Wheeled Mobile Robots

Prof. Santhakumar Mohan
Department of Mechanical Engineering
Indian Institute of Technology, Palakkad

Lecture - 34
Introduction to Motion Control of Mobile Robots Part 2

Welcome back to the Wheeled Mobile Robot; last lecture what we have seen, the Introduction to robot Motion Control. And then we have seen what are the trends and then we ended with one of the specific type of robot motion control based on the model.

So, whether if the model is available and you incorporating the model, then you call model base control; if there is no model you use, then it is called model free control. So, that is the classification we have seen in the last class.

So, now this class, this particular lecture, we would be moving little further, where there are actually like some issues will come; for example, model base.

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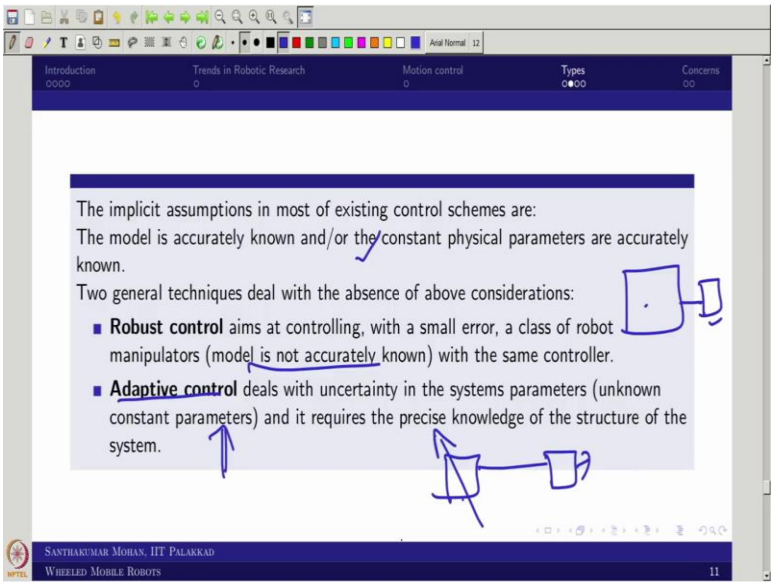

So, let us move to the slide, where you can see like these all the controller existing controller. What the implicit assumption? Either the model is accurately known or all the state variables are available. So, in the sense the model is accurately known in the sense, the constant physical parameter are accurately given to you. Then only you can naturally like incorporate, but in reality it is not.

So, then what happened? If you are actually putting these assumptions; if these assumptions are not actually like there, then what kind of techniques we apply. So, there are two popular approaches we use. So, I will not call as a classification, but two popular approaches we usually use. So, one is what we call robust control, the other one what we call adaptive control. So, what that it that means?

So, this is what we are actually like trying to see, one is robust control, the other one is adaptive control; although you can read in the slide, but I will explain what is robust. So, robust we usually said that, it is ignorant or you can say it is going to ignore whatever variation happening in your, you call the other side.

So, you have given a predefined input and if any disturbance incorporated, that would be ignored by this particular control, which we call sometime overwhelming control. So, in order to give little more you can say aspect, I will take a small example. You imagine, so me and my son, probably my son is actually like you can take 4 or 5 year old. So, me and my son went to a park. So, there is a seesaw, ok.

So, my son want to play a seesaw. So, I am putting him in a seesaw one side and I am actually like you can say playing it, suddenly I got a phone call. So, now, imagine, he is actually like little bit naughty; he should not actually like come down, so that he will run away from the you can say the seesaw play.

So, then what I am trying to do; I want him to stand on the top and saying that you stay and look at it all the around, but you stay on the top. So, for making him for a top; what I supposed to do? So, you know my son is actually like 3 or 4 year old; I assume that he is actually like approximately 10 kilogram or 15 kilogram. So, what I can do? I can actually like put little more than 15 kilogram on the other side of the seesaw, it would actually like stay back on the top.

Now, I said my son is naughty, right. So, now, he is actually like pushing down by his hand; what happen? It may actually like come down, right. So, now, you want to make him actually like rigidly on the top. So, what one can do in a robust side? So, you take a bigger you can say weight probably 100 kg. Just imagine, I am putting in the other side; even if he push, he cannot do it, right.

