Wheeled Mobile Robots
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Lecture – 18
Sensing and Perception

Hello everyone, welcome to the Mobile Robotics course. I am Asokan from the Department of Engineering design at IIT Madras; I will be teaching you the Sensing and Perception for the next 3 weeks and how this sensing and perception can be used for developing autonomous robots also will be covered.

In the last few classes, you have been listening to the details of mobile robots; the wheeled mobile robots, its construction, and the kinematics. And now by now you know that, mobile robot can actually move around; it can actually do many tasks. And once you know the kinematic parameters, you will be able to identify the position of robot and then identify its location; that is basically for the robot to know its location based on the sensors attached to the wheels.

So, in this part of this course, we looking at the sensors and how the sensors can be done to give a good perception of the environment to the mobile robot. So, that is going to be the focus of this course.

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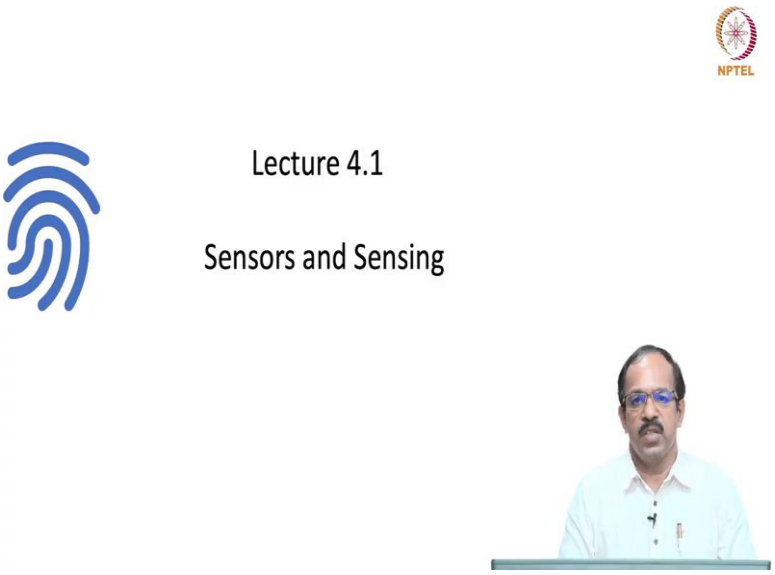

So, the first part of this course will be focusing on sensors and sensing. So, what are the different types of sensors used and how they actually do the sensing in the environment that is going to be the focus. But before going into the sensors and sensing; let us look at, why do we need sensors in robots or what is their role in the overall application of mobile robots for various applications.

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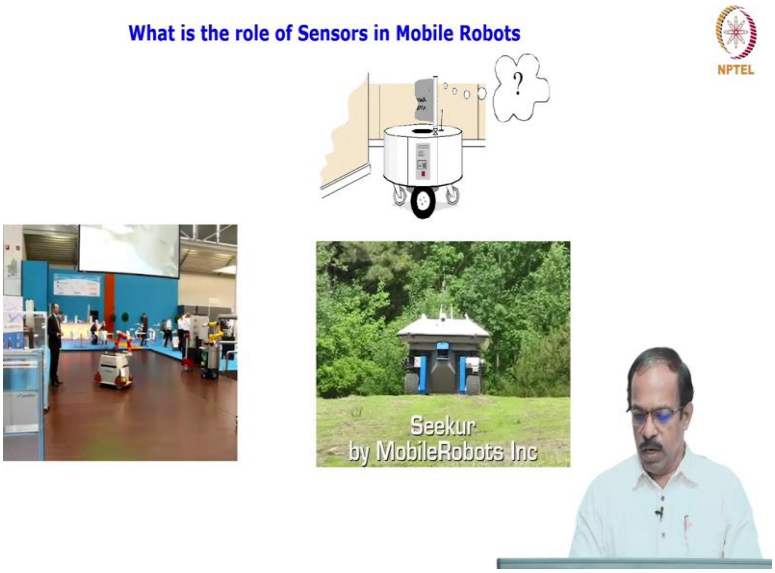

As you know there are different kinds of mobile robots available and some of them are remotely operated, some of them are autonomous; some of them are Omni directional. So, you will see that, the robots vary in their construction and their application. As you can see here in this one; you will see that, this is a mobile robots with a manipulator attached to it, except for the manipulator it is like a normal mobile robots.

And you can see that the robot has to do many task in this environment; so sometimes robot has to go and pick up something, sometime it has to insert something on a workpiece or sometime it has to do some inspection of some objects. In all these things, the robot has to make many decisions; the robot has to see whether it can actually identify the objects.

It can identify the location where the inspection has to be done, as well as the robot need to know its own position and where it is going and is there any obstacle also. Now, we will see that the other robot what we are seeing here, which is actually a Omni directional robots; we call this as the, it is a Seekur robots.

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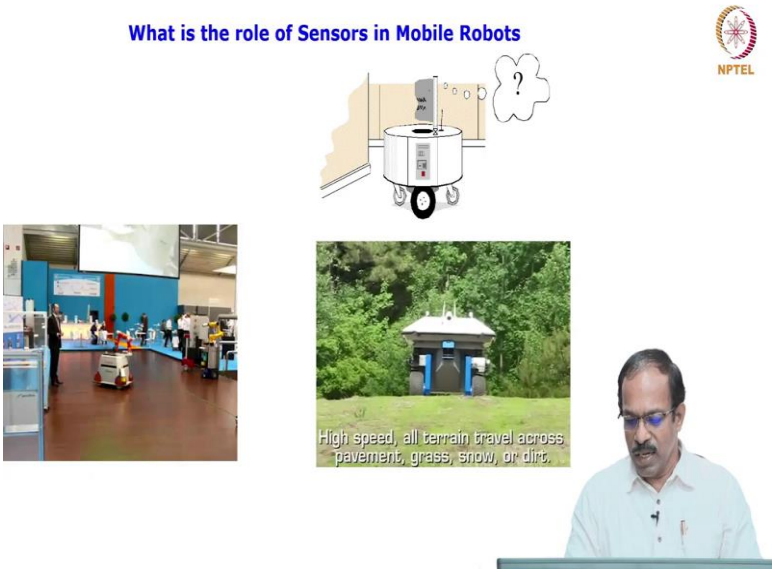

It has got 4 wheels and you can see that the 4 wheels are steerable as well as it is powered also. So, with this kind of a configuration, the robot can actually have Omni directional motion as well as it can carry out the task which are assigned to it; and you can make it fully autonomous also.

