Robotics
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Lecture - 05
Introduction to Robot and Robotics (Contd.)

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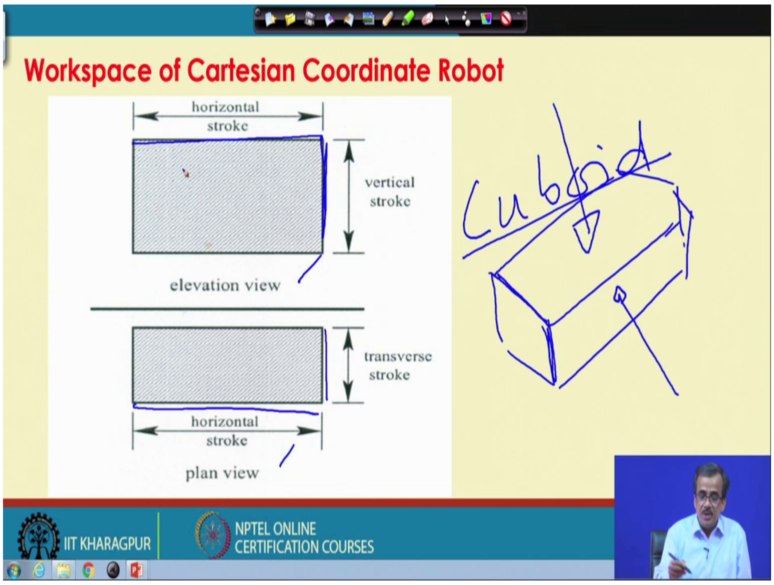

Now I am just going to find out the workspace for different types of robots. Now we have already discussed the based on the coordinate system. The robots are classified into four groups. So, we have got the Cartesian Coordinate Robot, then comes your the Cylindrical Coordinate Robot, Spherical Coordinate Robot and Revolute Coordinate Robot

Now, I am just going to spend some time to find out what should be their workspace. Now let us first try to concentrate on the Cartesian coordinate robot. Now let us see the picture once again, the Cartesian Coordinate Robot. So, this is actually the picture for the Cartesian coordinate robot and I am just going to find out its workspace

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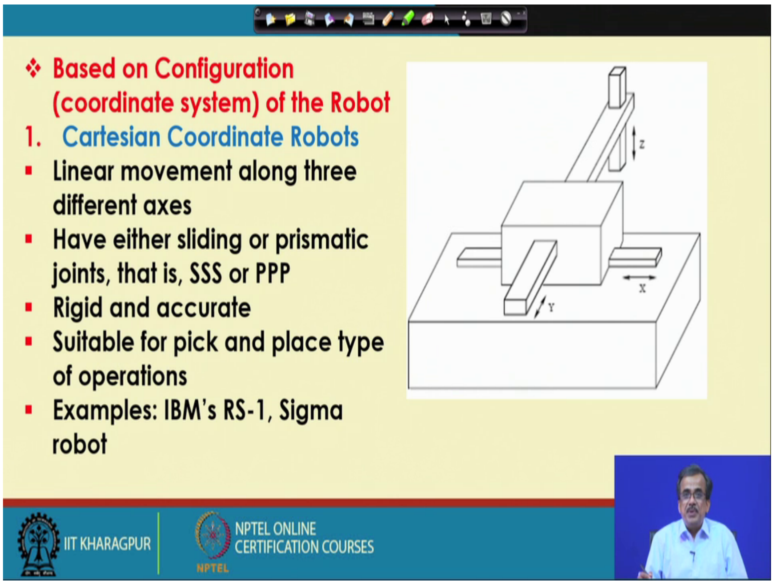

Now, here there are three linear joints. So, very easily we can imagine that the workspace for this particular the robot will be nothing but a cuboid. So, the workspace for this particular robot will be a cuboid. And this particular cuboid, I can draw this particular cuboid very easily. So, this is nothing but the cuboid and that will be the workspace for this manipulator

