Mechanics and Control of Robotic Manipulators

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Lecture – 37

Types of Robot Manipulator Control and Concerns

Now, welcome back to mechanics and control of robotic manipulator. In the last class we gave the introduction to motion control. So, in that sense I told like motion control required or controlled design required the familiarization of the physical system. Then we are comeback to the objective; this is the place where we stopped in the last lecture. So, here we are talking about the types. So, before talking to the types, I will just give the familiarization part.

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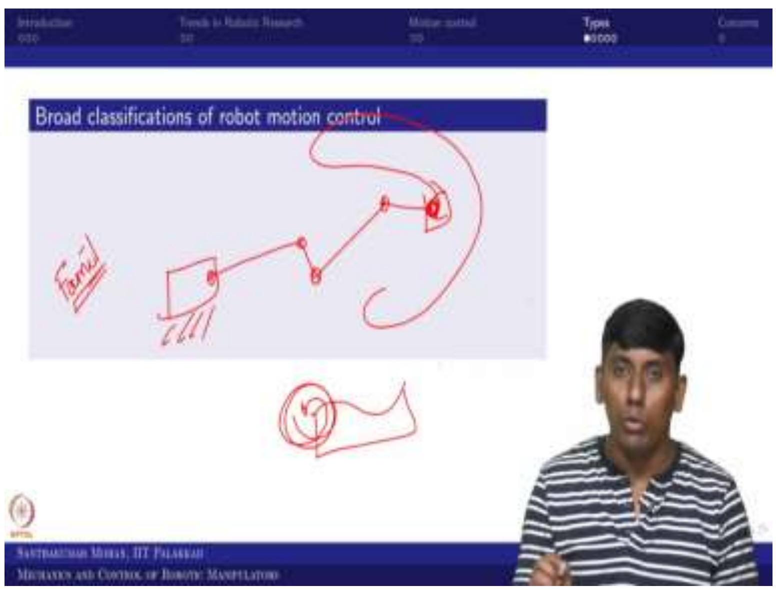

So, for example, I am just saying that, so the familiarization; so, in that case, for example, there is a manipulator. So, I am seeing this manipulator, so I am trying to show something. So, this manipulator is having something like free flowing. So, in the sense it is just moving it without doing any task; so, then you can see that this is different case.

Now, the same system is having a pen on the bottom; this is like a tracking on the screen, very simple example. Now, I am using this pen and touching this touchpad. So, now if I touch, then only it would be sensing, and it will be writing. So, the same sense if I think about the manipulator, so then this touching is also important and then following. So, then you should know the nature of the system, then only you can do it.

Other very simple example you have a laser cutter on the end of the manipulator or end effecter. So, it needs to cut the metal plank into pieces as per the seam given. So, in that case the given contact of the end effecter to the metal piece not at all there; so, it would be somewhere away from here, it would be like cutting it. So, in that case you can see like you can say situation for one and two were completely different.

One is like the marker tracing on the paper or tracing on the screen; so that is different from the laser tracker following certain path. So, that is what I was saying that the familiarization; so, now I hope you are understood that. So, now we will move to the broad classification of the robot motion control; so, there are two broad classifications we used to do.

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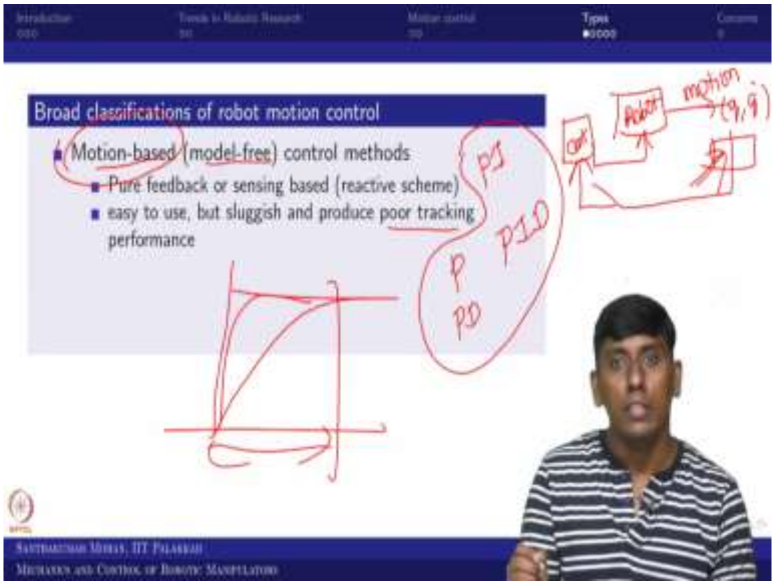

