Lecture 01: Introduction

I am Dr. D. K. Prathiar, Professor, Department of Mechanical Engineering, IIT, Kharagpur, India. I welcome you all to this swarm NPTEL course on Experimental Robotics. So, I am just going to give the brief introduction to this particular course.

Now, this particular course, I am just going to tell you the uniqueness in comparison with the conventional course available in NPTEL including my own course on Robotics. I will give a brief introduction to Robot and Robotics. Five experiments which will be conducted using five different robots will be introduced. Outcome of this particular course will be discussed in details.

Introduction to the course, now this experimental robotics is different from the conventional course on Robotics, which deals with all four modules of robotics like kinematics, dynamics, control scheme and intelligent issues. So, here, we are going to consider a robot as a whole and it can perform some pre-assigned task or the experiment. So, here, I am just going to start with experiments with five different robots to carry out different types of experiments. We will be discussing, in details, we are going to use a serial manipulator in the first experiment. In the second experiment, we are going to consider one tracked mobile manipulator as an agricultural robot.

In the third experiment, we are going to consider one hexapod or a six-legged robot. In the fourth experiment, we are going to consider a drone or an aerial vehicle and in the fifth experiment, we are going to conduct it on one humanoid robot. Now, this will be a 4-week course and there is no prerequisite to attend this particular course. This course will be suitable for the UG students, PG students including PhD. Now, to start with the concept of robots and robotics, robot is a computer controlled automatic and re-programmable machine, which can perform different types of tasks.

Now, this is an automatic machine and it is reprogrammable. That means, the same automatic machine or the robot will be able to perform a variety of tasks and to assign a variety of tasks, what you will have to do is, you will have to make some change in its program, so that it can handle the different types of tasks. Now, robotics is actually a science, which deals with the issues related to the design, development and applications of robots. Now, here in robotics, we try to copy everything from the human being like we try to copy the three Hs. The first H is the hand, second H is the head that is the intelligence and the third H is the heart that is nothing, but the emotion.

So, we try to copy the hand of a human being, the head of a human being and heart of a human being in the artificial way, so that a robot becomes intelligent autonomous and it also becomes a little bit of emotional. So, the aim of developing the robot, we copy these three Hs and we try to model it in an artificial way and we try to make it a robot and the robot will be able to perform the different types of pre-assigned tasks. Now, the robots are

available in various forms. If you see the literature, we have got the manipulators. Now, these manipulators, it could be actually of two types, it could be a serial manipulator or there could be parallel manipulator.

So, construction wise, if you see a robot, it consists of a few rigid links and two rigid links are joined by a joint. Now, this particular joint could be of different types, which we will be discussing after sometime, but here I just want to say that in a serial manipulator, the links and the joints are in series, whereas in parallel manipulator like Stewart platform, the links and the joints are in parallel. Now, if we compare the serial manipulator with a parallel manipulator, the load-carrying capacity of a parallel manipulator is much more compared to that of a serial manipulator and a serial manipulator looks like our hand. So, a serial manipulator can also be called as a mechanical hand. Now, in case of mobile robots, the base of the robot is moving and depending on the nature of this particular terrain, the mobile robots could be developed in the form of a wheeled robot or a multi-legged robot or a tracked vehicle.

So, if the terrain is smooth, we generally go for the wheeled mobile robot. If it is perfectly rough like there are a few staircases and so on, we will have to go for the multi-legged robots and if the terrain is in between, that is, it is neither very smooth nor very rough, in that case, we will have to go for the tracked vehicle and the drones or the aerial vehicles are also considered as the mobile robots. So, we have got different types of robots and as I mentioned that robotics has got four modules, namely kinematics, dynamics, control scheme and intelligent issues. So, in brief, I am just going to tell you the purpose of each of the modules. In kinematics, we try to study the motion or the movement at the different joints without considering the reason behind that particular the movement or the motion.

