Wheeled Mobile Robots
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Lecture - 45
Under Water and Aerial Robots

Welcome back to course on Wheeled Mobile Robot. So, far what we have seen actually like several of modern robots all we have tried to address. So, in the last class, what we have seen specifically?

We have seen the legged robot and hybrid motions right; so, in the sense hybrid robots. So, in this particular lecture, we would be seeing something like which is out of you can say ground. So, either it is actually like in underwater or aerial. So, these two robots, we are trying to cover in this particular short lecture.

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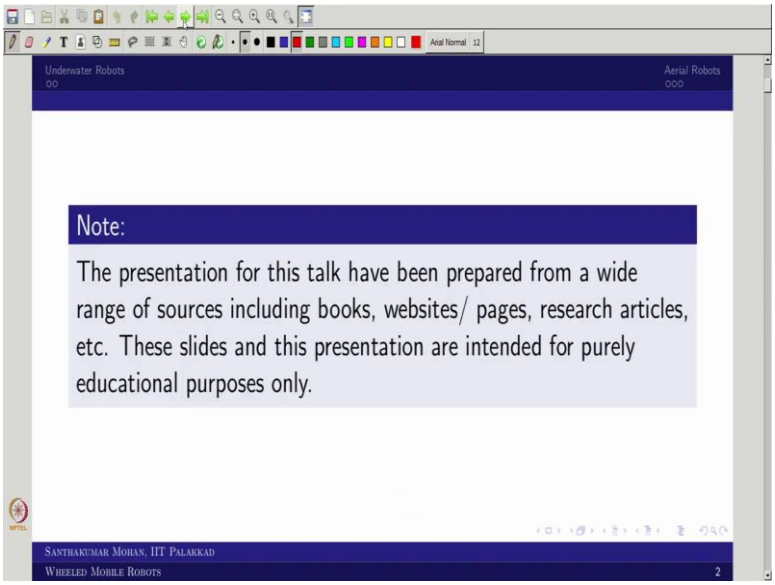

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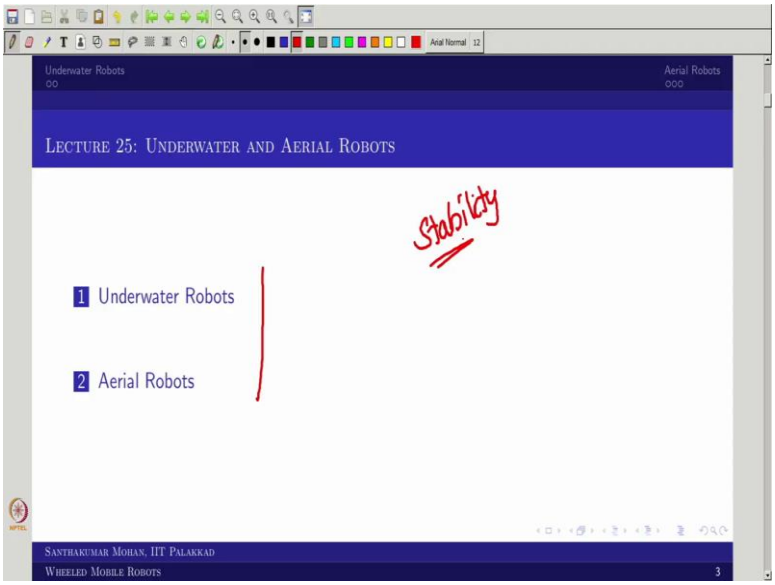

So, let us actually like move to the slide. So, where actually like you can see that both are actually like having three-dimensional case. So, in the sense, what we usually see? The wheeled mobile robot that would be play in a planar case; but when you talk about the legged, so where there is a semi you can say three-dimensional case have come, where you will actually like decompose in a frontal and the you can say longitudinal plane.

But now in underwater and aerial robot, you cannot avoid that. So, you have to actually like bring the three-dimensional case. So, and in addition to that what you can see in a ground robot you usually ignore the what you call external factor. So, for example, aerodynamic aspect, you never bother.

