Introduction to Robotics
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Lecture 1
Introduction

Hello good morning to all of you and welcome to this course on introduction to Robotics. So, this in an introductory course offered in the department which actually covers the fundamentals of Robotics.

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As you know, Robotics is a very interesting field, so we thought that we should offer a course on Robotics but we want to keep all the students from various disciplines part of this course. That is why we made this as a bridge course which students from any branch can opt for and we will teach the fundamentals of Robotics which actually covers the disciplines of Mechanical, Electrical, Computer science, and ensure that this bridge course will help the students to learn advanced courses in robotics and become a expert in Robotics.

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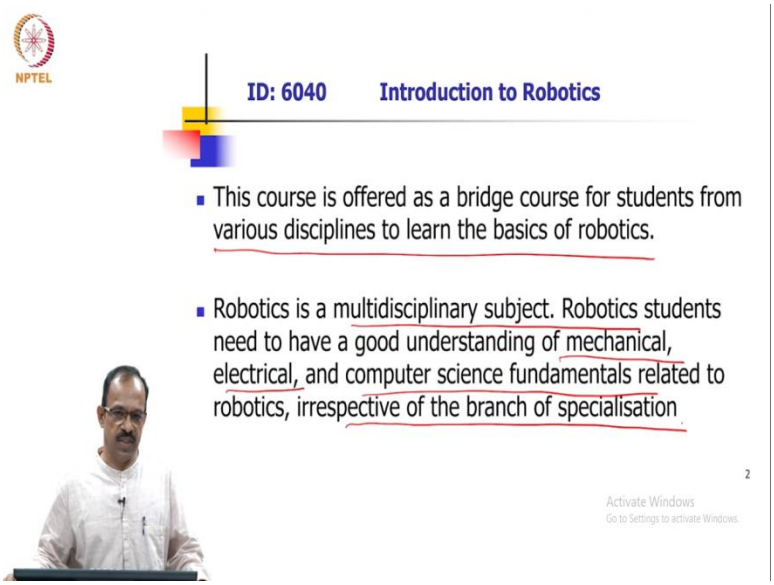

So, as I mentioned, this is offered as a bridge course for students from various disciplines to learn the basics of Robotics and since it is a multi-disciplinary subject, we want to ensure that the students get the basic understanding of mechanical, electrical and Computer Science fundamentals related to the Robotics and that is irrespective of their branch of specialization. So, we expect students from Mechanical, Electrical, Civil, Computer Science, Chemical, Aerospace, Electronics - so irrespective of their branch of specialization, we feel that Robotics will be a core area where the students would like to specialize and therefore, this course is being offered.

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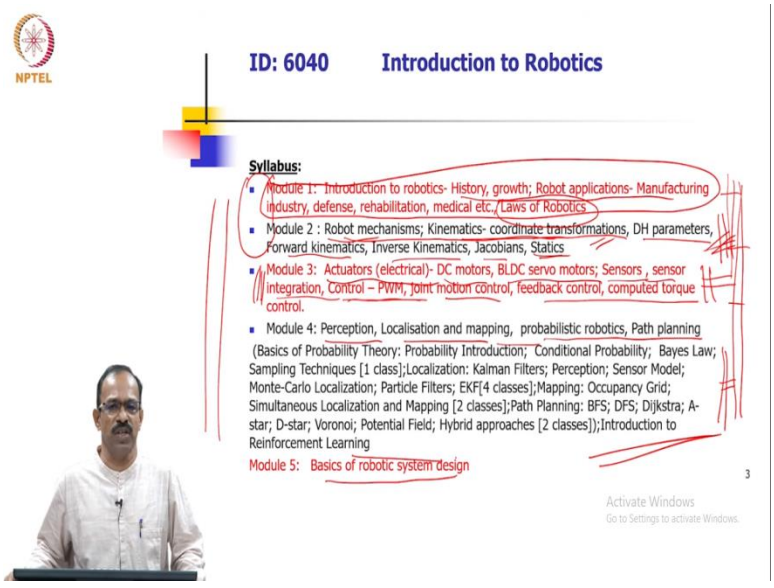

So, we have the course offered in four modules. As you can see here, the module 1, basically introduction to the field of Robotics, without giving too much of technical details, but we will look into the history, growth and the applications of Robotics. So, how the Robotics field started its growth and what is the current status and what are the various applications of Robotics Technology will be covered in the first module. And in... we cover some of the details about the laws of Robotics and other interesting aspects of Robotics. That module is basically to give you an idea of the wide applications of Robotic technology in various domains.