So, now imagine this seesaw is actually like more than a meter long and he is actually like standing; we assume that he is actually like properly packed, he cannot jump. So, now, imagine you put 100 kg in the other side, you would be always top, right. So, this is what we call actually like overwhelming or robust control.

So, robust in the sense, the name itself says that, it is actually like least you call influence on the external environment. So, you can actually take even small you can say silly example, you know like the olden vessels and all. The olden vessels and all actually like would be having a hemisphere in the bottom or at least a cylindrical circular base right, the bottom would be in a circular shape or hemisphere. Why it is so? Can anyone thought about it?

Now, modern actually like come in a very very different shapes; even the shape would be you can see a star, square, even heart shapes several shapes have come the utensils. But you imagine the olden days the utensils are not like that. What their phenomena here, you just imagine. So, you think that this utensil supposed to be washed, right.

So, the dishwasher will not be washing; the man would or you can say, the woman who is you can say doing this work is supposed to do manually. Imagine if it is actually like a contricator or you can say intricated shape; so the corner always actually like having a something, right.

So, that is cleaning is always a difficult; you and you notice when you have a square or you can say rectangular shape basis, so the corner is always difficult to you can say wash. But now imagine if it is a robust shape like a hemisphere, the two hemisphere. So, it is actually like very small right; it is just you swipe it, it will come. So, this is what you call robust.

So, that is what we are also bringing in a control aspect robust means, it is least influence in the external factor. So, that is what we call actually like overwhelming control; because usually it would be having a high control activity. For example, I gave a example with my son and me.

So, you see you supposed to have a control activity probably beyond not more than probably 15 kg. But I am putting 100 kgs pay load, in the sense the control activity; this is what we are trying to do, we are trying to do overwhelming, in the sense even the real performance would be ignored.

So, that is what we are actually like seeing it. So, this is actually like when it would be applicable, if the model is not accurately known, you can do it. This is one way of actually like overcoming this particular you can see case. So, the other cases actually like what you can say adaptive.

For example, now you are actually like getting change of your parameter. For example, you would take your mobile robot, this mobile robot is moving on the ground and suddenly there is one you can say weight which has dropped on that. So, now, the mass of the vehicle has changed, right.

So, now the robot performance which you did in a model base, which was defined based on the earlier mass; but now the mass has changed. So, your model based control will not work, because now added mass is there. So, now, what you can think? If you are actually like able to realize.

So, there is a addition in the mass; you are actually like able to find how much it is actually like added. And adapt that into your control manner or control input, that is what you call adaptive. Very simple example, so probably I am walking, ok.

So, I am walking on the ground and one of my student is coming and something; like he is actually like playing with me, he just pushed behind, ok. So, what I am trying to do? Do you think that I would actually like do a robust control there? No. So, what I will do? I will try to adapt his push, right.

So, now you can see there are two way I can actually like go across further and performance. What are the two ways? One I can actuality stop his hand, ok. So, the other way actually like I can actually like restrict the motion by seeing how much he is applying, right. So, now in the sense what you can do? You can directly adapt the forces, which is he is enduring, so that is what you call direct adaptive.

The other way around who is actually like creating and what way he is creating, I stop that; then what you call indirect adaptive control. So, in the sense you can see the adaptive in the sense, you are actually like adapting the variation and then you are actually like adjusting; in the sense here the compensation by you can say adjusting the parameter. So, in the sense I put the controller, the controller would be adapting ok; whereas the robust controller it is actually like overwhelming.

So, I am just putting the picture like this, this is the robot and this is the controller. So, here actually like you can see the, I put a bigger block in the sense high control activity; but here I put a arrow in the sense it is adapting its own nature. So, obviously we wanted either one of this or the combination of these two; because mostly in the real time, these two are actually like important.

And mobile robot is and inevitably it is actually like playing with parameter uncertainty and as well as external disturbance. So, in that sense, these are we are trying to attempt in this particular course. So, before going to attempt this, we can classify in other way also.