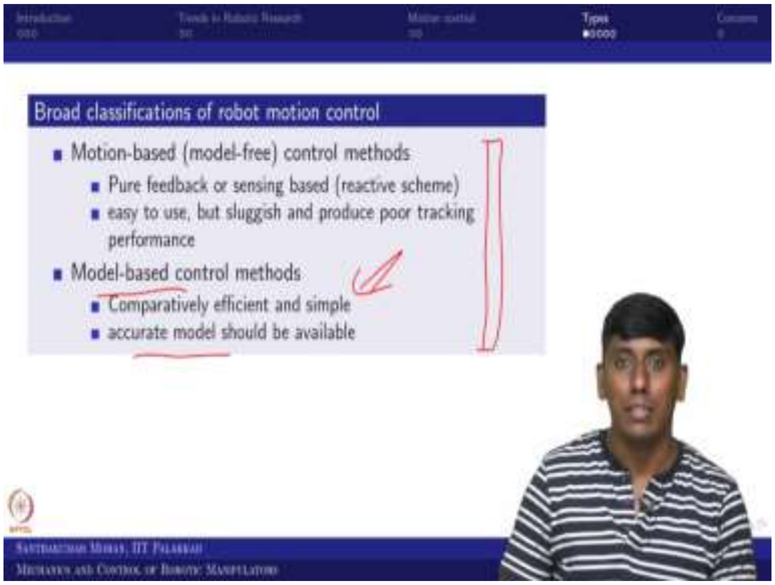

So, one is call the motion-based or some people call model-free. So, where there is no feedback, you can say there is only feedback; so, there is no model required, that is what you call model-free. So, what that means? So, you have your robot, so this robot motion. So, what you call this is q and q dot. So, you have taken as feedback, and you would do it in a control.

So, this you will take it as feedback; and try to achieve compensate this robot through this mode. So, in that case this is purely based on the motion; so, if the motion is giving a exact sensing value or your sensor whatever you put it here. The sensor is giving accurate signal, then you will be able to follow. However, the problem is so one is the sensor would be having a noise.

Second thing is usually this motion based controlled would be having poor tracking performance as well as sluggish. In the sense so you have as a step input. So, your so you can see controller will take time to reach this; so this much time is actually like lag. However, the model-based it will like probably go somewhere here.

So, that is the basic idea between the motion-based and the model-based; the motion-based usually people call model-free. So, one of the best example for motion-based, either you can take a proportional control or proportional derivative control, or proportional integral derivative control; even if it is like kinematic level, we can go even proportional integral controls and all.

Even the other way around we can go simple bang-bang control; or simple on/off control which we have used in the olden days A/C. So, like these all like purely based on the motion. So, based on the system motion or the feedback, we are trying to control the actuator signal.

However, the second method which is what we call model-based, which is definitely efficient and simple. However, the model is like inaccurate, so then this will not give a reasonable performance. So, that is what we said that accurate model should be available to do this. So, I already told so we are seamlessly integrating this, and we say that is hybrid.

So, we would be doing model-based control in your hybrid nature, where we try to compensate the model. And then we will go we will give the feedback based; so that is what the overall idea. So, further we want to see what are the other ways to classify?

