Wheeled Mobile Robots

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Lecture – 04
Degree of Maneuverability and Types of Wheels

Welcome back to the course on Wheeled Mobile Robot. So, this is lecture 4. So, last class itself we were talking about what would be handle in today. So, this is basically Degree of Maneuverability and Types of Wheels and last class what we have seen basically the mobile robot kinematics.

So, basically what we have seen there is actually just a mapping between you can say the velocity input commands and the time derivative of generalized coordinates time derivatives of generalized coordinate this is what we have seen. Even then we have seen there are two classifications. So, one is forward differential kinematics, the other one is inverse differential kinematics

And this particular lecture would be talking about how we include the wheel configuration, how that would be actually like making address. So, in the sense last class we have seen degree of freedom so, but here we would be seeing degree of maneuverability and then this degree of maneuverability is depend on the type of wheel. So, this particular lecture would be talking about types of wheel.

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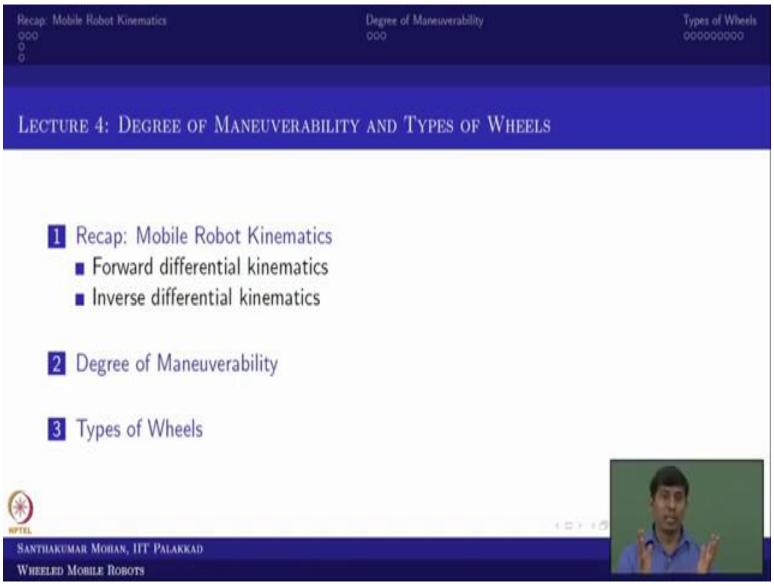

So, that is what we are actually like trying to see. So, you can see that the lecture 4 would be addressing several factor. So, one would be like just recapping what we have seen in the last lecture; then we would be going more on degree of maneuverability, types of wheel and some examples of we you can say land based mobile robot, how to find degree of maneuverability, these are the things we are trying to cover

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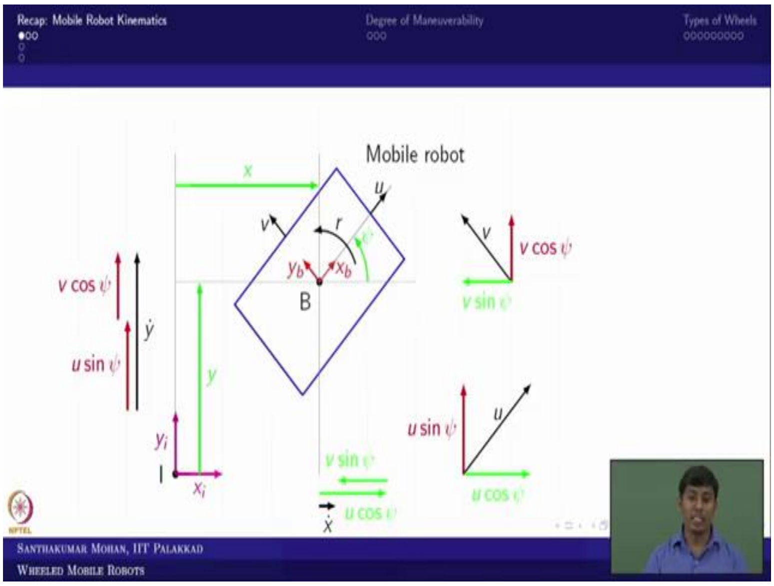

Let us actually like see what we have seen. So, the blue color box here what we have shown. So, this blue color box what we have shown this is what we assume as a mobile robot which is nothing, but a land based mobile robot. So, this would be actually like represented with the point B. So, this point B actually like can be represented with the fixed point I. So, that would be represent as a generalized coordinate called $\begin{bmatrix} x \\ y \\ \Psi \end{bmatrix}$.

But, these generalized coordinates are actually like dependent on the you can say the input command which we call velocity input command which we simply called body fixed velocity at instantaneous time. So, in the sense $\begin{bmatrix} u \\ v \\ r \end{bmatrix}$ are the dependent the sense these are actually like the cause of motion for this particular motion.

So, now, based on this we have actually like derive the relationship where we cannot actually like bring down this $\begin{bmatrix} u \\ v \\ r \end{bmatrix}$ into a you can say position domain. So, instead of that what we brought in. So, we have actually like elevated these x into $\dot{x}$ y into $\dot{y}$ and Ψ into $\dot{\Psi}$. So, this relationship we obtained here. So, where $\dot{x}$ I can write as u cos psi minus vsin(Ψ) where the $\dot{y}$ I can write as usin(Ψ) + vcos(Ψ) and we know already r is nothing, but $\dot{\Psi}$.

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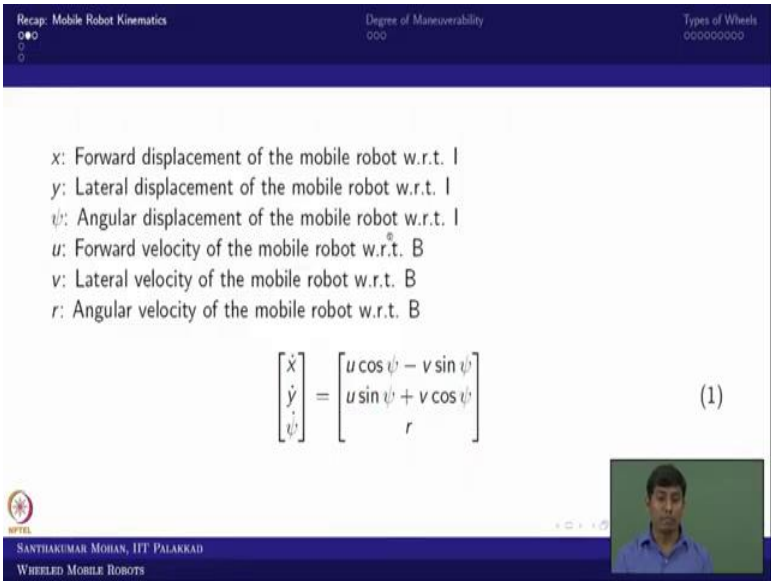

So, these are the relationship we obtained in the vector form.

