Introduction to Robotics
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Lecture 1.2
Evolution of Robotics

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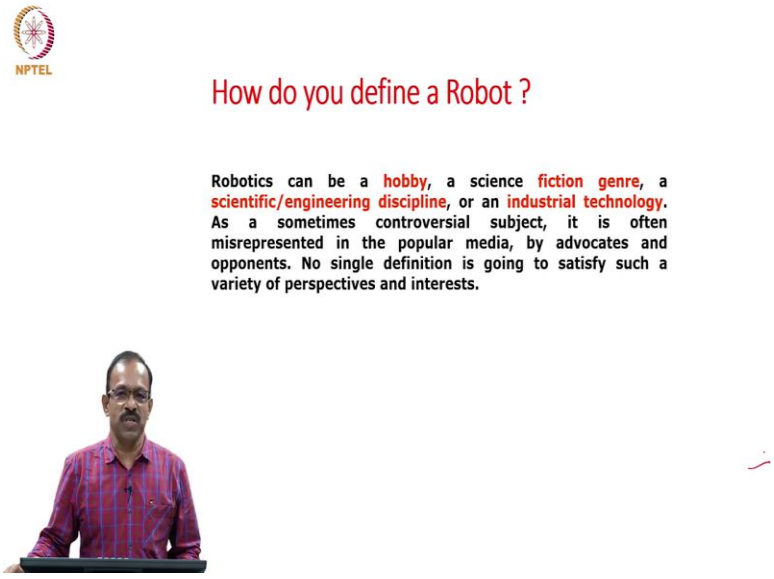

Welcome back. So, we will continue the introductory part of this robotics course. So, in the last class I briefly mentioned about the various applications of robots and then how people are actually using robotic in various fields. And we saw that because of the varied applications and the or all people from different works of life we have a difficulty in defining the robots, so for some time it maybe a hobby for many people, sometime it may be an engineering discipline or it's more of a technology used in the industry.

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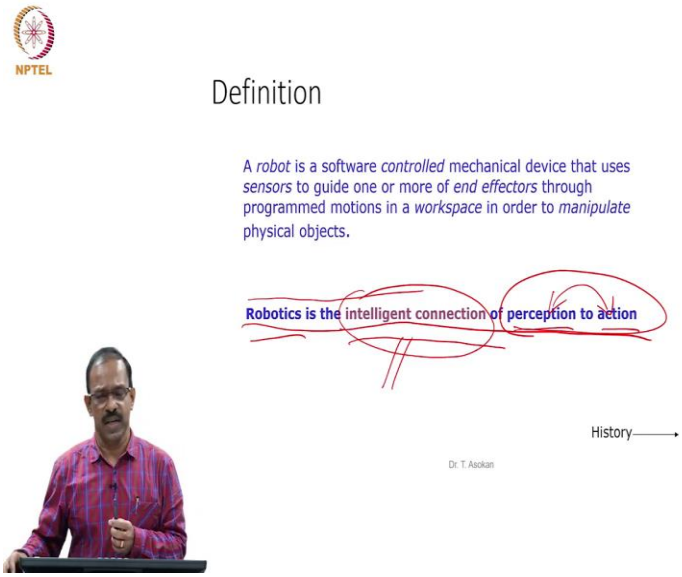

So, one definition is not really going to suit for the robotics and that's why we saw that the earliest definition or the definition existing quite some for quite some time, it is like a robot is a software controlled mechanical device that uses sensors to guide one or more end effectors through programmed motions in a workspace in order to manipulate physical objects.

So, that is more suitable for an industrial robot and then the current generation reports do not really fall into this definition that is why we got a new way of defining robot as the intelligent connection of perception to action. So, this is what actually we saw in the last class. So, when I say intelligent connection of perception to action, it basically says that, I have a perception of doing something which is not possible for me in the normal situation of using the current level of technology or the current level of products available I am not able to do, but I have a perception of doing that.

And if I can actually make it happen through some intelligent connection then we call it as robotics. So, to give an example assume that I have a perception or I have a perception of getting my lunch delivered to my office simply by pressing a button or activating something, so I do not want to go home, I don't want to take my car and then go home for lunch and then come back instead, I would like to have my car just when I press a button I want my car to go to my home collect my lunch and then bring it to my office somehow, if it is I mean that is my perception.

So, I have a perception of having my lunch delivered to my office, so this is my perception. Now, the question is that, if whether I can do it through an intelligent connection? So, one way of again have a assistant or somebody to do this or I can actually have a driver to drive my car and then come back with lunch or I can have a delivering agency doing this. So, these are all possible way to get my lunch without me going out of my office, so that is my perception. So, my perception is I do not want to go out of my office, I want my car to get my lunch.

And as I mentioned there are many ways to do this. But if you look at there are no intelligent connection in any of these because my perception of getting lunch and then delivering the lunch I said the action, the action is basically getting the lunch without me going out of my office. Now, if I can have a intelligent connection, for example, if I actually convert my car into a fully autonomous car and then program my car to go to my home and collect my lunch and then bring it back to my office, then there is an intelligent connection, I am actually connecting my perception to action through an intelligent means.

So, that kind of an intelligent connection if you can see in any of the systems or products then we call this part of robotics, so we call that as the robotics technology. So, this is the way we can define robotics because any other definition will not fit for all the type of robots existing in the fields. And that is where we say that, if you can have an intelligent connection of perception to action then we call it as robotics. And to what extend you can call just robotics as it depends on what extend is your intelligent connection, how intelligent your system or how intelligently you are connecting this perception to action through some means through actuators, sensors control of whatever it is.

And if that is having that intelligent connection then we call it as robotics. So, this is the way how robotics is defined nowadays. Of course, you can always question this definition because again it is not really defined what you mean actually intelligent connection, how intelligent it has to be? And we simply remote control or it can be a fully autonomous, so all those things are there.

But we do not go get into that those details but we will say in general we can say if there is a perception and there is an action and if these two are connected through intelligent means and if you are achieving this perception to action through an intelligent means then we can call it as a call it as robotics. So, that is the way how we can define robotics now. So, let us briefly look into

the history of robotics how the robotics technology evolved over a period of time and what is the current status.

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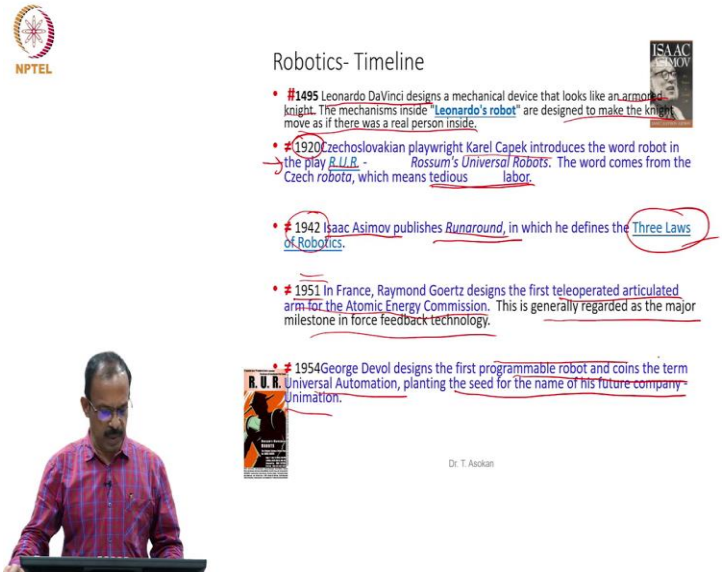

So, if you go back to the fourteen or fifteen century, it was Da Vinci, Da Vinci who actually brought something into the field or something called robot Leonardo's robots, which were actually make something like armoured it was a like an armoured Knight which move like a human, so designed to make the knight move as if there was a real person inside. So, that was the mechanical device that looks like an armoured men proposed by Da Vinci in 1495.

And it was only in 1920 this Czechoslovakian law can play right Karel Capek introduced the word robot in his play Rossum's universal robots and the word comes from the tedious labor, so robot actually means tedious labor. And this play actually introduced the word robot and we continue to use this one for many years now. And it was Asimov most of you must have heard about Asimov is a writer and he publishes the book run around in which he defines three laws of robotics and then actually we do not have any robot at that point of time and even this play also actually introduced the word robots and 1942 this three laws of robotics were this were published.

We will see what are these three laws more of any historical importance and then lot of things happened in 1951 at teleoperated articulated arm for the atomic energy commission was used because in electronic sorry in nuclear installations handling of nuclear fuel is an issue, so they

need to have something called the teleoperation that can operate the device from a remote location.

So, in 1951 France there in France they brought this kind of device and that was regarded as one of the major milestone in force feedback technology. And again in 1954 the first programmable robots was introduced the universal automation, planting the seed for the name of his future company, so it is a universal automation Unimation was the robotics company, so they introduced this program build robots for industrial applications.