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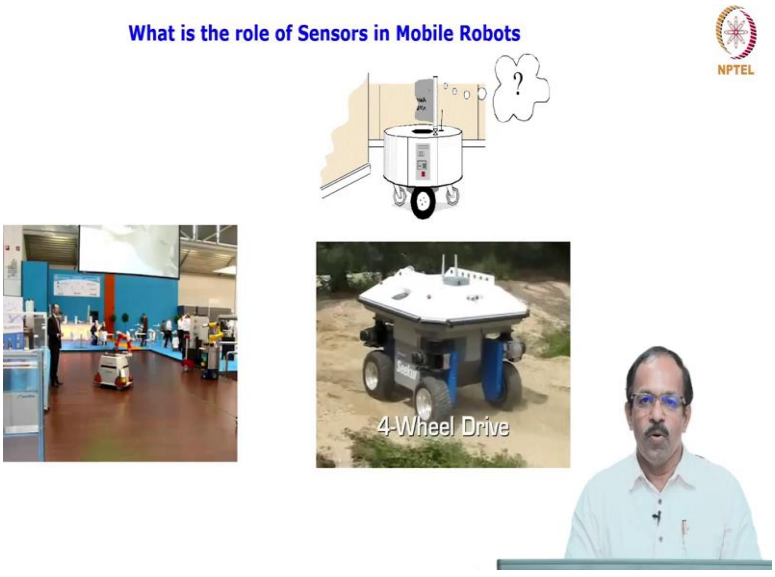

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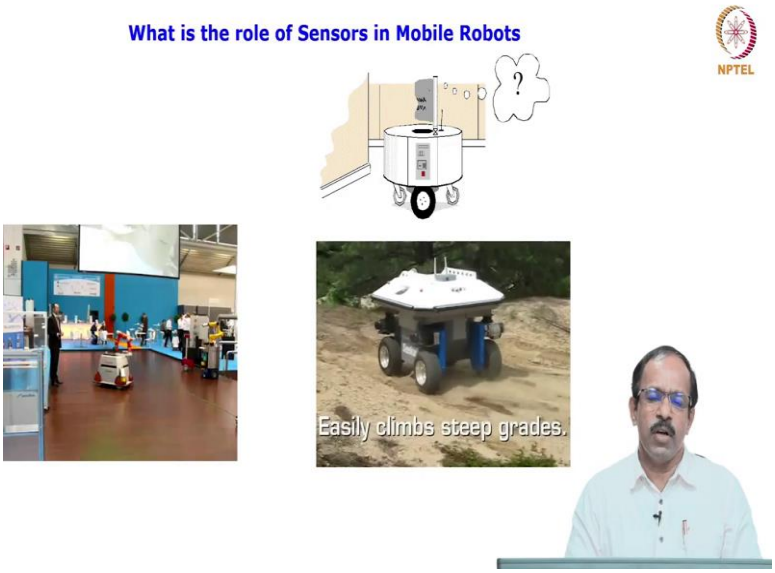

So, we will see ok, when we talk about a remote operation, in autonomous operation; there are major differences in the way the robot has to behave.

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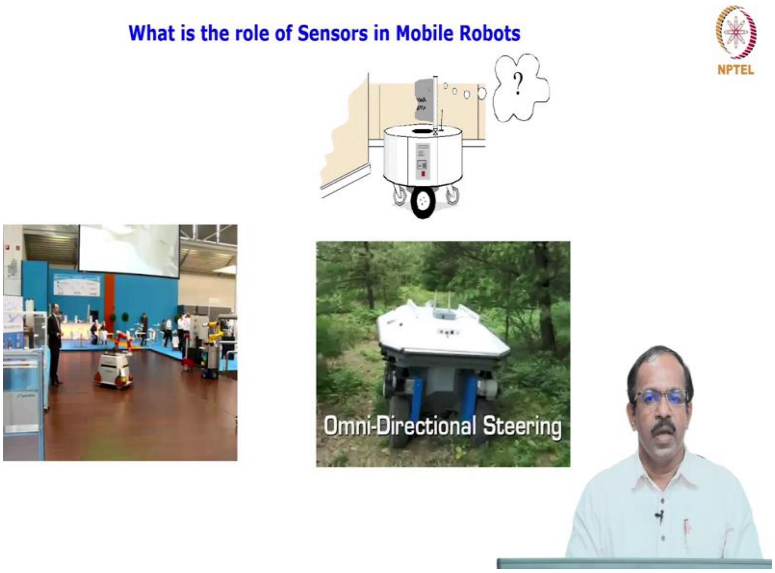

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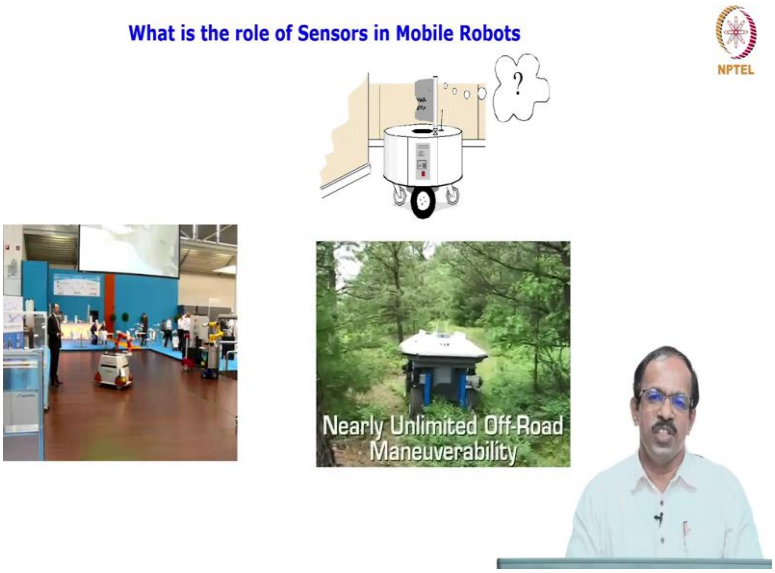

