Wheeled Mobile Robots
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Lecture - 42
Multiple Mobile Robotic Systems

Welcome back to course on Wheeled Mobile Robot. So, last class, what we have seen is actually like last lecture we have seen the modern robotics and what would be the top biggest challenge right. So, in this particular lecture, we would be talking about one of the specific thing which we studied as a can the robot work together right. So, that is what we are trying to address as the biggest topic here is so Multiple Robotic System.

So, this particular lecture would be addressing what is multiple robotic system and how that would be actually like coming further so, what are the subclasses, how that subclasses is actually like evolving and all. So, I already said this is a just introduction, we will see how we can actually like classify and what are the cases. So, let us move to the particular topic.

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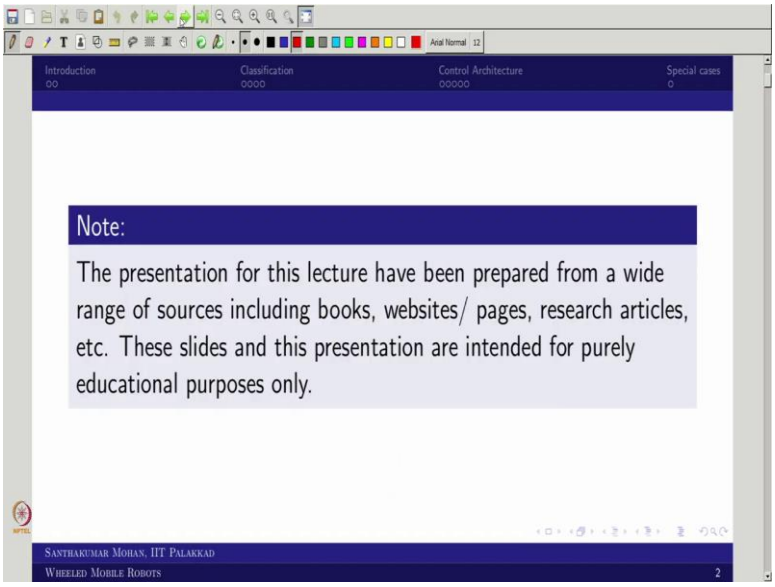

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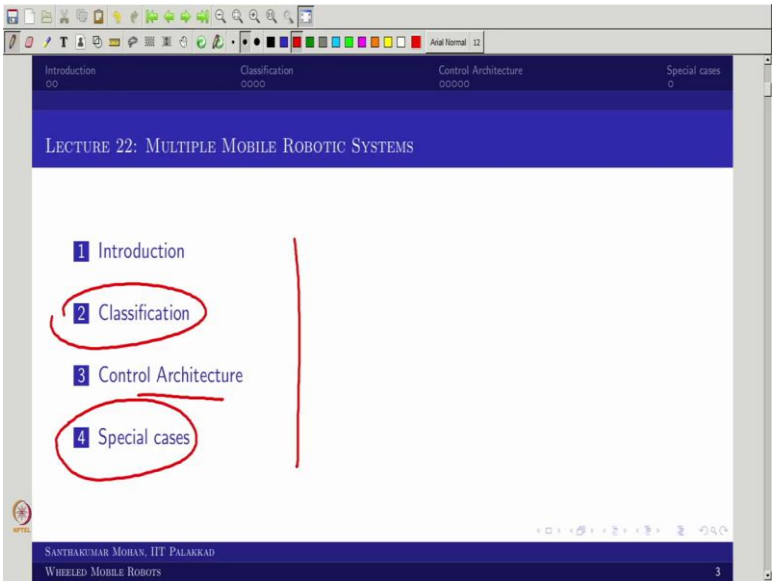

So, what we are actually like seen that so, here we will be talking about what is multiple mobile robotic system, we call multi robotic system so, then, we will see what are the classification we can make and what are the control architecture we usually uses for multiple mobile robot systems or robotic system and what are the special case apart from the classification which we made. So, that is what we are trying to address in this particular lecture.

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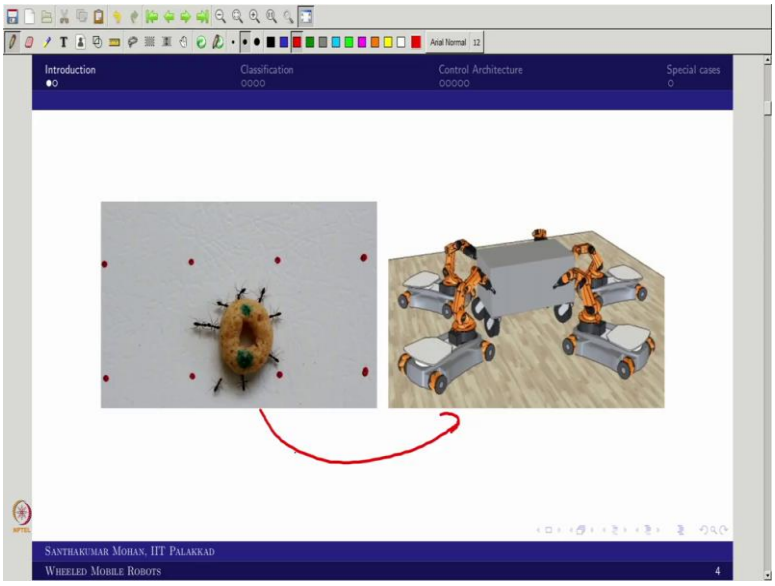