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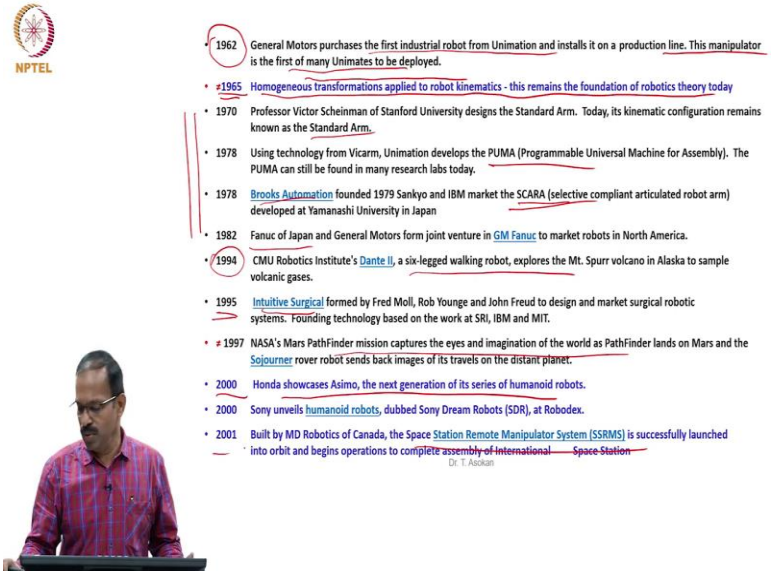

And of course 1962 General Motors purchase the first industrial robot from Unimation that is a universal automation company Unimation and it installed it on a production line. The manipulator is the first of many Unimates to be deployed, so it was somewhere in 1962 we had this first robot coming to the industry for practical application. It was somewhere in the same time in 1965 this homogeneous transformation applied to robot kinematics was published by Denavit and Hartenberg.

And that actually is one of the major milestone in the kinematic analysis of robots, so they proposed a methodology to analyse the kinematics of robots and introduce the homogeneous transformation methods. And then after that there were a lot of development taking place, lot of industries coming came up with robots like a PUMA, Standard Arm, then we have this PUMA robots PUMA and then Brooks Automation started introducing a robot called SCARA or

SCARA configuration and then Fanuc also started working on industrial robots and it was somewhere in 1994 so parallel with the industrial robot lot of people started thinking of various kinds of robots.

So, industrial robot was a fixed base one and people started thinking of mobile robots, walking robots etc. So, a six-legged walking robot was introduced somewhere in 1994 and it was somewhere in 1995 Intuitive Surgical came up with their medical robots and then NASA's Pathfinder missions started in 1997 and the mobile sorry the Asimov or the humanoid robots was introduced in 2000. And 2001 there were this space robot the Space Station robot was introduced in by Canada known as Canada Arm was introduced in 2001.

And after that after 2000 also a lot of things happened in 2001 to 2020 we had lot of applications being developed by various industries and academic institute's ok underwater robots were introduced and then space robots, robots were healthy elderly care, healthcare robotics, so lot of development took place. So, this was just to tell you that as a robot history is not very old, it was somewhere in 1960 the first robot came, so we are only 60 years old the field.

But it is actually spread very far and far wide applications and still lot of research and development is taking place, though lot of interest and lot of people are working still we have a long way to go because the technologies and the systems available are still far less adequate than what actually we expect the robots to do. So, these are just to tell you that research and development is still going on and a lot of work is to be done in order to make good robots autonomous robots to serve the humanity.

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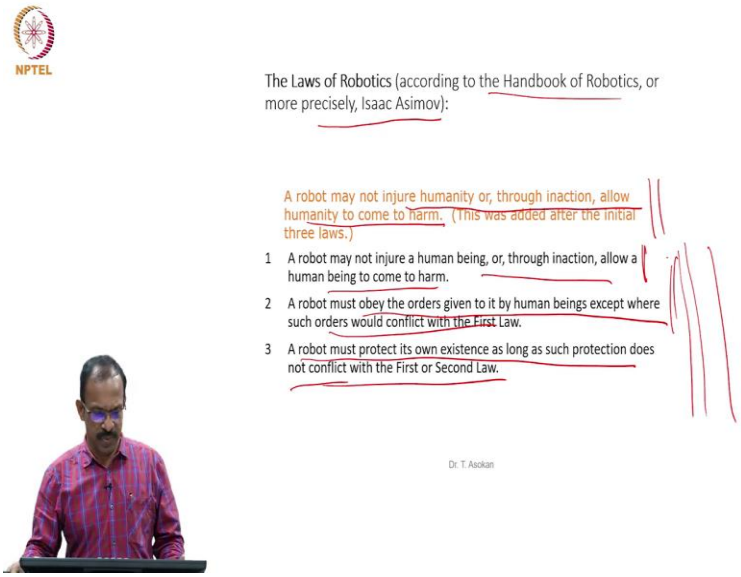

So, I mentioned about this laws of robotics, as I told you is was actually proposed by Asimov in his book handbook of robotics actually he proposed this three laws, it is off more of an historical importance but still as robotics engineers you should know somebody proposed these laws and then they are actually still have some kind of relevance in terms of human behaviours and humanity. So, the first one was basically a robot may not injure a human being or through inaction, allow a human being to come to harm. So, no robot should be allowed to bring harm to a human, so that was the first law.

And the second one robot must obey the orders given it to by human beings except where such orders would conflict with the first term. So, whenever instruction is given to the robot the robot should follow the human or whoever is giving the instruction the robot should follow. Provided it is not against the or it is not in conflict with the first law, that means you cannot ask a robot to injure a human being, then the other robot should not follow that instruction. And then the third one is a robot must protect its own existence as long as such protection does not conflict with the first or second law.

So, that is the second sorry the third law, a robot must protect its own existence as long as such protection does not conflict with the first or second law. So, the robot should not destroy itself or it should not take an instruction to destroy itself by someone, because that as per the third law it should not it should always try to protect its own existence. As long as it is not in conflict the

first or second law. So, this is the these are the three laws proposed by Asimov, long back. But someone thought that these are not sufficient to protect the humanity from robots, so it does not talk about humanity as a whole and it's possible that a robot may be in control of a nuclear station or a very lethal weapon.

And it can actually wipe out the humanity by action or inaction. That is why a zeroth law was added later to make sure that the robots are robots the humanity is protected or a humankind is protected from the acts of acts or non-acts of robot. And the zeroth law says that, a robot may not injure humanity or through inaction allow humanity to come to harm. So, as a humanity total human species should not come to harm through action or inaction of a robot. So, this was added as a third or zeroth law of robotics.

As I told you it is of more of historical importance still people I mean nobody will really checks whether the robot follows the laws 1, 2, 3 etc, there is no checking or standardization based on the laws. But as a moral principle or ethical principle of design of products, we still ensure that the robots do not injure human or robots do not harm the humanity. But many times it is not really feasible to follow all these laws because technically speaking a medical robot or a surgical robot is used to cut open the human body or to do some surgical procedures in human body.

And technically speaking it is actually injuring the human though it is controlled by a doctor, so we cannot really say that the robot should not injure a human being in that sense and that is why it is not possible always to ensure that all these laws are followed, but we look at the spirit of the law and then see whether we are able to follow the spirit of this law and make sure that the human as an individual or humanity as a whole is not getting affected by the robots action or inaction. So, that is about the laws of robotics.

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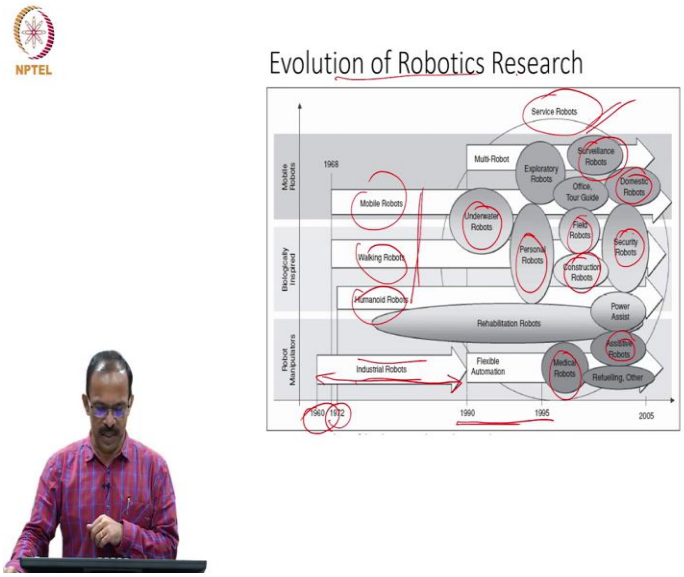

So, now let us look at the field how the evolution actually happened in the in this pictorial representation. So, this is from a paper published in IEEE magazine, so you can see that if you look at the growth the evolution of robotic research as I told you it was somewhere in 1960's the industrial robots actually started coming into the market to us, so this was the period where actually the industrial robot had very good growth and lot of robots came into the market and lot of industries started using industrial robots.