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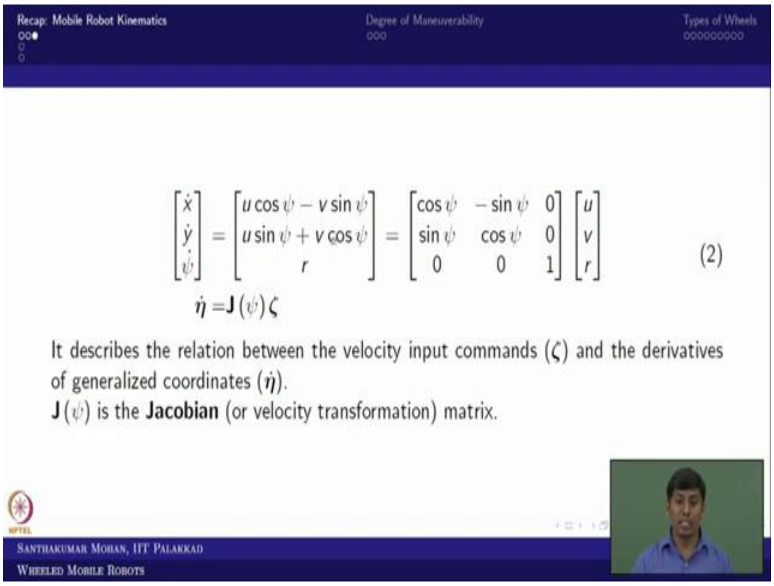

So, now this is actually like further what we did, we did as a matrix and vector form. So, this is what we are going to call as a you can say kinematic relationship. Here we are talking about differential kinematics. So, this particular relationship what we call mobile robot differential kinematics.

So, where ξ is actually like nothing, but a vector which called you can see velocity input command that would be vector of $\begin{bmatrix}u\\ v\\ r\end{bmatrix}$ and η is actually like a vector of $\begin{bmatrix}x\\ y\\ \Psi\end{bmatrix}$. So, here we are talking about z $\dot{\eta}$ which is nothing, but $\begin{bmatrix}\dot{x}\\ \dot{y}\\ \dot{\Psi}\end{bmatrix}$ that we are calling as the you can say vector of derivative of generalized coordinate.

So, now this relationship we obtained and this relationship is mapping with one particular velocity transformation matrix we call Jacobian. So, now, even some people call kinematic transformation matrix, but here it is actually like velocity transformation which is we generally call Jacobian. So, this Jacobian is actually like going to help.

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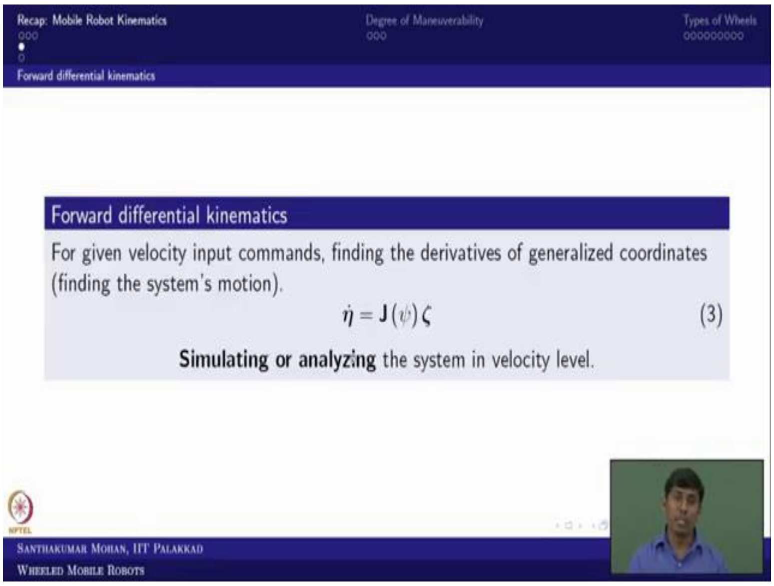

So, based on the Jacobian availability what one can see that if I know ξ I can find out the $\dot{\eta}$ this is nothing but simulating.

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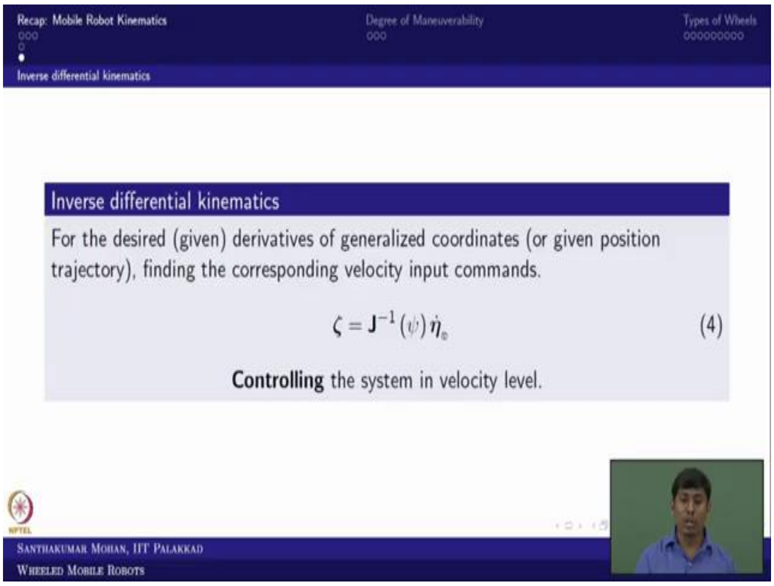

And whereas, the $\dot{\eta}$ is given in the sense the given position trajectory is given how to actually like find for the corresponding velocity input command; that is what we call ξ which is nothing, but inverse differential kinematics which is straight away we simply told about as a controlling the system in velocity level, these all we have seen.

