Robotics: Basics and Selected Advanced Concepts

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Lecture - 01
Introduction to Robotics, Science and Technology

Welcome to this NPTEL course on Robotics: Basics and Advanced Concepts. In this week we will look at some Introduction to Robotics. We will also look at some of the Science and Technology which go behind robotics. So, in the first lecture I will give you a little bit of introduction to the field of robotics, little bit of history, the type and classification of robots.

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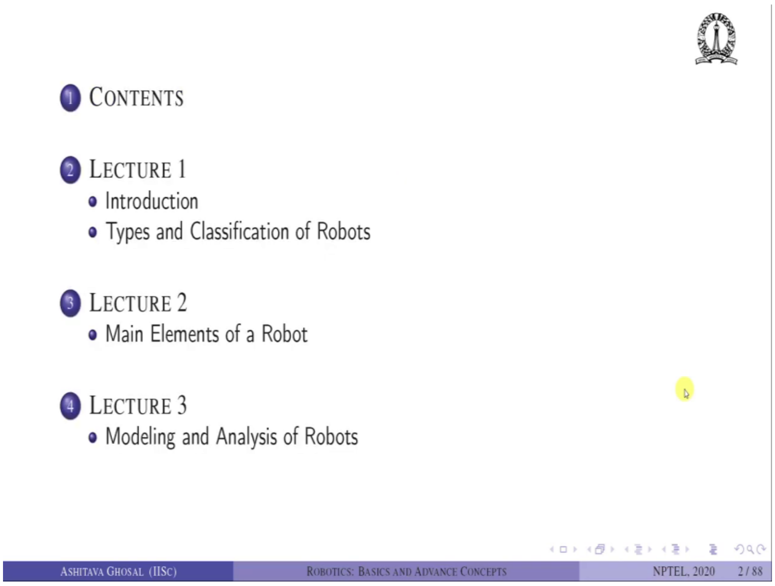

In the second lecture we will look at the main elements of a robot; the main mechanical elements and the sensors and actuators which go into making a robot. And in the last lecture we look at what are some of the tools used for modeling and analysis of robots.

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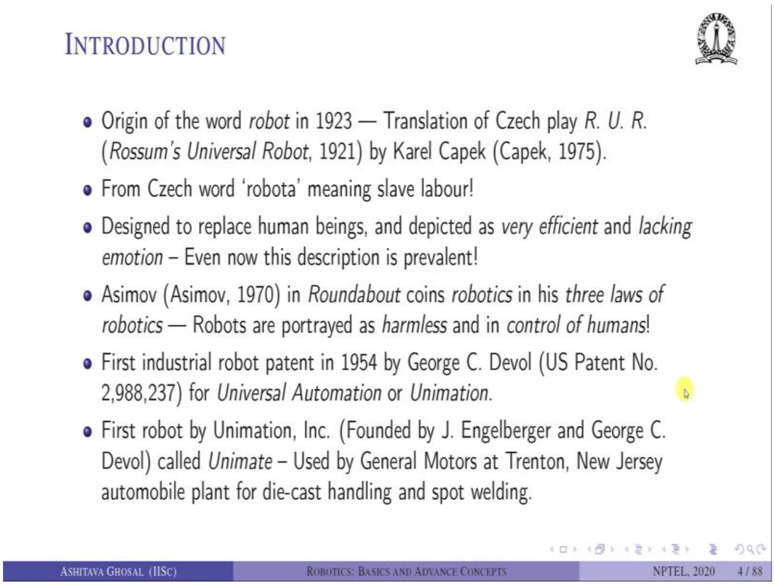

So, introduction: The origin of the word robot is in 1923, it is basically a translation of a Czech play called R. U. R which is Rossum's Universal Robot in 1921 by Karel Capek. So, this appeared in an article by Capek in 1971. So, the word robot is from the Czech word 'robota' meaning slave labor. So, in the play it is shown that robots are designed to replace human beings and depicted as very efficient and lacking emotion ok. Even today this description is very prevalent.

In 1970, Asimov wrote or coined the word robotics in this book or article called *Roundabout* and he proposed three laws of robotics and in his portrayal of robotics these are portrayed as harmless and in control of humans ok. So, there is three laws of robotics are very well known. So, things like a robot cannot harm a human being ok, a robot must protect the human being and so on ok. So, he wanted to make robots much more human friendly.

The first industrial robot patent is in 1954 by George C. Devol. So, this is a patent number 2,988,237 and it was called as *Universal Automation* or *Unimation* ok. The first robot was developed by a company called Unimation, Inc. It was founded by Engelberger and Devol ok, the same person Devol who patented universal automation and they called it Unimate ok.

So, this robot was used in a General Motors plant in Trenton, New Jersey ok. It was an automobile plant. This robot was used for handling die cast material and for spot welding.

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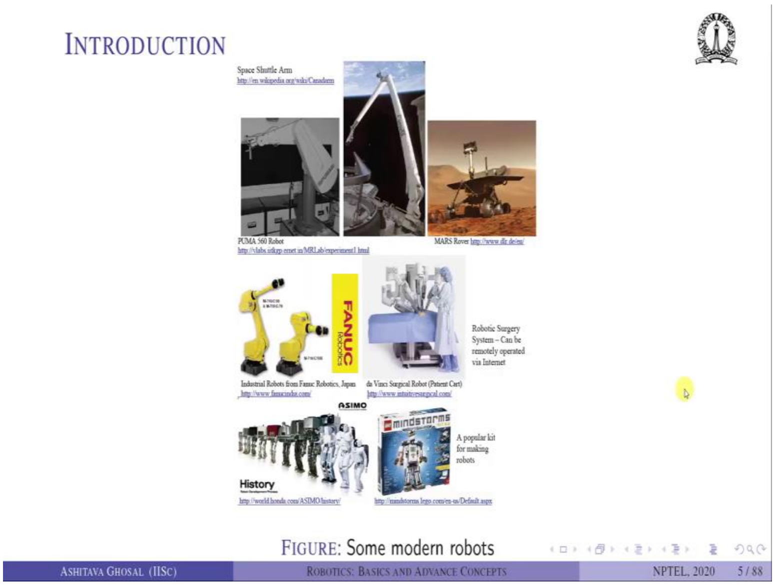

So, there are many many examples of robots and there are many modern robots. I am showing you a few in these pictures. So, for example, this is the very well known PUMA 560 robot. This PUMA 560 robot appears in all textbooks because all the geometry and parameters of these are known and we can do analysis and modeling of PUMA robot very well ok. So, this is used to teach robotics, kinematics especially.

The you also have this very well known space shuttle arm ok. This is a very lightweight flexible robot which was put on the space shuttle and it was used to deploy and retrieve satellites. You also have a mobile robot which is on MARS which is roaming around on Mars (Refer Time: 04:18). Then there are these well-known industrial robot companies ok. So, there is Fanuc is one of them ok. It is a Japanese company.

And they make this huge line of robots many many robots they sell lots of robots around the world for the industry. We also have robots which are now used in surgery. I will show you a video. So, this is that well-known da Vinci surgical robot. We also have robots as humanoids ok. So, there is a robot which was developed by this Honda company it is called ASIMO ok.

So, it is a humanoid robot which is smaller than the human beings, but it has many many features like it can walk, climb stairs and so on. There are also robots which are now available as toys which are used by children ok. So, you can build your own robot and this company is called Lego Mindstorm, it is very well known.

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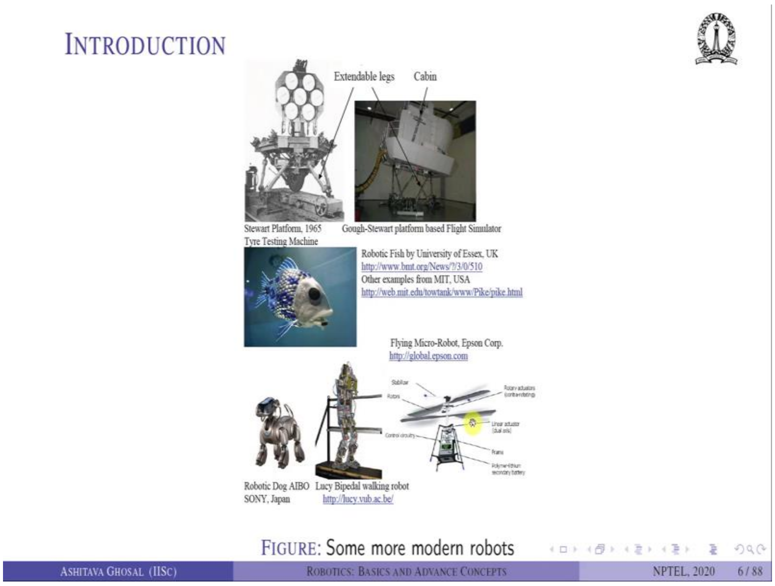

There are also other very famous robots. One of them is the Stewart platform ok. So, this was originally developed for tire testing ok. However, nowadays the Stewart platform is most often used in flight simulators. So, basically there is a cabin in which there are video screens and there are on the there are some joysticks and controls.

So, as you move the joysticks, so, there are these legs which can extend ok. So, if you have these 6 legs you can count there are 6 of them. As you extend or retract these legs this cabin can go up and down in xyz directions, all three directions and it can also do roll, pitch and yaw. So, a person sitting there can be trained to fly an aircraft by using all these video screens. There are also these nowadays new robots which are used for exploring underwater.

So, this is a robotic fish which has been developed in various universities. So, for example, MIT have worked on a lot on robotic fishes. There is also this toy dog developed by SONY in Japan. Then there are these bipedal walking robots ok. So, they walked like human beings. They have been proposed to be used in space and on surface of moon and mars and so on.

And then there are these flying robots; these are called drones ok. So, you can have a robot with some actuators which are basically propellers several of them and then you can go and fly and reach many places ok.

So, these have become very very popular nowadays because you can control these drones for large number of applications. You can go over forest, you can go over agricultural fields, you can go to places which is not so, easy for human beings to go and it can take pictures of that area.

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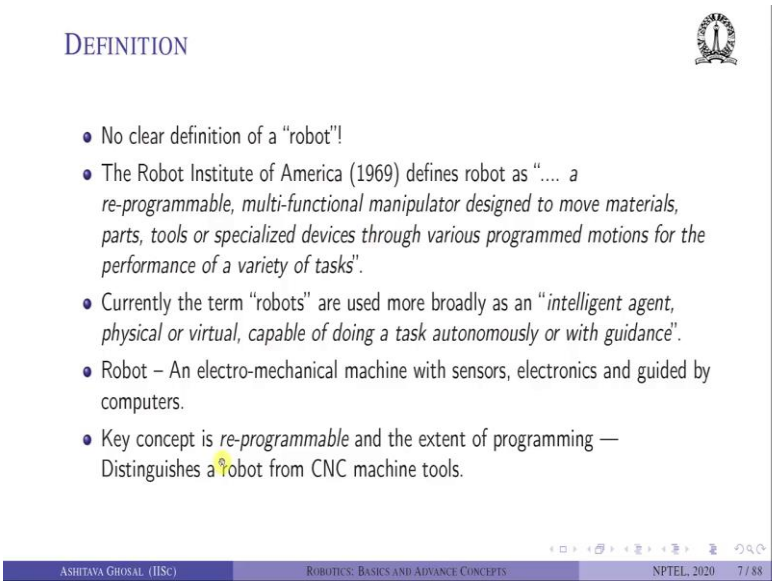

So even though there are so many different kinds of robots clearly there is no uniform or a single definition of a robot. So, the best possible definition is by Robotics Institute of America, it is a little bit historical nevertheless it is worthwhile noting how it was defined in 1969 ok.

So, a robot as defined by Robotic Institute of America ‘is a re-programmable multifunctional manipulator designed to move material, parts, tools or specialized devices through various programmed motions, for the performance of a variety of tasks’ ok.

So, all these words are important re-programmable, multifunctional, designed to move materials, parts, tools and so on. So, it is a little bit bias towards use of robots in industry nevertheless it is a very useful definition to keep in mind. Currently the terms ‘robots’ are used much more broadly ok. Some people call it intelligent agent some people can even say physical or virtual; it can be a virtual robot and it is capable of doing tasks autonomously or with guidance ok.

So, for our purpose a robot is an electromechanical machine with sensors, electronics and guided by computers ok. The key concept above in this definition which is still valid is that a robot is re-programmable ok. And what do we mean by re-programmable? A robot can do a variety of tasks ok.

So, it is much more programmable than a CNC machine tool. So, CNC machine tool can cut or mill or do various things, but the robot is much more flexible. It can do painting, it can do welding, so, variety of tasks; it can do material handling and so on. So, this word 'reprogrammable' is still valid and very important.

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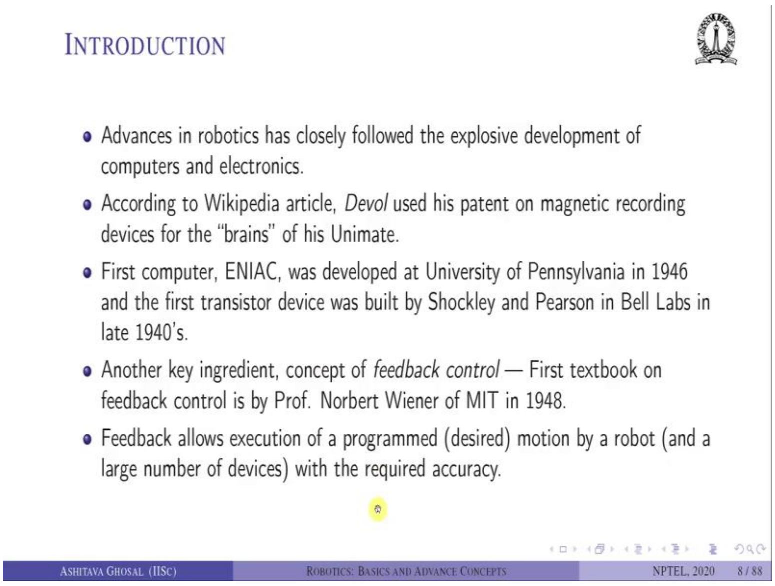

The advances in robotics has closely followed the explosive development of computers and electronics ok. So, according to Wikipedia according to a Wikipedia article Devol used his patent on magnetic recordings devices for 'brains' of his Unimate. So, this was the first robot which was built in sold ok. And in order to program them or reprogram them he used this magnetic recording devices.

The first computer ENIAC was developed at University of Pennsylvania in 1946 and the first transistor device was built by Shockley and Pearson in Bell Labs in 1940s ok. Both of these are very very important dates in the history of robotics ok. So, without these computers and without this transistor a lot of modern devices are not possible, are not so easy to make also.

Another key ingredient in the field of robotics or in the history of robotics is this concept of feedback control ok. The first textbook on feedback control is by Professor Norbert Wiener of MIT in 1948, ok. So, we will see that feedback allows execution of a program which is a desired motion by a robot and a large number of devices you can do program many other devices with the required accuracy.

So, I want a robot to do some tasks ok. Let us say I want to weld ok, but how do how do you make sure that it welds accurately? So, this whole notion of feedback is used to make sure that it performs the desired motion with reasonable accuracy.

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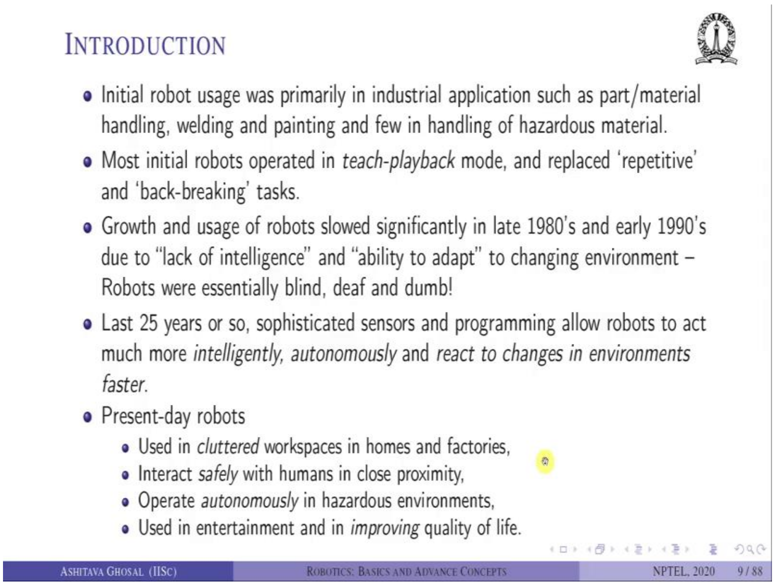

So, initial usage of robot was primarily in industrial applications such as part handling, welding, painting and a few in handling of hazardous materials ok. So, the initial die cast piece which was handled in this General Motors plant was very very hot. So, it is sort of not so easy for human beings to handle this object which is coming out from a die casting machine ok.

Most initial robots operated in this support teach-playback mode and replaced repetitive and back-breaking task ok. So, what is teach-playback mode? So, basically you teach the robot to do a set of tasks, you record the motion of the joints, you record the motion of the various parts of the robot and then you take it to the factory and then you play it back. So, it will repeat what you did earlier or what you trained or taught earlier. And the advantage of this is it can replace all this repetitive and backbreaking tasks ok.

So, if I want to do straight line welding a spot welding thousands of times in a day, I do not want that human being to do this repetitive task, a robot is much suit better suited for doing this task. Similarly, if you want to lift large weights it is much more easier for the robot to do ok.

So, growth and usage of robots slowed significantly in the late 1980s and early 1990s, ok. So, these robots which were basically in teach and playback mode. After a while industry saw that they were not that useful and it turned out that it is due to the lack of intelligence and ability to adapt to changing environments ok. So, robots before this 1980s were essentially blind deaf and dumb ok. So, you can teach a robot to do welding, but if the two parts are not there it will weld in air and it is wasteful.