And it was somewhere in the same time somewhere in 1970's, because of the success of the industrial robots to do many task in the industries people started using or thinking about can we use this for other applications also not only in industry and that is where the mobile robots walking robots and humanoid robots were actually started getting attention and many research centres and few industries started working on these robots.

But there was not much of growth in that area because most of the focus was on industrial robots, most of the people were looking at the application of industrial robots, especially in the automobile industry and all. And it was somewhere in 90's and beyond everyone realized that the industrial robotics technologies almost maturing and there is nothing much you can do because whatever we are doing we can do is being done in the industries because lot of robots are being used.

And there was improvement taking place in terms of the load carrying capacity controlled and sensors and things like that, but there was not much of research or development taking place in terms of new products coming to the market. And therefore it was actually saturating and people realize that the technology being developed for robotics, because lot of people were doing research in terms of control, development of controllers, development of sensors, actuators etc.

And the impact of those developments in the industrial robot was not very significant and that is where people started thinking, can we do this? Can we take this technology to other fields? Or can we take the technology to application areas where we have where we can bring the robot more closer to the human? And then we started this area of field and service robots that included underwater robots, personal robots, then construction robot it called as field robots, then security robots, medical robots, assistive robot, etc etc domestic robot, surveillance et cetera.

So, the current focus of robotics research is to see how we can use this robotics technology for an application, the field or a service application, can we take this technology use this technology or integrate this technology and the system in order to get a new application? That is where the focus of current robotics research is more on the field and service robotics. If you can actually find an application and develop a system a robotic system to suit that application then you are actually contributing to the field of robotics.

Otherwise, if you develop the technologies and then we are not able to use them effectively, then we are not able to take the take forward the robotics field and that is why lot of research is research and development is taking place in the field of field and service robots that includes robotic application in any field, so you can name any field and if you can find a robotic solution, then we are actually contributing to the growth of robotics.

So, if you are interested in robotics, once you take this basic course on robotics which actually introduces you to the very basic fundamentals, your focus should be on to see how can you take it forward or how can you use this knowledge to develop robots for field and service applications. I hope you got the fundamental principle of the robotics, how the robots a robotics field is growing and what evolution is taking place in this field.

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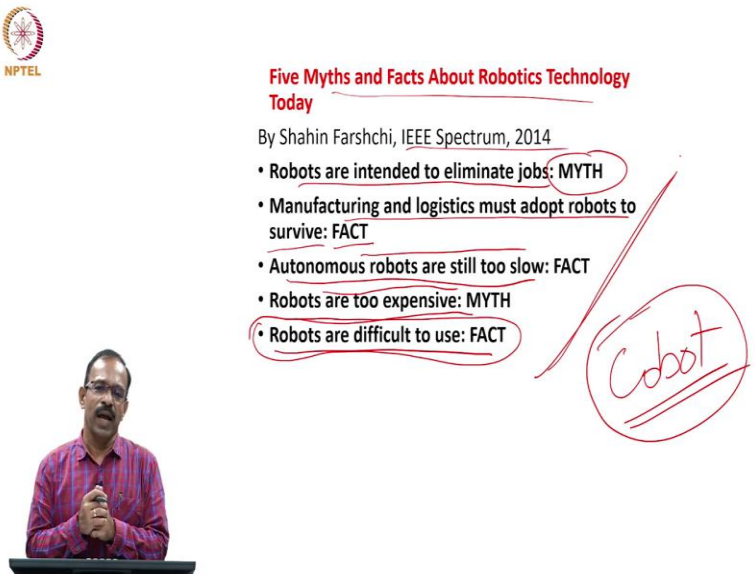

Just to tell you a few things about robotics, so there are many myths about robotics or people because as I told you there are lot of hype created in the media about robotics so there are lot of myths about robotics also. So, this was actually from IEEE Spectrum 2014, so one of the major myth is that the robots are intended to eliminate jobs. So, the first look if you see then you will see that there were a lot of industries were actually robots replace the human operators, may be true if you look at only that aspect.

But then they actually create a lot of jobs in many other fields and therefore the it was not it did not it really eliminate jobs, but actually it actually moved the jobs from the shop floor to some other place. So, that all that actually happened. So, there was therefore the robots are intended to eliminate job is a myth, in fact, it is actually to enhance the capability of a human and to enhance the productivity and to ensure that the quality of production and quality of output increases with the use of robotics technology.

So, elimination of job is not at all true and it is a myth. And one of the important facts about robotics is that manufacturing and logistics must adopt robots to survive. So, if the industry has to survive, it has to adopt the robotics technology because automation plays a major role and robotics is one of the key elements in industrial automation, which actually allows the industries to enhance their productivity improve the quality of production and that will actually help them to survive in the market.

And another fact is that the autonomous robots are still too slow, so just I told you, we have a long way to go to get a fully autonomous robots, so though there are lot of research going on both in terms of technology as well as in terms of products, we are still far away from having a fully autonomous robot which can function the way we want because most of the autonomous robots are too slow nowadays mainly because of the our limitations in sensing perception and control.

And robots are too expensive also is a myth, because the cost of robot is actually coming down and looking at the capabilities of the robot the capability of robot increases and the cost is also coming down and therefore the overall reduction cost is very high and therefore the notion that the robots are too expensive is actually a myth. And this still remains as a fact the robots are difficult to use and this is where actually we need to do lot of work to make the robots easy to use.

Still we do not I mean our robots are still not that friendly with the human, we still do not have full trust on the robots, so we keep the industrial robots away from the human, we try to have fencing and other things and the current trend of developing cobots some of you must have heard about this, cobot is basically a collaborative robots, so the robots are slowly getting replaced with cobots where the robots can actually work with human and the robots are made in such a way that it do not really hurt the human or cause injury to the human, so that is basically the cobots.

Though this kind of development is taking place there are again lot of challenges and we are having difficulty in using robots for practical application. So, these are the facts and myths about robotics and robotic technology, so we need to understand that like any other technology robotics has also got lot of advantages and lot of limitations.

And the focus is basically to see how can we overcome the shortcomings of robotics technology as well as the robots and then make it more and more user-friendly, more and more human friendly and that will lead to the acceptance of robotics were many more applications. So, every robotics engineer's focus would be to see how can we develop better applications and how can we make it come more closer to the human being and make it more useful to the human kind.

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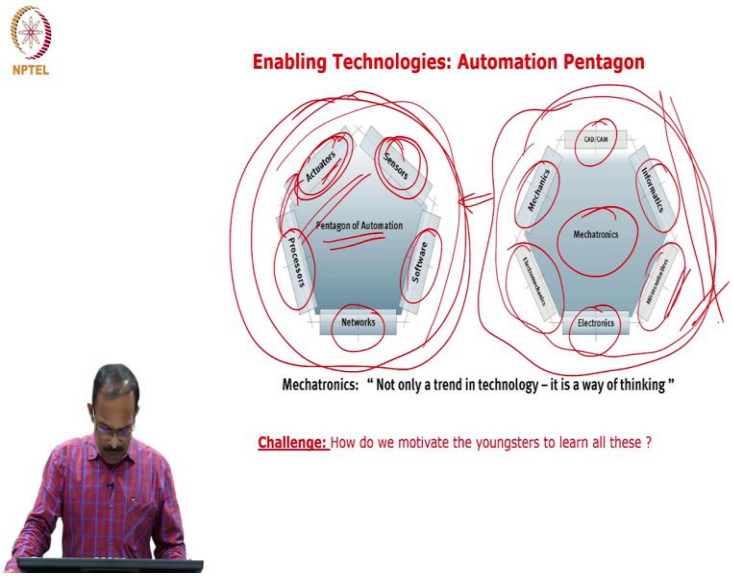

Now, let us look at the enabling technologies for robotics. So, we mentioned that robotics is an interdisciplinary field and then you need to have an understanding of interdisciplinary subjects or multidisciplinary subjects you need to understand in order to learn robotics as well as to do research or development in robotics field. So, if you look at the I mean robotics is also part of automation, so if you look at the pentagon automation, so this is known as the pentagon of automation, where we see that these five elements actually contribute to the automation field.

So, the most important part is the actuators. So, any automation we need to have a motive power to move things and that actually comes from the actuators. So, the actuators being an electrical actuator or mechanical or hydraulic whatever it is, so this actuators provide the necessary power for the system. And then we need to have sensors in order to get data and then based on this data we can get the actuators provide the necessary power.

So, sensors make some become an important element in the automation pentagon. And the other one is a processor, a processor is the one which actually process data and then take decision based on the intended motions as well as the current situation. So, it actually collects the information from the sensors and process the information and then give the instruction to the actuators to do work.

And in order to make this possible we need to have a network of communication, because we need to communicate between various elements in the system, so we need to have a network and

of course we need to have a software in order to link them together and then have a unified way of functioning. So, these five elements are known as the pentagon of automation and robotics also basically depend on all these five elements, if you look at a robot you can see all these elements are present in the robot also.

And the scientific discipline which actually provides you knowledge about all these elements is basically we call it as the mechatronics, where we have the mechanics the design and manufacturing, informatics, microcontrollers, electronics and electro-mechanics. So, the mechatronics stream really covers all these areas and the student who actually has got some understanding of mechatronics will be able to contribute well to the robotics field.