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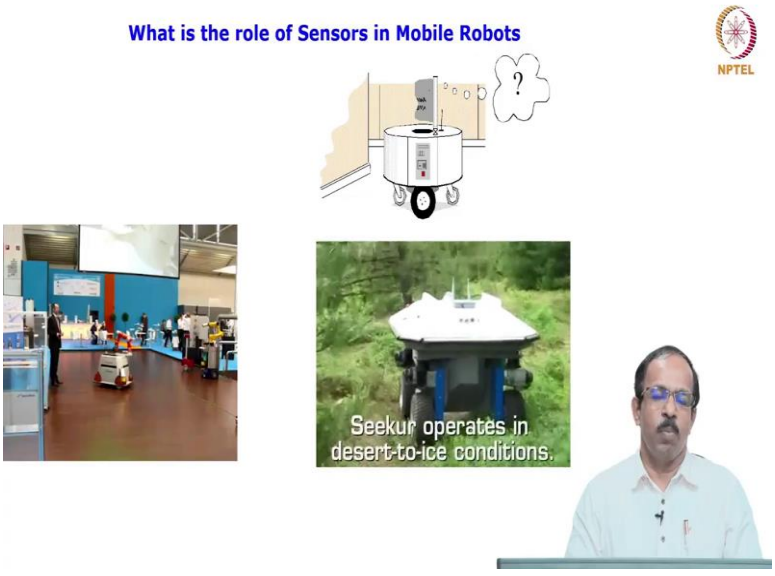

In a remote operation as you know, the robots just need to follow the instruction given by the operator, whether he is sitting close by or far away does not really matter.

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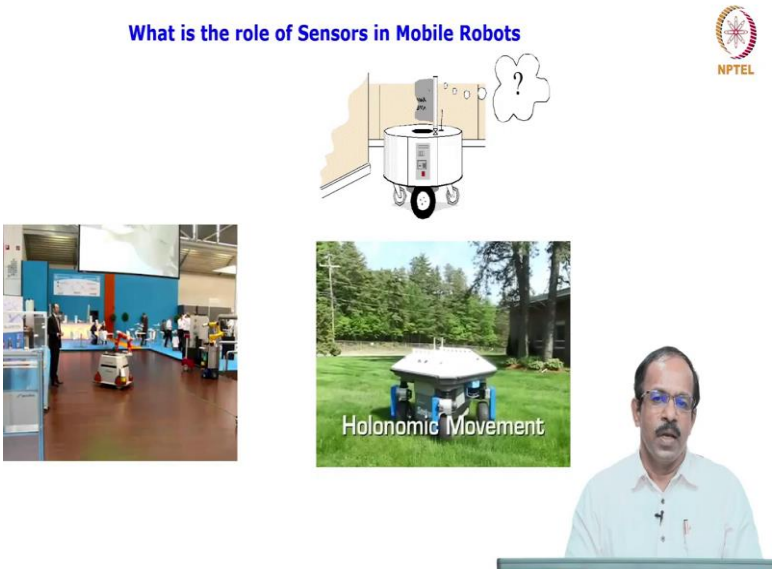

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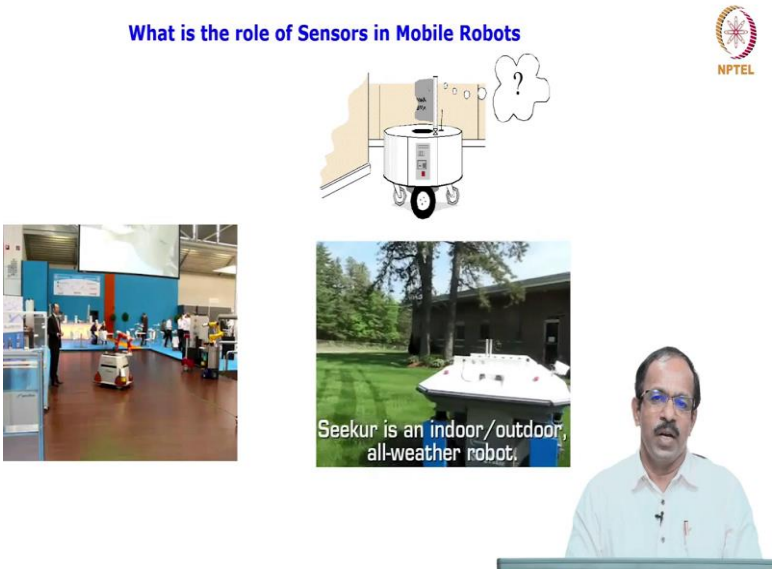

And there is no need of information processing or decision taking in the case of remotely operated robots.

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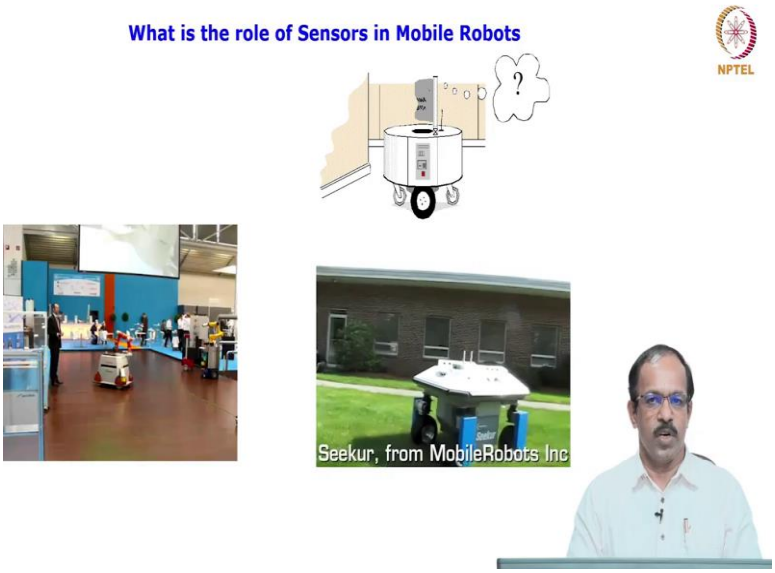

But in the case of a mobile robot which is autonomous, there are many other things robot has to do and this can be done only with the help of sensors.