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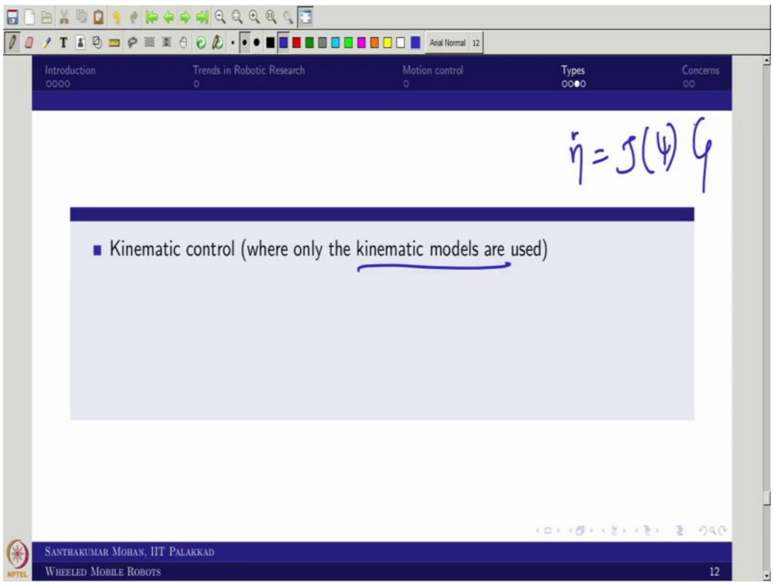

So, I am just giving that. So, what you can do? You can actually like take the mobile robot in a very simplified way. You know like mobile robot is actually like moving in the ground and its inertia is actually like always pushing in the ground. And you assume that the mobile robot is moving very slow speed. The inertia force compared to the mass of the vehicle is actually like very very small.

Then what you can actually like make it? As a small moving and it is on the ground and the mass along with the inertia force, the inertia force comparably negligible; then what one can see? You can do a simple kinematic control. So, most of the mobile in roboticians, what we used to do? So, the complex robots all we do very slow speed, which we do it with kinematic control; that is why you can see that dynamic control is not so popular in the mobile robot community with these assumption.

So, in the sense what would be the classification? So, the kinematic control is one. So, the other one is what you call dynamic control.

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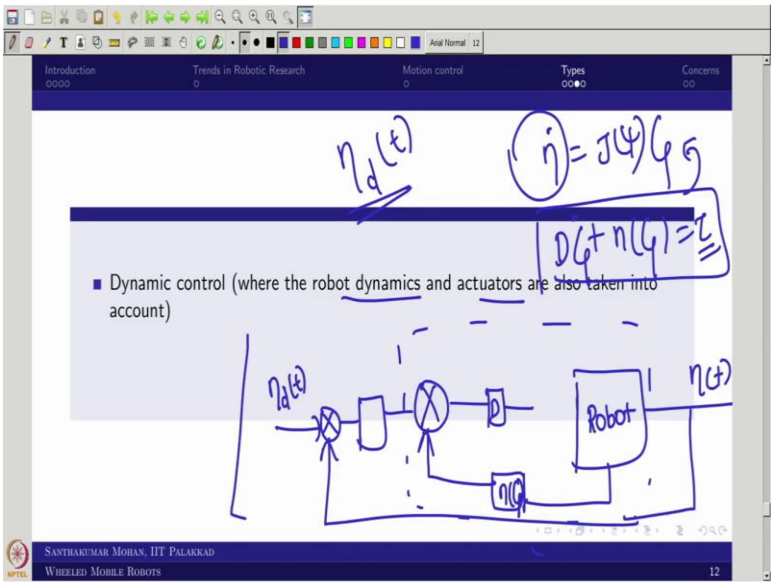

So, what the kinematic control, where the kinematic models are directly used in the sense you know this, right. So, this equation you use and then you would try to do it; even we try to attempt as a inverse differential kinematics, we will see what to be done. So, the other side what you call the dynamic control, where the robot dynamics and actuators are all taken into account and then we try to do it.

Then you see that both are having a pros and cons. So, why? So, you know this. So, just I am giving this as a case. So, what that means? So, I can actually like write. So, this is what my input, this input I can write it in a directly body frame. But this body frame velocity I can put it in the inertial frame and then this is what my desired, right. So, this is what my desired.

