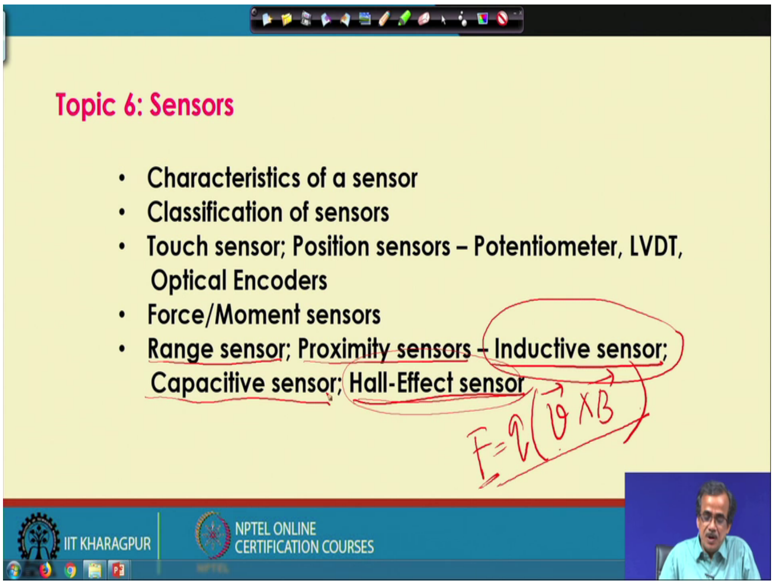

Now then comes your the range sensor; now this range sensor we use the principle of the triangulation. And using the principle of triangulation we can determine the distance between the object and this particular the sensor.

We can use light as a source or sound as a source in this type of range sensor to determine the distance between the object and your the sensor. Then comes your proximity sensor; we have got a few proximity sensor which are very popular. For example, say we have got inductive sensor then comes we have got the Hall-Effect sensor; these are suitable only for the magnetic material. And Hall effect sensor works based on the concept of that Laurence force that is F is nothing, but q multiplied by v cross B v is nothing, but the velocity with which a charge q is moving in a magnetic field of strength B; then it will be subjected to the force that is called the Laurence force.

So, using the principle of a Laurence force this hall effect sensor is working, then using the principle of the law of magnetic induction that is the rate of change of magnetic flux is proportional to the induced voltage or the induced current. So, based on that; so this inductive sensor is working these are suitable for the magnetic material, then comes your capacitive sensor it is suitable both for your the magnetic as well as the nonmagnetic material. So, these are some of the sensors very frequently used in robots.

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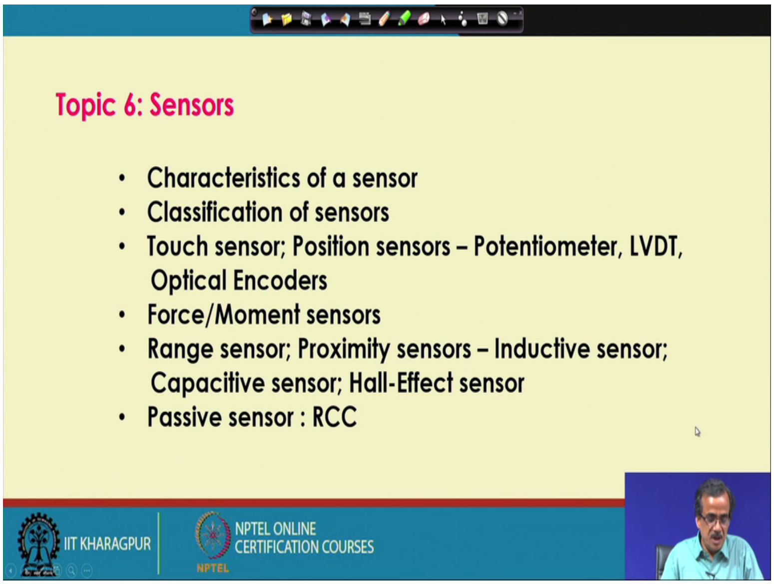

And there is a another sensor that is also vary frequently used that is called a passive sensor and this passive sensor actually we do not use any feedback for this passive sensor and Remote Center Compliance that is RCC is a typical example of this particular the remote center compliance.

