Wheeled Mobile Robots
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Lecture – 02
Introduction to Locomotion and Types of Locomotion

Welcome back to the course on Wheeled Mobile Robot. So, you have seen in the 1st lecture basic introduction about what is locomotion, what is the manipulation and then we have seen what is actually like mobile robot. In that sense, we have seen what are the number of components; in the last lecture itself I gave a idea that the next lecture would be talking about more on locomotion.

So, that is what this lecture 2 is actually like talking about Locomotion and Types of Locomotion. So, at the end of this lecture we would be seeing what is wheeled locomotion and then the types of you can see wheeled locomotion we will be seeing.

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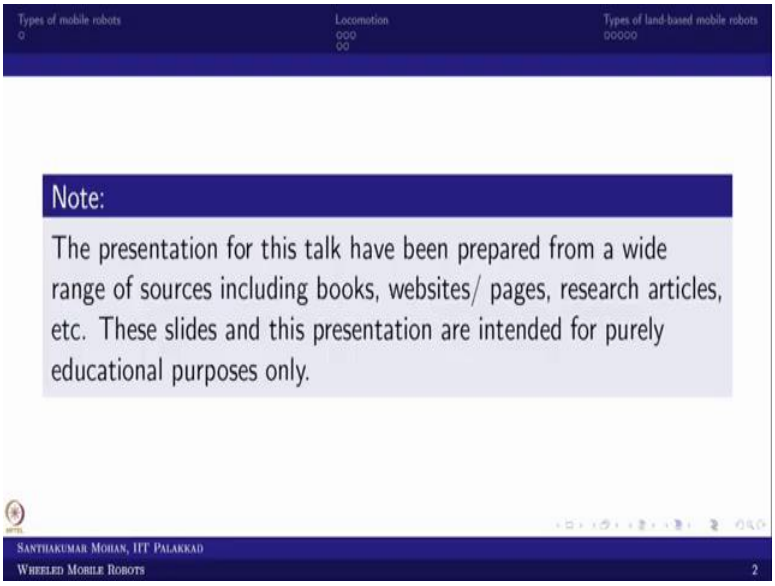

So, based on that let me actually I go; so, as usual the note I have given. So, the presentation or this particular talk is actually like mainly intend for educational purpose.

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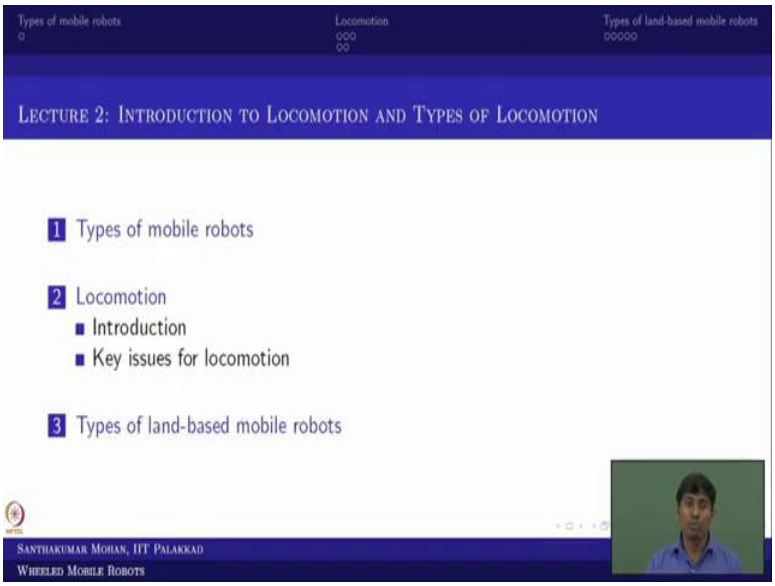

So, let us move to the content of this particular lecture. So, this lecture as I already told; so this is mainly focusing on the locomotion side. So, what are the key issues and what are the types of locomotion that we would be covering. So, the types of locomotion what I am bringing here is actually like types of you call mobile robot that too like I would be talking about land base because this particular course is on wheeled mobile robots. So, I will be focusing on land based mobile robot.

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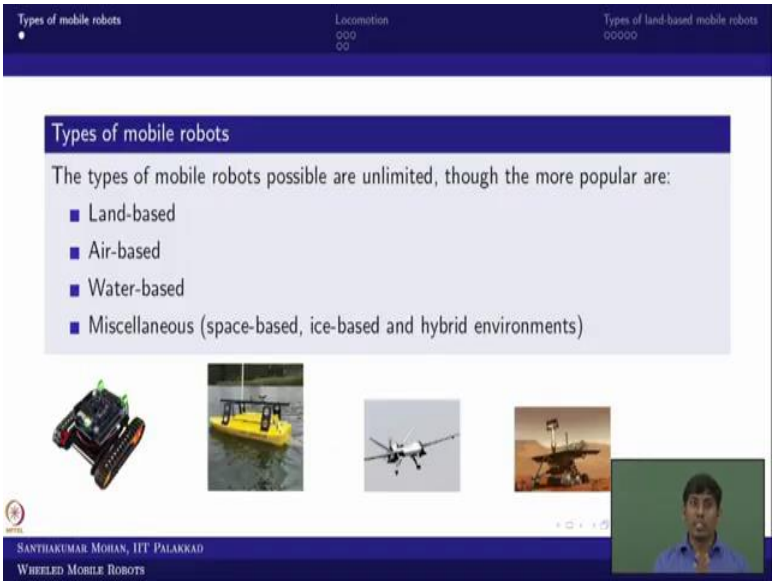

So, in that sense I start with a very basic you can see types; so in the sense that types of mobile robot would be the first slide of the lecture 2. So, which we would be talking about very broad the types of mobile robot can be classified in number of ways. So, I would be covering the one of the way which is what I am actually like making it based on where it is actually like employed.

The other way around we can actually like classify service, field, domestic and you can say some special application, but what I am actually like classifying is based on which environment it is actually I put it; whether it is on the ground or it is on the air in the air or on the you can say underwater or surface of water or it is actually like on the hybrid environment.

So, based on that the classification here is mainly focus on land based mobile robot; then you can see that the air based, water based miscellaneous all come. So, what that miscellaneous? It is combination of anything or it can be a dedicated environment.

For example, ice based you imagine; so you are driving a car on a normal road and suddenly you have end up with something like icy surface, you imagine; so you are in a Europe country; specifically you are actually like in probably a Northern European country; so you can see that the winter is very common.