Now, here for some of the robots you will be getting the workspace is so much complicated that you cannot make that particular work three dimensional view or it becomes bit difficult to visualize the three dimensional view. And that is why actually what we do is, we take the help of at least two views like elevation view and the plan view; just to identify or just to imagine, what should be the workspace for a particular the manipulator

Now, for this Cartesian coordinate system as I mentioned that the workspace is nothing but a cuboid. Now if I take the elevation view; that means, I am just going to take the view in this particular direction. So, I will be getting this particular, the horizontal stroke. So, this is nothing but the horizontal stroke and this is the vertical stroke. So, I will be getting the vertical stroke. And on the plan view; that means, if I take the view from the top: so I will be getting this as the horizontal stroke and this transverse stroke will be nothing but this.

So, the same 3D view, I am just going to draw here with the help of this elevation view and plan view. And I am just going to take the help of this just to indicate and just to imagine the workspace for the complicated manipulator. So, for this particular Cartesian coordinate system, it is very simple the workspace is nothing but the cuboid

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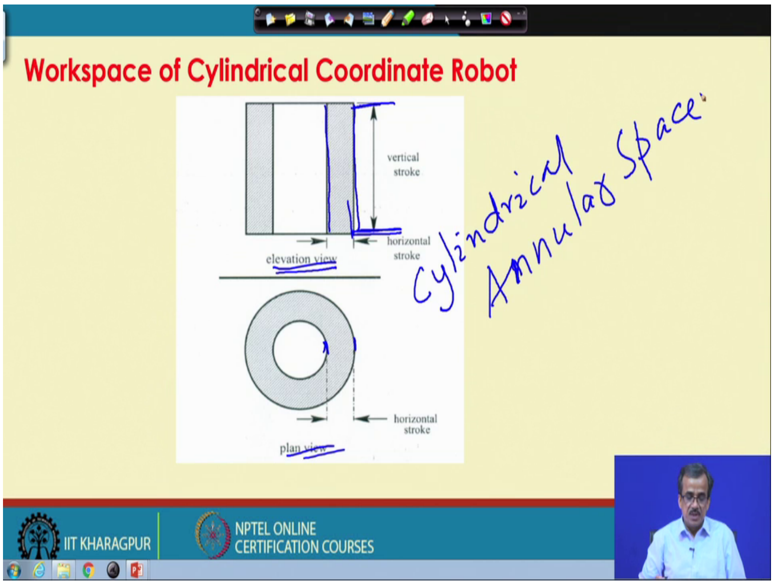

Now, I am just going to consider the workspace for the Cylindrical coordinate robot. Now if you remember the cylindrical coordinate robot, it was something like this. Let us try to see the cylindrical coordinate robot once.

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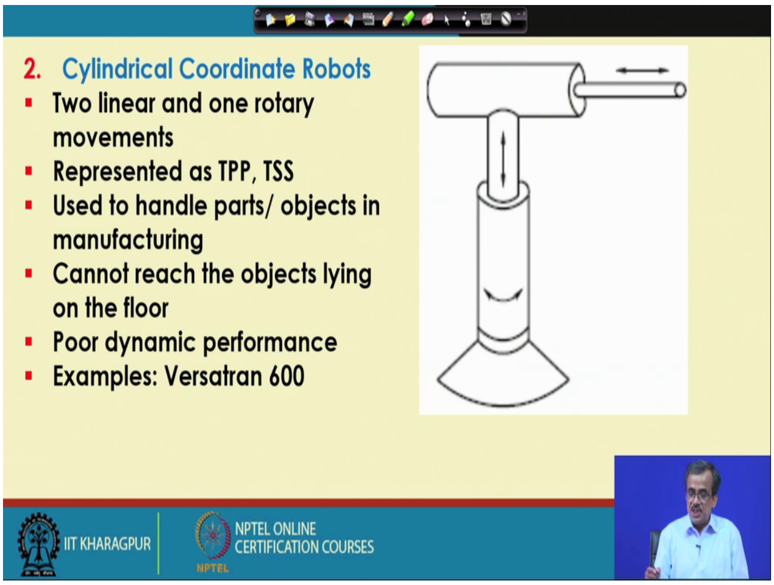

