**Wheeled Mobile Robots**
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**Lecture - 43**
**Autonomous Mobile Robots and Mobile Manipulators**

Welcome back to course on Wheeled Mobile Robot. So, last two lectures, we started talking about what is modern robotics and what are the challenges. In the last class, we were talking about multiple robotic system right. So, this particular lecture, we would be focusing little more.

So, where we would be talking about what is autonomous mobile robot with manipulator and without manipulator, then we will talk about what is mobile manipulated which is nothing but vehicle manipulated system.

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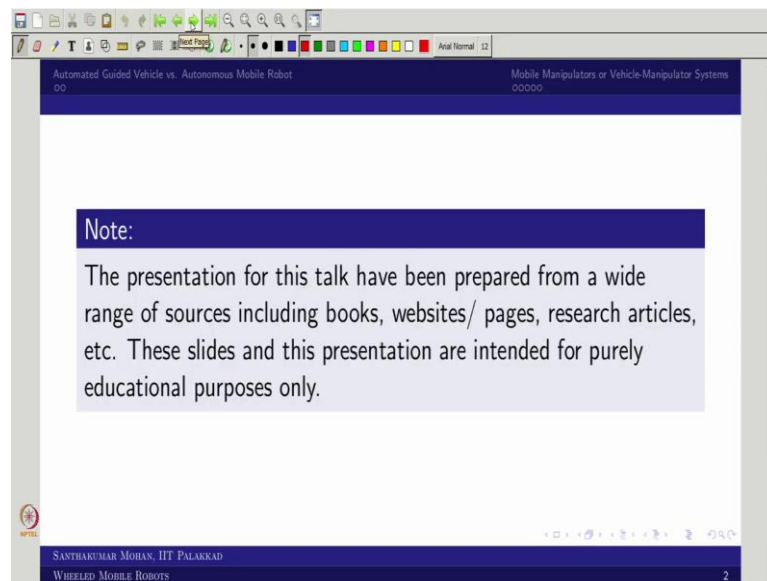
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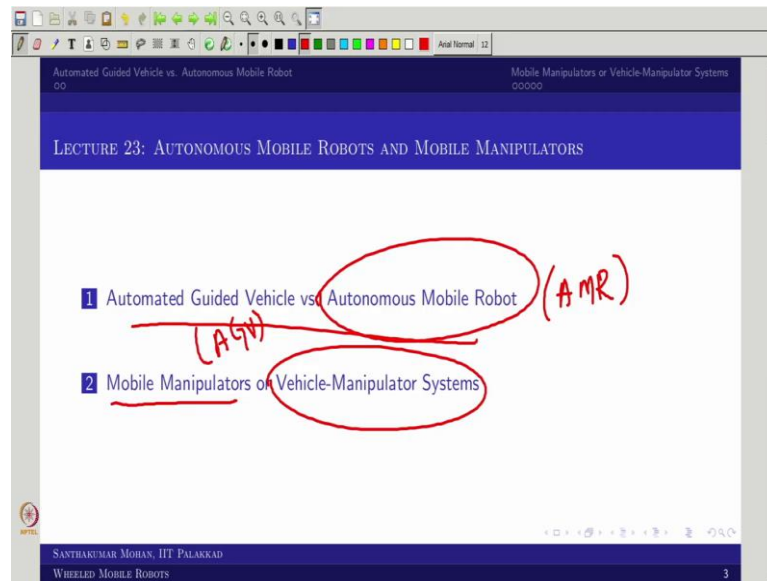


So, in that sense we will straight away we will go to the topic. So, what we are intend to do it. So, we are actually like intend to do two things; one we will talk about the autonomous mobile robot in broad. So, there we would be comparing what is AGV. So, nothing but Automated Guided Vehicle and what is Autonomous Mobile Robot.

We simply call this is AMR; so, the other one is we called AGV. So, we can see that what is the difference between these two, then we will go to the other topic what you call mobile manipulators. In general robotics or mechanical field, we call vehicle manipulator system. What are those and how that is actually like defined?