Let us actually like move here for understanding this, I am just putting this particular see picture here. So, what you can say that there is one heavy object which we usually call Vada. So, this Vada is actually like carrying by few ants right. You can see that this is achievable.

Can we replicate similar to this in a mobile robotic system where the heavier payload can be carried? So, this is where the mobile you can say multiple mobile robotics system is coming into a picture, one of the easiest way you can think about it. For example, now I took it as actually like KUKA, you call youBot.

So, there are 5 youBots are actually like grouped together and carrying a common payload. You can see that it is actually very close to the similar task which happened in nature right. So, this is what the whole idea began this what you call multiple mobile robotic system. Let us move further.

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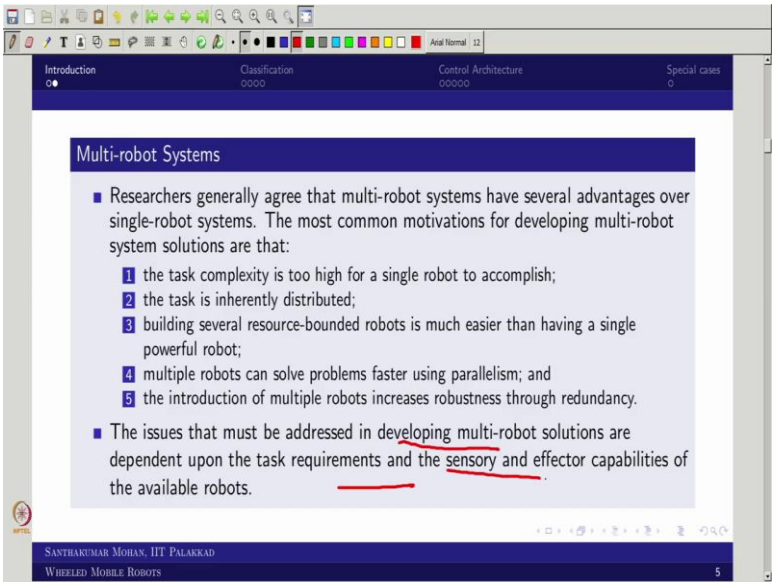

So, what that means, what is multiple or multi robot system? So, multi robot system in generally what we call agents ok. This is the way the computer science people call, but we are actually like a talking in a mechanical perspective so, which is actually like nothing but a system that has actually like several system group together.

So, then what would be having advantage? So, definitely this would be having several advantage over the single-robot system. So, the single-robot system will do actually like

task at a time with only one way, but if it is actually like multiple robot what can do? One can actually like see the navigation whether the path.

For example, you imagine so, there are actually a group of people carrying a heavy load. You would have seen that one guy always actually like try to make a route or try to make a path, you would have seen that right. For example, you would have seen in the railway platform so, which is very common right.

The porters will actually like carry a bigger trolley and probably 4 or 5 people in that one always say that a go go go go like that he will navigate although, he would be pulling, but you would take as a lead right.

So, similar sense, can we actually like a brought if it is a single-robot system, it is very difficult and further, I already told the single-robot system is actually like expensive. For example, I want to carry a payload of 100 kg so, then the pay the robot size itself is heavy and the actuator would be coming so expensive.

So, instead of that this 100 kg would be divide into 10 robots which would be less than this and these robot can be used for further purposes. So, that is what the whole idea.

So, in that sense, what would be the motivation for this? So, the motivation is actually like very simple. So, the task is complex for a single-robot. So, then we can actually like do it and then, the task is actually like inherent so, then it can be distributed for example, there is a you can say room cleaning just imagine. So, the room cleaning can be done in several way. One will actually like sweep, one robot would sweep, the other robot will mop, the other robot will dry it behind so, something like that I am saying.

So, instead of that if it is doing one robot, it is actually like making a three small robot which do so, it would be definitely in that sense what we are trying to do? We are trying to distribute it. So, further what we can see that the resource bounded robot can be actually like make it rather than single powerful robot. So, definitely that place also we can actually like adapt this multi-robot system.

Then, what you can see that the multi-robot system is actually like definitely faster. So, what that you can see that when you are running a complex code just imagine, you know

like what the supercomputer all about. The supercomputer will have actually like a multicore which run in parallel right.

