ROBOTICS

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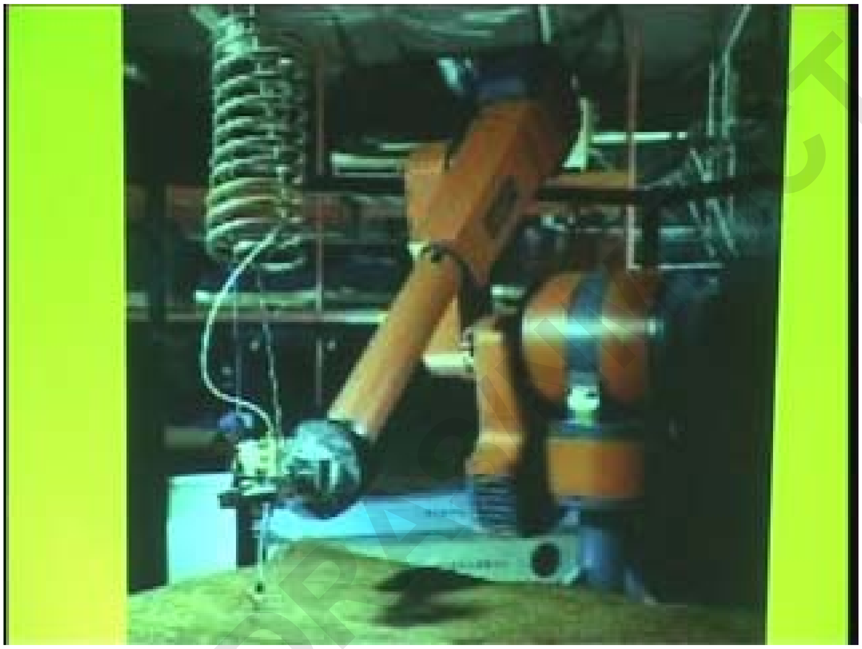
Lecture No-3

Industrial Robotics (Time start 1:10)

Today I will be speaking on industrial robots; you know, in the last two classes (refer Slide time 1:28 min),



last two lectures, we had seen several types of robots (refer Slide time 1:35 min)—

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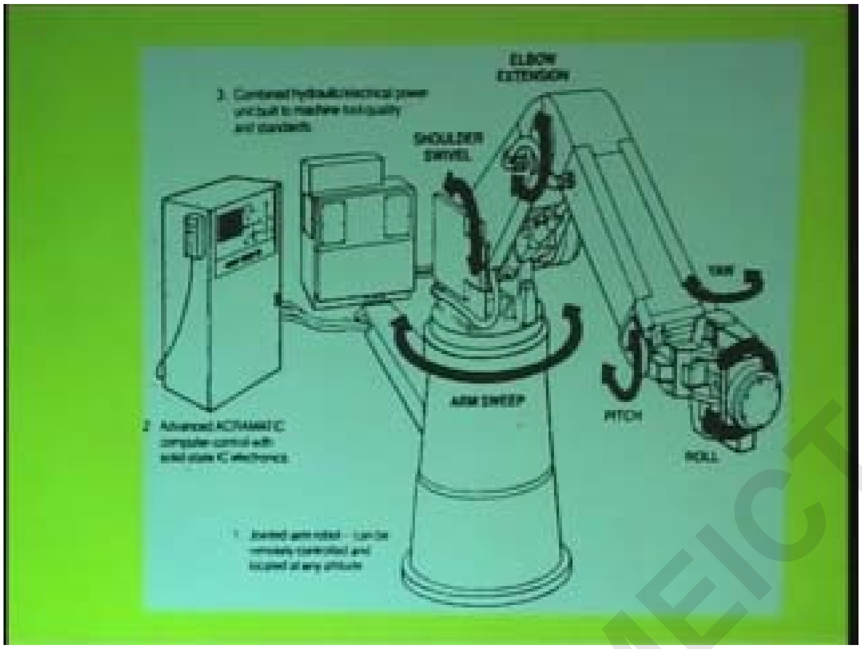
industrial as well as those which are used elsewhere. Now I will go and use the industrial robot as a means of telling you what is it that is involved in robot. We'll use this. Most probably, the entire lecture series will be mostly on industrial robots further on. In industries, there are two types of robots which are used: one are known as manipulators. Manipulators, industrial manipulators, are one class of industrial robots; the others are what are known as automated guided vehicles or, in short, agbs.

These are the two types of robots which are used in industries. Industrial manipulators typically execute tasks which a human hand does— picking up of an object or handling tools and the automated guided vehicles carry parts from one part of the workshop floor to other part of the shop floor, wherever they are required, picking them and delivering them. So these are the two types of robots which are used on industrial shop floors. We will be looking mostly at the industrial manipulators as we go along, because some of the concepts there as the same as those used in agb and vice versa.

Let's also have a brief look at the brief history of robotics itself. You notice that it started some time 1954: Devol and Engelberger, these two people built the first robot. In those days when computers had just come in, it was not the sophisticated controllers that were used; but nevertheless they had a programmable system,
which could be programmed do to variety of tasks. These were manufactured by a company called Unimation, which these two peoples had established. So, Unimation Robot became the first set of robots that appeared on the scene. Subsequently these were used in die casting applications in some motor automobile companies in manufacturing. You know in die casting, where metal is poured into a permanent die, then cooled and then removed. It is a very dangerous operation, so that is where they used this robot. They also started using agb some time in 1968; the first agb came and subsequently they were also being used on the shop floor. In 1970, somewhere in the 1970s, Stanford university built what is known as the Stanford arm, completely controlled by servo motors, electric servo motors and by a computer. It was powered by an electric servo motor and controlled by a computer that they could program; they could make it do a variety of tasks; they could make it respond to sensory inputs and all. That is why Stanford arm is historically an important arm. Subsequent to that, in 1979,
the Japanese in Japan came out with what is known as the scara arm. We will see what the Scara is. This was specifically designed for assembly. It is a very neat little arm, which is specifically designed for assembly and used to assemble. Later on, the Sony walkman came,
which is a very famous product as you all know—most management tools talk about the Sony walkman as a very famous product. There is another reason it is a very famous product: it was designed for robotic assembly

I have told you in the earlier classes that don't expect the robot to do what a human does like dusting, or whatever it is; try to redesign the product, tailor the product, so that the robot will find it easy to work on. So Sony walkman was one of those products, which was designed for robotic assembly. Let's go on to this particular lecture. (refer slide time 5:42)



Here is a typical industrial robot: those thick arrows show the various motions. You know, as you can notice, it looks like a human arm. There is a shoulder joint, and there is an elbow joint, and there are three wrist motions. All these units turn around a base: the arm sweep.

So these six joints are six powered joints; they have motors, servo motors or hydraulic motors or whatever it is, which enable the robot to reach objects which are far away from it. You know if you want to grasp an object which is far away from you, you typically move your shoulder and elbow and then reach for the object; above also use these two.

If it is above you or below you, you use these things. If it is to left or right then the arm sweep, or what we callthe base rotation is used. Notice that the robot is fixed in a place; the arm is mounted on it. The robot base is fixed in a place and the arm is mounted on it.

So three motions: the arm sweep, the shoulder motion, and elbow motion, together allow to reach an object which are far away or close to you which are above or below you, or which are to the left or to the right. Now

we have additional three motions: at the wrist the yaw, pitch and roll as you can notice, which are used to orient an object. This is not very strictly, typically the way we think. We think that the shoulder or elbow allows to reach an object

which is far away and we move the body to move left and right and the wrist is to orient the object. This is not strictly true but you know just for discussion, you could have seen it to be temporarily like that. Later on we will see that it is not strictly true; the wrist also contributes to some extent to positioning the, reaching the object, and the shoulder and elbow also contribute to some extent to orient it. They do result in change in orientation, motions of these joints and change in position. This is how we look at it. We say there is

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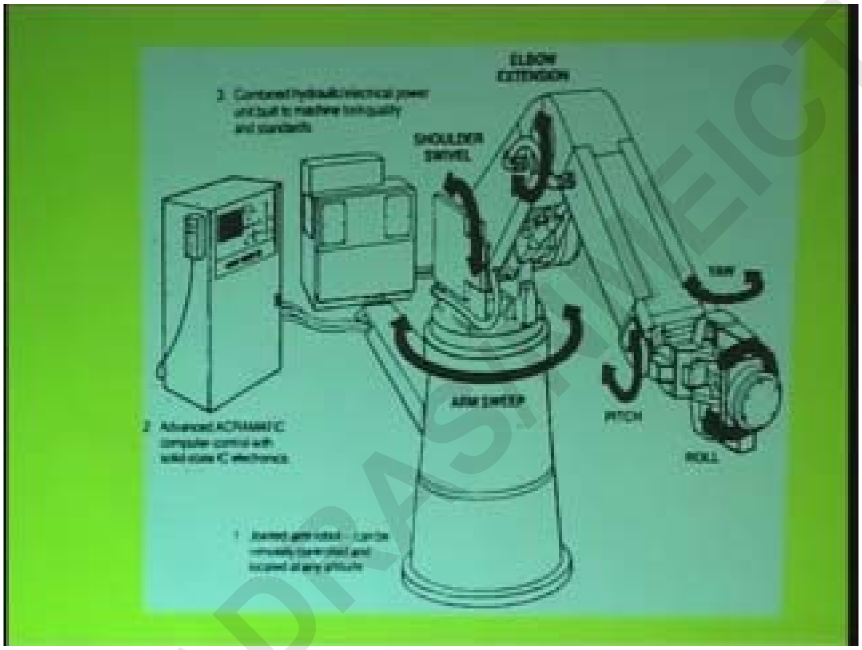
a main body consisting of the first three motions from the base and there is a resist. This is how we look at it. Now obviously all these six motions have to be controlled simultaneously in order to do a specific task—all six motions, now why six motions? Why not four? Why not five? There are robots with four motions, five motions. For example if you look at the roll motion on the wrist, if you are holding a symmetric object like a pencil, that roll motion is unnecessary, because you know, the pencil is symmetric, axisymmetric or a cylinder, axisymmetric. You can eliminate it; typically if you are using a welding rod, you may be able to eliminate; or you are using a chalk to write on a board, that particular motion will be less; one motion less, one motor less. (refer the slid time: 9:04)



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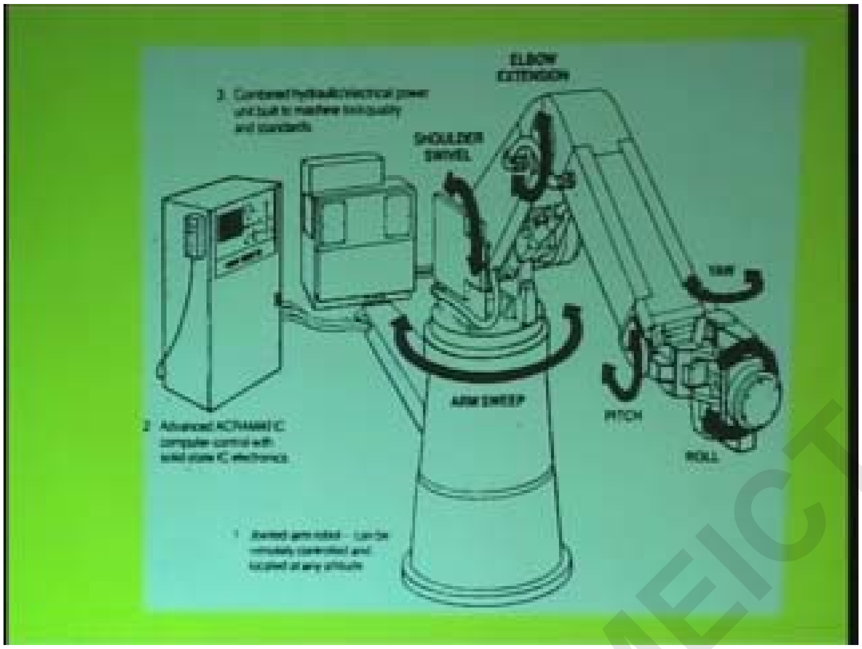
So depending on the application you might go for the five axes we call it the six axes motion. The word axis is borrowed from machine tool technology. In a lathe, in a machine tool, numerically controlled machine tool lathe, you have the job spinning. In the lathe, the job is rotating and we have a tool which traverses in two directions: in the x direction as well as in the y direction. So one x axis, we call it an axis; the second axis is a y axis, so we say a lathe has two axes and of course, we don't count it as a part; sometimes we count this rotation as a half axis, a lathe has two and a half axes, they say.