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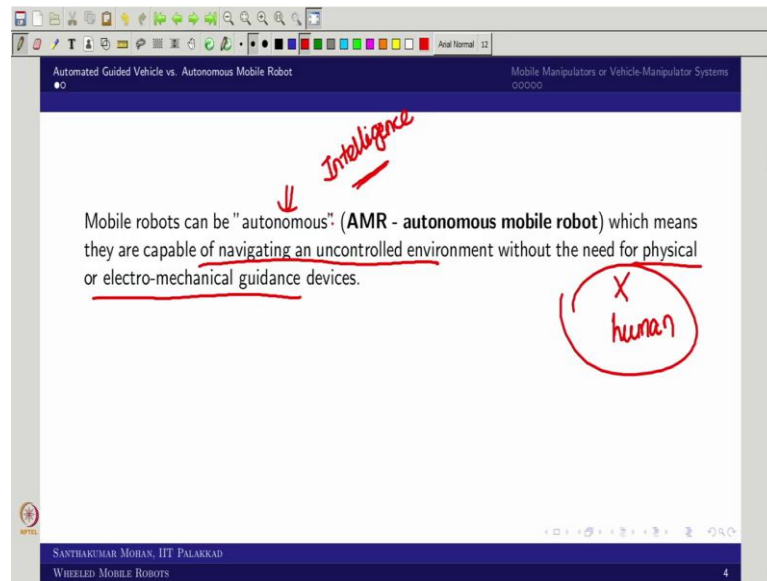


So, let us actually like go straightforward. So, what is mobile robot? You know like mobile robot means it as a locomotion right. So, now, if it is actually like autonomous, then what you can see? It is actually like capable of navigating an uncontrolled environment without the need of what you call physical or electro mechanical guidance devices. What that means?

So, it is actually like away from you call the human intervention. So, the human is actually like away from this. So, then you call autonomous. In the sense, what you are trying to do? So, you are trying to give some kind of you call intelligence. So, some kind of intelligence you are feeding so that you can call that is actually like autonomous mobile robot. So, then what would be the automated guided vehicle?

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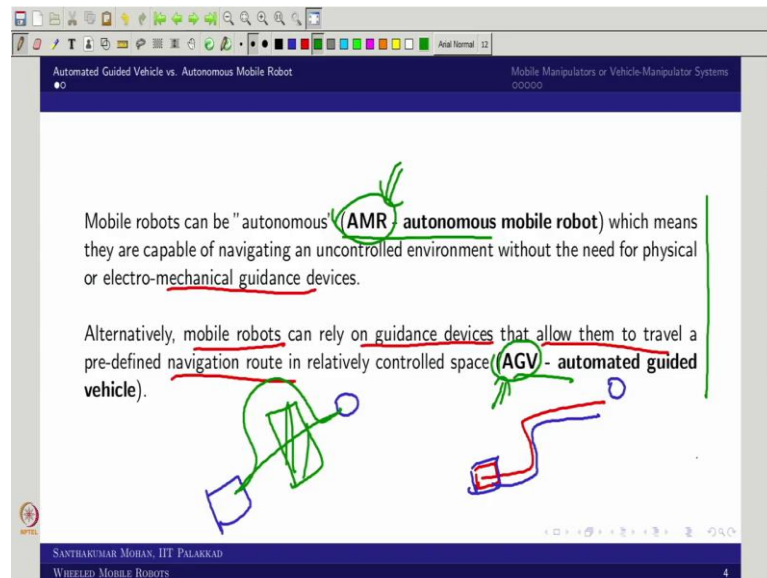


So, that is actually like same; only thing is actually like it is same as a mobile robot. But that would be rely on the guidance system; whereas, here it is not rely on the guidance system, but this is rely on the guidance system. What that mean? It allow them to travel a predefined navigation route in a relatively controlled space.

What that means? You can actually like take a line following robot. So, now, you put a robot here. So, now, you can actually like put a robo here, this robo will actually like follow this line; whereas, I am saying that this is the target. So, whereas, the other way around you say that this is the target and this is the robot.

So, this robot itself will actually like try to navigate without any you call the predefined navigation route and second thing is it is a intelligent. For example, here there is a obstacle comes. So, then there is a robot will navigate and reach. So, this is what we are actually like trying to see as a major difference between AMR and AGV because most of the you call modern days.