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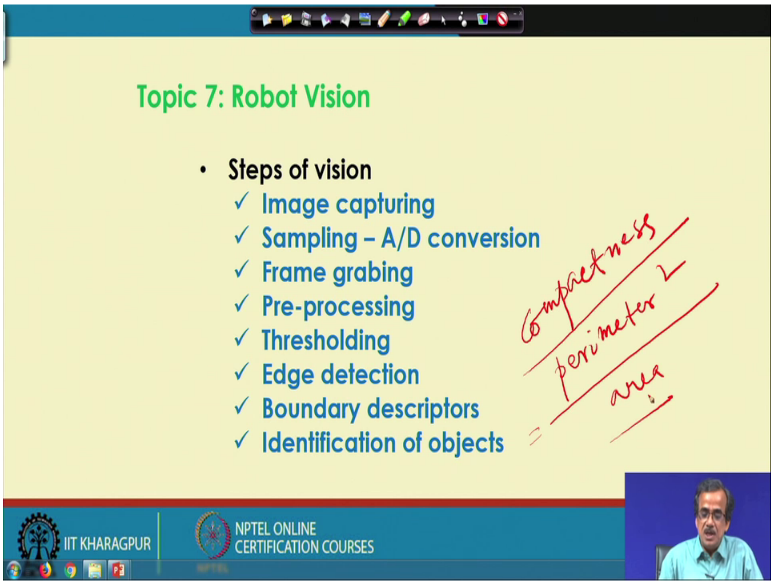

Next we started with the topic 7 that is Robot Vision, like. So, in place of sensor; if the robot is using some camera then how can it collect information of the environment? So, that particular principle actually I have discussed in much more detail.

The steps of the robot visions are as follows for example, we capture image or the photograph with the help of a camera. Generally we use some sort of CCD camera, then we go for some sort of sampling that is analog to digital conversion and for this particular sampling we take the help of some sort of electron beam scanner. And I have already discussed that we do this scanning along the x direction and y direction and on the electron beam scanner there are some photo sides. And whenever we have doing the scanning some amount of charge will be accumulated on the photo sites.

And amount of charge accumulated is proportional to the light intensity. So, using that particular information we can do some sort of sampling that is called analog to digital conversion. We use some sort of digitizer here and once we have expressed that particular image; say black and white image in the form of a matrix of numerical values; that means, your image I am just going to represent with the help of one matrix of number and this is what is known as the frame grabbing.

Now, this particular frame grabbing if you do so I will be getting that particular the image in the form of matrix form, but that may not be the correct and there could be some noise, there could be some lost information. So, we will have to go for preprocessing there are different methods of preprocessing which I discussed; for example, the masking operation then neighborhood averaging or median filtering.

So, these are all preprocessing method once we got the preprocess data; next we take the help of thresholding just to find out the difference between the object and that particular background. And to find out the boundary we take the help of edge detection technique; these are nothing, but the gradient operator we use the second degree gradient, first degree gradient that is the we that is Laplacian is the second degree gradient also.

Once you have got that particular boundary; now we try to express that particular boundary of the object in a mathematical way. That is we use some sort of boundary descriptor so that we can do some sort of further processing. And once you have got that now we will have to identify, now to identify actually as I discuss we try to find out the compactness of the different object.

Now by compactness we mean that is nothing, but the perimeter square; perimeter square divided by the area. And by knowing this particular compactness we try to find out actually your, we try to find out that that the different objects. So, this is actually how to determine that particular your how to carry out this to collect information of the environment; the next is your the robot motion planning.

