Advanced IOT Applications

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Lecture – 10
Simulation of simple algorithms for object detection

Let us look at Automotive IOT Applications. This is a hot topic and many many research groups, universities, R&D labs are working on this very hot area. And, any amount of time we spend on this module is insufficient. Therefore, it is quite hard for us to cover anything in a limited time. However, if you have to build something you have to start somewhere right.

So, let us assume; at the end of this module you will be exposed to at least do something by yourself, with whatever resource that you have in front of you. And, I assume that you have no access to any sensors and technology of any nature. But, you have a good laptop or a home computer and with this little resource you should be able to at least build algorithms test a few algorithms and so on. This means many things have to be done in simulation correct. So, we need a good nice simulator to which is essentially a tool for you to work on this area.

Now, what are the hot problems in this area? What is it that people are trying to solve in this area of automotive applications? Let us go at least I would say 15 or even 20 years back, when the first attempts at anything related to autonomous actually came into picture. The whole area of autonomous driving, or autonomous way of transportation, or intelligent transportation actually did not start so much with automobiles, but was really fuelled by airplanes.

Autopilot in an airplane not so famous today due to several recent crashes of the airplanes, it is not a very popular thing today right, you have problems related to angle of attack sensors; malfunctioning, reporting wrong values, and so on and so forth. So, they are all issues which are tightly integrated into the autopilot, but nevertheless landing of a plane is by and large because of autopilot. All the safe landing is that are happening today in the very harsh weather conditions are because of autopilot which means, man has all the time thought about how can I leverage a technology in a manner that it will benefit us. So, IOT is the best example of that right, you have some set of sensors, you

have set of end effectors, and you have human in the loop, and what else? it should create a lot of magic. Actually autopilot is already very mature. Several versions of autopilots have been released airbus has it's autopilot, Boeing has its own autopilot, doing several functions of the plane.

So, in that sense autonomous flying is around. So, if you now apply autonomous flying to autonomous driving on the on land it is not the same ball game. For instance at least today or at least I would say 15, 20 years ago the possibility of 2 airplanes colliding was uncertain. First of all there is an algorithm which will take care of ensuring that 2 planes will never have a collision at the cruising altitude. There is an algorithm built into the planes and planes can actually detect and then take some decisions, that is also something that the autopilot actually does. There the problem of collisions is not so, much because there is so much of airspace. And, there are no problems of obstacles, if at all there the obstacles it is an another plane perhaps.

But, then there are issues of turbulence and other related issues which the plane has to worry about,; like oxygen supply inside the planes and so on and so forth. Problems there are of one type; problems on the ground are different type, you have obstacles, obstacles include human's, trees, cattle. Major accidents happening because a dog crosses. So, you have to detect a high speed dogs cross or wildlife and so, many things.

So, the ground related problems of autonomous driving are the set of issues which are completely different compared to let us say an autopilot of an airplane. But, while the idea of autonomous is around the problems are different because a domains are completely different. Now, if you just say I have a car with me and the what is the minimal thing I want to do with this car in front of me or a 4 wheeler in front of me. And, I want to do some very simple things right. To simple automations that I want to do is considerably easy today because modern car actually does a lot of it right. It has control ability integrated by manufacturers.

For example, when you are backing you have a screen in front of you and there are sensors behind, which actually detects that you are hitting close to a wall or you are close to a perhaps a water gutter or something that will you know create a problem for the car and the things like that.

So, lot of nice things are already out there. You start putting all these things into a proper perspective, you realise that there are actually good standards which will tell you that there are different levels of automation that you can talk about. These are called ADAS levels. There are different levels of ADAS I think the highest level indeed is 5. So, that is really a highest level of autonomous driving. So, let us not worry about that; let us not get into that, but you just have to know that there are levels at, which one can talk about the complete automation or autonomous driving applications.

Question is; given this large space where does IOT come into picture, what are those IOT sensors, and what are their issues, and what can we do given this limited time in front of us? I want you to look at what have written on screen here.