So, we are actually like focusing more on AGV; because most of the you call the shop floor, they depend on something like the what you call the transferring the object from one point to another point, they dependent on you can say most of the machine which is nothing but AGV. In fact, AGV is there still probably since 1980, but the AMR is actually like upcoming, where you can naturally see that you can provide some kind of intelligent.

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So, why that is so? I will just give a comparison. Before that, I will just give a case. So, when I was in IIT, Madras. So, I had one you can say consultancy to my professor. I visited that particular firm. I do not want to reveal the name of the firm, but it is a automobile manufacturing industry.

Then, we went there they were saying that we have you can say several AGVs are there, but we are actually like having a problem. Can you study and give a solution? Then, I actually like look at it with my professor supervision, then what we found that this AGV is actually like dependent on some predefined path. So, it usually carry the chases of that particular automobile. So, it actually like carry to the you can say further sections. But what happen? So, it is actually taking away several human job ok.

So, I am giving a small idea. So, this human people always actually like push this you can say AGVs out of this path; but as per the industry regulation, these AGVs would not have any intelligent. So, if it is go out of the path, the robo would stop. So, now, what happen. So, the AGV teams supposed to actually like pay for making them to back to the normal route.

So, when they calculate the money, it is actually like very very high. So, that is why they induct us to actually like give a solution. Then, we have actually like gone through that way. So, then the AGVs actually like very much restricted with a predefined navigational

route, that too with very very small you call locomotion device. So, usually AGVs will have very minimal locomotion device.

So, what that means? The wheel configuration would be either differential wheel or you can say tricycle model which is having a less you call locomotion energy required. Otherwise, what you know? You know the wheel is actually connected with a rotary actuator, that rotary actuator will have you can say consume energy right. So, this is the overall idea.

So, now we will see then, so what is AGV and what is AMR; what is the difference. So, now, in that sense, so one you know like this is actually like on the fixed route; but what the AMR will give intelligent navigation. So, this is what in the modern robotics, we are looking at right. Second thing what you can see.

This fixed route restricting the AGV to apply to certain application What maximum it can do probably you can say carrying object to one section to another section or actually like it can do some other mobility aspect. Whereas, if you think about AMR, so it will give high flexibility because it can be programmed or you can say actually like feed the new mission at any time, it will adapt.

But if you want to actually like change AGV, then you have to change the route right. You have to actually like change all the protocol because AGV is almost like a fixed layout rather than the you can say flexible layout. So, that is what the overall case. So, then you can see that if it is AGV, then that is a traditional you can say business model.

For example, I have a plant which is actually like doing probably daily thousands of product; you can say daily per shift or something. So, then I can see that the design is not changing much, then I can adapt this. But you imagine, the design is keep on changing in the sense agile. So, then the AMR would be the best choice than the AGV. Then, people think about so AGV is actually like expensive or AMR is expensive.

When we are actually like understood and most of the researchers also what understood this, they actually calculate the overall cost for the predefined navigation route and you can say fabrication of the AGV compared to AMR, so the overall expense for the running cost and fabrication or you can say capital cost finally, it turned to be AMR is the best one. So, that is what it is saying.

So, the AMR is a cost effective than the expansive system AGV. Just for giving a small idea, you can see these are AGVs where these are the route, it is a predefined path. So, it is actually like moving it. But you can see these are two different AMR; one would be simply mobile robot, the other one would be having a manipulator arm. So, this is the biggest difference. Now, you got a clarity if somebody says AGV that is also mobile robot, but is actually like work with a predefined navigation route.

But what we are looking at is AMR, which is Autonomous Mobile Robot. The autonomy level can vary; but it is autonomous, that is what the overall idea. But both are mobile robot, you should be know that.

