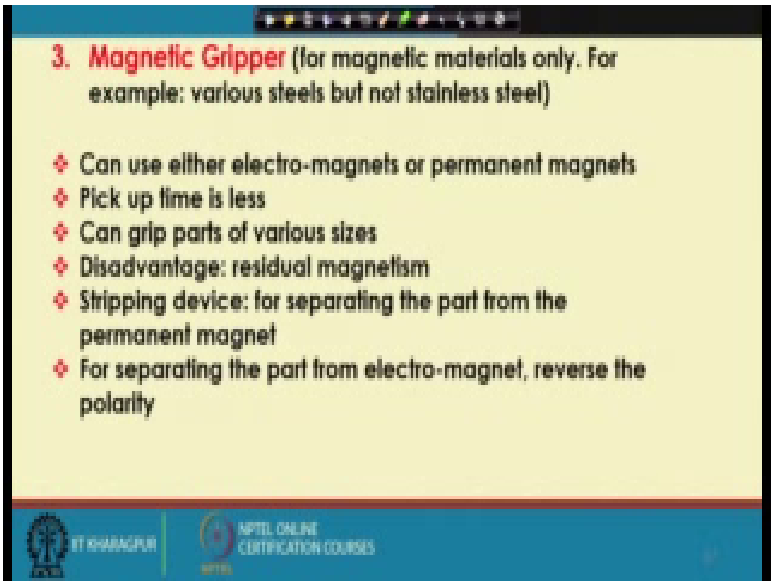
Robotics
Prof. Dilip Kumar Pratihar
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 08
Introduction to Robots and Robotics (Contd.)

We are discussing the working principles of different types of end effectors used in robots.

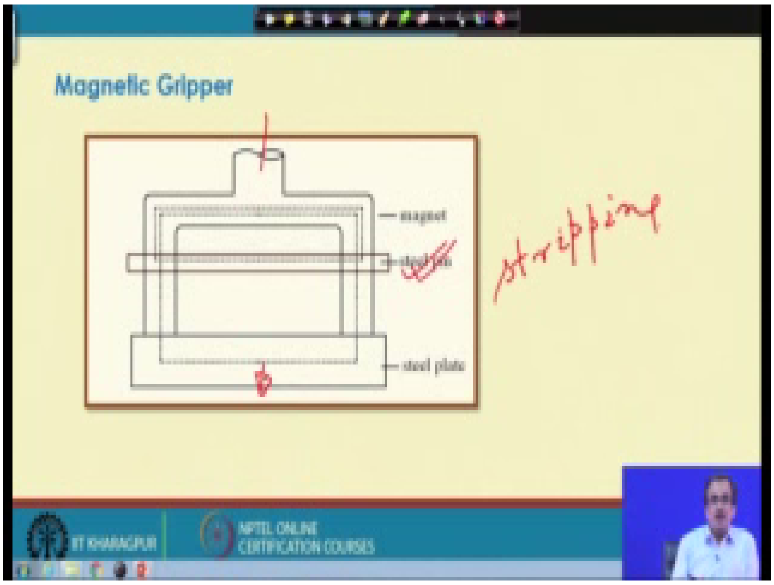
(Refer Slide Time: 00:29)



Now, I am going to start with the working principle of a magnetic gripper. Now, this magnetic gripper this is suitable for the magnetic material. For example, say if I consider say still a component made of steel. So, this particular magnetic gripper is going to work, but it will not work for the stainless steel, because stainless steel is not magnetic.

Now, here we can use both permanent magnet as well as the electro magnet. Now, if I use permanent magnetic the mechanism or this particular the figure will be as follows.

(Refer Slide Time: 01:17)



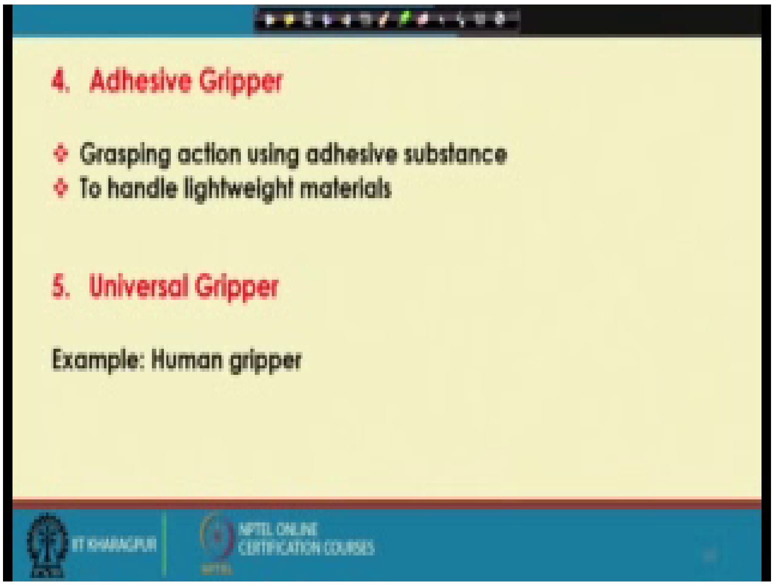
So, for example, say this is nothing but the permanent magnet and this permanent magnet will be connected to the robotic end effector. Now, if I see this particular the magnetic gripper if you use magnetic gripper we have got a few advantages, for example, it can it can grip objects of various sizes and moreover the pickup time will be less. On the other hand it is got some drawback like it is got some set of residual magnetism.