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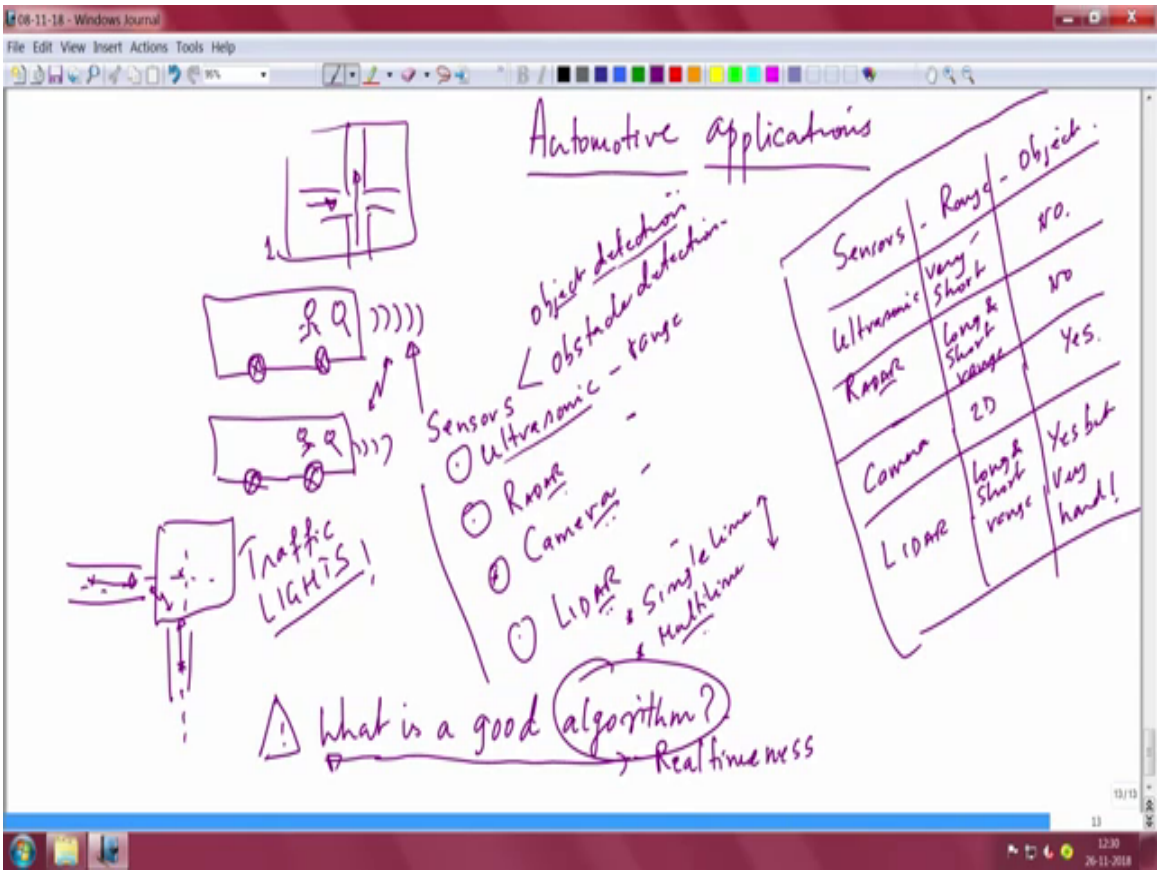


Here, I have shown a 2D representation of an automobile. I mean so, there only 2 wheels. I did not want to show the other part and then there is a steering and there is a driver. And, then some sort of link going out, which is trying to look for objects essentially and to see whether these objects are actually obstacles for us or not.

So, first is to do what is known as objects to check if there are objects in front of us which is essentially doing object detection. Then, leading to saying whether it is indeed an obstacle or not an obstacle, very simple look at just how you are driving in the most natural way. As you keep driving and steering on the road, you have the road, you have vehicles in front of you, you have vehicles on the left, and you have vehicles all round you, then you have trees and there are so, many other related things.

They are all objects which the eye is seeing. Now, how many of them are really obstacles is second part. If, you are very close to a car in front of you or a 2 wheeler in front of you then it becomes an obstacle for you and you have to brake and you have to do so many other related things. Otherwise you keep driving you have just objects which the eye is absorbing. So, quite like that there were lot of objects. So, you have to go and classify different objects. You have to go and say that this is a tree you actually not in the drive way. When you are driving without your knowledge you are actually doing that, saying this is a tree, this is a 2 wheeler.