So, in the summer what you are using the tire that cannot be substituted for the you can say the normal winter. So, you have to dedicatedly change the winter tire. Why? Because the; you can say the locomotion is getting different. So, that is why we are actually like making the classification also here. So, the land base, air base, water base is the broad category. Further, whatever we are actually getting a special case all we put it in a miscellaneous.

So, here are the miscellaneous; what I put as a sample photo or example is something like on the, you can say a lunar mover. The other three are very specific so, but we are focusing on the land base in this particular lecture.

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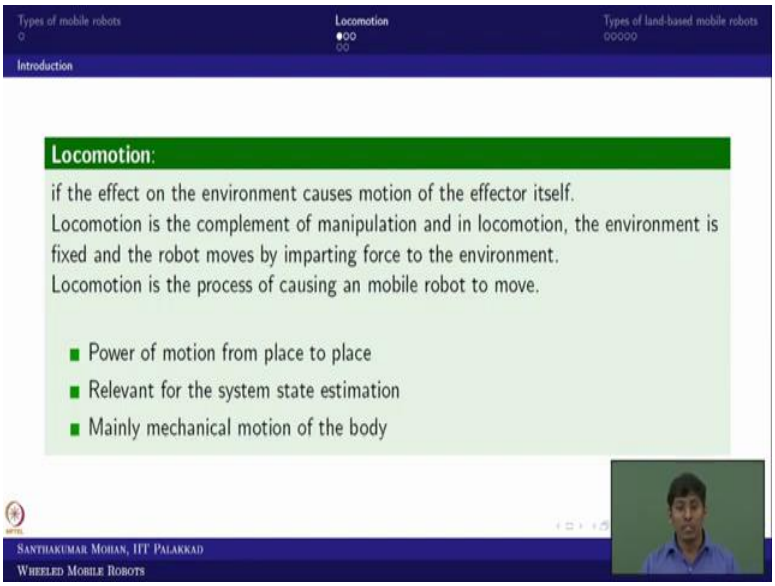

So, for that we will bring back I already told; so this particular lecture is going to talk about locomotion. You know what is locomotion; it is nothing, but the effect on the environment causes motion of the effector itself. This is what we defined as a locomotion, but there are other way to define.

So, what is that? The locomotion is the component; sorry its a complement of manipulation and you know like what is complement of manipulation means, it is actually like going to give the; you can say rather than fix, it is going to move. How it actually like move?

By imparting force to the environment or imparting the movement to the environment. So, then that imparting force to the environment or movement to the environment; what we are going to call as a mechanism, that mechanism what we are generally calling as locomotion. So, that is what the broad classification.

So, now, that is what I am putting in an next line you can see; locomotion is the process of causing and mobile robot to move that is what we are saying, how we impart the force on the environment so that the mobile robot will start moving or motion execution that is what. So, in that sense what one can actually see the locomotion is nothing, but providing the power right. What that power? So, power of motion from you can say moving one place to another place; so that is what the case.

So, now imagine I am actually like standing here, I want to move to a the corner of the room. What I need to do? I have to actually like provide some forces to the ground and in such a way that I can actually like execute. So, what that gives? So, that gives actually like locomotion system, but that locomotion system is giving idea, if I actually like make it that model. What I will get? I will actually like able to estimate the system right system state.

So, that is what actually like important the locomotion is what going to give the overall system state estimation. In the sense the system state propagation itself is providing by the locomotion system; this is what the idea. So, then what we are focusing here?

So, the locomotion means the mechanical motion of the body what happening that is what. It is not the controlled motion, the controlled motion will come on a motion control; right now you take a base and connect a wheel and actuate the wheel, how that wheel actually like making the mobile based to move.

Now, you put one wheel that would give a different kind of locomotion; if you have a two powered wheels that would give a different and you have actual like three wheel that would give different. For example, instead of wheel you put a leg that legged locomotion will give different way. So, in the sense what one we can actually like understand; here the locomotion means the mechanical motion of the body what it is providing; that providing mechanism what, we call locomotion system ok.

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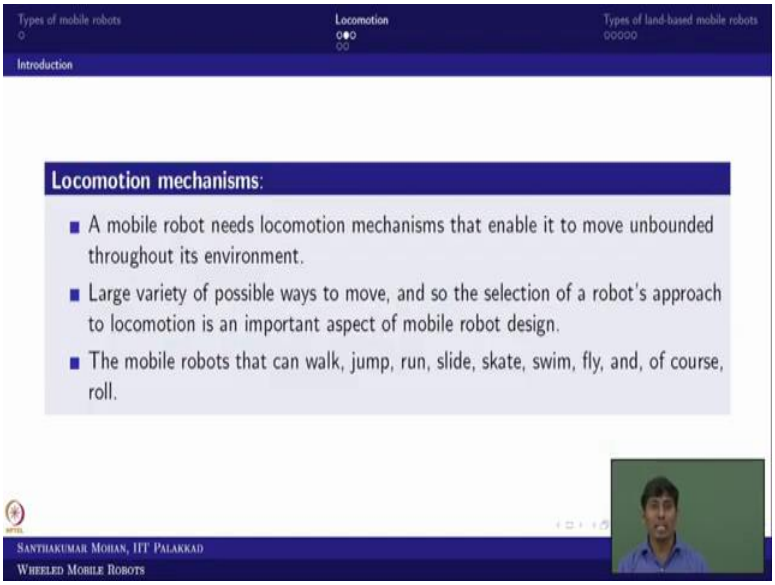

So, in that sense of what one can see; the mobile robot definitely need locomotion mechanism, why? That is actually like providing the motion unbounded throughout its environment. This is all actually like agree, but what exactly the issue here is?

There are largest or you can say there are several ways to do this. So, in the sense for example, even I can actually take the wheel, leg, track right. For example, if I take a land base; I can actually like put a wheel, then I provide a power to the wheel that will also like make a locomotion on the ground.

Now, imagine I put two bend wheel with a spring. So, even actually like there is a leg, with a wheel, but a spring; so now, it hit on the one of the probably a block. So, the spring will actually like make a hopping. So, now, in the sense you can see that there are several ways to do this. So, then one supposed to know what are the best way and where it suit this. In that sense, you need to make a understand began the locomotion mechanism and you have to select the appropriate mechanism for particular need.