So, this is the cylindrical coordinate robot. So, as I told this is going to show me the maximum horizontal reach and the minimum horizontal reach and this will give the vertical reach and here there will be some rotation. So, corresponding to this particular your cylindrical coordinate robot. So, I am just going to imagine the workspace for this particular the manipulator

Now, as I told that the maximum horizontal reach will be identified. So, this is actually the maximum horizontal reach. This is actually the minimum horizontal reach. This is the elevation view and this is the plan view. So, here I am just going to consider 360 degree rotation with respect to the fixed base and that is why we are getting this type of circle here ok. So, this is the plan view. And on the plan view also once again, we will be getting the maximum horizontal reach and the minimum horizontal reach. And in the elevation, I will be getting the maximum vertical reach and the minimum vertical reach and the way it is working.

So, it has got two linear and actually one rotary that is the twisting and this particular workspace which will be getting is nothing but your cylindrical annular space. So, you will be getting the cylindrical annular space. So, this workspace is nothing but the cylindrical annular space

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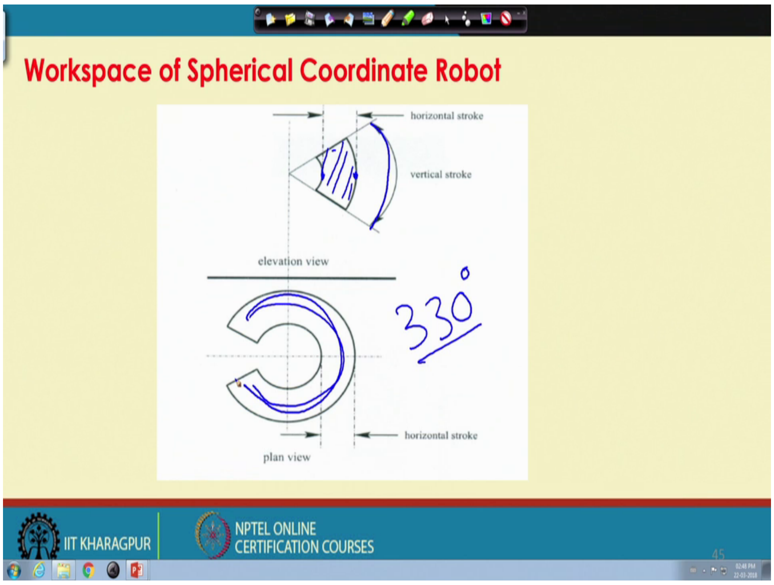

Now, next we try to find out the workspace for some other robot like your the Spherical coordinate robot. Now, let us try to see the picture of the spherical coordinate robot once again. So, this is actually the spherical coordinate robot. So, here I have got only one linear joint.

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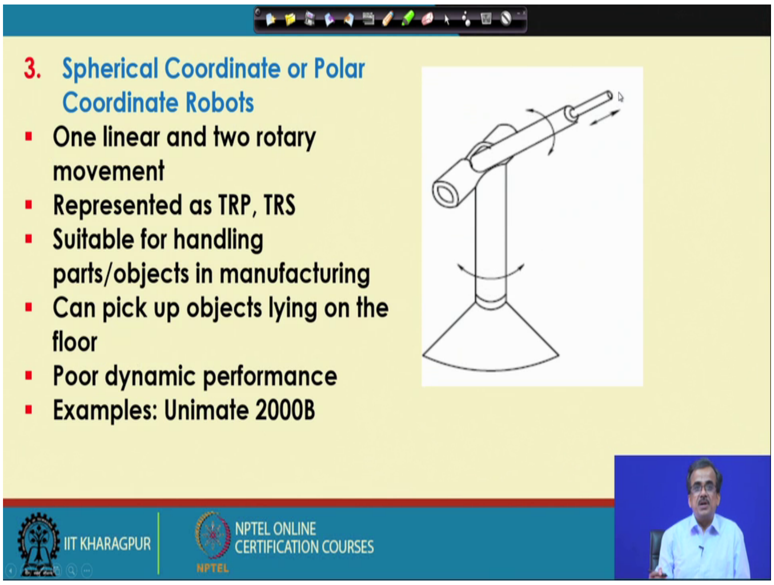