So, now what we are trying to see, this ξ can be written in the form of you call input velocities; so, in the sense wheel input velocities. So, wheel usually connected with what you call the rotary motor. So, in the sense the ξ can be written in the form of angular velocity of all the wheel.

So, now, we are bringing another transformation where ξ can be written in the form of ω which I am calling ω is vector of angular velocity that is what we are trying to find out.

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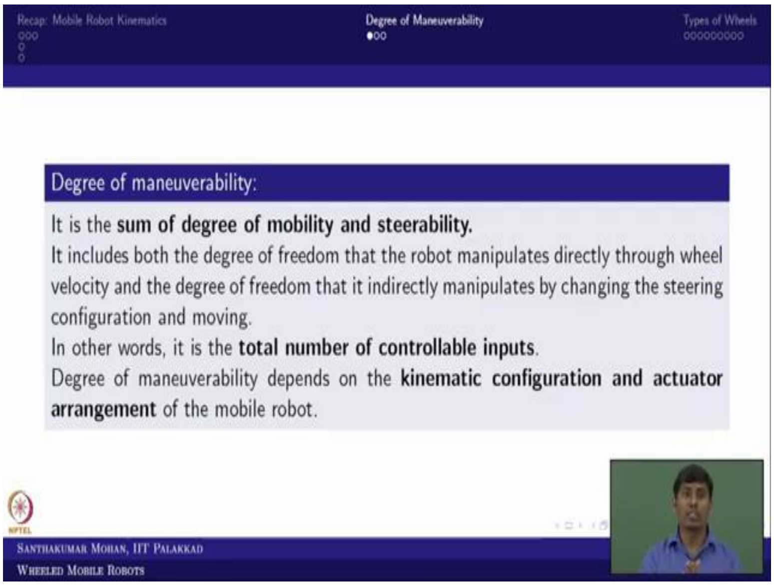

So, why that is required? Because that, is actually like defining based on the one another key word called degree of maneuverability. You see you know the system which is we call land based mobile robot the degree of freedom is fixed, because that is actually like moving on the plane where two translation and one orientation is actually like supposed to be required to describe the position or you can say the system.

Whereas the degree of maneuverability is actually like coming in the way of how the wheel are arranged in the sense so which are the wheel or power. So, in the sense the degree of maneuverability is straight forward you can see the number of controllable input, but that we are actually like talking in the general perspective, in the sense you can see that the system would be having some of you can say mobility and steerability that is what we call degree of maneuverability.

So, in the sense you take a car, the car would be actually like front wheel drive where the front axle is actually like a power driven and as well as the front axle is actually like steerable.

In the sense the car has although the degree of freedom of the car described is three, but what you can see that the number of controllable input is actually like one translation which you call the mobility which is actually like providing the traction on the wheel, the other one is actually like what you call steerability where the steering is providing that action.

So, in the sense the degree of maneuverability is nothing but sum of degree of mobility and steerability. So, what is degree of mobility? So, which is actually like what you can see the robot which is actually like maneuver directly through the wheel velocity. For example, now I take one box I put a one wheel and connect with a motor now you can see that what is happening. So, this this box is actually like maneuvering this box is actually like maneuvering directly because of the wheel action.

So, in the sense this relaxant is actually like directly providing the mobility of this particular box, in the sense what one can see this is actually like providing the mobility because directly you are actually getting the motion whereas, now you imagine; now imagine. So, you have actually like a steering the steering is connected with the wheel that wheel is actually like having already motor imagine.

So, now you are actually like steering that wheel what happened you are actually like indirectly maneuvering your wheel velocity into two different direction. So, earlier it was fixed on the longitudinal direction, but now because of the steering what happened this is indirectly getting two sub components. So, in the sense you are maneuvering that is what we call the indirect maneuvering or manipulating that is what you call degree of steerability.

Whereas, directly through the wheel velocity the manipulation or the maneuver of the system is actually getting that is what you call degree of mobility. Now you got a clarity, what is degree of mobility and steerability. So, now, you combine these two in the sense sum of these two that is what giving the degree of maneuverability.

So, now what that mean? Very straightforward, you can say this is just nothing, but the total number of controllable inputs. So, in the sense you have actually like two wheel drive system. So, in the sense you can see the degree of maneuverability is two, now you have three wheel, but only two are powered.

So, in the sense you can see that only two are actually like degree of maneuverability that is what we are trying to see. So, we will see little more examples with this degree of maneuverability. So, before that we will actually like see what actually like change or what actually like make this degree of maneuverability.

So, this degree of maneuverability is purely depend on the how you have arranging your actuator or how you are fixing your wheel that is nothing, but kinematic configuration and actuator arrangement of the mobile robot is actually like making the degree of maneuverability ok. So, that is what we are actually like trying to see so that is what more clarity.

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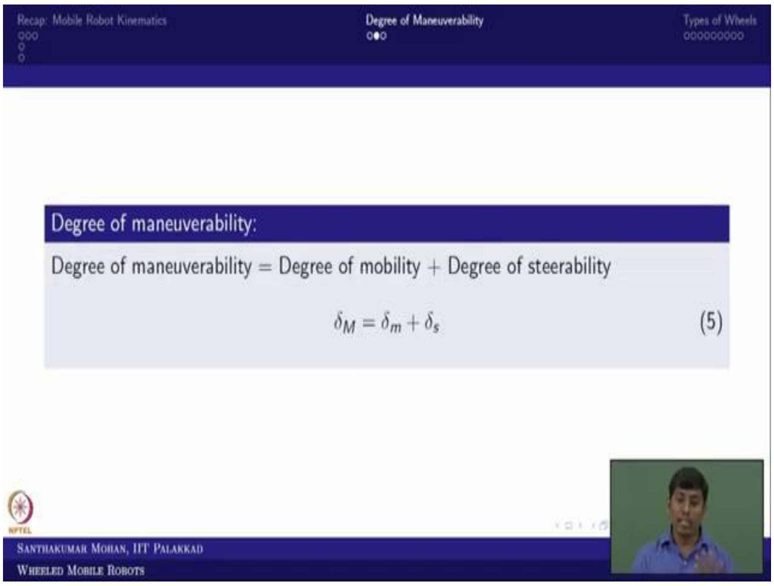

Again, I am actually like reiterating that the degree of maneuverability I am writing as a δ_M that is nothing, but sum of degree of mobility which is I am writing in a δ_m and degree of steerability I am writing into a small you can say δ_s. So, now, this is what the relation, we will use this relation for more example, but right now we will actually like go little forward.

