Lecture 03: Experimentation I

Hello everyone, my name is Deepak Deshmukh and I am a research scholar at IIT Kharagpur and I am going to discuss about the second task in teaching of serial manipulator for pick and place task. Second is the teaching of serial manipulator for continuous path task. So, this task we are going to continue one after another. So, first of all, let me give you a brief introduction about the robotic setup. So, this is the complete robotic setup UR5. So, this is a UR5 serial manipulator, it is a 6 degree of freedom system, this is the control unit for UR5 and here, it is the teach pendant.

So, all the electronics and hardware required for controlling this manipulator is done through control unit and teach pendant is used to provide the instruction to the robot. So, next, let us discuss about the UR5 robotic arm. So, it is since name is indicates UR5, it is a 5 kg payload capacity of manipulator. So, it can hold up to 5 kg payload at its end-effector including the weight of the gripper or any tool, the overall weight it can hold at its flange is 5 kg.

And, then, since it is a 6 degree of freedom system. So, it has 6 mobility level. So, first joint is base joint, second joint is a solder, third joint is elbow and then, 3 wrists are there: wrist 1, wrist 2, and wrist 3. So, then after the all 6 joints are rotary in nature. Now, we are going to discuss some basic details about robotic arm. So, basically when you are defining the robot, you need to define it with respect to some frames.

So, there are basically 3 frames, which comes into the picture when we are defining a robot, first is World frame, second is base frame and third is tool frame. So, first is World frame. World frame is the permanent frame, which is a root frame of all the frames and it is a reference frame, second is the base frame, base frame is mostly attached at the base of the manipulator and it is a reference of complete manipulator, third frame is tool center point frame, tool center point frame, where the object is gripped or any gripper is mounted. So, this is called tool center, tool center point frame. So, whenever robot is performing any particular operation. So, this position and orientation of tool center frame has to be known with respect to the base frame.

Then, next is trajectory planning before that we are going to discuss on how the robot is moving. So, there are basically 2 types of trajectory planning methods, which is used when we want to define a point from A to B in a work space, by work space what I mean is that a robot, it is a volumetric 3D space in which a robot reach at any point in the space, a robot can travel without any disturbance or freely. So, basically at any point in the work space, there is at least one solution for robot to reach at its end effector. Then, after that trajectory planning, if you want to define a space trajectory from one point to another point, there are basically 2 ways, one is joint space trajectory joint space trajectory planning, second is Cartesian or task space trajectory planning. In joint space trajectory planning, let us say if we are defining 2 points: 1 and 2.

So, from point 1 to point 2, the inverse kinematic solver of the robot will solve the kinematics for point 1 and point 2 and then, we will have a set of joint angle values for point 1 and point 2 and it will try to form/find a smooth trajectory between point 1 and point 2, this is joint space trajectory planning. In task space trajectory planning, path between point A and point B has to be defined and the trajectory of the joints are to be calculated based on the path. So, basically joint space trajectory planning, the path may be non-linear in nature or it is independent of the initial and end point, but in task space trajectory planning we have to define the path. So, this was the trajectory planning then after this now we are going to have demonstration we are going to demonstrate the first our first experiment that is controlling the robot U of I using teach pendant.

So, when you start the system you will see, this is the screen. So, currently all the brakes of the system are disengaged. So, when you start it is going to disengage all the brakes. So, all the brakes will be released that means the robot is ready to take actions from the teach pendant. So, once I click the start button all the brakes you will be hearing the disengagement of the brakes.

So, this voice if you hear that means all the brakes are disengaged. Now, we go to click ok and then this entire screen you will see there are different modes of operation that I am just going to show you once you exit it. So, this 4 modes you will be seeing. So, first mode is run program, run program is used for running a particular program, exit whatever existing program is there in the system or whatever stored program in the system you can run those programs. Then second mode is programmer robot programming robot you can create a new program or edit a program or you can from the scratch if you want to create that you can create you can save, you can make modification in the program or you can run the complete robotic setup manually as well.

Then, third mode is setup mode, the setup mode is used for initial setup of the robot or we update the form where software said other things if you want to update you have to use setup mode. Also, if you want to control the robot using external ways, using your script or other ROS environment or any other offline methods. So, in the setup mode, you have to set it up as an external mode and then you can control all the control you can get all the actions through your PC. Then last is shut down, so powering of the system it will power off the system then let us start with the run program. So, in this mode you will see 4 tabs, that is, run, move, input output and logs.

So, run will show the operation time and how much if you are running the program it will we have to just play and pause. So, second is move this screen is for navigating the joint of the manipulator. So, in the right side of the bottom you can see all the joints, you can give this keys, with this keys you can give the motion to each joint. So, as you can see this is for base joint, this is for shoulder joint, this is for elbow joint and then 3 wrist joints are there to move these 3 wrist joints: wrist 1, wrist 2 and wrist 3. So, all 6 joints can be given values

and it will move automatically.