So, the same way if it is a multiple robot so, for example, I want to clean that probably a particular street so, instead of actually like putting a one heavier robot which would be you can say cleaning, I am putting probably 10 robot in 10 different corners what happened? This robot all actually like clean and finally, you can see that within a short period of time, this would be cleaned. So, that is what we are actually like thinking about.

Then, what you can see finally, this introduction will definitely will increase the robustness and as well as it will give the redundancy. So, what that we that all about; that we will see in further slides. So, but what we are actually trying to address? We are trying to see that the multi-robot solution.

So, the multi-robot solution will actually like give something so, which are actually like improving or you can say for example, I am giving a task, the task is actually like having certain you call desire requirement right.

So, based on the requirement, I can see whether I can adapt a single-robot or multiple robot. So, for that what you have to see that your robot capability you have to think whether your robot is having that particular sensing, or the end effector is having that particular capability. For example, I am saying that the drilling, the I do not have a robot which is having a drilling and then, I cannot do it right. So, that is what the idea here you have to see.

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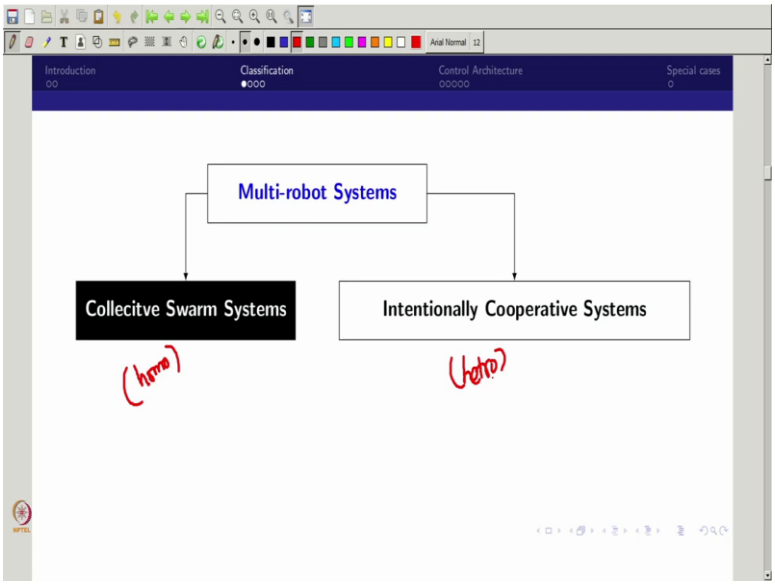

So, if that is the case, what one supposed to see? So, what would be the classification of this multi-robot system or multiple mobile robotic system in general? So, what that means? So, it would be definitely classified into two; one is actually like all the robots grouped as a homogeneous thing. So, everything is similar the other one is dissimilar. So, now, the dissimilar why it is actually like involved? It is intentionally involved as a group. So, the other one is actually like by nature.

For example, you put probably four people ok. So, four people actually like in that two of them are actually like speaking a common language, you can see that always actually like these two people would be cohesive. Why? Because they have a common medium. So, similarly what we are seen here so, there is you call one which is homogeneous, always actually like naturally group it.

So, the other one is intentionally we are grouping it that is what the classification here we are making it. So, one is actually like collecting swarm robot which is a homogeneous robot. So, the other one is what we are saying intentionally we are bringing it so, that is why we call intentionally cooperative system. So, now, the collective swarm robots are swarm system, I already say it is a homogeneous ok, this is actually a hetero.

So, what that mean? So, this heterogeneous also like would be associated based on the task, whether it is actually like associated just for you can say need. For example, you would have seen that there is a team, team of 10 people because of the team, they may be

intentionally joined, but they have their own you can say aspect right. So, that is what we see that whether they are weakly connected or strongly connected.

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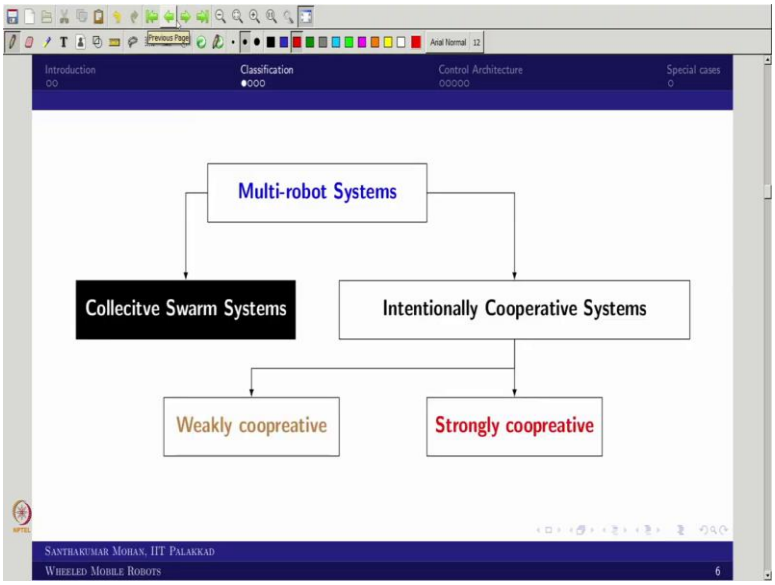

So, that is what the further classification where the intentionally cooperative system can be further classified as a strongly cooperative and weakly cooperative. We will see one by one in detail.

