Robotics
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Lecture – 44
Summary

Now I am going to summarize of this course on Robotics.

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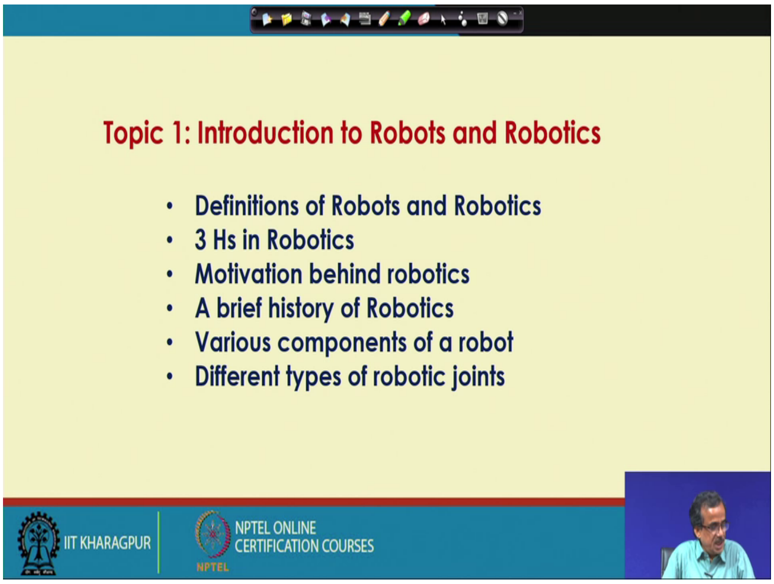

In this course in fact, there are 10 topics and all 10 topics have been taught. I am just going to summarize topic wise; the topic 1, the first topic that was on introduction to Robots and Robotics, we started with the very definition of the term robots and robotics.

And to recapitulate we mean a robot; an automatic machine which can perform a variety of task and the term robot was introduced in the year 1921 by Karel Capek. And robotics is actually a science which deals with the issues related to the design, manufacturing and applications of robots. And the term robotics was coined in the year 1942 by Isaac Asimov now in robotics we copy everything from human being. For example, we copy head, heart and hand of a human being in the artificial way and that is actually popularly known as 3 Hs in robotics. Now why should we study robotics?

Now, we have seen that the today's market is dynamic and competitive and if we want to survive so we will have to produce goods at low cost; at the same time the quality has to be good and the productivity has to be a high. And to avail all these or to reach all the requirement, so we will have to go for automation. And robotics is actually a flexible automation and that is why modern industries should go for the robotics.

We discussed little bit a brief history of the robotics; now, as we discussed the first robot, the first patent on the robot that was filed in the year 1954 by George Devol and he is known as the father of robot and after that so the different universities particularly different US universities, then NASA, USA then USSR; so, they started manufacturing a different types of a robots.

For example, say Stanford Research Institute they develop robots, Carnegie Mellon University; CMU could develop some robot, OU State University could develop some robot, NASA develop a few robots. And all of us we know NASA sent some intelligent robots to the mars like spirit and opportunity, curiosity and all such robots are nothing, but the intelligent robots.

Now, here as I told that the most sophisticated robot as on today might be the Sofia; which was developed in the year 2015 by Hanson Robotics; Hong Kong and Honda has already designed and developed sophisticated humanoid robots; so, this shows the brief history of the robotics.

Now if you see what are the different components of a robots now, in a robot we have got a few links 2 links are joined by a joint; joints could be of 2 types, the linear joint or the rotary joints. Linear joints could be either the prismatic joint or sliding joint; rotary joints could be either the revolute joint or the twisting joint. And of course, we have got a few special type of joint like the hook joint, then comes your the ball and socket joint those are also used in robots.

Now, actually in a robot there will be one controller or the director, there will be drive units, there will be links, joints, there must be some sort of gripper or the end effector. And if you want to make it intelligent the robot should be equipped with some sort of sensors; so, these are the different components of the robots. Now if you see we have got different types of robotic joints which I have already discussed.