That is not mean that you need to be an expert in mechatronics, but the point is that if you are if you want to be a good robotics engineer or a robotic researcher, you need to have an understanding of these elements, you cannot be in isolation, ok I know only software, so I do not want to be only a programmer for a robot that actually not going to help you as a designer or a researcher because you need to know what is happening inside the robot, what how is it functioning and to understand that you need to have some understanding of this technology areas.

And the challenge is basically how do we actually make sure that the students can actually learn all these field. There is no straightforward answer to that question, but one thing is that we start with some basics of these field and then you build upon that and then try to ensure that you are able to understand what is happening in other fields. So, you cannot remain as a mechanical engineer or an electrical engineer or a computer science scientist and still want to be a robotics engineer, you need to come out of your own domain and then make sure that you understand these areas also to some extent so that you can contribute well to the field of robotics.

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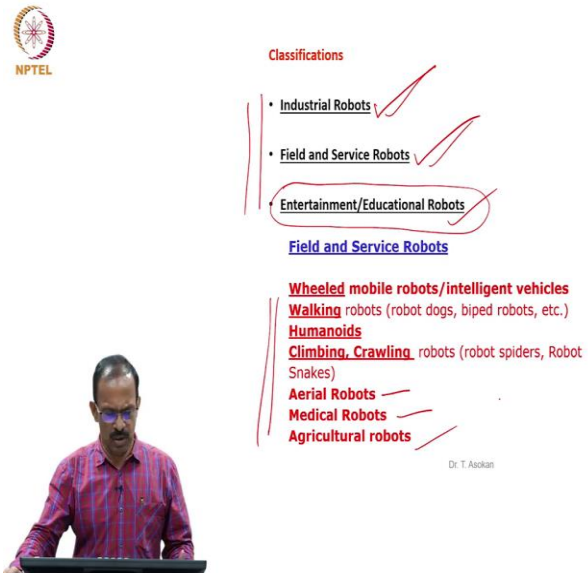

Now, we will so that is basically to tell you that an understanding of various discipline or an interdisciplinary knowledge is essential for the robotic engineer. So, let us go to the robotics field again and then have a very quick look at the various classifications of robots, I showed you few videos in the beginning just to tell you that these are the various robotics application. But let us have a little bit more close look at this classification, so we can say that this the fine classification is industrial robots.

And then one is the field and service robots. And then the we can say entertainment educational robots. So, this is a small area which actually does not have too much of interest for us, but this is these are the two areas where actually you can focus your attention. And under the field and service robots you have a large variety of applications like wheeled robots, walking robots, humanoids, climbing, crawling, aerial robots, medical robots, agriculture robots etc. Let us, just quickly go through this applications, the classification.

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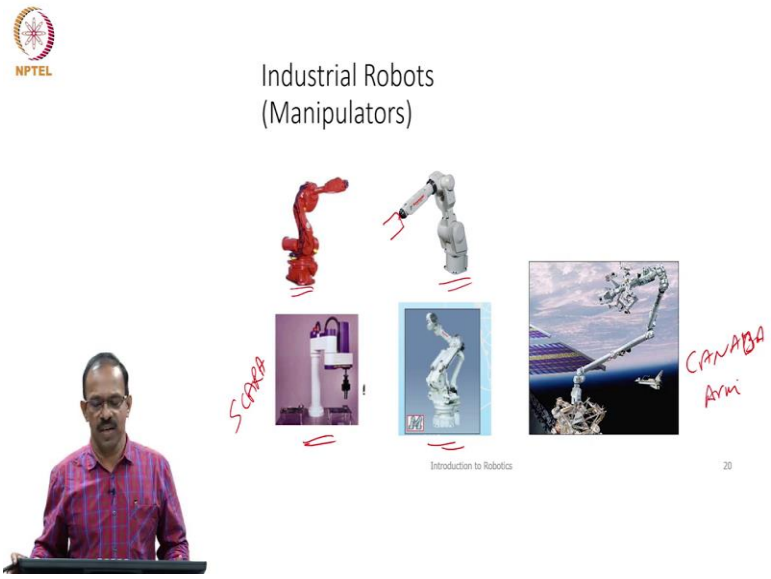

So, the industrial robots as I mentioned they are the kind of robots used in the industry, especially in the manufacturing industry for operations like pick and place, welding, assembly, painting etc etc. And there are various categories within the robots industrial robot, which we will see later when we go for the details of kinematics and other aspects, so you can see these are typical industrial robots, so up to this and then you will be attaching an end affecter at the tip and then it becomes a fully functional robots.

And there are different classification also within this, so this is known as a SCARA robot. And these are articulated robot arms and this is the Canada arm which is there in the space station, so space station international space station as put a manipulator arm for doing repair work and pick and place operations, so that is known Canada arm. Again it is a kind of industrial robot configuration.

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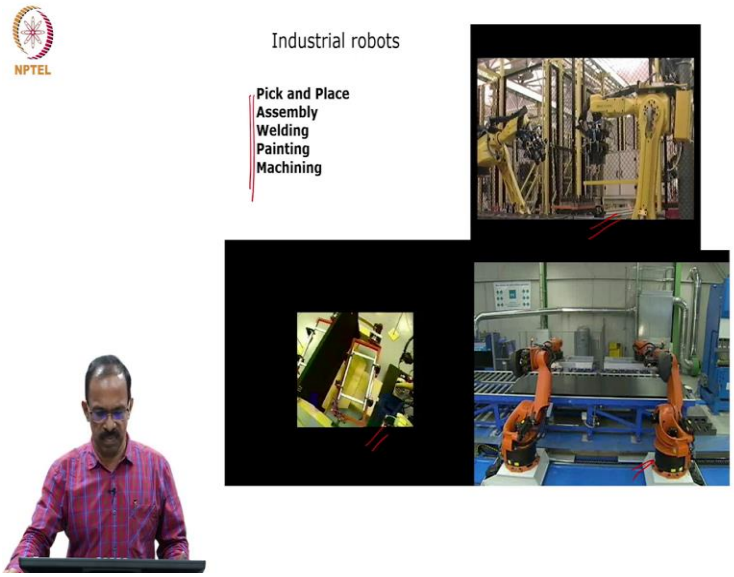

And these are some of the applications pick and place, assembly, welding, painting, machining, etc. So, I show you this video that the two robots working together in order to do some machine tending and then helping for I mean pick and place another operations. And this is actually a welding robot, this is an assembly robots, which are widely used in industries for various application, basically to automate the process in the industry.

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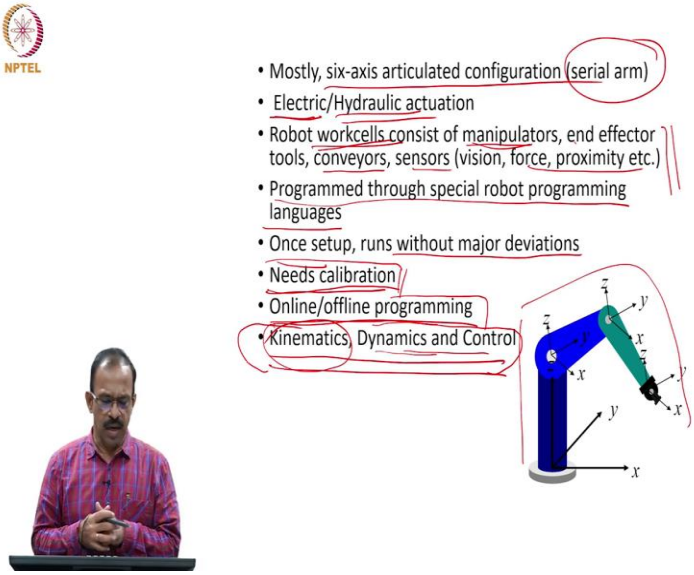

And what are the major features of industrial robots? Again this will be discussing it later also, so mostly these are six axis robots and connected like a serial chain like a human arm we have

joints, then we have links and then we have joined then link then join like that, so that is basically the serial way of assembly of about assembly of the links and joints. And most of them are electrically actuated nowadays, but there are hydraulic robots also when you did need to have large load carrying capacity, then we go for hydraulic actuation.

And having a robot alone is not sufficient we need to have something called a robotic work cell, because a robot has to do some work which has to have some kind of peripheral equipment in order to make sure that the robot is able to do its task, so basically manipulator is the main robot parts and then you have this end effectors, then conveyors sensors etc vision, force, so all those things actually become part of the robotic work cell.

And most of the robots are programmed through special robotic programming languages. So, most of the manufacturers provide a programming language so you can actually use that language and program the robot to do different tasks. And one of the advantage is that once you set up the robot, then it runs without any major deviation. So, it may take some time for you to set up everything and then make sure that it do its job perfectly.