Because your mobile robot is moving very slow speed; but when you talk about underwater, so the hydrodynamic factors are actually like very predominant. So, similarly, if you talk about aerial, then also like you can think about the aero dynamical aspect, then only you can plan.

So, in the sense, you can see like these two are actually like one additional aspect you have to bother. Further, what you can see like this is actually like not in a you call a ground. So, in the sense, what you can see that the stability is actually like one additional aspect. For example, you are taking a aerial robot and you are actually like just stopped, you can say the power condition what happen the aerial robot will fall, right.

So, similarly you take it an underwater robot that too like it is a negative buoyancy and something like communication broke, then it will also sink.

So, in the sense what you can see that the stability is one of the critical factor and further, since it is actually like moving in three dimensional space and further safety also one another concern. For example, now you take a multi rotor system in specific the quad rotor and it is flying and suddenly falling, the major components should not get disturbed right.

Even if it is falling suddenly, it should actually like hand on something like you call landing gear or something right. So, similarly underwater vehicle, if it is actually like communication or something is failed, then it will energize something and then it will come as a positive buoyancy, then it will float. So, that kind of protocol and all you need to see. So, let us see what is underwater robot and what is actually like all other case.

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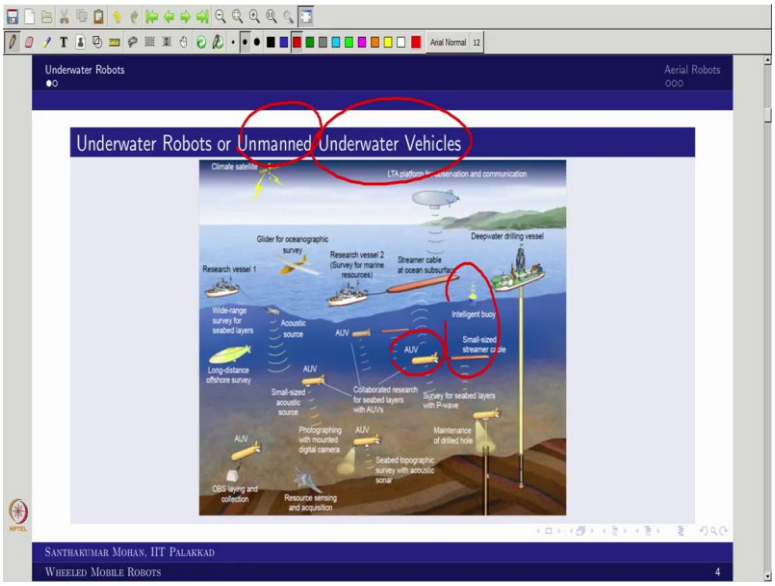

So, what we call underwater robot in specific that is nothing but unmanned underwater vehicles. So, when you talk about aerial robot that is also aerial vehicle and this is also like underwater vehicles that is all. So, one additional aspect, what one can see? It is unmanned. So, that is the only change. If it is a manned for example, shape or submarine, these all not come under in underwater robot.

So, when it will come under underwater robot? When it is unmanned. So, now, then unmanned is actually like having several form. Even this buoy, which is actually like also unmanned; but that is not a vehicle right. So, then what would be called as underwater vehicle? So, there can be actually like some kind of exploration vehicle or some kind of bottom crawler vehicle or just a glider ok. So, these all actually like what you call underwater vehicle.

So, then what you can actually like see? So, it is actually like a maneuver or locomote inside the water, in the sense deep sea water. It need not to be see all the side. On the sense, it is actually like move in under water; without you can say having any additional you can say intervention from the human being. So, that is what we are actually like bothering about unmanned underwater vehicle.

Then, what you can see that can be done in several form; one is actual like you take the vehicle like what the aerial glider. So, you just actually like throw it. So, then the vehicle will actually like move, then also you can do all the what you call observation and all. So, this is what you call glider. So, that is one sub classes we will bring it.

So, the other side, you can see like the power and the communication, you can do it through some kind of cable or it is actually like attached with the mother ship with some rod. So, then you can see it is a towed; the towed vehicle or it is actually like remotely operated with a cable operated vehicle.