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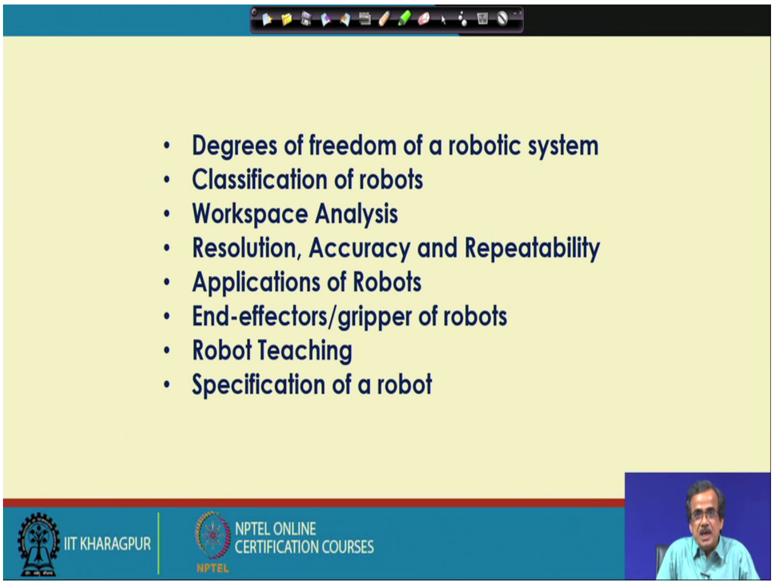

Now, the degrees of freedom of a robotic system; now before I go for the degrees of freedom of a robotic system, the first thing we will have to find out what is the degree or degrees of freedom or connectivity of the different robotic joints. For example, if I consider the prismatic joint it is having 1 degree of freedom or one connectivity, then comes your sliding joint has got 1 degree of freedom linear, revolute joint has got 1 degree of freedom, twisting joint 1 degree of freedom.

Then if I consider cylindrical joint which is having 2 degrees of freedom; then comes your the hook joint or the universal joint has got 2 degrees of freedom. Spherical joint or ball and socket joint has got 3 degrees of freedom. Now if I know the connectivity or the degrees of freedom of a robotic joint, we can also find out the degrees of freedom of a robotic system and we use actually Gruebler's criteria just to find out which I have already discussed in details to determine the degrees of freedom of a robotic system.

Now, if it is an ideal planar robot it should have 3 degrees of freedom; if it is an ideal special robot, it should have 6 degrees of freedom. Now there are a few special robot which are having more than 6 degrees of freedom; those are called redundant robots. There could be a few special robot which is having less than 6 degrees of freedom that is called the under actuated robots. Now then comes the classification, the robots have been classified in a number of ways; for example, the robots could be either the point to point robot or the continuous path robot.

The robots can be classified like the servo controlled robot, non servo controlled robot. Another classification could be based on the coordinate system; like Cartesian coordinate robot then comes your the cylindrical coordinate robot, spherical coordinate robot revolute or articulated coordinate robot. Another classification could be based on the mobility levels; for example, say we have got robots with fixed base those are called the manipulators, manipulators could be either serial manipulator or parallel manipulator.

In serial manipulator, the links are in series; parallel manipulator the links are in parallel. Now regarding the mobile robots it could be either the wheel robots or there could be a multi legged robots or there could be tracked vehicles. So, these are in short the classifications of the robots. Then we concentrate on the workspace analysis we define the terms like what do you mean by the reachable workspace and the dexterous work space.

So, in short the reachable workspace is that volume of space which can be reached with at least one configuration of the robot. And dexterous workspace is lying in that particular volume of space which can be reached with the different combinations of the your the joint angles. So, we discuss how to determine the workspace of different types of the joints; then we discussed the terms like resolution, accuracy and repeatability.

Resolution is nothing, but the least count of a robot and this particular resolution could be either the programming resolution or the control resolution. By accuracy we mean the precision with which the end effector of the robot can reach the computed point. And by repeatability mean the same robot if I run large number of times, so, there is no guarantee that every time it is going to reach the same point and there could be some deviation that particular deviation is nothing, but the repeatability.

We discussed in brief the various applications of robots; for example, the robots are used in manufacturing unit. Robots are used in medical science like telesurgery, orthotic device, prosthetic device or we use some sort of multi legged very small robot like in the form of capsules. Then robots are also used as your helping hand for the doctors, robots are used in seabed mining; just to find out the value valuable stones, then do some underwater repairing, maintenance job we use underwater robots.