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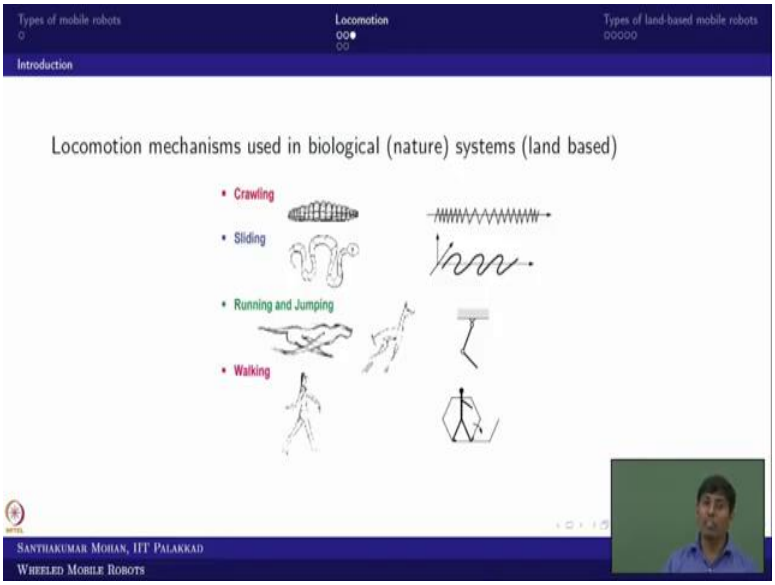

So, in that sense you can see that the mobile robot can walk, jump, run, slide everything you can actually like brought whatever the mobility we are getting into nature. So, in that sense; so first we will show or I will show the basic biological you can say locomotion system.

So, even the sliding is there, even there is actually like a flowing also there, but I did not put those. So, I am putting which is actually like more realistic. So, one is actually like crawling for example, caterpillar or something; you can take it and what it is actually like are worm.

So, the worm is actually like a having a crawling operation; what that mean? It actually like compress and expand compress and expand. So, this can be actually like make it as a mechanism, but this is actually very difficult in execution. For example, I put a two different actually like roller and put a spring in that. So, the spring would be energized and go forward, then again bring it the rear roller to the forward; I can actually like keep getting, but this is actually like very complex.

Similarly, you can see the snake motion that is actually like sliding on the surface, but what the complex in the case? So, the complex is actually like legged locomotion which is you can bring a walking, running and jumping. So, these are actually like very very important when you talk about locomotion, but what we are focusing in this particular course?

It is nothing about this right, we are actually like talking about these all the locomotion, but we are going to talk about the artificial; you can say locomotion mechanism. What that mean? We are talking about the rolled motion.

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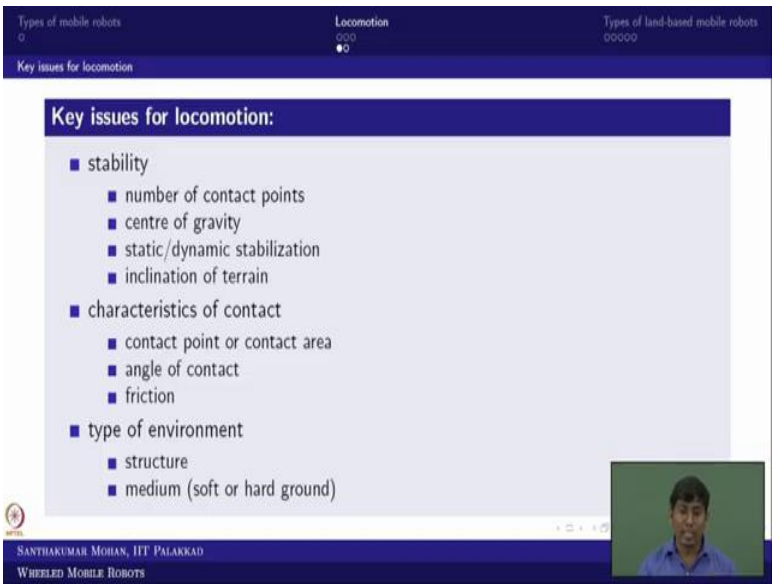

So, that is what we call the wheel. So, whenever you have a role; which is what we call wheel. So, before going to see their wheeled the locomotion in detail, I will just give a key issues I; as

I already said we need to understand and before that you should know what are the issues you need to talk. So, in that sense of one of the biggest aspect will come into locomotion is the stability.

You, if you talk about the stability there are two type of stability you need to talk; one is actually like at rest, in the sense there is no motion or constant motion execute; so that time, how the system is stable. So, this is nothing, but what you call static stability, but the static stability is not the important in all the cases of mobile robot. So, what the important thing? The dynamic stability.

So, now when you talk about the static and dynamic stability, what are the other character will come into picture? There is one which is nothing, but the center of gravity. So, the other one which we can talk about the zero moment point; so, these two are actually like making in one case where you are actually like having a surface contact. In the sense, so how many number of contacts? How that contact or nature of the contact?

So, in the sense you can see there is a number of contact points are very important. Very simple example I take a static stability, you see the static stability can be achieved with at least three point. For example, you take a stool with a three leg; now even you bend or you cut to one of the leg, probably a small portion; still you can see that the stool would be statically stable. Why? Because it actually like bend right, still it would be staying; when you take four; you can say leg stool.

So, now imagine it is actually like more than three; then what one can see if you have actually like cut it one small portion of one of the leg, what you can see? You can actually see that zigzag motion. Although, it is statically stable, but the motion is actually like execute. In the sense what one can see, so the minimum number of contact points required for statics table is three, but if you have more than you are to provide proper you call; you can say contact ensuring points.

In that sense, what one can see if you are making a three point contact. So, you have to see that where the center of gravity fall. So, if that is fall within the polygon which is connecting of these three contact points; so you are safe, so your static stability is there. So, similarly when you have a motion; again you are actually like putting your zero moment point where there is a moment which is zero. So, that point fall under within the polygon then also you are safe.

So, in the sense you have to actually like understand this. So, now, this understanding may go vary when the terrain is actually like inclined or bumpy. So, what then? So, you have to understand the stability is ensured or not. For example, now you have a ramp of probably like a 20 degree ramp, but you should know then based on your contact and friction. So, your friction is actually like sufficiently hold that 20 degree ramp; then you are safe.

So, that is what the stability is one of the critical point. So, now, you are actually like making a three point contact, but you are actually like length is keep extending. For example, you take a segway; the segway is actually like as a vertical pendulum, you can say inverted pendulum right. So, now, the inverted pendulum you are going to stand on the top of that segway. So, now it is actually getting some kind of you can say center of gravity variation; so, these all need to be understand.