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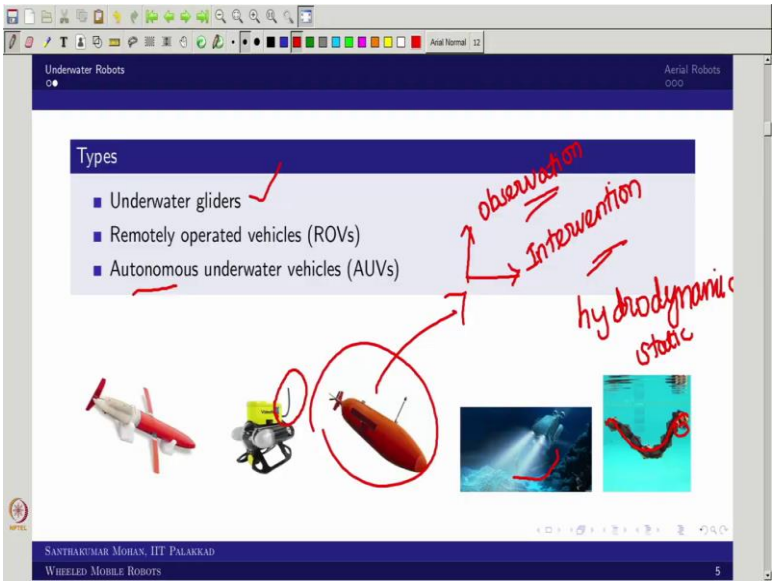

So, these two are actually two cases right. So, in the sense what you can see? The underwater robot can be broadly classified into. So, under water glider, then the remotely operated vehicle where you can see there is a cable. So, this cable would be actually like a medium for transferring the power and as well as communication.

The last one which is we are bothering which is nothing but autonomous underwater vehicle or generally, we call unmanned underwater water vehicle. But what this is actually like a further going to be classified this AUV, what we shortly call Autonomous Underwater Vehicles, shortly called AUV, this would be classified into two further category.

So, one is actually like observation class ok. So, even underwater robot itself can be classified in two way. So, one is observation, the other one is intervention class. So, what that means? Actually like it is actually like doing some task and this is just in observation or inspection. So, for example, you can see this is snake like underwater a robot. It is actually like just having a camera and it is observing.

But whereas, you can see here there is a manipulator inside, so it is actually like some kind of intervention task it is doing. So, in the sense, you can see like this underwater vehicle is actually like having a huge aspect. So, then, what are the challenges you can put forward? So, there are several challenges coming into picture. So, one of the easiest challenge you can think about it is nothing but you can say the hydrodynamic factor ok.

So, the hydrodynamic is actually like one of the critical fact; then, you can say hydrostatic also. So, what that mean? Your buoyancy is actually like one important aspect. For example, today you are checking the underwater robot in a probably a lake; later on, you are taking the same underwater robot into a sea. So, then the situation change right.

The hydrostatic case, it is changing. Why? The buoyancy is going to change; in the lake water, it is actually like probably the buoyancy would be 1000; sorry, not buoyancy, the density would be 1000 kilogram per meter cube approximately; whereas, if you go to a sea because of the salt content, the density would be higher. It may be 1030 or 1050.

Further, what you can see? The underwater if you keep on going, you know like due to the thermal or you can say temperature variation, there would be a wave generated which

we call underwater currents or ocean currents. So, these ocean current also can take it. For example, now you take a calm water. Calm water in the sense, swimming pool you would take it. In the swimming pool, you tested the underwater vehicle and it was working well.

Now, you take it to the lake or probably in a you can say dam. So, in the dam, there would be a underwater current passing in the underneath. You may not be knowing. So, now, you can see it is a standstill water you worked well. So, now there is a opposite you can say or you can say on the direction, there is a flow; then, what happen? This underwater vehicle may not perform as it is. So, then what you can see? These all the external factors you need to address.

So, in addition to the hydrodynamic factor, this is the second thing. So, further what you can see in underwater vehicle, it is not like a ground vehicle, where the communication is easy. So, in the ground vehicle the communication is straightforward. You can use electro you can say electromagnetic or you can say magnetic base communication and all you can do it.