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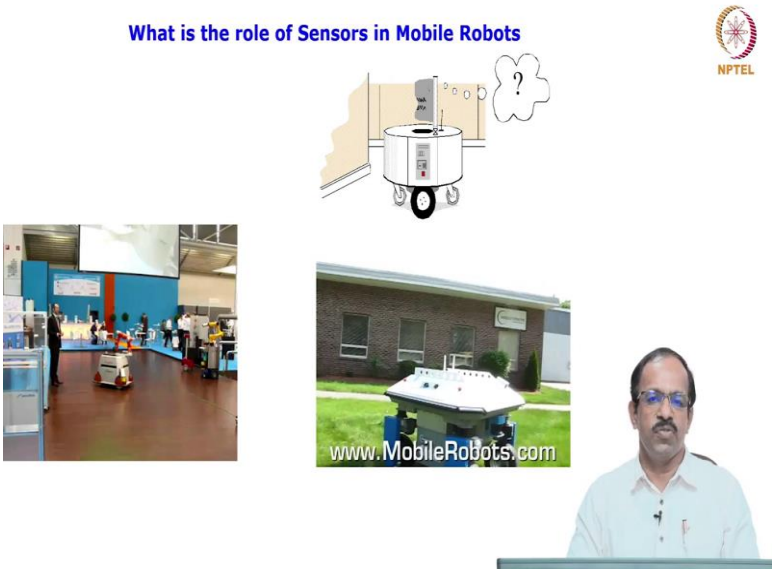

The robot needs to have different kinds of sensors and process the information in order to take a decision or even to know where it is and then to take decision and then execute its decision. So, this is one of the important requirement of a mobile robots.

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And for autonomy, we know that there are many things to be understood; for example, as you can see here in this video. So, it is not only the robot on its own; but the robot if it has to be autonomous, we can see that the robot has to collaborate with other robots also or they need to have coordinated motion also.

So, if it is fully programmed, the robot has to understand what is the environment, what is it is surroundings, how the other robots are behaving and based on other robots behaviour, the robot has to adjust its own behaviours also. So, in this case it is fully programmed, online decision making is not there; but in case there is an online decision making needed, then the robot has to observe its surroundings, understand the surroundings and then make decision.

So, are this require sensors? So, sensors are one of the major requirement in a mobile robot or for that matter any robotic system, sensors play a major role. But in the case of mobile robot, it plays an important role because of the perception it needs to have around surroundings.

The surroundings are not the same, unlike an industrial robot, where ones you fix it, the surroundings would not change drastically; but in the case of mobile robot, there is a large change in the surrounding. And that is why we need to have the sensors in order to give a perception of the environment to the mobile robots.

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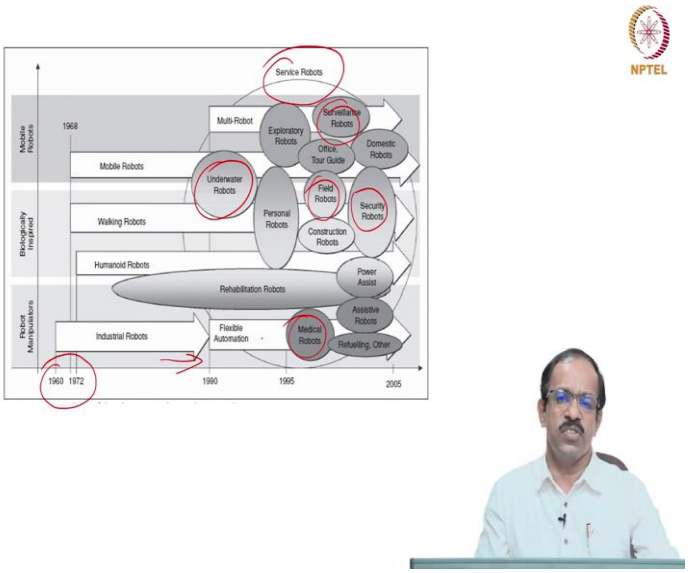

So, what are these kinds of mobile robots that we are talking about? Ok. This is just to tell you about how the robots evolved over a period of time and how that is actually changing the way we look at the sensors and the perception. If you look at the robotics growth or the evolution of robotics; you can see that it was only in the only 1960s or 70s we got the industrial robots.

Yes, industrial robots also needed sensors; they granted to have contact sensors or proximity sensors, touch sensors etcetera and even vision sensors were added to add some additional capabilities. Over a period of time, we had lot of development in the case of industrial robots and lot of technologies were developed.

Later on we realize that, we are still not able to go to the people or we are not able to go close to the human with the industrial robot and that is where we got these service robots or we called this is a field and service robots. This field and service robots play a major role now; because all the technologies what were developed for industrial robots and the technologies developed in the research centres for mobile robots, walking robots and humanoid robots.

They have, they come handy in developing new applications for robotic technology and that is why we have underwater robots, we have security robot, we have field robots, we have surveillance, we have aerial robots, medical robots, etcetera, etcetera. And all these

robots some of them are mobiles, some of them are not mobile; but whatever may be the case, we have an important requirement of sensing and perception.

Without sensors and without perception of the environment, no mobile robot can actually work. And that is why we need to understand the various kinds of sensors and how these sensors are used for mobile robot navigation.

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You can see that some of these robots like here. So, as you can see here the first one, this one is the rover, the mars rover and then you have this autonomous mobile robots wheeled robots. And most of you know about the latest trend in the mobile robots, which is the autonomous car.

So, there are lot of autonomous, automobile companies trying to develop autonomous cars by adapting the technologies available in the robotics field and then using it, integrating them with the automobile system in order to get driverless cars.

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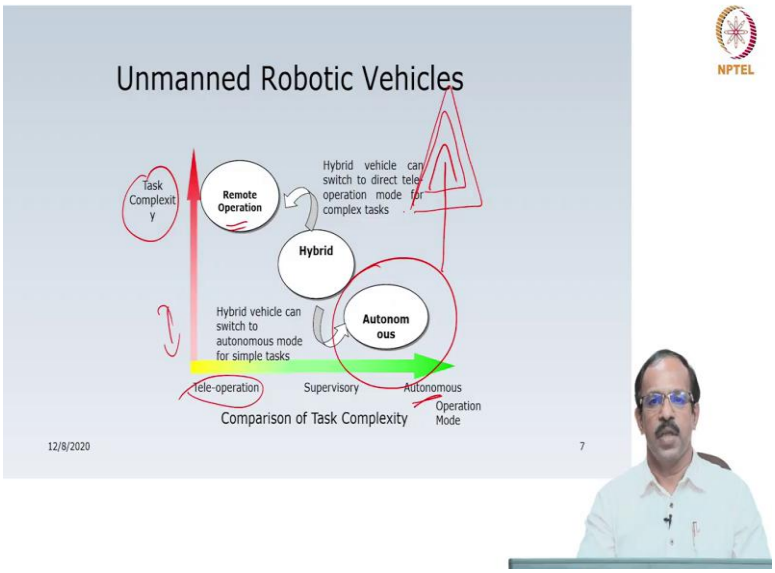

So, the sensing and perception is the most crucial in the case of such robots; most of you know that when you want to go for a, when you want to go for a autonomous car, you need to understand the why or you know to go for a. In order to design a autonomous car, we need to know that, the robot has to identify the road robot has to identify the surroundings, the robot has to identify the pedestrian, has to identify the signals.