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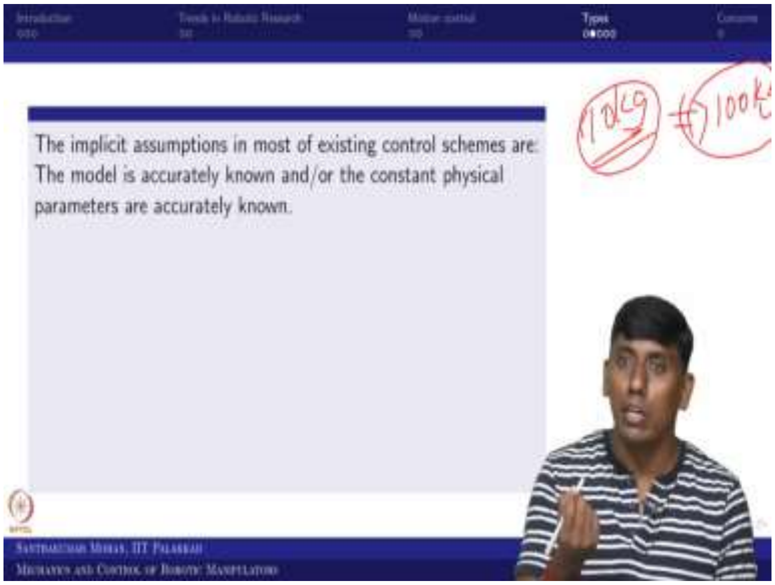

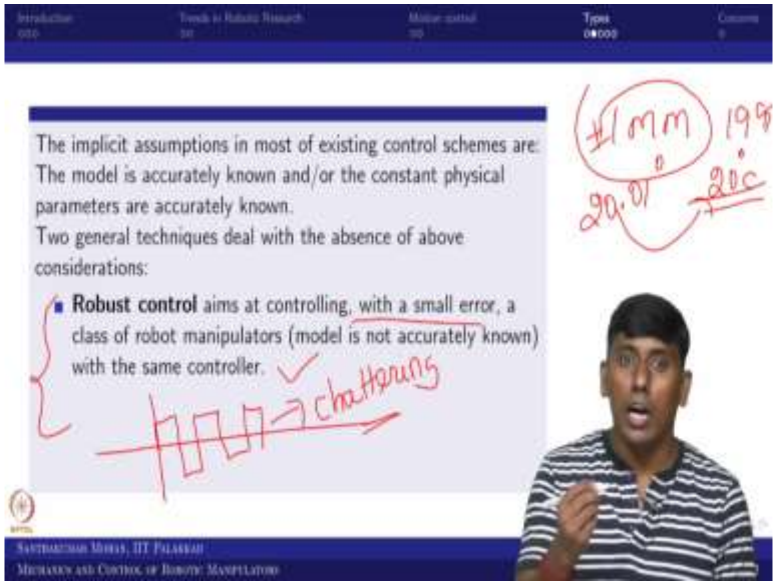

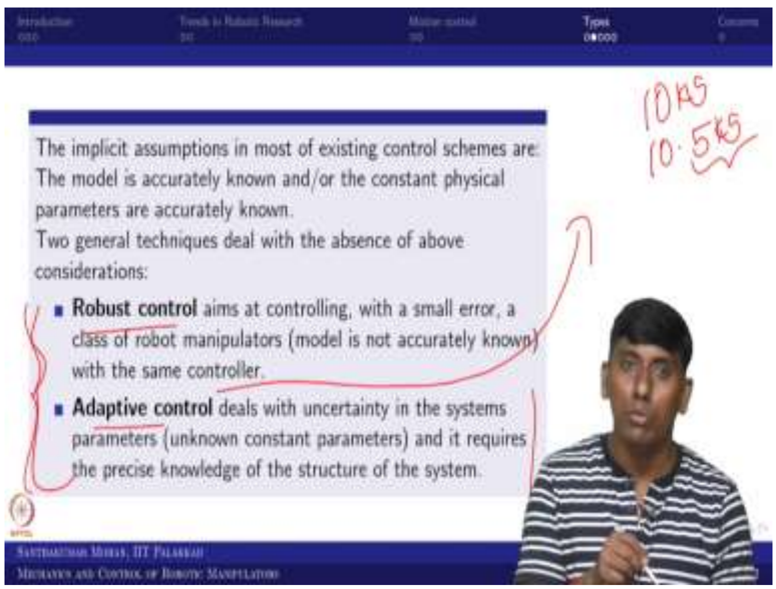

So, the other way so, so most of the assumption which we have done; so, either accurate sensing is available or you can say that this sensor noise is eliminated, or, accurate model are available to all of us. So, these are all implicit assumption which we have taken for the previous attempt.