Now, supposing that I am using a permanent magnet now. if I use this type of permanent magnet. So, this is this is actually the permanent magnet which I am going to use and this will be connected through the wrist end of the manipulator. Now, this is the steel plate which I am going to grip the moment I put this permanent magnet very close to the steel plate. So, the magnetic lines of forces are going to pass through this particular the steel plate and due to this so, this steel plate will be gripped by the permanent magnet.

Now, if I want to ungrip or if I want to remove this particular steel plate from this magnetic gripper so, I will have to use one stripping mechanism at that is nothing but a steel pin. So, this particular steel pin can be used as the stripping mechanism. The way it works is as follows. So, here on this particular permanent magnet I have got one circular hole here I have got another circular hole here and if I want to ungrip. So, this particular steel pin will be inserted through these two circular holes. The moment will put this particular steel pin so, some of the magnetic lines of forces will pass through this particular the steel pin and consequently the strength of the magnetic field passing through the steel plate will be weaker and due to this weakness or weaker of this particular magnetic field and due to the self weight of this steel plate the steel plate will be separated out from this particular the permanent magnet. Now, this is the way actually we can ungrip so, this particular steel plate from the permanent magnet.

Now, in place of permanent magnet if I use the electro magnet so, and if I want to grip it, it is ok, but if I want to ungrip so, what I will have to do is I will have to reverse the polarity. So, if I reverse the polarity of the electro magnet so, I am just going to ungrip this particular the steel plate. Now, this is the way actually one magnetic gripper works and its working principle is very simple and this is very frequently used for the magnetic material, but this will not work for the nonmagnetic material.

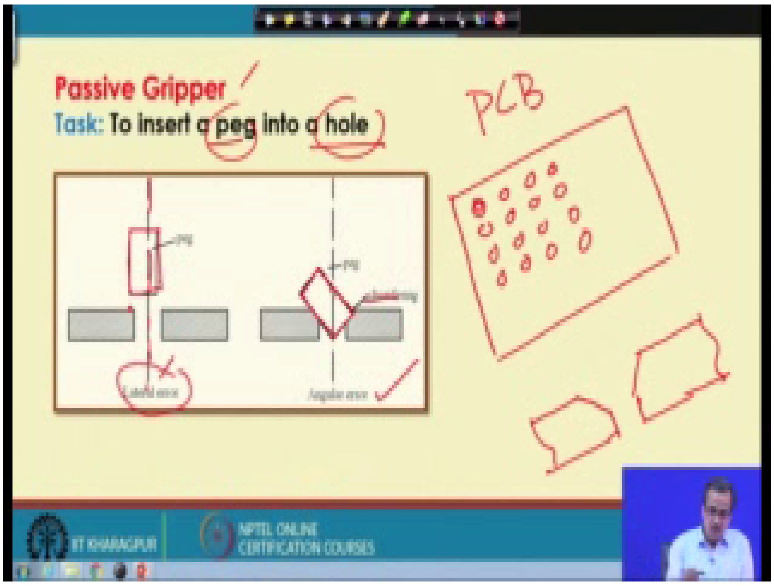
(Refer Slide Time: 04:21)



The next is the adhesive gripper. Now, this adhesive gripper is suitable only for the light object like the small weight objects and here we use some set of adhesive material just to just to grip that particular object we take the help of adhesive material. Now, this is almost similar to the situation the way a frog preys it is the way one frog catches its prey. So, on the tongue actually it put some set of adhesive material and that particular tongue will be thrown towards that insect and the insect will be caught with the help of this particular the adhesive material; so, this particular adhesive gripper, as I told you suitable only of the very light material.

Now, then comes the universal gripper. Now, our hand is actually true example of this particular the universal gripper because with the help of our hand actually we can grip different type of object and this particular our gripper that is the hand is universal and it is robust and it is flexible and it can actually grip a number of objects of different shapes and size. And, that is why this is a very sophisticated one and our gripper is known as the universal gripper.

