Robotics
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Lecture – 41
Intelligent Robot

Now, we are going to start with another topic and that is on Intelligent Robots, we will try to see how to design and develop an intelligent robot. Now, we call a robot an intelligent one if it can take the decision as the situation demands. Now, let us see how to design and develop; so this particular the intelligent robots?

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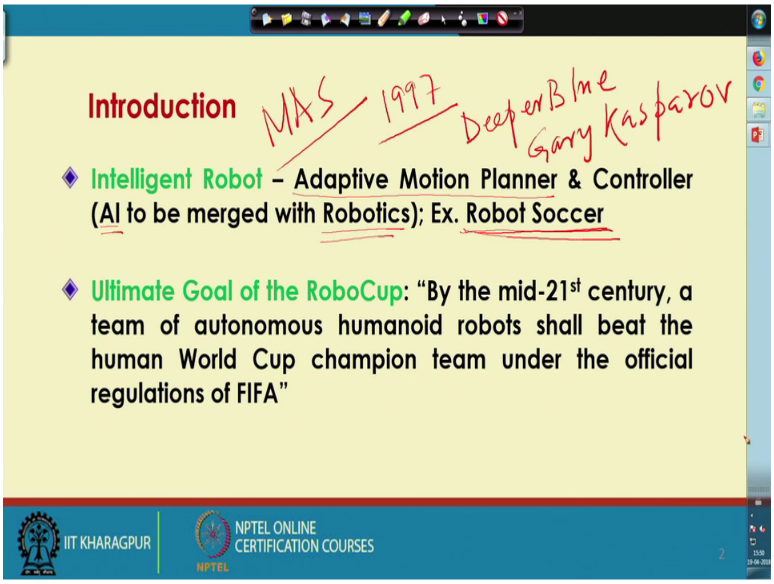

Now, this intelligent robots should have the adoptive motion planner, the reason behind this particular adoptive motion planner I have already discuss that it should be able to take the decision in a varying situation. And moreover there should be adoptive controller; now while discussing the control scheme of a robot, so we have discussed that each of this particular motor is equipped with one controller and if I use the PID controller; so, the gain values are to be determined.

Now, if I want to make it intelligent we will have to find out one controller which is also adoptive that been; that means, it can take the gain values in an adoptive way as the situation demands. Now if you want to design and develop this intelligent robot, so we will have to merge the principle of the artificial intelligence; that is AI with this particular the robotics and if we can merge the principle of AI or computational Intelligence that is CI to this particular robotics will be able to make the robots intelligent.

Now, here I am just going to take one example; the example of your the soccer playing robots; that means, your the football playing robots. Now, before go for this football playing robots I am just going to discuss a little bit like the way one expert system whose name is Deeper Blue could defeat the World Chess Champion; Garry Kasparov. So, we know that in the year 1997, one expert system the name of the expert system was Deeper Blue.

Now, this Deeper Blue could defeat Garry Kasparov; Garry Kasparov the world the chess champion and this particular expert system could defeat Kasparov using the principle of your the artificial intelligence. Now here, so this particular chess playing is a very simple task compare to this particular the soccer playing. Because the in chess playing the environment is static; so, we know what is happening here we know the position of the different players ok.

But here in your this particular the soccer playing that is the football playing task; the field is dynamic. So, the field or the scenarios are going to vary with time, so if the scenarios are going to vary with time; that means, your the dynamic environment. So, how to tackle? So, let us see and this particular problem is much more difficult actually what we do in soccer playing robots.

So, there are 2 teams and each team will consist of 11 players and among these players among the team batch there will be some set of cooperation and between the 2 teams there will be some set of competition. And using the principle of; so, this cooperation competition and updating. So, these particular the robots are going to play.

Now, each of the robot is having its own goal and that is nothing, but the function of the main goal of the team that is how to win that particular the game or how to score the goal? Now each of the robots as I told is having its own goal and that particular goal is a function of the main goal. And each of this particular robots are intelligent and they are called agent and that is why this soccer playing team is nothing, but the Multi Agent System that is MAS; Multi Agent System. Now here in this particular multi agent system each of this particular robots are intelligent or the agent and they are going to perform in the optimal sense so, that the team can ultimately win that particular the game.

Now, here as I told that we need adoptive motion planner and adoptive controller; that means, if I want to design and develop, the intelligent and autonomous robot. So, we will have to use the adoptive motion planner and the adoptive controller. And that is why the soccer playing robots has becomes so, much popular and the main purpose of this soccer playing robots is how to design and develop that particular intelligence of these robots.

And so that so these particular robots can work in a multi agent system and ultimately the team of this particular robots can win that particular the game by scoring goal; now, here the ultimate goal of the robocup was set as follows. So, by mid 21st century a team of autonomous humanoid robots should beat the human world champion team under the official regulations of FIFA.

So, that particular goal was said by the investigators or the researchers working in this multi agent system of robotics. Now to reach that particular goal actually many people are working throughout the world; some problems have been solved, but still there are many such open research issues which are to be solved in a very efficient way. So, that a team of autonomous humanoid robot will be able to beat the World Cup champion team the football team according to the regulations of FIFA.