So, then what one can see; I can actually like take the mobile robot. So, the robot. So, I am taking this feedback, where I call η, ok. So, I am actually like seeing that η desired of time. So, I am actually like comparing that ok and I am doing it something, which is in the only kinematic level, that I am feeding as a reference to the dynamic system.

So, I put this is n(zη) and this is actually like D. So, I am actually like what I am trying to do? I am actually like trying to make. So, one is actually like you call inner loop, so the other one is actually like outer loop.

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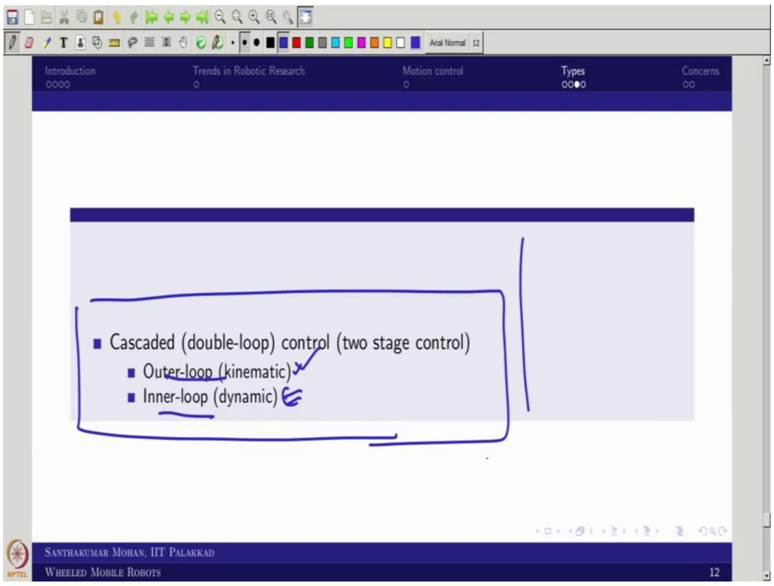

So, what that mean? I am trying to do a actually like what you call cascaded or some people call composite, some people call double loop or some people even call two stage, where the outer loop is the prime most. So, that we do it in a kinematic level; the inner loop what we do in a dynamic level. So, the inner loop directly we can incorporate with the help of system dynamics in body frame. Whereas the outer loop you can do it with respect to inertial frame.

The relation between initial frame and the body frame we use. So, these are the three cases we can do it in the what, we can actually classify the robot motion control. Most of the scenario we do this, very complicated robot when the speed is actually like reasonably large.

If the speed is very very small and the inertia force are ignorable, then we can do it in a kinematic control. When the inertia force is actually like not ignorable, but your model is more or less close to known to exact, then you can do a dynamic control. So, in the sense what one can expect in the next lectures. So, we will see the details about the kinematic dynamic and what you call the cascaded control.

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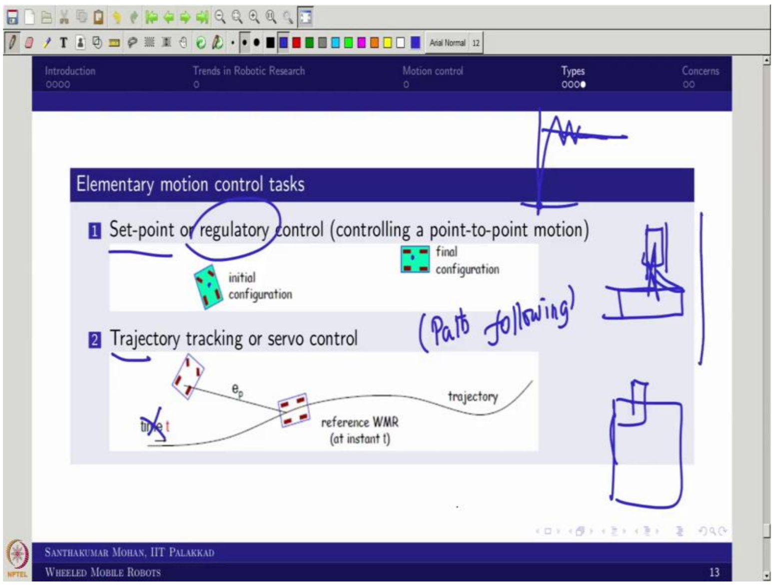

But this is not the end here. So, the end is actually like we are going to put a several questions. So, what are the questions? So, first we will see the motion control task is actually like path following or you call trajectory tracking. So, in the sense you can see like. So, here I am actually like, even this I can take as a path following.