In dynamics, we try to find out the reason behind that particular motion and if the joint is a linear joint, there must be a force and if it is a rotary joint, there must be some torque. So, how to determine the force, which is required or how to determine the amount of torque that is required to make that particular movement possible, we carry out the dynamic analysis. Then, we go for the control scheme because at each of the robotic joints, there will be a motor. So, how to control that particular motor, so that it can generate the necessary torque, it can generate the required force. So, these things are actually dealt in control scheme.

Then comes your intelligent issues, how does a robot take decision as the situation demands, ok. So, you will have to incorporate intelligence to the head of a robot. So, all such modules are generally discussed in details in conventional course on robotics, but as I told in this experimental robotics, I will be using all such information, but we will be using in a slightly different way just to carry out some experiments, different types of experiments using different robots. As I have already mentioned that robots are to be made intelligent, autonomous and emotional because we, human-beings, we are intelligent, we are emotional. So, any decision taken by us is a combination of our intelligence and emotion.

And, if you want to replace a human being by robot, the robot has to be made intelligent, autonomous and emotional. So, we will have to design and develop robots, so that it can act as an intelligent robot, autonomous robot and emotional robot. Now, how to design and develop a particular robot? So, before we go for designing and developing a particular robot, we try to understand the task, which has to be performed by that particular robot, which we are going to design and develop. And, depending on the task, we prepare some rough design or rough sketch for the robot, we carry out kinematic analysis, we carry out dynamic analysis of the robot and we try to formulate this particular problem as an optimization problem. We solve it and then, we try to find out what could be the optimal design of the robot from kinematics point of view, from dynamics point of view, from control scheme point of view.

So, considering all three modules, we try to find out what could be the optimal design of this particular robot. And, once you have reached the optimal design, then we go for like how to manufacture the components, how to control this particular robot and how to incorporate the intelligence to this particular the robot. Now, once you have designed, developed that particular robot, we try to control it, we try to test its performance in the laboratory and once it is found to be satisfactory, then we test its performance in the real field. So, these are the steps, which we generally follow to design and develop one new robot. Now, in this particular experiment, we are going to conduct five experiments.

The first experiment is the teaching of serial manipulator. Now, as I told that manipulator, that is a robot with fixed base, it could be of two types: serial manipulator and parallel manipulator. Now, here you can see one serial manipulator. Now, this particular serial manipulator is known as actually the UR-5. So, the name of this particular serial manipulator is UR-5 and it has got 6 degrees of freedom.

There are 6 joints, 6 rotary joints and the rotary joints could be of two types. So, one is called the revolute joint and we have got the twisting joint. Now, this revolute joint and we have got the twisting joint. So, here in this particular robot, we have got 3 revolute joint and 3 twisting joint. So, in total, there are 6 joints, each having 1 degree of freedom and these are in series.

So, this particular serial manipulator has got 6 degrees of freedom. So, in this particular experiment, we are going to show how to give instruction to this particular robot that you start from here, reach the goal through a number of intermediate points to solve some specific purpose. So, we are going to conduct this particular experiment in details. The next experiment that is experiment 2, that is control of tracked mobile manipulator. Now, this tracked mobile manipulator is construction wise, you can see that we have got one tracked vehicle and there is one serial manipulator, which is mounted on the top of the tracked vehicle and we generally go for this type of combined robot.

So, that we can increase its workspace and this particular robot will be used as an agricultural robot and we are going to control this particular robot. So, that it can move in the forward direction, backward direction, it can take the turn as the situation demands. So, in agricultural field, this tracked mobile manipulator is going to collect information of the plant leaves with the help of camera and this collected images will be analyzed just to decide whether the plant leaves are suffering from any disease. If it is suffering from any disease, then the type of that particular disease will be identified and the appropriate pesticide will be sprayed by this particular robot itself. We can see that at the top, we have got three white tanks and each tank contains a particular pesticide and depending on the requirement, so this particular pesticide will be sprayed to the plant leaves.

Then experiment 3 is on path and gate planning of a six-legged robot. Now, this six-legged robot is just like an insect. So, insect could have either six legs or eight legs and here, we are considering a six-legged robot or a hexapod. So, the six-legged robot will be able to follow a trajectory, it will be able to move in the forward and backward direction, it should be able to take the turn as the situation demands to perform some pre-specified task. Now, here the six-legged robot will have to make a plan of its own action and at the same time, it should be able to plan its gait, that is the sequence of leg movement in coordination with its body movement, which are required to perform a particular task.