But the model is not accurately known or the sensing sensor is having a error; so then how we can do it. So, for that we try to come up with a two different strategy; so, one is we called robust control, the other one we call adaptive control; so, both are trying to compensate the perturbation due to model uncertainty, or sensing or sensor noise and all.

So, in that case so the robust control is the name itself is robustness. So, what that mean? So, it is least affected on the external impact. So, for example, you are saying that it supposed to go in straight line, even you disturb in the lateral direction; it like least response to that, so, that is what you call robustness. So, very simple example I want to give as a layman style. So, imagine so you all might be knowing like so how to make South Indian idlis.

So, the idli would be having like hemisphere pot; so, why the hemisphere is there is of removal, so, in the sense least impact on the effort. So, when you want to remove that idli from the pot, you can just easily remove; it is because hemisphere. The same philosophy we are trying to give in the robust control. The robust control is more apparently come as the high control activity. What that mean? So, very simple example we want to give.

So, you want to compensate probably 10 kg effort; so, but you do not know it is actually like 10 kg. So, what you will plant? You will plant for probably. So, what would be the maximum threshold? So, you will plant for 100 kg. So, now so the load is like 1 kg or 100 kg; it assumes as a 100 kg and try to compensate. So, in that sense what happened? Most of the occasion the high control activity will come.

So, which means that, so it is supposed to come only 10 kg; but it is overwhelming. Because you are providing more control; so, that is why people call robust control more commonly called overwhelming control. So, this will be taking the effort; but what it does? So, even if any small error exists in the closed loop that would be ignored.

So, in the sense this is what is robust control; the robust control is more commonly I already said, the overwhelming or high control activity control. So, one of the popular robust controls is sliding mode control; so even this robust control has another impact. For example, you assume that 1 millimeter is the threshold; so, assume that plus or minus 1 millimeter is your error limit.

So, if it is exceeded or comes to 1 mm; so, what happened the actuator will start functioning. So, you take the; our conditions, so you put 20 degrees Celsius; you assume that it is just bang-bang control. So, now the controller is like planned for 20 degrees; so your system is reach to 20.01. What happened? So, your system will start, compressor will start, evaporator will start function; make sure that it comes to 20.

So, what happened? It may not stop at 20; it may go to 19.99 or something, so, then it will stop. So, if you look at the control sequence, so it would be on, so then off, then on-off like that it will go. So, your actuator would be like shuttling between one end to another end; so, which is what we call chattering. So, the chattering effect would be visible in most of the robust control; so that is why the robust control along with chatter-free is one additional phenomena people try to do.

Even the robust control people try to do with the neural network based, or probably matrix based all those things people try. So, these all we would be discussing in lateral part of the class. So, the other other type of control called adaptive. So, so whatever the effect due to that disturbance or the uncertainty; that try to compensate directly; try to calculate what happening due to that uncertainty, how much effort it is deviating; that much effort it would be compensating.

For example, so now I assume that the pay load is 10 kg; but unknowingly it is 10.5 kg. So, now this additional 0.5 kg, how much effort it is produced on your system; so that effort would be calculated and compensated at the actuator level. So, this is what we call adaptive control. So, the adaptive control more beneficial; however, the adaptive low may end up with even the system would be unstable.

So, because the adaptive controls mostly depend on the previous state; the previous state and the current state is having a difference, and the disturbances fast varying. Then the adaptive control may end up with something. And most of the adaptive control would be based on what we call regression matrix; will comeback what is regression matrix.

So, this regression matrix usually would be rectangular; so, the rectangular inverse you have to take. And in most of the cases the regression matrix inverse would be more prone to singular. So, in the sense their control input would go to infinity. So, this can happen, so that is why non-regression matrix or inverse free adaptive control all come up in the modern days. So, these are the two types of control apart from model-based and model-based.

So, here also it would be combine of model and motion; because the feedback also fed in, and as well as model also like incorporated. So, these are all in addition to that however this would be overcome the difficulty which we come across either motion or model-based control.