So, where I am actually like ignoring the, you call the time. So, then this would be a path, in the sense you would take a road and then you are actually taking a car. You are following as a path right, you are not doing any trajectory tracking. But imagine, you have actually like proper programmed train and then you say that this is the proper signal ok.

So, when you are moving the train, the signal supposed to be closed or opened. So, then you can see that, that particular instant you have to be there. So, then what you call, that is a trajectory tracking or some people call servo. So, the other way around what I said is simple parking problem right, where you have initial configuration and final configuration. You need to move one point to another point, which is what we call regulatory.

So, just for understanding you know regulator off so and so thing, right. So, what regulator means? You keep that output as something constant; for example, you take AC remote. What you are doing? So, you put 20 or 22 or something. So, what you are asking the air conditioner to do?

You keep the temperature of the room as 20 or 22; if it is exceed, you reduce; if it is actually like reduce, it may not actually like switch on. You imagine you have actually like you can say multifunctional air conditioner, it is not air cooler; it is having a heater and as well as you call air cooler. So, then it can actually like even if it is reduce or increase, it will play.

So, now what it is trying to do? It is actually trying to do regulate; in the sense this is what your input and you are actually like you have here and you are trying to go and you are actually trying to maintain this. Whenever you lower down, you go up and then do it. So, this is what you do in a parking problem also, right.

So, you have this is the slot and this is what your car actually like moving direction. So, what you do? You do several back and forth and then you will park it inthis lot, right. So, the same thing what we are doing it, this is what you call sit point and this is what you call trajectory tracking. In our course, we will do both and then understand how it can do it.

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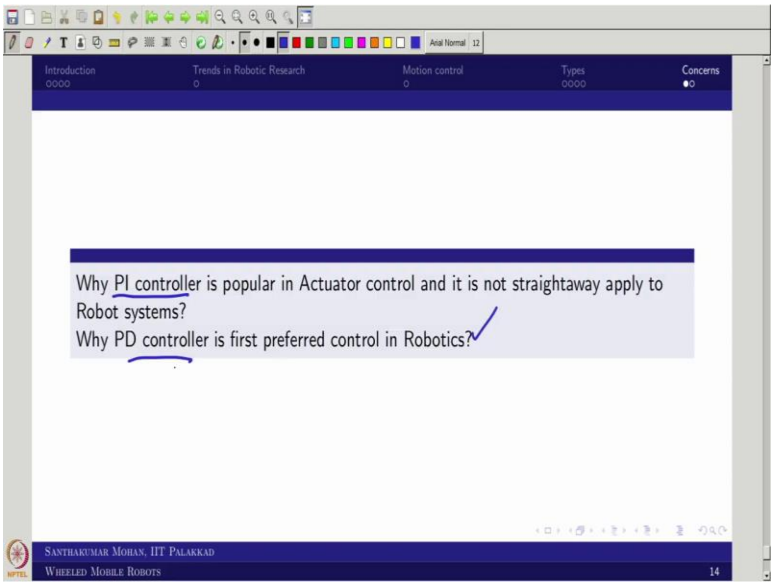

So, now there are several concerns will come into our picture. So, why the PI controller is actually like not using the robotic system, which are actually like very popular in actuator? For example, you take DC motor control; the very simple controller which we give for reference is PI control.

So, this answer I already you can say discussed, right. So, the open loop system, open loop you can say system of robotic platform, which is actually like unstable. So, how it is? There are second order dynamic equation if you look at it, so that does not have any you call dissipating term.

So, in the sense the term what you have obtained, it will give the system is unstable, right. Whereas, you want to make it a actually like unstable system 2 as closed loop system stable, the PI is not the right one; the PD controller is the right one. So, that is why in robot community, you can see the PD controller is very popular than the PI. Even people use PID, but not PI for directly for the robotic system control.