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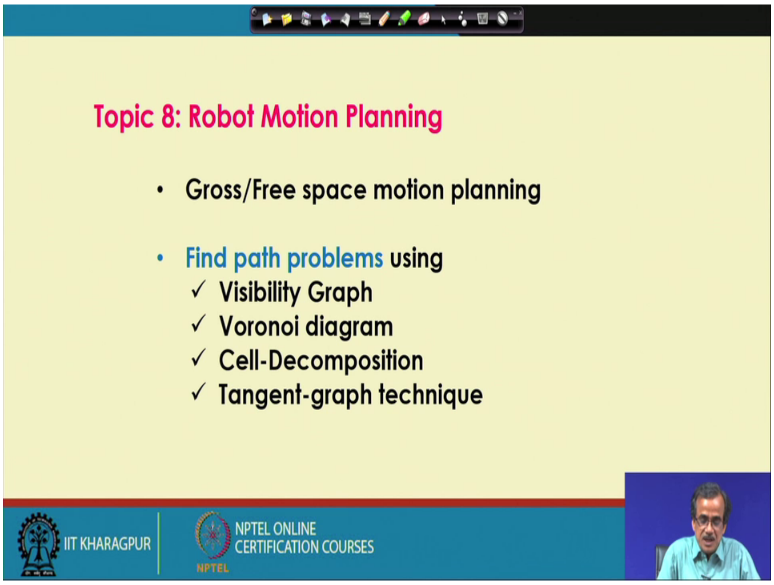

The aim of robot motion planning is to plan; is to determine the course of action. Now this robot motion planning could be either gross motion planning or free space motion planning. Now here we concentrate only on the gross or the free space motion planning.

We solved the find path problem using the different methods, graph based methods like the visibility graph which was proposed long back in the year 1969 and in fact, this is the first approach of robot motion planning that is the visibility graph. Then came the concept of Voronoi diagram, we tried to find out the locus of the points which are equidistant from 2 of the boundaries and that could be the feasible path for the robot.

Then we discussed the cell decomposition; so before we go for the cell decomposition so what we do is; so we try to find out the feasible and the infeasible zone. Now if I have got a physical robot and an obstacle; we try to convert it into a point robot and a grown obstacle and we will be getting some sort of your the feasible and infeasible zone.

So, the feasible zone that is divided into a large number of small small segments and we try to find out what should be the midpoint for each of the; your feasible region.

And then we try to connect all the feasible points by the straight line and that will be nothing, but the collision free path for the robot. Then we discussed the principle of tangent graph technique; so, we consider the bounding circle for the obstacle and we try to move, the robot will try to move along the tangent and the circular arc of this particular to reach that goal and that is the principle of tangent graph technique.

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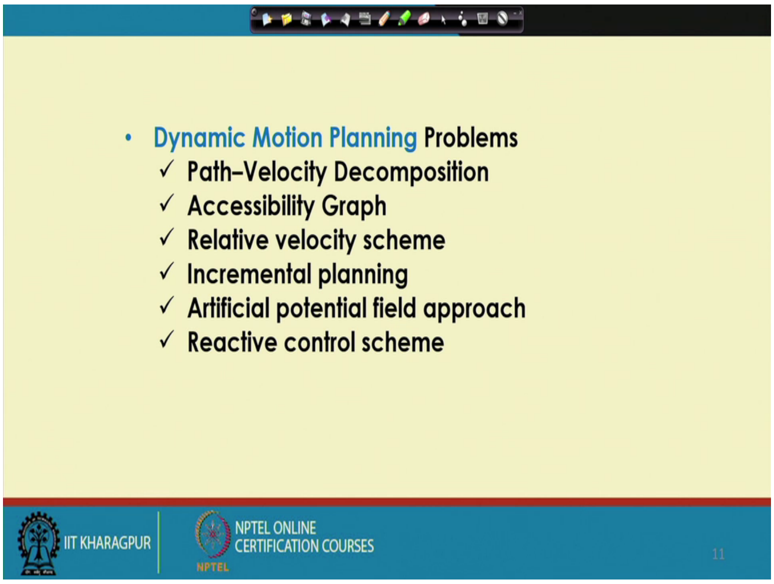

Then we discussed in details the dynamic motion planning problem. Now here in dynamic motion planning problem the robot is moving at the same time the obstacles are also moving and to solve that particular problem we took the help of a few approach; one is called the path velocity decomposition.