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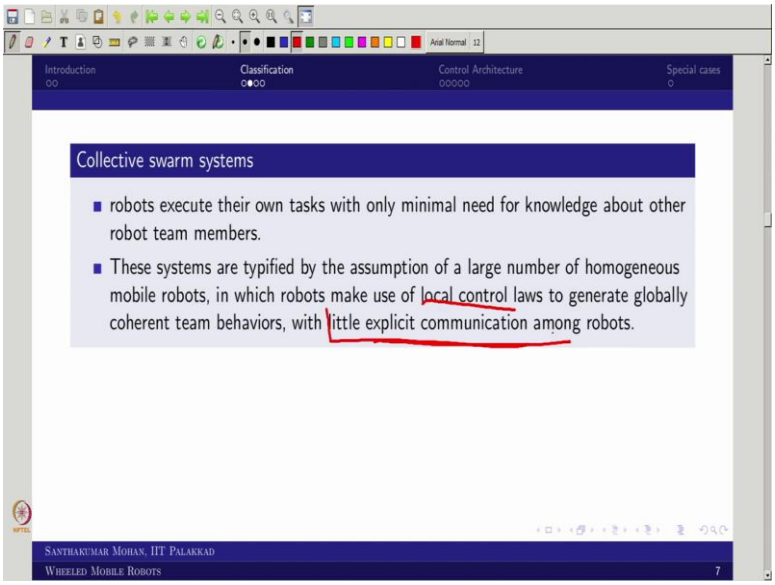

So, what that mean? We are trying to see what is collective swarm system. So, collective swarm system I already said it is all similar right. So, then what we can see that the robot

execute their own task with only minimal need of or for knowledge about their other team partners.

For example, I am saying that as a ant. So, ants are actually like grouply collecting and taking it right. So, now, the minimum knowledge only required. Only thing is common you can say communication mode is important. So, that is what we are actually like trying to see.

So, here large number of homogeneous mobile robots are grouped, but what you can see that they have a local controller which will generate globally coherent as a team behavior. So, but here you can see that the communication among robot is the little you can say; you can say hiccup, or you call setback or the limitation.

So, why it is so? Although, we are saying the ants can communicate, but the robots cannot communicate as similar to the ants. So, that is what we can see that the explicit communication is always actually like a problem, but you need to give the communication mode. So, that is what we are actually like saying as a collective swarm robot.

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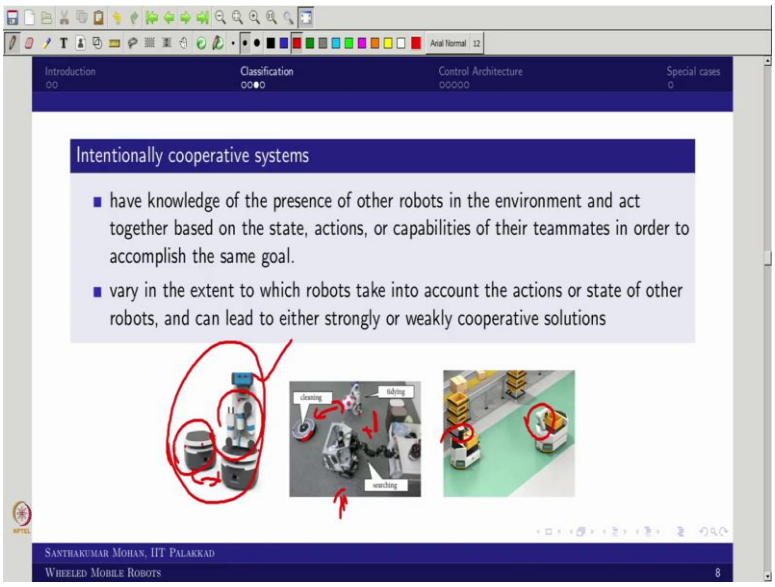

So, now, you have seen like there are several ways the swarms can come, but what we are thinking about the next classification where you call intentionally cooperative what that mean you are bringing this by force fully. So, what that mean? So, you have actually

like heterogeneous robot, but it is actually like collection in the sense, you are bringing all in a group and act together based on the state or action or the given task.

But what this collection for example, I have a robot which is painting robot, the other one is the actually cleaning robot. So, now, I am actually like intentionally making group because whenever it is paint so, there would be actually like you can say dirt followed by that so, this cleaning robot can do it.

So, in the sense, what you can see? The painting is the prime most task, but in the bottom so, the cleaning also need to be done. So, in the sense, what you can see that the same goal is just a painting, but that would be associated with two robots. So, like that you can actually like make a group.