Robots are used in space; just to collect information of the mars or the space, we can use the robots. Nowadays robots are being used even in agriculture for example, say just to spray some pesticides, just to spray some sort of say fertilizer in liquid form, for cleaning weights just speaking the fruits we can use the different types of robots. So, there are a large number of applications of robots nowadays. Now we concentrate on actually the different types of end effectors or the grippers used in robots we use different types of mechanical grippers.

For example the gripper design and develop using some sort of mechanism like piston and cylinder mechanism. We use some sort of gear mechanism to design and develop the end effector, we use cam and follower mechanism to design and develop the end effector. Then we discuss the principle of the vacuum gripper, magnetic gripper used in robots, we also discuss some passive gripper like remote center compliance. In fact, we have got different types of grippers; different types of end effectors we have discussed all such things in details.

Then the teaching methods we discussed in detail. Basically we have got 2 types of teaching methods to provide instruction to the robots; one is called the online method, another is called the offline method. So, by online method we mean those methods where while giving instruction; we will have to use the robots. And for offline teaching, we are not using the robots we are taking the help of some sort of the programming language.

Now, this online teaching could be either the manual teaching or it could be the lead through teaching. The manual teaching is suitable for point to point task and lead through teaching is suitable for the continuous path task. Then we prepared the specification of a robot; like if I want to purchase a robot; how to prepare the specification, what are the information to be given that we have discussed in details. Then we carried out some sort of economic analysis; through this economic analysis, we tried to take the decision whether we should purchase a robot by taking loan from the bank.

And here we define 2 terms; one is called the payback period of a robot, another is called the rate of return of a robot. So, if the payback period is found to be less than the techno economic life of a robot and the rate of return on investment if it is found to be less than the rate of bank interest; I am sorry if the rate of return on investment if it is found to be more than the rate of bank interest, then only we just go for purchasing the robots. All such things actually I discussed in your the first topic that is introduction to robots and robotics.

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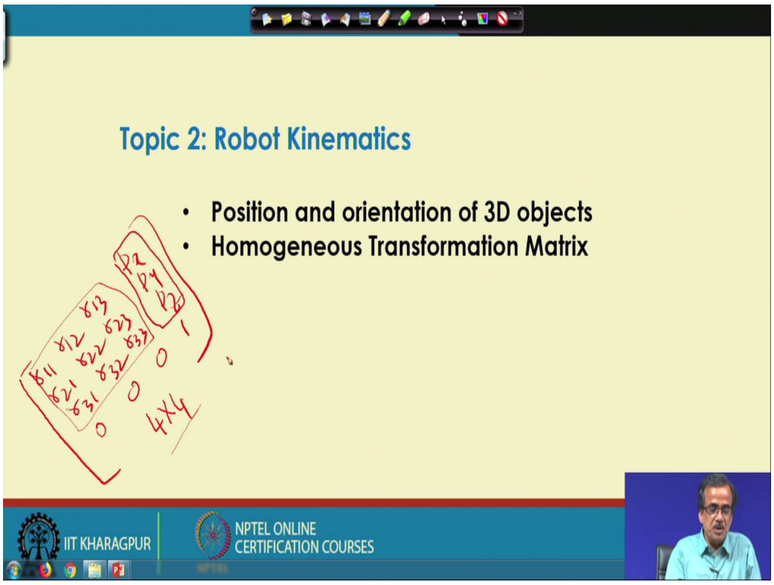

Then I concentrated on topic 2; that is your the robot kinematics. Now the purpose of kinematics is to study the motion or the movement of the different links, different joints without considering. The reason behind that particular the movement that is the force or the torque; now here the position and orientation of 3 D object in 3 D space; how to express that we discussed in details. For example, say the position can be expressed either in Cartesian coordinate system or in cylindrical coordinate system or in spherical coordinate system.

Similarly, the orientation can be represented in 3 coordinate system, one is the Cartesian or we can use the roll pitch and your system or we can use some sort of Euler angle representation for the orientation. Next we concentrate on how to derive the matrix that is the homogeneous transformation matrix which is a 4 cross 4 matrix. And this particular homogeneous transformation matrix carries information of this particular the position and orientation.

For example, say if I just draw one homogeneous matrix; so, r 11, 12, 13 21, 22, 23, 31, 32, 33, 0 0 0 1; px, py, pz; so this is nothing, but a typical 4 cross 4 homogeneous transformation matrix. Now here these 3 cross 3 matrix carries information of the orientation and this particular the vector; so, this is nothing, but the the position vector and this is nothing, but a 4 cross 4 homogeneous transformation matrix.