So, this is going to give the maximum the horizontal reach and the minimum horizontal reach. So, here we have got one revolute joint and here, we have got one twisting joint ok. So, I am trying to find out the like, what should be the workspace for this

Now, as I told that with the help of this particular the revolute joint; so, I will be getting the maximum vertical reach and the minimum vertical reach. So, let us try to see this particular the workspace. Now here, if you see on the elevation view; so I will be getting the maximum horizontal reach is something like this. And this is the minimum horizontal reach and the vertical reach. So, this is will be the vertical reach and this vertical reach will be getting with the help of that revolute joint. And here with the help of twisting joint. So, actually I am considering more or less say 330 degree rotation, not 360 and that is why this type of plan view, I will be getting.

Now, if I want to imagine the workspace the 3D view of this particular workspace. So, what I will have to do is; so, this particular elevation view whatever I am getting, the whole thing I will have to rotate through this particular 330 and then I can imagine like what should be the workspace in 3D for this particular spherical coordinate robot.

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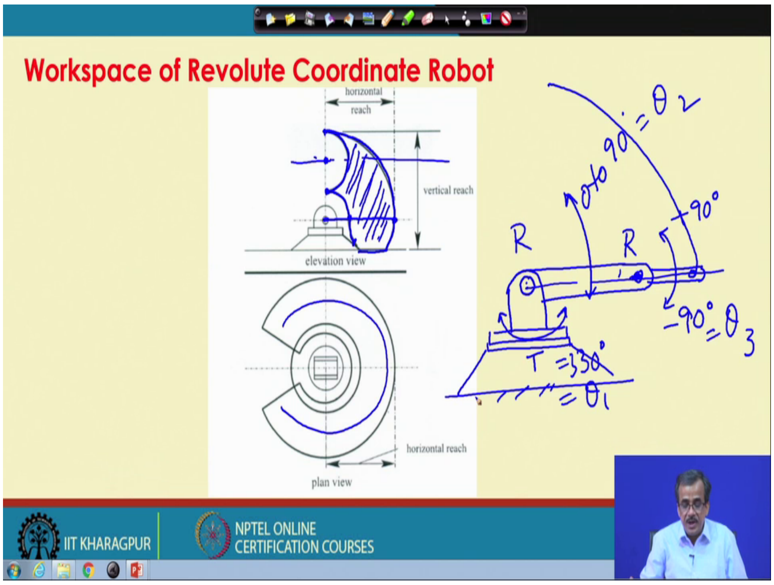

So, I hope you got some idea like how to imagine or how to determine the workspace for a particular the manipulator

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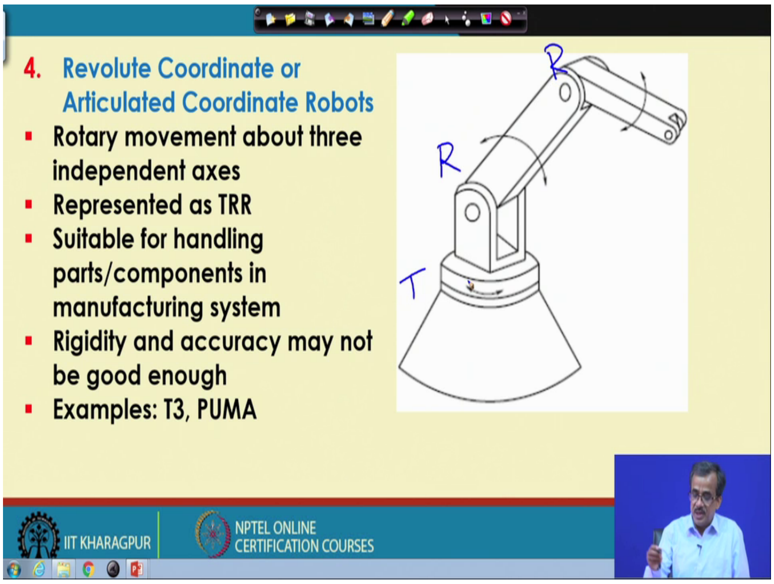

Now, I am just going to concentrate on another robot that is your the Revolute coordinate robot. So, this particular the revolute coordinate robot. Now here if I want to imagine the workspace, it is bit difficult. And as I told, we have got one twisting joint here. We have got one revolute joint here and we have got another revolute joint here.