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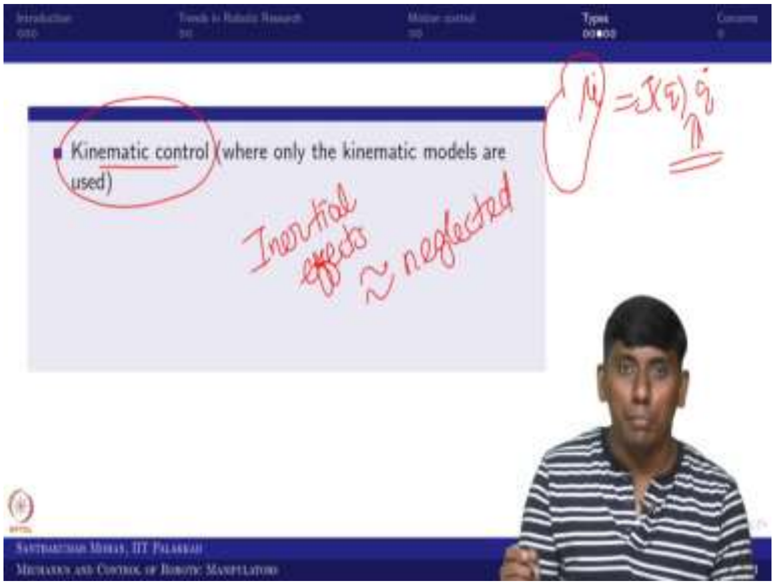

So, further what we can see the control scheme can be classified based on where and what way or what level you are trying to implement. So, your controller is like implemented at kinematic level; so, you have equations mu dot is j of q into q dot. So, I am trying to find out this q dot as the control activity, based on my desired or my position trajectory. I can do it, so then it is a kinematic control. In that case you have to take it one simple aspect: your inertial effect.

So, your inertial effect should be so negligible amount; so, here we are neglecting. If the effect is like non negligible amount; so, then the kinematic control may not work well. So, for example you have planer horizontal robot, that too like slow moving, probably it is rotating, probably it is maximum; one meter per second is the end effecter velocity. Then this kinematic level control will work very well. However, if you go for high speed or a spatial system; so, the dynamic control is important.

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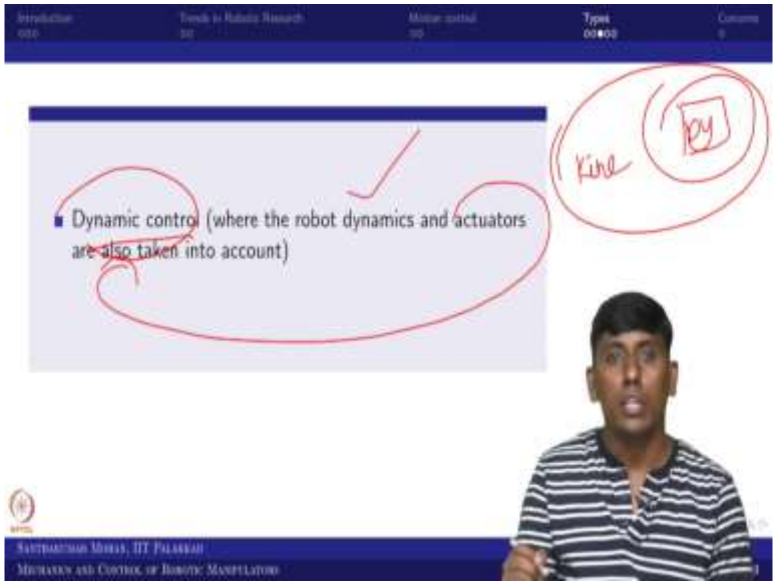