The space occupied by the 2 wheeler is of one nature compared to that of another 4 wheeler in front of you. So, you are classifying different objects. The brain is actually doing all that by using eye as a sensor. And, it is trying to lay a 3D map in real time right and then only you are very successful in driving without any accident. So, you are doing all of that as a first step. So, what kind of sensors can one think about? Again, I want to look at what exactly people do? the sensors essentially you can have are ultrasonic sensors; you can have a Radar for automotive applications. You can have a camera for automotive applications and you can also have LIDARs as part of sensors for both object detection and then leading to obstacle detection.

Now, when should I use what is a question. So, I put down this little chart it is a very high level chart, I am not written down anything very technical here, because I just want to introduce you to the possible range of sensors. Take ultrasonic; these are essentially a simple sensors, very reliable sensors, cheap sensors. And, they are typically used even today for detection of when you are parking the car right, you could be using simple ultrasonic sensors. And, they will give you a signal and they will tell you what is the range between the car and the obstacle, they will give you warning, actually they will give you signals and the whole IT system that is built around the electronics of the sensor actually gives you all kinds of annunciations like audio and all that.

So, you build a lot of intelligence around this basic using this basic sensors, only thing is they are restricted to very short and they cannot really distinguish and tell you what that object is. I cannot tell you whether it is a sort of a wall which is an obstacle for when you are backing the car, or whether it is a human that is obstructing it or just a stone, or whether it is a water you know for storm water drain, essentially which is at a slightly elevated height, you are not be able to make out any of that. So, that is really an issue.

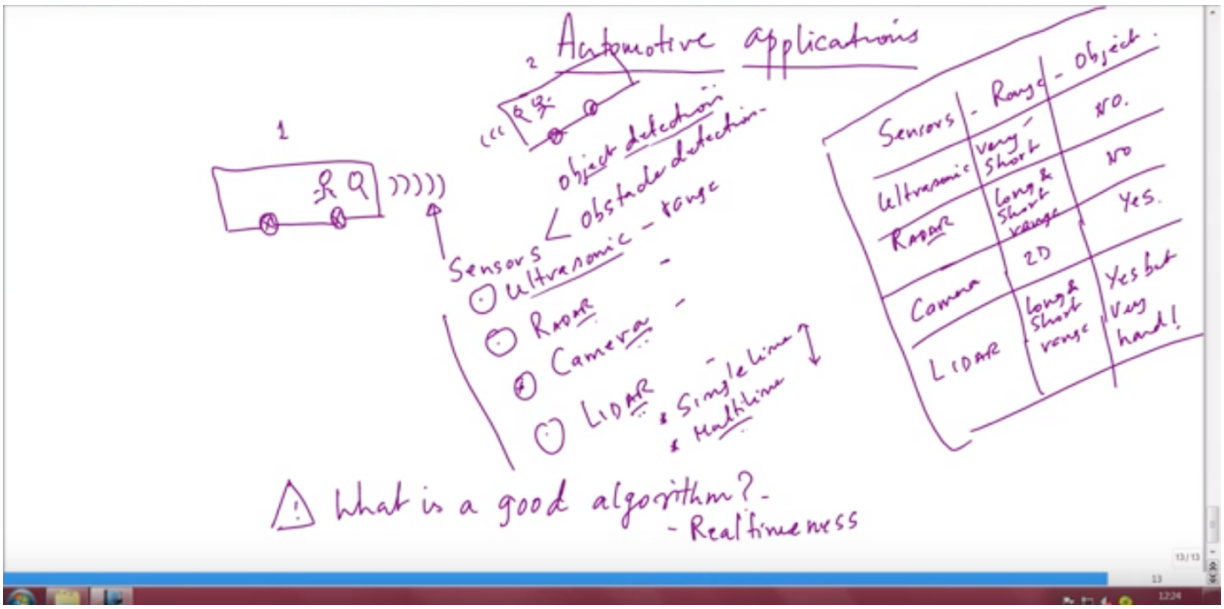
Look at radar: radar for automotive application very mature, you have pulse doppler radar, you have FMCW radars, that used for both long as well as short range. Again it is hard to do anything with them with respect to knowing what that object is. So, that is also, but it is indeed one of the important sensors, which are used in autonomous and automotive applications. Autonomous is one part automotive radar is an important thing.

So, we have to spend time in understanding how this automotive radar works. So, we should look at the range, look at frequencies of operation and so on. Then of course, camera; camera is a very good because it can tell you by looking the picture, you can do some simple image processing, video processing and actually find out what that object is and therefore, that is pretty good. Lidars are around for a while now they are some things which are used in autonomous driving. They are indeed both long and short range, there have been university efforts in trying to understand to look at what that object is using lidars, but it appears to be a very hard problem to do object identification using lidar data right.