Now, if I want to imagine its workspace; it is a bit difficult because I have got 3 rotary joints. Now for a rotary joints in 3D, we will be getting actually the partial sphere. We will be getting the partial sphere and there should be intersection of partial sphere. So, it is bit difficult to imagine the workspace for this particular the manipulator

Now, to make it simple; actually I am just going to prepare one small sketch here; so, that I can imagine the workspace for this particular the manipulator. Now let me do one thing. So, that particular sketch I am just going to prepare in that slide where I am just going to show you that particular workspace. So, I am just going to draw that particular picture there only

So, let me just draw that simplified version of that revolute coordinate robot. Now if I draw the revolute coordinate robot its simplified version. So, it will look like this. So, this type of the simpler version will be getting. Now here, as I told that we have got the twisting joint here. So, with the help of this twisting joint; supposing that I am rotating by says not 360.

So, let me consider it is rotated by say 330 degree. And I have got a revolute joint here. So, with the help of this revolute joint, let me assume that I am going to rotate by 90 degree ok. So, 0 to 90 say 0 to 90 degree; that means, starting from here. So, I am just going to rotate by 90 degree. And here, I have got another revolute joint and supposing that I am just going to rotate say from minus 90 degree to plus 90 degree ok. And supposing that this is equals to theta 1, this is your theta 2 and this particular angle is nothing but theta 3; that means, your theta 1.

So, this particular joint angle is say going to vary from 0 to 330, theta 2 is going to vary from 0. So, this corresponds to 0. So, zero to 90 degree in the anticlockwise sense and supposing that theta 3 is going to rotate. So, minus 90 to plus 90 say clockwise to anticlockwise 90 to 90; that means, total 180 degree. The moment we consider; so this type of configuration, then we will be getting starting from here. So, my position is here only. So, I am here.

Now what I am going to do? So, I am just going to rotate by 90 degree. So, if I rotate by 90 degree. So, I will be getting this particular point ok. Now, you see: so here I have got a joint with the help of this particular joint. So, that joint could be here ok. Now reference if I draw. So, parallel to this will be its reference. So, I can rotate anticlockwise, I can rotate clockwise. So, this particular tip is going to; so, this particular tip. So, with the help of this particular joint; that means this particular joint. So, this tip actually I can rotate something like this ok.

So, I have reached this particular point; the momentum here that is the folded back situation. Now I can rotate by 90 degree. So, I can come over here. So, here is the tip. Now if we just release it, the tip is going to fall. So, it is going to be obstructed here. Similar is the situation for your stretched condition. So, I am here. So, if I release this particular joint. So, it is also going to fall and it is going to be obstructed here. So, this will be your the elevation view of this particular manipulator corresponding to this rotation and here you can see that.

So, with the help of the first joint, so this can rotate by 330 degree. So, it can be rotate by 330 degree. So, if I want to imagine the workspace of this particular manipulator; so, this particular shaded portion. So, I will have to rotate by 330 degree and then only I will be able to imagine the workspace for this type of complicated manipulator.