So, in the last 25 years or so, sophisticated sensors and programming allow robots to act much more intelligently, autonomously and react to changes in the environments much faster ok. So, again robotics is a very hot topic. There are lots of robots which have been developed and importantly they are more intelligent, they are more autonomous and they can react to changes in the environment ok.

So, we have self driving cars for example. In a sense that is a robot, it can react to a passenger or a person coming in front of the car or some other vehicle coming in front of the car, so, it can stop. So, it can react. So, again this robotics field is catching on. Present day robots are used in cluttered workspaces in homes and factories ok.

So, once very well known robot nowadays is this vacuum robot ok. So, it can go around vacuuming your room or your house and it will work in this cluttered environment of your house because it has table, chairs various things ok. So, it can learn where this obstacles are and it will learn how to avoid them. It can safely react with or safely interact with humans and they can be in close proximity.

So, basically a robot can make sure that you do not hit the human. So, there are robots called Cobots which basically a human being and a robot will work together for a certain task. The human being will be doing tasks which it is better at doing and the robot will do some tasks which it is better at doing ok. So, even now human beings can do very precise tasks, whereas, robot precision levels are not that high. It can operate autonomously in hazardous environment.

So for example, this mars rover is roaming around in mars taking pictures taking, soil samples analyzing various things and it is also being used in entertainment and in improving quality of life ok. So, these are some of the modern present day usage of robots.

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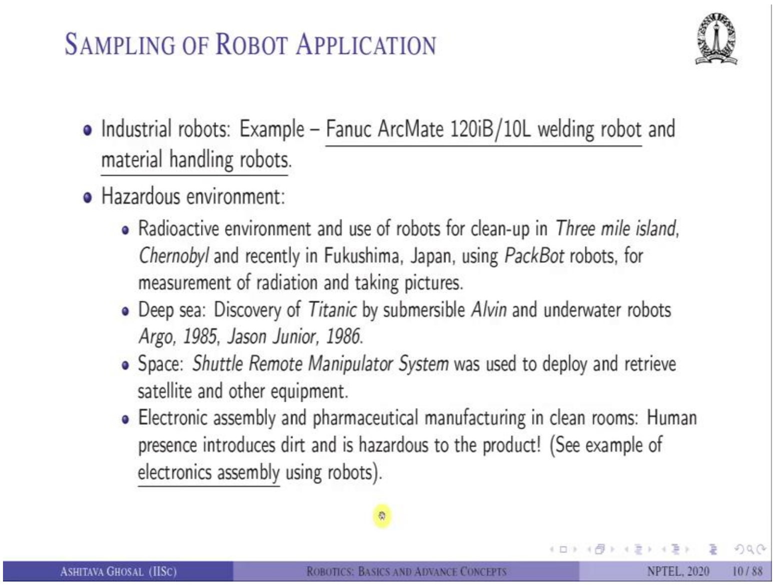

So, let us look at a few robotic applications. So, first was this example of a Fanuc arc welding robot ok. I will show this video after this two slides. We can also have robots which are in hazardous environment. So, for example, in the Three Mile Island and the Chernobyl accident robots were used to clean up this nuclear power plants.

Recently in Japan, there are robots called PackBots robots which were used to measure radiation and taking pictures inside that plant which exploded ok. We also have robots which are used in deep sea very very deep. So, for example, the Titanic ship was photographed by this submersible Alvin and underwater robots Argo and Jason Junior ok, it was discovered in 1986.

We also have this space shuttle remote manipulator system. So, basically it is happening in space and this was used to deploy and retrieve satellites and other equipment. We also have electronic assembly and pharmaceutical manufacturing in clean rooms ok. In these situations, the human presence introduces dirt and is hazardous to the product.

In the first three it was hazardous for the human being to be in that environment. If you want to go in a very very clean room it is best to send a robot because the robots will not be breathing and sending out particles. I will show you one video of electronic assembly.

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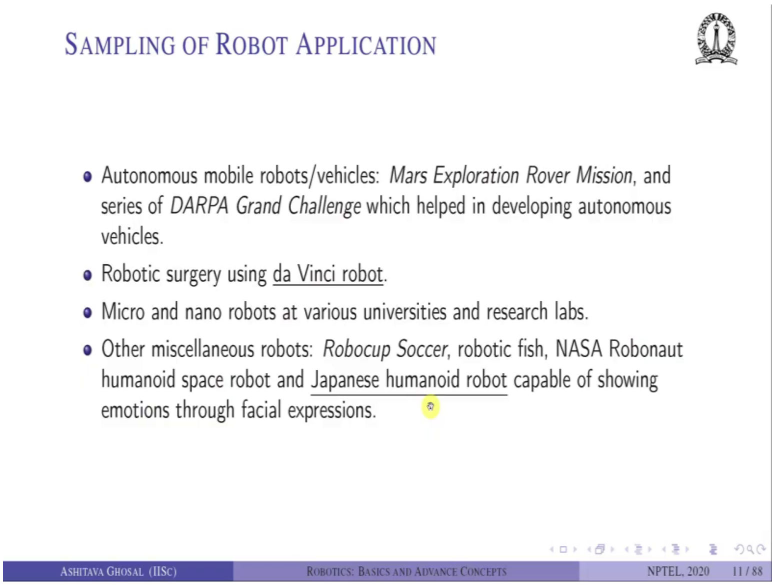

You can also have very well known autonomous mobile robots and vehicles ok. So, there is this Mars Exploration Rover Mission and more very more importantly they were this DARPA Grand Challenges in developing autonomous vehicles. So, DARPA the US Defense Agency said that if we should be able to travel so many kilometers in the desert or in some other place autonomously without intervention by human beings.

So, you would have cameras, you will have lots of sensors which will make sure that you traveled in this you know terrain autonomously. And many of these technologies which were developed during this DARPA Grand Challenge are now finding in this self driving cars ok, which are becoming more and more popular. There is also this robotic surgery using a da Vinci robot. So, I will show you a video.

One of the advantage of a da Vinci robot is that it can be very very accurate and it can be remotely located. So, I could be doing surgery sitting in ones place, but that patient is far away because I can send the signals using this computer networks and then the robot there will do the surgery ok.

So, we can do remote surgery and also very accurately ok. There are many other advantages. So, for example, a robot can remove tremors. It can scale up or down the motions of the surgeons hand ok. You can see very clearly the area where you are doing surgery and so on. There are also this micro and nano robots which have been developed at various universities and research labs ok.

So, we would like to send a very small robot into your body to go and let us say remove some samples for later on biopsy or some other reason or we want to take some measurements. So these should be very very small robots. So, these are micro and nano robots ok.

Then there are this miscellaneous robots which I call miscellaneous, but very interesting. So, for example, there is a Robocup Soccer tournament. So, basically you have to build the robots which can play soccer and following the rules of soccer.

There is this robotic fish there is a robot which has been made by NASA, it is a humanoid robot which will go into space for exploration of space. And then there are these Japanese humanoid robots which have been developed which can even show facial expressions and emotions. So, I will show one video of this later on.

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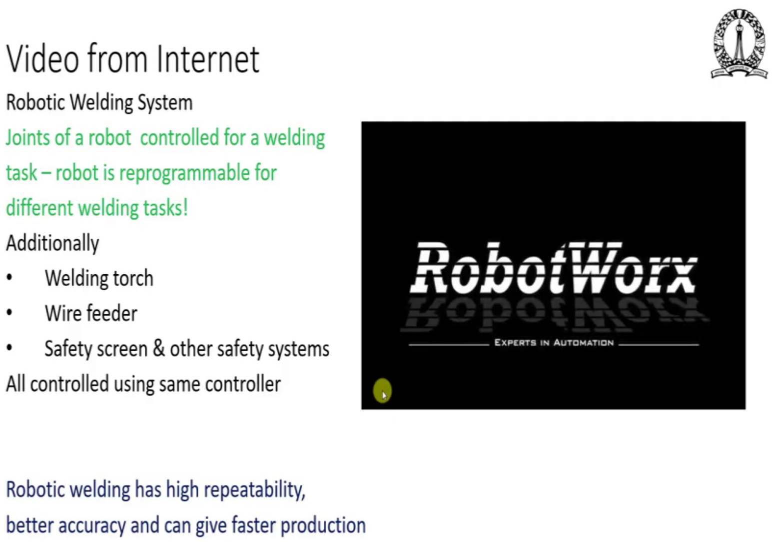

In the next few slides, I will show you some of the common applications of robots ok. So, some of these slides are from the internet. So, I will show you a robotic welding system, a robotics material handling system, a robot which is used in a clean room environment and then two sort of newer applications. One that have robotic surgery and one a robot which can show facial expressions and are being planned for used in service sector ok.

So, let us start. So, in this first slide I am going to show you a robotic welding system, this is from the internet ok.

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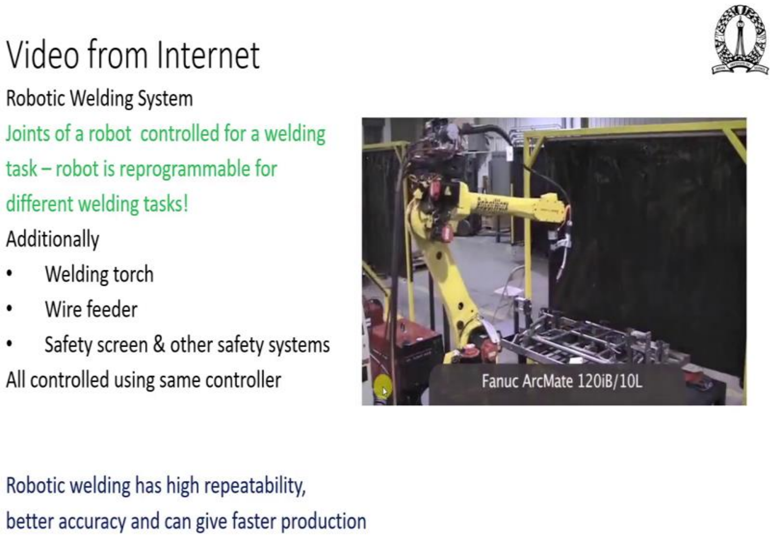

So, what you can see is a robot which is manufactured by Fanuc. It is very well known, it can do arc welding.

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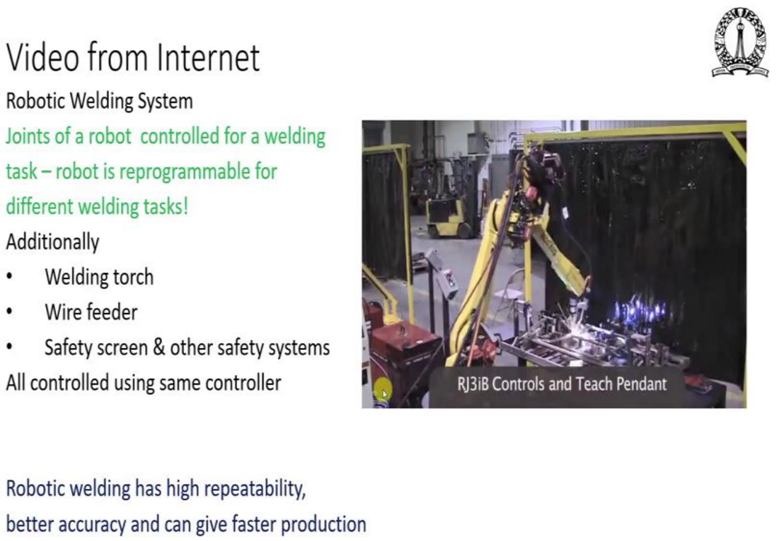

So, the joints of this robotic are controlled for welding tasks and clearly the robot can be re-programmed for different welding tasks.

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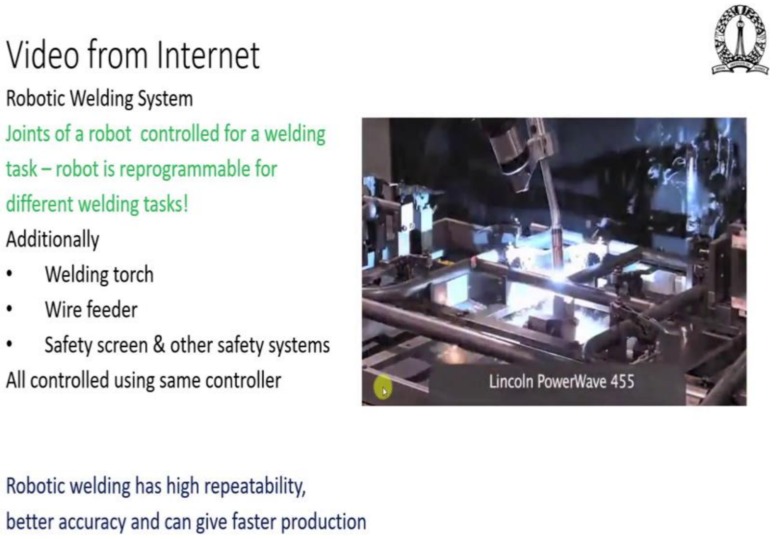

So, this welding is very very common in automobile industry where you want to weld certain (Refer Time: 21:24) automobile components. So, as you can see here the robot is moving the welding torch along the pre-program path.

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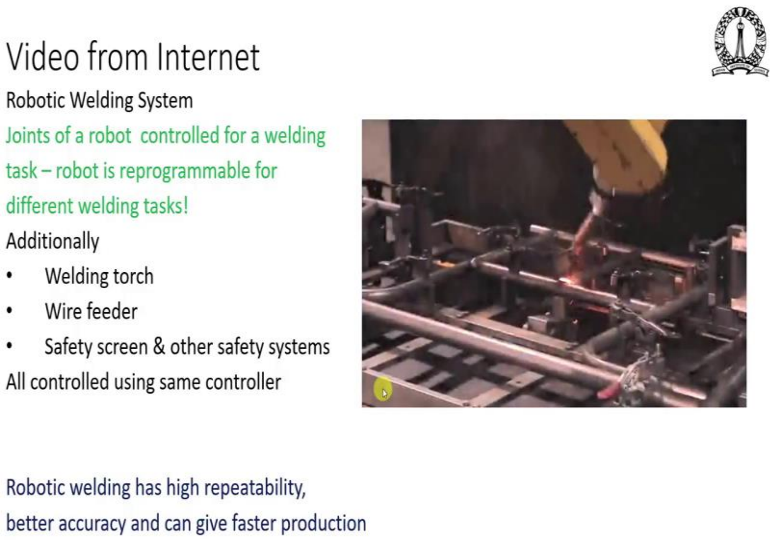

Secondly, it will also control the a wire feeder which will push in the wire which is used in welding. It also controls the safety screen and other safety systems. So, you initially you could see that there was a black curtain which went in front and at the end of the welding you will see that the black curtain is going back. So, all these things are controlled by the same controller. So, they are synchronized.

One of the advantage of robotic welding is it has very high repeatability, it gives better accuracy and it can give faster production.

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The next video is on robotic material handling. This is a robot which is made by Adept. It is a SCARA robot ok. It comes with the vision system.

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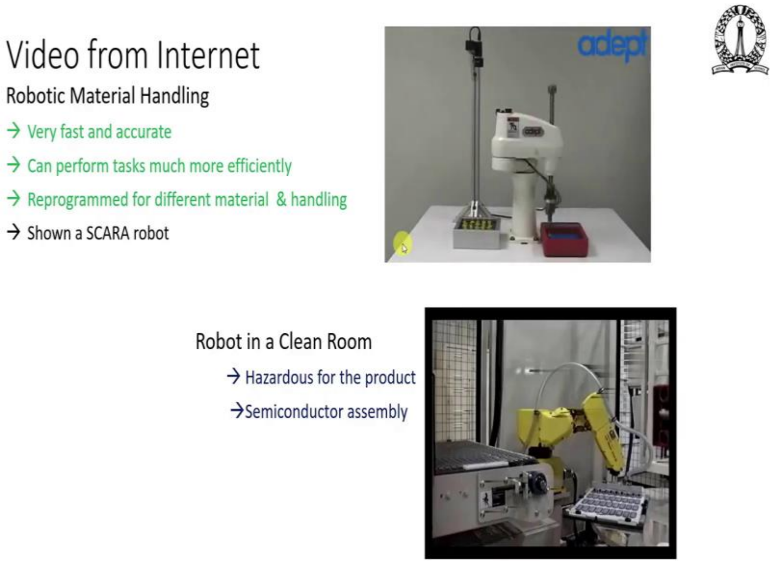

And as you can see it can move very fast and pick some objects from one place put it in another place. It can perform these placement picking and placing tasks very very accurately.

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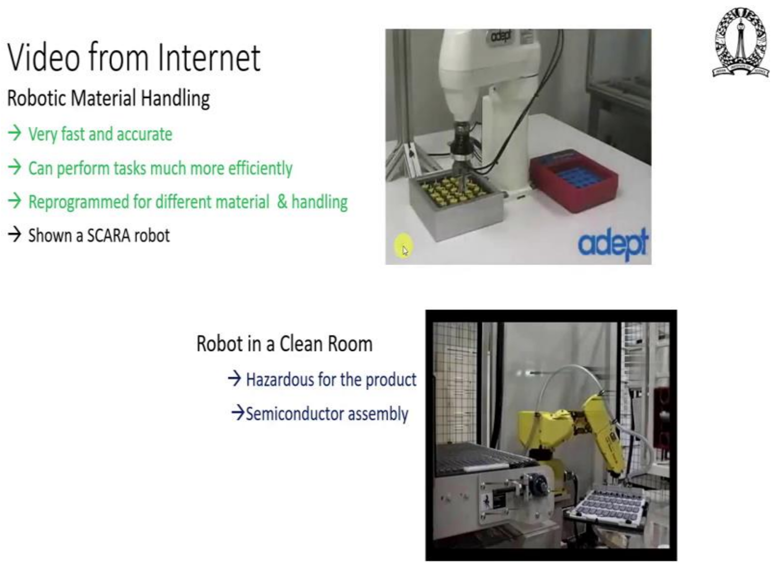

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It can be reprogrammed for different materials and different kind of handling, it is a SCARA robot. So, basically it has 4 degrees of freedom. So, the end of the pick can move in x y plane, it can also go up and down in z motion and it can also orient the tool or orient the part which it is handling about the z axis.