So, this is a very complicated task and to reach this particular that the target; so, we will have to make improvement in different areas so, that we can reach that particular the target. Now, let us see a simplified version of that like how to implement or how to design and develop one intelligent and autonomous robot?

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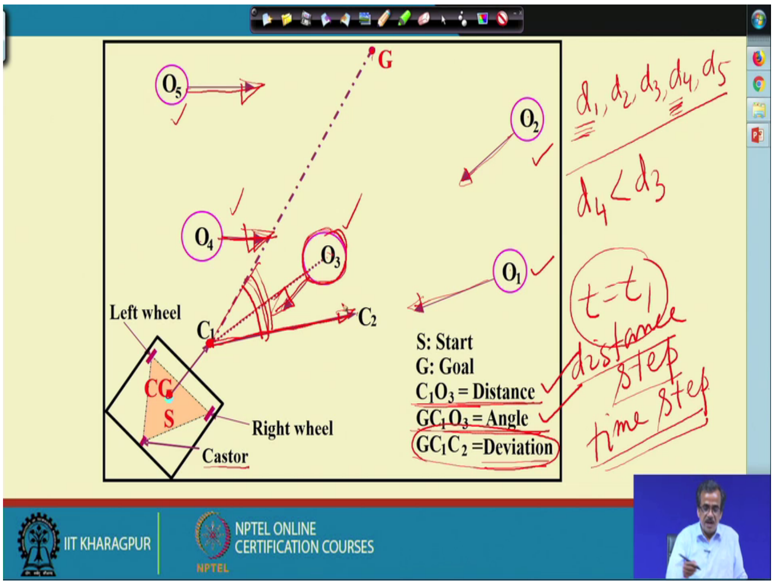

Now, here I am just going to take one scenario now this is a very simple scenario, but this scenario can be made much more complicated also. So, I am just going to concentrate on so, this simple scenario; now supposing that; so, this is actually the starting point for a particular robot and this is the goal and here we are going to consider a 2 wheeled one castor robot.

So, this is the left wheel, the right wheel and we have got a free wheel here or a support sort of thing and that is nothing, but the castor ok. Now, so, this point indicates the CG of this particular robot. Now, the physical robot I am just going to solve and I am just going to explain after sometime in much more details. But before that let me let me explain the problem which is going to be solved with the help of this particular the robot.

Now at time t equals to say t 1 say t equals to t 1 supposing that; so, this is nothing, but the CG of this particular the robot and supposing that this is the goal the G is the goal and we have got a few moving obstacles like we have got O 1, O 2, O 3, O 4 and O 5.

Now, for simplicity; so I am just going to consider only say 5 obstacles. Now, each of these obstacles are moving with some velocity or speed along a particular the direction. For example, O 1 with some speed it is moving in this particular direction; similarly O 2 is moving with this particular direction with some speed, O 3 is moving with this particular direction, O 4 is moving along this direction and O 5 is moving along this direction.

Now, here to solve this particular motion planning algorithm; our aim is to find out the collision free and time optimal path for this particular the mobile robot. Now to solve this particular problem we take the help of some sort of the concept of the distance step and your the time step. So, we consider the distance step and time step; now during a particular time step, so the robot is going to move through a particular the distance and that is nothing, but the distance step.

Now, at time t equals to t 1; supposing that this is the CG of the robot and these are all predicted position of this particular the obstacle. Now, here if it wants to find out what should be the collision free path for this for a particular time step; so, what we will it will have to do is first thing it will have to find out which one is the most critical obstacle?.

Now here there are 5 obstacles and we consider the distance between the present position of the robot and the position of this particular obstacle the different obstacle. And we try to find out what should be the distance between the robot in this particular the obstacle, the robot and this particular the obstacle. So, here there are 5 obstacles; so, I will be getting 5 distance values and out of those 5 distance values. So, we will try to find out that which one is the minimum.

Supposing that the distance values are d 1, d 2, d 3, d 4 and d 5; d 1 is the distance between the obstacle 1 and the CG of this particular robot and. So, this is nothing, but the d 1; similarly I will be getting d 1, d 2 up to d 5; we compare all the d values and we try to find out the minimum. Now, supposing that; so out of all such d values and if you concentrate on this particular scenario. So, this d 4 is found to be the minimum; that means, your; so, this particular obstacle that is O 4 obstacle is physically found to be the nearest to this particular the robot. But here; so this particular the obstacle O 4 is moving in this particular direction; on the other hand, so the O 3 another obstacle is moving towards this particular the robot.

Now, if I compare the distance now here; so, d 4 will be less than the d 3, but as this particular obstacle is moving towards the robot. So, this will be considered the most critical obstacle, but not O 4; that means, your O 3 is consider as the most critical obstacle because it is moving towards that particular the robot. Now if I just select these as the most critical obstacle the distance between; so, this particular the present position of the robot and the obstacle. So, this is nothing, but the distance input for the motion planner, so C 1, O 3; C 1, O 3 is nothing, but the distance input for the motion planner.

Similarly the angle between the goal; the present position of the robot and the obstacle O 3 that is your G C 1 O 3; so, this particular angle is another input for the motion planner. Now here for this motion planner I have got 2 inputs; one is the distance another is the angle. And to avoid collision, now we will have to find out like what should be the angle of deviation. Now here; so this angle G C 1, C 2 is nothing, but the deviation angle; so this is nothing, but the deviation angle.