Let's not worry about it but essentially you have one axis for the x motion and one axis for the y motion. The same terminology has been borrowed by robotics for the simply reason that the first robots were built for the shop floor; so on the shop floor, engineers are familiar with axis, the word axis. So that's how it goes. (refer slide time: 10:10)



Here is a six-axis robot as you see. These six axes are required to position and the orientation of an object. In any object in space, if I want to tell you where the object is in space, I have to give you three coordinates: x y and z. That is where generally the object is. But if you want know how it is oriented, you require a lot more information. If my finger is pointing towards something, you can tell me where my finger is by giving me the x y z coordinates, where we have the base of the finger and then, you have to figure out typically three angles to tell me how I am coordinated. It is symmetric here; let us not worry about it, but still, you have to give me typically three axes. So you need six independent pieces of information to tell me where a specific object is in space and the way it is working. If you want manipulate an object in space, you will consequently need six independent motions: a motion along x axis, a motion along y axis and a motion along z axis, and the rotations around the three axes.

This is the simplest way to look at it. The machine should also be able to provide all these six motions. You can put the industrial manipulator together by having several types of main bodies and race, which will provide these six. This is basically how to study industrial manipulators. Driving individual motions could be through electrical motors, pneumatics, hydraulic, that is secondary. Essentially there should be six axes, which are driven independently and later synchronized by a computer to get what you want. Now let us look at the main body. Here are the typical main bodies which are used in robots. (refer slide time: 12:17)

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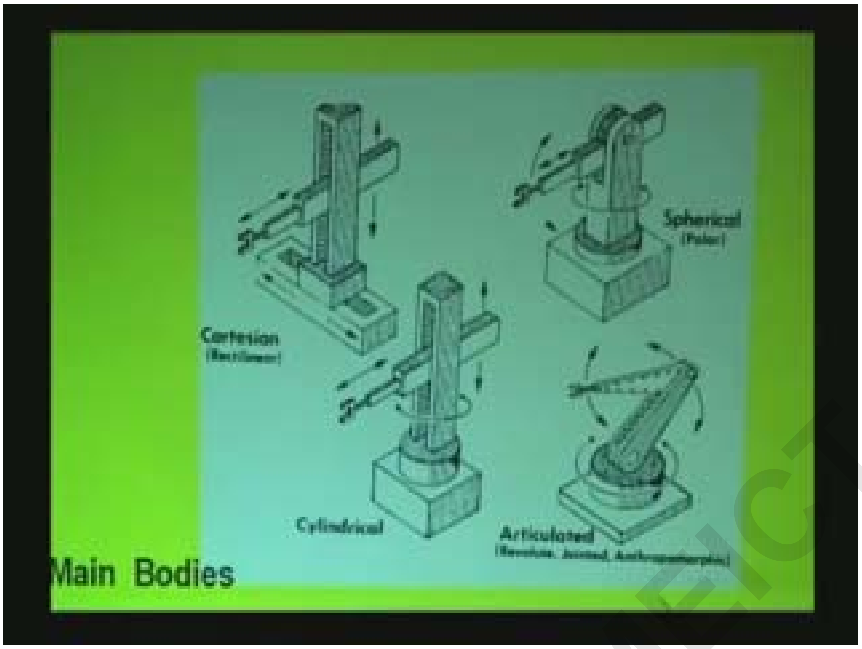

They have three motions available, typical motions. Many of these are familiar to us through machine tool technology. The lathe typically has an x and y motion tool; so the Cartesian main body, which you see there—as you can notice—it has three motions: x, y and z, which allow it to position an object anywhere. Let's say that you hold an object. What is the orientation of the object when you hold it? You can see the grippers are the end of the Cartesian. Suppose you hold an object, let's say a torch, beam of light, and then you have Cartesian robot holding the object.

Let us say the light is pointing in one direction, as I move the Cartesian robot axis, do you think the light's orientation is going to change, point in more or less in the same direction? The position is clear. So you see here, the Cartesian robot is not going to change the orientation. The main body does not have any effect on the orientation of the object. The object keeps on moving parallel to itself, the Cartesian. Then, you have the cylindrical robot, with a cylindrical main body (refer slide time: 13:37)

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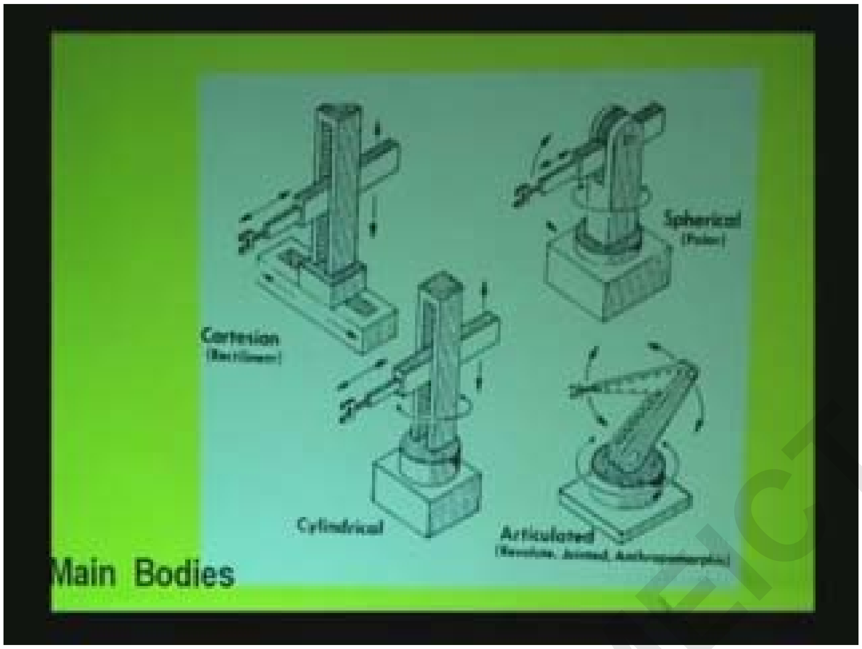
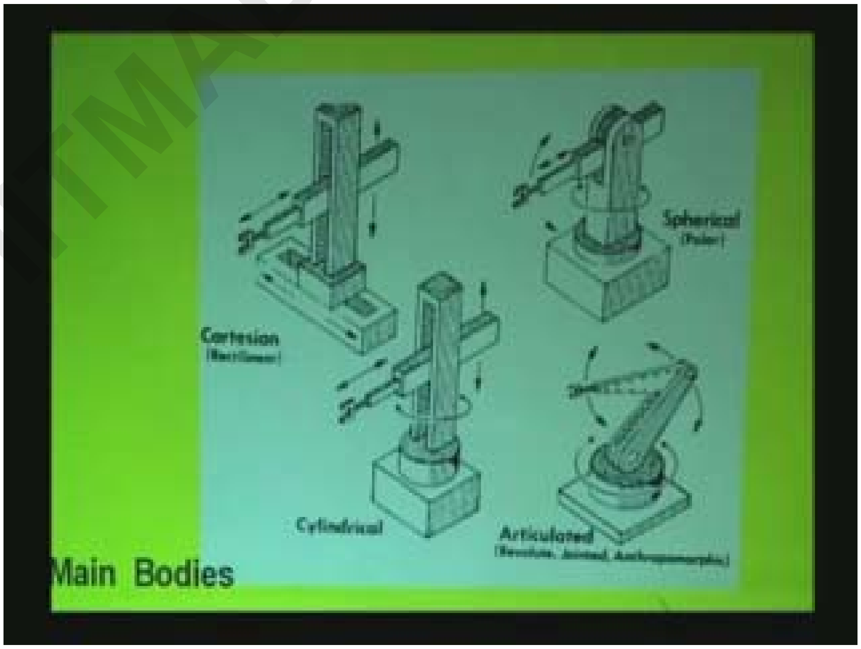


I should use the word main body rather than robot. At the bottom, we have the cylindrical main body; we have seen this main body in the shop floor typically in some form or the other. This appears with the drilling machine. We can raise that drill head up and down, we can rotate the arm on which the drilling unit is mounted to it; we can rotate that arm and you can sometimes move it out radially and in inversely. So this is the cylindrical main body. This way you have an r and theta—as you move out and in from the base you have an r and theta, as you rotate, you get the theta, and you have the three motion, red motion also as you move up and down. So we call this the cylindrical main body. Then, there is the spherical or polar main body (refer slide time: 14:43)



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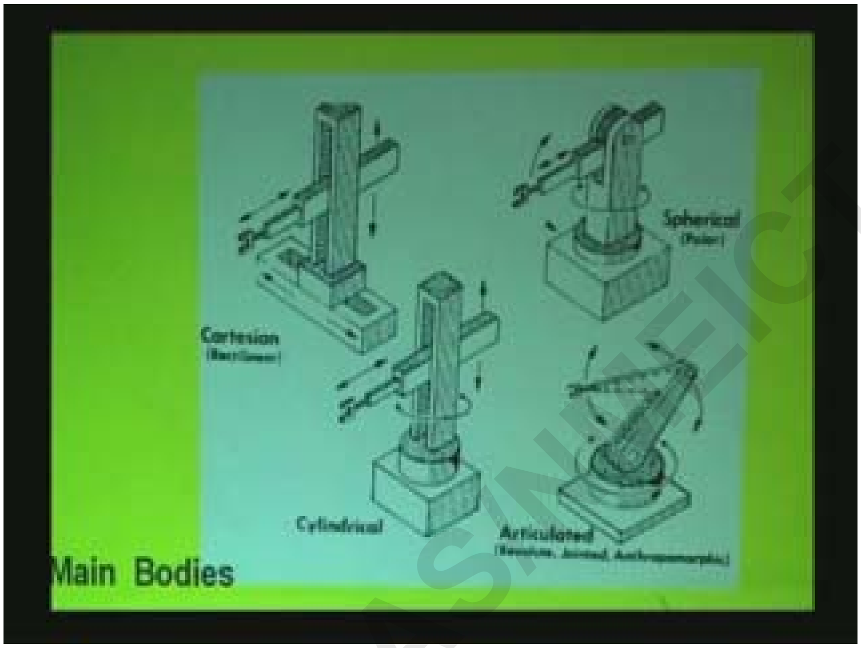
which you see at the top right corner; the spherical or polar both these. As you notice, they have a base rotation; then the arm swings up and down in order to reach; and then the arm projects, it comes out and in, in a sort of the telescopic motion. The fingers come out; so that is the spherical or polar arm. Then there is articulated arm
which is at the bottom right.
(refer slide time:15:18)



This is typical to the human arm. You have the base rotation, which we just saw, you have the shoulder and the elbow; and then the gripper itself. This is just like your arm. Now you can see each of these have three degrees of the three axes as shown in each of these bodies.

Now all these four are used by engineers to design the robots, industrial manipulators, which has its own advantages and disadvantages. Let us look at the Cartesian to begin with. As I told you, the orientation is not affected. The object moves parallel to itself by the motion of the various axes. That is one thing. The second thing that happens is that this is a very stiff manipulator. It is a typical motion that has been adopted in machine tools; this structure is stiff, but also tends to be heavy. In a lathe, when we are cutting, structures occur on the tool structure has to withstand that particular posture. So for stiffness, they use this. It is very stiff provides a stiff structure, a stiff body to get some work. That is one of the advantages; but can it dip into a bucket? The way the fingers are shown in the picture, can it dip into a bucket? Can it scratch its own back? It cannot; whereas an articulated arm can dip into a bucket and scratch its own back. So lot of dexterity is available in an articulated arm, which is not available in the Cartesian. You imagine you can scratch your own back with shoulder and elbow joints working together, of course you also add something to that. So you know, at one extreme you have a lot of stiffness, at the other extreme, you have a lot of dexterity. To withstand forces, acting on the end effector—we call all those fingers and all with a general name for the end effector also called gripper, tools we just call it end effector—if we are holding a drilling

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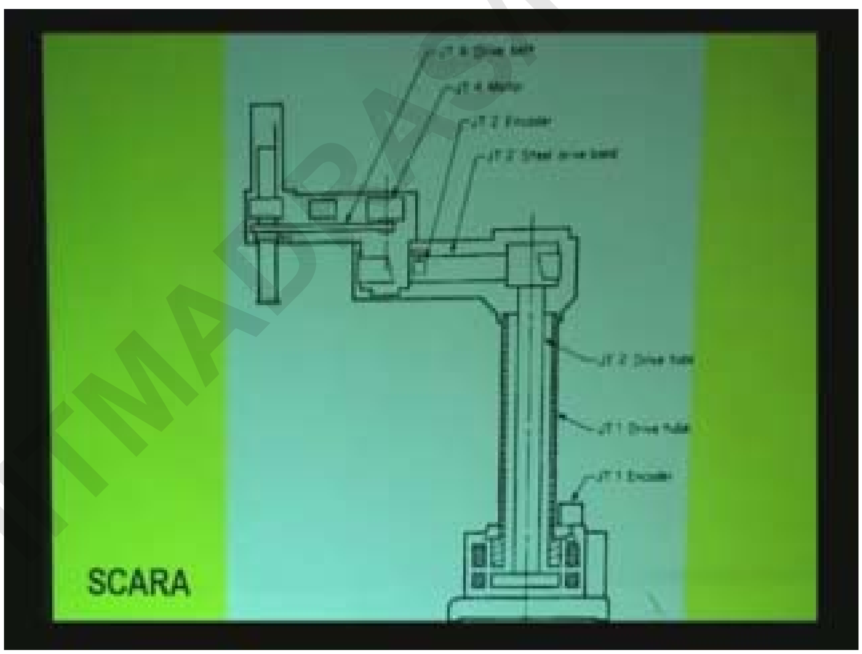
machine and trying to drill, there is a force on it, that is, end effector, the force on the end effector can be taken on directly by the mounter in the case of the Cartesian robot, but in the case of the articulated arm, the motors are rotating. The other two arms somewhere in between. Also there is the question of workspace. How much is the work and where, these things come up when you look at these four main bodies. So there is another thing, which is easily controllable. That is also another thing in a very simple sense. Now if I have my drill sitting at the point at x_1 y_1 z_1 and I have to take it to the job, which is sitting at x_2 y_2 z_2, so now

you have to tell the robot how much distance it has to go in x direction, y direction, and z direction to bring drill from where it is kept, to pick it up and bring it to the job; you have give these. Which of these—let us look at the two cases, Cartesian or the articulated arm—is it easy to give this information to?