So, this is a very well-known robot that is that is been for the long time and it can move very fast and very accurately. Typical speeds of this robot could be more than one meter per second.

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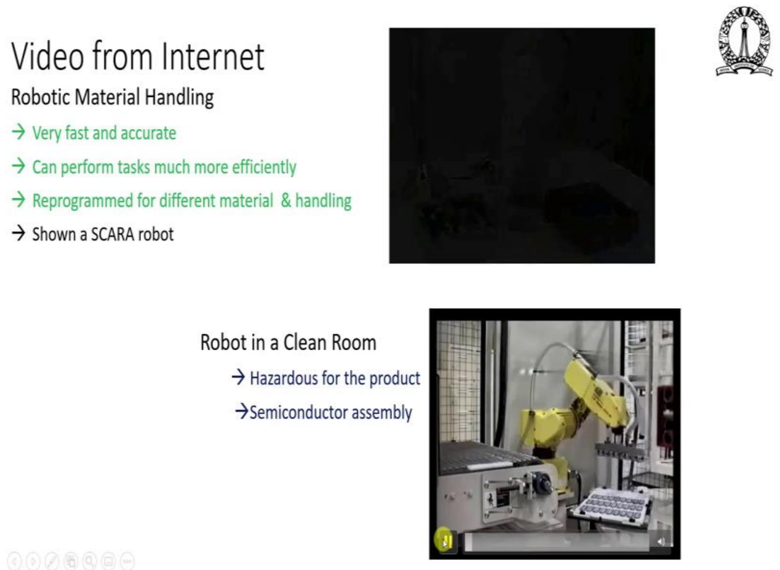

The next video which I am going to show you is a robot in a clean room ok.

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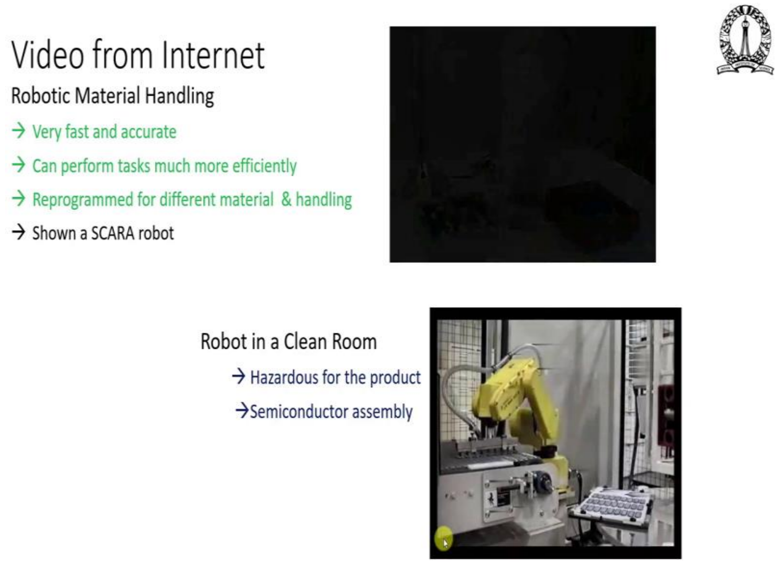

Clean rooms are basically in electronics and semiconductor assembly places. So, in such situations actually the product is hazardous if a human being is there. The environment if a human being is there in the environment it is hazardous for the product. So, human beings will generate dust, breathe, vapor and that if it falls on this PCBs and chips and wafers it can spoil them. So, in semiconductor assembly robots are used extensively in clean rooms.

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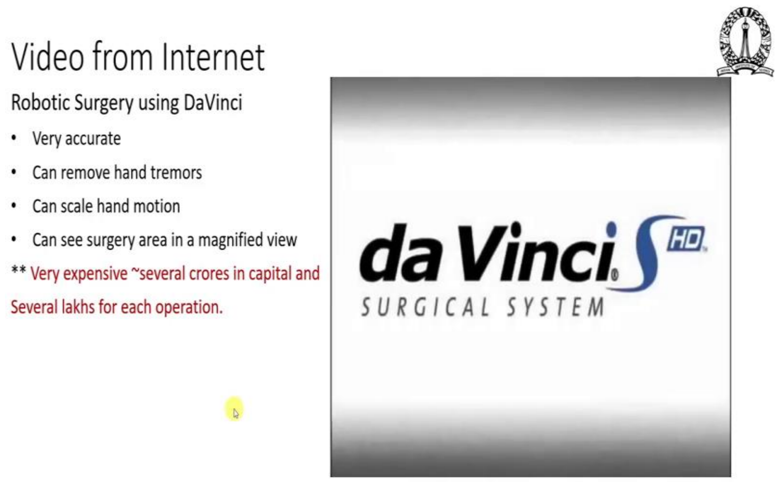

The next video is also from internet and this is a very well known product this is called as a DaVinci surgical robot ok. So, this is becoming very very popular. The reasons being. DaVinci surgical system is most advanced platform. (Refer Time: 24:36) phase of surgery (Refer Time: 24:38).

That it is very accurate. So, as surgeon operating this robot can do it remotely ok.

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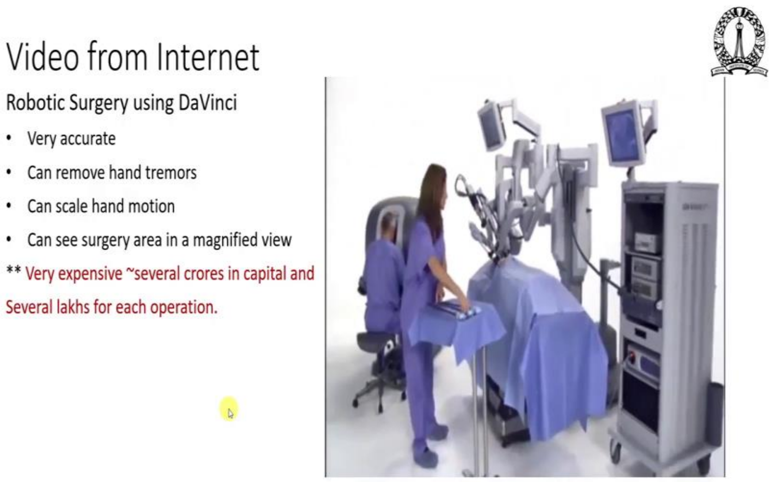

(Refer Time: 24:40) 3D view. (Refer Time: 24:44) surgical procedures.

It can remove the hand tremors. So as you can see the surgeon is seeing through some video screen and the robot is far away and the robot contains all this surgical tools, it can have several arms also ok.

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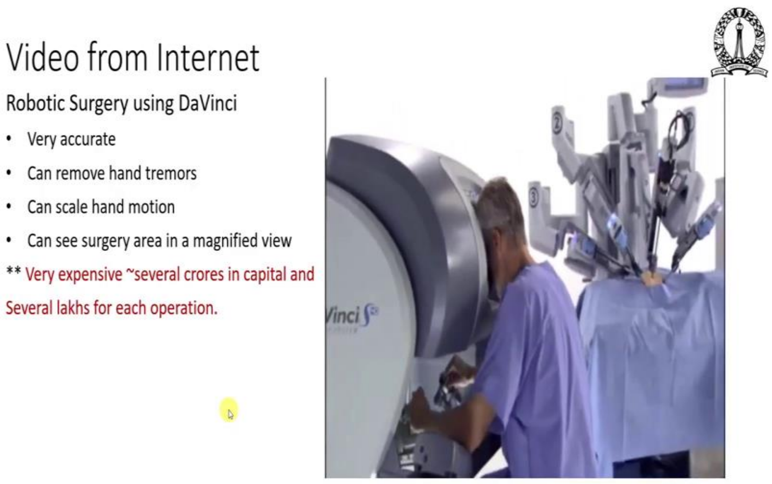

So, let us going back.

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You can see the surgery area in a very magnified view.

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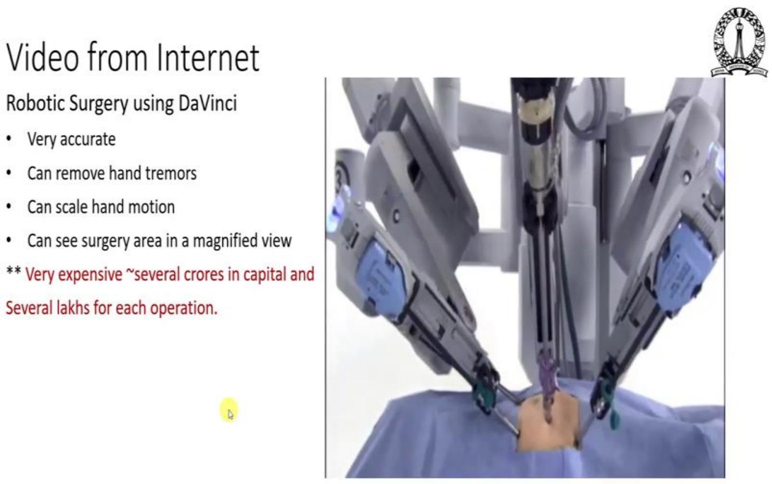

The computer system can also scale the hand motion.

(Refer Time: 25:08) with four interacting robotic arms.

It can make it very fine motion or it can move very quickly.

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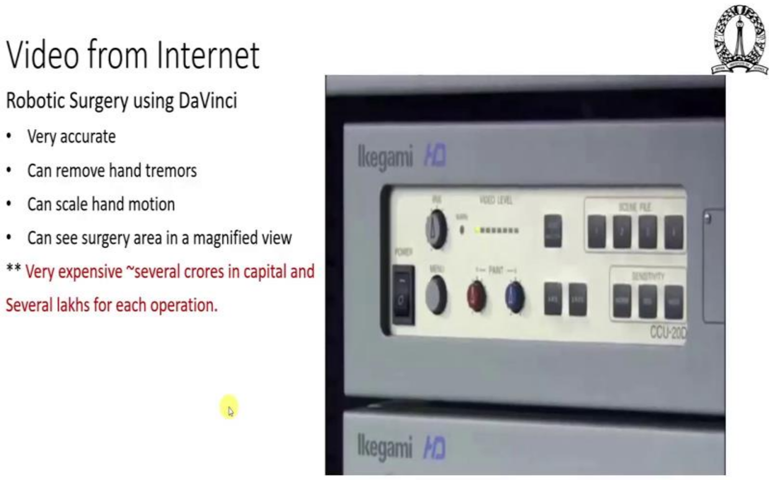

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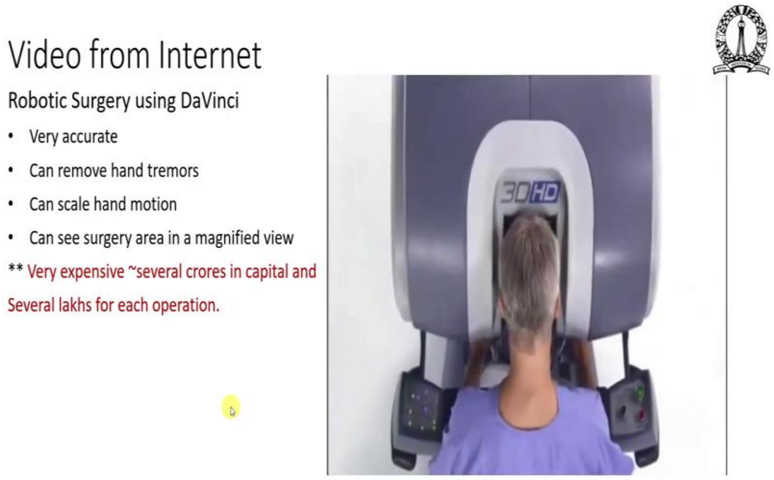

(Refer Time: 25:13) 3D vision system. (Refer Time: 25:17) da Vinci (Refer Time: 25:20) difficult field.

So, you can do for example, move the joystick which the surgeon is manipulating large distance, but the actual tool will move much much finer ok.

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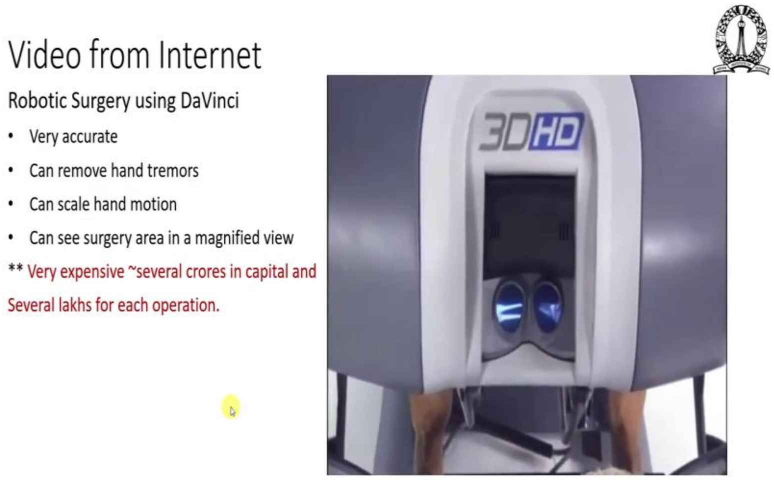

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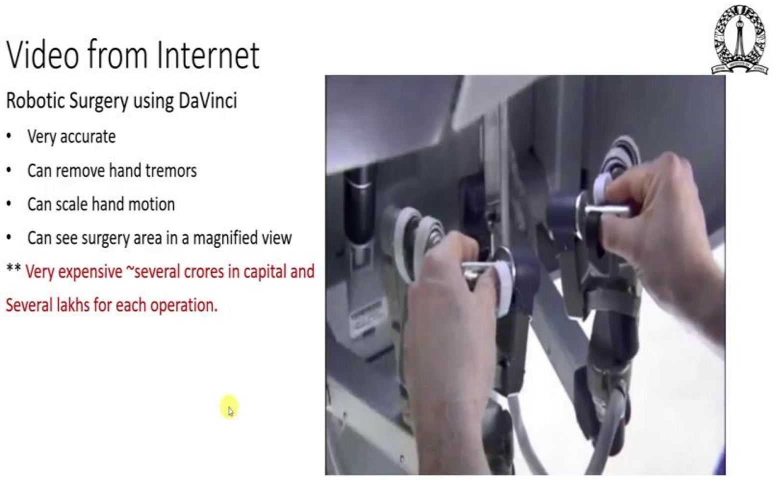

These scales are (Refer Time: 25:26).

So, you can do surgery at very very fine scales. So, as you can see there are these two joysticks. So, basically you can move the end effector in this case these tools by moving those joysticks.

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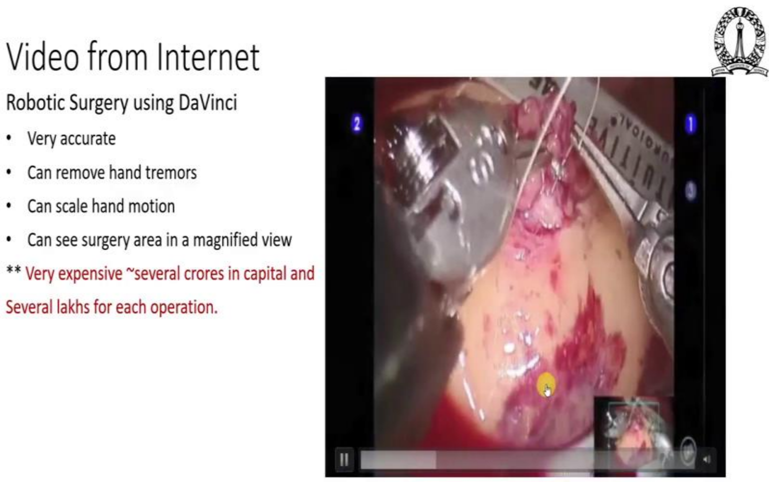

(Refer Time: 25:37) these system (Refer Time: 25:39) that is both (Refer Time: 25:42) dimensional and (Refer Time: 25:44) surgery.

So, this is a surgery of something I do not know, but it is as you can see you can do suturing, you can do cutting, you can do various operations remotely by the surgeon ok.

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The precisely controlled the movements of the da Vinci instruments are enabled by the computer processors of this system.

So, this is a very.

These dedicated processes (Refer Time: 26:00).

Popular and very expensive robot also.

Over the core (Refer Time: 26:04).

So, there are very few of them in India they cost several crores in capital cost.