Now, whenever you are going to give any task to the manipulator, the workspace analysis is very important and without this workspace analysis actually, we should not proceed to solve a particular task. And we will have to find out whether the tip of the manipulator that is the end effector is able to reach that particular workspace in order to perform that particular the task

So, this workspace analysis is very important. And as we know that we human being can visualize only up to three dimensions. We take the help of this plan view, elevation view, elevation and plan view and tried to imagine that particular the 3D, but supposing that I have got a manipulator having says 6 degrees of freedom like say puma. And puma has got 6 rotary joints, 3 twisting joint and 3 revolute joint and it is bit difficult to imagine the workspace of this particular the puma. So, there will be lot of confusion, if you want to imagine the workspace for this particular industrial robot like puma having 6 degrees of freedom. So, the concept of workspace analysis is very important

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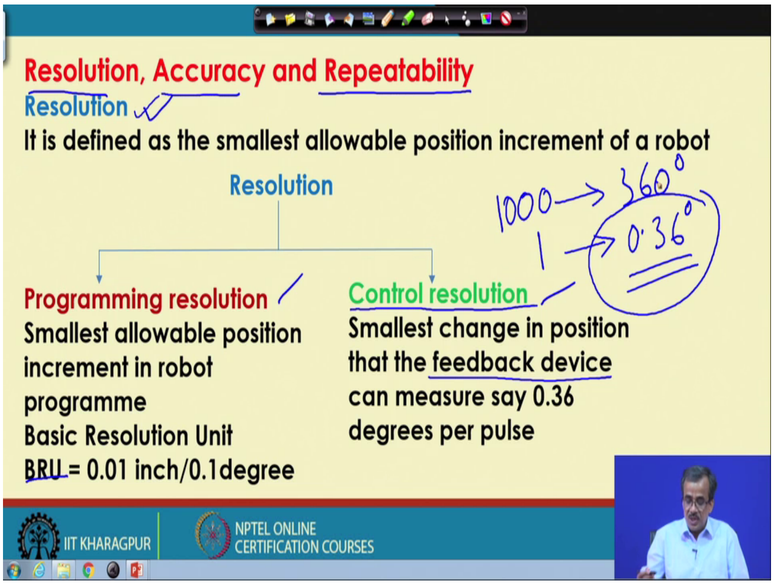

Now, I am just going to discuss, I am just going to define 3 terms actually which are very important and very frequently we use, but truly speaking these 3 terms are not the same and there is a difference between among these 3 terms. So, I am just going to define these 3 terms like your resolution, accuracy and repeatability of a particular manipulator

Now, this particular the resolution accuracy and repeatability; this information is required, if you want to design the specification of a robot which you are going to purchase. So, you will have to clearly mention, how much resolution you want, how much accuracy you want and what is the repeatability you want. And let us try to understand the difference between or the difference among these three terms like resolution, accuracy and repeatability

Now, before I start let me mention that these three terms are not the same. There is difference among resolution, accuracy and repeatability. Now let us start with the one that is your resolution. Now the resolution is nothing but the smallest allowable position increment that the robot can measure and this is almost similar to the concept of the least count for a particular the measuring device. For example, say if use screw gauge or if use slide calipers, there will be lists count. So, that particular list count is nothing but the resolution of that particular measuring device

Now, this resolution could be of two types. There could be programming resolution or there could be control resolution. Now whenever we write down the computer program, just to teach a particular robot which I have not yet discussed, I will be discussing after some time. So, we should know like 1 basic unit corresponds to how much displacement that we should know. So, this particular the programming resolution is nothing but the smallest allowable position increment allowed in computer programming corresponding to 1 unit

Now here, so this particular programming resolution. So, that is expressed in basic resolution unit. Now in short this is known as BRU. So, 1 BRU equal to 0.01 inch or in millimeter, this could be 0.001 millimeter nowadays is also available. And for the rotary movement, so this particular BRU could be 0.1 degree. So, whenever we are going to purchase a robot. So, we will have to mention how much is the programming resolution we want and what is the least count programming least count for this particular the manipulator

Now, then comes the concept of the control resolution. Now as I mentioned that your if I want to use the servo control robot like the closed loop control system. We generally use some feedback device. And in robots very frequently, we use different types of sensor to measure the position. And out of all the position measuring sensors, your the optical encoder is very popular

Now, if I consider one optical encoder to measure the angular displacement of a particular rotary shaft. Now let me take one example. Supposing that, this is the output shaft of 1 electric motor. Now here, I want to measure the rotation of this particular output shaft of the electric motor. So, how to measure? So, what I do is here we put one optical encoder and optical encoder is nothing but a collection of a number of concentric rings placed one after another and on these particular concentric rings, there will be a dark region and your clear region.