When you talk about LIDAR immediately what should occur to user is, is it a single line or multiline LIDAR. So, you have to note this unless you have multiline 64 line LIDAR, your reconstruction under all possible scenarios will be very difficult. So, you must look at multiline LIDAR systems. Now, all of this essentially means fine very good you have good sensors, you have extremely good sensors which scatter to different range requirements and so on and So forth. But, what is the good algorithm how do you do obstacle and object detection and obstacle avoidance if required right.

So, you have to really lay emphasis on those basic algorithms which you should use. Before, I go into the detail of this these algorithms, it is good to see 2 demonstrations, but before I do that demonstration I am going to add an additional dimension to this

discussion. Look at these 4 sensors that I have put in the screen shown. These are the 4 sensors ultrasonic, radar, camera, and LIDAR.



How good are these sensors? How good are these sensors if, there is another automobile if there is another automobile which is perhaps also on the same path.

So, they will has this automobile 1 and automobile 2 both are equipped with these sensors 1 or many or all sensors let us say. Question is what can you do if there are 2 automobiles. This indicates that they are about to, you know sort of collide into each other, but that is just a representation I just wanted to show you that another vehicle is there, which means or for you know I am not scaring you in the first class. I will erase this here and I will put it next to this, vehicle picture draw in the screen show above. This might help you to complete the course without worrying about major collisions and accidents and so on and so forth right.

So, there are vehicle next to each other. These sensors like Ultrasonic, Camera, LiDAR, Radar are for getting information inside a vehicle. What, if you had a wireless link between the 2 of them. What can you do, what kind of nice things can be achieved is the question? And, I am sure you will be able to replicate this demonstration quite easily on your own laptops and on your own computers. Complete source code will be given to you can build it on your own.

First exercise we should help you to get started on this system by playing with the code that is made available to you. Think of a scenario which is like 2 vehicles, which are trying to approach from 2 tracks. And, there is an intersection, and there two vehicle approaching each other towards intersection. So, there are 2 vehicles and the idea is without colliding, but using communication between them the 2 vehicle should cross each other.

One simple thing is if I am able to communicate the distance no rather the current location and speed, then by passing this information I could come out with the simple algorithm, which will allow this vehicle perhaps because it is closer to the intersection not to cut speed. But, this vehicle perhaps either cut speed or completely shuts down or sorry stops. Allows this vehicle to pass and then moves over. What will this do? What will this experiment do it is something very simple right good thing is you can get rid of traffic lights.

You do not need traffic lights anymore if you do this right. Then no way by which you need red and green anymore, if this communication between vehicles happens, if the first vehicle here let us say if there are multiple vehicles behind. If the first vehicle and the first vehicle on either direction is able to communicate, and that information is passed on to all the vehicles that are behind the first vehicle. Then, you have a nice scenario of not even having a single traffic light anywhere in the city. Doable well I think it is doable and our goal should be to attempt something like this towards building an application of that nature.

What does all that all of this what does it mean; which is written in the screen show above? The whole area of automotive work that you want to do is about algorithms. What are good algorithm, you have to study those algorithms. If, you understand the basics of these algorithms build these algorithms then you have a framework for building automotive IOT applications. So, this course this particular chapter indeed is highly algorithmic by nature ok. Having given you this background without wasting any more time let us see a demonstration on a simulator, what that simulator is all of that I will handle separately soon after you see the video – " https://www.youtube.com/watch?time_continue=893&v=jrOjmeFMeS0 "

But, this simulator is this video that you see here is also a little bit I would say hilarious and I am sure you will appreciate where that fun element actually comes from, let us see the video let us see the problem.