That means, to avoid collision with this particular moving obstacle, the robot is going to follow this particular path or the robot is going to deviate from this particular path just to avoid the collision with the moving obstacle. So, the output of the motion planner will be your; so this particular the deviation angle that is nothing, but G C 1, C 2. So, this is nothing, but the deviation of the motion planner and we can also consider another the output of the motion planner that is nothing, but the speed of the robot or the speed or the acceleration of these particular the robot.

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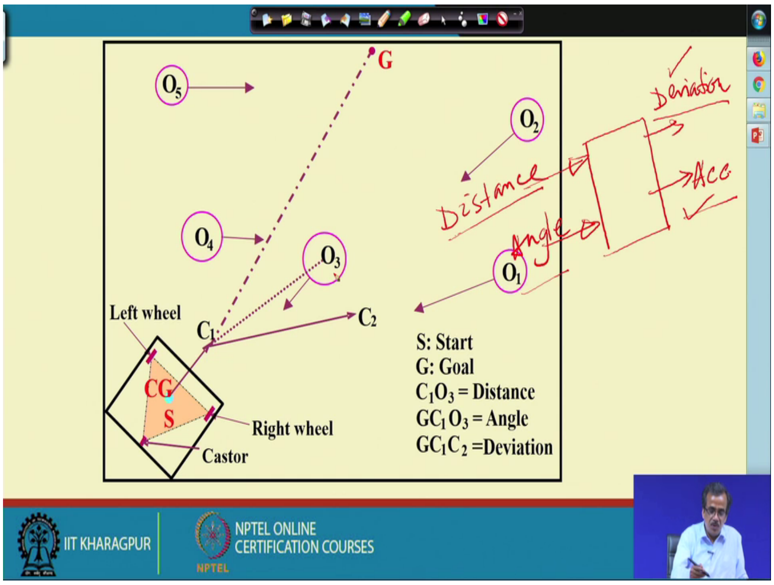

So, if I just try to find out what should be what should be the inputs and outputs of the motion planner; now if I just draw the block diagram of these particular motion planner, there are 2 inputs one is the distance input the distance input and another is your the angle input. And there are 2 outputs one is nothing, but the deviation angle and another could be the speed or the acceleration of these particular the robot.

So, if I know the acceleration we can also find out the speed. So, there are 2 inputs distance and angle and there are 2 outputs that is a deviation and acceleration of these particular the robot. And using this particular your motion planning algorithm; so we can find out; so what should be the angle of deviation and what should be the acceleration so that the robot can avoid collision with this particular the moving obstacle. Now, let us see how to implement in the real experiment.

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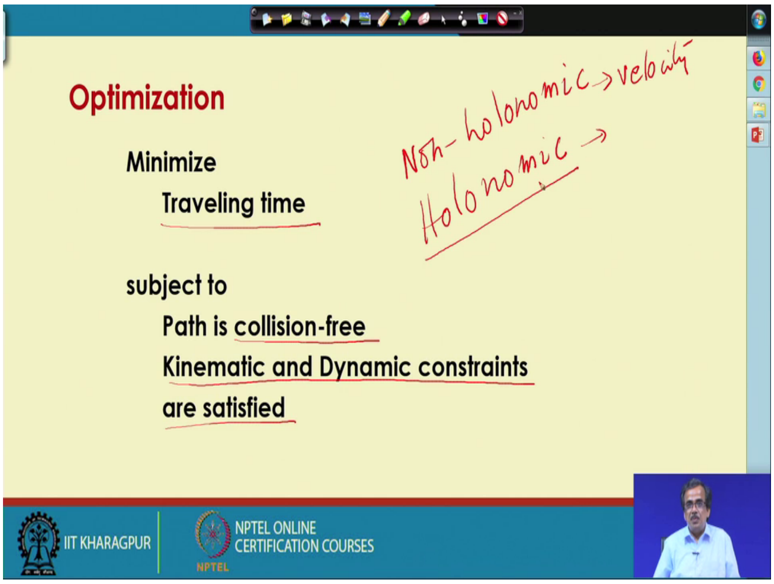

Now, here we can consider the this is nothing, but an optimization problem and our aim is to minimize travelling time; that means, the robot will be able to reach the goal, starting from the initial position in minimum time. And at the same time the path should be collision free; so there should not be any collision between the robot and this particular; the moving obstacle. And moreover the kinematic and dynamic constraint of this particular robot is to be the fulfilled.

Now, regarding these particular kinematic and dynamitic constraints actually before I discuss little bit; so, I will have to show the physical model of these particular the robot and now I am just going to show you the physical robot the physical model of this particular robot.

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Now, this is nothing, but a 2 wheeled one castor robot; now we can see that we have got one wheel here, we have got another wheel here and we have got one support and that is nothing, but; so this is the castor. So, this is a 2 wheel one castor robot and this is nothing, but a 2 wheel one castor differential dry robot.

Now, for each of this particular wheel; so we have got a separate motor. So, this motor is connected to the wheel and of course, for each of this particular motor; there must be a controller. And here we use some sort of PID controller just to control the, this particular the motor. So, that we can generate some speed at the 2 wheels and accordingly will be getting that movement of this particular the robot.