So, let me show you how I am going to move base joint. So, this is the motion of the base joint in the anticlockwise direction, this was in the clockwise direction and then this is about shoulder joint, then elbow joint, then wrist 1, then wrist 2, then wrist 3, then last wrist, that is the twisting of the tool center point. So, this is the joint space commands. Now, this screen here in the screen here you can see 6 values x, y, z, rx, ry and rz to define any object in a 3D space, you need 6 arguments for 6 variables. So, these are Cartesian coordinates about x, y and z you want x direction value, y coordinate, z coordinates and rotation about x rotation about y and rotation about z.

So, to define you can use this to you can either use to enter manual values as well as you can use, you can manually enter the values of x, y, z, rx, ry, rz or here also, you can manually enter the joint values. So, everything you can manually enter and robot will reach to that particular location. Then, in the center you can use this screen, you can see is a real time simulation of the robot. So, whatever configuration robot is at particular time, it is just going to show you that position of the robot. Then, at the left at my side, this screen, you can see here these arrow bars are for linear motion of the robot.

So, if you want to move robot in x direction, y direction and z direction in a linear way. So, these tabs you are going to use and then, these tabs are used for rotating the tool center point about x, y and z. So, about x if you want to rotate you have to use plus and minus this left and right arrow up and down arrows are for y axis and this is for rotation about z axis of the tool point. So, let me go to one position and then I am going to show you the linear motions. Let us arrange so for this robot, this is its x axis positive x axis, this is positive y axis and this is positive z axis.

Similarly, this is negative x, negative y and negative z and this button here you can see is the home button. So, at whatever configuration a robot is it will just go to home position when you press this home button. So, now I want to draw say I want to draw along x direction, I want to move the robot in x direction. So, if you press down so this is the linear sorry this is the linear z motion in negative direction. Similarly, this is z linear motion in z direction positive.

So, now if you want to move the robot in positive x, this is positive x, this is negative x. Now, if you want to move the robot in y direction this is negative y and this is positive y. So, by this you can manually interact with all the joints and all the position you can control manually. Then when if your task is complete if you want to go to home position just click the home button and then press the robot it will move the its to its original position press ok. Then so this was about run mode and move mode this input output mode is given for if you want to add some additional devices with the end-effecter of the robot.

So, let us say if you want to add a gripper or a sensor or some vision based devices. So, in

that case, you have to integrate those with the controller. So, you can enable these input output ports to interface those devices with your robotic arm. Then, this is the log what is going to happen in a continuously and you can see what is the current ampere rating taken by each joint and what is the temperature of the system ok.

So, this was run mode ok. So, second mode is second task is programming a robot for pick and place task. So, now, we are going to demonstrate how to create a new program and how to write step by step. So, that we can perform a pick and place task. Pick and place task basically we are going to show point to point motion how to move a robot from one point to another point and store those locations.

So, let us start. So, you have to go in the program mode, you can either load existing program or you can use pick and place directly program is there or if you want to create from scratch you can create a empty program. So, here you will see the programming screen. So, whatever you are going to give commands these commands will be stored here and you can see one by one after another commands. Then, you the graphical structure you see the robot simulation in the structure these are the commands with which you can create a particular program. So, at first I am going to describe all the commands one by one.

So, first is move command when you press move command you can see here in the tree, the move j has appeared. So, basically there are three types of move commands move j, move l and move p. So, move j command is a joint space command that means that is just the thing which I have already explained the robot will move in joint space. So, we define a way points two way points if we define the then from robot from point a to point b, it will move in joint space. Similarly, this mode you can change from here.

So, currently here, it is a move j second mode second command is move l, move l command is used for linear motion of the robot. So, when you select this move l command. So, robot will move in a linear direction either x y or z whatever you have given or any point between two point $(x_1, y_1, z_1)$ to $(x_2, y_2, z_2)$ it will go in a linear motion. Third command is move p, move p is the command in which it will maintain the constant speed from point a to point b actually move j command does it independent of the path. So, it does not depend on the path if you select point a point b it will go from point a to point b independent of the path, in the move l it will follow the path in a linear way, move p command it will give us it will move the from point a to point b in a at a constant speed will be constant here.

Then, when you select move j. So, since it is joint space. So, you can give argument in the joint space only. So, you can limit the joint speed as well as you can give the joint acceleration. In case of move l command, you can have it, since it is a tool task space it is planning in task space. So, you can give tool speed and tool acceleration you can define the tool speed and tool acceleration and similarly, move p is also in task space command.

So, here also you can define the tool speed and tool acceleration and also you can define

the blend radius that means if you are performing a task in using move l commands only. So, your robot will have a jerky motion from point a to point b, point b to point c. So, initial and final speed will be changed, but if you use move p command. So, at those way points it will form a curve and the robots motion will be smooth. So, we have selected here if we have selected 25 mm radius.