So, there would be one question will come. So, what is actually like the group size? So, the group size is more than one is what you call group. So, even you call as swarm robot, or you call intentionally cooperative system, both you can think about group means at least should have two. So, that is what we are actually like bringing it.

So, in that sense, you can see that I am giving a idea so, one is actually like you can see that this is a heterogeneous where one robot is simple, you call basket carrying. So, other one is actually like carrying a manipulator arm. So, now, you can see if I apply this into a supermarket, this robot will actually like pick the you can say objects and this robot will actually like collect the you can say object in a basket.

So, now you can see here also like heterogeneous so, where you can see this robot is searching and this robot is cleaning, and this is actually like tiding up. And similarly, you can see this is a similar robot ok, but what you can see? It is having addition like similar to here, but you can see that these are actual like intentionally cooperative cooperating in this particular scenario.

So, now you can see that this is weakly connected. Why it is weakly connected? So, the tiding and searching is not at all associated together but tiding and cleaning probably you can see it is closely connected or strongly connected, but these two are actually like strongly connected because if this is not picking, the basket carrying robot does not have any role right. So, that is what we are actually like seeing in the further cases.

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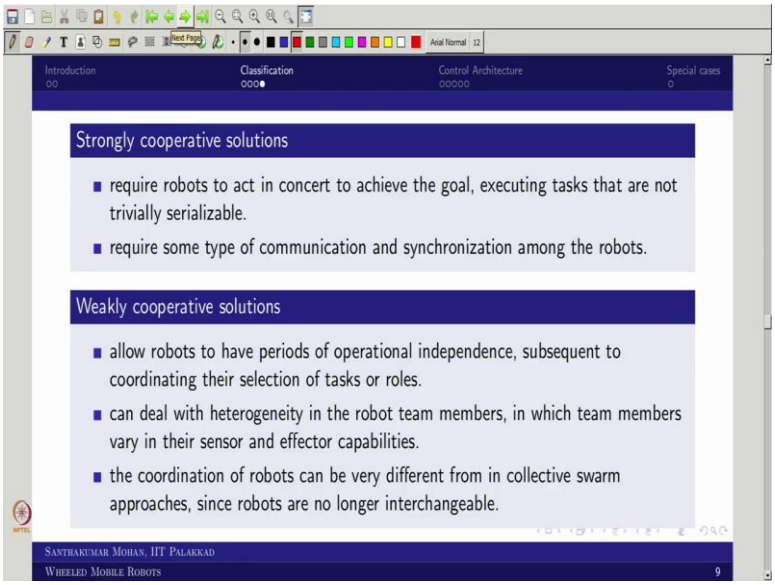

So, where you can see the strongly cooperative solution what says? The require robots to act concert to achieve the goal, executing task that are trivially you can say serializable. So, in the sense what? So, it is actually like not serializable. For example, I take a you can say common payload carrying a robot. So, now, it is actually like not series right. So, all together I need to carry.

So, now, you can see this is strongly connected. So, now this robot can be heterogeneous, but you can see it is strongly connected. So, that is what we are actually like saying the strongly cooperative system. So, then what you can see that there is supposed to be a type of communication and synchronize among all the robot. Since it is a heterogeneous, you have to see it.

So, then what would be the weakly cooperative? So, the weakly cooperative is actually like very simple. So, the task can be independent, I already show right, the tiding and you can say a searching is not actually like dependent right, it is independent task. So, in that sense, you can see that is weakly cooperating solution.

So, in the weakly cooperative what would be the case? It can be heterogeneity, but what you can actually see that their sensor and effector capability you are putting into that group that is all so, it need not be group because this particular association required some kind of heterogeneous robot that is why we are bringing it.

So, in that sense, what the coordination is not really you can say necessary, and it is definitely different from the swarm and strongly cooperating robots that is what we are actually like seeing it. So, in that sense what one can actually like see.

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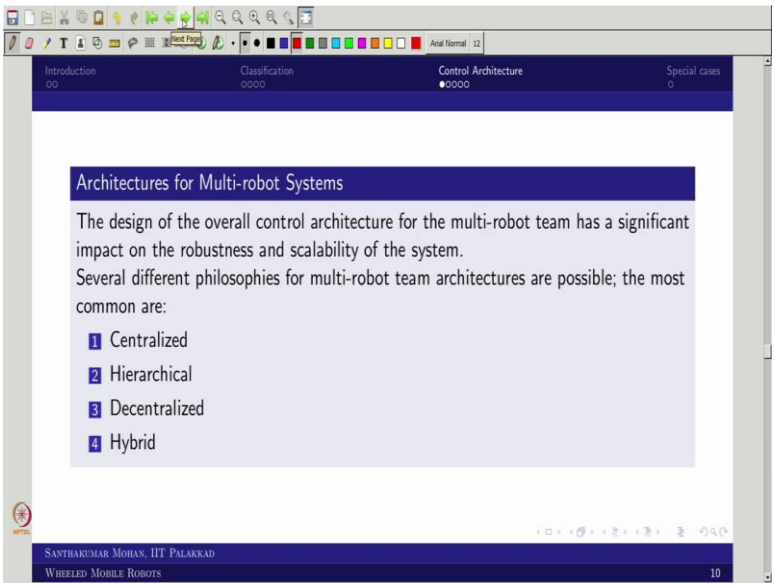