Now, we will be discussing in details how to make it intelligent? But before that let me tell you now regarding this kinematic and dynamic constraints; so, the kinematic constraint for these particular robot could be of 2 types. For example, say there could be non holonomic constraints, there could be non holonomic constraints; so, non holonomic constraints non holonomic constraints and there could be holonomic constraints.

So, by non holonomic constraints we mean those constraints which are dependent on velocity. So, these non-holonomic constraints are dependent on velocity of the robot and these holonomic constraints are independent of the velocity. So, these constraints are to be fulfilled otherwise we cannot generate the movement of this particular robot particularly whenever it is taking a term.

Now, if I just concentrate once again on the physical model; we can see that supposing that it is going to take a turn, the robot is going to take a turn. Now if it is going to take a turn on the left side; so, on the right hand side actually the RPM or this speed of this particular wheel should be more compared to that that of the other side, then only I can take a turn.

And while taking this particular turn; so these particular constraints like non holonomic and holonomic constraints are coming in to the picture. And moreover each of this particular the motor is controlled by the controller and this motor is going to generate the torque required just to give some sort of rotation to the wheels. Now, to determine the power rating of this particular motor; so we always try to find out how much is the torque requirement of these particular the wheels?.

And so, these dynamic constrains is going to tell us like how to decide the power rating of the motor so that your these particular motor will be able to provide the necessary torque; so that it can generate that particular RPM to this particular the wheel. So, these kinematic and dynamic constraints are to be fulfilled and at the same time the path has to be the collision free. Now let us see how to carry out; so, this particular the real experiment.

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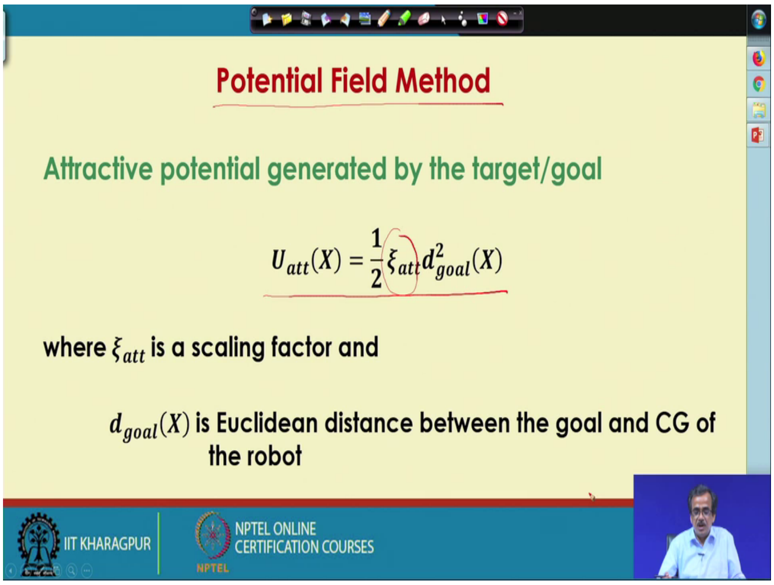

Now, before I go for this particular real experiment the motion planning algorithm which I am going to use for this experiment is nothing, but the potential field method. The principle of which I have already discussed in much more details and as I told now this particular potential field method is going to work based on the concept of the attractive potential and the repulsive potential. Now, let me repeat that this attractive potential U attractive X is nothing, but half zeta attractive that is nothing, but a constant value d goal X square and this d goal X is nothing, but the distance between the goal and this particular the CG of the robot.

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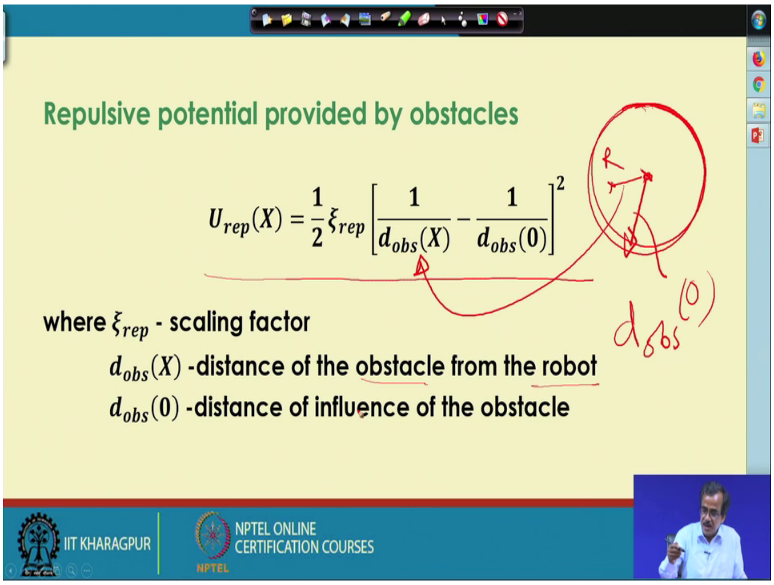

And this goal is going to attract that particular robot and on the other hand we have got one repulsive potential which is nothing, but your U repulsive X; this I have discussed in much more details and here I am just going to consider. So, this particular expression for the repulsive potential half zeta repulsive multiplied by 1 divided by d obstacle X minus d obstacle 0 square.