(Refer Slide Time: 06:03)



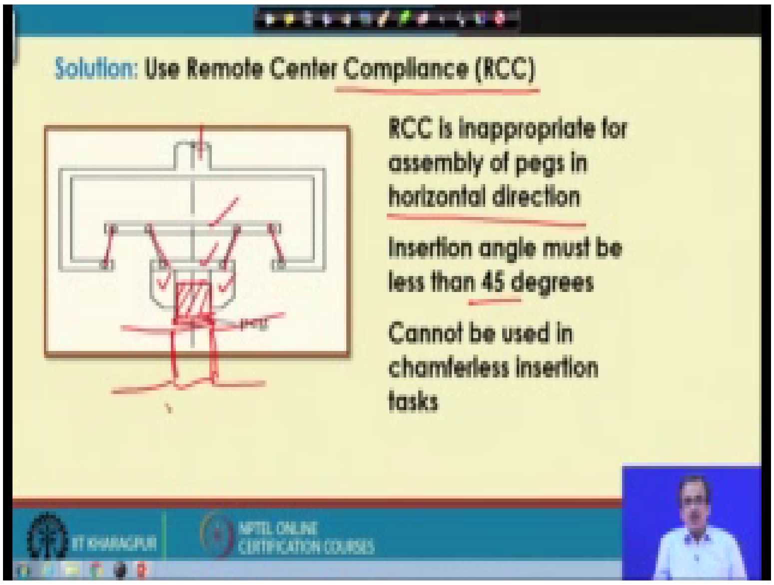
So, now I am just going to start with the working principle of the passive gripper. Now, this passive gripper is used whenever there is no such sensor I have already mention that by passive gripper we mean those grippers where we do not use any such sensor. Now, before I proceed with these the working principle of these particular gripper. Now, let us try to understand why do you go for this type of gripper. Now, let me take one very simple example. Now, supposing that I just want to develop one printed circuit board PCB or the printed circuit board and on the printed circuit board there are some small small circular holes. And what we will have to do is depending on the requirement of this particular electrical or the electronic circuits so, what I will have to do I will have to insert some sort of small elements like register, capacitor and so on, just to design and develop a particular the printed circuit board.

Now, this particular task if I give it to the manipulator if I give it to the robot and at the end effector actually we will have put a special type of gripper which is nothing but the passive gripper if I want to insert some small small items like register capacitor into this particular the hole. Now, here the problem which we are going to face is like it is bit difficult to insert a peg into a hole. Now, this particular problem in robotics is the actually very popular so, how to insert a particular peg into a hole now here. So, this particular schematic view it shows that I have got a steel plate and on the steel plate we have got one circular hole.

Now, on this circular hole like this actually we will have to insert this particular the peg. Now, supposing that so, this particular is the central line for this hole and I have got this particular peg which I will have to insert now, this peg is actually gripped with help of the gripper and now that robot is going to just put this particular peg into the hole. Now, if we to wants to put this particular peg into the hole so, there is a possibility that this part of the peg is going to collide here and due to this so, it will not be able to insert. So, this particular peg into the hole and this is what is known as the lateral error. So, the robot will not be able to insert this particular peg into the hole and it will be obstructed here so, this is called the lateral error

Now, to remove this lateral error actually what we do is we put some chamfering that means I have got this type of plate and I put this particular chamfering sort of thing. So, here I am just going to put the chamfering. Now, if I just put this particular the chamfering and try to insert this peg with the help of the robot; so, there is a possibility that this particular lateral error that will be solved. But it is going to create another problem might be this particular peg is going to take the position something like this and it is going to create another problem another error and that is called the angular error. So, by inserting this particular chamfering there is a possibility we can solve this lateral error, but we are going to phase another problem that is called the angular error; so how to solve both errors so that I can insert this particular peg into the hole.

(Refer Slide Time: 09:58)

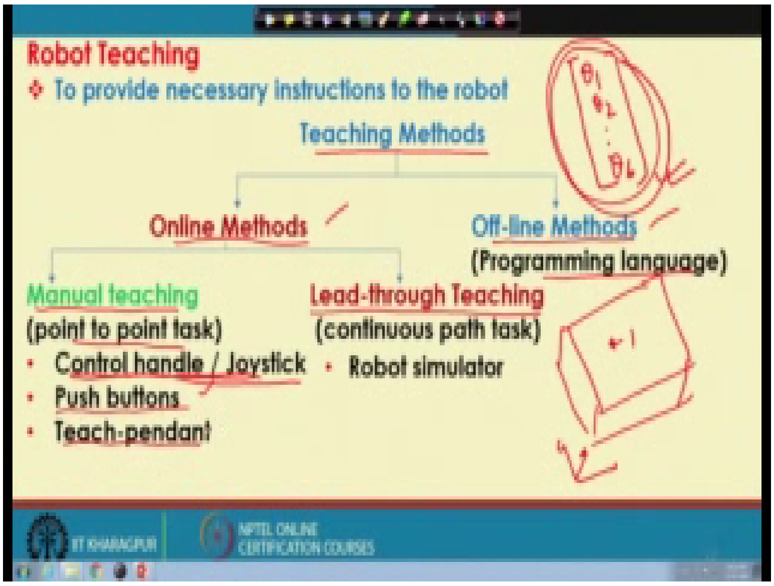


Now, to do that actually we take the help of one passive gripper and which is very popularly known as remote center complains and that is nothing but is your RCC insert that is known as RCC. Now, the construction wise it is very simple. For example, say so, this part this is connected to the wrist end of the robot and here I have got one steel frame sort of thing I have got another frame here steel frame sort of thing I have got another steel plate sort of thing of small thickness and this particular plate and that particular plate are connected with the help of four such links like this and here we have got two fingers. So, this is finger 1, finger 2 and with the help of this two fingers we just try to grip this particular peg. So, this is actually nothing but the peg. So, this is the peg which I will have to insert into that particular the hole.