So, what would be the architecture would be coming? So, what mean architecture? The control architecture. So, the control architecture can be easily you can put it. So, one is centralized, the other one is hierarchy. So, that the centralized, but it is actually distributed in a hierarchy way or decentralized completely so, then the final one is actually like hybrid, you combine. So, these are the subclasses which we are actually like seeing it.

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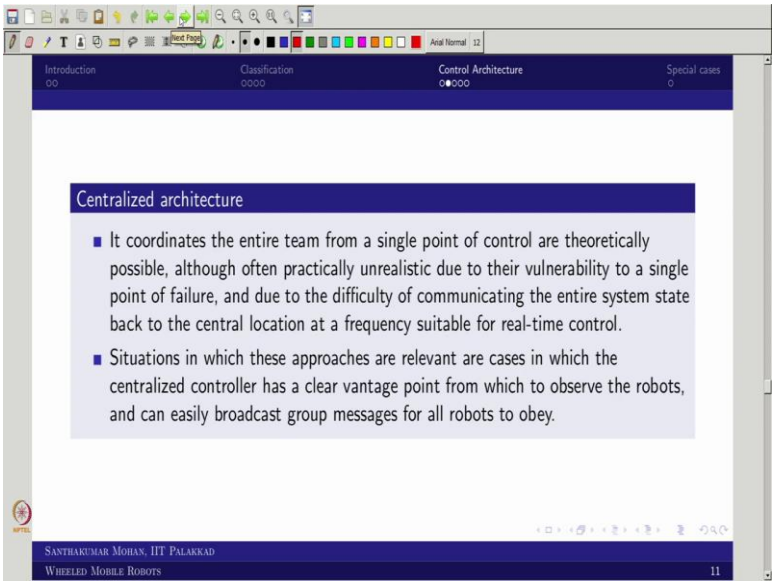

So, we will see what would be the centralized architecture. The centralized architecture one, issue or one important thing is it is a single point control. So, wherever it is actually like necessary, you have put it a single point control. So, for example, the group of robot, all the command is coming from the single node.

For example, if I am taking a class, there are 40 students so, what I can do? Now it is a single point control. So, I am actually like a commanding right. So, this is a single point control. Now, imagine so, I am actually like taking these 40 student into the lab, I am making it into a 5 group so, each group associated with a task.

Now, what I am doing it? The task is actually like on the top, it is actually like divided into further so, that is what you call hierarchy. Now, I am actually taking a 3 or this 40 student into 5 group, but I am actually like not putting into the lab and I am saying that you take care of something like you can say room management, you take care of the lab management, you take care of this thing ok.

So, now, what I am actually like I am saying that the overall all task I am decentralizing it. So, I am not going to have any control over it. So, if any issue comes that particular management team will take it. So, that is what we are actually like seeing it. In the sense, what you can see the robot would be completely you can say decentralized. So, that is what we are actually like seeing it.

The centralized means it is a single point control where you can see that the difficulty is actually like if the single point is something like some failure happened, then the complete system is failed right. So, that is the important aspect which I want to give it, but what you can see that these are actually like relevant where you want actually like have only one option which is there as a single point control like a class, I was giving right.

So, similar way the robot is actually like having a broad for example, there are several micro robot, but the micro robot is not having any communication mode, there is a one mega robot which is sitting in the behind so, that is actually giving all the commands further. So, then this is actually communicating to the control station, then you can have only centralized right. So, that is what the idea.

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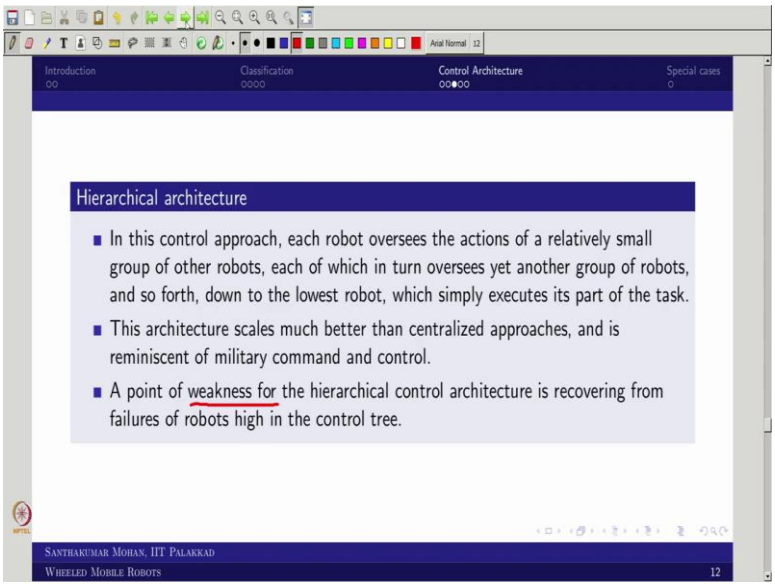

So, now, the hierarchy I already said right. So, you have actually like several hierarchy so, that is what we are actually trying to see. So, in that sense, what happens? So, each robot oversees the action of the you can say relatively small group of other robots and each of which in turns oversee it another group.