And then we will go into the module 2. Module 2 is basically the mechanical aspects of robotics. We talk about the robot mechanisms, the Kinematics of Robotics - basically covering the coordinate transformations, DH parameters, forward Kinematics, inverse Kinematics, Jacobians and a bit on the static analysis of manipulators.

And that actually is more towards the mechanical aspects of robots, basically the robot construction and how the Kinematics play a major role in the design and controls of robots will be discussed. And this mainly, for the benefit of students from other than mechanical streams so because some of the mechanical stream students will be aware of some aspects of this, but for others, especially those who are from Civil or Electrical or Computer Science background, will be having very limited knowledge in this aspect so we wanted to ensure that those students also will get a good understanding of the mechanical fundamentals of Robotics.

Then the module 3 is on actuators. Basically the different kinds of actuators are used in Robotics, of course there are electrical, hydraulic and pneumatic actuators, but this module 3 covers electrical actuators and the selection of actuators for Robotics or robot applications. So, it will be covering the DC Motors, BLDC Servo Motors, then a bit on the sensors and the sensor integration and the control.

So, we will talk about PWM control, Join Motion Control and a bit on the feedback control and computed torque control. This is purely on the electrical side of robotics and students from electrical background will be knowing most of these aspects. But still we wanted to ensure that how these are applicable in Robotics field is being discussed in this particular module.

And the third module, sorry the fourth module is on the computer science aspects - basically the perception, localization and mapping. And we will talk about the probabilistic robotics where the

path planning and other aspects of Robotics will be covered. This is purely from the computer science perspective - that will be a lot of algorithm development and how these algorithms are used in Robotics for path planning, localization and mapping will be discussed.

So, this is the overall content of this course and as you can see, it is a, three distinct things are being covered in this course and therefore we have three faculty teaching this course. The module 1 and 2 mostly talk about the mechanical aspect of Robotics, will be covered by me. And then the electrical part will be covered by a professor from the Electrical department and this will be taught by a professor from Computer Science department.

So, as you can see here, the focus is not exactly on the detailed robotic analysis or robot design, but the objective here is to make sure that the robotic students get an overview of these three distinct field which are playing a major role in the design and control of robots. And this will form as a bridge course or a base course for all of you to make sure that the advance courses in Robotics will be easy for you to follow and you will be able to take many courses in this field whether it is electrical control courses or advanced actuation and control sensing courses, or the courses on localization or perception or artificial intelligence, machine learning.

So, all those things you will be able to take as advanced courses so that you can actually specialize in one area but you will be aware of the importance of other domains in the design and development of robots. So, that is going to be the content of this course.

And as I mentioned the, of course the module 5 will be more on the application side, I mean how do you actually integrate these modules into a design project or design of a particular application robots. That will be the module 5, but more of integration of these four modules.

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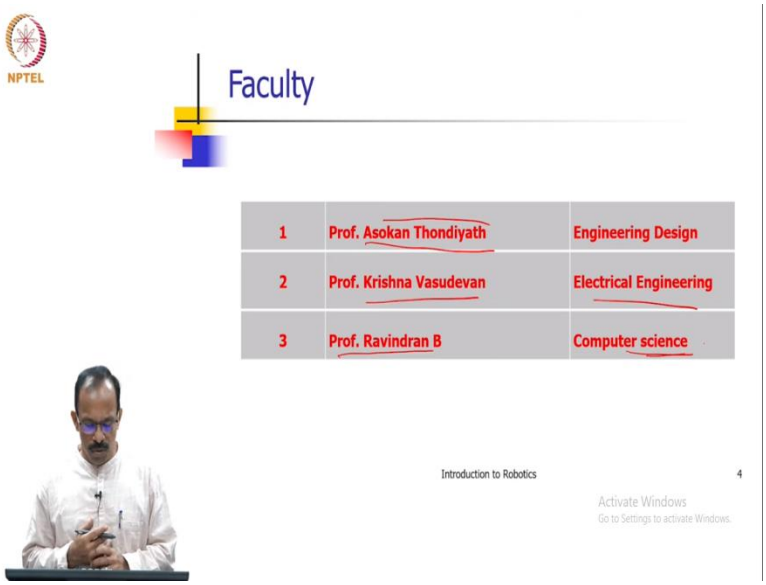

So, the teachers as I mentioned - I am Asokan, I am from the department of Engineering Design, so I will be teaching the module 1 and module 2. And Professor Krishna Vasudevan, who is from the Electrical Engineering department will be teaching the electrical model and professor B Ravindran who is from the Computer Science department, he will be discussing the module 4 which discuss the computer science aspects of Robotics.