Now, this is connected to the wrist end as I told. Now, so, this particular peg will be brought very near to the hole and supposing that the hole could be here. So, might be the hole could be here and here actually what we do is so, this particular peg will have some sort of oscillated movement like this and due to this particular oscillation and due to this error and trial. So, this peg will be inserted into this particular the hole with the help of this RCC which is nothing but a passive gripper.

Now, this RCC will work provided we just put some chamfering at this particular plate otherwise it may not work and this angle of chamfering has to be less than 45 degree otherwise there could be some sort of angular error and moreover so, this RCC can work in vertical direction, but it will not be working in the horizontal direction, but this particular gripper is very popular like just to solve how to insert small small electronic items into that particular the printed circuit board. So, this is the way actually this particular the passive gripper works.

(Refer Slide Time: 12:15)



So, this is all about the end effectors the different types of end effectors which is generally used in robots. Now, here I just want to mention the depending on the requirement depending on the task so we will have to design the special type of gripper, special type of end effector. So, the working principle of a few gripper few end effector I discuss these are actually very simple very simple design, but depending on the complicated task, depending on the task the nature of the task will have to design the most suitable gripper and that is why we see the task and try to design the end develop the gripper.

Now, I am just going to start with the teaching methods like how to give instruction to a robot. Now, supposing that say I have got say one robot say one serial manipulator and I just want to give the instruction that you start from a particular point say the tip of this particular the marker and you reach this particular point the tip of this particular the finger through a number of intermediate points.

Now, how to give this type of command how to give this type of instruction to this particular the robot; now here, actually the purpose of teaching as I told to provide necessary instruction to the robot. Now, these teaching methods are broadly classified into two groups. We have got online methods and we have got offline methods. Now, by online methods we mean those methods where while giving instruction, so, we use this particular the robot. That means, we are going to teach a particular robot, but while giving instruction or a while teaching so, we will have to use that particular the robot. So, that particular method is known as the online method.

On the other hand, if I do not use the robot while teaching. So, that particular method is known as the offline method and here in offline method we will have to take the help of some sort of programming language. Now, let me first concentrate on this particular the online methods. Now, these online methods are once again classified into two subgroups one is called the manual teaching, another is called the lead-through teaching. Now, let me let me try to discuss the working principle of this particular the manual teaching first.

Now, supposing that I am just going to use one serial manipulator having say 6 degrees of freedom like PUMA and I am just going to do some sort of drilling operation on a steel plate. So, what I will have to do is supposing that so, this is the plate and on this particular plate I want to just do some sort of drilling here at location – 1. So, what I will have to do is. So, this twisted drill bit has to be gripped by the gripper of this particular the manipulator and the center of this particular hole and the tip of this particular the twisted drill bit they suit coincide.

Now, this is in 3D for example, it has got like x y and z axis. So, this particular object is in 3D. So, how to reach this particular point a 3D point in 3D pace space with the help of that particular manipulator having 6 degrees of freedom. Now, to reach this particular point in 3D space with the help of your a manipulator having 6 degrees of freedom there could be several combination of the theta values, for example, say there could be several combination of theta 1, theta 2 up to say theta 6 values with help of which I can reach this particular point say point 1 and out of all the possible combination of the theta values if I know at least one so, my purpose will be summed.

Now, how to collect this particular the information to collect the information, what I can do is so, I can take the help of manual teaching which is suitable for point to point task and this is nothing but a point to point task. So, there are several methods for this manual teaching, for example, say we can take the help of control handle or joystick. So, with the help of this control handle or joystick through some your error and trial; so I the tip of this particular the twisted drill bit will be able to reach the center of this particular hole.

The moment it reaches the center of this particular hole we store all the theta values with the help of optical encoder which are mounted at each of the robotic joints. And we measure all such theta values and once we have measured all such theta values corresponding to this particular hole which is to be drilled on this plate. So, what I do is so, we replace this plate by second one and we make this particular drilled hole exactly at the same location, then once it is done on the second plate we go for the third plate and solve; so for a large number of plates exactly at the same location so, I can make this type of the drilled hole.

Now, to collect this particular information of theta 1, theta 2, up to theta 6, we take the help of this control handle which is nothing but a manual teaching. Now, then comes the push buttons. Now, we have already discussed that for each of this particular robotic manipulator. So, there is a director or a controller. Now, on the body of the director or the controller; so there will be a few push buttons and with the help of this push buttons actually we can control the movement of the tip of the manipulator either in Cartesian coordinate system like x, y and z or in joint space like in terms of theta 1, theta 2, up to theta 6.