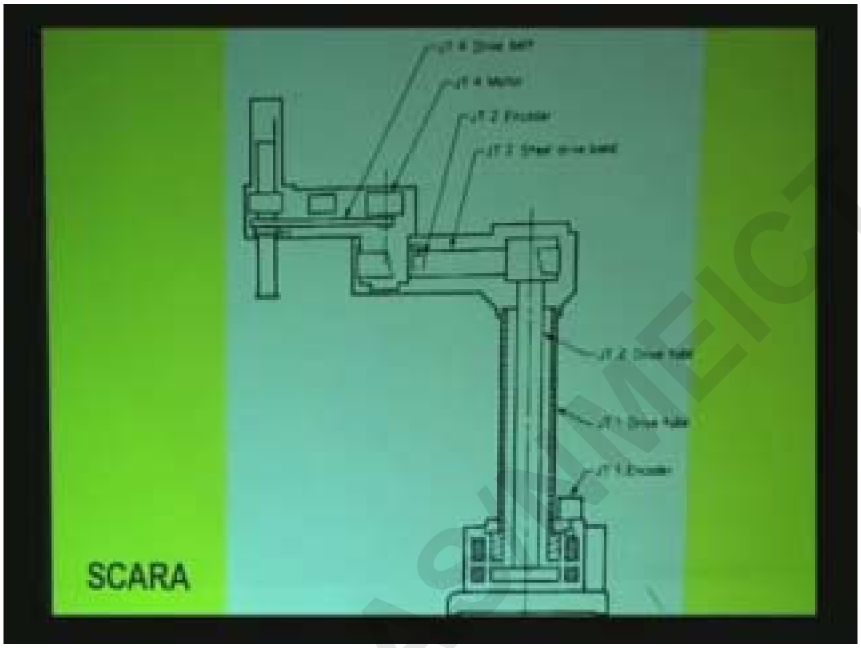
In the Cartesian it is simple, just subtract x_2 minus x_1, y_2 minus y_1, whereas in an articulator arm, you are going to encounter trigonometric entities so that means, when you start controlling, you have to solve set of equations that contain all this trigonometry. So it is much easier to do it with the Cartesian. There are advantages and disadvantages in the various main bodies. There is a lot of flexibility available: dexterity is available in an articulator body. I am using these words in a very loose term. There are definitions, we will come to that later on, let us not worry too much about it right now. But just keep in mind that one guy can scratch one's own back while the other cannot. (refer slide time :19:54)



Similar to the cylindrical configuration, people came out with what is known as the SCARA configuration as you can see. Essentially, you know, imagine moving your arm in a plane like this; that's the way you move your arms; you move your arms in a plane.

One joint here, a rotation; second joint here, a rotation; may be a third joint. And then, there is something which goes up and down, this is scara. Notice that this SCARA is typically used for assembly. In assembly, somebody realized, I believe it was Japanese.

Most of the time you tend to hold the screw vertical and do the assembly. The tool is always held vertical in the assembly—you want to screw down something, you want to push something in, you want to put one gear in a gear box—you tend to hold both the frame as well as gear box vertical, this side. Why do you need all the complex, statically related motions? He came out with this robot SCARA Let us see what the word SCARA means (refer slide time:21:22)



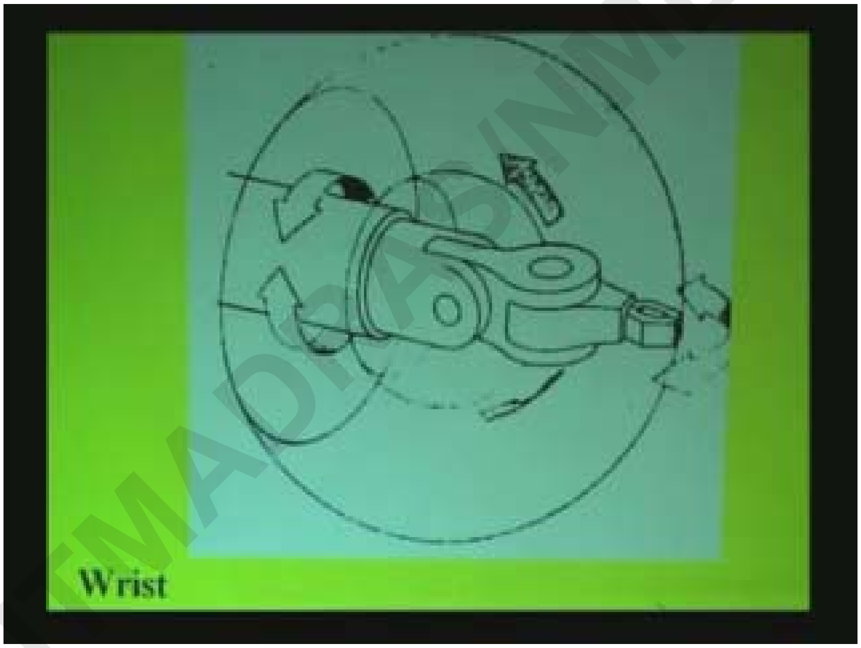
because the word scara has become such a name that nobody expands it—what is S for, what is C for—we'll come to that later. SCARA robot is cylindrical

You just compare the two and you will find that it is equivalent to cylindrical which was used for, what you call the assembly of the Sony walkman. If you open the Sony walkman, you will find that the entire assembly was done by putting parts from one direction. Let's say this is the base of Sony walkman, or the body of the Sony walkman. This itself was used as a palette and assembly was done by putting in the gears and other things, whatever, springs and others. That means extensive redesign of the tape recorder mechanism was done to permit assembly from one direction. You don't have to tilt the body this way or that way; that means, on a conveyor, the body moves by these robots. Everything was done that way, so that was a historic project. These assembly robots are special in the sense that they move very fast to fetch the part, because that is idle time, and then do the assembly. So this is a well-known robot. This is one of the places where the SCARA robots started using belt drives in order to drive these. They kept the motors at the base, transfer motion by belt drives, steel belts.

So now we have seen the four bodies: the cylindrical, the articulated, the Cartesian and the polar or spherical. You have seen these main bodies, and we had a look at the wrist, the wrist in general. Here is a wrist which is shown, there are three motions; obviously, each of these three motions is powered by a motor. These three angles are required to reorient an object, any way you like. The wrist also contributes slightly to the workspace, but then, you don't tend to count the space in which the robot can work. If I am sitting here, this is the space in which I can work. So the wrist is not generally counted. These are the so-called end effectors. The robot has a band at the end of the wrist, which can hold things or grippers.

Here we see a welding torch at the top left; at the bottom you can see something that can pinch, that is what we call the pot welding machine. See the complex contours of a car; we have to bend here, and here and here to carry these pot welding guns, which are quite heavy, sometimes of the order of about 20 kgs.

A man has to lift the weld, he has to position it properly and then, will he get a quality weld? If you want a consistent quality, these robots don't tire at all; they keep on maintaining the same quality throughout the day. And there is a riveting gun as you can see. These are some of the tools which are used. Now plenty of tools are being used. A printing gun nos something is carried by many.



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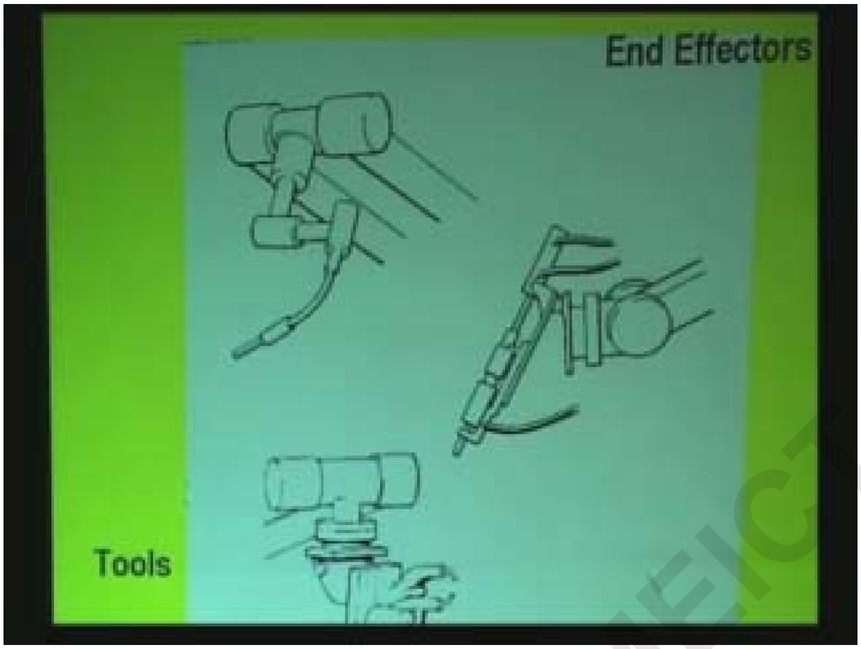
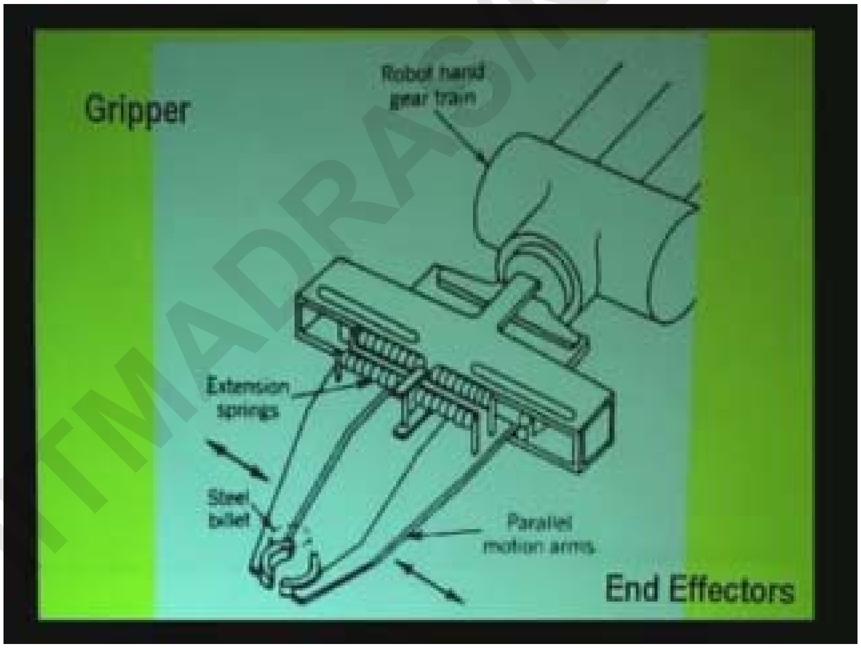


Or you may have grippers (refer slide time: 25:40) to hold an object



you can design these grippers gripper design itself is a big thing. The robot manufacturers typically sell you the robot and he will ask you what tools you want to mount on it. He may provide the tool or he may have a plan

which will accommodate somebody else some other manufacturer, tool manufactured by somebody else a tool manufacturer. But when you want to handle products he may design a gripper for you or he may say you make your own gripper mount. Many a time, they would be ready to make the gripper for you, because they would have done it for so many