But when you talk about underwater after probably few meters, so the communication link would be disabled for the electromagnetic, where you can see that GSM mode or Wi-Fi mode is stopped. Then, how will you communicate? So, definitely you have to think about something like a sound or probably you can say acoustic in the sense sound base. So, you have to think about acoustic modem or some other you can say sound wave or a light wave kind of thing which can travel further.

So, in that sense, what you can actually like see, the communication also further you can say deteriorate. Although, you know like underwater vehicle is not the construction wise is so big or not difficult; but you can see like in the implementation side lots of lots of challenges are coming. Further, what you can see? Since, it is in the three-dimensional that too like you have several effect, the overall dynamic system is actually like completely coupled.

For example, now rolling motion is actually combined with what you call the other you can say linear motions. So, now, in the sense, the coupled motion cannot be avoided; whereas, in the ground robot. So, what will be the rotation? Only z axis rotation right.

So, now, still you can actually like decouple the motion of x, y and you can say angular orientation of z axis; but here it is not that.

So, the highly you can say non-linear coupled dynamics and further limited sensing and communication and additional factors all involved.

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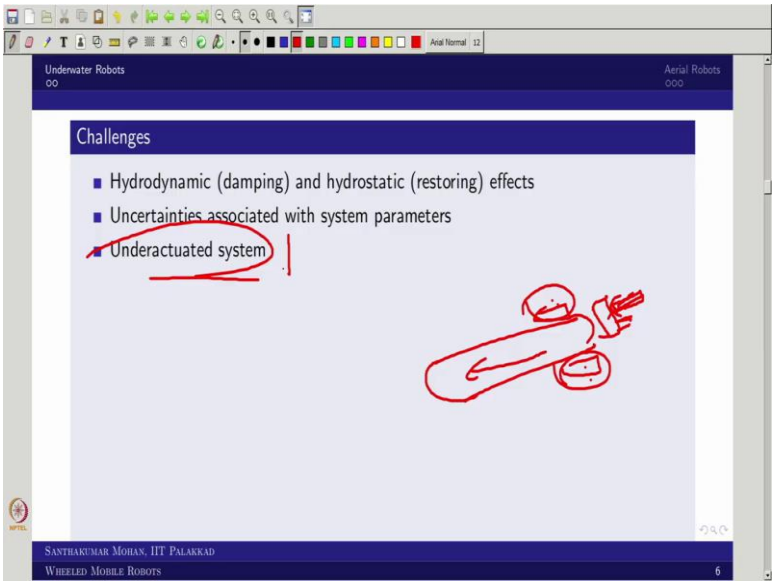

So, that are actually like making a challenge for the underwater vehicle. So, one is I already said hydrodynamic factor. Then, the hydrodynamic parameter making the system is uncertain. For example, I design the underwater vehicle based on the what you call the normal density; but now, I am putting into a probably a sea water, the density change.

So, now what happen? The parameter uncertain right. So, further what you can see that system can be under actuated. What that mean? It is very close to what you call non-holonomic; but it is in the dynamic level, where your acceleration cannot be written in a integrable form ok.

Your motion in dynamic, in the sense your acceleration equation cannot be written in the form of you can say integrable form. Then, you call it is under actuated; in the sense, certain motion cannot be directly controllable. For example, you take car in non-holonomic, you cannot move in a lateral direction right.

The similar sense, so in the underwater vehicle in dynamic sense, it cannot move in certain direction or it cannot rotate in certain direction. So, that is all actually like coming

into a picture. Then, you can ask why are you making under actuated system? So, most of the observation or you can say inspection system, need not to have a high-power system.

So, for example, I take a cylinder shape and I put only you can say 2 fin and 1 thruster, that can actually like maneuver wherever you want. But in the case, what you can see? Only 1 thruster which is power and you can see there are 2 control fins are moving it right. Even you want actually like lateral motion, you can put another radar in the back. So, that is all. You can see like these are actually like passive in the other sense.

So, when there is a power from the propeller, it is moving in certain velocity, then only these are all meaningful right. So, in the sense what you can see, a low power consumption system you can design as a under actuated system. So, then you can see this challenge is actually like coming into a picture, when you are trying to control all 6 you can see states.