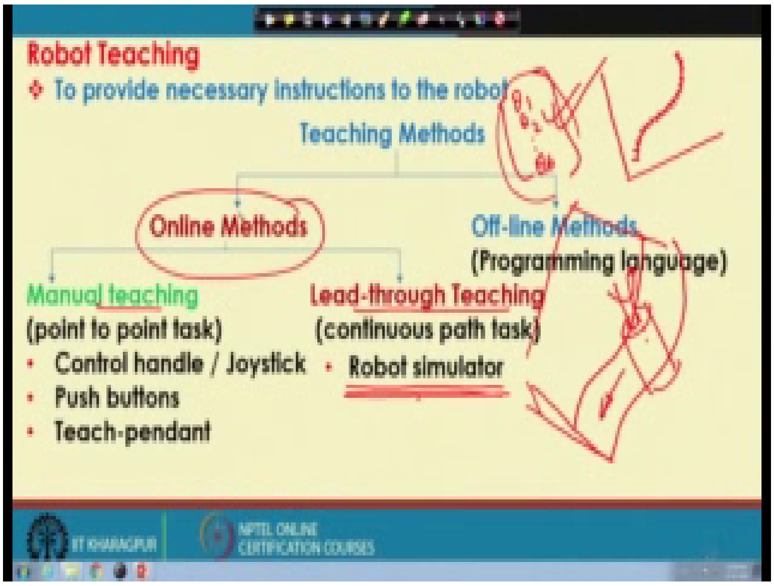
So, we can increase the value of theta 1, theta 2, up to theta 6 we can increase and decrease the numerical values for this x movement y movement and z movement then through some trial and error the movement it reaches this particular point. So, what I do is we store all such theta values with the help of optical encoder. So, this is how to use the push button.

Now, next I am going to discuss how to use a teach-pendant for the manual teaching. Now, this teach-pendant is nothing but one remote controller for this robot. So, just like the remote controller used in TV so, the look wise almost similar, but slightly larger in size. Now, this teach-pedant can be operated either in the Cartesian coordinate system or the world coordinate system that is in x, y and z. It can also be operated in the joint scheme that is in terms of theta 1, theta 2, up to theta 6. It can be operated in your the tool coordinate system and so on.

So, we will have to select a particular operating system or the coordinate system and then using this particular teach-pendant so, manually we can control the movement of the different joints. The moment it reaches the tip of this particular the cutting tool reaches the center of the hole so, what I do is your we store all such theta values with the help of optical encoder and the same set of theta values we use for a large number of plates. Now, this is the method of the how to use the teach-pendant to solve to incorporate the manual teaching.

Now, I am just going to discuss the principle of another online method that is called the lead through teaching. Now, for this lead through teaching actually this is suitable for some sort of your the continuous path task which I have already discussed and for this particular continuous path task the tool should be in touch with the job continuously.

(Refer Slide Time: 20:58)



Now, let me let me take the same example which I took for this particular the continuous path task supposing that this is actually a profile which I will have to cut on one side of a steel plate so, the way it has to be done is as follows actually we use some sort of your milling cutter. So, this type of milling cutter we use and so, this milling cutter they should be a rotation and it should be able to trace this particular the complicated profile.

Now, this is in 3D. Now, if I consider the 2D view supposing that x and y, so, this type of profile I will have to cut how to cut this type of profile to cut this type of profile actually what we do is we divide this profile into a large number of small segments and the more the number of segments. So, the better will be the precision. Supposing that we are going to divide into say one thousand segments now, for each of this particular one thousand or one thousand one points so, we cannot find out. So, easily the sets of theta values like theta 1, theta 2, up to say theta 6 and moreover so, once we have got it somehow. So, we will have to store this particular the theta values. So, it requires a huge amount of the memory, but the more difficult thing is actually how to determine like one thousand or one thousand one sets of such theta values.

Now, mathematically it becomes very difficult to determine theses one thousand one sets of theta values and that is why. So, we will have to use some other practical method like how to collect this particular the information. Now, one method could be like if this is the cutter so, this particular cutter is gripped by the gripper or the end effector. Now, here so, this particular cutting tool; so it is going to trace this complicated profile now, we can try if this is the cutter so, I can just grip it and try to trace this complicated profile which I am just going to cut.

Now, if I want to trace this complicated profile manually it becomes very difficult because at each of the robotic joint there are some motors, there are some brakes, there could be chain drive, gear drive, belt drive and so on. So, it becomes very difficult like if I just grip it and try to move according to my choice. So, it becomes very difficult to move manually. Then how to trace? How to trace this particular complicated profile and if I can trace this complicated profile which I am going to cut and while tracing at regular interval so, if I can store the theta values with the help of optical encoder so, I will be able to collect the sets of all sets of theta values.

And, once we have collected those sets of theta values so, we try to fit some smooth curve which I will be discussing after some time just to find just to ensure the smooth variation for theta 1, theta 2, up to theta 6; and once we have got that smooth variation. Now, I can operate and I can run that particular the robot, but here the problem is that we will not be able to trace this complicated profile. Now, actually one method has been suggested that we are going to use one manipulator, a second manipulator that is called the robot simulator.