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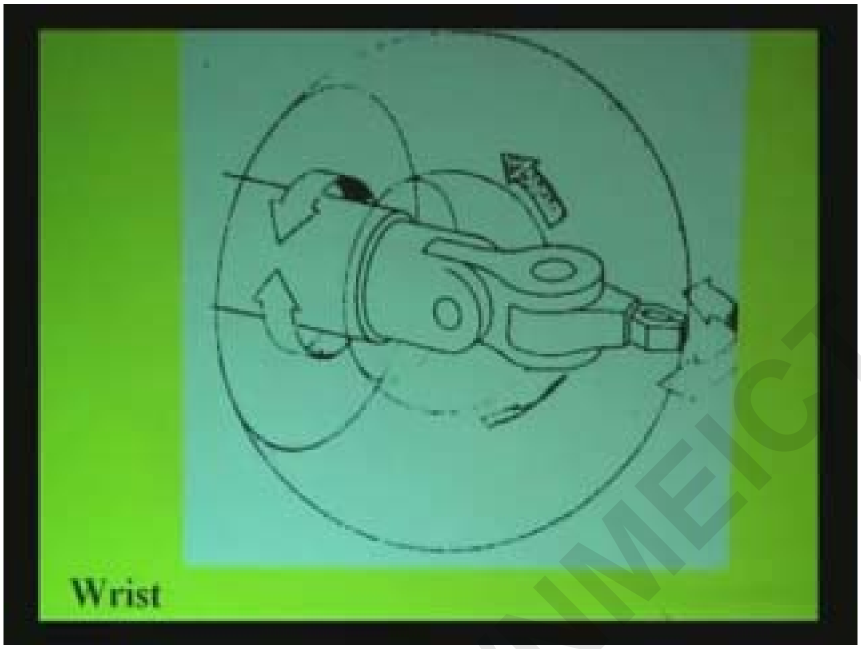
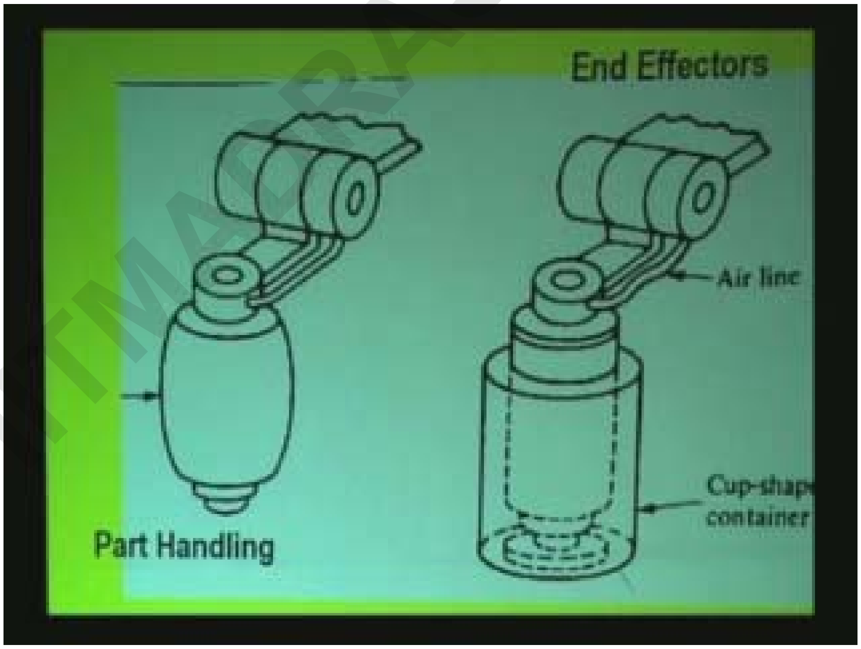
people, so they would find it easy. Here is gripper which has a handle with [inaudible] (refer slide time: 26:24)



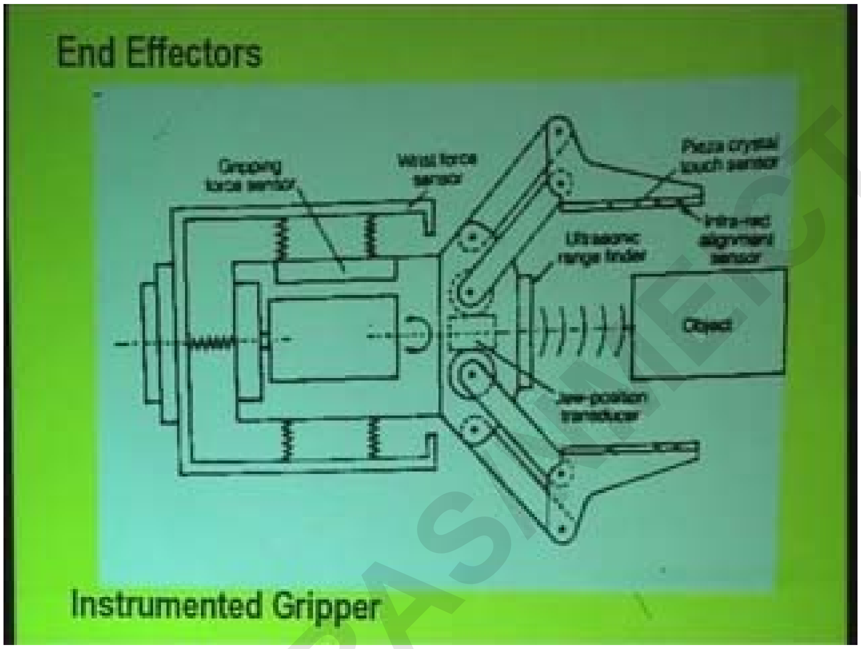
You can see that, gripper technology is (refer slide time: 26:31)



a very special thing. It can handle a cup, container or a hollow cylinder. It is using a balloon when the balloon is deflated you insert it into a hollow cylinder it will inflate the balloon; it will hold on to it. On the right-hand side you have the deflated balloon going into the hollow cylinder.

On the left hand side the inflated balloon is shown just like that. The gripper is very strong. We had done this in the lab for some other purpose; we had a vertical tube. A balloon was gripped with a gripper inside of the tube and the student could virtually climb with a rope through the whole thing hung; it was about 60-65 kilos.

It is a very small balloon not the balloon children play with, it is slightly stronger. Sometimes the end effectors also could be intelligent [inaudible] (refer slide time:27:27)



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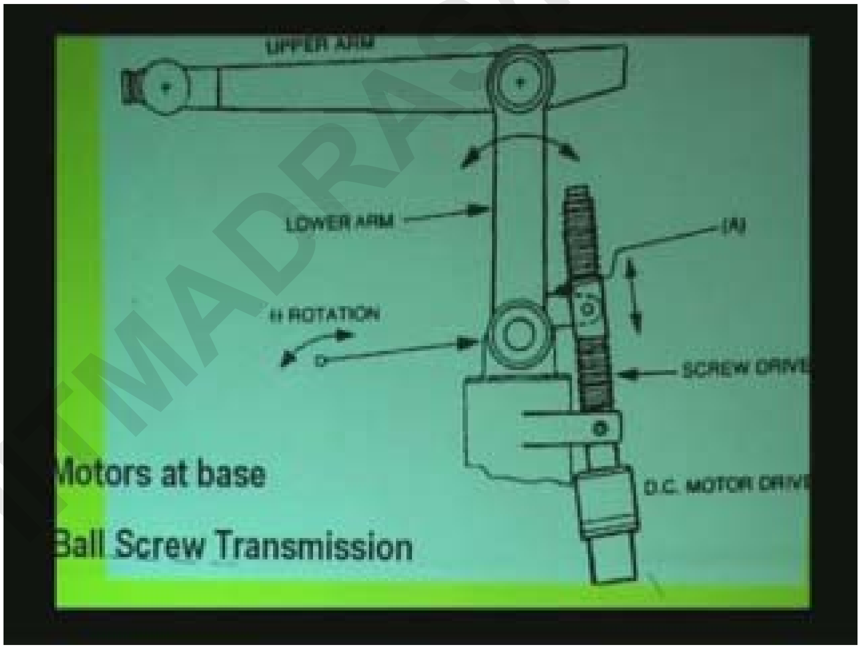
So the ultrasonic finder detects where the object is; it approaches the object. Yesterday I showed you I showed you some pictures—these are all simple. You should remember that in the shop floor they won't tolerate our laboratory experiments. Something should work; that it. The matter ends there. Period.

One tends to go for very rugged sensors and if that solution, that rugged sensor limits you to do, go for it. There is nothing wrong in doing it. Or use some infrared or ultrasonic sensors to detect where the object is; it is not going to detect

where the object is, it may also be just detecting whether the object is there, or how close I can go to the object. Obviously this signal must be sent to the control (refer slide time: 28:26)

So we have seen these various types of grippers and all now we will have a look at the transmissions. (refer slide time: 28:43)



Yesterday I had told you that we would like to have all the support motors on the base because you know then the shoulder doesn't have to carry the wrist motors; the shoulder doesn't have to carry the elbow motor and all. You try to pull as many motors to base as possible. We talked about the ball screw drive, motors with a ball screw drive and so on.

This has been used in welding robots typically because you may have to go through the space when you are assembling, welding a car body and part of welding is done,

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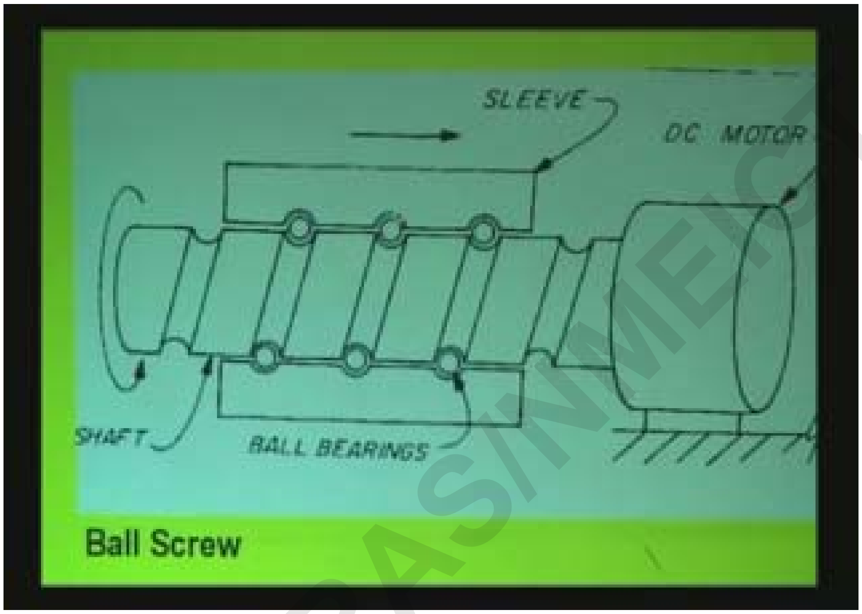
you will have to go through where the doors are. Imagine carrying a heavy welding gun through the door of the car and trying to do something on the roof or near the roof. The arms cannot be very huge—they should be clean and slim. If you put motors, the motors go and hit the roof. So it is important to have something like a human arm for example.

You don't want to see some things jutting out, some motor jutting out. You would like to pull all the motors to the base, for welding robots, spot welding, painting robots. This is the ball screw; you can see the ball. (refer slide time: 29:54)



It is a ball bearing quality. Many a time this comes in two parts which are tightened together so as to eliminate backlash. You must have seen a lathe with a backlash. We can eliminate that; the sleeve is cut into two halves; they are radially cut into two; they are tightened against each other. It is preloaded;

the ball screw is preloaded. In addition to the load you impose, the load is also preloading. **[30:36]** They use it to cut down the, what is called backlash. You want to position it. Alternatively, (refer a the slide time: 30:48)