But once it is set up then you can actually leave it to the robot and the robot will work continuously 24 hours 7 days a week without major variations or major deviation from its performance characteristics. Of course, the mechanical damages and wear and tear will cause some deviation, but you need to as long as you take care of those aspects, then the robot will be able to work continuously without measure deviation as well as measure interventions.

So, the wear and tear and then other mechanical damages warrants the calibration of robots, so maybe once in a year or so you need to calibrate the robot and then make sure that you are program and the parameters what you obtain from the mechanical parameters what you use in the programming they are correct or there is no variation, so that can actually be done using the calibration of robots.

And we can do online or offline programming again online programming you can actually program the robot as a robot and the robot is doing its work or we can do an offline programming using some offline tools and then port the program to the robot at a later stage and they start working. So, important aspect as engineers, what we are interested in is in the kinematics, dynamics and control.

So, these are the three important aspect of robots as a designer will be interested. Of course as a user you do not really worry about this, but as a designer as an engineer, you need to know about the kinematics, dynamics and control of this robots. And that will be the focus of the course, of course, the dynamics and control will be not be that detail in this particular course, but of course they will be you will be having additional courses available which talks about dynamics and control, so here we will talk more about the kinematics of the industrial robots.

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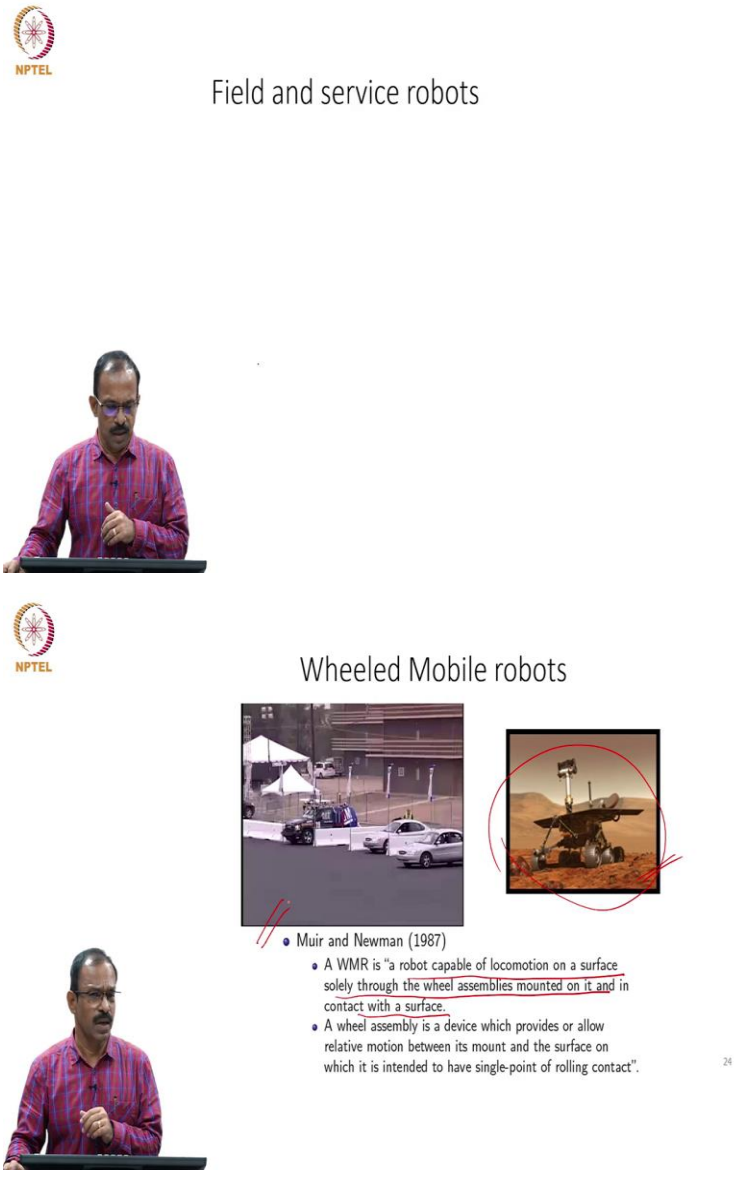

Coming to the field and service robots, as I told you there are different kinds of field and service robots, so wheeled mobile robots are the one which actually very popular and it actually the

research started very long ago and lot of development took place in this field and it's defined as a robot capable of locomotion on a surface, solely through the wheel assemblies mounted on it and in contact with a surface, so that is known as the wheeled mobile robots.

So, you can have various configuration, you can have two wheeled robots, you can have three wheeled six-wheeled, you can have robots for different terrains, so lot of development has taken place in the field of mobile robots or wheeled robots, so this is actually a robot for space application. And an extension of that mobile robot wheeled robot is now the autonomous cars, it is actually an extension of wheeled mobile robot. Now, we are actually using this technologies what we developed for mobile robots and then porting it to a real auto mobile and then see whether we can actually get autonomous operation of these cars.

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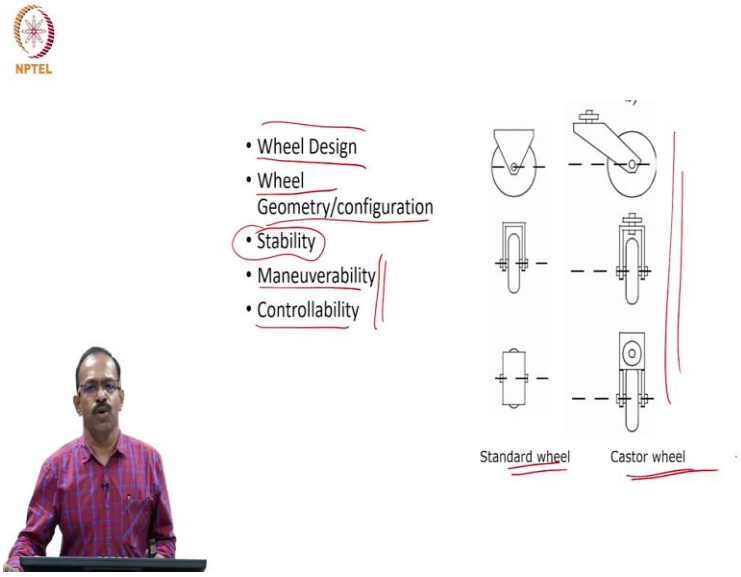

So, important issues in the wheeled mobile robots are the design of the wheels and the wheel geometry and configuration and an important aspect is the stability of wheeled robots, so you cannot have always the stability assured and then we need to make sure that the robot is stable under various operating conditions and the maneuverability and controllability are the two aspects when the it comes to the design we need to ensure that it has got good maneuverability and good controllability also. And this actually shows the various ways in which the actually the we can have different types of wheel, the standard wheel and or a castor wheel based robotic design can be done.

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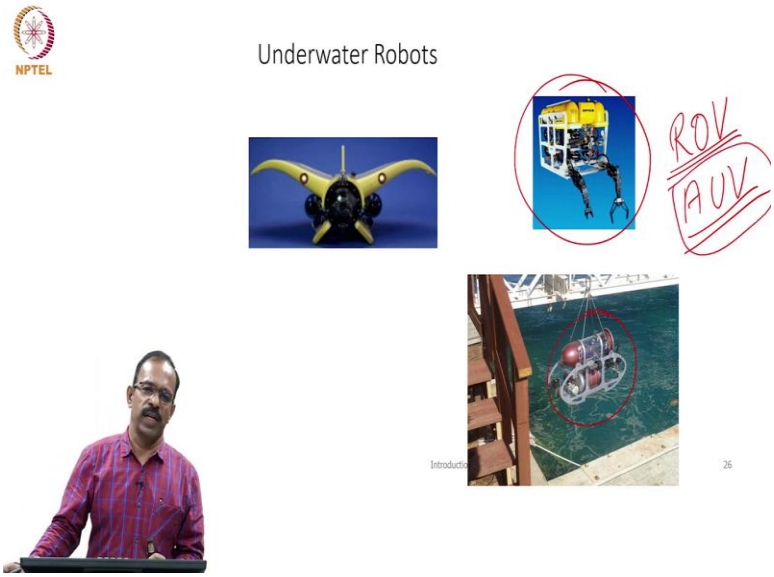

Quickly go through the other fields also underwater robots, robots which are being used for underwater applications, so these are some of the commercially available robots and this is a student robot which is used for autonomous robot, so there are two categories one we call just remotely operated robots and an autonomous underwater vehicle. So, remotely operated vehicle and autonomous underwater vehicle. A remotely operated vehicle is operated on a remote location with the cable is connected to the robot and to the operator and operator sits at a different remote location controls it, AUV is fully autonomous, you do not need to have any pilot or a controller sitting and controlling it.

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So, it is defined a mobile robotic device designed and developed to work in underwater environments to accomplish specific tasks, which are normally performed by human operators are known as underwater robots.