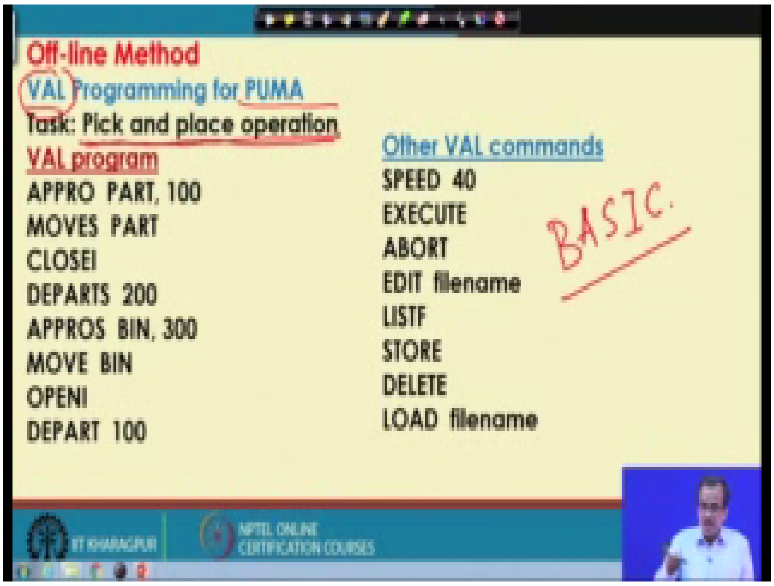
Now, this robot simulator is actually not a simulation package. So, this is actually physical robot and this particular robot is kinematically equivalent to the main robot which I am going to touch and by kinematic equivalent. So, I mean. So, both the main robot and this particular robotic simulator are having the similar type of joints similar type of links, but this robot simulator could be in one is to one scale with the main robot or it could be scaled up version or scaled out version.

Now, in these robotic robot simulator actually there is no such motor, there is no drive unit, but at each of the joint we have got the optical encoder. Now, if you have the optical encoder at each of the joint, but there is no such drive unit, there is no such gear no breaks nothing now, I can just grip this particular the end effector or the this particular cutter which is connected to the end effector and I can trace the complicated profile which I am going to cut and while tracing at regular interval with the help of optical encoder I am just going to store this particular the theta values.

Now, this is actually known as actually the lead-through teaching. Now, this robot simulator is actually the master robot and the main robot which I am going to control that is called actually the slave robot and this is in fact, the working principle of master and slave robot. Now, so, this is actually the lead-through teaching. So, both lead-through teaching and manual teaching are coming under the umbrella of your the online methods.

Now, I am just going to concentrate on the offline method and here in offline method actually we will have to use some sort of programming language.

(Refer Slide Time: 27:00)

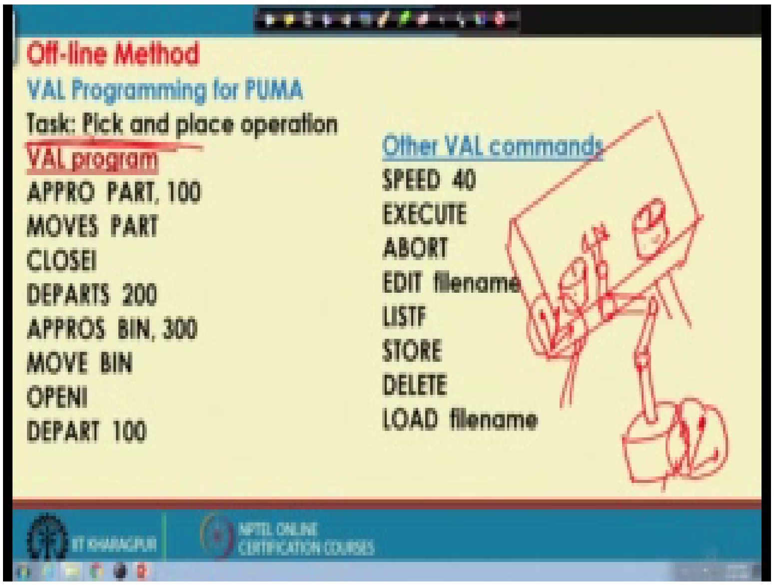


Now, if you see the offline method. So, we will have to use some programming language just like your computer program. Now, here actually we can use a language like VAL programming for the PUMA series robot. So, this particular example I am just going to take for the PUMA series robot using the VAL that is versatile assembly language or variable assembly language and this is suitable only for puma that is programmable universal machine for assembly.

Now, here in this VAL programming actually we take the help of a few commands from the BASIC language that is your beginners all purpose symbolic instruction code. Now, here we will see that the some of the codes are exactly the same, but we add a few extra the commands also in this particular the VAL.