So, this is what one of the concern, you may actually like get it; because some of you might be in electrical background. Then you can see that the PI controller is very vast used in your robot, not robot motor control. But when you talk about robot, even manipulator theory you would have studied PD controller is the first preferred control. Why it is so? Now, you got it.

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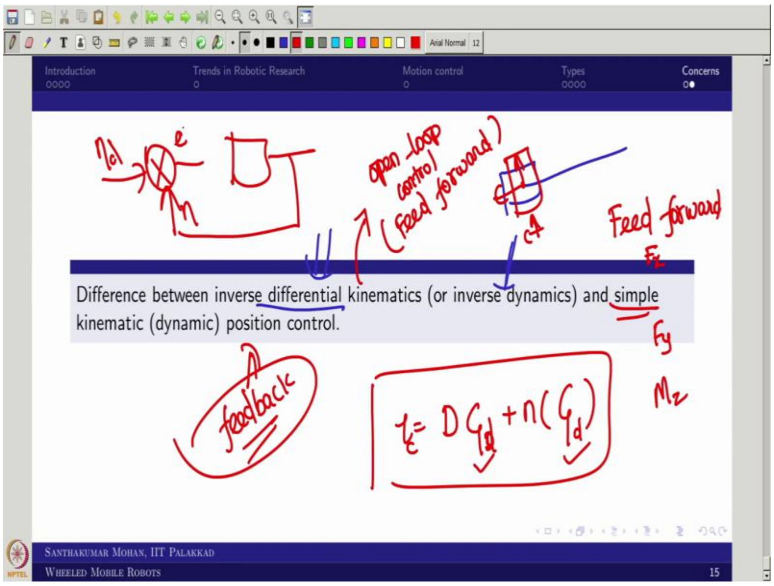

Now, there is a another concern. What is inverse differential kinematic? Sir, you told in the inverse differential kinematics or inverse dynamics, it is one of the controlling problem. But I gave a disclaimer or the warning says that, it is a open loop control, not close loop, right.

Why it is so? I give a example also in the simulation; when your vehicle supposed to go in this, but your vehicle initial orientation is like this. So, then what happen? If you are doing the open loop, which is nothing but the feed forward. So, what you will actually like see that, you will assume that the x axis direction force, y axis direction force and M_z you will give, but now your body frame is like this, right.

So, then what happen? So, you are giving this direction, but this will take this and this. So, then what happen? The vehicle will completely go out of scope. So, that is why what we call; the forward sorry inverse differential kinematics and inverse dynamics what we call, it is open loop control and as well as some people call feed forward.

So, what that mean? So, you imagine this is what you have taken as a control activity, which is we talk about this one, ok right. So, this is actually like what you are doing? This is actually like user given, right. So, in the sense what you are doing? You are taking without comparing what is actual; you are actually seeing what supposed to be given and then you are doing.

For example, you take a footballer, the footballer actually see the goal post and he just kick it, right. So, we do not know like whether the force is actually like sufficient to go or not. So, now, imagine that ball is having some sensing and that ball is having something like wheel control activity, by looking it and it can actually like maneuver. And then it is actually like take away from the opposite team and it can go to the goal post, right.

Imagine this kind of scenarios. So, that is what we are actually saying that is a closed loop, but this is the open loop. So, now, you got a clarity what is actually like you can say position control; that means it is actually like feedback. The feedback can be several form, but the feedback is one of the important thing. So, in the sense, you would be comparing your actual and desired, ok.

So, in the sense you take a robot. So, you take your feedback ok; then you are actually like giving your reference and this you are comparing and that you call error. That error only you are going to manipulate; whether it is model base or motion base, but you are going to do this.

So, in the sense what you are actually like going to see in the coming upcoming lectures; you would be seeing feed forward. And as well as feedback control, that to we start from kinematic level and then we move further up to cascaded. And if actually like time permit, we will see the robust and what you call adaptive control and then we will actually like close the control part, then we will go further,.

So, with that this particular lecture is end. And in the next lecture, we will see one the simplest kinematic controls technique and then see the example with you can say board, ok. So, in that sense, see you then, bye.