So, there are lot of things the robot has to identify from its environment and this is possible only through sensors and pursuing the environment using the sensor data. But just before going into the sensors, let me just tell you the main difference between these two; that is the remote operation and the autonomous operation and why the autonomous operation is still not coming to the level what we are expecting.

As you can see from here, the autonomous robots, their autonomy is very high compared to the tele-operation or the remote operated robots; but you can see the task complexity is very less. So, it is actually very less here. And if we want to bring this to the next level, we need to provide more capabilities for the robots.

And one of the challenges in developing autonomous robots or one of the challenges in bringing the these robots to the next level is basically how do we actually ask, hello the robots to perceive its environment and take decisions the same speed as what we human do. As a human we actually take lot of decisions, we actually get lot of sensors, sensor

information from our natural sensing organs; but the robots is not able to do it as fast as we can do.

And there are many challenges in that, because the robot has got sensors which again working work based on the principles that we have, like whether it is a sound based or light based sensors; sensors are not very accurate, sensors are not able to give you the decide accuracy. As well that the robots are not able to, the sensors are not capable of distinguish between different objects many times.

So, all these are actually creating problem for autonomous robots. So, one of the main challenges in developing autonomous robot is basically providing a good perception of the environment at the rate at which the human can do. So, once that is provided, then the robots are capable of executing it very fast; but unfortunately our sensing and perception itself suffers from many things.

So, we need to have better methods and better algorithms to take the autonomous robot to the next level of complex task complexity, where robots can work without really; I mean robots can do complex tasks without having any interventions from the human.

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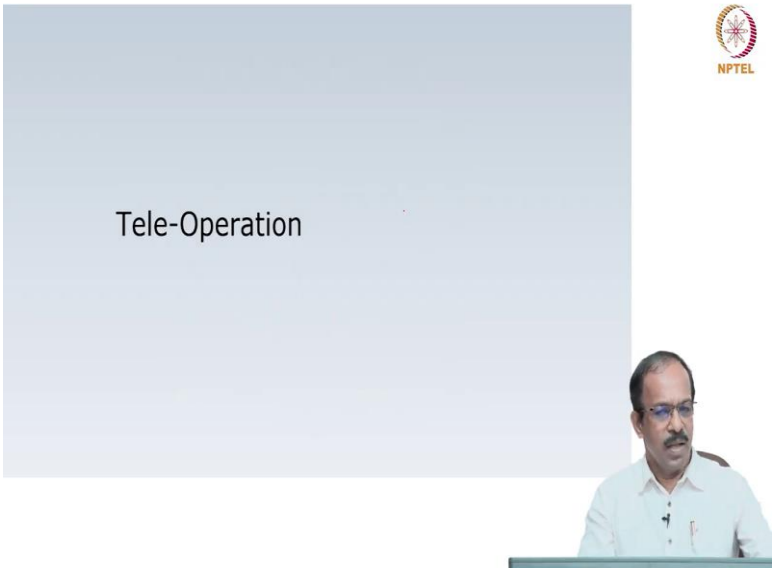

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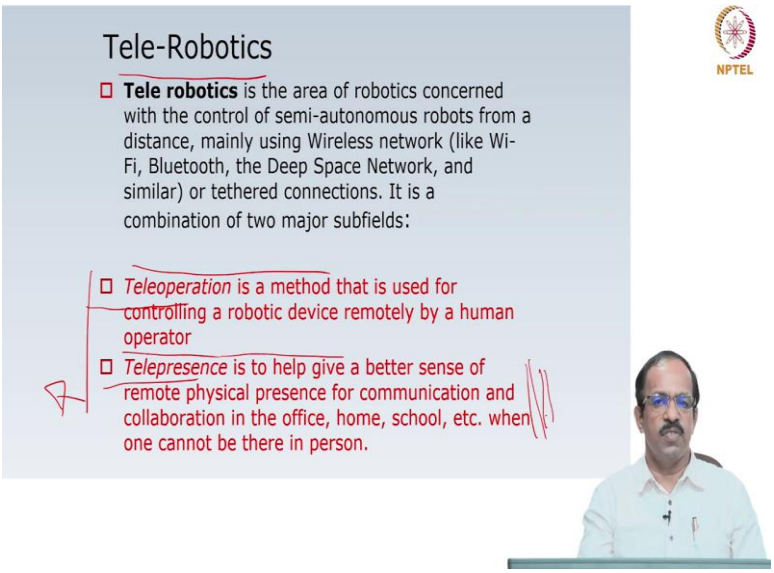

So, the teleoperation as I mentioned, there are 2 things in teleoperation; that is the tele 2 thing in tele robotics. So, one is known as the teleoperation, the other one is the telepresence. So, teleoperation and telepresence are part of the tele robotics. And then teleoperation, we just give the command to the robot and the robot will actually execute the command.

But what we need the telepresence, where the robot needs to give the give feedback to the operator about its surroundings, so around its environment, we need to have feedback. And this feedback comes through sensors.

So, here in tele robotics the sensors basically function as data collection points or data collection devices, which will just send the information back to the operator and operator do all the processing of the data. And therefore, in tele robotics, the role of sensors is very limited; you need to have many sensors, but the role of sensors are very limited.

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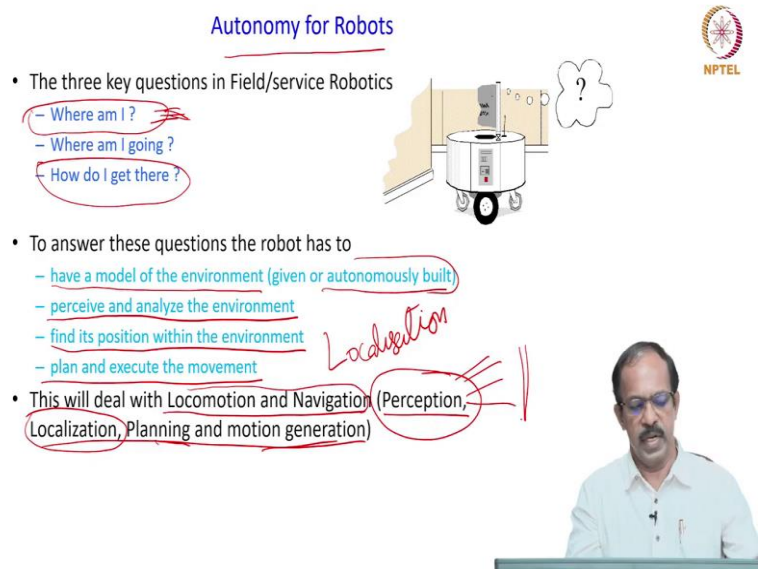

In the case of autonomous robots, just collecting the information is not sufficient; sensors can still do the same thing as in tele robotics, it can collect the information, but processing of information is very important. So, what are the things that we need in a robot if we can understand that; then we know the importance of these sensors play or the sensor and perception play in mobile robots.