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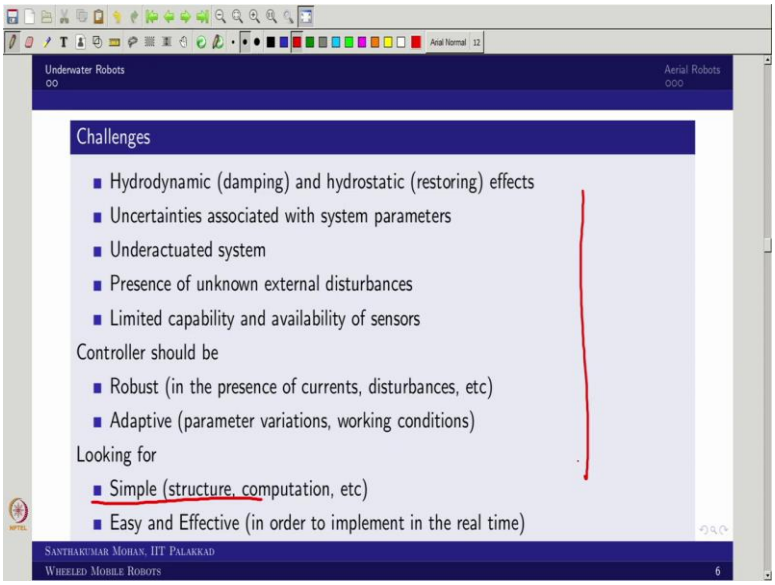

So, then what one can see the unknown external disturbance. I say ocean current or external you can say disturbances, all are actually like a presence in the underwater. So, then, in addition to that what happen? Your sensors are actually like having a limited capability or it is actually like availability itself is actually very difficult.

For example, you want to measure the you can say a linear velocity of the vehicle, then you have to use a doppler velocity log. In the sense, you have to apply a doppler effect. So, then the doppler velocity log is very expensive. So, then not everyone can afford like what you used to do it in the wheeled mobile robot.

So, that is what you said the availability of sensor is actually like one of the problematic and further, what you can see in the controller side, it is supposed to be robust and adaptive. And if you are looking at the other side, the design aspect it supposed to be simpler and as well as easy and effective side. So, what that means? So, your maintenance supposed to be very simple and all.

So, in that sense, what you can see underwater a vehicle is having lots of lots of challenges, so that we are trying to address in you can say like real time. So, now, you I have seen what is underwater. Now, we can see in the aerial, what would be the difference. So, in the aerial what you can see? So, it is again it is a aerial vehicle, but it is unmanned.

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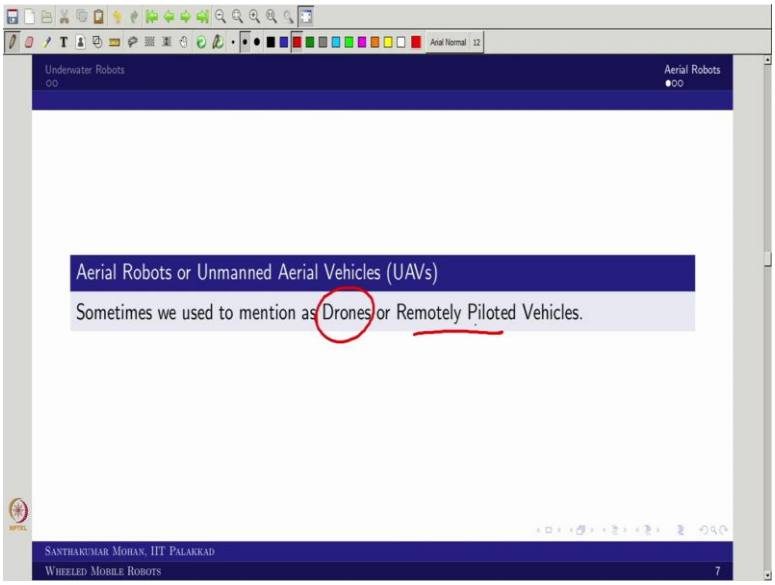

So, we call UAVs. So, earlier you call AUV and this is a UAV. So, then this is some sometime people call drones; most of us we called drones which is nothing but unmanned aerial vehicle, what we called drones. Some of the military side, they called actually like remotely piloted vehicle ok. So, there is no pilot; the pilot would be remotely controlled right. So, these are the aerial vehicle. Then, what would be the case?