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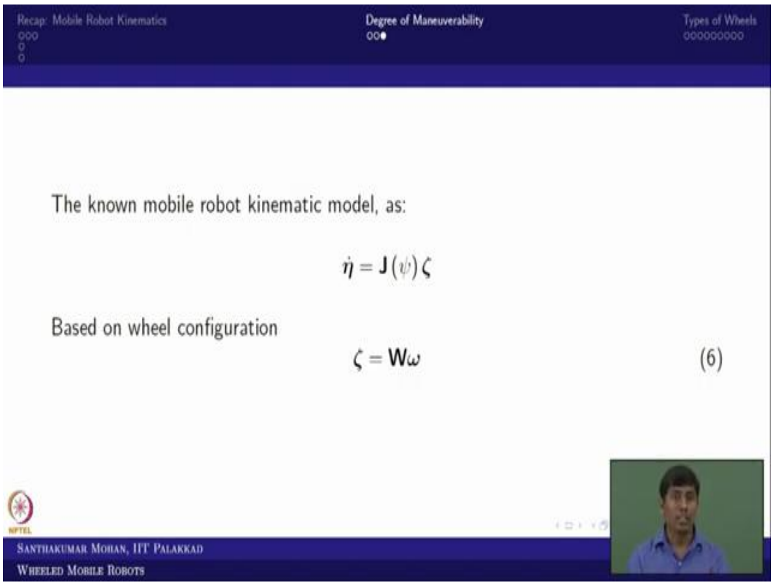

So, what little forward? So, we know the mobile robot kinematic model which is what nothing, but the differential kinematics where eta dot you can write as $J(\Psi)\times\xi$, but what I have said?

This ξ is actually like although input velocity commands, but that is actually like depend on the angular velocities. So, now, what we are trying to bring out based on the wheel configuration we are bringing out the $\xi = W \times \omega$, the ω is vector of angular velocity and the W is nothing, but your input configuration matrix.

So, now based on this input configuration matrix one can define whether all the three states are achievable or not, but right now that is not our focus for this particular lecture, this particular lecture is actually like focusing about the ω. So, how this ω vector can be incorporate? So, for that what we need to bring out? So, we have to bring out the type of wheel then only you can talk about the wheel configuration.

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So, for that what we are going to bring? The next subsection we are going to talk about types of wheel although this would be talking about in single slide, but we are actually like seeing about all the possible wheels here.

So, generally the wheel would be broadly into two case, one is the wheel would be a solid or the solid wheel would be having some kind of inflation in the sense a pneumatic tire. So, where there is a one which is nothing, but a wheel; so, the other one is wheel with something like a tire. So, now, that is what we call inflated wheel the other one is what we call solid wheel.

So, in the sense that types of wheel broadly into two, one is solid wheel, the other one is inflated wheel whereas, the inflated wheel can be easily characterized or easily we can study the inflated wheel configuration with one of the sub classification of solid wheel. So, that is why we are not going to focus the inflated wheel in this particular lecture or in this particular course, we are going to talk about generally solid wheel.

So, what that mean? The solid wheel would be having two classification; one is conventional wheel so the other one is non-conventional wheel, even the conventional wheel would be having two sub classification. So, the two pictures which I put it in the slide would be addressing those, but what is conventional wheel that I need to address now.

So, the conventional wheel what theoretically speaking. So, it is pure rolling. So, what that mean? It would not have any lateral slip and there would not be any longitudinal slip. So, the pure rolling can be described or characterize or understand with the help of simple what you call the motion of the wheel. So, for example, you take one of the wheel and you rotate 360° rotation or 360° rotate. So, what one can see.

So, it would be actually like cover the distance of you can say $2\pi r$, where r is the radius of the wheel or you can take the d is the diameter of the wheel. So, πd supposed to be traveled. So, what that indicates the wheel did not have a longitudinal slip or lateral slip. So, that is what the conventional wheel all about. So, conventional wheel means pure rolling. So, pure rolling means there would be infinite resistance in the lateral direction what that mean.

So, infinite resistance in theoretical speed for example, you take a car and you push even the car is in neutral you push in lateral direction will you able to do it? No. So, what that mean? So, there is a infinite resistance is actually like happening on the lateral direction whereas, now the car is in the neutral, but you are pushing behind the car in the sense along the wheel direction what you can see? So, that would be start rolling in the sense there is no resistant in the longitudinal direction this is what the conventional wheel.

So, now, in that case there are two possibility can come. So, what that mean? The wheel hub access is fixed. So, that is what we call fixed wheel ok. So, I will come back to the non conventional now we will talk about this. So, where the wheel hub backs is actually fixed it cannot be rotate about the vertical axis.

So, whereas, the other one you can see that the other wheel it is actually like steel conventional, but you can see that that wheel hub axis can be rotatable with respect to vertical axis. So, this is what we call orientable or steerable wheel, the other one is fixed wheel.

Now, what would be the conventional to non - conventional difference? So, you know the conventional means it is a pure rolling, there is no lateral slip infinite resistant offered in the lateral direction now you want lateral direction motion. So, then what one can see you take the fixed wheel and put the passive roller on the bottom imagine you take a wheel or imagine.

So, when you are having actually like a foot mat the foot mat is actually like rigidly formed when you put your leg so, you will not fall. Now imagine the foot mat is actually like on the bottom some kids are actually like playing with you. So, he put a several marble in the sense the balls. So, and you do not know you put your leg what happened it starts slipping right.

The same scenario you take a fixed wheel and put a passive roller on the bottom ok. The passive roller can be a small ball or just a passive roller like you take a chalk and put on actually like on a you can say a rectangular box as a duster. Now you actually push the duster what happened it would not move on the longitudinal because of this inclination it may go lateral also right.

So, now that is what we are actually like bringing into a non - conventional wheel, where you can actually like see the sub classification of the solid wheel, one is conventional the other one is non-conventional. Now the non-conventional wheel brought by one of the you can say you can say swiss company we call Swedish wheel that is why, but there is no clear cut definition this is actually like Swedish wheel because of the swiss into a picture, but what one can see that there are actually like wheels will come with the passive rollers. So, that is what we are important.