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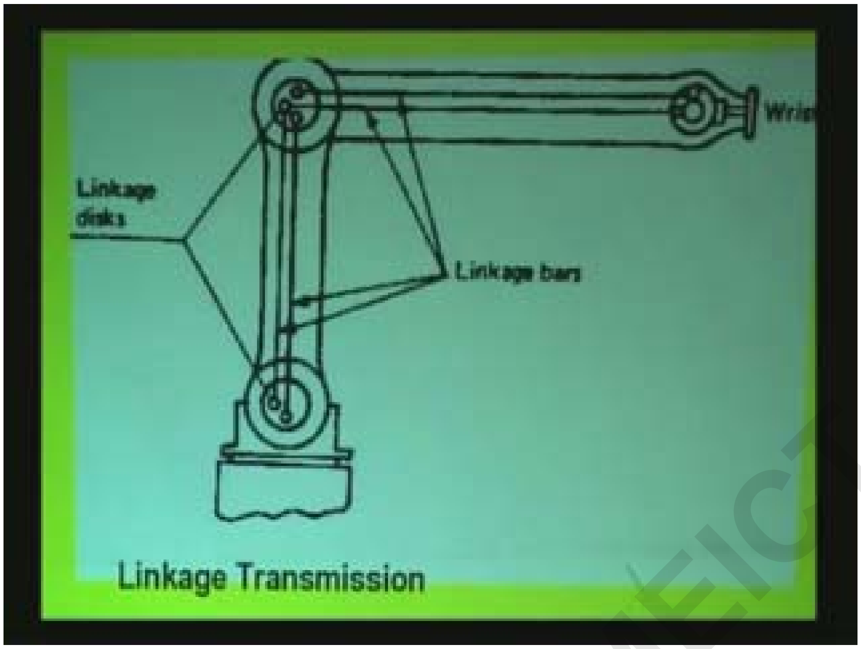
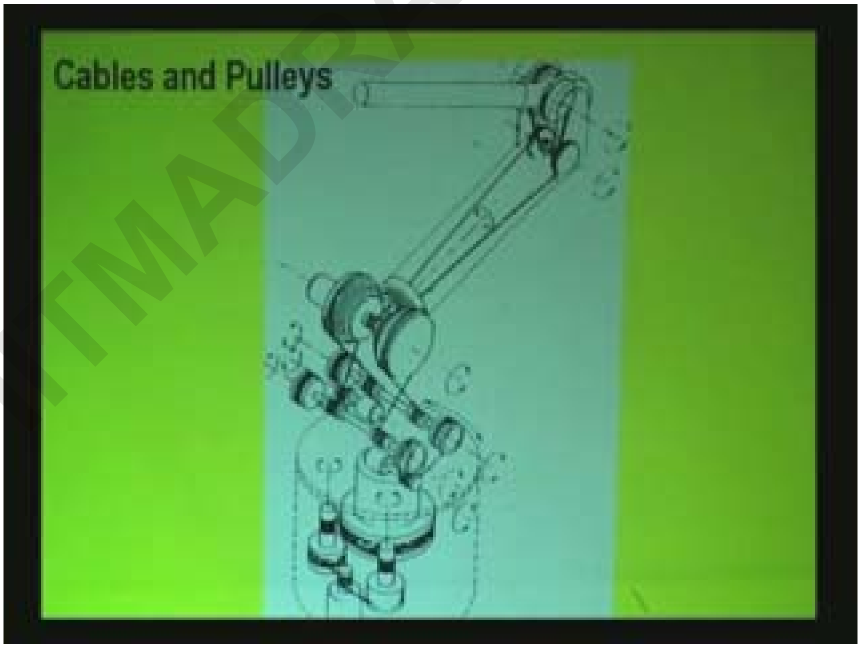


We can use linkages of the transmission motion this is some thing like your cycle brake you have the wire brake. Most of today's cycles have the wire brake, but if you see the older models there is series of linkages from the handle bar to the front wheel or the rear wheels, similar to the (???31:08). And you can keep the arm very free, or you can use cables and pulleys. (refer slide time: 31:12)



I had been telling you. You look at the complex figure, and using dies, cables and pulleys. The whole motion is transferred; the arm is seen. When you want move at very high speed like the scara robot I told for assembly,

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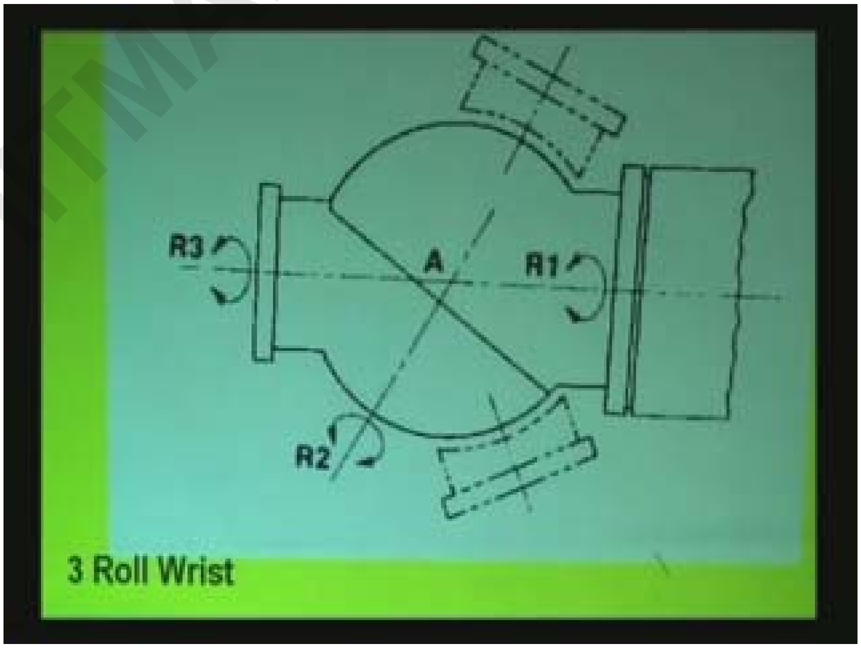
when it wants to move at very high speed, you need ideal motions of petting the path of petting the tool, use of geared drive will give rise to the (???31:38), and that may spoil the dynamic list of the dynamic of the system, nor allowing you, it won't permit you perhaps to touch very high speeds. So get rid of all those fluctuations in the velocities through use of smooth drives like a bell drive, or the rope and pulley drive. (refer slide time:31:59)

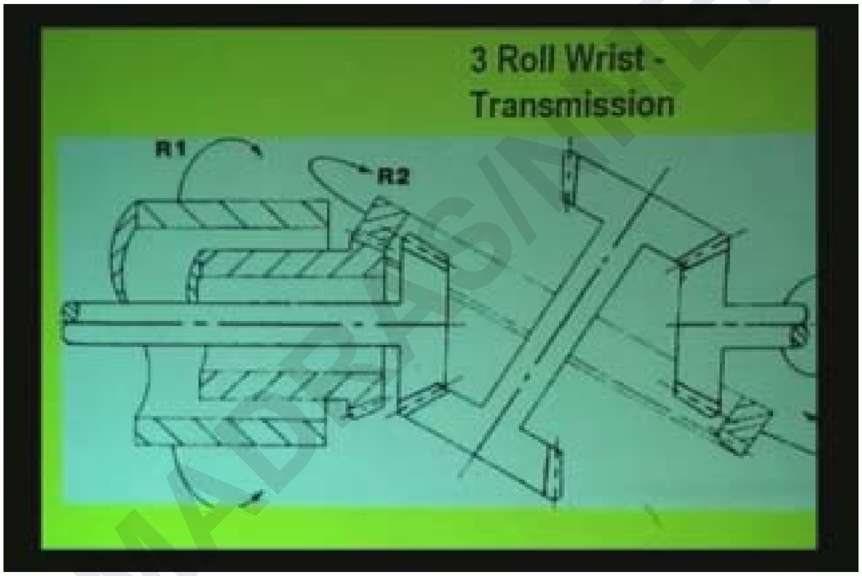
Now here we are using a linkage to get these things robot built. It's a typical planar robot. It could move at very high speeds. By the way the arm is built, the parallel arms move parallel to themselves, then some of the forces get canceled by the very nature of the various mechanisms used. The wrist motion, also, (refer slide time:32:26)



you (???32:30) try to keep it and transmit the motion to the wrist, to the tubes and the gears. Here is what is known as three roll wrist. So let as imagine a wrist as a ball and socket joint; the wrist is imagined to be a ball and socket joint, then there is an advantage in having a ball and socket joint.

We can position the object where you like and then you can orient the object, then do it with the conventional process, but there is an additional advantage. I would leave it to you to figure out if you talk about it as we go around along. But if all the three (???33:15) intersect at a point, and it effectively becomes a sort of a ball and socket, there is an advantage.

I will leave it to you to figure out what is that particular advantage and subsequently have a look at that advantage. So that is known as three roll wrist. You can see all the actions intersect. The three motions, R 1 R 2 R 3 as shown, they all intersect. (refer the slid time:33:40)



Here is the transmission, here, inside all tubes, one tube in the other, one tube in the other. Now this becomes very popular, okay? It becomes fairly popular. (refer the slid time :43:02)

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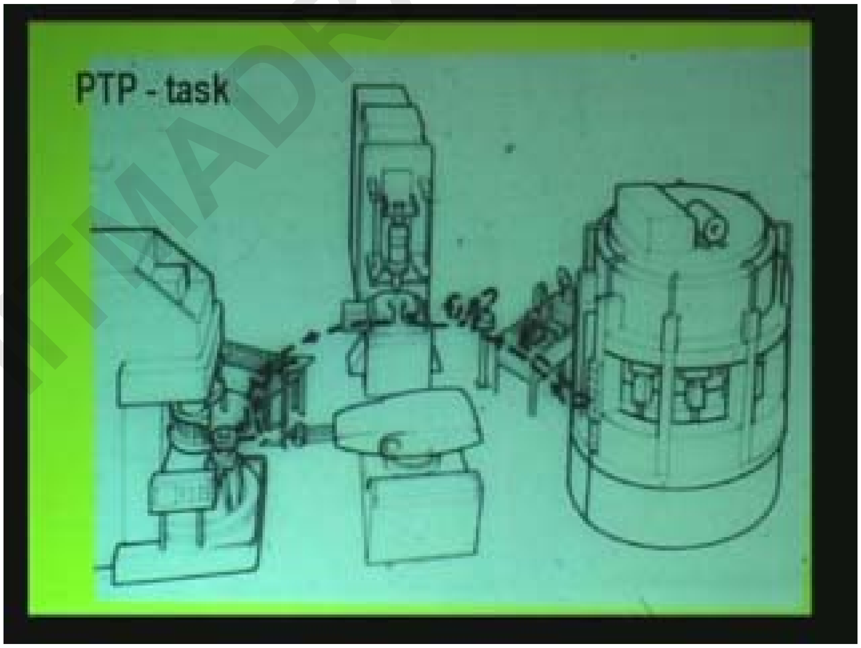
Now what are the tasks that these industrial manipulators are called upon to do? Before I go to the next class, next lecturer, where I am going to start discussing various concepts in robotics one should have a clear picture, because then I will be telling you when it does this task and that task and all that, one should have a very clear picture of what these things are. That's one of the reasons this lecture, why I am going a bit slowly on some of these (???34:29). The point-to-point tasks, (refer slide time:34:32)



essentially fixed, take up an object from one place and deliver it to another place. Most of the time, the object is fixed from a known location and delivered to a known location in

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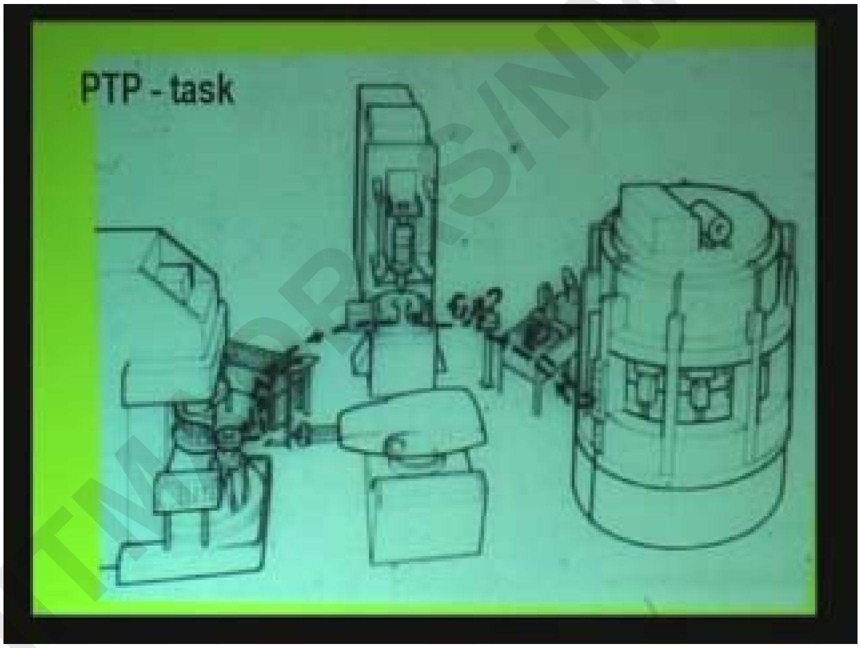
top floor. So, if you know where the two end positions are we call it the point-to-point task. We can see the robot is servicing three machines.

It is sitting in the middle, it is servicing three machines. It picks up an object from machine 1, or, delivers it to machine 2 at the specified location, in the specified orientation. I won't be using the words "specified orientation", it is implied.

When I say the object has to move from position a to position b, I won't say object has to move from position a and orientation a to position b and orientation b. There is no point. It is implied that orientation is specified at a as well as at b, okay?