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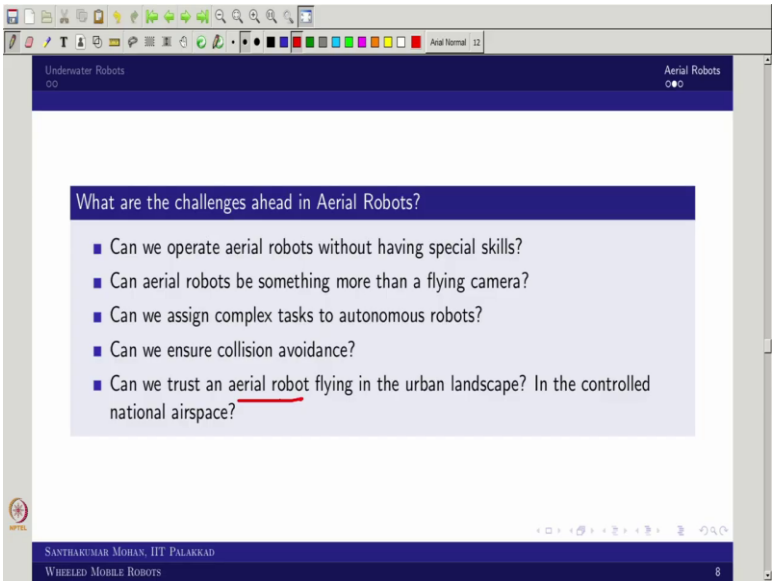

So, what are the challenges here? So, you have seen the what you call challenges in the underwater vehicle; but what would be the challenges here? So, here also the same way you can put. Can we operate aerial robot without having special skill? So, can we actually like make it? So, that is one big question we can ask.

So, then you can say that can aerial robot be something more than flying camera? You know like most of the quad rotor system or aerial robot even you take a military side, they will be using for only surveillance. So, they take a camera and then take a video or images and they bring back and you can actually get it or it will communicate to the control station through some kind of mode right.

So, if that is the case, can we think about something more than a flying camera? So, what then what we can think? So, can we think about actually like assigning a task some kind of complex task? For example, now a days people thinking about drug delivery by autonomous drone or you can say simply, you can say courier delivery with autonomous drone and all; that is what.

Can we think about autonomous robot which will do that kind of complex task? Even we can adapt one of the manipulator; one or two manipulator, then it can do a some kind of complex manipulation. So, that all actually like think about. So, then we can actually ensure collision avoidance.

So, that also like one factor which is usually happening in you can say most of the aerial robot which has you can say the slam, which we call simultaneous localization and mapping. So, that would be adapted, then it would be easily avoided this collision; but that can be make it as actually like one additional intelligent. So, then we can see that can we, you can say trust this. You know like a several urban land base, flying you can say even quad rotor beyond certain you can say altitude, it is actually like a banned.

Why it is so? So, there can be some kind of a issues can come. So, in the sense, can we trust these kind of robots? So, whether it is actually like micro or meso or macro size, can we actually like a dependent on this, in the sense, can we actually like use this in the normal you call the aerial base, can we use it? So, these questions all actually like bring it.

So, before going to answer; anyway, we are not going to answer. I said this is just introducing these challenges. So, let us actually like move to the classification. The broad classification, we can actually classify the aerial robot into micro air vehicle, then meso.

So, then you can say macro air vehicle or macro, it is like a air taxi. The meso is actually like smaller where the drug delivery or other things. The micro air vehicle which is mainly for you can say surveillance purpose or small inspection purpose. So, this is a broad category.