So, now the passive roller direction of you can say axis. So, now, the passive roller direction is actually like you can see the passive roller which is marked here is actually black. So, this black wheel is actually like you can see the hub is actually like here and the black wheel longitudinal axis is actually like perpendicular right. So, although it is not intersecting, but it is actually like perpendicular.

So, now, in this case what you can see the wheel hub is actually like generated the traction so that time the wheel will go longitudinal direction. Whereas, even you push in the lateral direction what you can see, this passive roller will roll in that sense the wheel will not rotate only the passive roller will rotate it go in the longitudinal to lateral direction.

So, in the sense what one can see, this is providing the you can say least resistance on the lateral direction. It is contradict to the conventional wheel, conventional wheel would be having infinite resistance to the lateral direction here least resistant in the sense it is allowing the slip. So, that is why it is called non-conventional.

So, now this you call the roller is actually like perpendicular to the wheel hub axis then it is called omnidirectional wheel. So, whereas, the passive roller is inclined towards your hub axis wheel hub axis for example, in this case the passive roller is actually like inclined right. So, this is what we call Mecanum wheel.

So, this is what we are actually like talk about this very detail. The fixed wheel means it is fixed it is just to rotate it about that fixed axis; whereas, the steerable or rotatable mean. So, this would be rotating with respect to that axis on top of that that would be steerable in the sense the wheel axis would be same, but the direction can be changed.

So, that is the difference between a fixed and rotatable wheel. The rotatable wheel in general we call caster, but the caster can be as simple you call balls caster which is nothing, but a spherical wheel I would not be talking about the spherical wheel here because the spherical wheel can be brought into a steerable wheel that is why we did not.

So, now we come to the other case the omnidirectional wheel means the passive roller would be perpendicular to the hub axis. So, now, this would provide least resistance in the lateral direction, but wheel how it is actually like rotate that would be moving on only longitudinal direction whenever there is a resistance or some force on the lateral direction it can slide that is the difference.

Whereas the Mecanum wheel it is not that way, what happened? When you hit on the ground this passive roller also will take some energy in the sense if you imagine the only you have a Mecanum wheel and all Mecanum wheel are actually like having only one directional inclination then the vehicle will start moving in the lateral direction. So, that is what we call Mecanum wheel you know now the difference between Omni and Mecanum.

So, both are actually like going to provide lateral resistant least in the sense it allows lip to lateral, but one would be actually like taking the wheel hub in the sense the power would be used only longitudinal direction; whereas, the Mecanum wheel would be using both you can say in that sense you will get both x axis velocity and y axis velocity for Mecanum wheel; whereas, in the Omni directional it would not happen that way that is the basic difference right.

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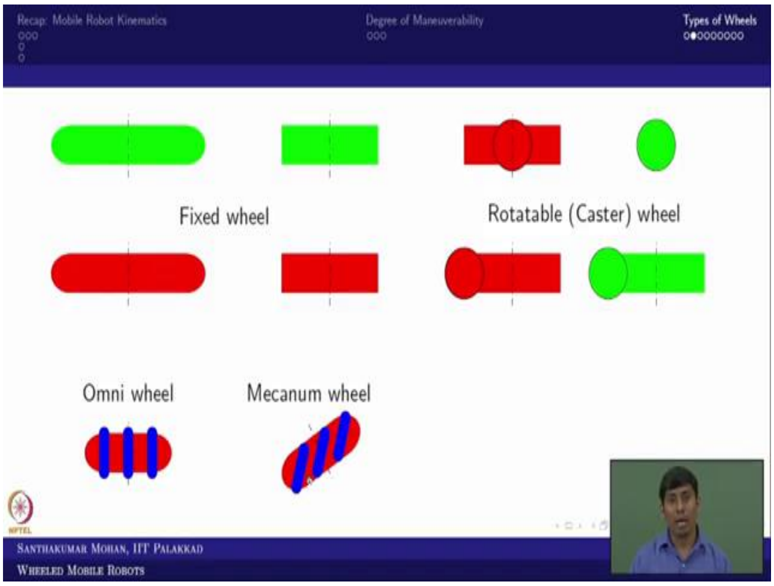

So, now we will move to the cases. So, what we want to do it? So, definitely this particular course will go long way. So, we need to see how we represent the wheels right. So, for that I am just giving this particular picture. So, if it is a fixed wheel, so the wheel can be actually like a small you call ellipt or you can say rounded rectangle or it is a simple rectangle then you can imagine that is actually like fixed.

So, mostly I will be using actually like what you call you can say green and red color. So, what that mean? So, green means there is no power actuated in the sense it is a simple passive wheel it is just connected to the particular shaft, but if it I put a red color then it is nothing, but a powered wheel, powered in the sense that would be connected with actuator rotary actuator or motor that would be energized.

So, now in that sense you can see that the rotatable also there. So, the rotatable will be having a fixed, but that would be having one vertical axis rotation that is what we are actually like showing here you can see. So, there is one vertical rotation I am showing as this way and if it is actually like a simple ball that is what we call ball caster that I represented here.

So, now, you can see that here also I gave a sub classification. So, these two are powered wheel and this is actually like non power. If anything I draw green that is a passive wheel if anything I draw a red color that you can imagine that that is powered.

So, now you can see that the Omni directional people usually they simply they call as Omni wheel. So, the Omni wheel you can see that this is the passive roller you can say axis. So, now, you can see that this small you can see the small you can say line that is actually like indicate the wheel hub which is the red color is the wheel hub that axis and the another small stud which is coming as the passive roller direction.

So, now you can see that these two are perpendicular. So, imagine this is actually like rotating about this axis and this is rotating about this axis; this is what the representation here after I would be putting in the you call in my lecture. So, in the sense this is omni wheel and the roller is actually like inclined towards the plane or towards the wheel hub axis that is what you call Mecanum wheel. Now you got a clarity right; so, how I would be representing.