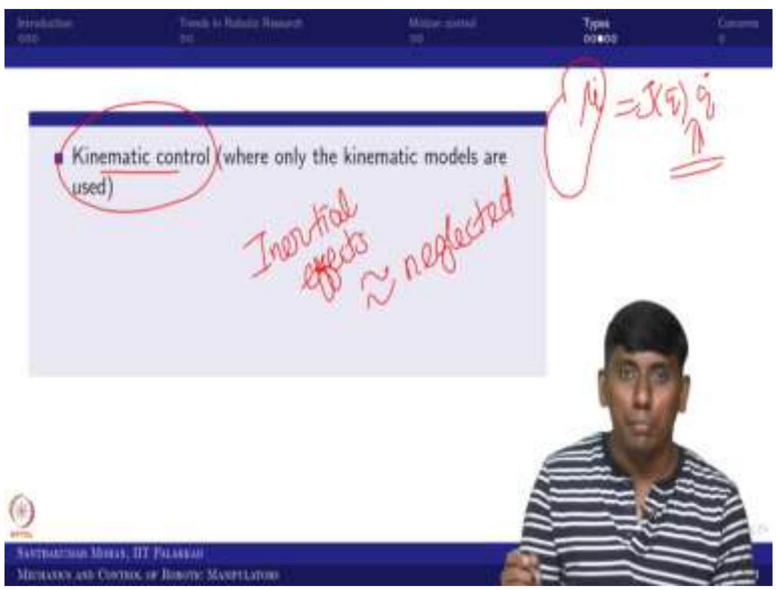

So, then the dynamic control means the robot dynamics also like consider; and the actuator would be considered as per the robot dynamics. So, the earlier case we bother about only the speed of the actuator; but right now, we consider what would be the torque required, how the torque would be obtain from the electrical motor or hydraulic motor and all that we will see. So, most commonly people try to combine this kinematic kind and dynamic.

We call cascaded or dual loop, where we would be seeing the inner loop would be dynamic level. And the outer loop will be kinematic level.

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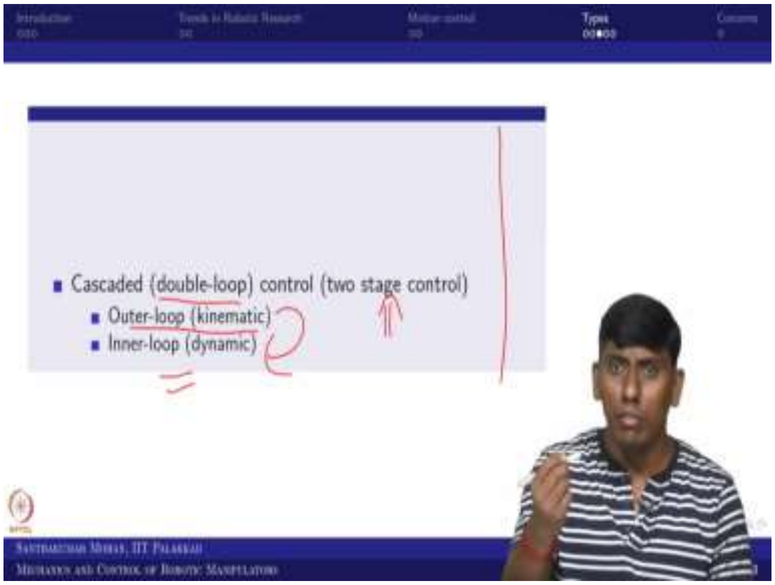

So, that is what we call cascaded or dual loop or double loop, which is like two stages. So, outer loop would be kinematic; based on that the inner loop desired characters will be designed or defined, then we will do it. So, we would be seeing all these in detail in upcoming lecture; so, will see what are the other classifications can come?

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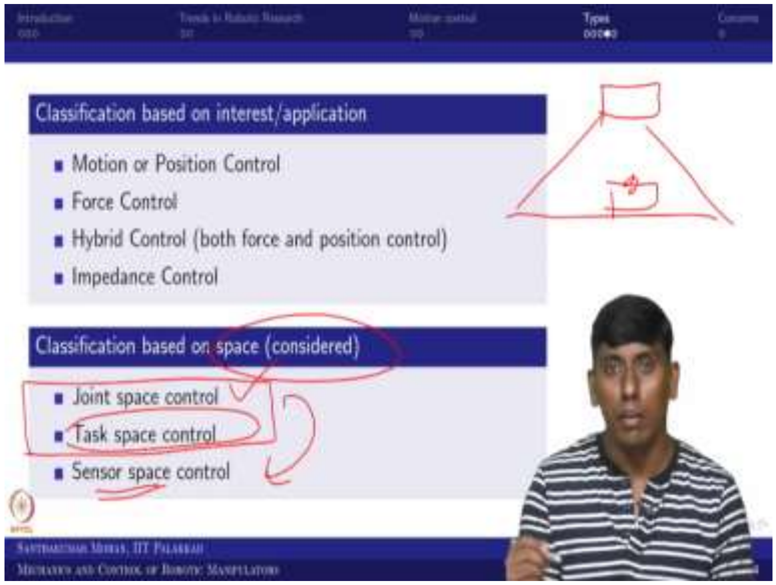