Now, if there is opaque region the light will not be able to pass, but if there is clear region or the light region, the light will be able to pass. So, here we have got this particular optical encoder. Now on one side, we have got the light source; other side, we have got the photo detector. So, with the help of this photo detector your shaft is rotating the whole optical encoder is rotating and on the left this side we have got the light is on; on other side, we have got the photo detector. And corresponding to this particular rotation; so, there will be some the number some your binary number generated

Now, by decoding this particular binary number, we can find out what should be the angular displacement of this particular the rotary shaft and this particular angular displacement is compared with the target value and we try to find out the error and this particular error is compensated

Now, the working principle of this particular optical encoder, I will be discussing after some time in details. Now for the time being, let me consider that we are using one optical encoder as a feedback device and supposing that so, this particular feedback device is going to give one complete revolution that is 360 degree and corresponding to these 360 degree, there is say 1000 electrical pulse. So, 1000 electrical pulse corresponds to your 360 degree rotation of this particular shaft. So, one electrical pulse corresponds to your 0.36 degree and we cannot think of the faction of one electrical pulse; that means, the control resolution or the resolution of the feedback device will be 0.36 degree.

So, this will be the control resolution for this particular the feedback device. So, this is the way actually we define this particular the resolution of a particular the robot.

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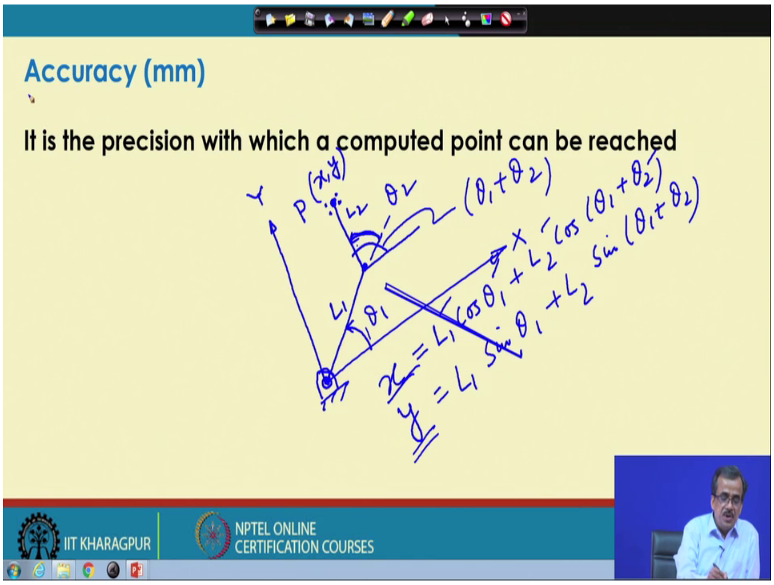

Now, I am just going to define what you mean by accuracy. Now this accuracy is nothing but the precision with which a completed point can be reached. Now let me just try to take one a very simple practical example and for simplicity let me take the example of a 2 degrees of freedom serial manipulator. So, let me draw one 2 degrees of freedom serial manipulator. So, this is X, this is Y in Cartesian coordinate system. So, this is the base and I have got one link like this and another link is something like this ok. The length of the first link is L 1, the length of the second link is say L 2. The joint angles; so, this particular joint angle is theta 1 and this particular joint angle is say theta 2 And supposing that the tip of this particular manipulator is denoted by P and it is having the coordinate like x comma y

Now, here at this particular joint, I have got a motor here, I have got another motor here. So, with the help of this motor, I am just going to generate this particular the joint angle. Now supposing that; so, this particular joint angle is theta 1 and with respect to these L 1. So, here the joint angle is theta 2. So, with respect to X; X axis, the total angle will be your theta 1 plus theta 2. So, this is your theta 1 plus theta 2. So, this particular angle is with respect to x that is theta 1 plus theta 2 and here with respect to x. So, this is nothing but your theta 1