Then experiment 4 is related to the navigation of drone and drone is nothing, but aerial vehicles. Now, let us take a very simple example, supposing that we have got one flood-hit area and we will have to send some medicine, some food to the flood heat area, which is disconnected from the other part of the land. So, there this type of aerial vehicles or the drone could be used, there are many other applications and it is one of them. And, supposing that starting from a particular location, we want to send some food, medicine to the flood-hit area. So, we can use this type of drone, we can navigate so that it can start from an initial location and then it can reach its goal, deliver the goods and once again it can come back and this is a remotely controlled the drone.

So, this is the remote controller for this particular drone and this is the drone. So, we will be doing some experiment related to navigation of the drone. Now, experiment 5 is related to the path and gait planning of humanoid robot. Now, this is the humanoid robot having 25 mobility levels or degrees of freedom. So, this is a very sophisticated one and this now robot can move, can walk in the forward direction, in the backward direction, it can take the turn, it can also interact little bit with human being and it should be able to perform the task like it should be able to walk on the plane surface, it should be able to negotiate some rough terrain like your staircase of some limited height, it should be able to negotiate to perform some pre-specified task.

So, there must be gait planning, that is the sequence of leg movements, there must be the path planning, so that this humanoid robot can perform the task by consuming the minimum amount of energy and by maintaining its dynamic balance. Now, this humanoid

robot is the most difficult robot to design and develop and control out of all the robots. And, here out of the many problems which we generally face, is how to maintain its balance because all of us we know that humanoid robot or we human beings, we are all dynamically stable. Now, a six-legged robot or an eight-legged robot, we can consider both its static stability as well as dynamic stability, but for a humanoid robot, we will have to consider its dynamic stability only because even if we human being, we are standing at a particular location, we may not be statically stable, our body tries to maintain the dynamic balance even if we are standing at a particular location. And, maintaining this particular dynamic balance while performing some pre-specified task is one of the most difficult hurdles to be crossed.

And, we will see through this particular experiment that this humanoid robot can perform some pre-specified task by maintaining its dynamic balance and by consuming minimum energy through its path and gait planning. So, these are the five experiments which we are going to conduct using this particular the new NPTEL course. And, while doing experiments with these five different types of robots, we will be gaining a lot of experience regarding their construction details like what is the type of links used, what is the type of joints used, then comes your how do we control one robotic joint to get the movement. So, all such experience we are going to gain through the real experiments. Then, we are going to know how to teach a robot, that means, how can you pass some instruction to a particular robot to perform some pre-specified task, how to control a particular robot and how to make a robot intelligent.

So, starting from the different components of the robots, how to control it, how to teach a particular robot, how to make a robot intelligent, so that a robot can replace one human being. So, all such things will be shown through this particular course through the real experiments in a lab, that lab is called the Center for Excellence in Robotics, which we have started at IIT, Kharagpur a few years ago. So, all five experiments will be conducted, the real experiments will be conducted at Center for Excellence in Robotics, IIT, Kharagpur and we will see that we can conduct the different types of real experiments with different types of robots. So, this is not only a theoretical course, but here we are planning to do the real experiment with the robots. So, that will be the uniqueness of this particular NPTEL course, the new NPTEL course on Experimental Robotics.

So, I hope all of you people will be enjoying this particular course and learning a lot through this particular course. Now, regarding the references, to know the fundamentals, if you want to have a look, you can see the textbook written by me. So, this is the textbook that is Fundamentals of Robotics published by Narosa Publishing House, New Delhi in 2017. It is the modified version, where the fundamentals of AI has also been added, it is in place and it is in production, in fact, and it will be coming very soon. And, of course, you will be getting the reference manuals for the different experiments.

So, at the end of each experiment, I am just going to give you the information related to the

reference manuals of each of the experiments. So, I once again welcome you all to this particular course. Thank you.