You want something to be assembled. Is it sitting here? You want it be delivered here repeatedly, throughout the day. This position is fixed, as well as the orientation, here also the position. This is known as the point-to-point.Your interest is mostly in the two end positions and the orientation. You are not bothered as to whether the robot will move it like this or take it this way, right? This is known as the point–to-point task. You can see the robot is (???36:08). Typically in this, what it does is (refer slide time :36:11)



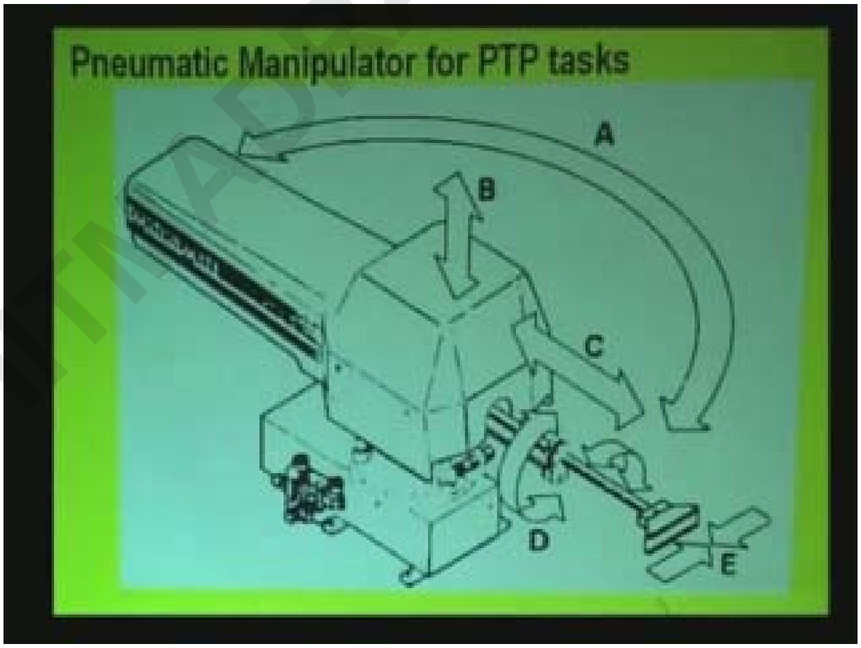
(???36:10) What you called convey an object, places it in the first machine, then goes the third machine, unless the third machine the job which has been worked upon there, puts it in the outgoing conveyor, then comes back to the first machine, or goes to the second machine, picks up the job that has been completed, loadas it in the third machine, then goes to the first machine, takes the job, loads it in the second machine. Typical; this is the way it keeps on doing throughout the day. It's a tedious job, obviously. Now, if you are doing this in a press, where a fifty ton or hundred ton press is working on sheet metal, punching holes in it, and the worker is supposed to load and unload that sheet, and if he puts his hand at the time the press comes down, many accidents have happened. That's a

hazard that's (???37:02). Or to load and unload diecast very hot metal. This is where this ptp task, is typically demanded, and they are used.
Now here you notice, the objective go from point to point. We are not worried about this. If there is a machine member here, or something else, you may have to go like this and keep it instead of going straight like this. So the robot must be trained or equipped to handle that, but most of the time

we know how the whole system is, we know what is on the shop floor, so it's easy. Many things one should, safety is very important here. Gripper design, I told you, the gripper is holding on to the object and moving very fast, if it loses it's grip on the object, the object could fly and injuresomebody.Secondly, the robot might have loaded machine 2, unloaded machine 3, and then it finds that machine 1 has not completed the task, simple switch(???38:08) whether the task is complete or not, the robot is waiting before it makes the next program to move. At the that time, instantly,

you decide go and see what the gripper looks like, and the robot suddenly moves. Accidents like this nature have happened, so safety is a very important aspect of robotics. Objects might be thrown away by the robot,

robot may move away suddenly, it is a programed motion, you can't blame it. It is doing it's job. It is moving in a programed motion, and you walk across and try to decide that is the time at which I want to see how the gripper works. So, safety is very important, and that is to be taken into account in all this. But use point-to-point tasks (refer slide time :38:49)



typically for a long time, the pneumatic manipulator. Most of the, when you say that Japan has the highest robot population, the majority of that population is pneumatic. You can see one of those pneumatic robots; you can see how many motions are there. There are 1 2 3 4 motions. The big arrows show the four motions A B C, okay?

These are the four motions, same thing, you know, the cylinders. For the rotary motion you convert the linear motion of the piston and cylinder in piston in a cylinder into a rotary motion through a rack and pinion or some such linkage. Now the gripper is usually not counted as an axis, the axis is only those motions

which serve to position or orient, not the gripping. That's not counted. Don't count it. So, whenever you look at a robot catalogue, if you hear the six axes, it implies that these are the six which serve, you know, help you position and orient the object. The gripper's motion is not counted because you can keep on. So, don't count it. You know this is a pneumatic robot, and

I told you yesterday, to control, you have pneumatic logic sequencing to control in the sequence in which you can move. You can move (???40:11) can be executed after B, okay? And C, and then D. This is the way put, or, you could have B first C, this sequence is decided by what is known as pneumatic logic, a small circuit, pneumatic logic circuit

which are available. You just have to, but there is lot of piping has to be changed, lot of pipe just like you have a bread-board, electronic bread-board, where you put the pipe you know wires, it is pneumatic logic,

you sometimes have to do some time piping work. Modern ones are all microprocessor controlled. Still, the older ones are here. So, through that piping, changing that logic, you can avoid an obstacle. So, let's say you are going from here to here, and there's an obstacle here,so you change the sequence so that you don't go and hit that. You move over from that obstacle, then execute (???41:06). So there are some limits, but they are accurate, because you know where it stops at the other end of the cylinder.

So, if you want they are (???41:15) on the piston rod you put some thing, and you can carefully adjust that so that you can always fix from this point to this. they move (???41:29), and as I told you they are not energetic. (Refer slide time:41:30)

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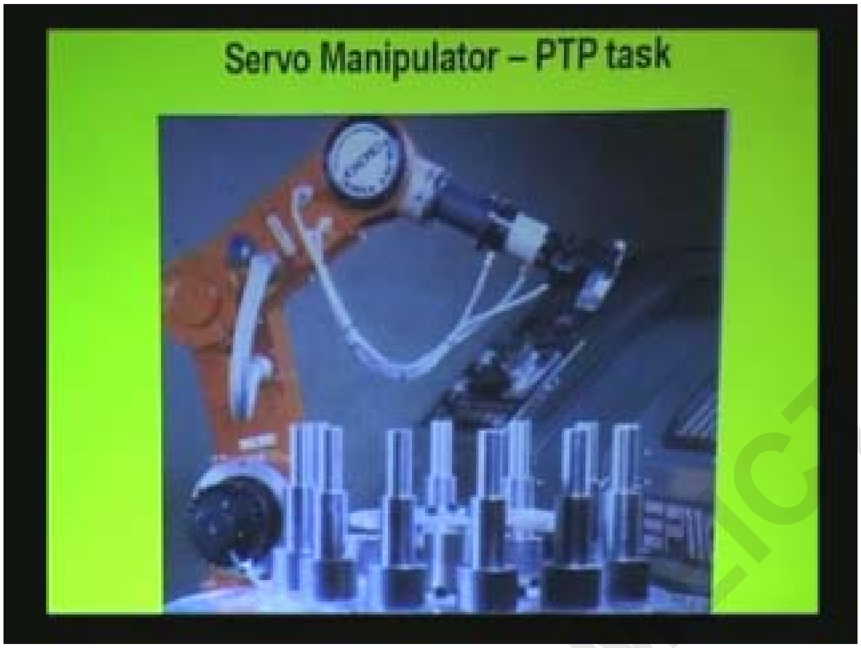

The servo manipulated is much more flexible. I can load this component today, I can have some other component being loaded tomorrow, because each component will demand a specific way of loading on to the machine. Some have the same way of the loading two components. Here is the servo manipulator, they articulate their arms, loading a lathe with those cylinders job.

Now you notice that the job which is waiting to be worked upon are loaded, are sitting on a circular table. The table might be indexing to bring the job into the specific position from the where the robot will always pick it up from that position the table rotates to bring the job.

So I have made sure that the robot starts (???42:25), it doesn't have to go around searching for the job. That enhances productivity. Even on a shop floor, you know, if you present the work, even a human being is working, if you present the worker the job at the specific place, you can work faster, you can do a better job. Now you can do painting. (refer slide time: 42:45)

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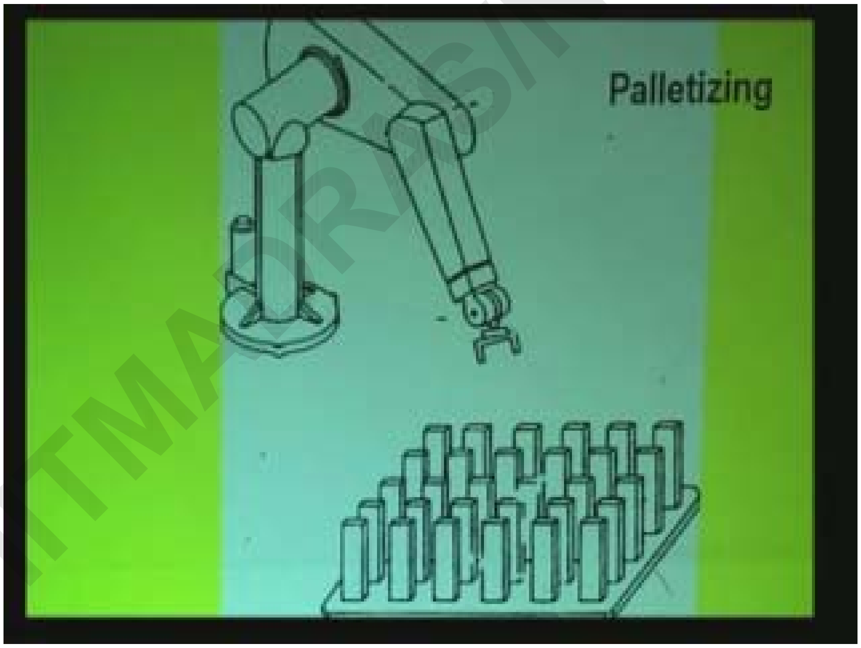
As you can see how the complex motions are required to articulate the arms okay? (refer slide time:42:53)



This is another task which robots are called upon: palletizing. You have a number of soft drink bottles, and then you want put them in their crate which is used to take them all over there. They pick up the first soft drink bottle, put it in the crate at the top left corner, the next one goes in to the next corner, like that. This is known as palletizing task.

If you have loaded and unloaded soft drinks in your for any party you will know (???43:27) Xerox. You put one here, than the next one here, the third one here. That's palletizing task. Robots are particularly useful for these palletizing tasks.

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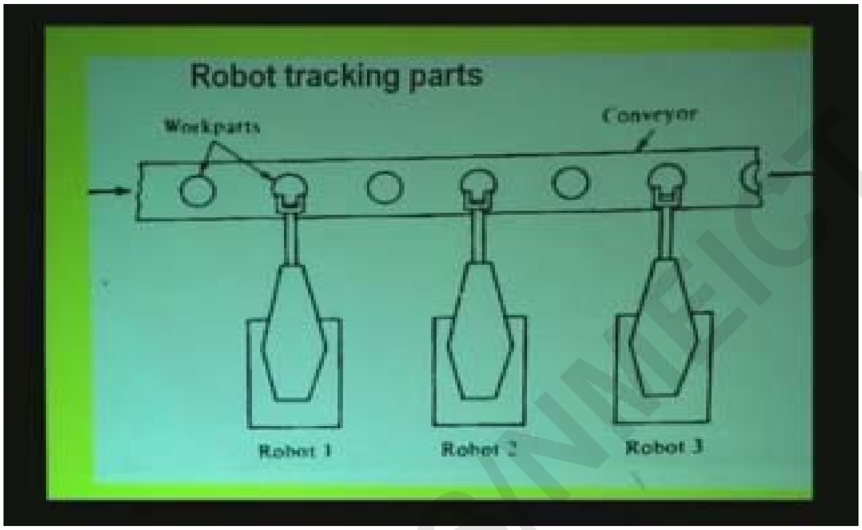
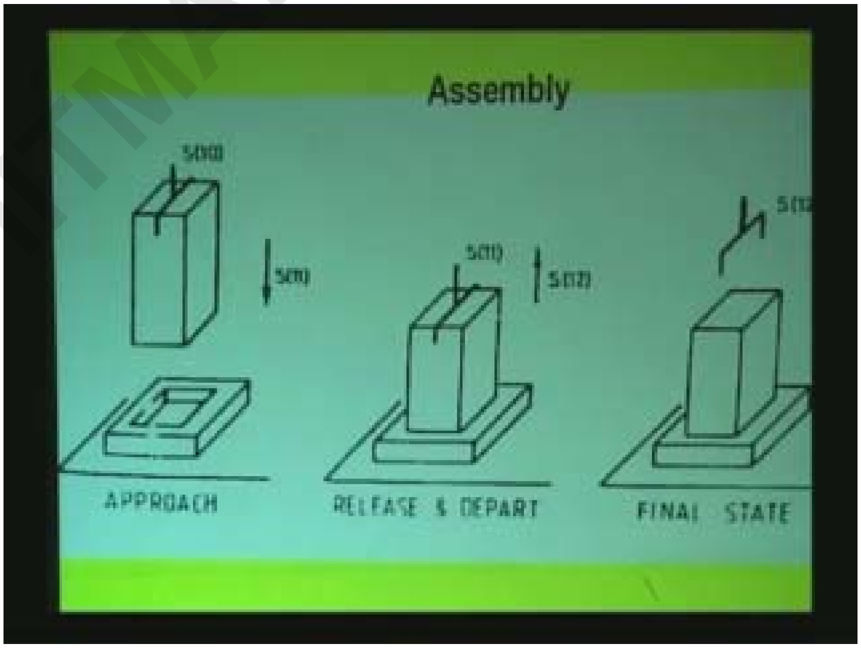
You can see that. Here are some of the special tasks the robots do, but all these are, the point-to-point task is one, the painting task defines the continuous task,

whereas in the palletizing, from one spot, you are taking the bottle and delivering them to several known locations. Many a time parts arrive on conveyors in a shop floor. We are continuously doing, the robot issupposed to pick it up. (refer slide time :44:04)