So, now, we will actually like move already I have given a hint. So, the robot which has manipulator on top. So, then what you can call? That is a mobile manipulator or you call it is actually like mobile manipulation device or in general, what we call vehicle manipulator system right.
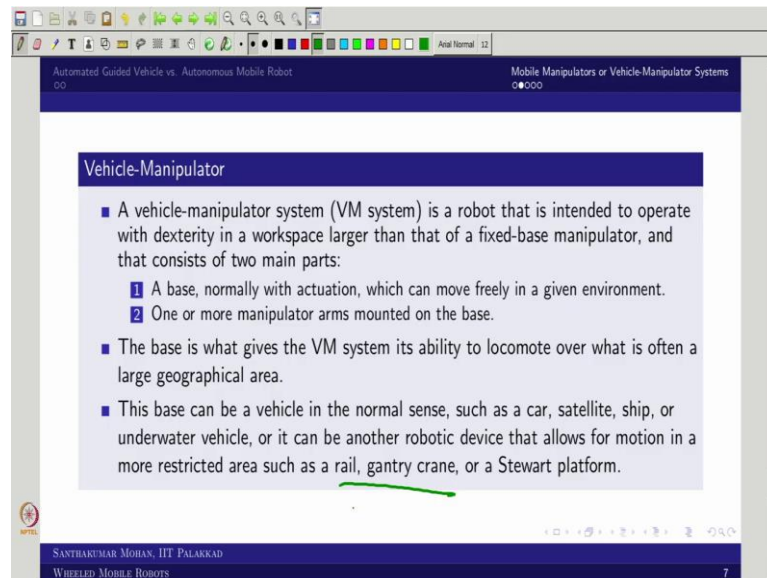
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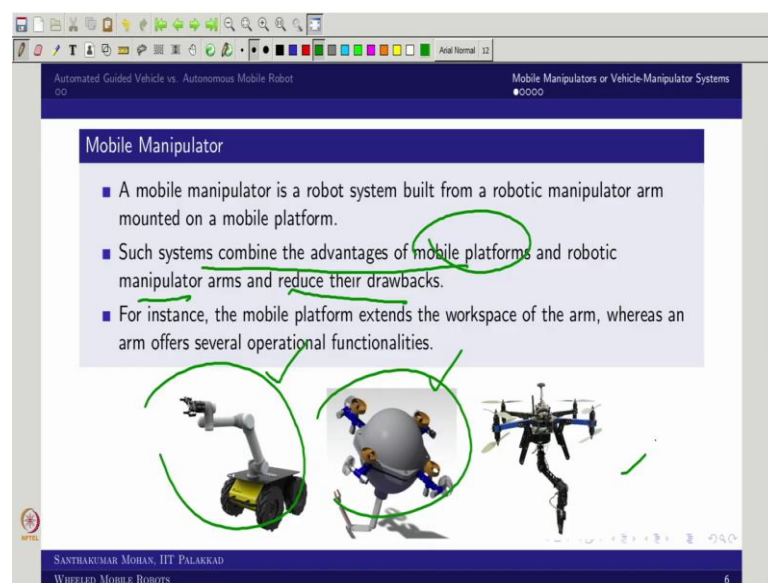


So, that is what we are actually like seeing. So, in the sense what it is? It is actually like giving the combined advantage of both, you can say mobile platform and as well as robot manipulator or robotic manipulator arm, which we have seen in the very beginning of the first lecture itself right.

It reduce their drawback, but it is actually like increasing some kind of complexity in terms of controller that we will see further. But right now, you can see that the you call vehicle manipulator or mobile manipulator can be in any form. It can be ground base or it can be underwater base or it can be aerial base. So, then, what would be the classification?

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So, that would be the next case, but before that let me actually like give a small idea what is the difference between the fixed base and the vehicle manipulator system? So, the vehicle manipulator system is actually like what it is intend to operate with dexterity that is what the overall idea. What dexterity? In the sense, you are providing some kind of flexibility that is what important. So, that is why we are bringing the vehicle manipulator system.

Then, you can actually see so several of ships are having a crane on the top right. So, that is also like vehicle manipulator system. The manipulator is your crane and your you can say ship is your vehicle right. So, now, your ship is having that what you call the crane system that is also like vehicle manipulator system.

Then, I already told in the very beginning lecture. So, the backhoe or you call earth movers. So, that is also one additional you call the other aspect, what you call vehicle manipulator system. Now, in order to understand the vehicle manipulator system, I will give a small you can say example.