So, that is the syllabus and the faculty. Now, I will start with module 1 today and then module 1 and, 1 will be very short, we will be having maximum two lectures and then we will start the module 2, then go ahead with module 3 and 4.

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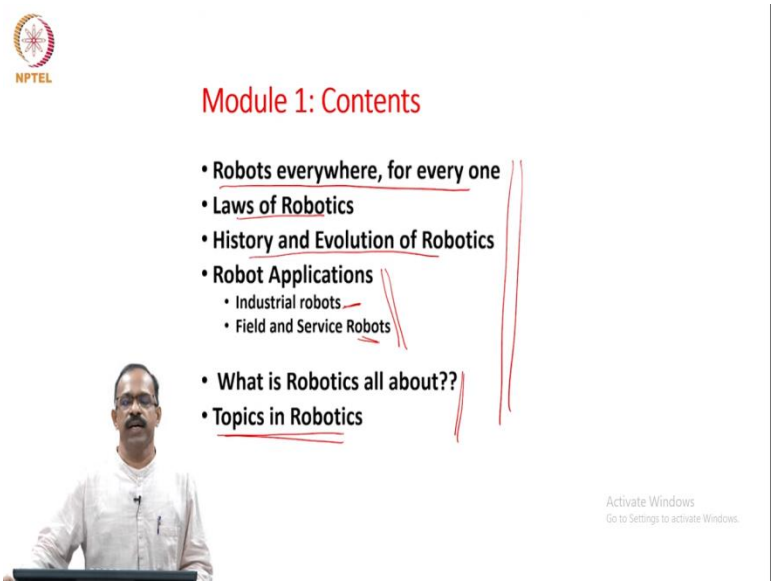

So, the contents of module 1 will be more of a generic introduction of Robotics. So, I will be talking about some interesting applications of Robotics with robots everywhere and for everyone. And then we talked about the laws of Robotics and a little bit on the history and evolution of Robotics. And then a brief description of various applications of Robotics Technology, especially the two main areas of industrial robots and field and service robots.

And then we will look into the various topics and other aspects of Robotics - what is Robotics all about and what are the major topics in Robotics which you should be aware of as well as which you can decide to specialize in one or more of these topics, so that you can be an expert in one area of robotic technology. And at the same time you will be able to apply the technology for the design and development of any new robot application. So, let us go to the first model and the details.

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So, if you can look at the Robotics Technology now or the robot application, you can see a robot almost every field whichever you can think of. For example, if you think of a robot for underwater, yes we have underwater robots. If you think of a robot for elderly care, yes there are elderly care robots. You talk about robotics for medical applications, yes that are a wide variety of applications for medical robotics. And you talk about defense applications, you talk about aerial application, you talk about entertainment you can see that Robotics application is almost everywhere in the world, in the field.

So, if you look at this application - so what you are seeing here is a underwater robot. As you can see here - this is an underwater robot which can actually go into the water and it can go the depths of 500 to 1000 meters and carry out important tasks like either an observation kind of work or salvaging of an underwater, sunken object are carrying out small repair works under water. So, that is one major area of application of robots nowadays and lot of research and development work is going on in this area.

And another application of this you can see here is a industrial robots where robots are being used for various applications in industry. So, probably one of the oldest application of robotic technology in the production field - you can see these two robots, the two robots are working in cooporation. They are actually holding a work piece and this work piece is being loaded to a machine and a robot is helping the machine to hold the object while the object is being machined

or operated upon by the machine. And then, after completion of the work the robots are actually able to take it back, reorganize it, reorient the work piece and then feed it again to the machine.