So, the other classification based on the interest or the application; so, whether it is a pure motion or position control; or you want to have pure force control or it required a combine. For example, now my hand is going to carry a bottle; that bottle is like a fragile, so, I cannot compress it. For example, I am carrying egg. So, then I need to make sure that the position also needs to be followed, and as well as the force applied to the end; so that is also important.

Then we need to think about the hybrid, so the other way around. For example, your end effecter is just pushing it. So, there is a conveyor, there is an object; so, this object needs to be pushed by the end effector, after inspection. So, then the force needs to be provided in such a way that this would be push. So, not only the motion but here at the end, the force is sufficient. So, then these are all come into a classification; but the other which is kind of impedance.

So, the force control also can be brought into impedance and admittance control; but here the impedance what we are trying to mean that it is something like a tele-operation. So, you have a master robot and slave robot; so, this is smaller sized and it is like exact replica of the master slave robot, so to the master. So, in that case so you need to have feedback.

What exactly the original manipulator is doing that feed you need to have it. So, then we will provide the impedance control; so, this is most commonly used for tele operated or active device. So, that is what we have out it as separate. So, based on the interest or the application, the control can be classified. But this particular course is focused more on position tracking or we call simply motion control.

So, further the control can be classified based on the space which we are using it. So, either it can be a joint space; so you are doing entire control activity in a joint space. Or, you are trying to control the end effector space, which means task space control. Some modern controllers come in a sensory task space. So, you have camera; the camera is put it like on the top, but your manipulator is working somewhere here.

So, based on this I can make it all the desired things modified. So, then it is like what you call sensory task space; so simply people call sensor space control. So, olden days we call only task space and joint space, now modern community broad this sensory task space. So, this is one of the important areas we can do it; so, it is based on which space we consider for the control activity. So, further what we can see whether you want to control since we are talking about manipulator.

You want to control independent joint, or you can say synchronously with the multiple joint; so this also can become. So, independent joint means it is very simple, because you can go with the actuator level, and you can even go with simple PI control that is sufficient. But if you are thinking about multiple joint control; then we have to depend on further end; that is what we are going to see in upcoming lectures.

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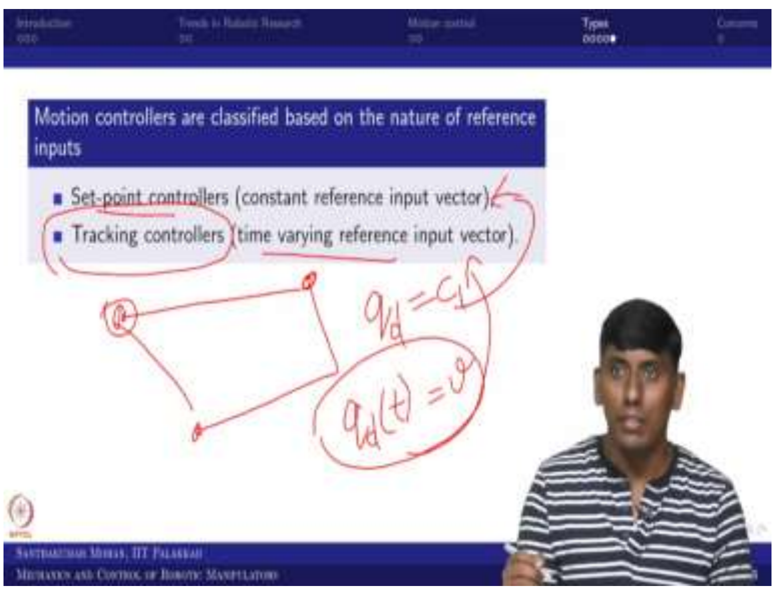

So, further the controller can be classified based on the nature of the reference which I have already told. One is the regulatory control, which is nothing but the set-point. So, you have desired, this is given starting point, and this is the desired. So, you do not bother about which time it would reach; so, in the sense it is a set-point; you need to stay remain after a while.