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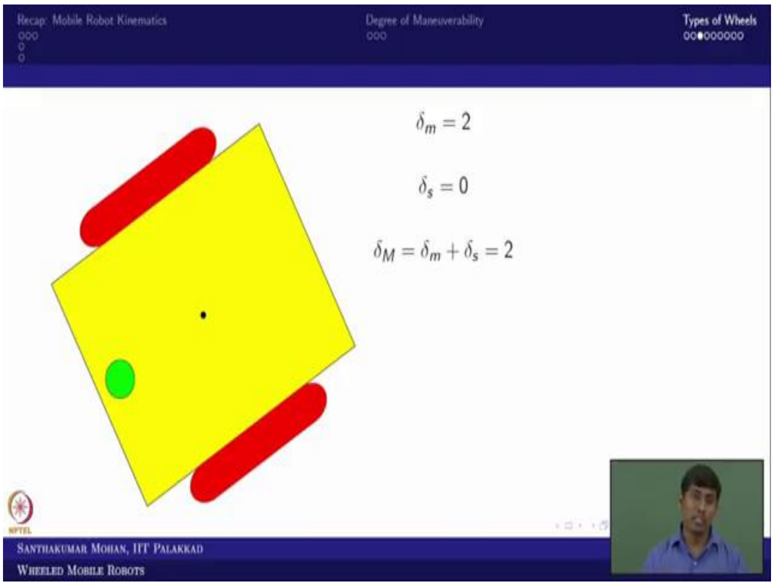

So, now, we will move forward. So, there is some other way also represent that we will see, but right now you can see that this is one of the mobile robot. I will not talk about what the type of mobile robot here, imagine this mobile robot is having one ball caster in the rear and two you can see that two red fixed wheels are there.

So, now if you talk about degree of maneuverability what would be that? So, it is sum of degree of mobility and steerability, but here by looking itself you can see that there is no active power for steering right. So, then what you can see these two are actually like powered which is providing the mobility. So, in the sense what one can see? The degree of mobility is 2, what would be the steerability?

Here 0, in the sense the degree of maneuverability would be 2 + 0 which is nothing, but 2. Now, you got a clarity right. So, now, the degree of maneuverability you can able to understand.

We will see few more example and then I make sure that you are actually like comfortable in this you can say identifying the degree of maneuverability.

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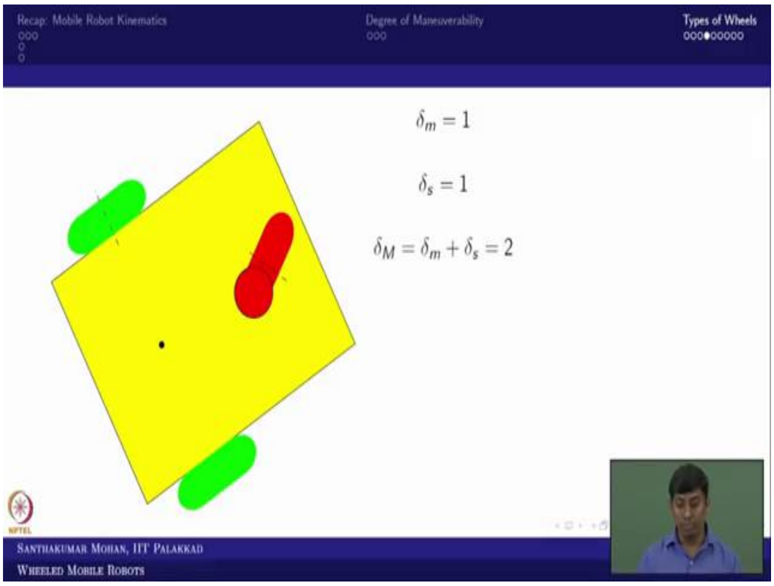

So, now we will go further you imagine it is something like olden auto where the front wheel drive and as well as steering. So, in the sense it is actually like a handlebar that handlebar wheel would be powered and as well as it is actually like making it rotation. So, now, you can see that there are actually like 2 passive wheel which are fixed.

So, there is another wheel which is actually like powered and as well as that is actually like powered for orientation. In the sense what one can see, the degree of steerability is 1, degree of mobility also 1 in the sense the degree of maneuverability is 2 that is what we can actually like understand.

So, now what is steerability you know like. So, this is actually like having a longitudinal velocity, that longitudinal velocity you are actually like converting into longitudinal and lateral velocity by rotating it. So, that is what it is actually like steering, but the mobility is actually due to the traction of the wheel generated. So, now, the degree of maneuverability is 1 + 1 = 2.

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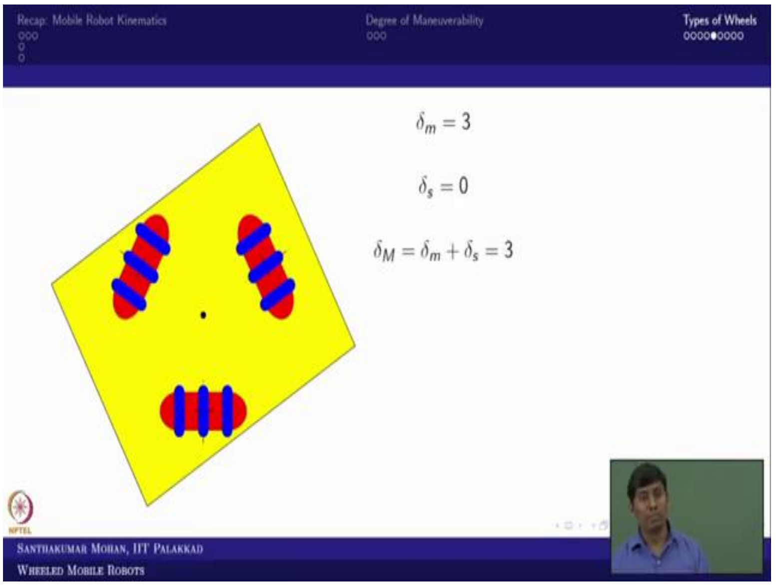

Now, we will move little forward. So, I will take a simple omnidirectional wheel. So, you can see there are 3 omnidirectional wheels. So, you know right. So, there is no steering here and this passive roller is actually like allowing to slide, but there is no power.

So, in the sense what you can see? This is very similar to a fixed wheel. So, this is providing one mobility and this is another this is another. So, in the sense degree of mobility is 3 and degree of steerability is actually like 0 and; obviously, then you can find it, degree of maneuverability is again 3 + 0 = 3.