So, further what we have to take further; the second thing the stability is ensured based on the characteristic of the contact. So, what that mean? The locomotion is not only depend on the stability, it is further depend on the characteristic of contact. So, how it is actually like making contact with the ground or wherever it is actually like maneuvering.

So, the characteristic is actually like talk about two things. So, one is actually like the friction; so the body which is actually like in contact two bodies whether it is ground and the wheel; so that friction is how it is ensured.

So, now this friction is not the only thing; so this is actually like ensured based on the contact region. So, whether it is a point contact or line contact or it is contacting in a area. So, for that you can take a example; you take a normal car, so the car tire would be having two things right one is radial base.

So, radial and base tire or you call radial tire and non radial tire right. If you take a radial tire, that is more generally used in the normal days. Why? The radial tire will actually make more contact area, it actually like flattened; it sit.

So, that is what we are actually like understanding; when you are talking about the wheeled locomotion or the legged locomotion, the characteristic is actually like important based on the friction and the contact point. Now, you take one simple aspect; now you are standing on the leg ok. So, now, you are standing on a barefoot, now imagine the next scenario; you are actually standing on a roller wheel. So, definitely the characteristic of contact is changing right.

You see although you are situation is same, but one case it is actually like on the barefoot, where the friction is ensured; where the other one is actually like rolling contact where the point contact. So, these are the cases; which is supposed to be addressed when you talk about the locomotion.

One more aspect definitely you need to know the type of environment; the environment is proper structured or it is actually like soft or hard or actually like it is something like semi. So, these all the medium and structure need to be addressed. So, if you know these things and you can actually like bring all the locomotion mechanism and then you can take which would be suitable for that particular task.

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So, that is what we are actually like addressing in the next slide. So, we are actually like bringing back the mobile robot locomotion. So, there are three locomotion mechanism we are bringing it. So what that mean? So, in order to produce the motion, we are actually like providing the forces and torque to the mobile base. So, how we are actually like applying?

There are several way, but we are taking the common approach which is executed in the mobile robot which is nothing, but wheeled locomotion or tracked locomotion or legged locomotion. Then one thing immediately will brought in our mind what that? So, what is the wheeled locomotion?

It is nothing, but a rolled navigation sorry; not navigation rolled locomotion right, whereas, a track that is also rolled, but it is something like more like sliding on one line longitudinal; slide slip or skid whereas, the leg is actually like it is a proper locomotion with naturally; nature inspired.

But the problem here is the point is actually which is hitting on the ground, the support reaction would be coming upward; whereas, that wheel or the track that would be can be generated in other way around, but here it would be always support reaction which is coming upward.

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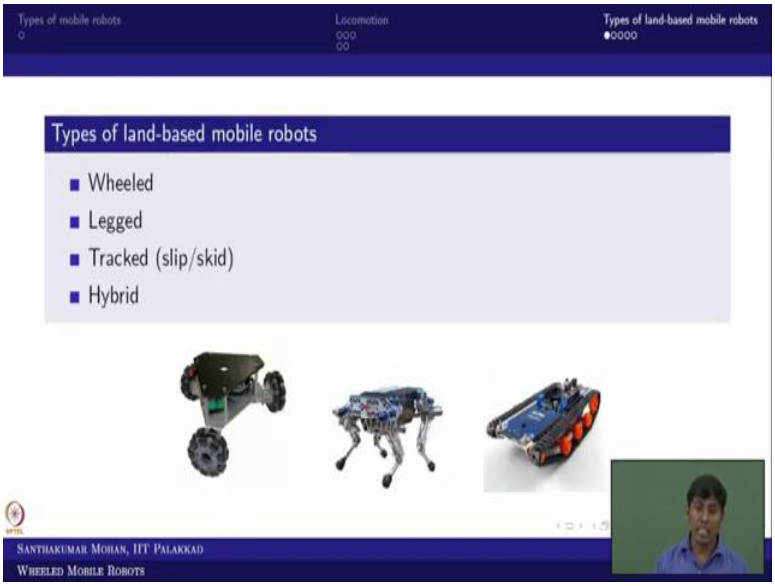

So, based on that what one can see; the land based mobile robot can be classified into three major way. So, one is based on the wheeled locomotion, the other one is legged locomotion, the third one is track which is I told a slip or skid, but some cases we may not use all three or we may use something like combined. So, in that sense what one can see the fourth classification we can bring it as special or hybrid.

So, very simple example when you have a field robot; the field robot when the surface is flat. What you can do? You can actually like make a rolled locomotion, in the sense wheel; so it go faster. But when it is actually like some kind of hurdles are there; for example, there are several obstacles, then you can actually like see that the wheel cannot topple or you can say wheel cannot actually like go on top of that obstacle.

Then, what you can do? You can actually like elevate and move on the leg. So, in the sense you can see like you can use a hybrid locomotion, but right now what we are going to address. So, what would be the benefit or what would be the challenge or what would be the limitation of these locomotion in a lighter way? Because this is not the core course on our you can say aspect. So, I will be talking about what are the benefit in the wheeled locomotion in few slides.

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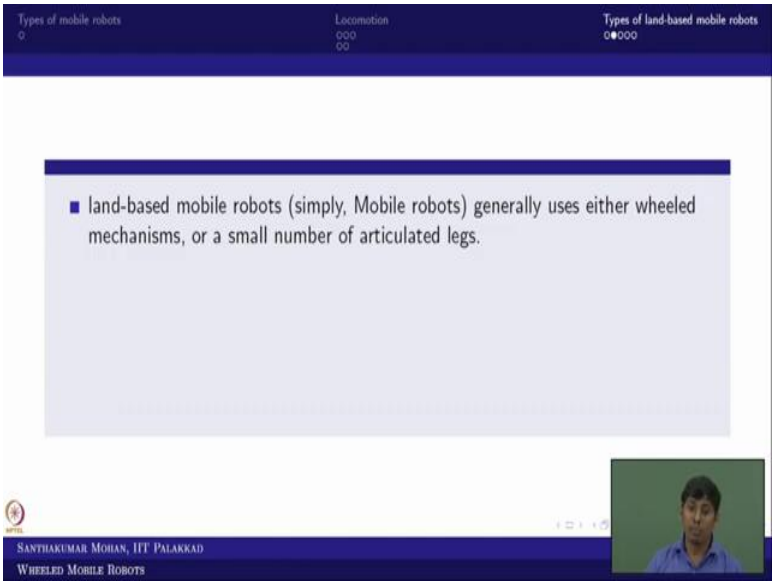

So, in the sense what we are talking about? So, wheeled mobile robot is our focus, but what we have classified? Land based mobile robot simply in most of the robotician; mobile robot mean that is nothing, but land base. They are have to specifically mentioned aerial robot, underwater robot or surface robot; otherwise mobile robot means land base. So, in this sense what we have to see?