So, your reference is constant, so this is one sub classification; we call set-point or regulatory control. Some people even call a stabilization, where from any non-zero initial condition can be come to the home position; that is what we call stabilization. But, more commonly we use the tracking; so, the time varying reference input would be given.

For example, q desired is the reference; so, this is constant for the set-point. So, q desired of time, which is variable, so this is what we use for the tracking control or servo control; so, these are the types. So, now will come back to one concern; with that we will end this particular lecture.

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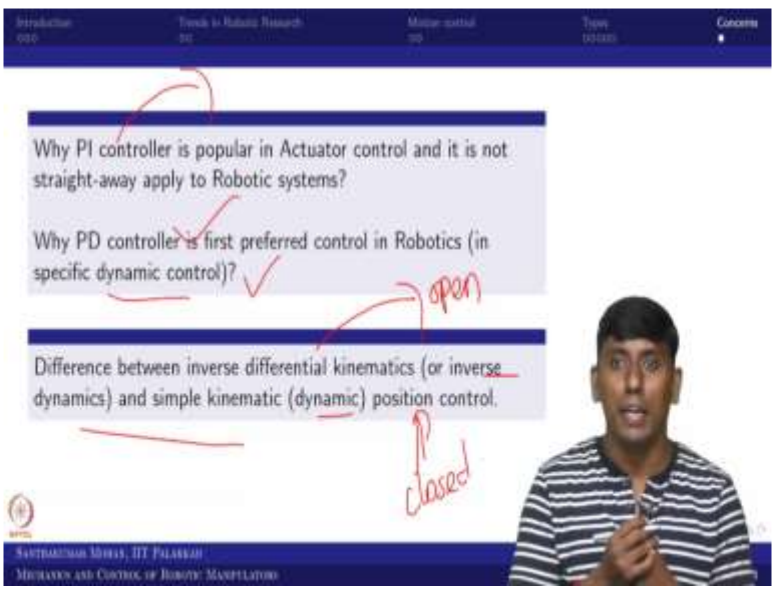

So, what is a concern? So, you might have heard about PI control in your actuator level. When you talk about DC motor, or you talk about servo motor and all; so one of the standard control is the PI control. But the PI control is not straight away applied to the robotic system, because so the robotic system open loop control is unstable; or you can say open loop system is unstable.

The second order dynamics is unstable; so, if you apply even PI control that may not make it stable. It may end up with further unstableness; so that is why PI control is not straight away applied. So, in that case what people use? So, the PD control. So, the PD control is the preferred control on the robotics; so is specifically like a dynamic level.

So, the PI control would be common if we do in a kinematic level. But the kinematic level is not common in robot manipulator community, because so the actuator dynamics and the motion dynamics are not negligible amount. Further, most of the manipulator would be working on multiple body that too in spatial; I hope now this is clear.

The second part is what is the difference between inverse differential kinematics and the kinematic position control, you already know. So, even you can talk about inverse dynamics and dynamic position control. You know this is feed forward, in the sense this is a simple open loop, whereas, the position control or the motion control, which are like closed loop.

So, inverse differential kinematics are inverse dynamics, nothing but it is a feed forward control; where the kinematic or dynamic position control are the feedback control that is what we should know. So, now I hope you are getting familiarized about what is motion control, and what are the types, and why PD is required, when we can use PI; and when we can use inverse differential kinematics or when we can use closed loop.

So, these all we have seen. So, in the next class will see a simple kinematic control, which start from inverse differential kinematics; and we end with what you call kinematic control with proportional or proportional integral in the next class. Until then see you then bye.