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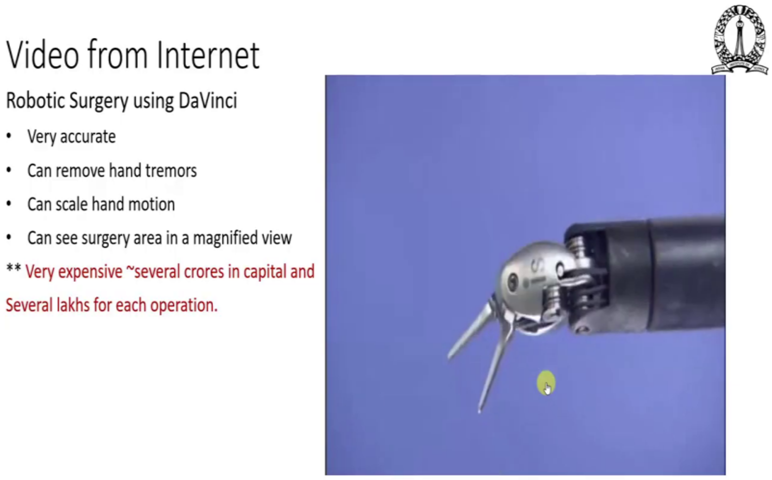

Instruments by designed with (Refer Time: 26:12).

They also have a lot of consumables. So, each time use this robot some of the things have to be thrown away.

Reader.

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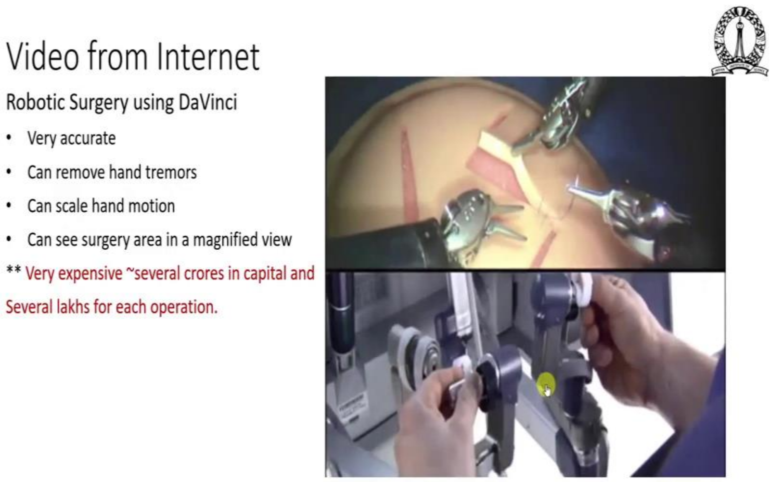

So, what is being shown here is the end effector of this robot? So, you can move in various directions you can also grasp.

Tools.

Things like threads.

Surgeon.

Cut things like skin and so on.

The system filters out hand tremor.

So, some of these things need to be thrown away after a few number of surgeries. So, there is lot of consumable and it is known that it can cost several lakhs to do some surgery.

The surgeon to tailor the ratio of his hand movements to a corresponding micro movement at the instrument tip. The system requires that every surgical maneuver is under the direct control of the surgeon. Redundant safety (Refer Time: 27:00) for the entire OR team.

Another big advantage of this da Vinci surgical robot is the surgeon could be sitting someplace and a robot could be sitting far away and then the surgeon could do surgery remotely.

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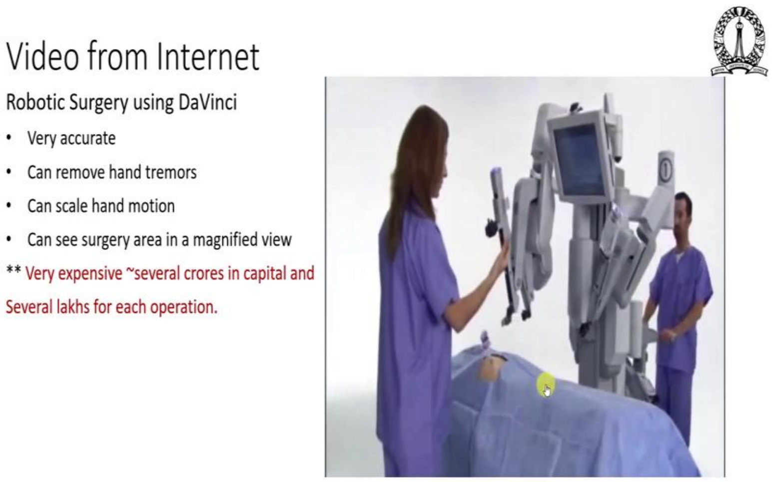
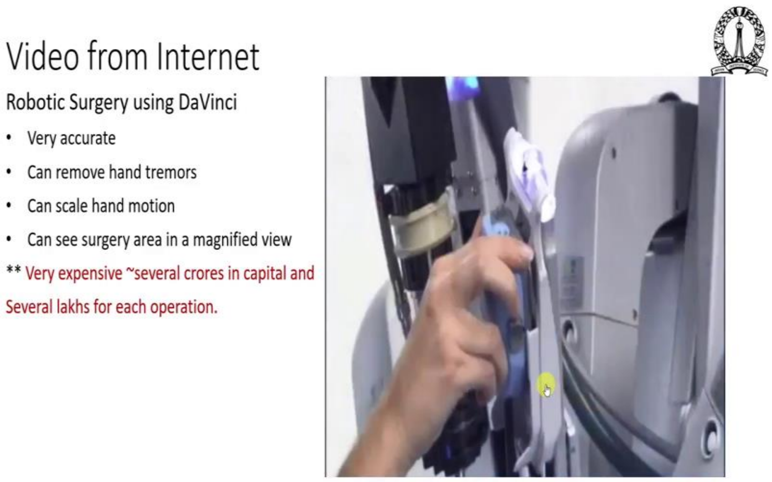


Da Vinci (Refer Time: 27:16) provides fast, full proof set up stated in a motorized (Refer Time: 27:21) for simplified (Refer Time: 27:22). Rapid instrument exchange (Refer Time: 27:29) 2D of (Refer Time: 27:32).

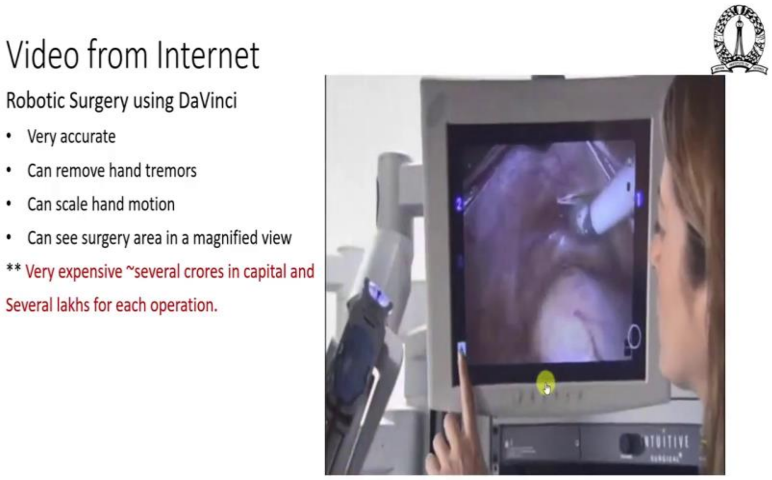
(Refer Slide Time: 27:25)

(Refer Slide Time: 27:27)



And it has been shown and demonstrated long time back that the surgeon was sitting in Europe and the surgery was being done in America ok, transatlantic distance are shown (Refer Time: 27:34).

(Refer Slide Time: 27:30)



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Intra operative communication between the entire OR team.

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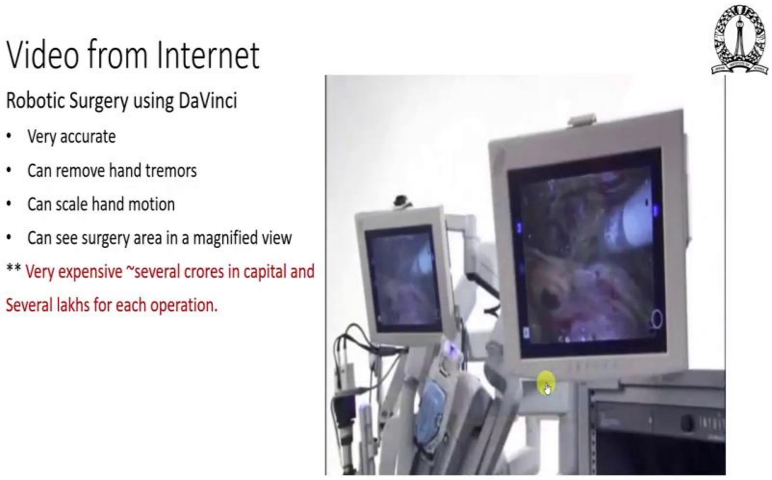

And as I said you have a very good viewing system, you can see the things in a very magnified form and you can see very clearly where you are doing the surgery. So, it has lots of advantages.

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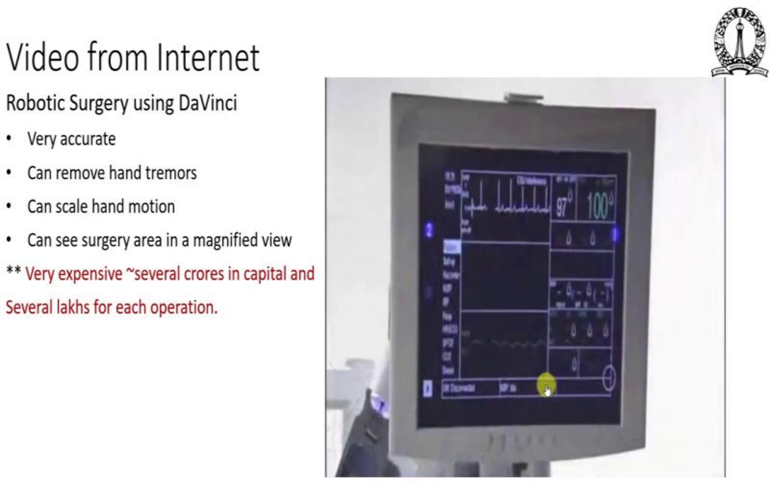

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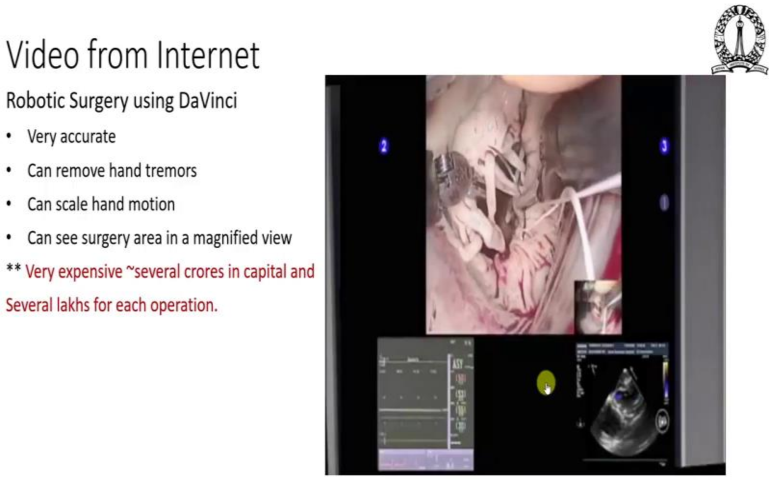

Display patient.

Ok except for the fact that it is extremely expensive and hopefully the prices will come down in future and this will become more prominent popular.

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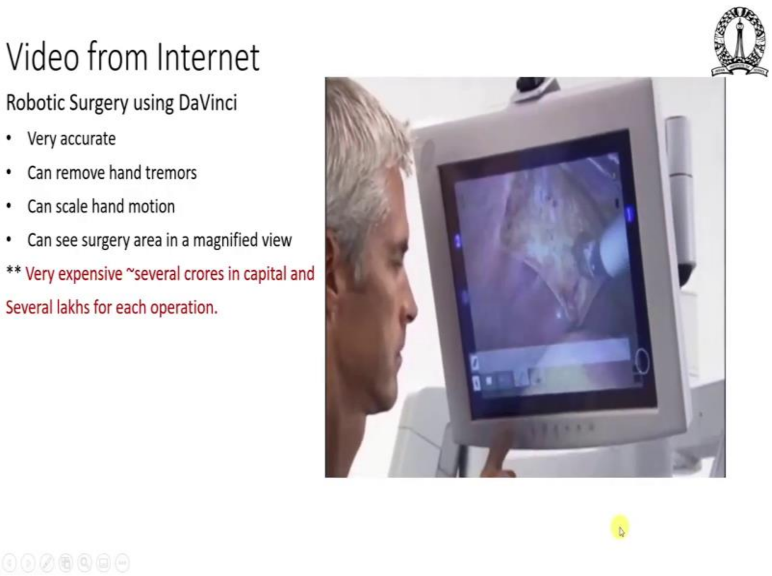

Notations drawn on the patient cart monitor can be seen by the surgeon as an overlay.

So, I think I am going to stop here.

(Refer Slide Time: 28:11)

The two channel endoscopic.

But.

Camera.

Let us continue.

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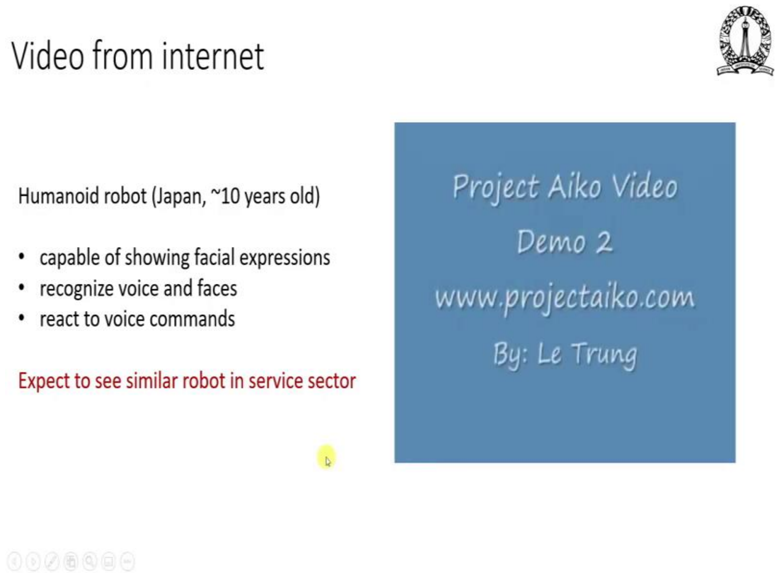

This is another video from internet. It is a for humanoid robot. This video is about 10 years old and it was created in Japan.

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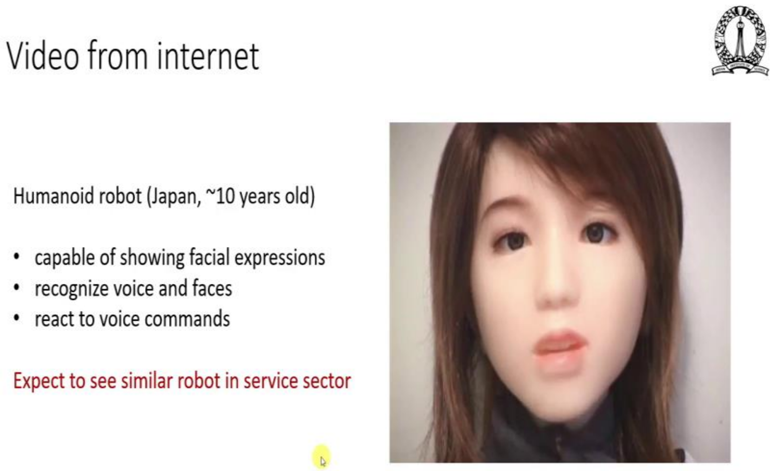

So, as you can see it is shows a humanoid robot which is capable of showing facial expressions. It can recognize voice commands, it can react to voice commands ok.

[FL].

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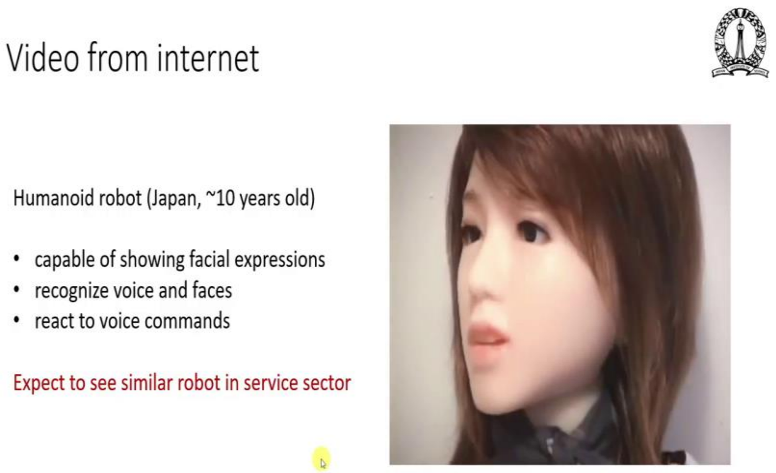

So, you can see how realistic this robot is. The emotions of the face, the lips and the eyes and neck everything is becoming more and more realistic.

Hello my name is Echo. I was created by law trumps. I have the ability to have conversation (Refer Time: 29:05).

(Refer Slide Time: 29:06)

And robots such as this are expected to be seen in the banks, in various other places where you require information. So, they are going to come in the service sector ok, where the person asking can ask very different questions and the robot has to react to those questions ok. So, it is showing lot of autonomous behavior and intelligence.

These are some of the features I can do. However, a full demonstration of my ability will be performed during my public appearance. Hopefully, one day my creator will be able to make me walk and interact with.

So, this video does not have voice, but as you can see it can move its lips.

My name is Echo.

It can as if it is talking.

Echo how is the weather outside?

The current temperature is 17 degree with clear sky and no precipitation and.