You are you can see the nature and as well as you can see what the artificially we made. So, most of the artificial robots which are actually like wheeled or small part of you can say leg either two leg or four leg or six leg. What that mean?

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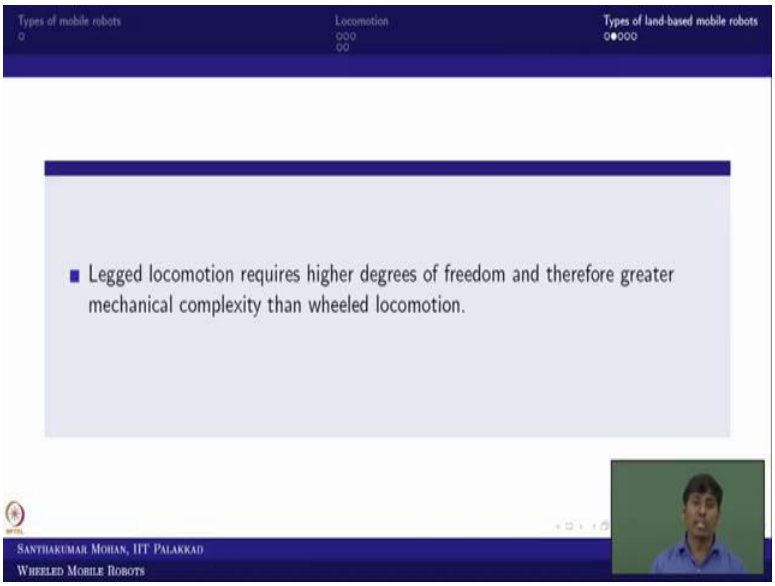

So, the legged locomotion is actually like one of the important aspect which is actually like very very you can say; you can say a challenging one, but what additionally benefit; it is actually like provide a higher degrees of freedom.

If it is anything higher; higher power consumption, higher expensive, but what you can actually like see that the mechanical complexity is higher, but it is actually like very good in terms of locomotion system. But what we are actually like seeing? We are seeing the cheapest, simplest thing; then the wheeled locomotion is one of the best.

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So, that is what I am putting; the wheels in addition to be being simple, what you can actually like make it? Most of the engineering environment, what you call the artificially we made. For example, this surface these are actual like flat right; you can actually like not required to have a leg. So, in that sense what we can actually like say that the wheeled locomotion is extremely suited for the real time engineered environment; that is what we are saying engineered environment.

Now, I am putting this wheeled robot on a; you can say forest, that is not right because the forest would be actually like terrain. So, there the legged locomotion may be benefit, but what we are saying that this is extremely suitable for the engineered environment.

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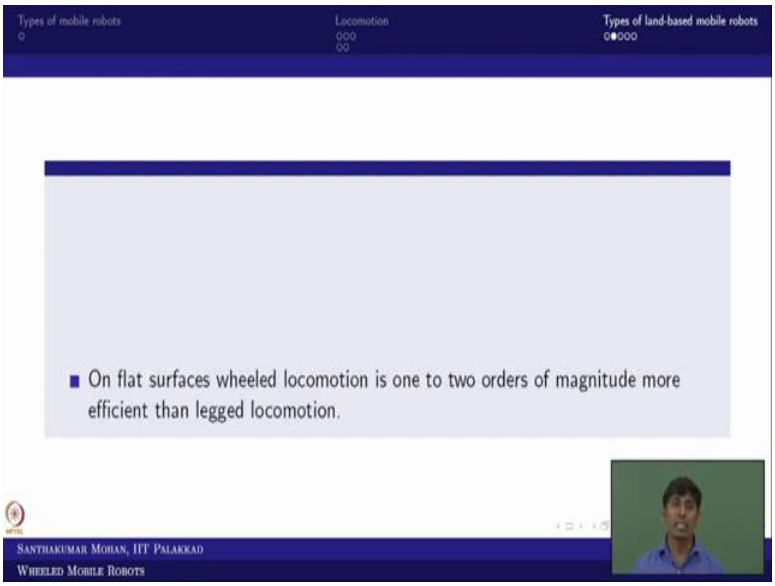

That is what I mean to say. So, in the sense of what one can see on the flat surface; the wheeled locomotion is one of the best or you can see only the best also you can say. Why? It is actually like having two or three order of magnitudes which is actually more efficient than the other two locomotion; one is legged, the other one is you call the tracked one.

Even the tracked can be actually like brought in, but the compared to legged locomotion; the wheeled locomotion is at least two to three times are actually like higher in magnitude order ok.

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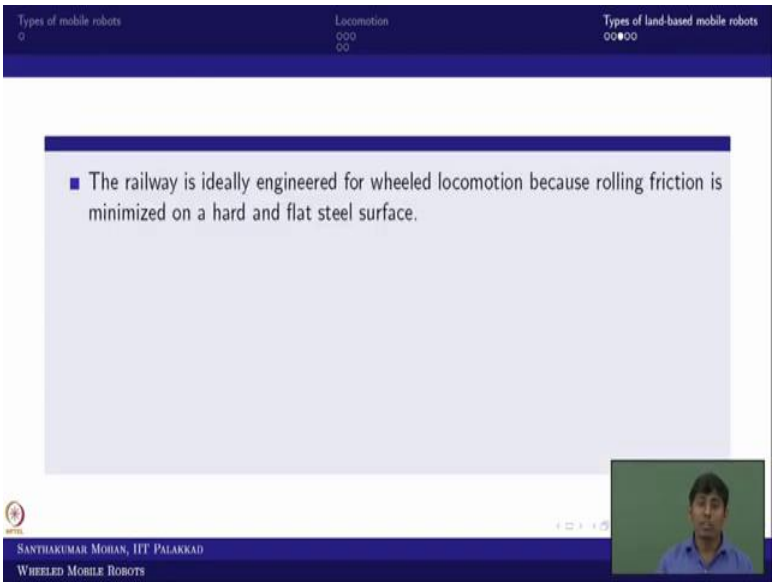

So, then what one can see? So, then why there is a railway or you would have seen in western countries or you can say developed countries; on the peak hours they would be running the tram rather than the buses. Do you know why? So, there is one important aspect in the locomotion. You know the railway is ideally engineered. What that mean?