Now, before I just can write one program with the help of this VAL programming. So, I just want to define the task which I am going to give to the robot and that particular task is nothing but the pick and place type of operation. Now, let me discuss little bit this pick and place type of operation first, then I will be discussing like how to how to write down that particular the VAL program so, to solve this the problem

(Refer Slide Time: 28:43)



Now, let us let us try to define the problem which I am going to solve supposing that I have got a table sort of thing. So, this type of table I have and on this particular table. So, I have got two bins say I have got say one bin or the bucket here. So, this is one bin and this is another bin another bin or bucket here. So, this is bin – 1 and this is bin – 2 and here. So, this particular the table the top of the table so, this is the top of the table say.

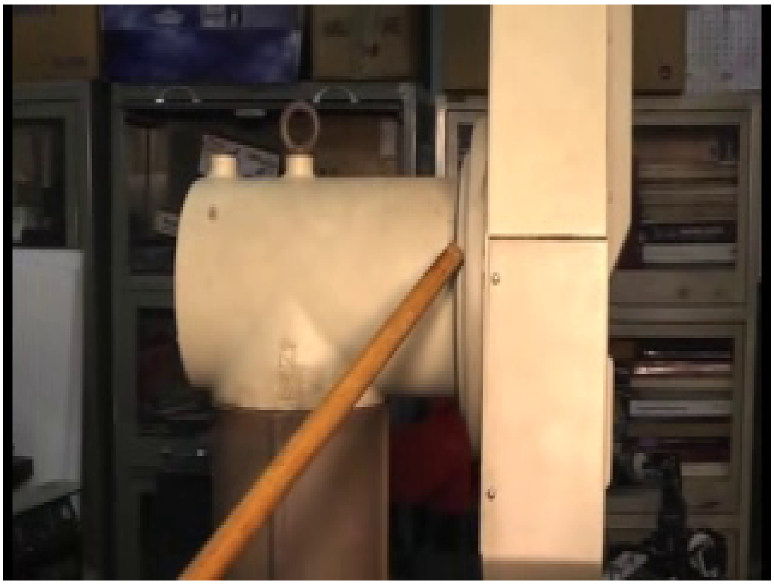
Now, here actually I do is I have got a manipulator say serial manipulator sort of thing for example, say I have got a manipulator like this very simple say manipulator I am just going to consider here supposing that I have got a this type of manipulator and here we have got this particular your the gripper or the end effector.

Now, this manipulator is having one coordinate system one base coordinate system, like x, y and z coordinate system and this particular table is having another coordinate system here like x, y and z here, ok. So, if I want to give instruction to the robot that that you just go to the bin – 1 and collect a particular job and place it to the bin – 2. So, I will have to do is. So, this particular coordinate system has to be known in terms of so, this particular the coordinate system or the base coordinate system of the robot and supposing that, so on this particular bin I have got an object a 3D object and we know how to represent the position and orientation of this particular 3D object. So, here to represent the position and orientation we need actually six information three for the position and three for the orientation.

Now, let me take a very simple example supposing that this is the 3D object. Now, if I want to represent the it is position and orientation I need three information three for the position and three for the rotation that is the orientation. So, I need six information supposing that the position and orientation of the object we is lying on this particular bin – 1 is known and the position and orientation of this particular the bin that is the bin – 2 that is also known and all such information I have stored at the top this particular the program. So, here at the top of the program so, I will have to write down the position and orientation of the bin – 1 position and orientation of the bin or the bucket – 2 and the position and orientation of this particular the item the 3D object.

Now, once I know all such things now, let us see how to how to write down, so this particular the VAL commands. Now, we are going to discuss how to teach a robot practically. Now, here the robot which we are going to consider is the PUMA that is programmable universal machine for assembly. Now, this PUMA is nothing but a serial manipulator having 6 degrees of freedom, there are six joints. All six joints are rotary joints and out of six we have got three revolute joints and three twisting joints.

(Refer Slide Time: 32:32)



Now, here so, this is actually the PUMA. Now, this is a robot with fixed base.

(Refer Slide Time: 32:35)

So, this is the fixed base the first joint that is nothing but the twisting joint. The second joint is the revolute joint.

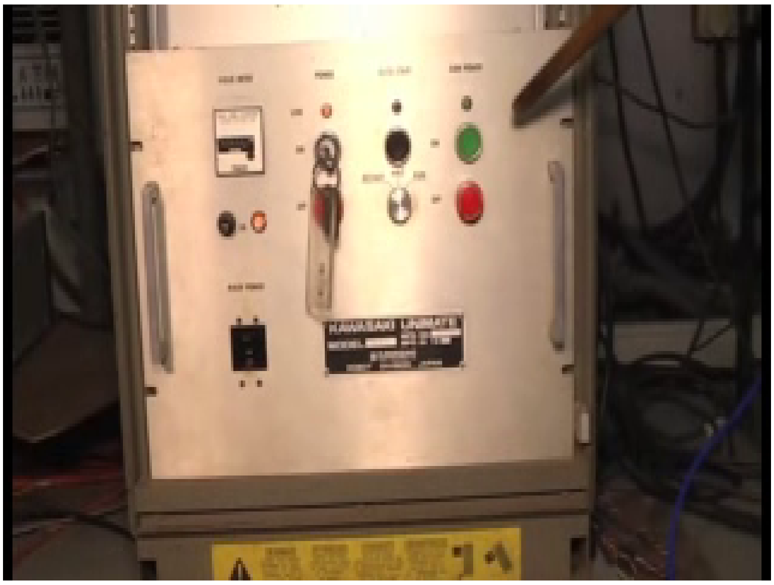
(Refer Slide Time: 32:46)

The third joint is another revolute joint.