Now, imagine, I am standing on my barefoot and I am keeping one toy. Suddenly, I dropped somehow ok. So, now, I am bending and lifting that object. What I can see? I can easily do it right. So, now imagine the same situation. So, instead of bare barefoot, I am actually like putting in a skating wheel. So, now, again the same situation happens, where the object was a dropped.

So, now, I am trying to bend. Do you think that the same situation would be exist, what I did earlier? No. Why? When I am bending, it my wheels start getting locomotion. What that mean? The wheel start sliding, I may fall or I have to actually like adjust. You would have seen that somebody is having a you call the wheel on their leg, they would be actually trying to stabilize right. So, why it is so?

So, there is a coupling effect which is happening because your body weight along with you call your arm right, now you are binding it is actually like manipulator system. This manipulator system is providing a dynamic coupling to the mobile base. So, that is why the mobile base is getting some kind of traction. So, it is actually like getting more. So, this is the whole idea.

So, now, you recall now just you recall you take a backhoe, what you call the JCB Poclain or some people call earthmover or you call simply you can say construction robots ok. You can take it. So, whenever it is actually like doing some kind of digging operation, if you note down very closely, you would have seen that there would be two arm in the front that would be actually elevated and uplift this wheel.

In the sense, it would have a rigid support. Why it is so? So, you are trying to convert this into a flux, you can say fixed manipulator rather than the mobile manipulator in order to avoid this mobility; otherwise, what happen? The driver always supposed to control his vehicle and as well as he has to control the what you call the digging operation which is very complex right.

So, that is why they elevate the vehicle and then, they do the digging. So, in the sense, when they do manipulation object or manipulation task, they actually like restrict the locomotion. But this you would have seen if the vehicle is actually track base. For example, instead of wheel base backhoe, it is having a big military tank and all would be having know that kind of track base. You would have seen that that usually they will not elevate, usually; but some cases they will also elevate.

But usually, they will not elevate. Why? The traction has a you can say what the first situation happened to my barefoot, the friction is very high right. So, similar way the traction was having a very high friction. So, which will arrest the dynamic coupling effect. So, that is what we are actually like seeing in this particular case. You can see that this would be having two component; one would be the mobile base, so the other one is actually like one or two manipulator arm.

So, then what you can actually see that the base will actually like give the total system to have a locomotion and what you can see the other sense that would give the manipulation right. So, I have said the rail or gantry crane or even you can take a one robot would be manipulator arm carrying another manipulator arm.

One of the easiest one you know the parallel robot one of the popular cause Stewart platform. The Stewart platform usually used for the you call the 3D animations and all ok. So, not the cartoon animation.

For example, you go to a 3D theatre, where the seat would be actually like move based on the you can say picture right. So, this mobility who is providing some of the parallel manipulator in the bottom. So, now, imagine, so that kind of parallel manipulator you are carrying one serial manipulator arm. So, what you can see? This is actually like giving a mobility further and it is combined. So, this is also like some people call a restricted as a vehicle manipulator; but there is no mobility at all ok.

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So, that is one sense you have to see. So, in that sense, what would be the classification? The classification broadly into field the field can be war or agriculture or any other field. Then the field can be further superimposed, then what we can say? It is actually like work in water that too like deep sea water, then you call under water robot.

Then, you can see if it is actually like moving for example, ship with a crane that is a free-floating right or aerial manipulator that is also free floating. Then, you can see that the forced base motion system I said right. So, where there is a Stewart platform like this and on top of that you are putting a manipulator arm.

So, now, what happen? This would be actually like give a mobility and this manipulator arm would be moving it.

So, further, you can see all the domestic robot; for example, you take a humanoid robot, that is actually like vehicle manipulator system or you take a dog robot, that would be having a leg and as well as the overall system is actually like loco mode and manipulate because the leg would be actually like manipulating something right. So, in the sense, all the domestic robot would be brought into a vehicle manipulator system.

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Then, what would be the case? The nature of things is actually like it is merge in two way. So, what? So, it is actually like completely you are actually like taking out the fixed manipulator and the locomotion device and combining into two. So, then, what actually?

It would be classified into two; one is actually like the first system, where the mobile base is actually like designated to a mobile and versatile and robust as possible.