So, for autonomy for robots, so if a one to give autonomy to a robots; we need to understand how a an autonomous system work. Assume that when we are human, human beings we are autonomous systems; so we do many things autonomously, we do not depend on any other person to take decision.

So, we actually get the information from surroundings and then we take decision and then we execute the decision; that is what we do normally in our day to day activities. If I had to go someplace, I will or if I need to get something done; I will look at what are the things around me and then based on all the information, I will process that information, take decision and then execute it.

A robot when you want the robot to be autonomous, we need to make sure that the robot is also able to do the same thing; because there is no human intervention, the robot has to do the task on its own. Now, we need to know, what are these capabilities for the robot to be autonomous? So, the first thing what a robot need to know or what the robot, the capability what the robot need to have is to see or to understand where is it.

So, the robot should be able to know where am I. So, there are 3 key questions which robot should be able to answer in order to be autonomous. So, first one is, where am I? So, what is the current location of the robot? In a in environment, where is it is position; what is it is position is to be understood, that is the question where am I.

The next question is of course, the where am I going; what is the target for me or what is my destination? So, this actually comes from a mission planning or the robot the user would have planned it. So, once the robot knows where am I and where not, where am I going; so if these two are known, then the robot has to decide, how can I get there? So, that is the next question.

So, where am I, where am I going, how do I get there; if a robot can actually answer these 3 questions, then the robot is autonomous. How can we make these robots understand these or answer these 3 questions with the critical issue in autonomous mobile robots? Or in autonomous robots these 3 questions are very important. And we know that we are capable of doing this; even if it is an unknown environment, by looking at the surroundings, collecting data from others or from surroundings, we will be able to identify where we are.

When you are in a totally, when you are left in a totally unknown place and you do not know where you are; then what you will do, you will just go around and then try look at surroundings, look at for sign post or some landmarks and based on all these information, you will decide or you will make the decision that ok, you are in the correct this particular location.

The same way robot also has to do it and for that, the robot needs to have sensors; robot needs to capable needs to be capable of analysing the sensor signals and then taking decision based on this data. So, that is what actually needed. So, the first part, this part is very crucial for a robot where am I and that actually can be given only by sensors and the sensor data. So, that is where the first the thing comes into play. And how do I get there actually is a question of path planning and execution of paths through controlled signals and other things.

But the first path the answer of where am I is to be answered and this on many times we call it as the localization of a robots. So, to answer this question, the robot need to have a model of the environment given or autonomously built; the robot needs to have a map of

the environment, a digital map is to given or the robot should be capable of building a digital map.

So, there is one requirement for the robots. And then within that environment, it has to perceive and analyze the environment and then find its position within the environment. So, this is basically known as the localization of a robot; the robot needs to localize itself. So, this is the requirement of a robots in answering the question where am I. So, if there is a map, then use the map and the information coming from the sensors, analyse this and then decide where it is, that is the first thing.

And then plan and execute the environment, it has to plan and execute the environment. And this 1 basically we call this as the locomotion and navigation of the robots. So, for any mobile robot, we need to have a locomotion and navigation mechanism; this is to be built into the robots in order to make it autonomous. And that is the job of the designer to ensure that the robot is capable of doing these locomotion and navigation in a an environment, then only we can make it autonomous robots.

And this can be achieved through these 4 steps; that is the perception, localization, planning, and motion generation, ok. So, perception is the one which actually help the robot to collect information from the surroundings using sensors and then perceive its environment, analyse its environment and then localize itself, ok.

So, it uses sensors and then sensor data, analyse it and then try to localize itself and then of course, the planning and motion generation. So, these are the others steps that the robot needs to do. So, it basically I am just explaining this basically to tell you that, any robots need to have this capability of perception and localization in order to have autonomous capabilities.

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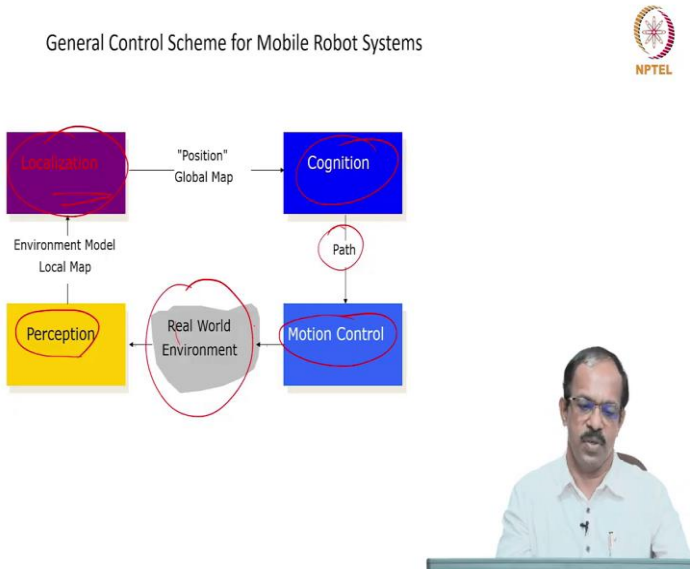

So, this has been explained here. So, if the robot is in a real world environment, the perception process will help the robot to analyse the environment and then it should be able to do the localization. And then based on the current position of the robot and where it as to go, it has to process this information, cognition is the processing of information and taking decisions.

And that will generate some path and then based on the path, the robot will be having its motion control and it will start moving in the real world environment. So, this is the way how a mobile a robot will be moving in its environment and this will be a continuous activity, it will be a it be working on a cycle. So, every step this will be continuing the perception, localization, cognition and motion control.