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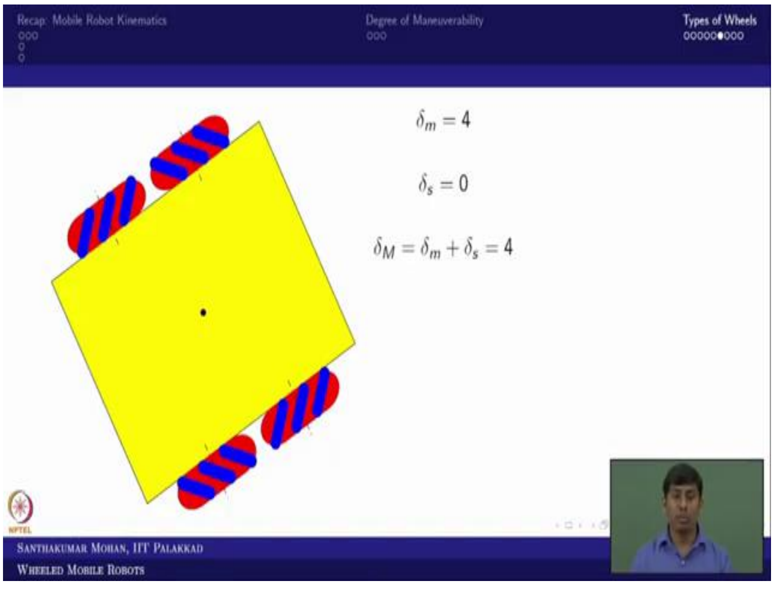

So, now, we will go a Mecanum wheel base. So, you can see that here there are 4 Mecanum wheels are actually like attached. So, now, this would provide one mobility this is another mobility, this is another and another.

So, in the sense 1 + 1 + 1 +1 = 4, but you can see that there is no steering provided, but this this particular robo can move longitudinal lateral and rotation about z axis. But, there is no steering directly, in the sense you can see that there is no indirect you can say way of maneuvering this vehicle.

So, in that sense what you can see the degree of steerability is 0 in this case. So, the degree of you can say mobility is 4 and degree of steerability is 0, then the final one is 4 + 0 as you can say a 4 the degree of maneuverability. So, these are some kind of example we have seen, but one can actually like see ward or you can say vast you can say resources there is other way of actually like showing it.

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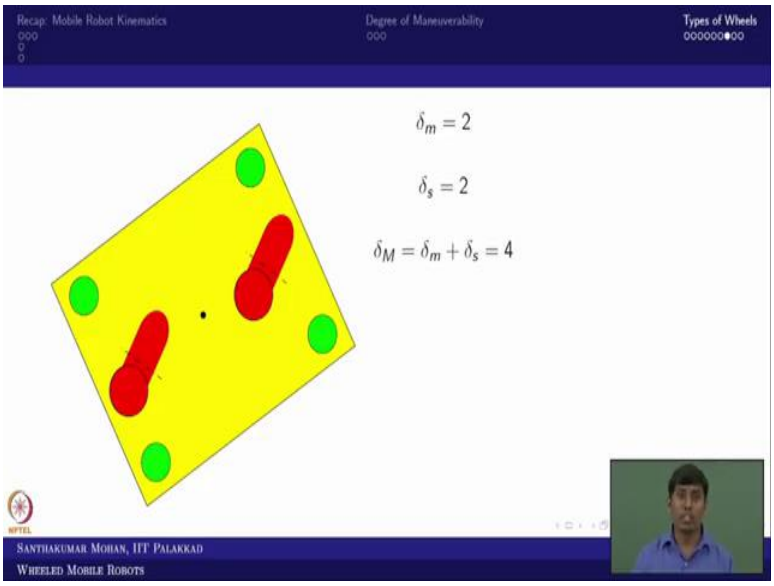

So, before that I will show you one another way. So, there are actually like you can see 4 casters are attached, but there are 2 power steerable wheels are there. So, now, what would be the degree of steerability in this case.

So, there are 2 and what would be the degree of mobility? So, these two are powered in the sense one mobility provided by this another mobility and there are 2 red circle are given that would be giving one steering and second steering, but these 4 green you can say circles are ball casters.

So, which are actually like passive there is no power, in the sense by looking itself you can see there are 4 controllable input in the sense the degree of maneuverability is 4. So, that is what we are also obtained. So, the degree of mobility is 2 and degree of steerability is 2 and the degree of you can say maneuverability is 2 + 2 is 4.

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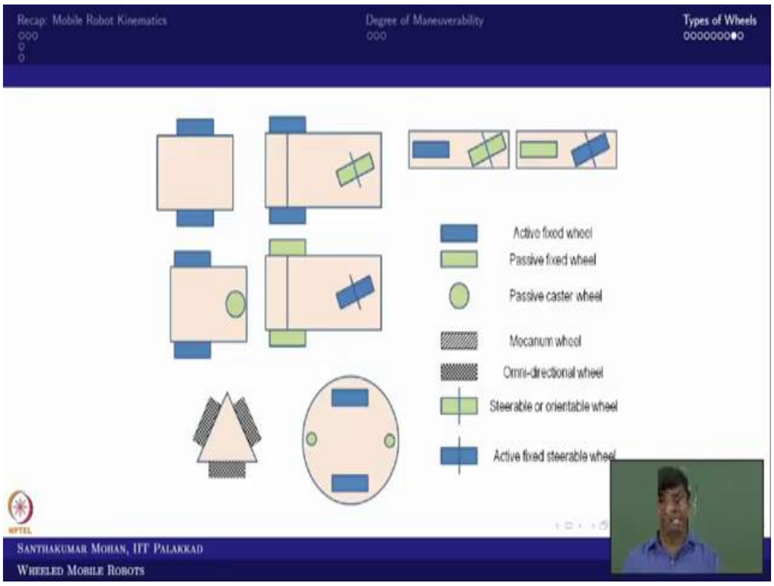

So, as I told already. So, there are vast of because the vast resources are available you should know what are the other way of you can say representing this wheel arrangement. So, some people would be actually like solid fill, that would be active wheel if it is actually like light color or no fill that is actually like passive fixed wheel and all the caster wheels they actually like put it as actually like a green.

And Mecanum wheel would be actually like hatched with inclined line where omni directional is hatched as a dot and you can see blank. And the steerable or you can say orientable wheel would be actually like shown with one axis on that. So, in the sense this is actually like steerable. So, in that sense you can see that that can be actually like filled with solid color then that is active. So, now, based on that you can see that several configuration I put it here.

So, you can see this is actually like bicycle model and this is actually like a same bicycle, but it is a front wheel drive. So, now, you can see that what would be the degree of steerability here? Here 1 and what would be the degree of mobility? Again 1.