The second system is your manipulator arm. Merging these two actually like giving several you can say open research question. Although, it is giving several advantages; but it is actually like giving several open questions.

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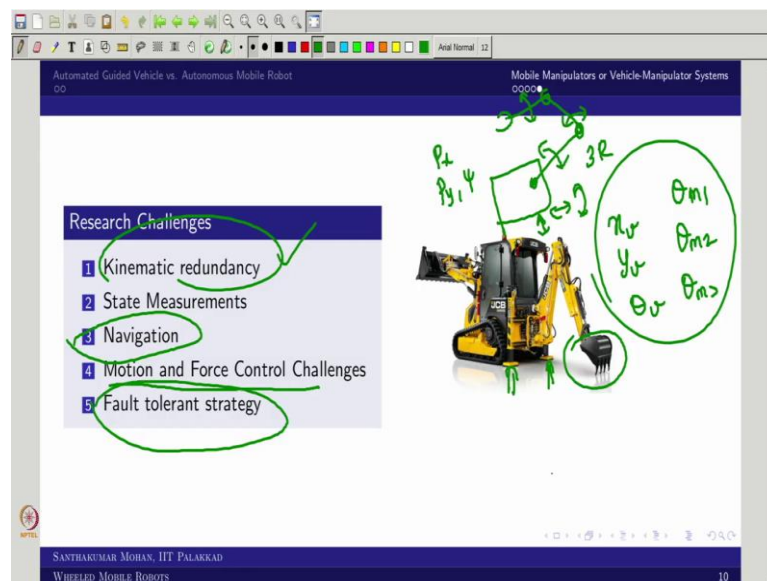


What are the challenges? So, one biggest challenge is the kinematic redundancy. For example, you imagine I am actually like you can say mobile manipulator. So, now, I want to keep this pen. So, how many degrees of freedom required? So, 3 you can say position, 3 translations and 3 orientation of this pen right.

But how many degrees, you can say the maneuverability is there for this. So, my arm my leg all those things I can keep this pen I still roam around here right. I keep it and I am start running right. So, then what you can see? So, you have actually like infinite number of solution what that mean? Your kinematic configuration is redundant. So, that is what you call kinematic redundancy.

For example, I just wanted to show. So, this is actually like you call serial manipulator ok. So, serial manipulator is having a you can say 3 R that is put it on a planner mobile robot. So, now, this mobile robot is having so these 3 degree of freedom and this manipulator is having again 3 degrees right.

So, in the sense what you can see? This robot if I put it in a plane, so this point required only $P_x$, $P_y$ and $\Psi$ right, the these are the points. But you can see like how many variables are there to control. So, $x_{vehicle}$, $y_{vehicle}$, then you can say $\theta_{vehicle}$, then $\theta$ one manipulator arm, so $\theta$ manipulator arm 2, then 3. So, in the sense what you can see, it is controlled with a 6. The configuration is redundant.

So, this is one and state measurement is not easily achievable, it is limited state measurement; some of the state measurement cannot be achieved because it is mobile base. So, it is depend on inertial. So, obviously, you have to actually like do some kind of estimator. So, then what would be the next task? The navigation. Since, it is a very close to a mobile base.

So, then the navigation is always a problem. Further this manipulator system put it on the mobile base. So, now, what you have to see? Earlier, it is having a complex, so now, you are actually like making much more complex. Your total mobility also should be controlled and as well as you have to actually like manipulating device also supposed to be controlled.

Further, your system is having some failure. For example, your sensor is failed or your actuator is fail, how you will actually like overcome? So, this is the picture was I was wanted to show. You see this is one of the earth mover, you can see these two rods which is actually like pushed right. Although, it is a track base, but it is a you can say small vehicle that is why they are putting.

Now, they elevate so that whenever they are digging with this, so it was actually like fixed manipulator rather than the mobile manipulator. So, these are the cases. So, now, you have got a clarity what is AMR and what is mobile manipulator. So, now, you got some more idea what is AGV and what is AMR and what are the types of mobile manipulator right.

So, similar way, we will see few more configurations in the upcoming lecture. Until then, see you. Bye, take care.