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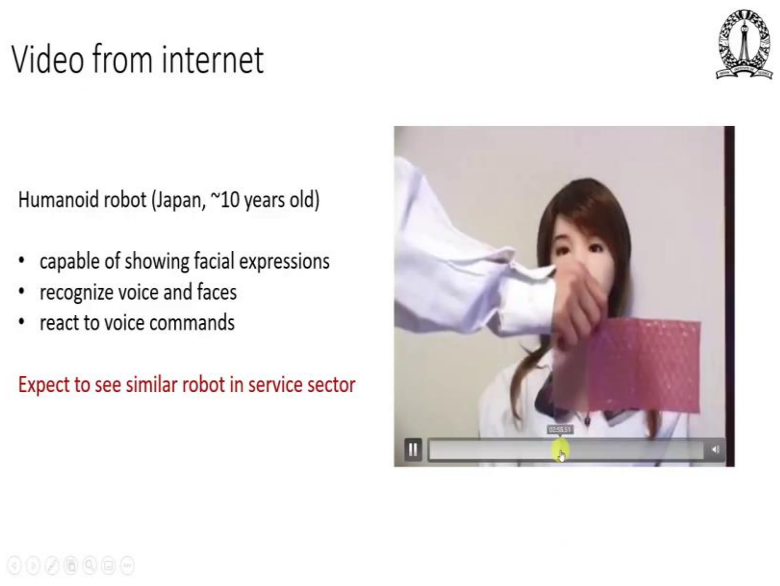

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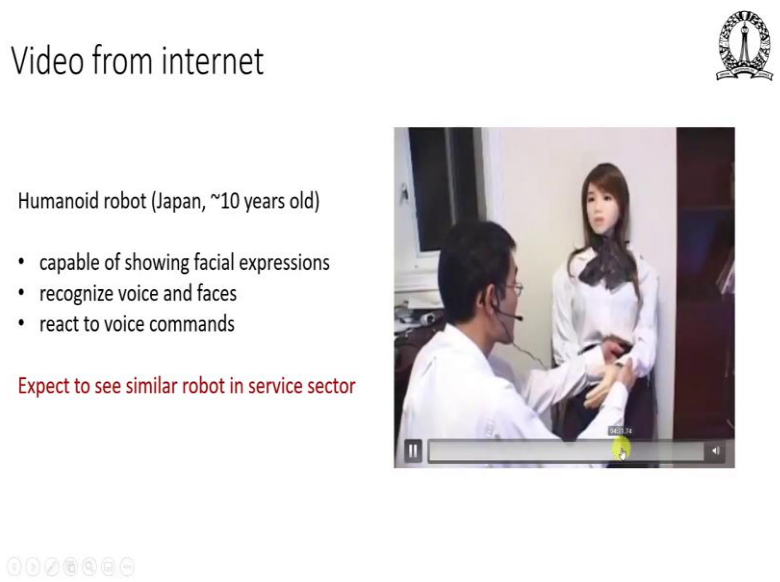

Let us fast forward it can even recognize objects.

Echo.

It can even.

Echo can you (Refer Time: 30:17).

Understood, I will (Refer Time: 30:19).

Respond to speech and move its arms,. So, it can do various things almost like a humanoid ok

Please let go of my arm. You are hurting me.

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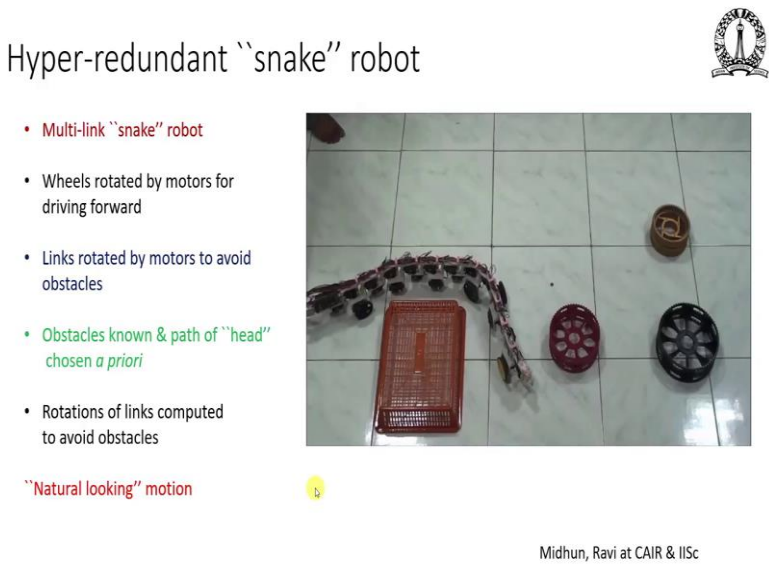

So, with this we will stop here. Now, let us come back to IISc and what are some of the work which we have done in IISc. So, I am going to first show you a hyper redundant snake robot ok. So, this is a multilink snake robot and as you will see shortly it consists of 12 links. So, there are 12 motors which can rotate these links and there are also some wheels which are also rotated by motors. So, the wheels have to drive this snake robot forward.

So, we compute the motion of the robot using this tractrix algorithm which I have discussed earlier or we will discuss later. So, it makes sure that the robot avoids all these obstacles. So, in this case this is moving on the floor and these are some obstacles which have been put there. The path of the head and the location of the obstacles are known a priori ok.

However, later on if you have a sophisticated robot with enough computing and enough sensors it can look ahead and see where this obstacle and then plan the path. In this video it the path is given ok. So, basically what it is doing is the algorithm is showing you that it can compute the motion of the body of the robot such that it never hits any of these obstacles and you will see that it will the motion looks very natural.

So, this is the work of students Midhun and Ravi and the work this robot was actually built and demonstrated in CAIR, but both are students my students and the research was done in IISc, ok.

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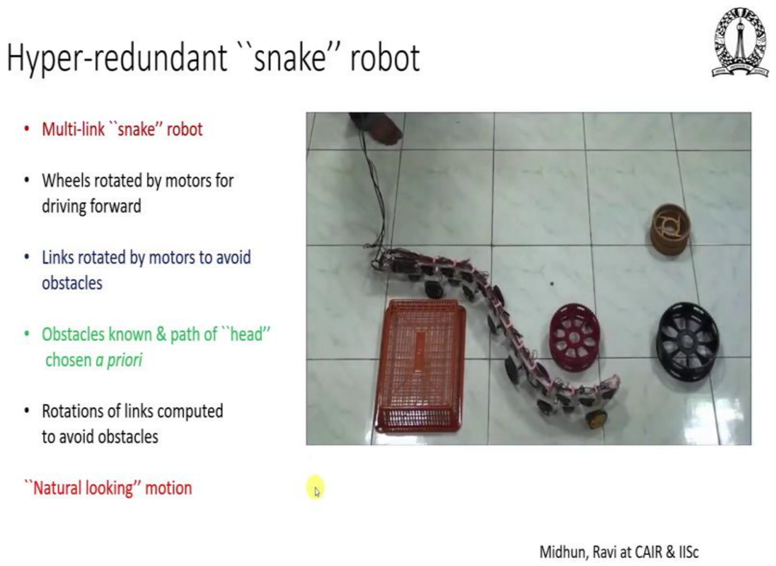

So, all the computation is done by a laptop which is student is holding in his hand and walking. So, you can see these cables. These cables are sending commands to the motors and it is also sending power required for the motors. In an actual snake robot the computing, the power source everything will be on the robot itself.

So, one of the thing is this algorithm of this robot is looking very natural you can see that the links of the robot the body of the robot will only bend when it is required and it is near the obstacle. So, as you can see the head here is going straight and this part of the body is only bending this part is little straight. So, this gives a very natural looking motion to this robot ok.

Let us see once more ok. So, now, the head is moving such that it is trying to avoid this obstacle then go through this path. The rest of the body is still straight ok. This is what I meant by very natural looking motion.

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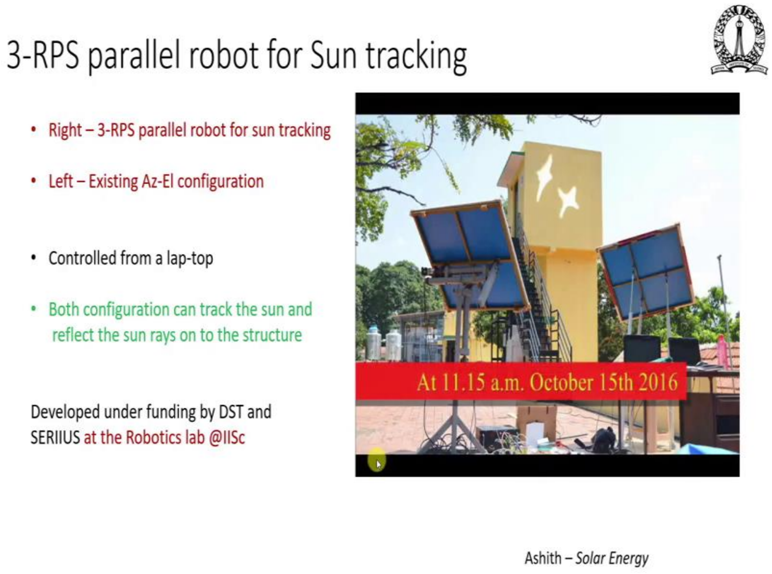

The next video is that of a 3-RPS parallel robot which was built in IISc by students for sun tracking ok. So, in solar energy one of the approaches is to provide a mirror or use a mirror which can reflect the incidence sunbeam on the onto a receiver ok. So, if you have lots of these mirrors and all of them are working properly and focusing the reflected beam onto a receiver that place will become very hot and then you can use a engine or some working fluid to run an engine such that you can eventually get electricity.

So, one of the important part of this solar energy investing is to track the sun. So, we know how the sun moves across the sky throughout the year and you know on a particular day. So, it moves roughly east west, but it also moves a little bit north south during the season.

So, there are various parallel robots and serial robots which have been used to track the sun and focus the deflected beam onto a receiver. So, on the right of week I am showing you a 3-RPS robot, it is a parallel robot which have been built in IISc which we have discussed earlier and on the left is a serial robot which has two motors one after another. So, there is a motor which is vertical. So, it gives the vertical or motion about this vertical axis then there is another motor which gives the elevation.

So, this is called as the Azimuth elevation configuration. So, by rotating these two motors properly they can make sure that the reflected beam from the sun as the sun moves across the sky is always on this receiver ok.

So, what I am going to show you is that there are these two robots which were built two mechanisms ok.

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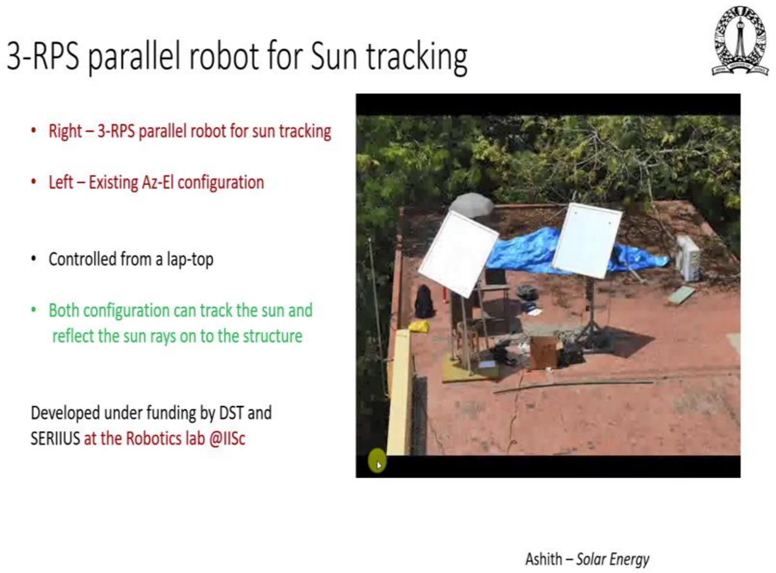

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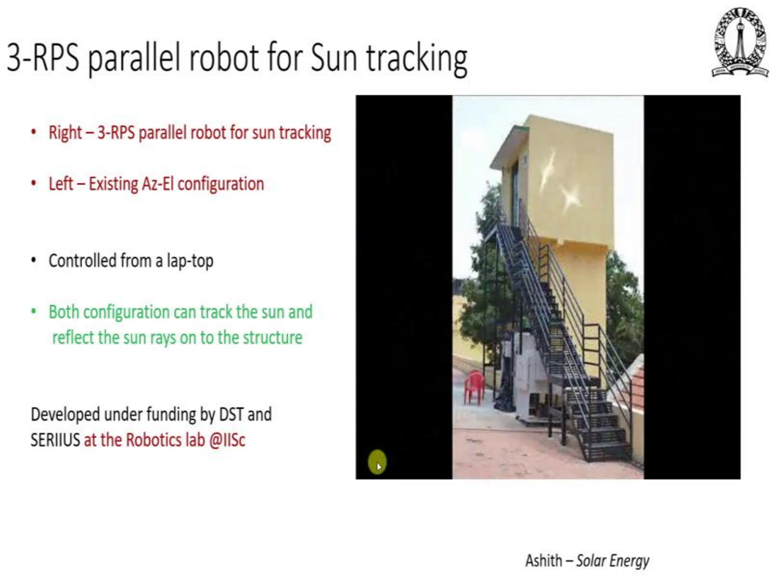

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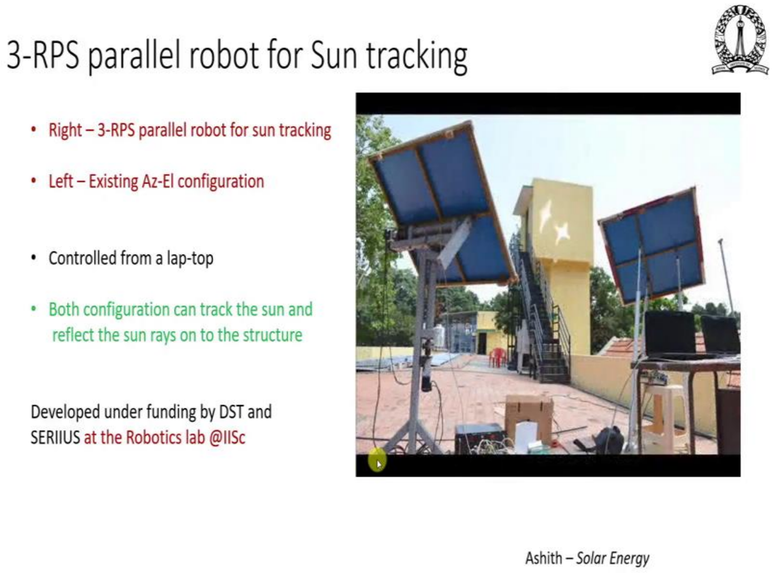

One is a 3-RPS robot and one is this Azimuth elevation configuration both are controlled from a laptop.

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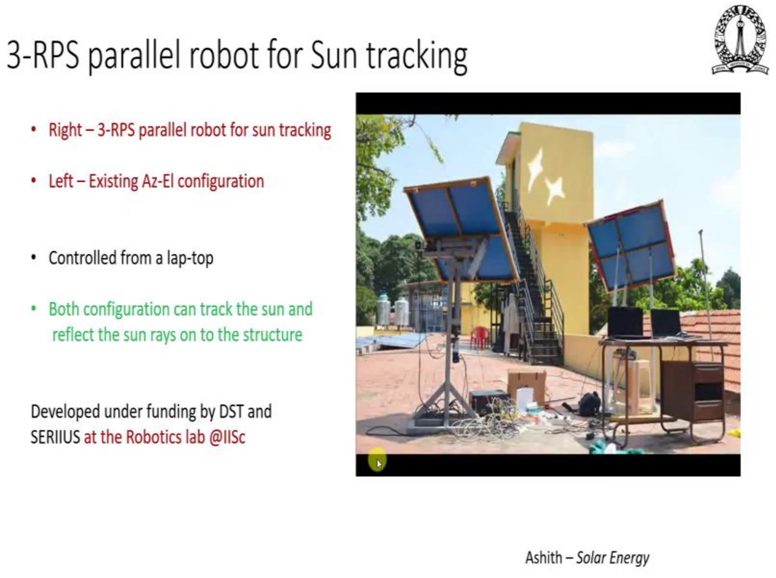

And you can see both of them are moving in a way such that the beam is focused on to that tower or to this water tank actually ok.