So, it is actually a very complex operation which may require three or four people to continuously tend to the machine. Here, these two robots are capable of doing it without any human intervention. And this is possible because of the mechanical system of the robot, the electrical sensors and controls and of course the algorithms which actually help the robot to carry out the task in cooperation. And this kind of applications are becoming more and more popular nowadays and there are a lot of industries which actually using industrial robots for their day-to-day production activities

And here, you can see in this one - a mobile robot and this mobile robot - you might have seen this kind of robot in many applications, so they are actually wheeled robots and we can have wheeled robots or we can actually have tracked robots or we can have some other way of locomotion also. And you can see these are autonomous robots. So, they can actually, they can be planned to carry out some interesting task or they can be planned to go from point A to B and then to C and then come back to its original location.

And as it moves, you can see that they can actually, it can avoid obstacles and it can identify the path where it is going. It can, it will be able to locate its path and localize itself, transfer the data back to the control station and carry out any task assigned to them and then come back to the original location.

So, this kind of mobile robots are also becoming very popular nowadays and it is being actually extended many other applications like on-road vehicles, autonomous vehicles and many other applications. So, mobile robots, they actually moved out of the laboratories nowadays, they are actually going into the field and trying to see whether we can actually use it in industry space, workshop floors or in hospitals or in many other places where we want to have autonomous mobility for robots.

And this one, this is very familiar with you - this one - which is known as the aerial robot. These aerial robots are nowadays, they call, we call just drones or sometimes we call just quadrotors when there are only four rotors. And here you can see, it has a got six rotors and they can actually vertically takeoff and land - that is one of the advantage of this kind, we call just VTOL,

Vertical Takeoff and Landing, and they are widely used in nowadays for many surveillance applications and they are being used in the agricultural applications. And of course there are no limits of applications; we can actually find many applications for this kind of robots, they are becoming very popular.

And this is only one kind of an aerial robot, there are different kinds of aerial robots. There are fixed wing aeriel robots and there are flapping wing aerial robots. So, you can actually see that the area robot itself has got multiple categories and applications. And what you are seeing here - this is kind of robotic systems which students will be developing as part of their academic activities because you can see this is like a kind of a spider, we can have legs and then we can have controllers, motors, sensors, actuators and we can actually program it to move in a particular direction or can have a circular motion or a straight line motion and we can plan and execute these task.

This is more for students to learn the basics of Robotics because here there is a sensor module involved, there is an actuator module involved, there is a mechanical system involved and there are programming and controls involved. So, by designing this kind of systems you will be able to learn the basics of integrating various systems, sub-systems into a robotic system and then develop it as a application based robots.

And this is the best way to learn the basics of Robotics because many students asked me I am interested in Robotics, how can I start working in Robotics? There is no direct answer to that, of course you need to learn a lot to do this. There are a lot of theory involved, a lot of practical exposure needed and there are lot of interdisciplinary knowledge involved. So, you can actually, you can learn the theory and parallelly you can work on practical implementation of hardware systems or integration of hardware and software and then start making a few simple robots and then slowly you can learn the technology.

And probably the most complex and most fascinating type of robots are the humanoid robots - a lot of talk about humanoid robots. And people have been trying to develop humanoid robots for a quite long time. There was, there were a lot of interest in developing human like robot. Everybody wanted to have the robots which look like human and behave like human and if

possible having emotions like a human. Unfortunately, we are still far away from having a robot which can actually mimic the human behaviors. There are a lot of challenges.

So, what you are seeing here is a humanoid robot, developed by, it is known as Asimo and this robot is quiet a old one, they have developed more, improved its further. So, this robot can actually walk and then push something or can talk to people or it can respond to the queries from people - so that much of work is possible to be done by this kind of robots.

Unfortunately, we are far far away from having a robot with actually, which can actually do task like human. The challenges are mainly in having the decision making capability and of course the mobility and the control aspect. Because human has got lot of capabilities to control the motions and dynamically stabilizing the body as well as making decisions based on a lot of information but collected from the sensors and at the same time using our memory and our learning while making the decisions.

Unfortunately, robots are still far away from reaching that stage and hopefully artificial Intelligence and many other developments taking place may lead to a lot of improvement but still it may take another 20 or 30 years for us to have something very basic or a very basic system which can actually mimic the behavior of a human to a very basic level.

What we require in terms of a humanoid robot is if we can actually have the intelligence of a 6 year old child or the agility of an 8-year-old or the strength of a 15 year old - if we can actually... or the decision-making capability of a 10 year old boy, and if you can actually have that kind of capabilities built into a robot, that itself is more than sufficient for our applications. Unfortunately, we have to go a long way in order to reach this stage. So, this actually gives you only a very few applications and there are multiple applications which you can think of.