(Refer Slide Time: 32:50)

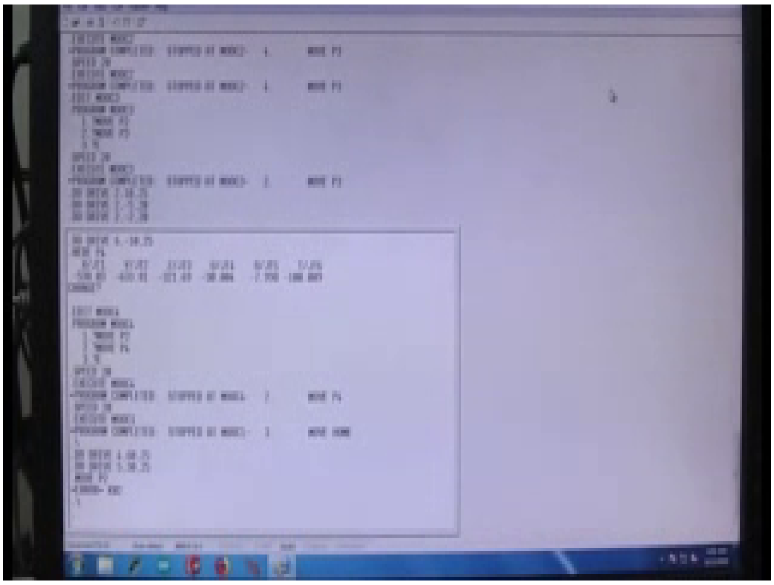
The fourth joint is a twisting joint. The fifth joint is another revolute joint and here we have got one twisting joint. So, we have got six joint each joint is having one degree of freedom. So, this serial manipulator is having 6 degrees of freedom.

(Refer Slide Time: 33:13)



Now, if I see the different components. So, this is the body of the robot. This is the controller or the director of this particular the robot. Now, this is equipped with one display, but that display has become out of order.

(Refer Slide Time: 33:25)



That is why, so, this particular display is used as the display for the controller or the director of these particular the robot. As we have already discussed that the robot can be taught using either online or offline method. Now, out of these online methods we have got the manual teaching and the lead-through teaching. Now, here I am just going to show like how to control or how to teach this particular robot using a manual teaching method that is with the help of one teach-pendant.

(Refer Slide Time: 33:59)

Now, this particular teach-pendant is nothing but a remote controller for this particular robot. Now, with the help of this particular teach-pendant the robot can be controlled either in world coordinate system or the cart Cartesian coordinate system or we can control it in joint space like in terms of the theta space or in tool coordinate system.

Now, these teach-pendant is used for the manual teaching. Now, regarding this offline teaching method as I have already mentioned that we use some programming language now, for this particular puma series robot the programming language which you are using to teach this particular robot is VAL that is a versatile assembly language or variable assembly language. Now, this versatile assembly language we can use to write down the program to solve some practical problems. Now, here I am just going to discuss two practical problems and to solve this two practical problems we are going to write down the VAL commands and we are going to control this particular the manipulator.

Now, let us first concentrate on the first task. Now, the task is now, we will give command with the help of the VAL programming like the first the robot will got to its home position, then from the home position so, we will directly to reach a particular point a predefined point say point A and after that so, from point A, it will once again go back to the home. Now, to solve this particular problem so, we are going to show you the

VAL programming first and then with the help of this VAL programming we are going to teach this particular the robot.

Now, here actually this shows the VAL commands like with the help of this VAL commands actually what we can do is, the home is already defined and we are going to defined a particular point say either point 1, point 2 or point 3 or point 4 and from this particular the using this VAL command we can give the command that you go to the home then from home you just go to the point A and once again you come back to the home. Now, we are going to execute this particular program to control the robot.

The second task is related to the pick and place type of operation. So, at location one there is an object. Now, the task of the robot is to pick that particular object and it is going to carry it to another location and it will place it there and this is very popularly known as pick and place type of operation.

Now, we are going to show you like how to use the VAL programming, so that the robot can perform so this particular the task. Now, this is the VAL programming. So, what we have done it here so, we have the find the different points. So, its coordinates of the different points we have already saved in the program and then we are going to just give the command like a move to that particular point move to that particular point another point. So, this is the way actually we can write down. So, this particular the VAL programming to solve the pick and place type of operation.