And as I mentioned that this is the first approach proposed to solve the dynamic motion planning problem. At this path velocity decomposition that consists of 2 sub problems; one is called the path planning problem another is called the velocity planning problem. Then comes your accessibility graph now this accessibility graph is nothing, but the modified version of the visibility graph.

Now here the obstacles are moving; so at time t equals to t 1, I will be getting one visibility graph one collision free path at time; t equals to t 2 another visibility graph. So, the visibility graph is going to vary with time and that is nothing, but the concept of accessibility graph. Then comes the relative velocity scheme; so, in dynamic motion planning problem the robot is moving, obstacle is moving.

So, here actually what we do is we try to find out the relative velocity of the robot with respect to the obstacle as if we consider the obstacles are stationary and we try to find out the velocity and considering that we try to find out the collision free path. Then comes your incremental planning, so at time t equals to t 1 say the dynamic motion planning problem will become the fine path problem.

So, we make a plan considering the problem as a fine path problem then the robot is going to start moving; the moment it faces problem and if there is a chance of collision the robot is going to stop and it is going to re plan and once again it will try to find out the collision free direction, this is the principle of your the incremental planning. Then comes your the artificial potential field method here the robot is going to move under the combined action of attractive force or attractive potential of the goal and a repulsive force or the repulsive potential of the obstacle.

And due to this combined effect of this attractive and repulsive force the robot is going to move towards the goal. So, this is actually the principle of your artificial potential field method, then comes your the reactive control scheme. So, here each of the robotic action is divided into a large number of the primitive robotic task and each of these primitive robotic task is controlled at a particular layer of the controlled scheme.

Now, supposing that a particular task has been divided into certain primitive behaviors to design the control scheme there should be a 10 layers and over and above there will be one centralized computer and which is going to control all the 10 layers. So, this is actually the scheme for the reactive control scheme and based on this reactive control scheme one field of robotic research started that is called the behavior based robotics.

But as I told that behavior based robotics has got a few drawbacks and that is why the currently we are working on evolutionary robotics. And evolutionary robotics is going to actually overcome the problem faced by the behavior based robotics, but as it is out of scope of this particular course. So, I did not discuss the principle of the evolutionary robotics.

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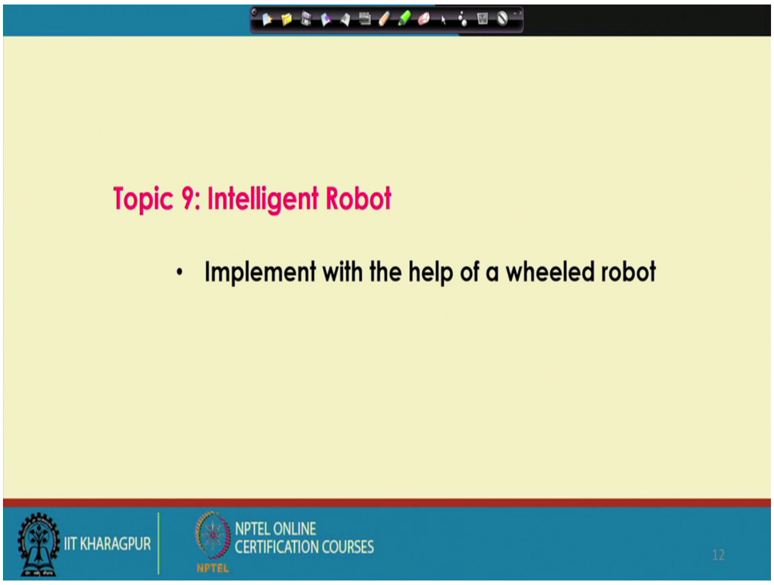

Now, then comes your we started discussing on intelligent robot like how can a robot take the decision as the situation demands and that we implemented with the help of the wheeled robot.