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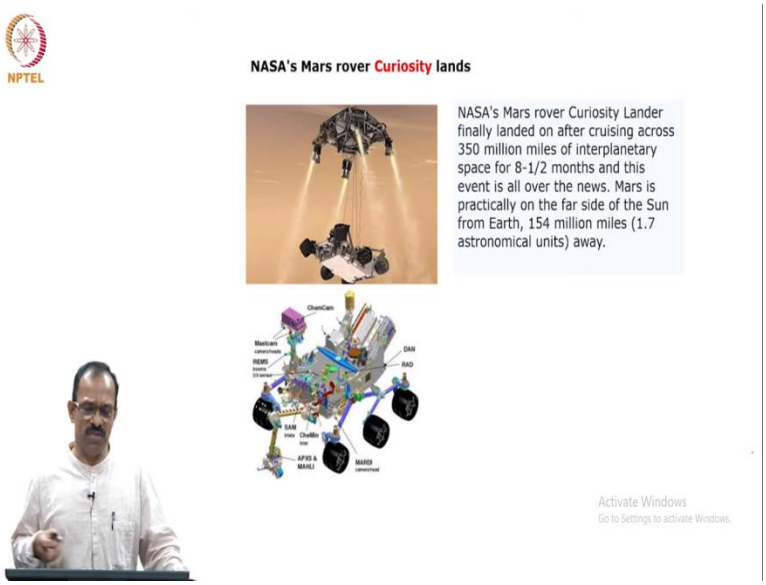

There are applications in space, there are a lot of space robots; you might have heard about the Mars Rovers.

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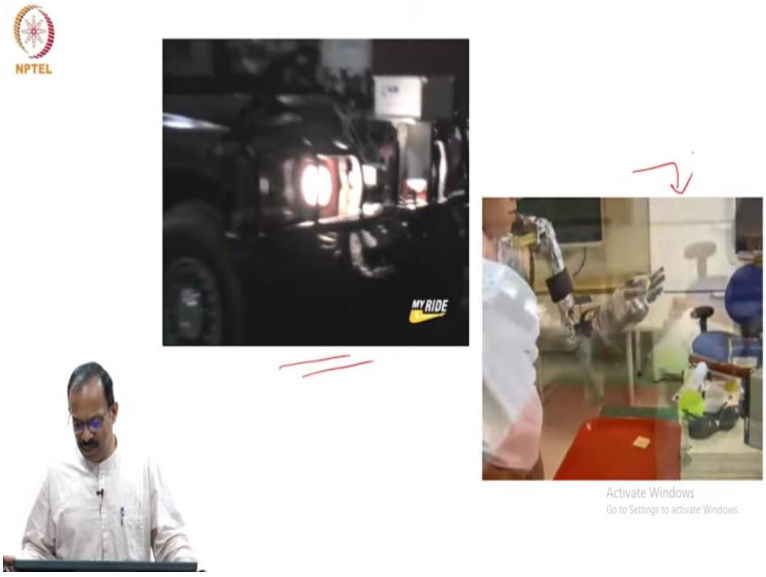

And apart from this, okay, the current trend is basically to look at how to use these technologies for developing autonomous vehicles. So, a lot of hype is created in developing autonomous vehicles. So, DARPA challenge is one challenge initiated a few years ago in order to develop autonomous ground vehicles or autonomous road vehicles. And you can see that a lot of people compete in this, a lot of universities compete in the design and development of autonomous cars.

Of course, in the first few years it was not very successful but then later on, many universities could come up with the design of robots, multi-terrain robots which can actually go from different... it can go across different terrains and carry out simple task and come back to its Of course, in the first few years it was not very successful but then later on, many universities could come up with the design of robots, multi-terrain robots which can actually go from different... it can go across different terrains and carry out simple task and come back to its original location.

And what you are seeing here is the robot applications for medical field. What you are seeing here is in a video, of a robot or a robotic arm attached to the person - a person who has lost her limb or the hand... can be attached with a mechanical arm which has got all controls associated with normal operation.