For example, now I am actually like seeing that there is a assembly task. So, one place actually like where the fabrication task is happening. So, now, I am actually like associated with only the integration part, but now that another group is not doing, I am saying hey, please do it because I am waiting. So, that kind of collection that is what

hierarchy. Although, I am actually like looking at only the integration part, but sometime I oversee the others ok. So, that is what it is actually like one of the easiest thing.

So, what that means? You can go to the down to the lowest robot where you can execute the individual task. So, it is actually like very close to a single point, but it is actually like you can say decentralized in certain manner and you can say like a connection between one to another.

For example, I have account section and purchase section. The accounts and purchase section can be interact, but if it is actually decentralized, the account section independent and purchase section is independent. The similar way what you can think about here the hierarchy, but this is actually like definitely much better than the centralized approach and this is actually like one of the easiest one what the military command and all do right.

So, you would have seen that some of the movie. So, the initial commando will actually like give further subgroups right, the subgroups keep communicating to the other groups and as well as the main commander, but if you take only from the main commander point, it is look like a single point, but he has already grouped you take care of this, this like that right the similar case that is what we are saying hierarchy.

But this is actually like only issues actually like the failure also like a create problem. For example, I have a hierarchy means a tree structure right. Even one tree get failure so, then you can see that particular activity would be fall, even you cannot oversee to one to another group. So, that is what we are actually like seeing it, which is very similar to a single point, but single point is one failure happened, complete set of actions are stopped, but here at least the remaining groups still go ahead that is what the advantage.

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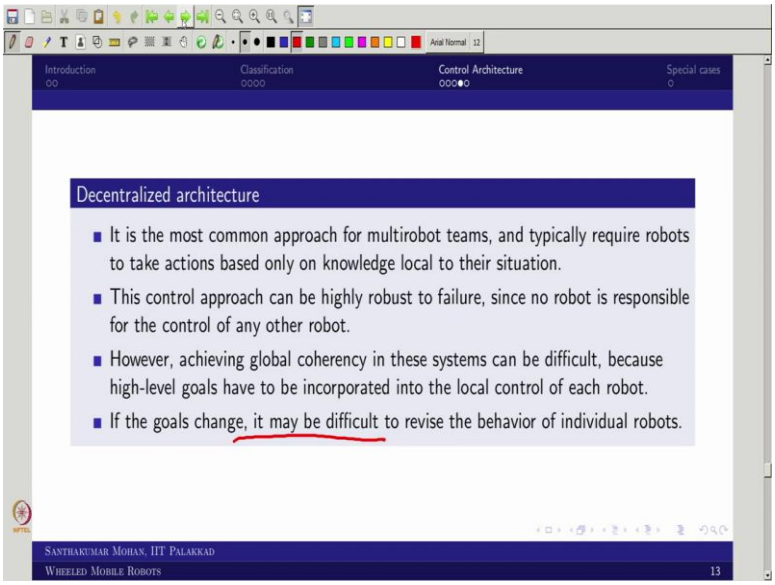

So, now we come to the decentralized architecture. So, it is completely decentralized right, this is the most common approach in multi robot because it is easy and you can actually like dictate individual task and it is actually like robust to failure, but the problem is actually like no robot is responsible that is the problem ok.

So, in that sense, what we are actually like looking at? So, the global coherent is actually like not try to achieve so, you have to actually like may some kind of high-level goals. So, that is what you have to actually like make. So, in the sense, your major goal you have to actually like make a local goal which is actually like fulfilled that would be fulfilling the higher-level goal because none of the robot is actually like responsible for that.

So, that is what actually like we are saying. So, now the goal change, the robot does not know like what is supposed to do. If it is a single point on hierarchy, it would be communicated, but in this case, it is not that way that is the biggest disadvantage in the decentralized.