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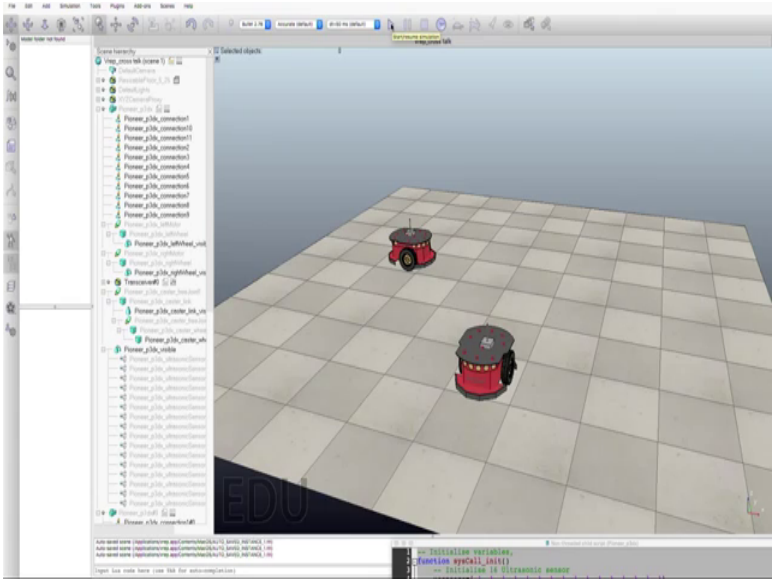

The problem is pretty straight forward; tow robo should move towards each other, towards intersection .The robo has to cut across so, it is an intersection right.. There is a T or a L I would say, it is a T perhaps actually it is a cross more like a cross right like a cross.

And, you can see there is something popping on top, there is something sitting on top. That is essentially are nothing, but communication devices, communication modules. And, these communication modules essentially are sort of the ones that are used for communicating, the current location and the speed at which the vehicle is moving.

So, let us start the video and see what actually happens? You can see that both the vehicles have dropped out of the screen and that is the fun part. So, you saw that nice demonstration in a simulation environment right. It was quite hilarious the 2 wheeled robots that you saw on either side they just dropped off after the platform right. Clearly those situations were not handled in the simulator. And, often in it should not happen that when you do when you put your algorithms in place, that these car autonomous cars or these thing should not just drop off a go off the road or drop off a cliff right.

So, that is where the real trick is how do you plan everything for your vehicle in a manner that, it moves in a coherent way in a coherent manner and it is able to reach it is destination. So, if you have seen the demonstration you may also be wondering, what is that simulator, what is it doing and all that? So, for that I wanted you to get introduce to this simulation environment simulator called V-REP ok. I have written it here.

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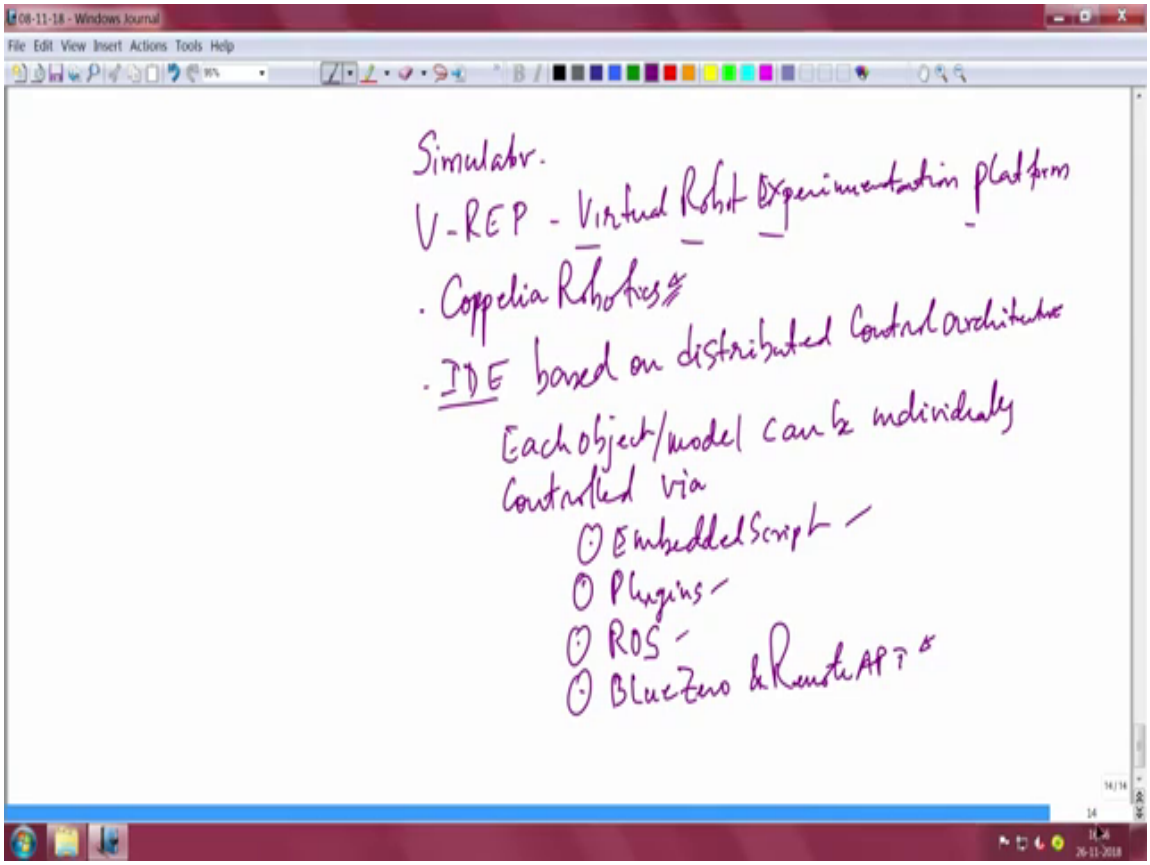