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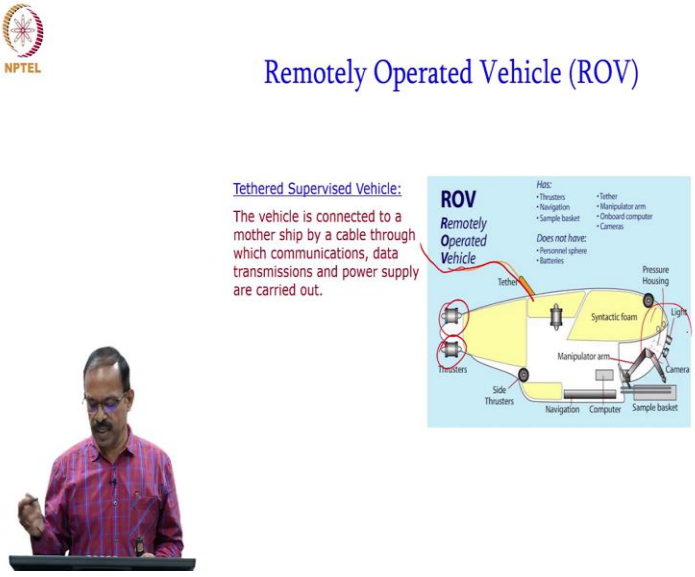

So, as I mention the two categories are remotely operated vehicle. So, remotely operated vehicle will be having a tether a cable which will be connected to the operator and then this thrusters will be used to propel it and using the cameras and other information other sensors the information will be relate to the operator and operator can control the robots.

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So, these are some of the commercially available remotely operated vehicle. So, ROV technology has come to a stage where it the lot of commercial applications and there are lot of commercial robot available in the markets and people are using it for many applications like inspection of underwater structures, pipelines, cables, etc etc.

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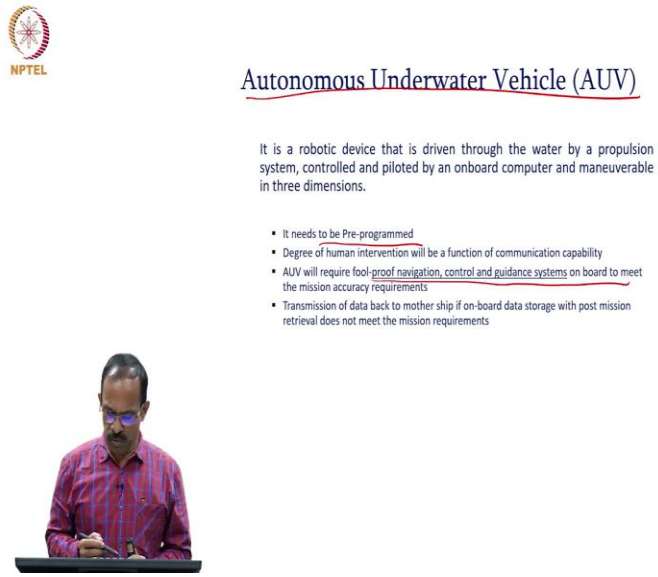

So, autonomous vehicle is extension of remotely operated vehicle, so instead of having it control from a remote location you program everything in the robot itself and then make sure that the robot goes from one location to another location and carry out all the tasks and come back

without any human intervention. So, that is basically the autonomous underwater vehicle. So, it needs to be programmed and it requires a fool-proof navigation control and guidance system on boards to meet the mission accuracy requirements.

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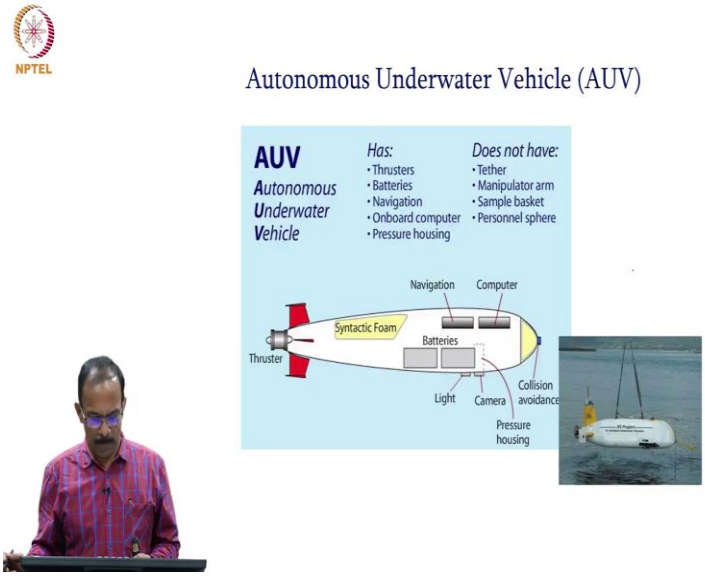

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So, this is a video of a autonomous underwater robots this was actually developed for Indian Navy and we were actually part of the development of this robots the control navigation and guidance algorithms were developed by us so this shows the sea trial of these robots carried outs in the Bay of Bengal. So, once it is released from the ship you can switch on the system and it starts moving and it goes to the depth indented depth and then carry out its tasks and then comes out.

Now, you can see it is being released from the ship and once it is given the command to go or based on the program it decides what time it has to start and you can see the thrusters getting activated and it starts going inside the water and of course after sometime it will you do not see it and it will comes up after some time and then you collect it from when it surfaces or it can actually program it to come back to at whatever location you want. So, that is basically the autonomous underwater robots.

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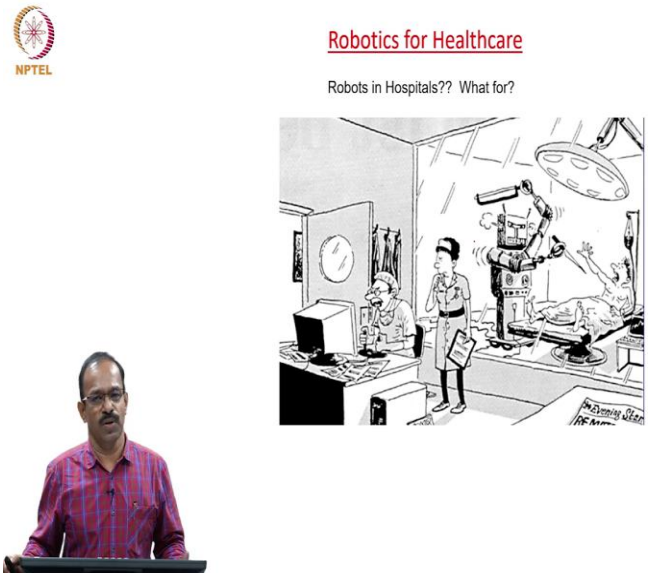

So, another important area is robotic for healthcare. So, healthcare area is getting lot of technologies from the robotics field and lot of robots are being developed for healthcare applications. So, many times where people think that why do we need a robot in the hospital or if you see that a robot is going to replace the doctor and then we will be under the control of robots, so it is not that case, the case is that we are actually using robot as a tool to help the surgeon or the healthcare provider to help him in the day-to-day activities or specialised activities of activities like surgery or rehabilitation.

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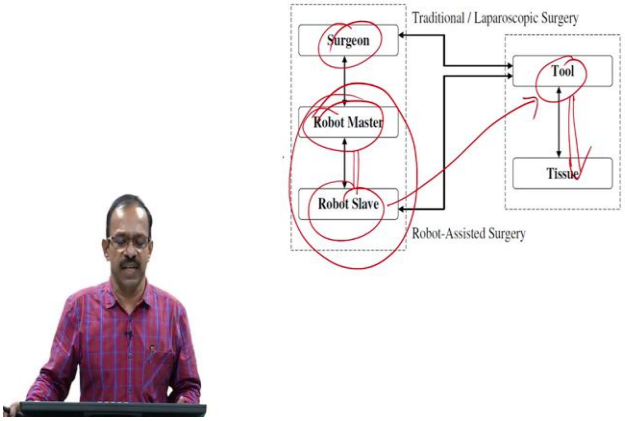

So, in a typical surgical robots, what actually happens is that the normal laparoscopic surgery surgeon holds the tool and then he interacts with the tissue, in the case of a robotic surgery what happened surgeon uses a robot master robots and the master robot is connected to a slave robots and the slave robot is holding the tool and then doing the procedure.

So, the surgeon is not directly connected to the tissue but he is connecting through a something called a master slave robots. So, the master slave robotic system or a telly robotic system is used in the robotic surgery and that actually helps the surgeon to improve the accuracy of the procedure as well as to reduce the fatigue and other related effects.

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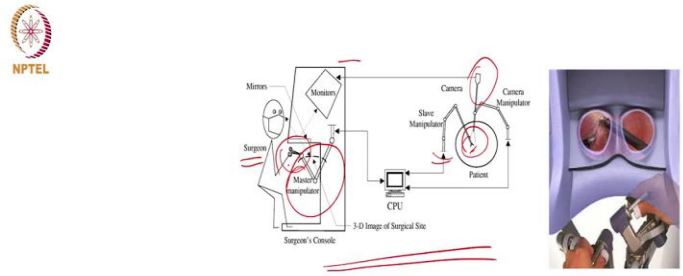

So, this shows a typical surgical robotics system where you have a you have the surgeon consolable where the surgeon is sitting at this location and here is the master manipulator and he creates the I mean using the master manipulator he decides what kind of motion he has to make if he has to do a cutting or he has to do a switch ring, he can actually imitate that motion here is in the master and the master is connected through a controller to the salve robots so the slave robot is holding the tool and whenever the master is when the surgeon is making a motion the slave also is making the same kind of motion at the patient and do the motion there.