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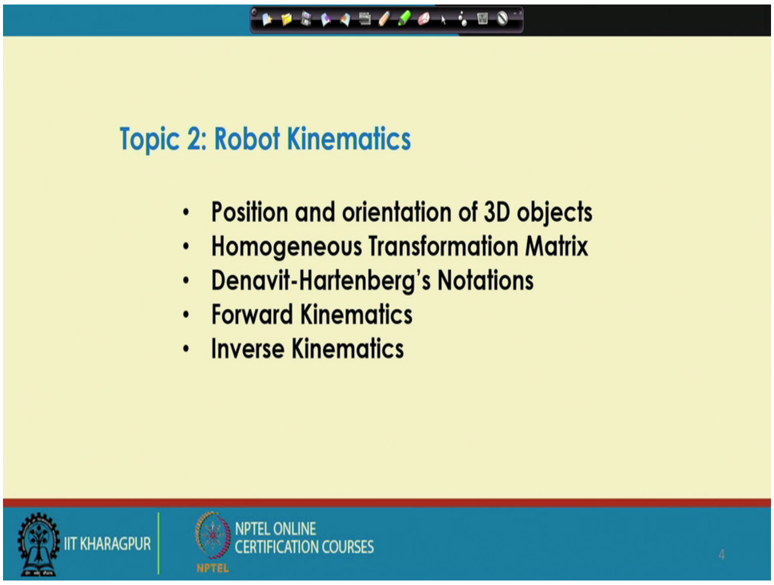

Then we discussed the Denavit-Hartenberg notation; like how to assign the coordinate system at the different robotic joints so, that we can carry out the kinematic analysis. We concentrate on the problem of forward kinematics; that means, if I know the length of the links and the joint angles, then how to determine the position and orientation of the end effector with respect to the base coordinate system. Then we concentrate on the inverse kinematics.

Now, here the positional orientation of the end effectors are known and we will have to find out the joint angles provided the length of the links are known; so, this is the problem of inverse kinematics.

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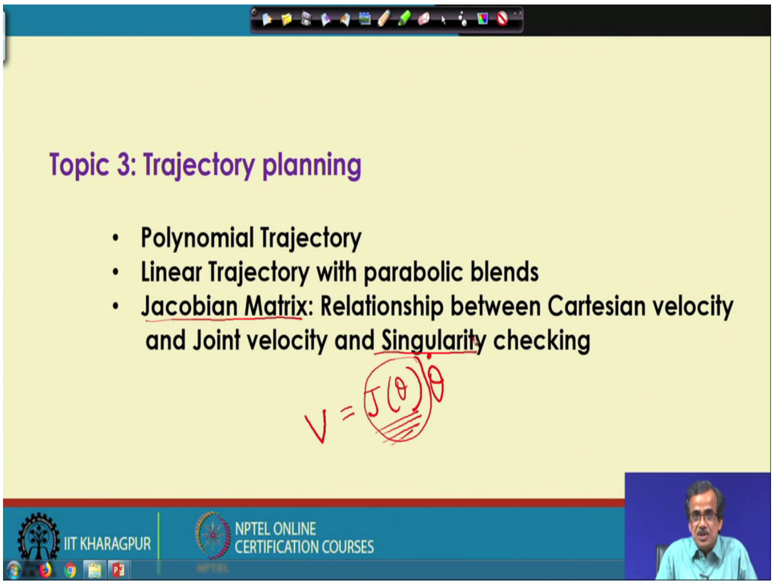

And once we have completed this inverse kinematics; we started with another topic that is called the trajectory planning. The purpose of trajectory planning is to fit a trajectory so, that we can ensure the smooth variation at the different robotic joint.

Now, this trajectory planning problem can be solved either in Cartesian system or in joint space, but if I solve trajectory planning in Cartesian coordinate system, then I will have to carry out the inverse kinematics online. And that is why we try to follow the joint space scheme of trajectory planning; that means, in the space of theta or the joint angle. Now to fit a smooth curve so that it can ensure the smooth variation of this particular; the joint angle, we take the help of some trajectory function.