The rolling friction is less and what you can actually like make it because of the flat and hard surface; so you will actually like get more benefit on the power which we provide. So, now, you take a two buses and wheeled locomotion and instead of that one tram, that one tram would take a lesser energy to commute these people. More than that what one can see the track what you can make it that would actually like guide and it give actually like very good you can say locomotion execution.

That is what we are actually like doing it; that is why we are actually like intend to do, you can say more on railway rather than you can see the wheeled locomotion; you can get now idea right.

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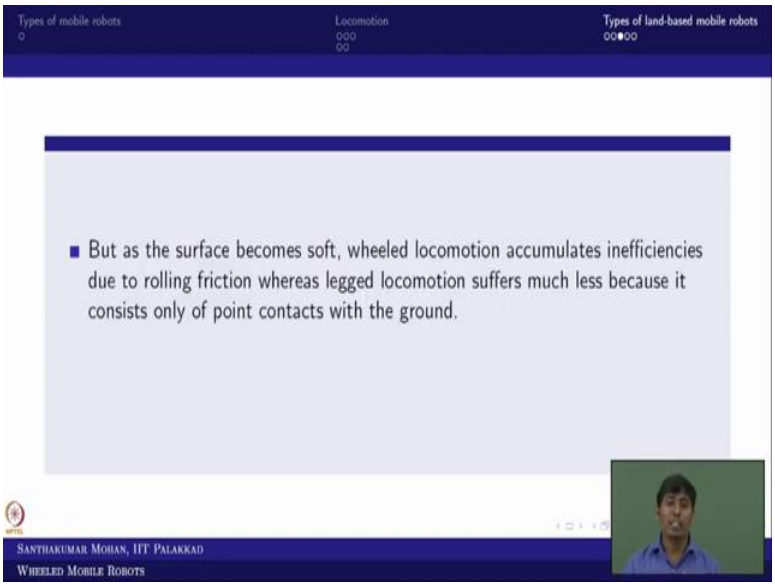

So, now you can see that if the surfaces are actually like become soft; what would be happening? The wheeled locomotion would not generate the enough traction force; in the sense the effect of the effect on the environment would not be sufficient. So, then what it can accumulate?

Accumulate insufficient, you can say traction force it cannot execute; that is what you would have seen. When you are actually like executing the same wheel, when it is a hard ground for example, you take a tar road or cemented road that may be going good.

Now, imagine the cemented road is a having probably a mud which is actually like some kind of semi solid. So, now you can see that it would be start slipping; in the sense what happened, the surfaces actually become soft; although the support in the big end is there, but the layer which is actually like hitting on the wheel, that is actually like soft. So, in the sense what happened? The traction is insufficient in the sense you can actually like make that the rolling is not really happening.

So, then what we can see? We can actually like make the legged locomotion; there it would be actually like hinge and then go. There even the soft surface would actually like taken forward that is what we are actually like trying to make a point here.

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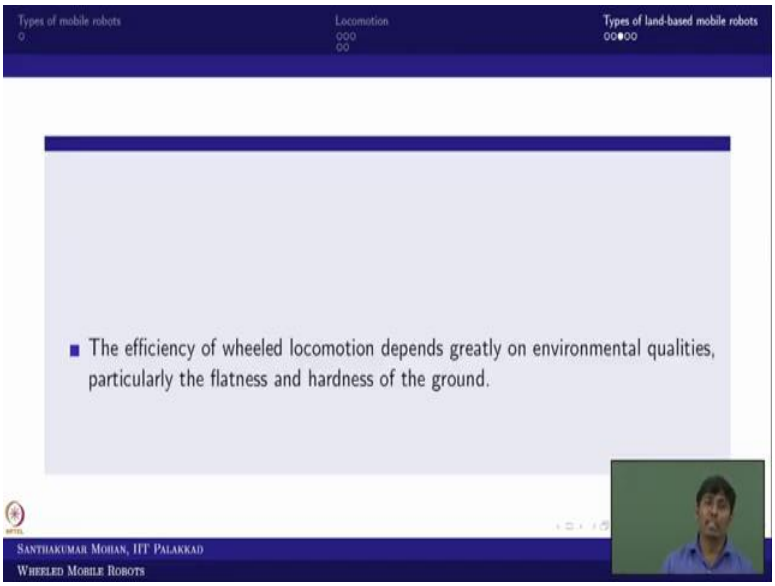

But further, what we can actually like see that the efficiency talking. So, when we talk about the efficiency; the wheeled locomotion is definitely good, but what it actually like making, it is depend on the several factors. One of the important factor already we discussed; the environment right whether it is soft or medium or you can say hard.

So, in the sense the efficiency is actually like purely depend on one of the primary factor; the environmental quality. So, whether it is a flat or hard and as well as it is actually like not having a ramp or bump; so that all we need to think.

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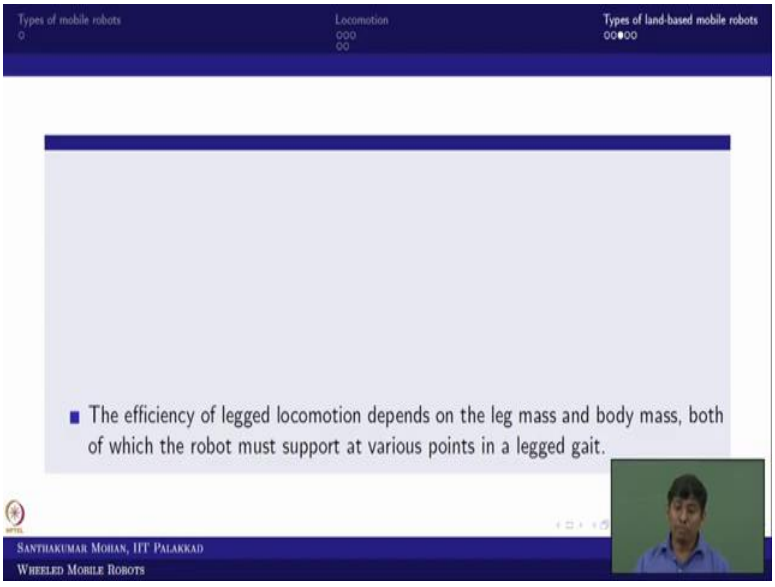

So, then what we can actually see the other way around; the efficiency of the legged locomotion is actually like depend on one of the important factor what your body all about. In the sense, what you can see the mass of the body and mass of the leg. So, both are actually like important that is supposed to support on the points which are making the contact on the ground.