We can see that V-REP stands for virtual robot experimentation platform. And, this is essentially from a company called coppelia rep robotics. This is a name of the company and this company essentially is giving away this robotic platform, simulation platform, free if you are an individual, or you are a student, or you are part of an educational setup like a university and so on.

So, as far as this course is concerned if you are representing yourself as a student of this course, I think there is there are no issues in downloading V-REP installing it on your laptop and experimenting with V-REP. But, if you are part of a company setup you have to be very careful read the licence which is out there very clearly, ensure that you are not

violating a single rule as mentioned by the company. So, I am assuming that you are student of this course and therefore, this is ok to download and experiment with all right. Now, what is this V-REP? V-REP is an IDE essentially Integrated Development Environment, it is based on some sort of a distributed control architecture which the company themselves have put in place.

And, here each of the objects that you see within a simulation environment, it could be sensors, it could be controllers, it could be end effectors whatever be the objects which are within the simulation environment. Each of these objects which is nothing, but a sort of a model even if it is a model they can be individually controlled. And, these this control can happen in many ways. One is you can control through an embedded script, you can control through plug-ins, you can control through robot operating system or ROS, or bluezero and remote API, which is also a very important requirement.

So, bluezero essentially is a cross platform. So, let me put it down here.

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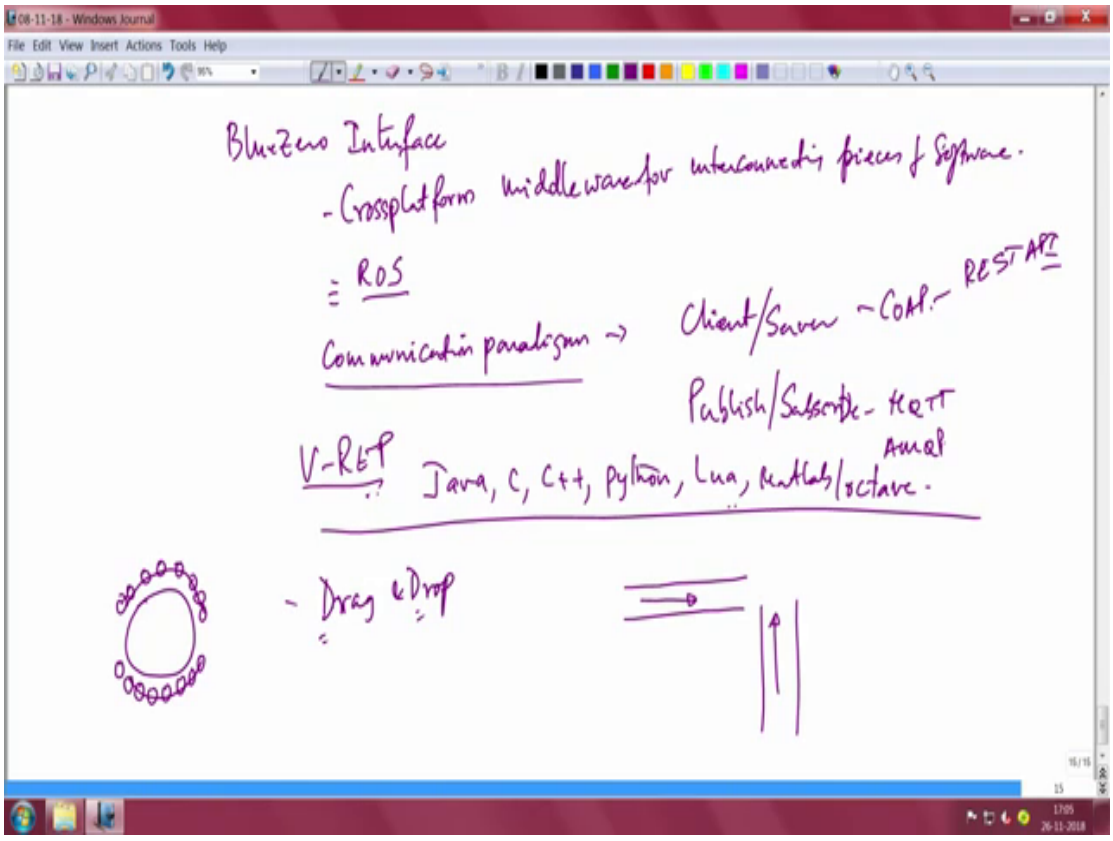