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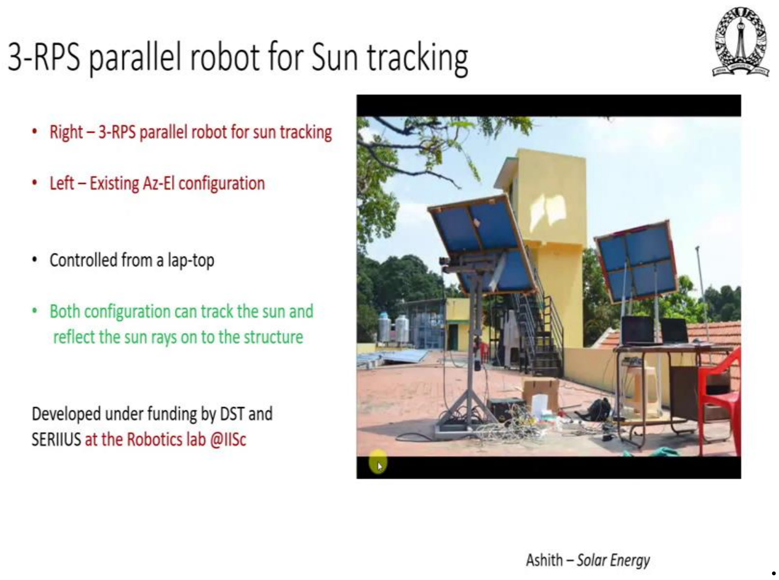

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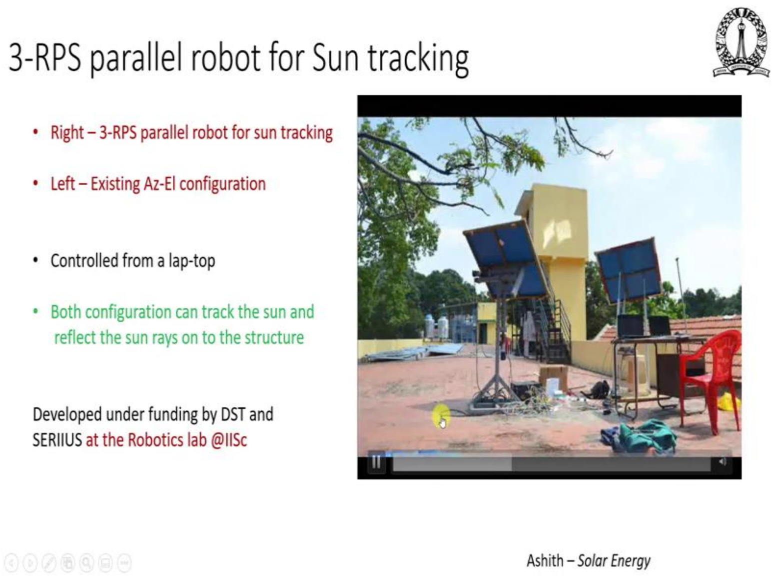

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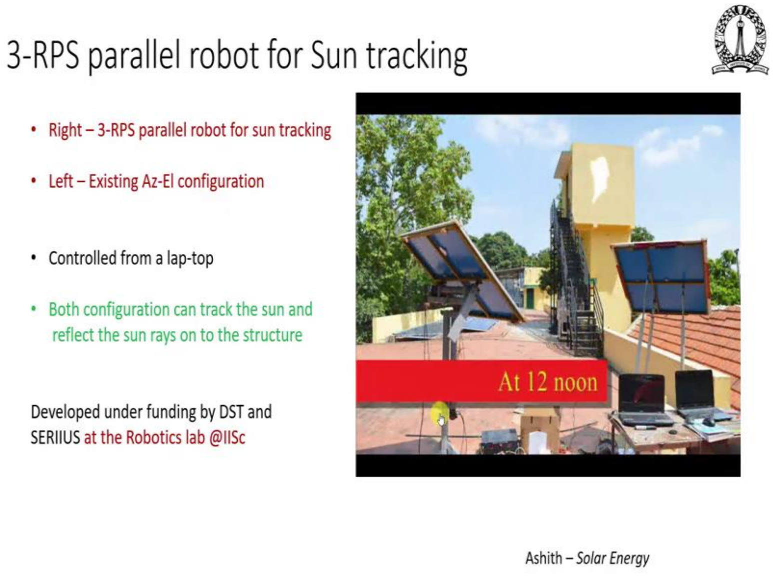

So, both configuration can track the sun and reflect the rays onto the structure.

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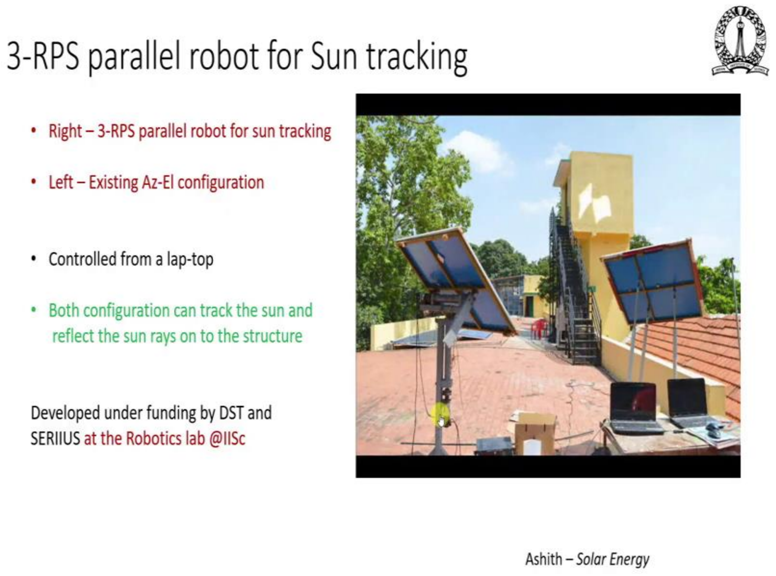

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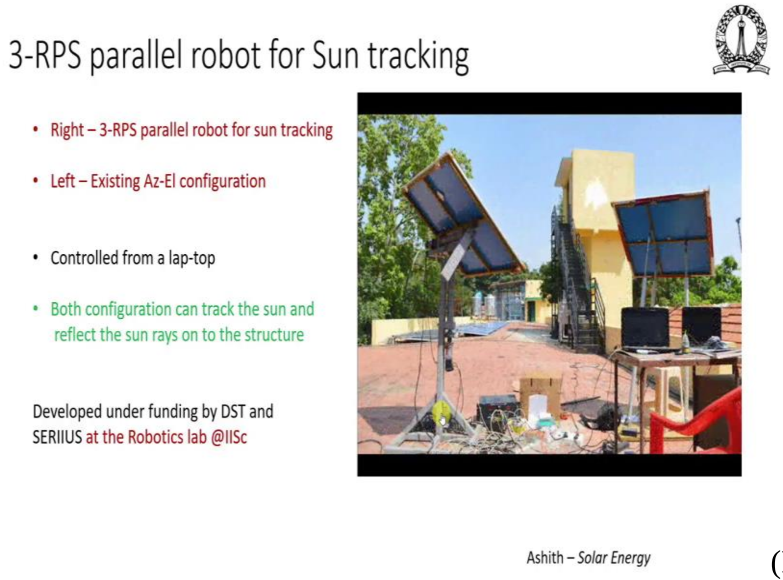

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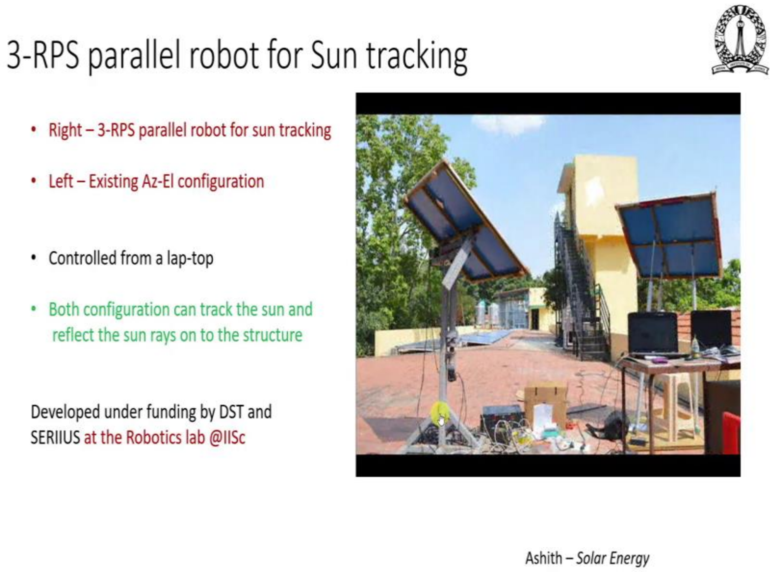

So, at different times we have taken these pictures and then we have animated this picture. So, as you can see that the mirrors are moving ok.

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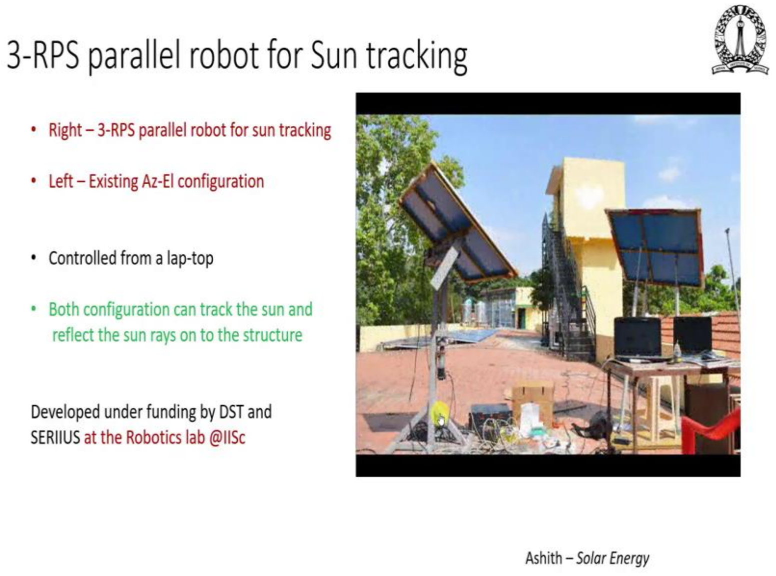

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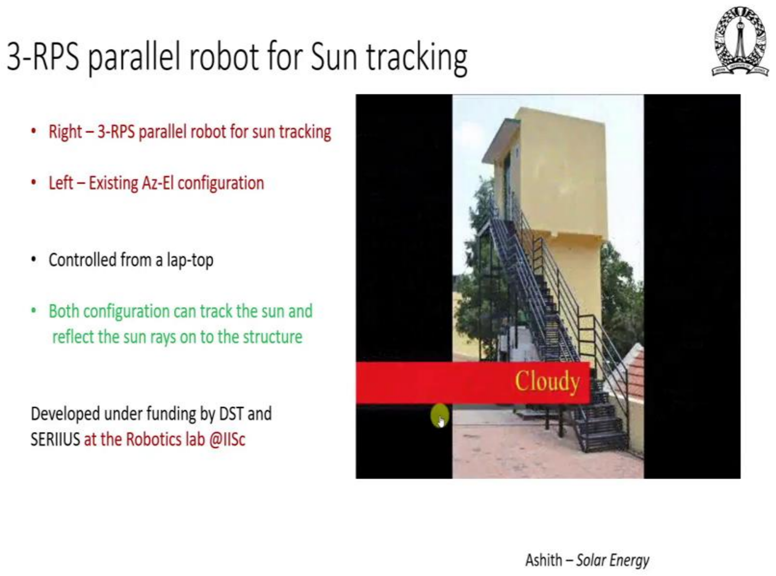

So, there are of course, some errors. Ideally it should be exactly focused at the same place all the time and of course, you saw that there was a cloudy period, but there was no reflection ok.

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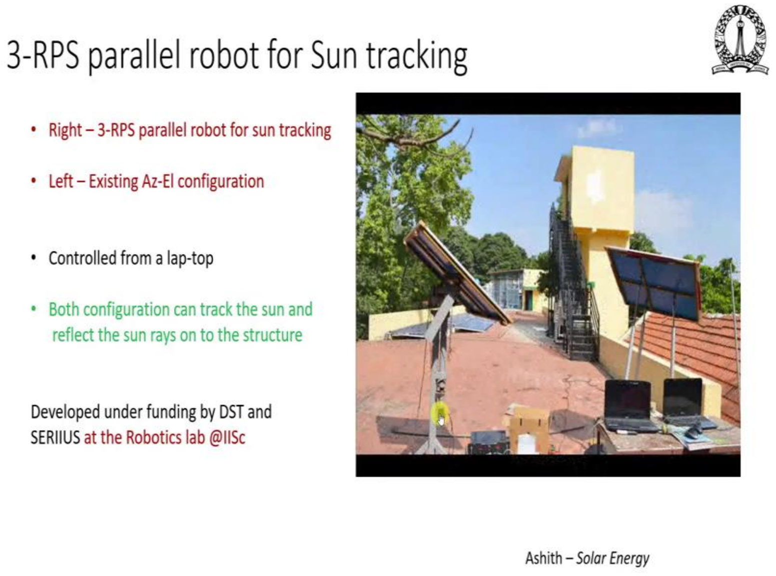

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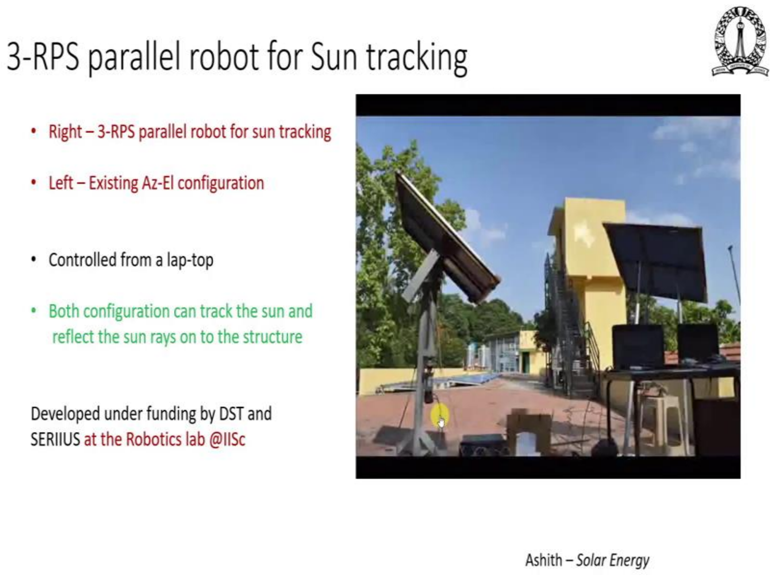

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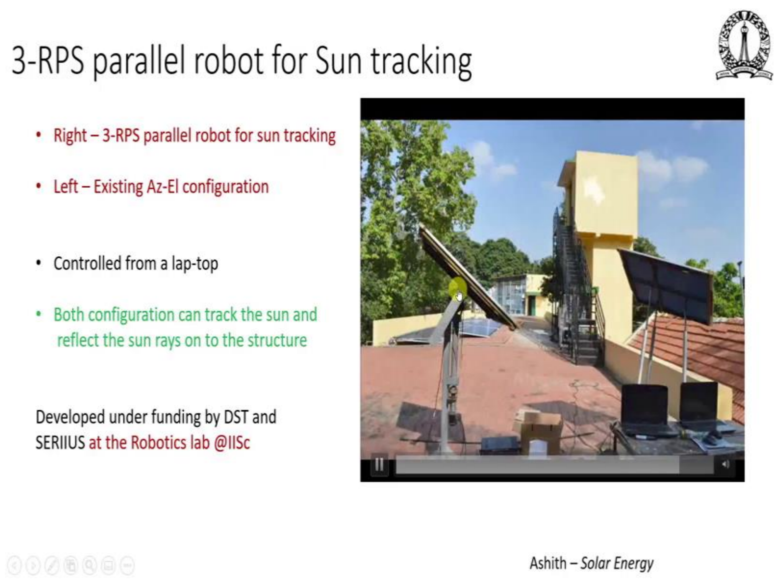

So, as you can see now it has rotated quite a bit as we go towards the afternoon late afternoon.

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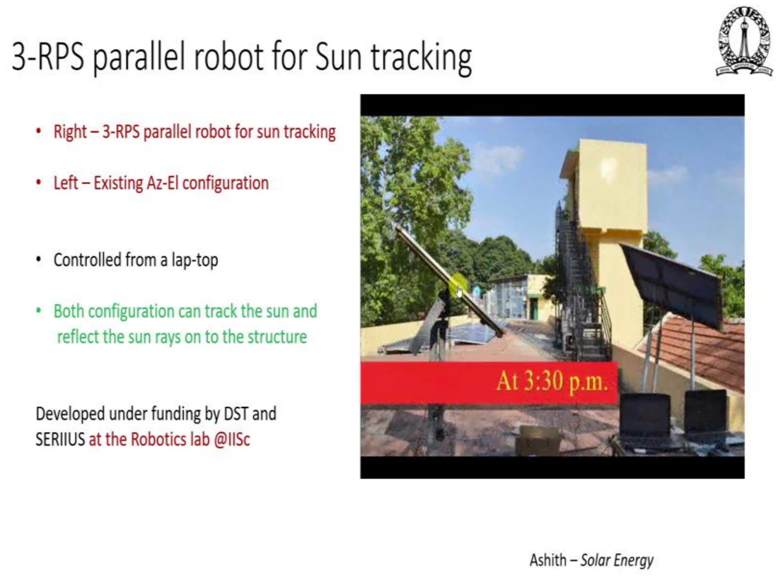

So, this robot was developed by students PhD students at IISc. This is the roof of one of the so buildings where interdisciplinary research and solar energy was being done. These are solar panels and we also put up these two mirrors which are sun tracking.