And these signals for the controls can actually be taken from the human body itself. It can be taken using EMG signals or Muscle Innervation using S-EMG signals and processing these signals give the intention of the person. And this intention can be converted to the command signals to the robotic arm and the robotic arm can actually carry out the task what the person wants to do. So, this is a practical, available system from a company called DEKA, or you can search for DEKA robot - you will see this kind of development happening in the robotics field. (Refer Slide Time: 23:42)

And then of course, we have many other robots which are known as elderly assistant robot. Elderly assistant robots are the robots which actually can be used for people who are alone at

home - elderly people who are alone at home. This can be used as a assistive robot. It can actually interact with the person, it can talk to the person and help the person in few basic day-to-day activities.

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So, actual field applications of Robotics technology. And now you can see that there are, apart from that, there are a lot of interest, interest generated for robotics and Robotics technology by children; especially in the field of educational robots and entertainment robots also. And there are a lot of industries which actually come up capitalizing this interest of students and others in Robotics Technology - they come up with robotic kits.

And there are a lot of movies developed or... based on Robotics. So, most of the time, a robot is projected as a kind of a human or human like robot which can do a lot of things which are mostly of fiction. And... but people believe that a robot can actually do all those things. Only the Robotics people or robotic scientists are not able to develop it for practical application.

So, there are a lot of hype created by this kind of the movies and media and the commercial establishments about robotics. And that actually, sometimes it is a good thing, so that we get a lot of publicity and a lot of interest and a lot of curiosity. But at the same time it creates a lot of confusion among people also about the real capabilities of robots and how actually how actually, what actually a robot is or how actually we can define a robot or how is, what is the difference between a robot and the automated machine and things like that.

So, this is something which as a robotics engineer or a person who is interested in Robotics or an engineer who is interested in Robotics, we need to have a little more clarity on all the things. So, we cannot be like a public, a person without much knowledge about Robotics thinking that robots can do everything or robotics is a solution for every problem. As engineers, we need to have a more clarity on all these things and the purpose of introducing these things to you is to make sure that you have a better understanding of Robotics and Robotic Technology.

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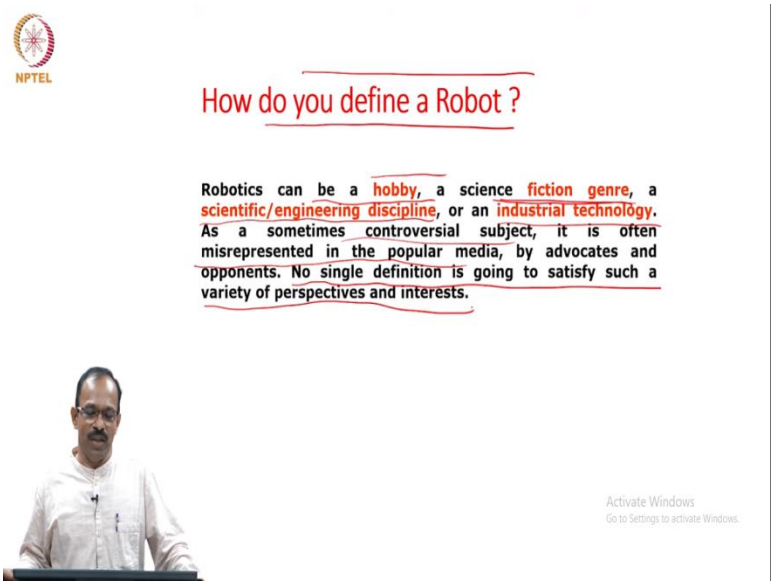

Now, looking at all the things, the question is that - how do you actually define robots? Because you saw that there are multiple applications and there are multiple fields where actually the Robotics Technology can be applied and there are a lot of hype created about Robotics also. So, we need to have a little bit of understanding about how do we really define a robot.

So, you can say that it can be a hobby for many people. So, Robotics can be a hobby for many people. You can see that especially students and those who are interested in electronics and controls and all, they take it as a hobby. So, they will build some small machine which can actually walk around or it can actually do some predefined task. Or sometimes it is a science fiction, because there are a lot of fiction written about Robotics, there are a lot of movies made about robots and robotic technologies and it's actually a scientific or engineering discipline also. And of course, now it is a industrial technology.