So, if this is the situation. So, very easily we can write down the general expression for this particular x and y. For example, say from trigonometry, you can write down x is nothing but L 1 cos theta 1 plus L 2 cos of theta 1 plus theta 2. Similarly y is nothing but L 1, sin theta 1 plus L 2 sin of theta 1 plus theta 2

Now, if I know the values for this particular L 1 and L 2. And if I know the values for this particular theta 1 and theta 2, can I not calculate x and y? We can. So, we can calculate what should be the numerical value for this particular x and y. Now I am just going to give that command to this particular robot which is having the length of the links like L 1 and L 2 and I am just going to generate theta 1 and theta 2 and supposing that I have started the robot has started working. So, starting from on some from some other position; so, corresponding to this L 1 and L 2, supposing that it is going to reach this particular point

Now, what is the guarantee that it will be able to reach exactly the same point? There is no guarantee. There could be little bit of error and in place of reaching this particular point, the point it is going to reach could be here or it could be here, or it could be here, or it could be here. So, there could be some small deviation from the computed point or the calculated point

Now, this particular the deviation from the computed point and the point which has been reached is known as the accuracy of this particular the robot and that is expressed in terms of millimeter ok. Now it could be either positive or negative. It depends on whether that point is exceeding that. So, I can find out in both the ways. So, accuracy it could be either the positive or negative

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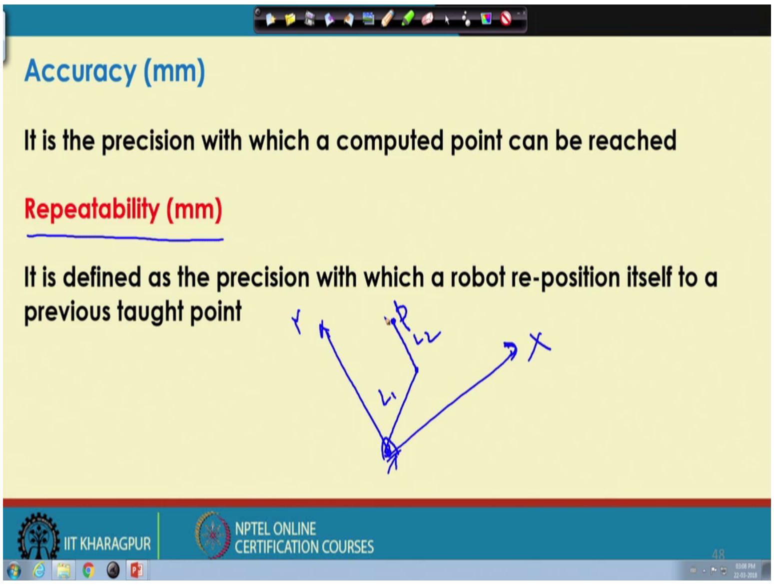

Now, I am just going to define another term that is called the repeatability. Now this repeatability, by repeatability we mean supposing that we have taught a robot that you reach a particular point and there are several teaching methods which I will be discussing after some time. So, with the help of that particular teaching method; so, I have say taught the robot that you reach a particular point say the point a. Let me take the same example of say 2 degrees of freedom serial manipulator. So, this is nothing but the manipulator this is L 1 and this is L 2

So, I have taught to reach this particular point. This is L 1 and this is L 2 ok. Now once I have taught, now if I just run this particular the robot say 20 times. So, at each for at each of the 20 times, there is no guarantee that it is going to reach exactly the point which I have taught; there could be some deviation. Now this particular deviation is known as the repeatability of this particular the manipulator ok.

So, this is the way actually we define the repeatability of this particular manipulator and once again let me repeat like, if you want to prepare the specification of a robot. So, we will have to mention what is the resolution, accuracy and repeatability which we want and based on our requirement, the manufacturer are going to manufacture that particular robot to supply it to us.

Thank you.