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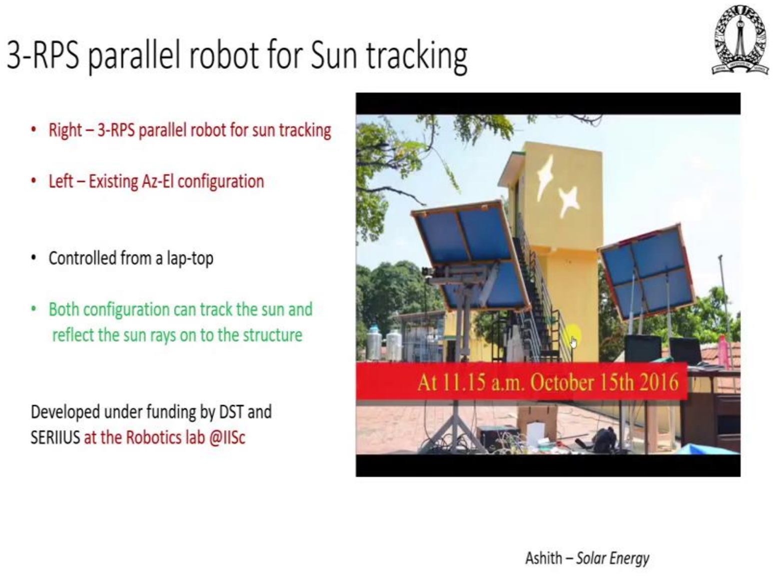

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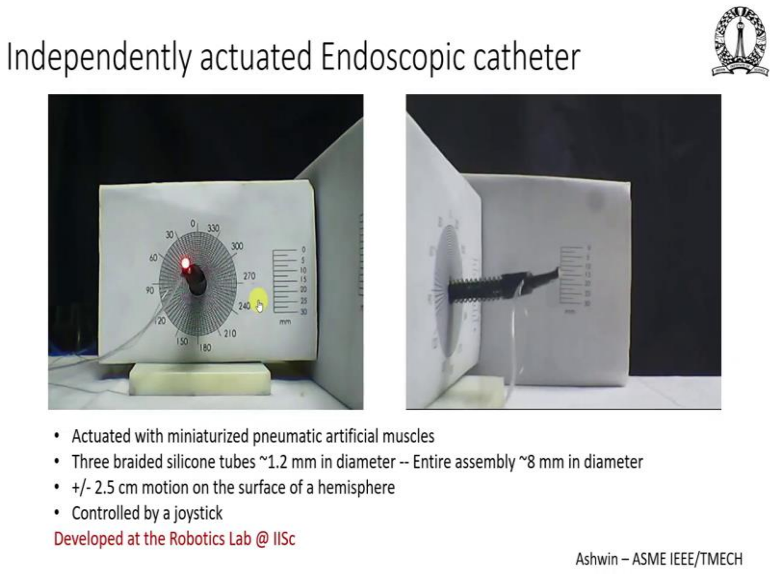

The last video which I am going to show you is a flexible manipulator ok. So, basically these are two videos two side-by-side videos of an independently actuated endoscopic catheter ok. So, we will see what is an endoscopic catheter also or as we have discussed this earlier.

So, basically at the end of an endoscope we will put this device and then we can independently actuate this device so that you can visit different points inside the stomach ok. At the end of this device where this LED is, it could have something else. You could have a grasper or it could have a scissor which you can articulate and you can take samples ok.

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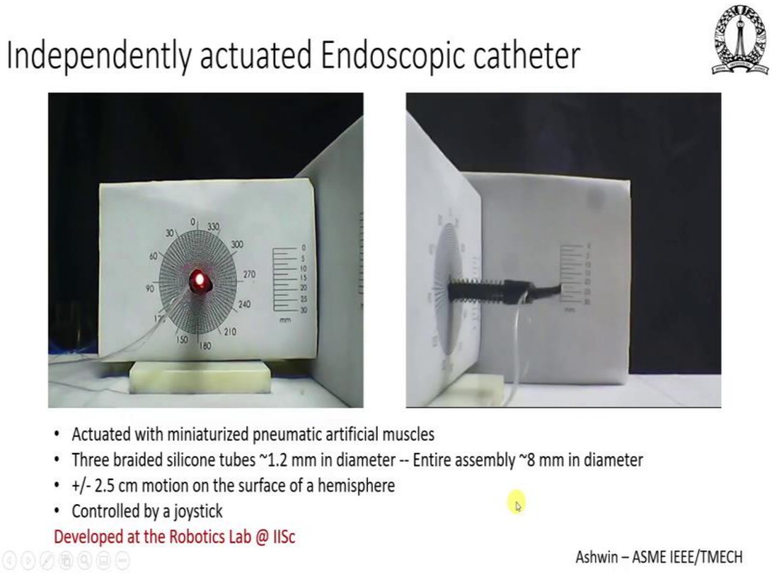

So, the interesting part of this product is that these are actuated by what are called as miniaturized pneumatic artificial muscles ok. These are very thin 1.2 mm diameter braided silicon tubes. The entire assembly is about 8 mm in diameter and by pressurizing these tubes from an external source of air pressure I can contract these silicon tubes.

Now, there are three of these silicon tubes and on this actuator endoscopic catheter and by energizing them in a certain way. So, for example, if I energize two and leave the other one thing the it will contract in two directions and hence it will move in a resulted directions.

So, these three tubes silicone tubes are arranged 120 degrees apart and by suitably pressurizing one or more than one at a time I can make this end move on the surface of a hemisphere ok. And as I am showing you we can move about plus minus 2.5 centimeter from a central place and this motion can be controlled from by a joystick from outside ok.

So, the key feature is that these are very very thin actuators. So, the everything is fitting inside 8 mm diameter because in an endoscope we do not have too much space. You know when you are doing endoscopy the clinician will put this through your mouth and maximum diameter near your throat is of the order of 12 mm 12 to 14 mm ok. So, your device which you are going to push into your stomach to take pictures or do some diagnosis cannot be very wide and we build this device which was very very thin diameter.

So, as you can see from the scale it can move between plus minus 0 to about 20 mm both sides and the other view also shows some 0 to 25 mm ok; (Refer Time: 40:44) little more than 25 mm. It moves not very fast, but it does move as you can see ok.

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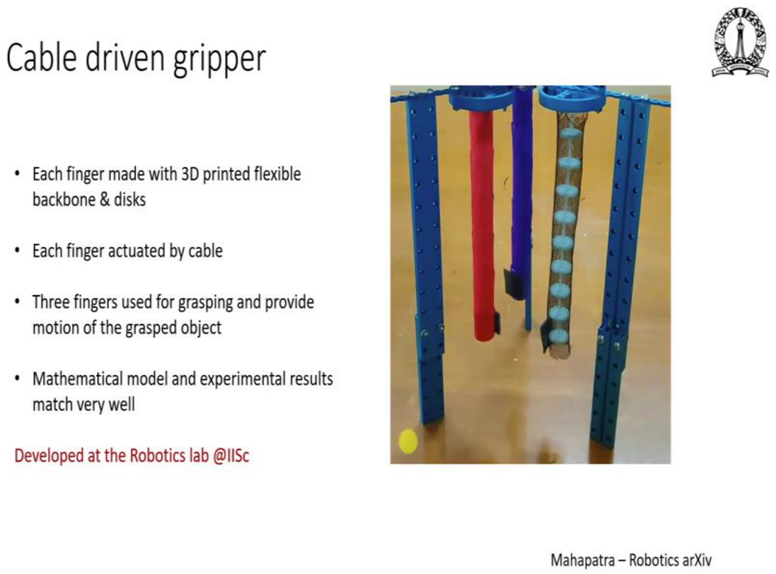

So, the last video which I am going to show you is that of a cable driven gripper ok, this is the continuing work. So, basically we want to make very flexible fingers ok, which are driven by cables ok. So, each finger consists of a 3D printed flexible back bone with the discs.

So, in this finger that is shown ok. So, these are discs and there is a backbone and when you pull these cables these fingers will bend ok. So, each finger is actuated by one or more cable. There are three fingers which are used to for grasping and provide motion to grasp object also.

So, as you can see we pick up something or we grip something and then we can move it ok. So, a large amount of mathematical modeling has been done to arrive at some reasonable mathematical models and it is shown that the mathematical model and the simulation results matched reasonably well with the experiments ok.

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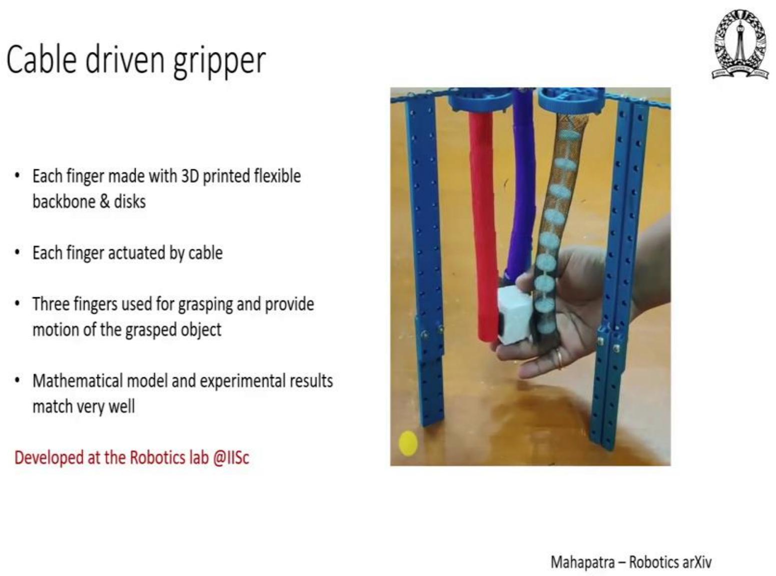

So, this is also developed by students at the robotics lab in IISc. So, all the three fingers are identical, but depending on what kind of motion you give to each finger the object will move in some different ways.

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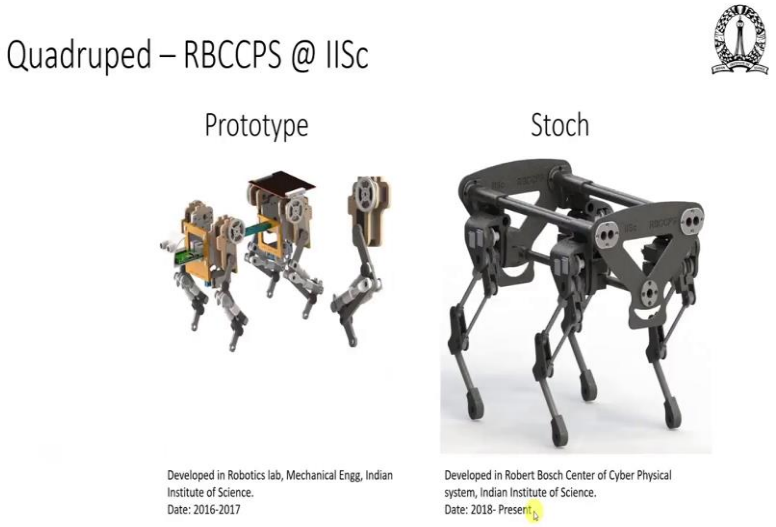

One more set of videos is from a collaborative work done with the Robert Bosch Center for Cyber-Physical System. So, we are working on this four legged quadruped ok. So, the basic idea is that these quadrupeds can go over uneven terrain, it can explore uneven terrain. So, initially the work was started in the robotics lab, but now it is taken over and done in much more sophisticated manner in the Robert Bosch Center for Cyber-Physical System ok.

So, I am going to show you a video which will show what was the initial state and what was being done then how the new robot quadruped called Stoch was designed and fabricated and then how some sophisticated learning algorithms had been ported on this robot so that it can learn to walk properly ok.

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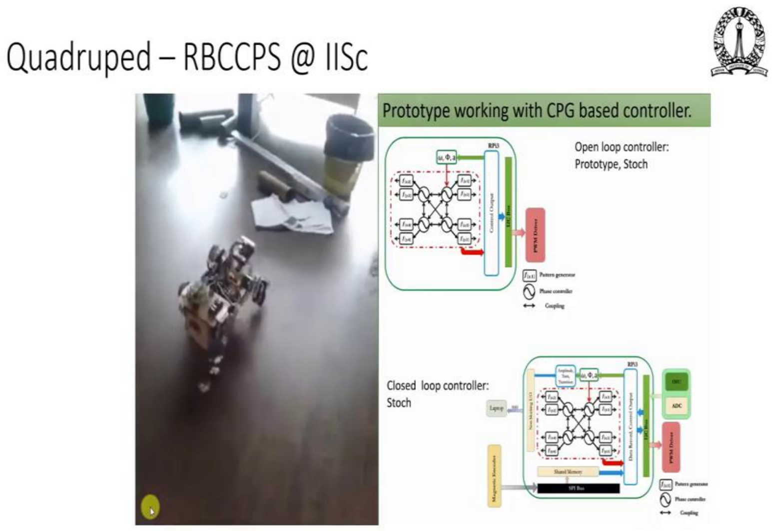

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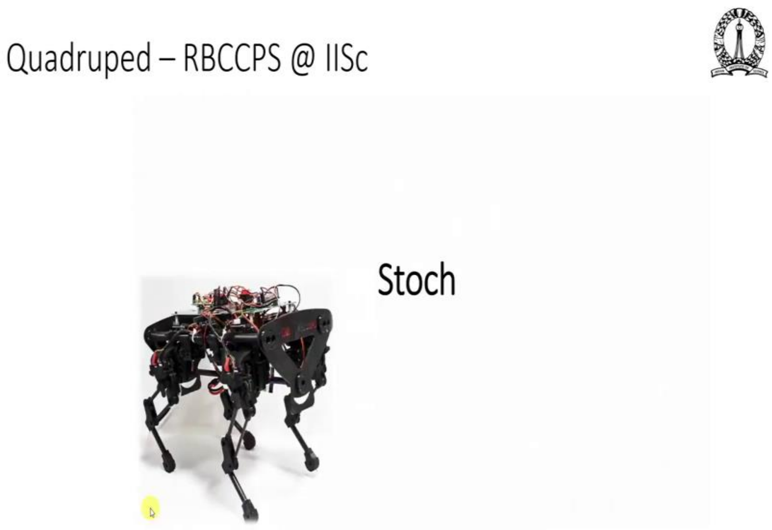

So, on the left what you can see is this robot which is four legged and it was walking using some algorithm (Refer Time: 44:59) generated.

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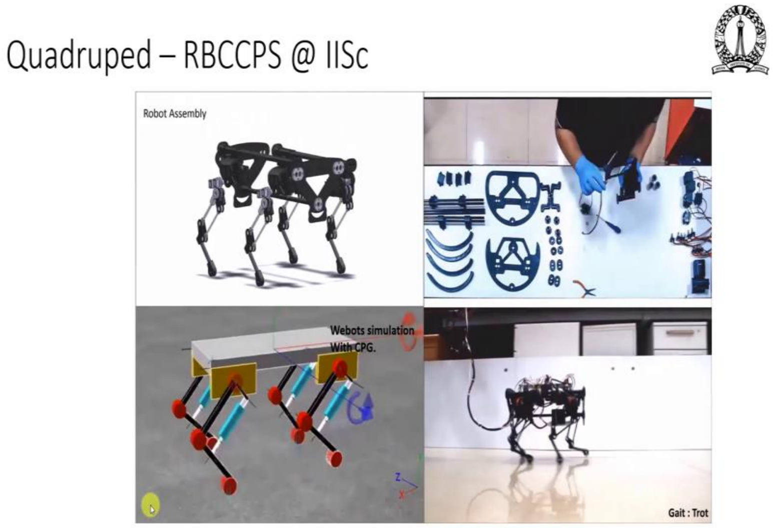

Next it is showing various stages of assembly of the more refined Stoch robot quadruped. All the parts are being assembled and you can see that we have also done some simulation.

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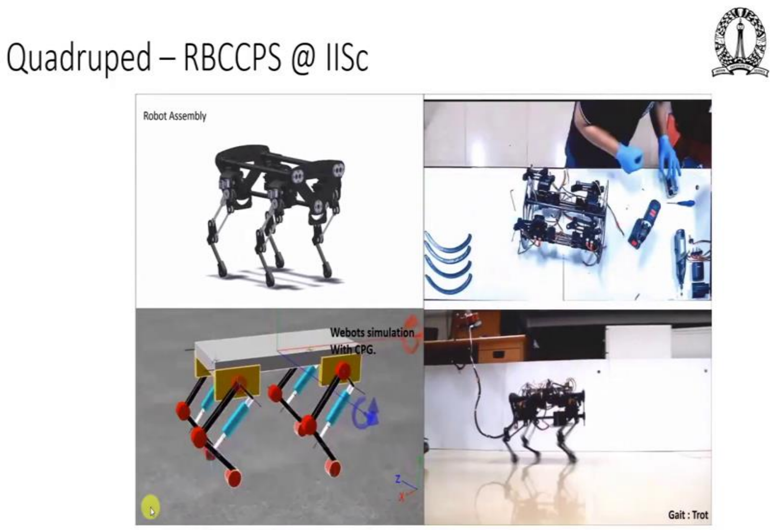

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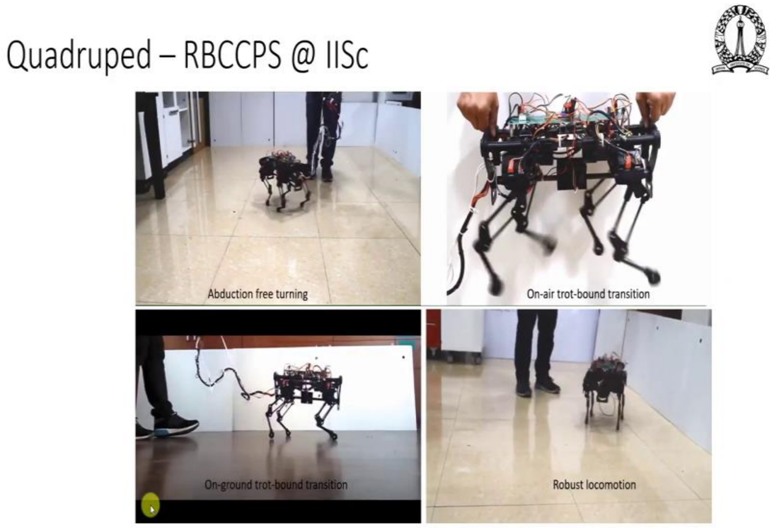

And then we can show that it can turn, it can trot, it can bound and it is also robust, the motion is quite robust because even if you push it to one side it will come for back on its track.