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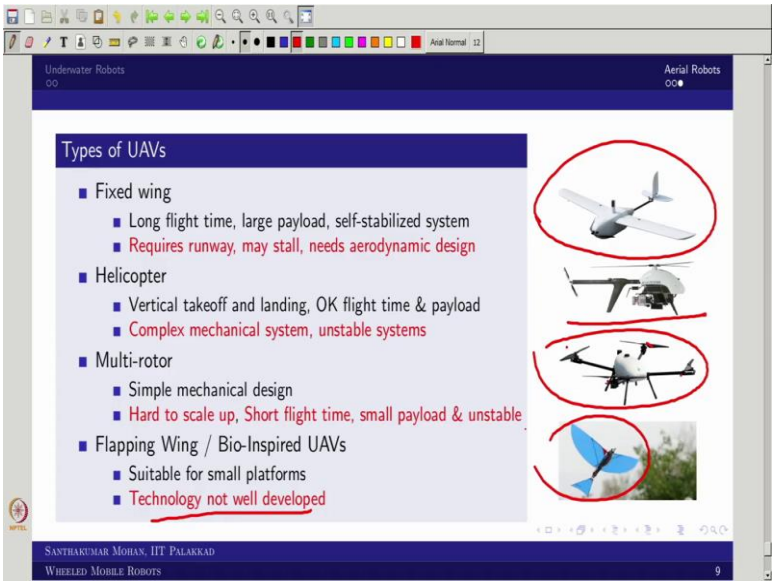

But apart from that based on the construction, we can classify based on you can say conception or mechanical design; we can classify as a fixed wing or flexible wing or helicopter type. So, if it is a fixed wing that is actually like giving a long flight time because it is a fixed; but only thing is actually like you can actually say that you required runway like what you have a aero plane. So, that aero plane required run way right.

So, then you can actually like cannot stall immediately, so you need some stalling area, then you can actually see that the designs supposed to be aerodynamically better. So, further the other side is actually like advantage it is. It can carry a larger payload and it is still stabilized the system; but whereas, the contradict here fixed wing.

So, in the sense, you know like aero plane will actually like run and fly, where the helicopter actually like a first hop and then, fly right. So, these are the two difference. So, in the sense the fixed wing we have seen. So, now, we have seen one rotor and attached with another rotor system. It is also like a two rotor system.

But it is one of the simplest way, we call helicopter system, where this is actually like vertical takeoff and landing. But what the disadvantage actually it is a OK flight time, not like long; it is actually like reasonable flight time and payload. But what would be the disadvantage? It is actually like a mechanical system is very complex and rolling stability is one of the critical fact.

In the sense, it is actually like easily become a unstable system. Then, what people thought about it is actually like two rotor or some kind of propulsion system, can we modify this? So, obviously, the multi rotors have come. So, where the multi rotors start with the quad and then, hexa and you can say octa like that comes. So, the multi rotor is actually like what the advantage here.

So, you can actually like make the simple mechanical design, you take and attach with number of rotors that is all. But what the fact here? It is hard to scale up. For example, now I want to make it as a bigger size, I cannot make it as a simple way what I have done earlier.

So, then what additional issues, it is actually like you can see this is a long flight time; but this is a short flight time. It is a large payload and this is a small payload and this is also unstable; but this is a stable design. So, then what we can think about? We can think

about something else which is actually like it is a fixed wing, can we think about a flexible wing?

In the sense, you can see flapping, flapping wing. So, which is actually like what people usually call bio inspired, it is like you call you can say something like butterfly or bird or even you can actually like say some other insect and we can actually try to replica that. So, then what would be the advantage?

So, advantage is actually like wherever you have a small platform, you can use it; but when you are actually like making it a bigger, this is not feasible. So, then what you can actually like see it, it is technology is not well developed. You can see here, so this is actually like fixed wing and this is a helicopter type.

This is actually like multi rotor, where there are 4 rotors are there and this is actually like what you have seen as a flapping wing. So, in that sense what one can see here, so in this particular lecture, we have seen what is under water robot and what is the aerial robot and I have just a thrown a challenges.

So, some of you may be interested in or you can say pursuing your career in robotics, then you can see like what are the challenges across in underwater and aerial. So, you can take up that as one of your objective, and then you can try to go ahead with that. So, that is the whole idea of this particular lecture. So, now, you have seen this and one more you can say special robot, we will see in the upcoming lecture. So, until then, see you. Bye.