So, for example, this is your foot; this foot would be actually like I make it as a single point contact, this is the point which is actually like making the support reaction. This support reaction supposed to hold it; for example, now I am standing in one leg; so, the one leg would be actually like giving all the support reaction. So, in this sense your leg mass and body mass supposed to be; you can say optimally designed for that particular case.

Now, I am actually standing on one leg, but there is a; you can say larger flat, you can say body given on top of my head; now I may not be able to stand on a stable location. So, that is what we are actually like talking about here.

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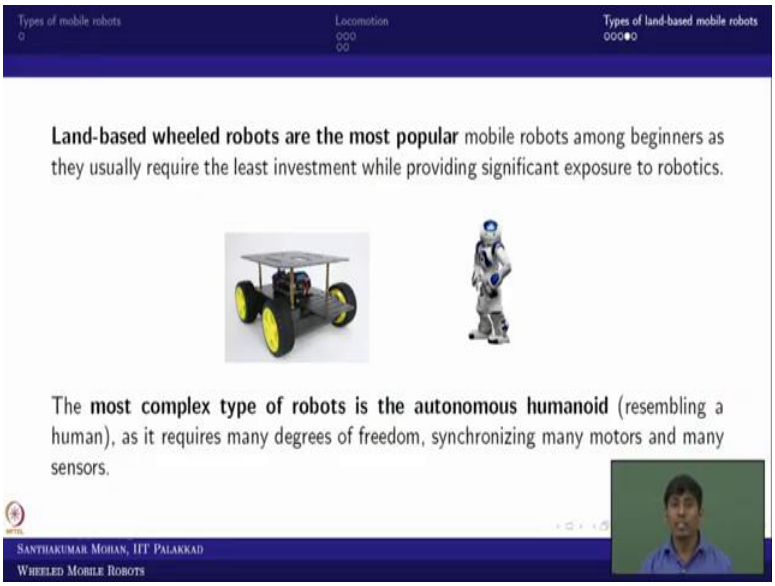

So, then one can easily bring it; so land base means what is the popular, you can say type of robot? Nothing, but wheeled why it is? So, one of the easiest is cheap, simplest; further thing is easily you can actually like understand the overall picture. For example, if I have a wheeled locomotion; I can predict what would be the motion more or less closer to the actual.

But if it is a legged locomotion, it is not at all happening. Why? There is actually like complexity coming into a picture. Further, the wheeled locomotion is easiest to you can say

bring it to the beginners; that is what we are bringing it. The most complex type in the land base is nothing, but humanoid that to autonomous; why it is so? There are several, you can see degrees of freedom what you call even there is a 40, 50 motors.

But the depending on only two supports which are on the foot; in the sense you take one stick and put it on your hand and you try to stable it. How difficult it is; you have to actually like keep on moving. Now, imagine I am actually like putting that stick with a flat surface which is a larger base; then you can actually like have it. So, that is what you can see the old and humanoid and all, you can see that the foot would be very very broad with foot.

But nowadays, we are actually like going further and further, we are trying to minimize that. So, in the sense what you have to think? So, you have to actually like see the complexity is coming in the legged locomotion; that is what the idea behind here.

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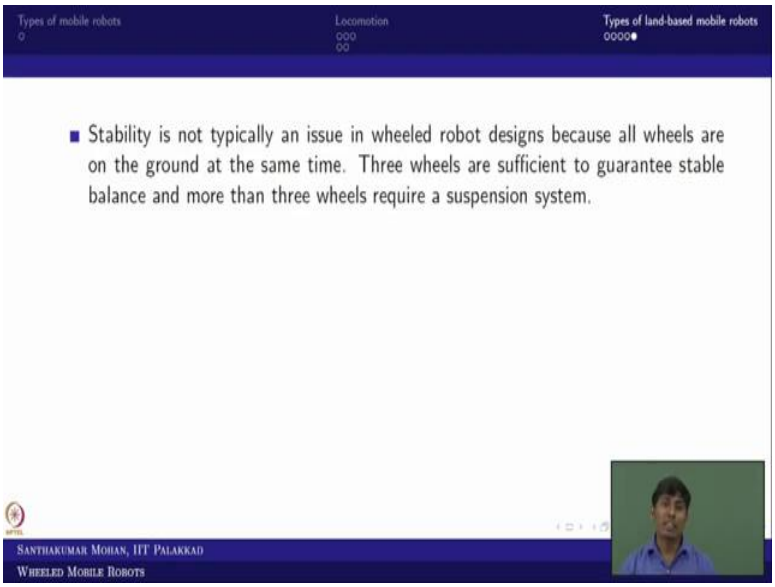

So, now in that sense; so as we told already there are several points right. When we talk about the locomotion, there are three key issues; one is stability. So, if we talk about stability; this is not at all an issue in a wheeled locomotion, as long there are three or more wheels. If you have more than three, then you have to provide a proper suspension, but if it is actually like three or you can say more; definitely the stability can be ensured.

If it is only one wheel or two wheel, then you have to make sure that the stability is actually like ensured; otherwise you can actually like make it easiest; so, that is what given in this.

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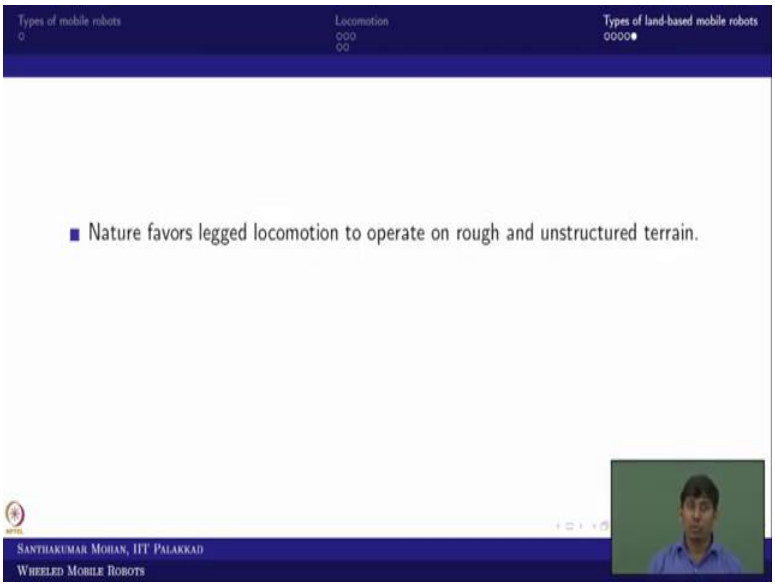

The second thing is you know already like nature favors legged locomotion, we all actually like nature inspired we have a legged or animal it is all based on legged. Why it is so? It can be actually like fitted into any unstructured terrain, but as I already told we are engineered environment right which are actually like flat, in that sense we can definitely go with what you call wheeled locomotion that is what we can actually like talk about.