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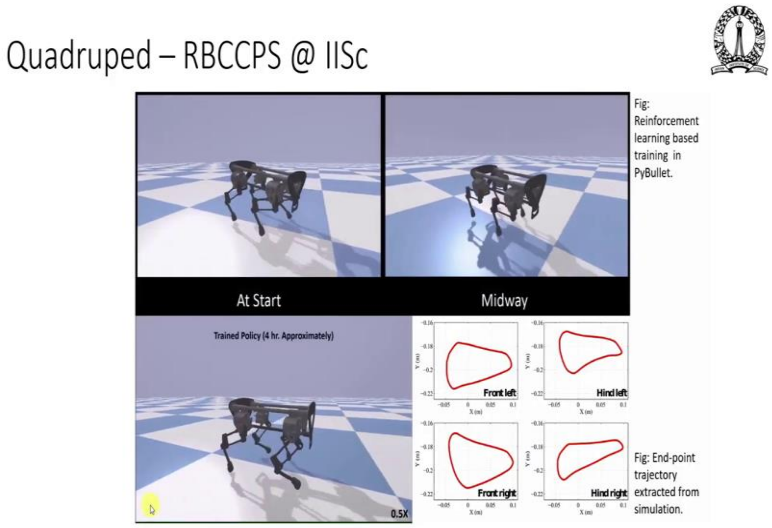

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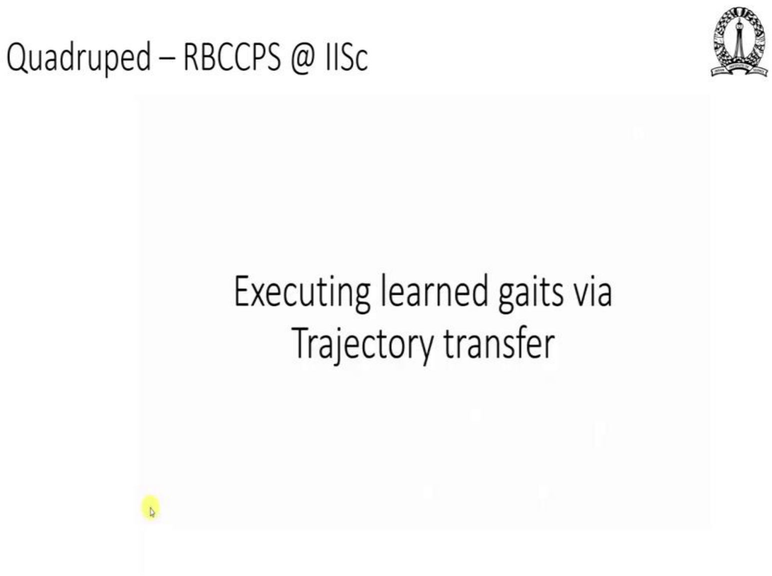

So, a large amount of learning and reinforcement learning is being done using some software tools.

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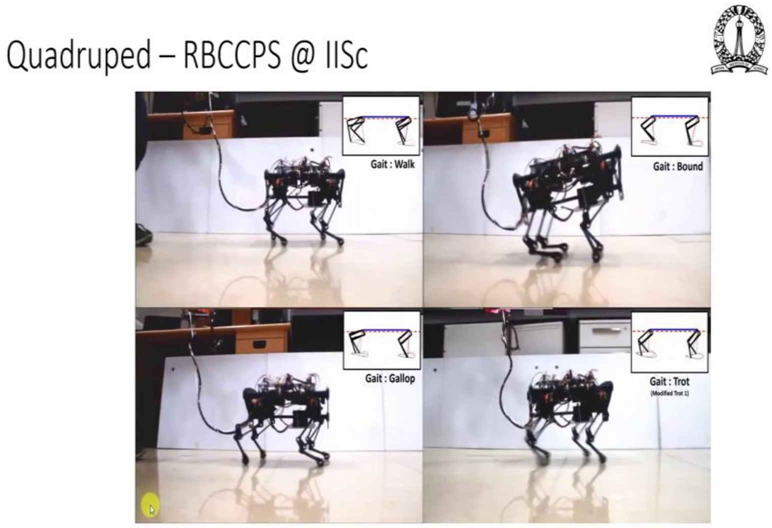

So, what we can see is it has learned how to walk, it has learned how to bound, gallop, trot, various kinds of walking it has learned ok. So, let us continue. So, let us look at some types and classification of robots. So, there are various ways of classifying a robot.

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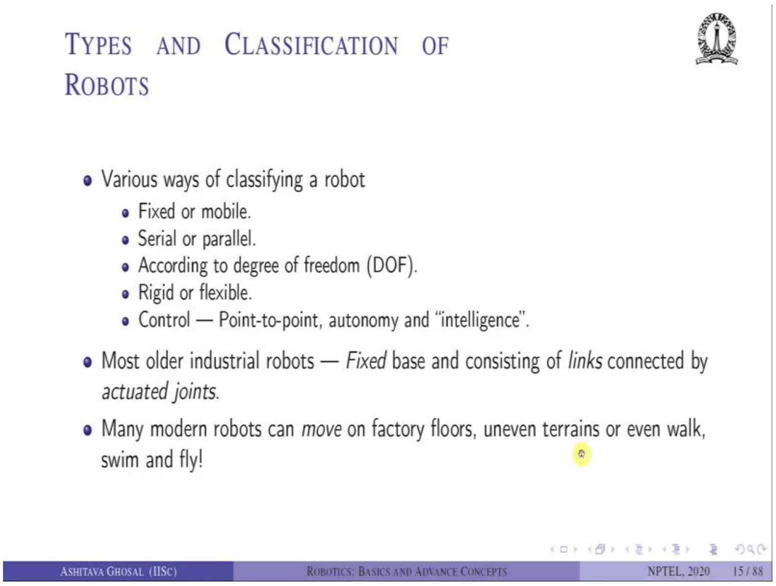

So, a robot could be fixed or mobile obviously, it can be serial or parallel I will show you examples and also it can be classified according to the degrees of freedom. It can be rigid or flexible and it also depends on how it is controlled. So, it could be a point to point control, it could be autonomous, it could be intelligence and so on.

Most older industrial robots had fixed base and consisting of links connected by actuated joints ok. So, out of this fixed and mobile most original industrial robots had fixed base ok. There are a few mobile robots which can now move in the factory floors, transporting materials and tools from one place to another. it can even move on uneven terrain and there are robots which can even walk swim and slide, ok.

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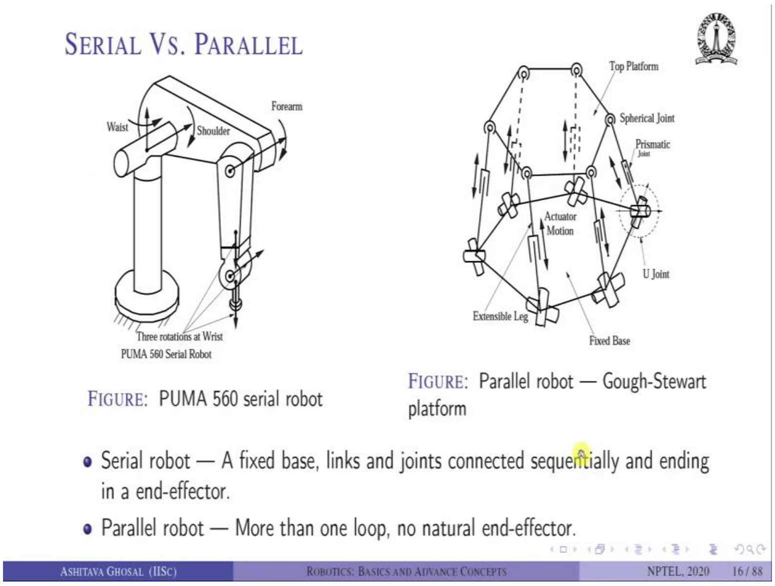

So, how about serial versus parallel? The robot on the left is a very well known serial robot. This is the same PUMA robot which was originally made by this company Unimation Inc ok. So, it is 6 degrees of freedom. So, basically there is a joint or a motor here there is another motor here and there is another motor here.

So, this shoulder and forearm can move all with respect to the waist at the base and at the end there are these three joints which intersect and form a wrist. So, it is very similar to human arm and that is why sometimes these were called anthropomorphic robots ok. So, this is a serial robot because we have one link. Second link is after the first link. The third link is after the second link and so on, it is one after another. You can also have parallel robots and the most famous parallel robot is this Stewart Gough or Gough Stewart platform.

So, basically in this robot there is a fixed base and there is a moving top platform and in between this top platform and the fixed base there are these legs these things are called legs ok. A leg consists of a hook joint ok, a universal joint, a spherical joint and a sliding joint ok.

So, by moving this sliding joint in and out ok, so, changing this length of the link I can make the top platform perform various kinds of motion ok. So, we will look at this both this PUMA and Stewart platform later on in kinematics of serial and parallel robots ok. So, as I said a serial robot has a fixed base, links and joint connected sequentially and ending in an end defector. So, at the end there is an end effector where you can fix a welding gun or a paint can or various other things ok or you can even carry a screwdriver go and tighten some screws.

A parallel robot on the other hand it is not sequential, it is not one after another there are what are called as loops ok. So, I can start from here, go to the top come back and again and then one loop. So, there are several such loops. So, one loop, this is the second loop and so on ok.

The other feature of a parallel robot is there is no natural end effector ok. So, in the Stewart Gough platform it looks like the top platform is the end effector that is a natural end effector, but there are many parallel robots where you can have more than one output link. You can choose your output link.

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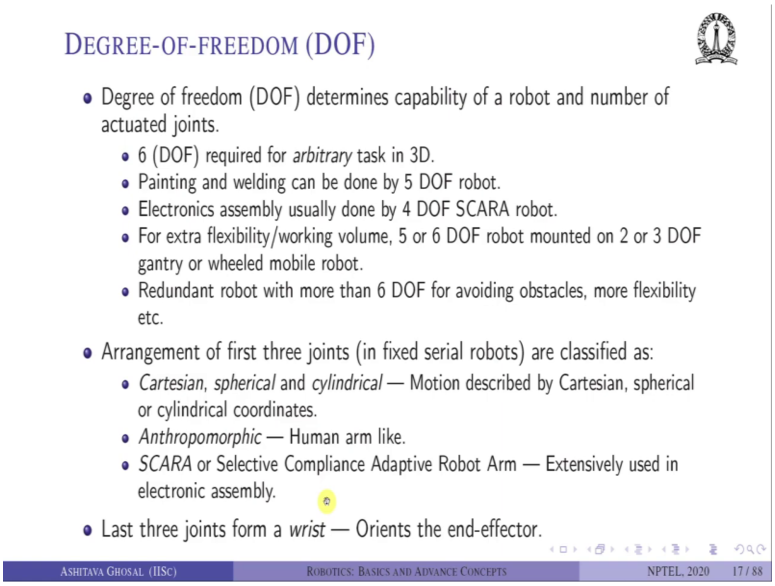

A robot can also be classified according to the degree of freedom. So, this degree of freedom determines the capability of a robot and the number of actuated joints. So, if you have a 6 degree of freedom this is what is required to arbitrarily position and orient a object in 3D space ok.

So, in 3D space you have xyz position and also orientation. To achieve this arbitrary position and orientation, we need 6 degrees of freedom ok. Painting and welding can be done by 5 degrees of freedom because there is not much gain in rotating the welding torch about its last axis. Electronic assembly can is usually done using 4 degrees of freedom SCARA robot ok.

So, I want to move in xyz, go up and down and also in xy and also rotate this pin or chip such that it enters the PCB ok. For extra flexibility and working volume a 5 or 6 degree of freedom can be mounted on a 2 or 3 degree of freedom gantry or a wheeled mobile robot.

So, I can have a 6 degree of freedom robot, I can put it on a mobile robot and it can go various places. So, the entire system now has much more than 6 degrees of freedom. You can also have redundant robot with more than 6 degrees of freedom for avoiding obstacles and flexibility. So, I will show you; I have shown you a video of a redundant robot which can be used to avoid obstacles ok.

So, there are many more joints in this redundant robot or many more degrees of freedom than what is required. The arrangements of the first three joints in fixed serial robots are sometimes classified in three ways actually four ways. One is called Cartesian, spherical or cylindrical.

So, basically the motion can be described by Cartesian, spherical or cylindrical coordinates ok. So, the first three joints would be x, y and z or it could be spherical r θ ϕ or cylindrical r θ z. We also have anthropomorphics, so, like the PUMA ok. So, we have one shoulder, we have one upper arm and we have one forearm ok.

This words anthropomorphic as I mentioned it means human arm like. We can also have SCARA or selective compliance adaptive robot arms; SCARA stands for that and this is extensively used in electronic assembly. The last three joints form a wrist ok. Most of the time it is used for orienting the tool or the end effector ok

So, the first three joints typically are used to position the object in 3D space and the last three joints can be used to orient the object at the place where you want to be ok.

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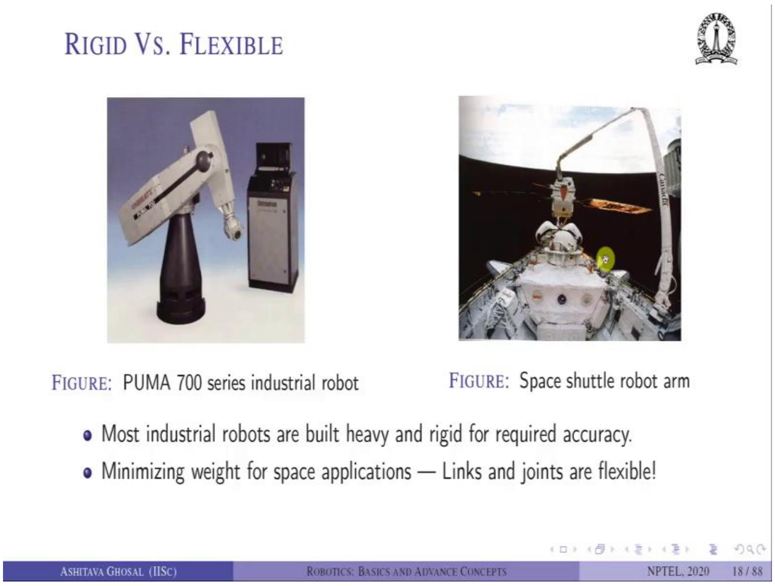

So, rigid versus flexible. So, this is an example of a rigid robot. So, this is again another PUMA not the 560, but another PUMA which was developed by the same company. So, this is a 700 series industrial robot ok.

This is very very rigid very heavy and rigid because I do not want any vibration ok. I want to position this tip very very accurately without vibrating. Whereas, the space shuttle arm is very flexible. Why? Because in order to send a heavy robot you have to spend a lot of energy. So, weight comes with the penality for space applications.

So, the links of this space shuttle arm are really really flexible they are. So, flexible that you cannot move them on earth easily ok. You have to go inside a swimming pool and make sure it is floating properly and then move it and do all the testing ok. If you move it in gravity normal gravity in air it will bend.

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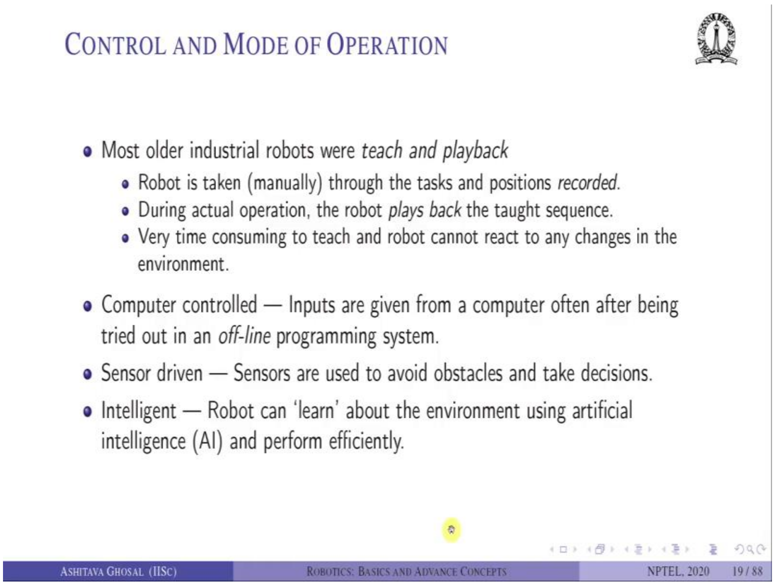

Most older robots were teach and playback as I mentioned. You teach a certain trajectory, you teach a certain task and then you play it back ok. So, the robot is taken manually through the tasks and positions are recorded. During the actual operation the robot plays back the taught sequence that is all which does. This is very very time consuming to teach and a robot cannot react to any changes in the environment ok.

So, if you are doing welding and then somebody suddenly comes in between it cannot react, it does not know because it is playing back what it remembers or what has been taught. You can also have computer control. The inputs are given from a computer often after being tried out in an offline programming system ok.

So, these are that you have this off-line programming system which is basically nothing, but a CAD model of the environment and the robot and then you move the robot inside this environment, make sure that it is doing the tasks properly, it is not hitting anything and then you play it back using a computer on the actual system, ok.

So, these are the two main control and mode of operations for the robot. You can also have sensor driven. So, basically sensors are used to avoid obstacle and take decisions ok. So, this robot which is vacuuming in your house if suddenly something comes in front of it will stop ok.

So, the mode of operation is based on sensor input. You can also have intelligent robots. So, the robot can learn about the entire environment using AI tools and then learns as you make it keep on doing more and more and it becomes more and more efficient ok. So, this is a very new trend in robotics, basically, learning how to do a certain task.

So, with this we will come to the end of this lecture. I have looked at what is the definition of a robot. I have looked at some of the types and classification of a robot and I have also shown you some videos of robots from internet and what is available from the research done at IISc ok. In the next lecture we look at some of the main elements of a robot.