If you stop the coveyor, pick up the parts, that is one way. Not a very efficient way. Another way, you let the robot track the conveyor, that means, the robot moves in such a way, that all the joints move such a way that gripper moves at the same velocity as the conveyor, so that the rated motion between the conveyor, the gripper and the part is 0, and it picks up the part, or delivers the part, whatever. (refer slide time:44:33)



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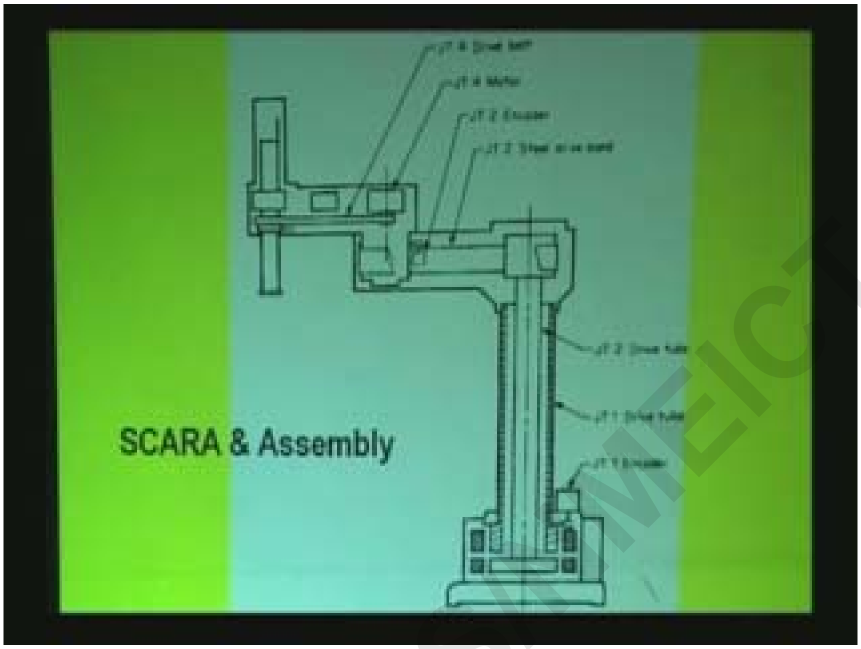
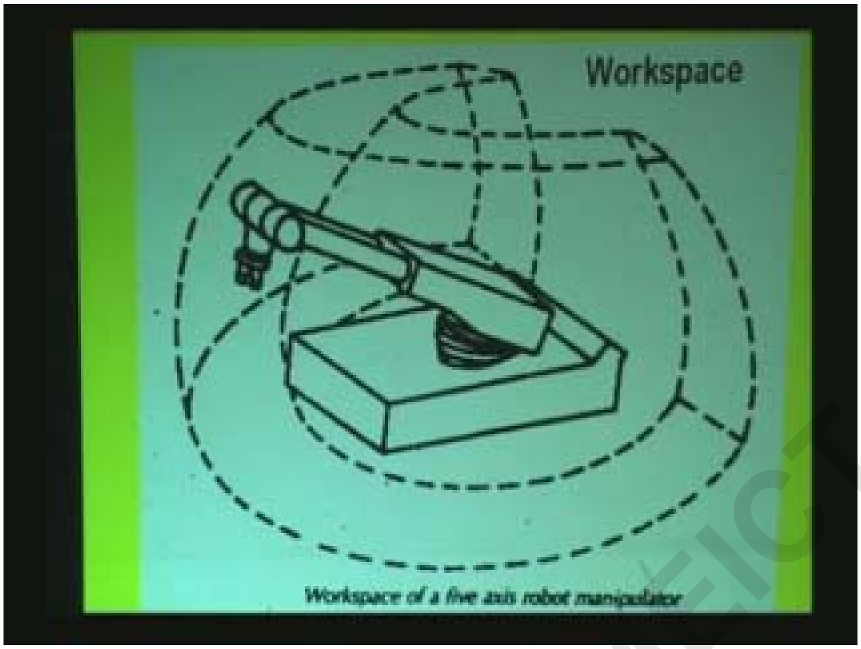
(???44:33) spoken is subsequently about this assembly task typically always that kind of whole assembly. You look at the assembly, any kind of assembly, can always be looked upon as the peg being pushed into a hole. All assemblies, more, majority of the (???44:55) (refer slide time:44:58)



I told you this is SCARA robot, so, taking advantage of that we build this robot, the bell drive (???45:09)
(refer slide time:44:10)

Now we come to some of the geometry concepts. Look at, (refer slide time:45:18)



we can see what is known as the workspace of the five-axis robot manipulator, because, you see, most joints in the robot, most axes, they do not rotate 360 degrees. Even your shoulder, or your elbow do not rotate 360 degrees.
The robot also does not rotate through 360 degrees. The base rotation is also not usually 360 degrees. So consequently, just as you and I have a limited reach when we sit on the chair, and we are trying to do a task, we cannot reach objects beyond a particular distance. Likewise, every robot has its own workspace.
46.06
You can see one of the workspaces (???46:06). It's a complex shape. This (???46:11) user would like to, okay? When I want to purchase a robot, or to service three machines, I should be able to know weather the robot can handle the explicit volume, work volume, you know move within that particular volume. So, the manufacturer is to give me
what is the shape of the workspace, and the dimensions of the workspace of the of the robot. So, this is very important. How do we determine the workspace? This is a very important question which we will be looking at. For the three-dimension robotthe task is not so simple, but we could look at some simple robots and try to figure out out how do we determine this. So, for a cylindrical robot, for example, the workspace will be a hollow cylinder. We call it a hollow cylinder. That will be the workspace. Ffor the polar robot, typically, the workspace will be spherical, hollow. We can work within that. (refer slide time:47:13)

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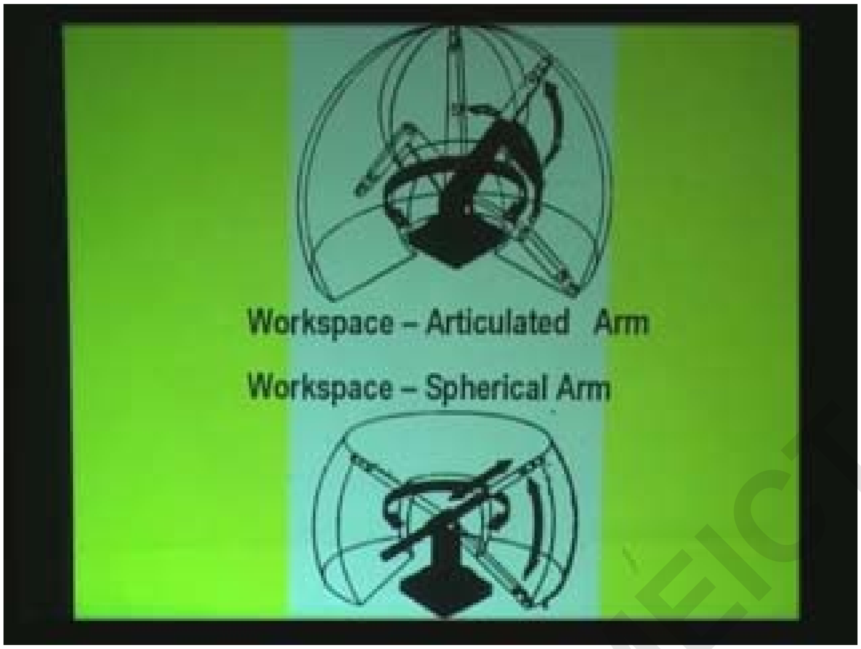

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Now, here are the, for the articulated arm, like the human arm, the workspace is a complex entity. We see that there, in the task. You can see that short of the spherical arm, mthe sphere you can see at the bottom, but at the top you see that the workspace is something different, okay? Now, the choice of the robot

we could like to use not only depends on the other factors I had mentioned, like you know, the dexterity which it promises, than the stiffness which we require depending on the object you are picking up, but also the workspace, you have look at the workspace. These are all peculiar things in the workspace that

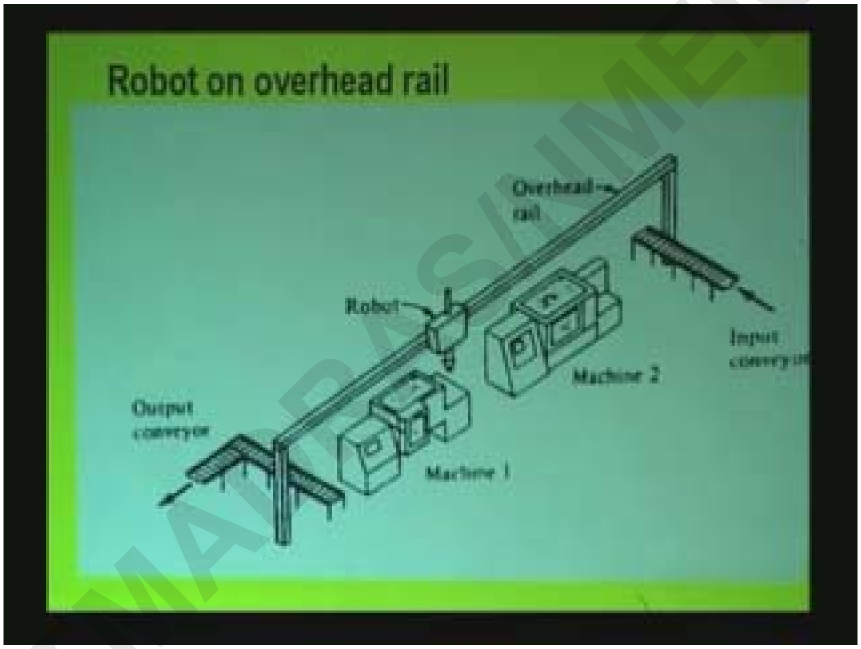
we have to know about. Can I position and orient an object anywhere and anyway I like inside the workspace? I repeat that: can I position and orient an object anywhere I like inside the workspace, throughout the workspace? Or, are there some restrictions from some portions of the workspace as I go to another portion of the workspace? There might be some restrictions. For example, what is the maximum reach

I have as I sit in this chair? Let us assume I am tied to this chair, reaching (???48:42). Now, if you give me an object and ask me (???48:47) here, something like like. this orientation somewhat is possible to some extent. Something like this is possible, okay? But then, my hand is a very, what you call device which has several degrees of freedom unlike the robot, which has fewer degrees of freedom.At this position you may find that in the robot there is only one orientation is possible. You cannot (???49:15) That means the position and orientation at some location may meet in a sort of dependance on each other, particularly at the edge of the workspace. That's why the workspace is important. You may(???49:28).You might say that okay,
if I can take it here it's fine; it is within the workspace, but you also have to see whether you have that ability to orient it (???49:38) additionally, or the rotations are not seen to be 360 degrees. So those restrictions have to be looked at by all of us as we go along.We

will look at it in a very simple way. People have tried to come out with how do I tell you what is the workspace, and how do I tell you in which percentage of the workspace there are certain limitations. How do I represent that (???50:01)? An engineer on the shop floor is not (???50:05)

you should know these things at a glance. (???50:09) look, this robot has this particular capability, and that was what (???50:15) This are the issues that we will be discussing as we go along and start looking at more and more at this area. (refer slide time:50:26)

In order to allow the robotics to work over a larger space, we can mount it on an overhead rail as I have shown here. That means we have added one more axis to the whole system, if not to the robot. The robot may be the (???50:40) robot (???50:42), as you can notice. (???50:45) servicing more than a few machines, mind you there is a difference between a wheeled robot going on this (refer slide time: 50:52)



Okay, because here, you have the whole thing guided along the particular strictly and guided, guided in a proper manner. You can improve and increase the work area, or you can change to more than one machine. That's what it is. The robot workspace will remain the same but now, (???51:14) (Refer slide time:51:15)