Now, this particular d obstacle X is nothing, but the distance between the obstacle and this particular robot. And your d obstacle 0 is nothing, but supposing that I have got an obstacle here. And surrounding that obstacle we consider one circle and that is called the circle of influence. Now if this is the center of the circle; so, this is nothing, but is your d obstacle O set of thing. And these d obstacle X; supposing that the robot is here; so, this particular distance is nothing, but is your d obstacle X ok.

Now, using this actually the obstacle is going to put some set of repulsive force on the robot. And using this attractive and repulsive force are attractive and repulsive potential, the robot is going to moved towards the target or the goal. And ultimately the robot is going to reach the goal and this robot will be under the combine action of attractive and repulsive potential or attractive and repulsive force.

And I have already mentioned that we consider that there are 2 inputs for these motion planer that is your distance and angle. And there are 2 outputs that is nothing, but the angle of deviation and acceleration or speed of this particular the robot. Now, this I have already discussed in much more detail. So, I am not going to spend much time on this.

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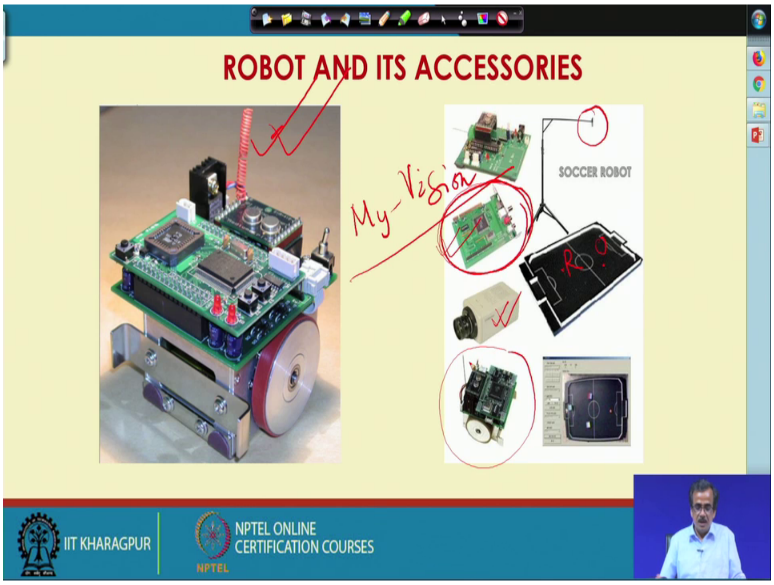

And now I am just going to show you like the robot the physical model; I just showed a few minutes ago. Now, this is actually the photograph of the same robot now here you can see that so, these are the wheels castor we cannot see.

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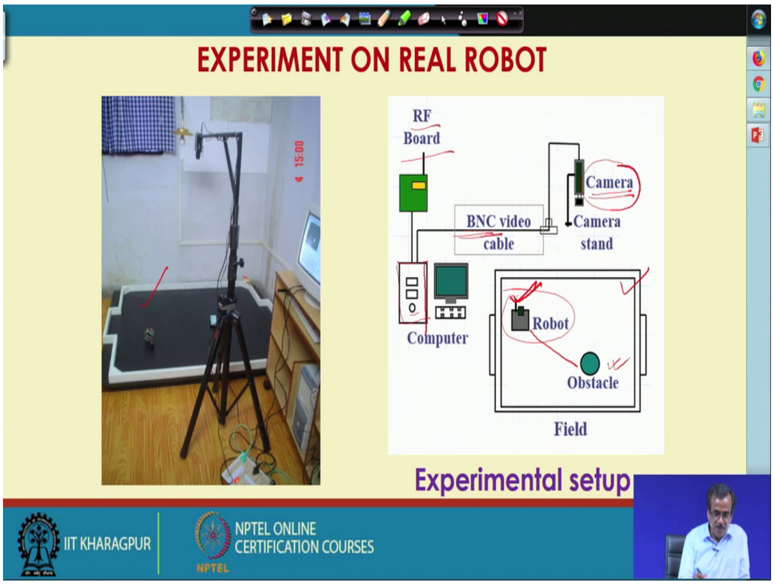

Now this is nothing, but actually your this is nothing but the antenna use for the radio frequency module. Now, this robot is wireless; so, we will have to use some sort of RF module or the radio frequency module. So, which I am going to discuss in details and with the help of this particular antenna; so, you are going to send signal to the controller for this particular the motor.

Now, as I told that to control the movement of this particular, the wheel we have got a motor. The motor is not visibilities there inside and each of this particular; the motor is connected to the controller and these robot is having actually the mic controller. So, that little bit of calculation little bit of the decision it can take with the help of that particular motion planning algorithm.

Now, let us see how does it work? Now here actually we are going to take the help of one camera. So, this is nothing, but a CCD camera and this is the stand of the camera. So, here we actually inside that particular the camera and this is the field on which we are going to carry out this particular the experiment. So, on this particular field we have got said the robot say robot is denoted by R and we have got some obstacle say it is denoted by O.