So, during motion of those way points the robot will smoothly form a curvature of 25 degree radius in during that way point it will go in a smooth way. Whereas, in case of move l, it will give a jerky motion and it will give a jerky motion. So, this was about move command then let us go to other commands. So, way points under the move commands you have to select the way points whatever way points your robot wants to move you want our robot to program that way points you have to define. Then wait, wait command if your robot has to wait for some time for getting instruction from other like, if you have added a gripper on the end effector.

So, to perform gripping and gripping action after reaching a particular location you want to give a wait, you want to give a wait, waiting time. So, wait you can use then pop up you can use for giving a alert or warning or any kind of indication during the program. So, pop up is used for that purpose then halt, halt is used for for stopping the program whatever program we are writing here that will be continuing in loop. So, one after another the same task will be repeated if you do not use halt if you are using halt then the program will be terminated there and it will stop. Then folder is there and comment is there, for the user to understand the code properly you can write your comment that this program to so that other person can understand if I have written the program some everyone should be able to understand.

Folders you can create if you have, if your program is too long, if you want to save it as a subsections of the program. So, you can save it in different folders and you can execute the program as usual. Then, there are some other operations like move copy paste cut so that you can perform the operation with the like if you want to move up this particular command if you want to move up or down you can use move command move up move down copy if you want to copy some command from somewhere else and paste it somewhere. So, this copy paste if you want to delete particular command or if you want to suppress, the suppress mode is there. So, this is the basic commands which you can by using those commands you can create a pick and place task.

So, let us start I am now I am going to delete all the commands and I am going to perform I am going to write program for pick and place task. So, I am going to start with the move command I have to set a way point where the robot will start. So, I will select a way point then you have to go in the command then you have to set this way point. Now, robot has to move to a position from where we want to start. So, for pick and place task, let us assume that from home position a robot will go to a particular location, then second position, then third position.

So, pick up point it will go to some intermediate position and it will go to drop position. So, three way points I am going to define. So, I am setting up first way point. So, this you can do two ways either you can enable free drive, which basically, what it will do, it will free all the joints and you can easily move the robotic arm by your hand itself. So, you can move the robot at a particular location and you can store those locations.

Otherwise, in other case you have to use these commands to reach to a particular location and store those location. So, let us say I am using free drive to store a particular location. So, free drive can be enabled either from this screen, this from this button as well as there is a back side of the this each pendant there is a button, which can be pressed continuously and a robot can be end effector can be moved to particular location. So, now I am going to press it and store at a particular location.

So, let us assume, this is our first way point. So, from home, robot will go to this particular location, then we have to store, now way point 1 is green that means it is saved. I am using move j command from point 1 to home position to point 1. Then, second way point, we have to set again I am enabling free drive moving the robot to this particular location. The second way point is added then add way point after third way point I am going to add move robot here. So, change this, sorry I have to move the robot to third position.

So, let us say this is third position. So, robot has to let us say this is the third position. So, these three positions now we have stored now the robot will when I initiate the program the robot will follow the same commands one after another. If I want to add a halt in program if I want to stop the program, I will just add a halt. So, after this task are completed robot will stop.

So, let us check whether the program is running. So, now it has gone to first position now robot is going to perform these three points. I have added a halt here, if I delete this then robot will perform this in continuation. So, now once again I am going to indeed. So, when I run it will run in loop. So, these three points it is going to repeat it one after another.

So, this was taken place, now, we are going to start our task three that is continuous path task from in continuous path task what we are going to do we are going to come from home position to a particular location near the board, from there we are going to select four way points which are on the board. So, these way points we are using these way points we are going to use move L command and by this way command way points the robot has to trace in a linear way. So, these commands I am going to do. So, first way point, I am going to save.

So, this is first way point. Then next way point I am going to say, this is my next way point then I am going to use move L command. So, this is the first way point of the first way point of the rectangle then I have to move to next point next point. So, select another way point then go to command set this way point now move the robot linearly. So, this is one then you

have to go to next command, next position set this as way point two way points are added then add another way point afterwards.

Now, we have to set this way point then go in Z direction. So, first was X then this is Z. So, set this way point again then fourth way point move add way point afterwards then set this way point set this way point. So, this is our third point now last point we have to complete the loop. So, add way point after then we are going to save this fourth way point. Now, our program is completed once the program is complete we want to stop the robot.

So, we are going to use alt. So, this program is completed now we are going to save it file go to file save as R E C P rectangle. Now, program is saved now if you want to run just press play button it will go to auto home this is our first way point now the robot will continue will draw same rectangle on the board. So, just play if you want to run it in loop. So, you have to remove the heart delete this heart and now the program will be running in loop. So, now in addition to these three tasks we have added one more task in which we are going to write the name of our lab.

So, the similar way program we have to write the way points, we have to select and linear through linear commands, we have created this particular program. So, this is the particular program and now I am going to run it and it is going to write the name of our lab that is C F E R that is stands for center for excellence in robotics. So, let us start. So, it will go to home position and then it is going to start writing. So, this was the task. Thank you very much.