So, you can say that it can be a hobby to somebody, it can be a fiction and entertainment for somebody or it is really a scientific discipline or it can be a real technology which can actually solve many problems in the field. Now, so it is very sometimes controversial and often misrepresentation in the media. So, media actually create a lot of misrepresentation about Robotics. So, whenever you say you have some robot, a robot which can do something without really checking whether it can really do or not, people will go immediately, go to the media and try to create a hype about it.

So, because of all these things, no single definition is going to satisfy such a variety of perspectives and interest. So there are, as you can see, there are different applications and different way Robotics is being looked upon. It is very difficult to have a single definition for robots.

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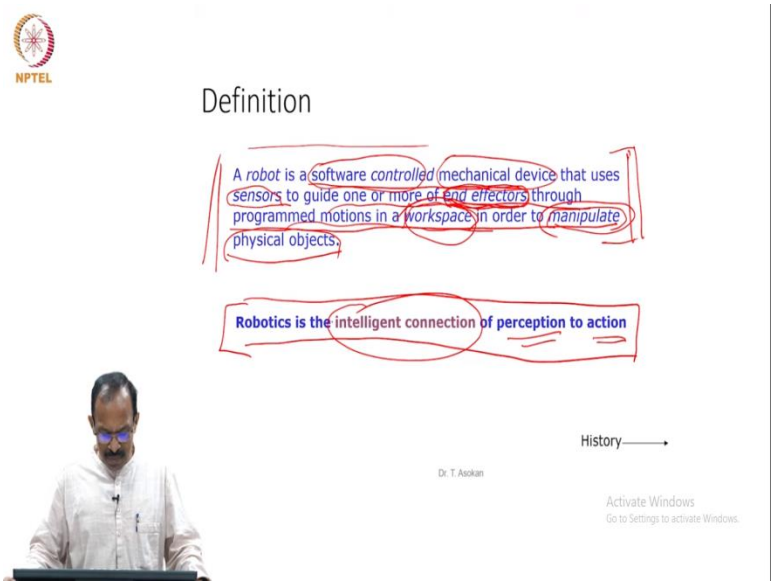

So long ago, Robotics was defined as a... or a robot was defined as a software controlled mechanical device... sorry a software controlled mechanical device that uses sensors to guide one or more of end effectors through programmed motions in a workspace in order to manipulate physical objects. So, this was the definition given for robots long ago.

And at that time, a robot actually meant as an industrial robot. You know, that was the first kind of a robot that actually came into the market and the definition was given based on that robot. So, you can see that it is a mechanical device and it is controlled by a software and it uses sensors

and to get one or more end effectors... end effector is nothing but the tool attached to the robot. If it is welding robot, there is a welding tool. If it is a assembly robot or pick and place robot, there will be a grasper associated with that or if it is a painting robot, there will be a paint gun. So, that is basically known as end effector. And so, the end effector has to move around so that is to get one or more end effectors through programmed motions in a workspace, in a workspace, in order to manipulate physical objects.

So, that was a definition given. So, you have an end effector which can actually manipulate physical objects. When I say manipulate, so I can take an object and manipulate it and place it somewhere else - that is the manipulation. So, and in a workspace, in a fixed area or in a fixed space, I can actually move this object. So, that is basically the manipulation.

So, the robot was defined in that way. So it had a software controlled mechanical device which has got sensors, which has got end effectors, which can be programmed and using program, we can actually move around the objects using the end effectors. And that definition is really true for the industrial robot. But we can see that, you can see that definition is not really applicable nowadays. Because most of the robots what you see in the now, the present scenario, you will see that need not need have a end effector.

So, the robot need not have an end effector, it need not have a fixed workspace, it need not manipulate objects also. So, many of these like, for underwater robot or a surgical robot or an aerial robot, it need not manipulate objects, it need not have a fixed workspace - and therefore, they given a new definition for robots which is known as the - Robotics is the intelligent connection of perception to action.

It says that if we can say that I have a perception of doing something and if I can actually make it happen, using some intelligent connection, then I call it as a, call it as Robotics. So, this is the current definition given for Robotics and with this definition, we can actually bring a lot of things, under the umbrella of Robotics. And we will see how this definition really helps to, helps us to have a clear understanding of what is a robot and what is not a robot.

So, we will discuss this in the next class. So, I will explain what actually we mean by this intelligent connection of perception to action. And then, we will look into the history and the

development of Robotic technology and then we will look at more detailed applications also. So, thank you very much for listening. I will meet you in the next class. Thank you.