Now, let us see how can this particular robot take the decision just to avoid collision with these particular the moving obstacle. Now, here we can see that this is nothing, but is actually the my vision board; so, this is my vision board. And this particular the hardware; now it is for how to carry out that image processing online with in a fraction of second? Now this particular my vision board, so we will have to put it in the CPU or the computer and I am just going to tell you the method we just carry out this particular the experiment.

So, this my vision board has to be put in this particular the CPU and once a put this particular the my vision board. Now let us see how can you send this particular information of the environment so that we can carry out; so this particular the experiment and this is actually the whole view of this particular the robot.

Now, let us see how can you implement that this particular the principle of the motion planning to make it intelligent ok? Now this shows actually the experimental set up we developed; now this is nothing, but the field. So, this is nothing, but field in a real experiment; so, this is the field in real experiment, the same field I am just drawing it here and as I told that we have got this particular robot. So, this is nothing, but the robot and we have got the obstacle here.

Now, let us see how can a take the decision to avoid collision with this particular the moving obstacle. Now here we use one camera that is called the overhead camera, I can also use onward camera; that means, the camera can be mounted on the body of this particular the robot.

Now, here we had just going to a put one the overhead camera and this camera has to be calibrated. So, the camera calibration is the first task actually the quality of the image collected with the help of camera depends on a number of parameters. For example, say if depends on your what should be the focal length of the lens; it depends on some set of scaling factors and some other factors those factors are to be determine with the help of the calibration. So, this particular camera has to be calibrated first and supposing that so this camera has been calibrated. Now with the help of camera; so, we can collect information of these particular the environment; that means, we can take the snap of this particular environment at a regular interval.

Now, depending on this speed of this particular camera; so, we can take snap of this particular environment at regular interval. And this particular information that is the information of the environment or this particular image that will pass through the BNC cable and through this BNC cable; the information of the image or the environment it will go to the; the CPU or this particular the computer.

Now, here inside this particular CPU; we have put that my vision board or the image processing software. So, the information of the image will enter this my vision board and there will be some sort of image processing. And through this image processing the principle of which I have already discussed in much more details; we can find out the information of this particular the environment.

That means, I can find out the distance between the robot and this particular obstacle and the angle through which; so, this obstacle is moving towards the robot and these 2 are nothing, but the inputs of the motion planner. And once we have got the inputs of the motion planner; now the motion planning algorithm that is the potential filled method is going to determine what should be the output; that means, what should be the deviation and what should be the acceleration or the speed of the robot.

And using this particular deviation angle and the speed of the robot; so, through some small programming; we can find out what should be the RPM of the 2 wheels ? Now, once we have calculated; so this particular RPM values, so, what a do is. So, this particular information will pass it through this particular your the radio of frequency module that is nothing, but the RF board or the RF module.

And this through this RF module; so, we are going to pass the information through this particular robot. And in this particular robot we have got your antenna; so, through this wireless communication the information regarding, the RPM or the speed requirement of the 2 wheels that will pass through your; the controller of this motor which is connected to the 2 wheels of the robot.

And now with the help of this controller like the PID controller or PI controller; so, this particular motor is going to rotate the wheel and we will be getting this particular movement at the 2 wheels of the robot. And consequently the robot will be able to move in the forward direction or in the backward direction; it will be able to take some turn either clockwise or anti clock wise. So, this shows actually your the photograph of this experimental set up this is nothing, but the overhead camera.

And this is the field and we can see that; we have got this particular the robot here and we have got the obstacle here ok. And this is the CPU which you use for the carrying out this experiment and this is the display of that particular the computer. And let us see how can you carry out; so, this particular the experiment.

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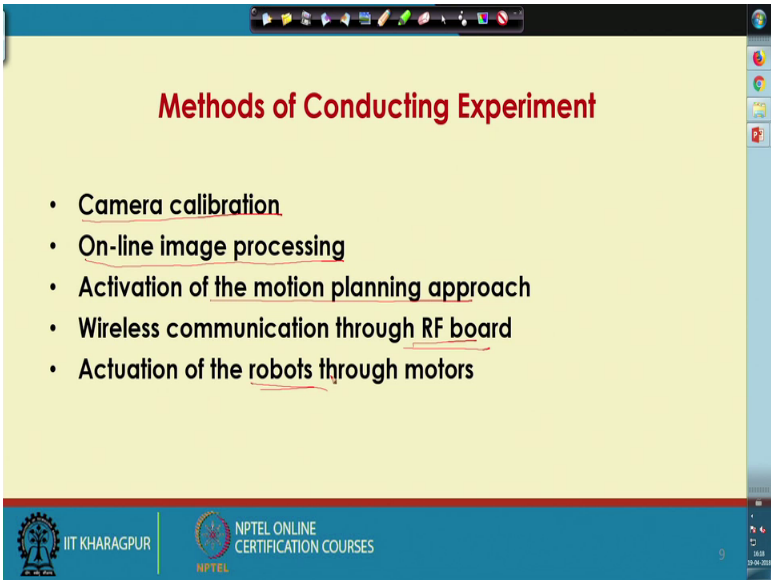

Now, to carry out the experiment as I told that these are the different steps which are to be followed; for example, the first step is we will have to calibrate this particular camera. Then we can go for some sort of online image processing which I have already discussed, then we will have to activate the motion planning approach; that means, here we are going to use the potential field approach.