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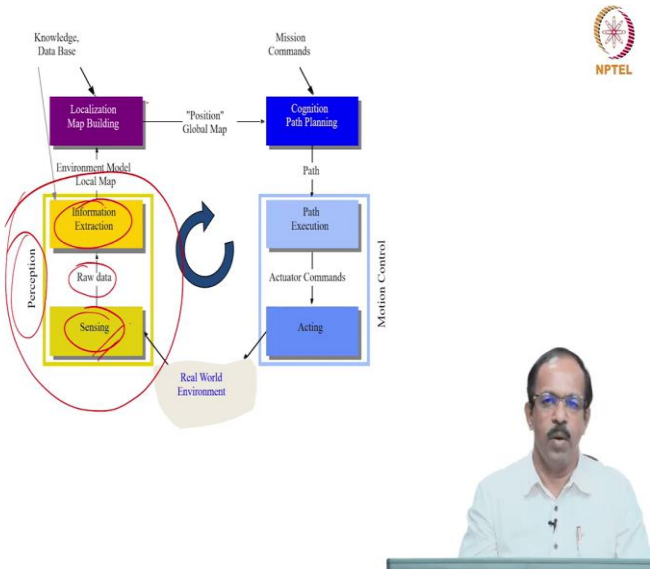

So, let us look at this perception part because that is of interest to us; we will talk about localization slightly later, but perception is the other first part, ok. So, perception includes the sensing and information extraction, ok. So, sensor will be giving you the raw data and from the raw data, you need to extract the information.

So, how do you extract the information is important and what are the challenges in extracting information is important. But even getting the raw data, there are many challenges in getting the raw data. So, we look at those issues as we progress.

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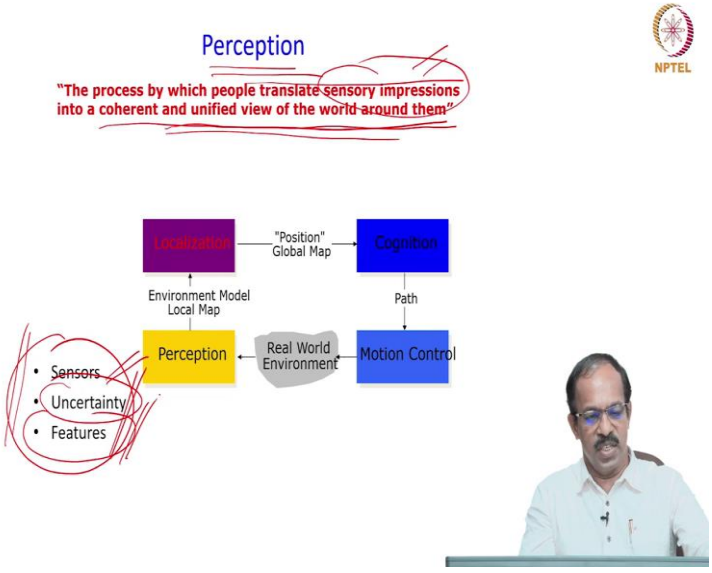

So, the sensing part, the perception part we can see that the sensors are the main element in the perception, ok. So, the process by which the people translate sensory impressions into coherent and unified view of the world around them is known as perception. So, this is what actually the robot need to have, the perception capability. So, how do we process the sensory impressions?

We have many sensors or the robot has got many sensors; so how do he actually process this information sensory impression and then how to convert that into a unified view of the worlds? So, you need to create the unified view of the world of the or the environment and that process is known as the perception process.

So, there are two things; one is the sensory impressions, the other one is the conversion of that into a coherent view or unified view of the environments and that is done through sensors. So, sensors are the first element, which actually collect the information; so get the sensory impression and we use many different types of sensor to do that.

But when you use the sensor, there are many challenges in using the sensor; one is about the uncertainty in the sensors and then the feature extraction of, right a feature extraction from the sensory signals. As human we can actually extract many features just by looking at once; just by having a glance, we will be able to extract many things in the environment.

For a robot it is not possible; because its sensor does not have any intelligence on its own, it will just give you a raw data, it is up to us to interpret what is actually there on the scene. And again this information changes depending on the lighting condition, the temperature, humidity and many other condition. And the robot is not able to distinguish between these variations also.

So, unlike a human being, who can actually distinguish many things when in a, when in a sunny or in a cloudy day or during rain or during mist will be able still be able to distinguish things when what we are seeing; but that may not be the case with the robots, specially because of the sensor limitations.

So, that is what actually we need to understand; how the robot can actually do this even under different condition or what can be done in order to have the robot the capability to

overcome these issues and still do a decent job of a perception and give a good feel of the environment to the robots. So, that is what actually we need to understand.

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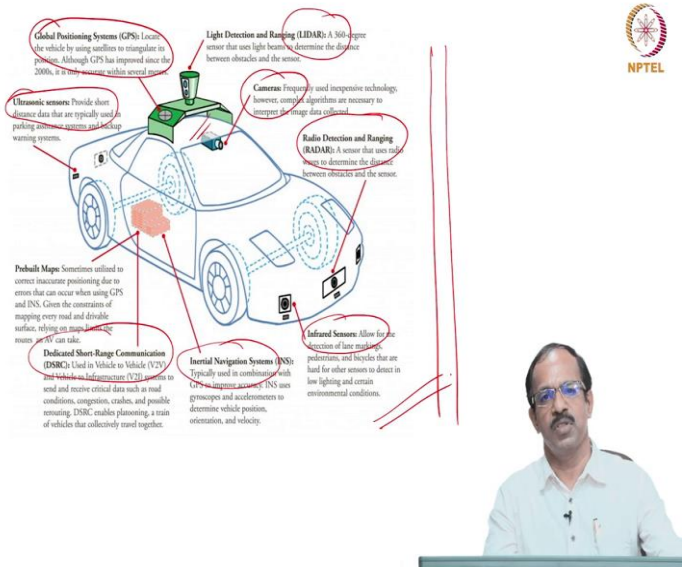

So, you can see in order to do that in a, suppose you want to give a perception of the environment to the robot in the case of a car like this on an autonomous car; you can see there can be so many, there need to be have so many sensors so something for the positioning systems or you use a GPS sensor, then for ultra-sonic sensors to look for a obstacles or objects around.

Then you have the RADAR and then you have the cameras, you have this LIDAR and the infrared sensors, inertial navigation system and the dedicated short range communication and many other things also. See you can you need to have so many sensors in a robot in order to get the information from the surroundings.

Now, when we have so much of information, we need to process all these information in order to get a get the perception of the environment. And when we are to process all these information, it takes time also and that is why many robots are very slow, many autonomous robots are very slow; because of the large processing of information and then trying to overcome the uncertainties and then have a good estimate of the surroundings that takes a long time.