That is how we get the telly robotic process done. And the surgeon is able to see the site through camera and we shall feedback system and it can actually also have a force feedback, so depending on the forces acting at this point the surgeon will be able to get the force feedback at

this end and he will be able to get it done. So, both visual feedback and the haptic feedback had the surgeon to carry out the surgery in a very effective way.

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Figure 1.2: The da Vinci Surgical System. System components include (a) the master

So, this shows a typical I mean this is the Da Vinci robotic surgical system and one of the only surgical robot available in the world currently.

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Rehabilitation Robotics

Rehabilitation robotics is a field of research dedicated to understanding and augmenting rehabilitation through the application of robotic devices. Rehabilitation robotics includes development of robotic therapies, and the use of robots as therapy aids instead of solely as assistive devices

And another application of the rehabilitation area, so I will quickly go through the application.

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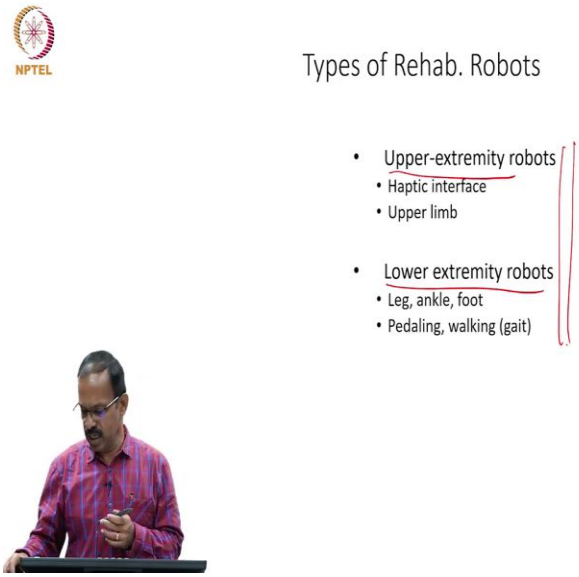

So, there are two types of rehabilitation one is known as upper extremity that is the upper part of the body and the lower extremity robots before the lower extremity lower part of the body. If you want to have a rehabilitation exercises or rehabilitation for a person who has bought a problem with his upper body or lower body, we can use robotic technology to do for rehabilitation or for getting some treatments.

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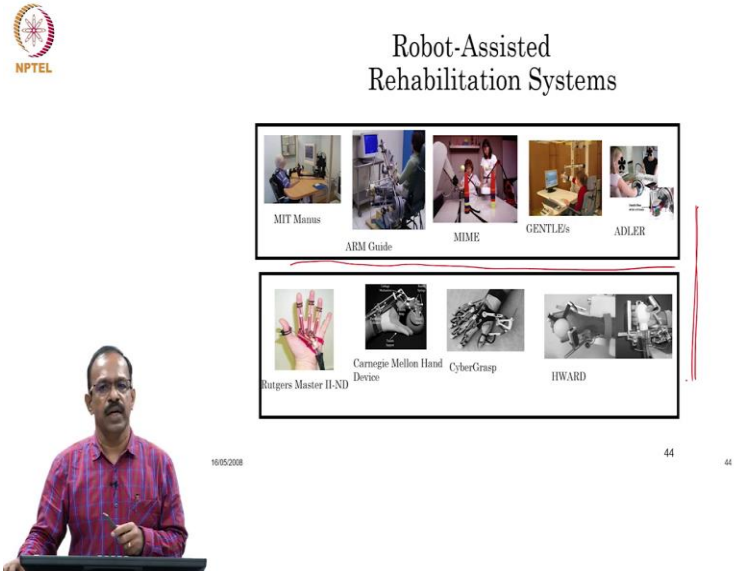

So, these are some of the rehabilitation robotic devices available in the market and currently under development. So, there are a lot of ways in which we can use a robotic technology to help

the people who require rehabilitation. So, when your rehabilitation or any other rehabilitation requirement can be done with the help of robots.

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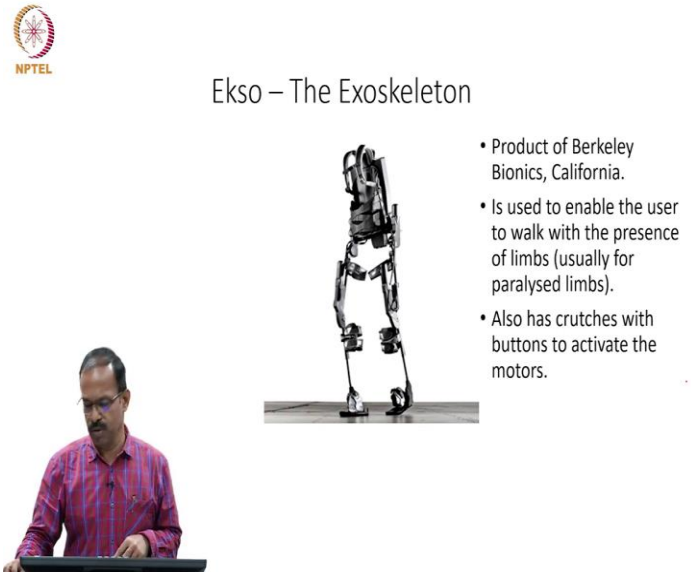

This is an exoskeleton which can be used for helping the people to walk when they don't have capability to walk because of some physical issues.

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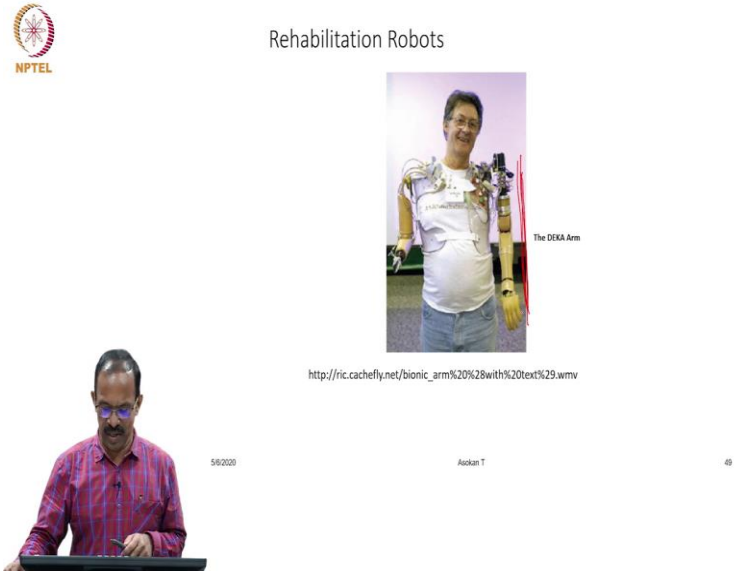

And the other one there is the bionic arm, so you can see somebody who has lost his upper body parts we can use mechanical devices to can be attached or robotic device can be attached to the body and then we can use the robot signals from the body to activate these devices. Of course, I

am just giving you a glimpse of what is existing and you of course you will be able to get more details either through courses additional courses or from internet you will be able to get information.

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This one this video I already showed you that how this device can be used to help the person to carry out normal activities with the help of a robotic device.

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Finally, the last one is the aerial robotics.

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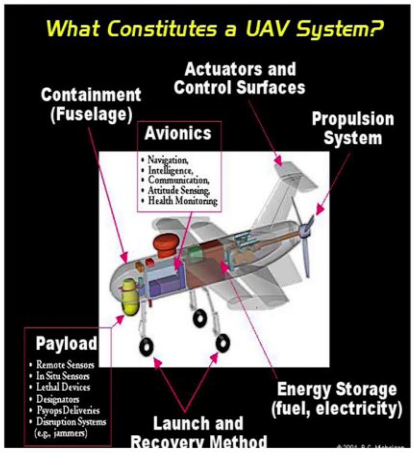

Aerial robotics basically a robotic device which can actually it is an autonomous mostly autonomous or mostly autonomous which can actually carry out tasks without the human intervention. So, we can actually have different kind of aerial unmanned aerial vehicles, so you can have it like a winged one.

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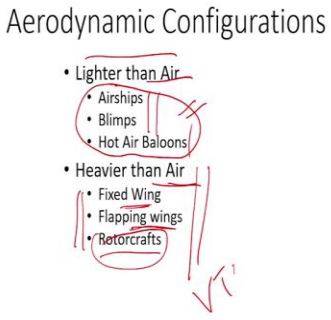

So, with fixed wings or you can actually have it a vertical a kind of lighter than air and heavier than air system. So, in the lighter than air you have this airship, blimps and hot air balloons. And then the heavier then air you have this fixed wing, flapping wing and rotorcraft. So, these are the

one which are not really we called as robots, but if you properly instrument it we can make it as a robotic device also.