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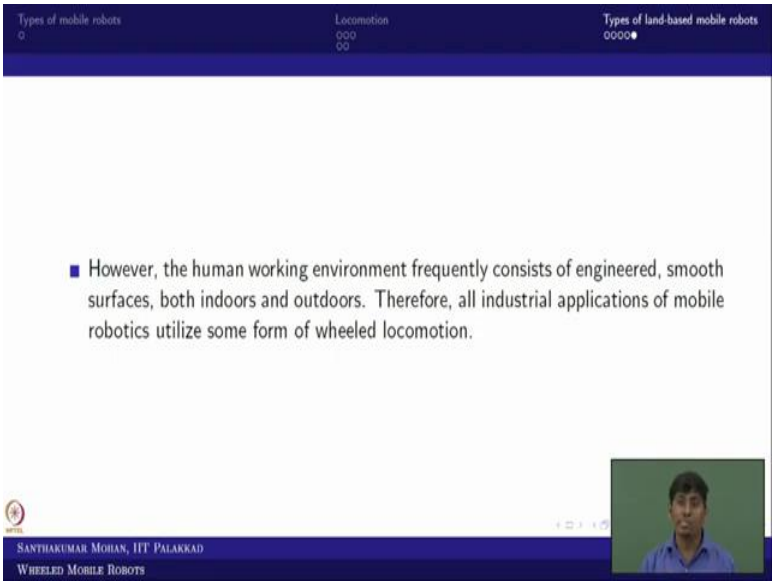

In the sense, all the industrial application would be you can say preferred to have wheeled or track.

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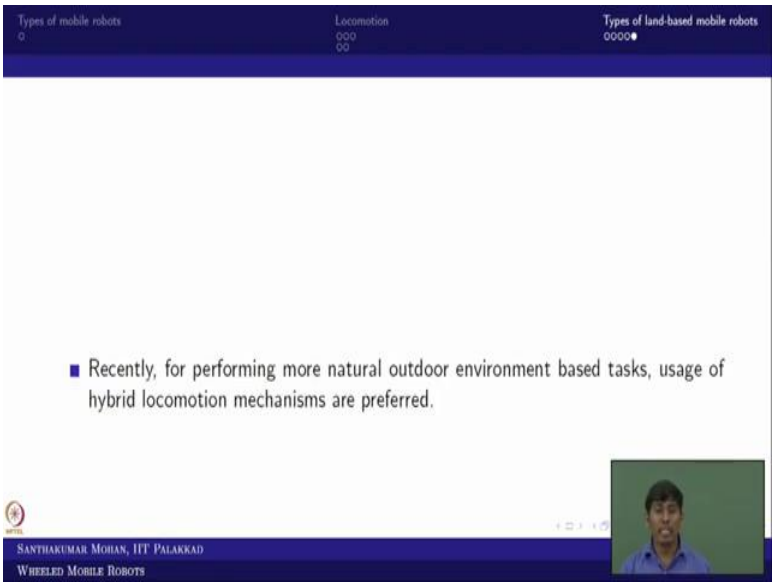

So, in the sense what one can see; the recently performing in the case natural outdoor environment, we are actually looking as I already told earlier. So, we are trying to bring the hybrid; so wherever the surface is flat, you apply on the wheeled locomotion, wherever there is a rough terrain comes; you apply the legged or similarly wherever there is a friction more required, you can apply a track and then you can elevate to a leg. Like that you can actually like have a combined in the sense hybrid locomotion.

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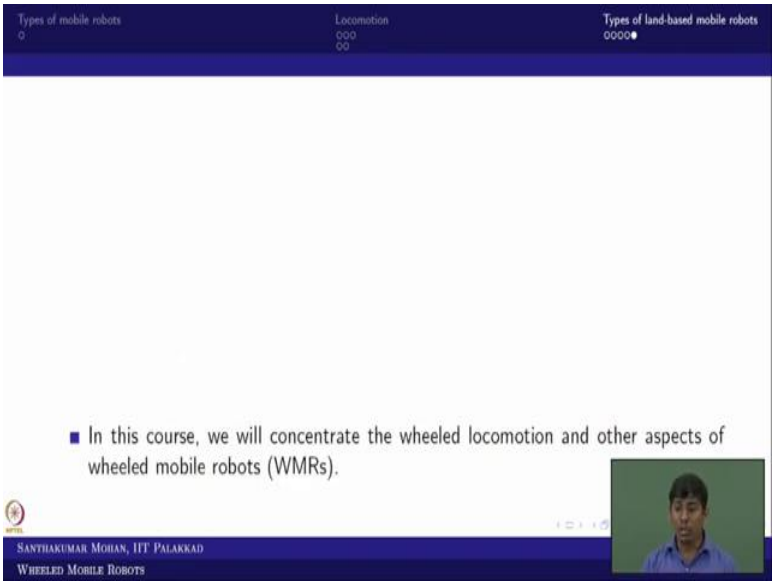

But as I already told, this particular course is actually like going to concentrate mainly on wheeled locomotion. So, that is what we are actually like going to talk and lots of other aspects on the wheeled mobile robot we are going to concentrate. And at you can see the wheeled mobile robot; what one can see, what would be the types of wheel and how these types are actually like playing a major role on the wheeled the configuration; these all need to be look at it.

So, that is what the next two lectures would be talking about; the kinematic aspect of the mobile base and the types of wheel of the wheeled mobile robot; so, these are going to talk. So, the next class we will start with the kinematics of land based mobile robot; in the sense it is a planner system.

So, we will talk about what is robot kinematics, what is mobile robot kinematics and then we will actually like address; so how we can actually like make input command to the you can say execution part, in the sense study of motion. So, with that we are ending with the lecture 2 and we will see lecture 3 with the kinematics and we will go more and more aspect of wheeled mobile robot on the go.

Thank you, see you then bye.