Then there must be some wireless communication through the radio frequency module. So, that we can pass the information of the required RPM at the 2 wheels to the respective controller of the motors and with the help of this particular controller the motor is going to generate that particular the required motion or the required torque. And then will be able to get some set of mote band of these particular the robot ok.

Now, I am just going to show you one video just to show you this particular experiment; the way we carried out this particular the experiment. Now here I just one to acknowledge we got one DSD project that is Department of Science and Technology; Government of India projects.

With the help of this particular project actually we conducted this particular the experiment and the video of this particular experiment I am going to show you. And here one SRF worked on this particular the experiment Dr. Nirmal Baran Hui who worked on this particular the project to develop this particular the experiment.

So, we are just going to show the video of our experiment like how could we develop the intelligence to the robot; that means, how could you design and develop an intelligent the wheel robot, the mobile robot. So, I am just going to show you that particular the video.

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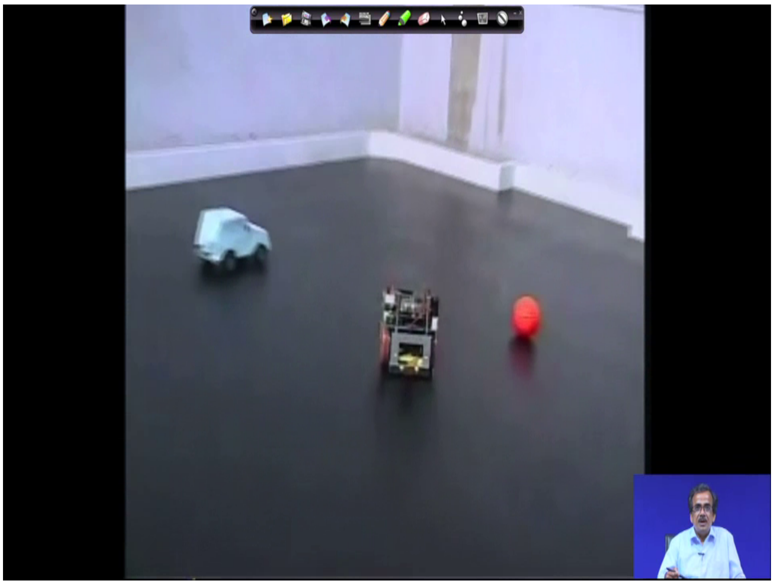

Now, this is the robot which I actually showed you and here so the robot is now moving in the forward direction. And it will be able to move in the forward and the backward direction. And now I am just going to show you the way it can avoid the collision with the 2 static obstacle. Now this particular robot, the wheel robot can move in the forward direction and backward direction. Now, I am just going to show you that how can you avoid collision with the one static obstacle; so this is nothing, but the static obstacle.

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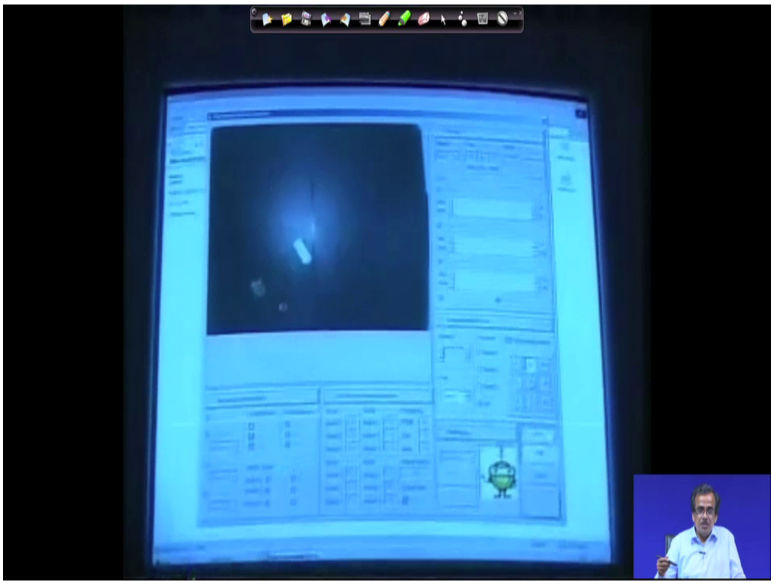

So, with help of this particular the robot; with the help of the motion planning algorithm, we will be able to find out the collision free path.