So, that is one of the reason we still have difficulty in having a fully autonomous systems or fully autonomous cars on the roads. This there is talk about autonomous car or there are lot of people talking big about autonomous cars and you must have heard about Google car which is already undergoing trials on the roads.

But it looks like we are still far away from having a fully autonomous car which are, which can be commercially operated on the roads; maybe it will take 10 to 20 years before us to get a really a fully autonomous driverless car on the roads. Because of the challenges involving many things and many uncertainties are there and the environment is highly unstructured and robots are not capable of handling the unstructured conditions.

So, once you have a very structured condition, the robots are very good to do work; but the moment it goes unstructured, then things become very difficult. So, these challenges need to be overcome in order to get a fully autonomous robots.

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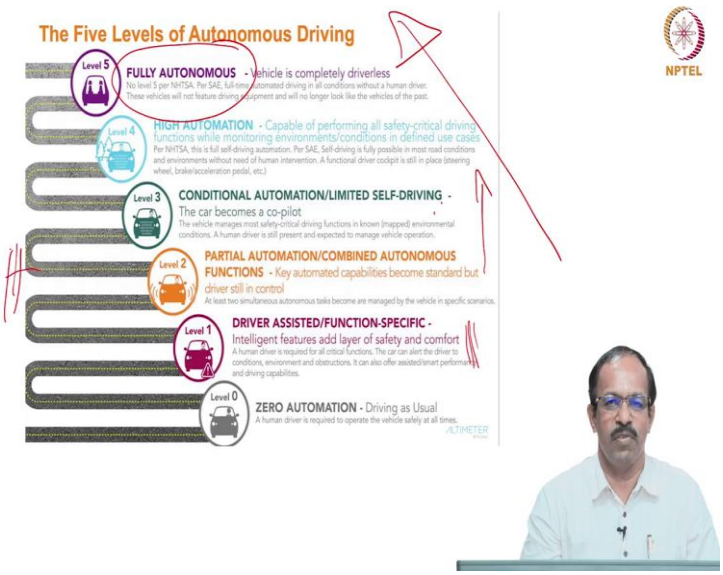

So, the full autonomy is as I told you it is far away. But now-, we need to go by step by step. So, driver assisted functions are one way to move forward. So, you must have heard about this screws control and other feature in cars, where actually you can fix a speed and then the car will be going at that speed, of course without much of any intelligence. But then we can actually add intelligence, the car can actually identify the, there are cars which can actually identify the curves and then go in the middle of the road.

So, like that we can add the little bit of intelligence that is basically the driver assisted functions. And then as we go up, we will be adding more and more autonomy to the robot and finally we will become a, we will have a level 5 autonomy or we call it as the fully autonomous car. So, it is a long way to go; but we are already in the level 2 in this stage, but I think we will have, we will be moving forward and get into the level 5 maybe in another 10 or 15 years.

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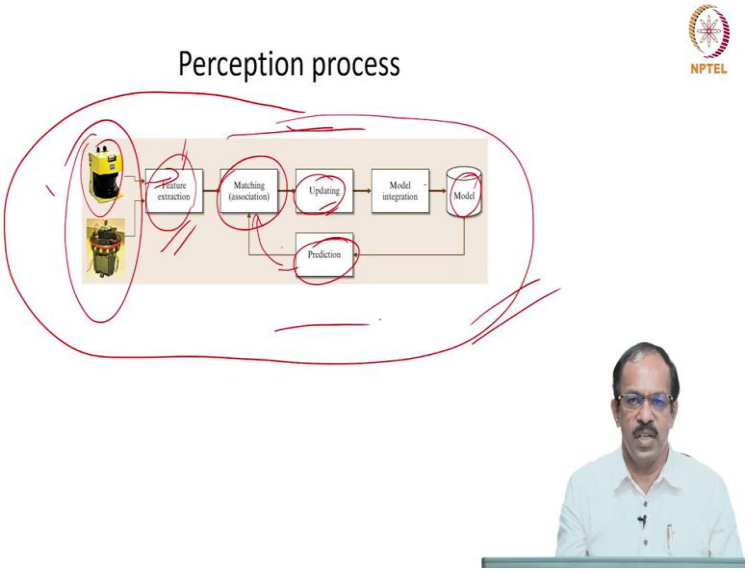

So, that is about the general introduction about the importance of having sensors and perception and why we need to have a good perception systems in the mobile robots. So, before going to the sensor, let me just tell you what is the perception process itself is; anyway we will be going through these steps in detail, but the perception process basically involves the sensors.

So, we have the sensors and then sensors will take the information from the surroundings and then give it to the robot; then the robot controller will just extract these features from the data. Suppose the camera sees an object, it will try to identify whether it is a tree or it is a wall or it is a you know human or a car or whatever it is.

Similarly, this RADAR also can identify a many things like the walls and other objects also. Now, this will be a raw data coming from the sensors, then that this is to be processed and we will extract the features and identify ok there is wall at 5 meters away

from this location or at a particular orientation that kind of information can be generated that is basically known as feature extraction.

Now, with the feature extraction, we get a feature and then we will check whether it is actually matching with something already given to the robots. So, if the robot is given a map, it will check whether there is already there or it is a new feature that is coming and that will just associate itself.

And if it is not there, then it will update the database; it is on a map given to the robot, it will update a create a map with the updated information and then it will integrate with the environment model or the model of the surroundings. And then using the map itself, it will say ok; now the robot is moving, then the robot will there, because there is a map already.

So, it will predict ok something you can see after some time and then that is basically the prediction; the robot will be able to predict that now if you are in this location, you will be able to see something based on the model that is available. And when the robot is seeing that one it will actually check whether this is seeing it or not and if it is seen; then the robot is in that position, if it is not in some it is not able to see, then something is wrong with the position estimate or it is the surroundings of the robot has changed.

And this process will keep on happening, it will continue throughout the operation of the robot and continuously the robot will be looking for information using the sensors, extracting the features, matching with the model and then updating the model and then keep on predicting and updating it. So, this process will keep on happening in the robot in order for the robot to get a good perception of the surroundings.

And that actually that perception allows the robot to do its localization and all other activity. So, the primary thing for a robot needs to have is the perception, a perception of the environment and that perception comes through sensors and then processing of this information and following the perception process. So, this is what we are going to learn in the next few lectures; how the sensors can be used to collect the information, and how this information can be processed to get features.

Of course there are many feature extraction exercises which will not be going through in detail; but just want to explain few things and then we will see how that can, information

can be used for localization of a robot also, ok. So, we will stop here for this session and continue this in the next lecture.

Thank you.