Because since they are lighter than air they can actually go up in the air and then we what we need is the control of its motion, but then heavier than air you have this fixed wing, flapping wing and rotorcraft. Fixed wing is like our normal aircraft when you convert that into an autonomous thing then it becomes a unmanned vehicle, flapping wing like birds and other insects you can have and rotorcraft is the vertical take-off and landing type of vehicles.

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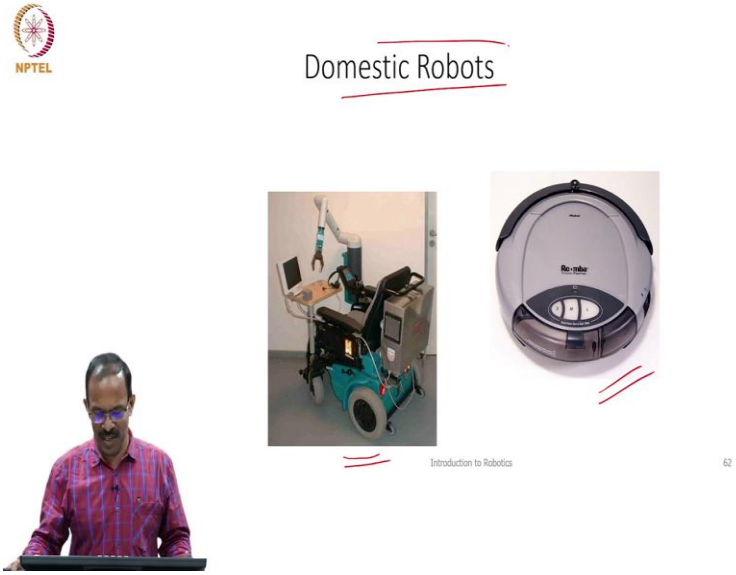

And there are a lot of domestic robots are also coming up, so like Roomba was introduced as a vacuum cleaning robots and then you have this wheel chairs to assist people, so these are known as the domestic robots and people are working on these to make it more and more user-friendly. Currently they are not so friendly with the people and not so useful, so the question is, how do we make it more and more user friendly?

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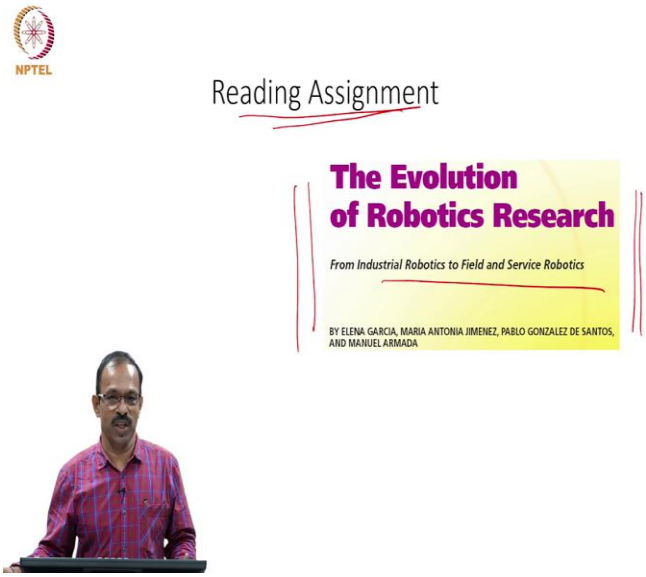

Before I conclude I would like to give a small reading assignment to you. So, I want you to go through this paper the evolution of robotic research I showed you a picture from this paper in one of the slides, I want you to go through this paper and then prepare a short report on the evolution of robotic research and what you understood and probably your own estimate or your own understanding of what will be the future of robotics based on this evolution that is happening.

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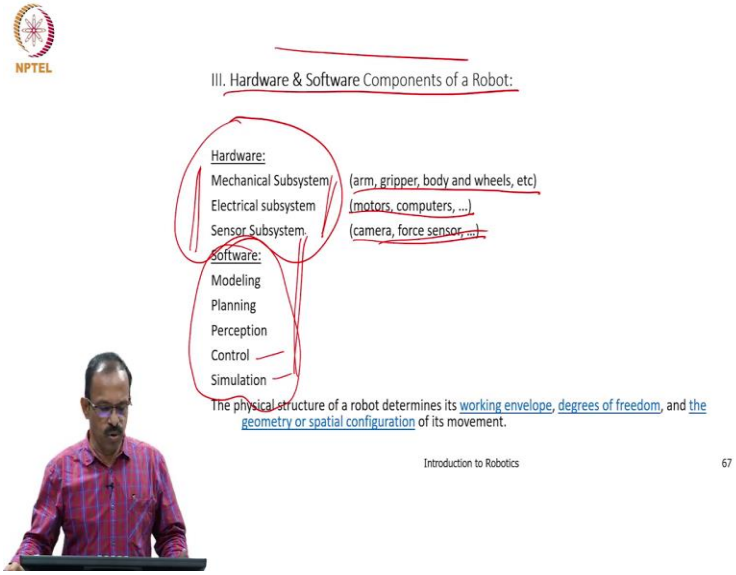

So, just before conclusion, I will like to talk about the few things what is basically the hardware and software components of robots. So, we have this hardware part as the mechanical subsystem

where we have the arm, gripper, body and wheels and then we have the electrical system which we call the motors and computers and sensor systems also. So, this part is the hardware part of any robotic system where it is an industrial robot or a field or service robots you will be having this as the hardware in the robot.

So, without this hardware you cannot really have a robots. And then of course you need to have the software to make sure that the robot works well. So, you have this modelling software you have the planning and the perception then controlled simulation and an understanding of these two is very essential for any robotic engineer. So, what are the hardware's to be used? And then what are the software's to be used? Need to be understood very well and that actually leads to many topics in robotics.

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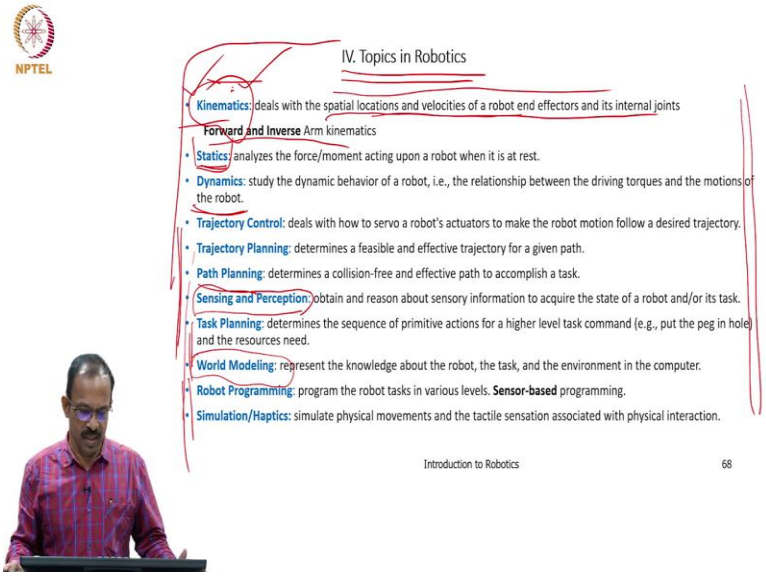

So, the topics as listed here kinematics is one of the first and foremost thing what you need to understand, it deals with the spatial locations and velocities of a robot end effectors and its internal joints. So, we have forward and inverse kinematics which is most important whether you are a computer scientist or a civil engineer or a chemical engineer and if you want to be in robotics field, you need to know that kinematics of robots.

Then comes the statics which actually analyses the forces and the static condition, dynamics talk about how do you actually activate the robot? What kind of forces are needed or forces of thrust are needed in order to make the robot move? And in connection with that you have many things

like trajectory control that how do we actually make sure that the robot moves in the desired fashion that includes the path planning also.

And if it is to happen we need to have a lot of lot sensors and then the sensors need to collect the data and then create a perception of the environment, that is sensing and perception. And then we have the task planning to create a task for a robot and to execute the task and that includes the modelling of the world or the environment and then you have the programming and simulation also. So, these are the major topics that need to be covered in the robotics or robotics an engineer need to have a clear understanding of these topics to a great extent and therefore we start with the kinematics in this course.

Of course, kinematics and to some extent we will consider the statics also. We will not be able to go deep into any other areas in this course, but the courses which are available later we will be able covering many of these topics also. So, in the next class onwards we will start the kinematics of manipulators, which basically talks about the spatial locations centre, position and velocity relationships of a robots with respect to a base frame.

And that is though we will be discussing about kinematics of industrial robots, kinematics of mobile robots and the other robots also can be understood once you have the basic knowledge about the kinematics of industrial robots. So, from the next class onwards we will start the topic kinematics. So, let me stop here we will meet in the next class. Thank you very much.