For example, we take the help of polynomial trajectory; we generally consider cubic polynomial or higher order polynomial like fifth order polynomial and the coefficient of the polynomials are determined with the help of some boundary conditions or the known conditions. Then we concentrate on the linear trajectory, but we cannot use the pure linear trajectory function because there will be infinite acceleration and infinite deceleration at the end if I use the linear trajectory function and that is why we use 2 parabolic blends at 2 ends of the linear trajectory function.

Then we concentrate on the Jacobian matrix; now this particular Jacobian matrix is used to relate the Cartesian velocity with the joint velocity. For example, say if V is the Cartesian velocity that is nothing, but the Jacobian matrix multiplied by your the joint velocity. So, this J theta is nothing, but the Jacobian matrix and moreover with the help of this Jacobian matrix; we studied the singularity of a manipulator. And by singularity configuration we mean a configuration where the manipulator is going to lose one or more degrees of freedom.

Now, with the help of this Jacobian matrix we can also carry out this particular the singularity check checking. So, all such things in fact, we have discussed in much more details.

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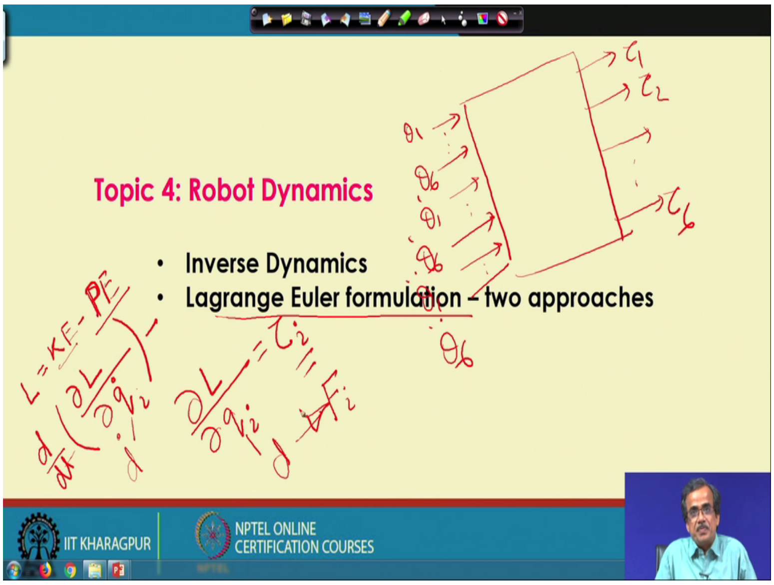

Then we concentrate on the robot dynamics and truly speaking here; we concentrate it only on the inverse dynamics. And by inverse dynamics we mean that we have got all such joint angle values and their velocity and accelerations are known. For example, say theta 1 up to say theta 6, then comes your theta 1 dot up to say theta 6 dot, then comes theta 1 double dot, then comes your theta 6 double dot.

So, these are all given and I will have to find out all the torque values your like tau 1, tau 2 up to say tau 6. So, this particular problem is nothing, but the inverse dynamics problem. Now here to solve this inverse dynamics problem; actually what we do is; we took the help of the Lagrange Euler formulation. And according to the Lagrange Euler formulation, we tried to find out what is Lagrangian of a robotic system that is nothing, but the difference between the kinetic energy minus potential energy.

So, to derive that particular expression what we do is before we determine the Lagrangian for the whole robot, we try to concentrate on a small point or a differential mass lying on a robotic joint; we try to find out the kinetic energy and potential energy. Then we tried to find out for the whole link and we considered all the links just to find out what should be the kinetic energy for the whole robot and what should be the potential energy for the whole robot and we tried to find out the Lagrangian.

And once you have got this particular Lagrangian; then we use this Lagrange Euler formulation which is nothing, but d dt of partial derivative of the Lagrangian with respect to your; with respect to q dot that is theta dot minus the partial derivative of L with respect to your q i that is nothing, but the tau i.

So, this is the way we can find out the joint torque and if there is a linear joint so in place of this particular tau; so, I will be getting the force that is nothing, but F i and of course, so this particular q will be replaced by the d; that is the offset. So, this will be replaced by d dot, this will be replaced by d; if it is a linear joint and if I want to find out the force. So, using this actually we tried to find out what should be the joint force or the joint torque in robot dynamics.

Thank you.