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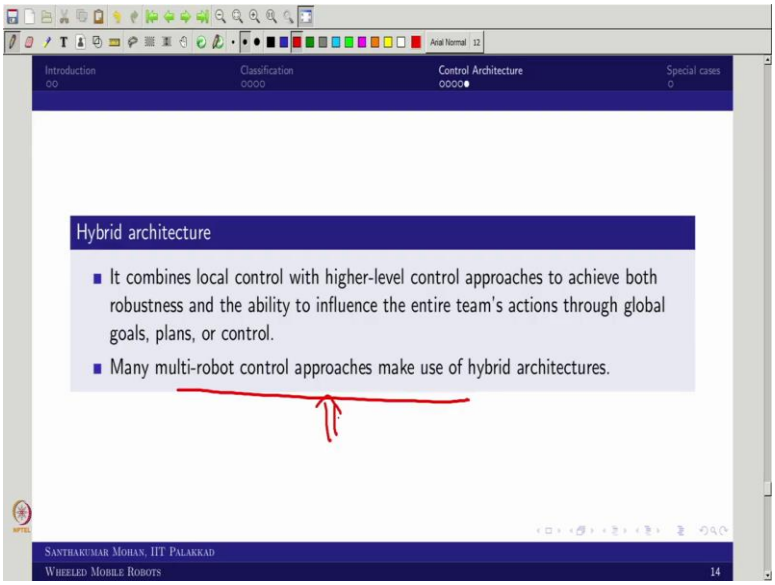

So, then what people thought about? They thought about combining hybrid usually what the combined hierarchy and the decentralize usually do it. So, what they do? They combines local control and higher-level control, they merge in order to get better robustness and as well as we can influence all the team action. If it is a decentralized, what happened? The independent will work as its own way, but now you bring as a team, but as a hybrid architecture.

So, in that sense, what you can see this what actually like we are seeing it. So, what this will give advantage? So, you will work as the independent team member, but whenever there is a you can say team required your you can say need so, then you will come back to that, that is what the overall idea of this hybrid architecture.

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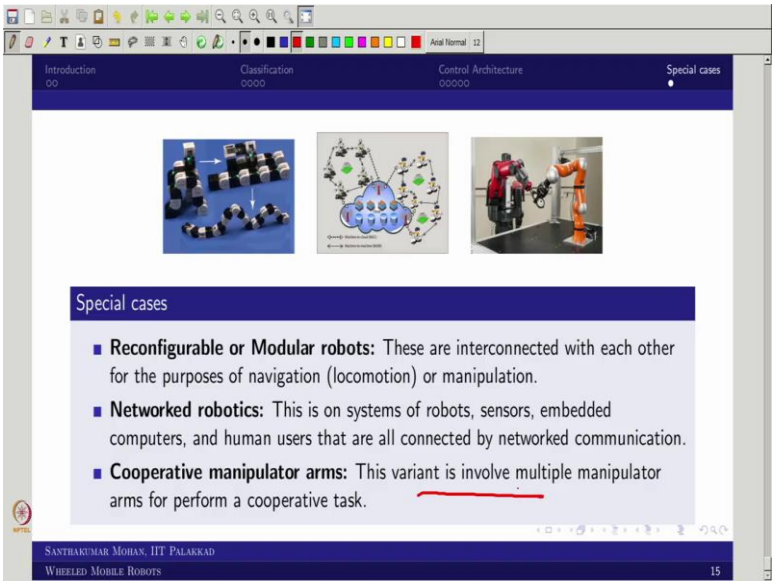

So, with that we have done the control architecture. We will see something what you call the special case of multi-robot system. What that mean? You can see that the same robot can actually like you can say reform its shape or you can say reconfigure it shape. So, initially it look like this, then it modified this way, then finally, it modified. Even it can go back like this.

So, in the sense, what happened? It is actually like mode is getting change. We people call multi model or some people call reconfigurable, some people call self-configurable all so, which is actually like once sub cases. It is actually like break into several robots. So, these all collectively group together and make a multimode. So, that is what one special case which we did not discuss as a classification.

So, similar way what you can see the other way round. So, where the robots are actually like network connected. So, which is come under actually like supposed to be controlled, but you can see there are a group of robots which are network connected. So, one centralized station it is connected, further you can see it is connected, but these are connected with another network. So, these all come under as a network robots, the broad subject called network robotics, this is also we did not discuss in the classification.

So, what would be the next one? So, the cooperative or you call collective action. So, you can see heterogeneous, but it is a manipulator arm. We did not talk about mobile

robot, it is a manipulator arm, heterogeneous, but it is actually like cooperating in one particular task. So, that is what we are actually like bringing it as a case.

So, in that sense, what we can say the special case come, one is reconfigurable or a modular robot or multi model where this would be usually come for you can say purpose of navigation and manipulation.

So, the other one is actually like network robot, it is very similar to a swarm or anything, but only thing it is actually like connected by a network communication where the control activity or you can say the transmission is in the network that is what we can say.

So, what would be the last one? The cooperative manipulator arm, this is actually like variant involve multiple manipulator arm to perform a cooperative task or a common task. So, these are the subclasses. So, now you got so, what is multi robotic system, in specific what is multiple mobile robotic system and what are the types.

So, now, we have actually like see even seen the special cases and with that I am actually like closing this particular lecture and in the next lecture, I already said so, we will see few other interesting topic towards the modern robotics. So, till then, see you bye.