Now, I am just going to discuss in short the way this particular thing was implemented it is very simple. So, we have got a field and in the field we have got a robot and some moving obstacle at the top we put the camera that is the overhead camera; so, with the help of this overhead camera we take the snap at a regular interval and that particular picture collected with the help of camera goes to the a computer through BNC cable.

And in the computer we have got the my vision board that is nothing, but the image processing hardware and there we carry out some sort of image processing within a fraction of second. And based on that image processing we try to find out what is the position of the robot, what is the position of the obstacle, which one is the most critical obstacle and so on. And based on the critical obstacle we use the motion planning algorithm just to find out the angle of deviation and acceleration or the speed so that it can avoid collision.

Now, the motion planner whatever decision we have got; now we will have to implement. To implement that we need that we will have to give some instruction to the controller of the motor because the motor is connected to the wheel of the robot; now what we do is we took the help of some sort of wireless communication radio frequency module. And with the help of this radio frequency module the information related to how much RPM is required on the left side wheel, how much RPM is required on the right hand wheel that information we are going to pass it to the controller of the motor.

And the controller of the motor is going to generate that particular RPM so, that this particular wheel robot can take the left turn or the right turn or it will be able to move in the forward and backward direction as the situation demands. So, this is the way actually we could make the robot intelligent and we did real experiment and in this course we showed some video also for that real experiment.

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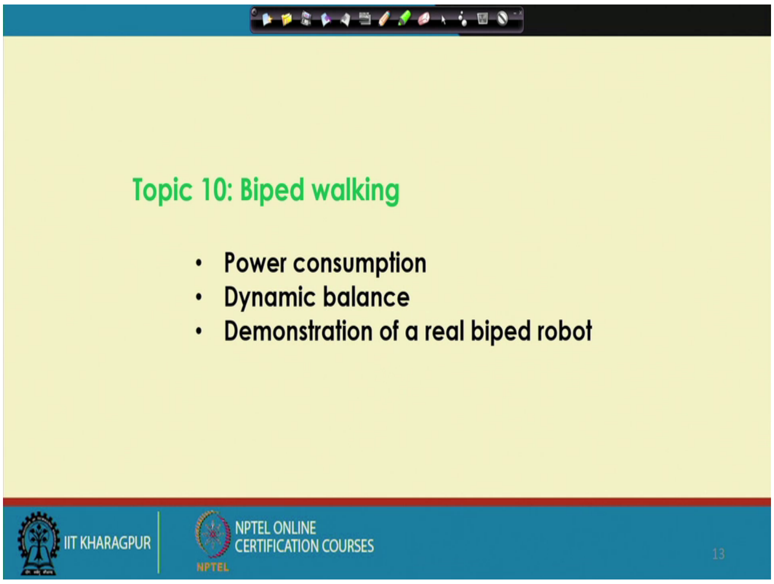

Then comes your the biped walking. So, we concentrated on the biped walking, we consider how to find out the power consumption for the biped walking; how to maintain the balance of this particular, the dynamic balance of the biped walking and I did not discuss the mathematical derivation in details like how to derive the power, expression for the power and as I told that is available in the textbook of the course. So, those who are interested they can see from this particular textbook and after that with the help of a small model on a biped robot we can we showed some movement some forward and backward movement of that particular the biped robot.

And the video of the real experiment has or also been shown here and it has been demonstrated. Now this particular course we have come to the end of this particular course on robotics and I am sure all of you have enjoyed this course and have learnt a lot through this particular course, but this is simply the beginning. So, if you want to learn robotics and if you want to be the true roboticist; so, this is the thing which I have discussed the fundamentals, the all 4 modules of robotics which I have discussed. Those things we will have to understand, we will have to start that will give you the initial momentum so that you can learn this particular subject in future in depth.

And robotics once again I should mention that this is the future so, we will have to go for this type of multidisciplinary fields in future and using the robotics we can solve different types of real world problems. So, I think there is a very good future for this particular the robotics. I thank you all and I wish you all the best.

Thank you.