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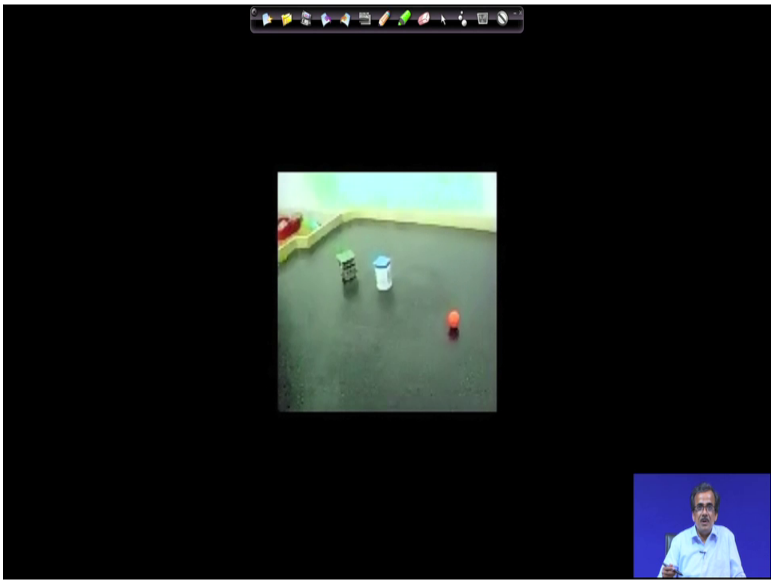

Now, this is another example like how to avoid the collision with the 2 static obstacles? So, the robot is going to a avoid collision with both the static obstacle and it is going to reach the goal.

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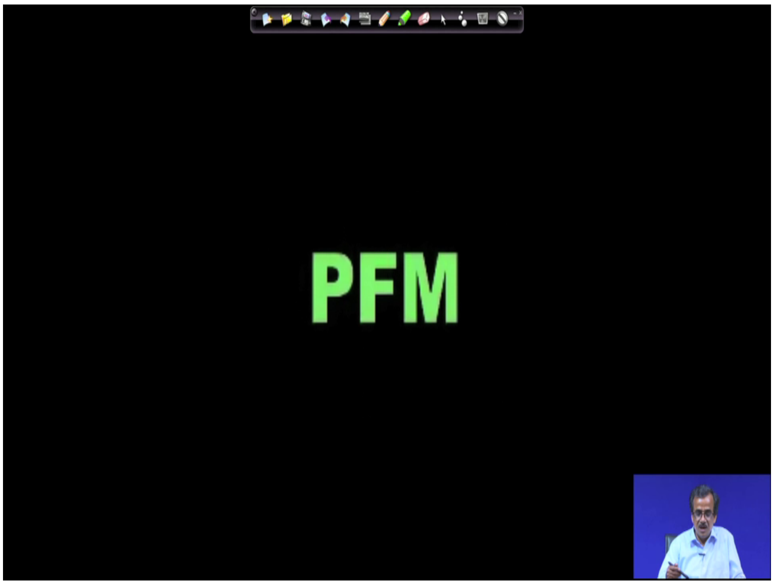

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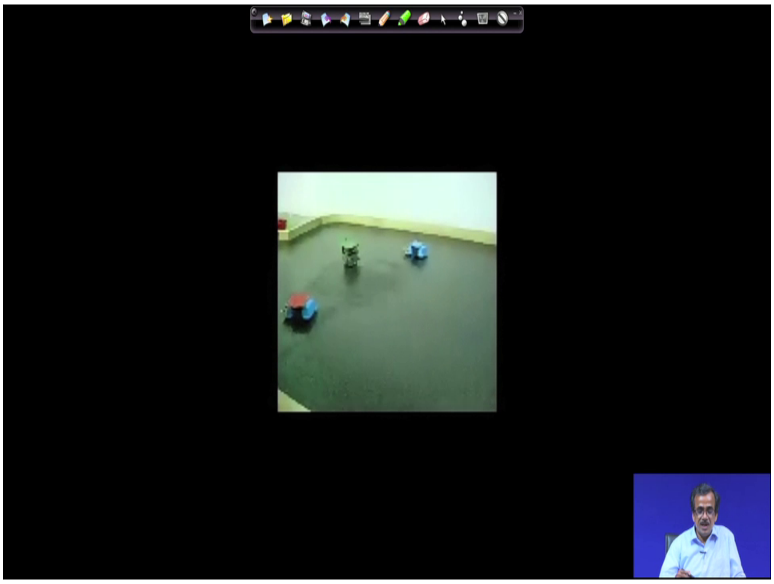

Now, I am just going to show you how to use the potential fill method? Now, you can see that the robot has become almost stationary and after it has crossed the obstacle the moving obstacle, now it is moving with the high speed to reach that particular the goal.

Now, this is the way with the help of the motion planning algorithm and with the help of this controller; we can incorporate intelligence to this particular the robot. Now here although we used some set of motion planning algorithm to make it intelligence, sometimes we take the help of some set of reactive control along with some set of the motion planning algorithm; just to incorporate intelligence to these particular the robot.

Now, the principle of which you have used here to make this particular wheel robot and intelligent one more or less the similar type of principle we can use to make the different types of mobile robot intelligence. For example, we can make say multi legged robot like say 4 legged robot, 6 legged robot or 2 legged robot and intelligent one using more or less the similar type of principle.

Now, here if I just consider a legged robot; so, beside this motion planning we will have to consider the gate planning also. Now, we are not going to discuss the gate planning and other things in details ok. Now, if you are really interested you can have look appeared text book that is the fundamentals of robotics written by me. Now, that particular book is the text book for this particular course as I mentioned earlier if you have some interest to no more. So, we will have to concentrate on that particular text book just to collect more information.

Thank you.