So, here rear wheel drive this is 1 and this is another 1 is steerability; in the sense what would be the maneuverability? You know already it is number of controllable input. So, 1 + 1 = 2 right and here also it is 1 + 1 = 2, but what difference between these two? So, here the wheel is powered and as well as steerable, but here it is actually like just steering and power is separate it is something like what you have your normal cycle.

So, now imagine this is same thing as a cycle rickshaw. So, you can see that the rear wheel is 2 wheels, but it is attached with a single axle. So, in the sense these two cannot be independently rotate, but what you can see that is powered. So, in the sense you are you can say paddle would be connected with the rear wheel, but your handlebar is free.

So, in the sense you can see this is a degree of steerability is 1 and degree of mobility is 1, in the sense it is again degree of maneuverability is actually like 2 right 1 + 1. So, now, coming to this; so, this is actually like 2 independent power wheels. So, you can actually see a degree of mobility is 1 that is same as degree of maneuverability.

Now here you can see this is just a passive roller there is no roll and here also there is 2 passive roller there is no roll in the sense the controllable input is 2 and 2 here and here also 2 only thing this is actually like as a cycle rickshaw this is something like olden auto and this is 3 wheel you can say Omni directional wheel. So, this is actually like only mobility provided it is actually 3 this is we have seen already right.

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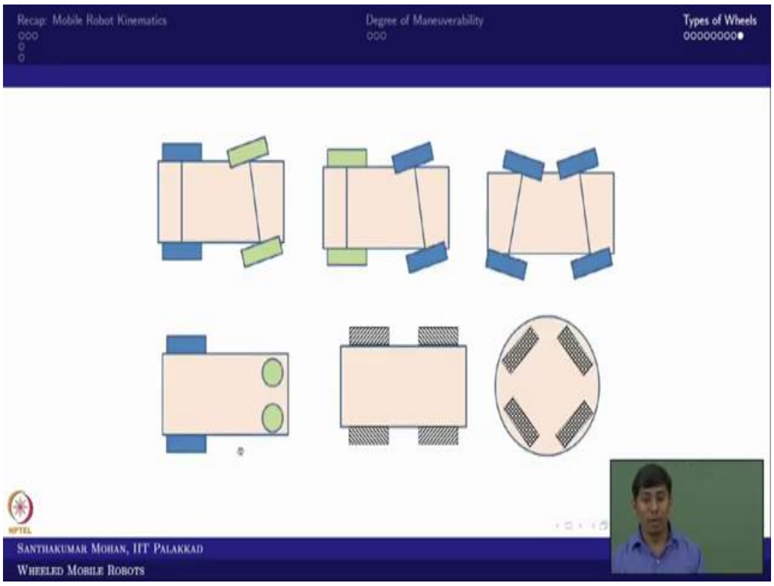

So, similar example we have seen further you can see this is actually like kind of tempo where actually the rear wheel is actually like powered and the front wheel is actually like you call you can say steerable. So, in the sense 2 wheel attached with a single axle, but that is steerable and the rear wheel is attached with the single axle, but that is powered.

For example, truck or you can say van or tempo and all. So, this is actually like you can see number of controllable input is one is with the locomotion which is providing the traction the other one is steering the sense two.

So, this is actually like a car where the steering and the front wheel is actually like powered. So, that is what, but this is you cannot see on the regular road, but this can be implied in your what you call in mobile robot where 2 steerable and as well as powered. So, both axles are actually steerable and as well as powered axles.

So, in the sense you can see that number of steering or steerability is 2 and number of mobility also 2 in the sense 2 + 2 = 4. So, this is actually like quite you can say confusing configuration; even some of the robots are available in this particular configuration, we will see over there you can see you can say lectures we will see some of the pictures of those and we will understand

So, right now what one can see this is another way of you can say seeing 2 independent power wheels these two are just caster this for providing more suspension we have 2 caster rather than you can say 1 caster that is all.

And this is a Mecanum wheel 4 Mecanum wheel you can see number of controllable inputs are 4 and this is straight forward the maneuverability is 4. And this is actually 4 you can say omnidirectional wheel then here also you can see degree of mobility is 4 in the sense degree of maneuverability also 4 right.

So, these are actually like some of the examples for identifying the degree of maneuverability. So, now, you got some kind of clarity what is actually like degree of maneuverability and what are the types of wheel.

Again I am reiterating the types of wheel, we are classifying based on you can say standard way solid and inflated wheel and the inflated wheel we are not going to address because that is very close to the fixed and steerable wheel in the sense it is very close to the conventional wheel we no need to address that further, only benefit is because of the inflation in the sense because of pneumatic wheel.

So, you have actually like shock absorption and as well as actual like ease of movement these two are actually like additional. For example, you take a rough not rough surface, you can actually take a normal trolley suitcase you can just see that is a solid wheel right.

So, now you drag that trolley suitcase in the airport you may not get a noise right, the same trolley suitcase you put it on a concrete floor then you can see some kind of noise the same car you can say same wheel you put it on a normal road or you can say mud road, you will get a difference right.

Now imagine the same thing is actually like inflated as a tyre. So, now you can see that almost everywhere you will get a smooth you can say motion there would not be any noise because of that motion. So, that is what the case. So, small you can say vibrations or you can say small hiccups which is actually like going knock that would be addressed by the pneumatic tire.

So, that is the basic difference between solid and pneumatic tires, but if you are talking about vehicle dynamics, I would be talking more detail. But, right now this is actually like restricted to a wheeled mobile robot we are actually like focusing only on the difference between solid and inflated wheel. So, we would be focusing on the solid wheel.

So, with that I am actually like closing this particular lecture. So, the next lecture would be on the simulation of you can say kinematic model. So, we will take a generalized land based mobile robot kinematic model and we will try to simulate how that goes and how to simulate also we will see. So, I would be using one of the easiest package or you can say simplest package called MATLAB. I hope most of the academic institute would be having a license on that, since our institute is having I am trying to use it.

Even if you want to actually convert this code into Python which is open source or you want to use in a Scilab definitely you can use it, only thing a small syntax variation would be happening here and there, but that is actually like you can do it. So, with that I am actually like closing this particular lecture. So, the next lecture would be on you can say simulation model the 2 in a kinematic level in the sense velocity kinematic model ok, with that I am closing.

Thank you, bye.