Blue Zero is interface; essentially is a cross platform middleware. I would say it is used for interconnecting several pieces of software, nice interesting kind of a cross platform software. And, you can be running it in multiple threads in processors and all that and it has quite some similarities to ROS.

So, there are quite similarities to ROS, but it's main focus appears to be on communication paradigms. If, you want to know more about this you should do the first course on design for IOT where we talk about client server as well as publish subscribe ok. Typically, MQTT, then AMQP are all part of a publish subscribe and COAP kind of protocols essentially from the client server kind of paradigms right. Basically, all the restful architecture REST API. So, it is seem to be concentrating more on the communication paradigms.

Now, in V-REP any controller that you design can be coded in several languages. Java a supported, C supported, C++ is supported, python is supported ok. And, Lua which is also very native to V-REP, is supported, Matlab and Octave are supported.

So, this is in brief about V-REP; there are several videos on how to install V-REP, How to work with V-REP, How to set up a first experiment in V-REP and so on and so forth. So, you could look up any of those videos and I think it will be a repetition if you sort of do all that here. Instead worry you so, much more about our own example on automotive IOT applications. But, nevertheless if you want to start somewhere how do you by just looking up the videos may not help you in this course. So, what we will do? Now we will take a very simple drag and drop drag and drop kind of application, we will just take a few objects connect them together and put back this interesting demo we saw under V-REP ok.

So let us start with that and so, that let us now move on to V-REP simple drag and drop application.

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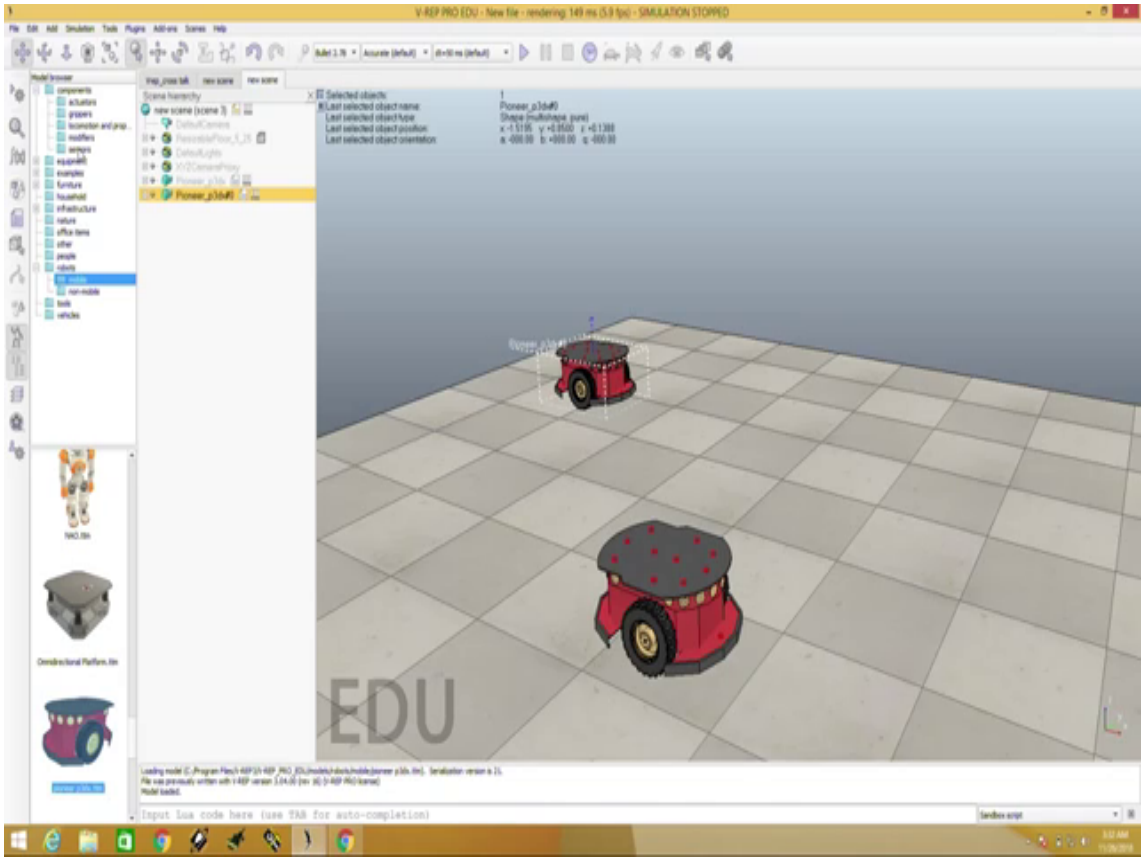