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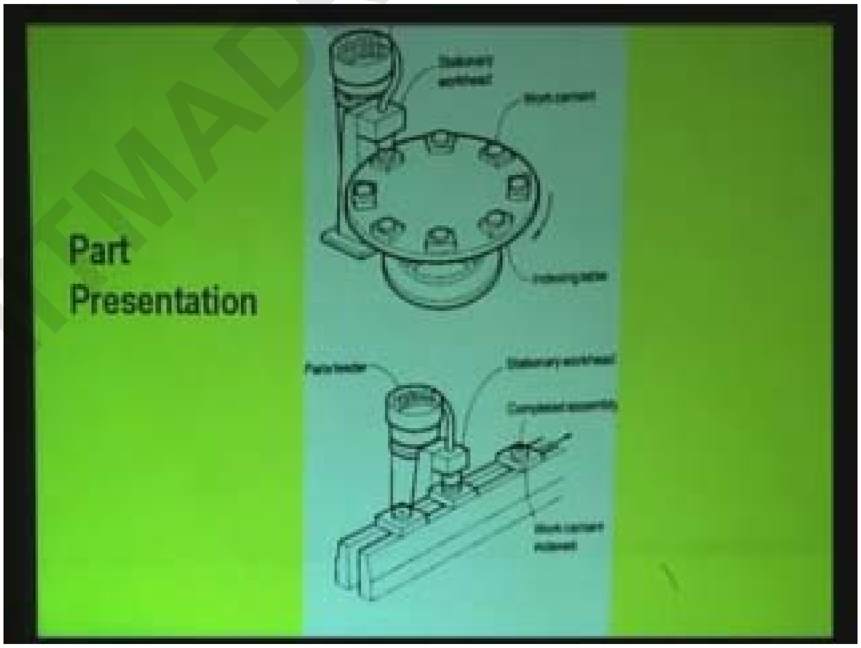
So, all this while we talked about industrial robots you can (???51:19) whether you want to put in some intelligence, what level of intelligence you would like to put, and all this things. Let us look at this. As I told you, in the point-to-point task, for example, it picks up an object from one positionand keeps it there.We have to present the part to the robot. If you want, other, you may say why don't I put a camera there, sense the part, and then ask the robot to pick it up. Fine. But then this will take some time for the camera to (refer slide time:51:48)



look at the part, decide what the part is, sense it, find out it's location, then transmit that data to the robot and tell it to move over to that position. (???51:59 that on the shop floor

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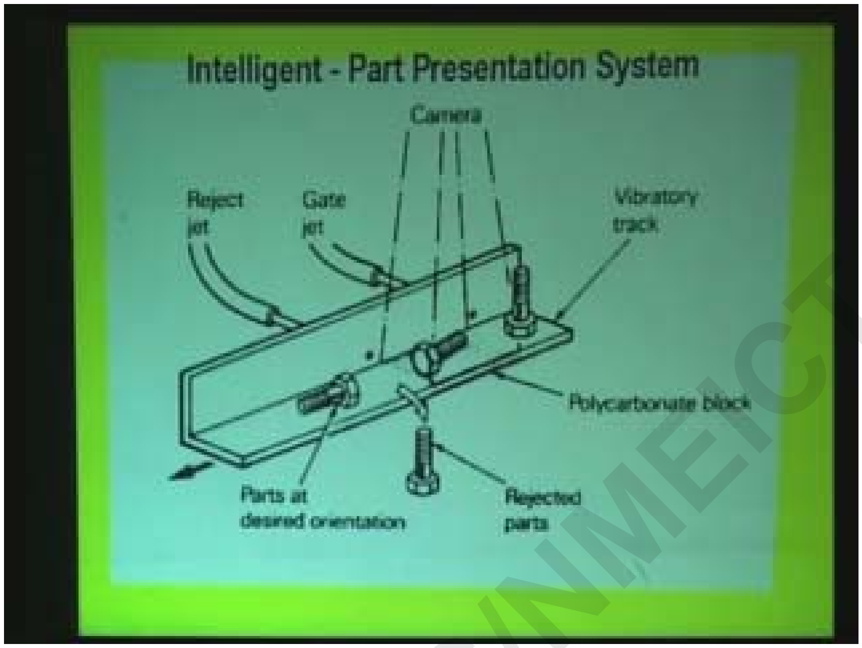
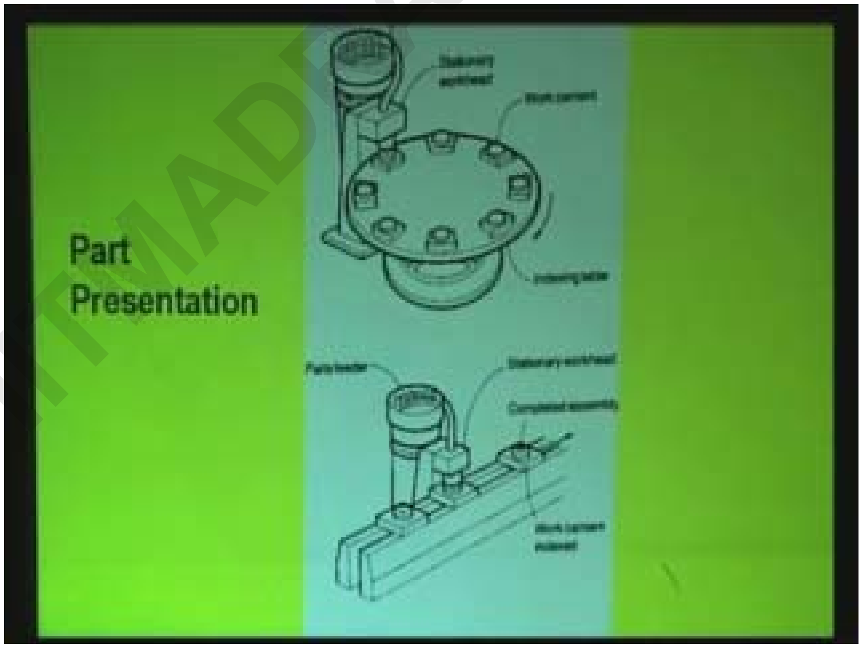
they try to, what you call that increase the, they try to increase everything, the productivity, by presenting it wrongly. The job is presented to the robot (refer slide time: 52:18)



properly. So, many a time, (refer slide time:52:21)



the application engineer finds that the presentation systems are more expensive than the robots. When I say presentation, not only the position of the job must be specified, but also it's orientation, both. So, (???52:38) part presentation systems are innumerable

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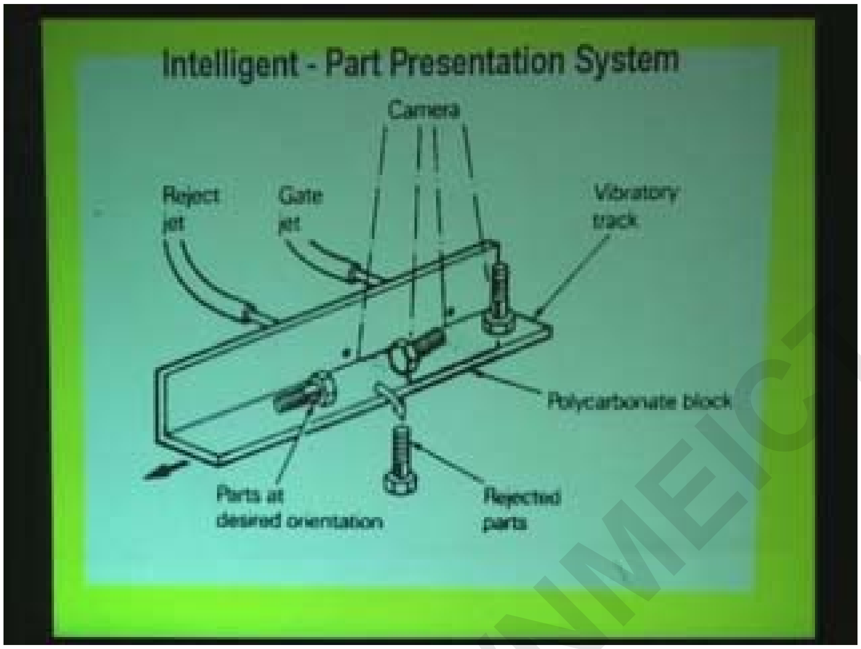
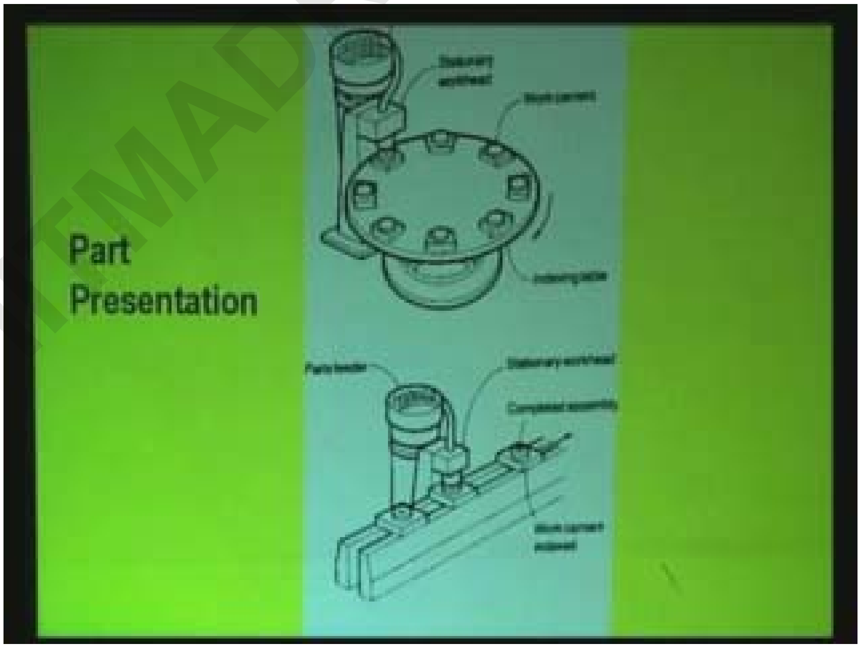
(???52:41) which brings the part, orient it the way you want, and then bring it to (???52:49) (refer slide time :52:48)



the robotics can pick it up. Usually, we would requirethis at the first stage, because when it goes to (???52:56), it is properly loaded with the proper orientation. Then when it is unloaded, it is again positioned properly for the next stage. So, at the very first stage is where you typically require this part presentation. (refer slide time:53:06)



This is very important. Many a time the practicing engineer doesn't budget for the part presentation system, and finds that the part presentation system is more expensive than

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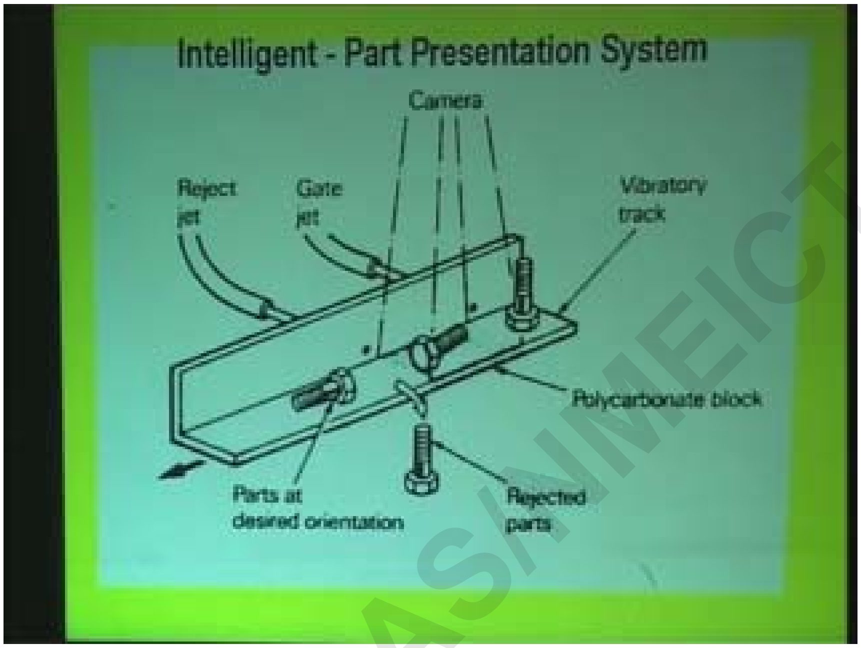
the robot. Now part presentation system, typically, we will have a communication with a robot.. So yesterday,

when I showed you that movie, I told you that the container was sitting on a little limit switch, and only then the robot started. That means that somebody has to place it there, otherwise there is know job that the robot needs a (???53:40) (refer slide time:53:43)



you could have intelligent part presention systems also. No. Unless the part is in a specific orientation the jet of air will throw it out (???53:53)

So, I have just given you an overview of industrial robots, and what they are capable of, what they can do, what is expected out of them. In the subsequent lecture, we will discuss a few concepts and a few principals, or a few, what you called as simple concepts to help you understand what will come further down when we go deeper into this subject.

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