So, I am assuming that this screen you will get soon after you install it on your laptop ok. And, all of that is set, now what I suggest is you should first go and take a new sort of a scene take a new scene. So, you are ready now, and you will now go to basically the model browser go to the model browser and pick a mobile robo which is perhaps called pioneer right.

By the way it is important for you to realise that if you see a pioneer P3_dx kind of a robo, you can be more or less sure that you can physically buy pioneer. Most of the models in V-REP are essentially those components, which essentially are available as either robotic platforms end effectors sensors and so on. So, all these are nothing, but software components. So, if you can't invest in a physical purchase of a pioneer robo by installing this V-REP simulation software and then you try out in all the applications within that system.

Now, look carefully we want this scenario right you want 2 robo to move towards each other. So, you want 1 robo to move in the direction towards intersection and you want

the other robo to move in the direction towards intersection, which is coming in the other way. Now, go back to the V-REP demonstration you see that both the 1 robo is appears to be good and the other one in the simulator should be rotated.

Therefore, now you need to go to the tool browser and pick the rotate right you see the object there you rotate it and you rotate it by 90 degrees. So, now, you have rotated it. Once you rotated let us understand what this pioneer dx robo is all about it actually integrates ultrasonic sensors. So, let us go back and put this system here you have a robotic platform, you have a set of ultrasonic sensors in the front, and you have a set of ultrasonic sensors at the rear side. There are 8 in the front and there are 8 on this side. So, this is 1 part then there is also a requirement to add a component which is essentially the wireless transceiver part. So, let us put that wireless transceiver, go down and pick the wireless transceiver, and associate this wireless transceiver as part of this robot. So, essentially you can think of this as a parent the robot as a parent and the transceiver as a child of this parent. So, this association is being done.

So, they are now part of 1 unit and should we place it on top let us move it on top. So, there is 1 parent and 1 child another parent and another child. That is good and take that and place it there right. Now, look carefully at the pioneer robo, you see in the front side the ultrasonic sensors that are shown behind are also a set of ultrasonic sensors. Now, what we will do is we will essentially run an algorithm. You can see now –" https://www.youtube.com/watch?time_continue=893&v=jrOjmeFMeS0 at 34:23" that quite similar to the airplane example we took no 2 planes can collide at cruising height cruising altitude they come extremely close dangerous close, but decide to take 2 separate paths very intelligently and just move away from each other perhaps in the plane case changing their directions and also the altitude.

So, that they are not in the same plane anymore, 2 planes are not in the same plane perhaps that is what the algorithm actually does. In this case what is that algorithm? You can see on the left side there was a flash of hello world this is my number 2 3 2, hello world this is my number 2 3 3. Why did this happen at all, because transceivers were in the range and they realised that they are within the range, but they did not know how close they are.

So, next step is being in the range the other is to actually estimate the how close they are in terms of applying a sort of a threshold. And, once they come within a threshold distance they need to kick in this algorithm. And, decide in a manner that they do not have a collision right, this is the key point.