Robotics
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Lecture – 31
Sensors

We are going to discuss another topic that is topic 6 that is on Sensors. Now let us see like how to design and develop the sensors, how to use the sensors, what are the different types of sensors used and how can we collect information with the help of sensors?

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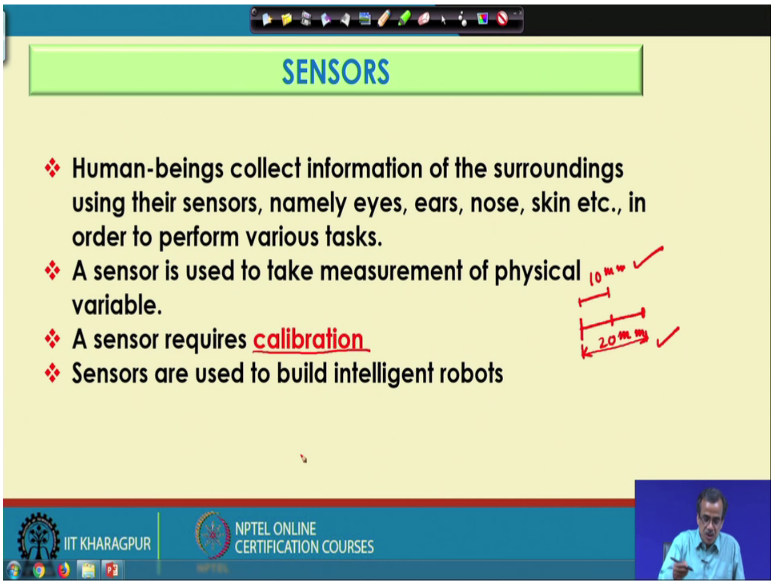

Now, we human being we use different type of sensors like we have got the eyes, ears, nose, skin. In fact, we use multiple sensors to collect information of the environment. And the data collected with the help of this multiple sensor are actually there will be some processing in your brain and with the help of this particular processing, we can collect information of this particular the environment.

Similarly, if you want to make robot intelligent we should put a few sensors and these sensors will help the robot to collect information. Now here let me define the sensor is nothing, but a transducer and we generally use sensor to take some measurement of physical parameter or physical variable and here this sensor; if you want to use as a measuring device; so, definitely there must be some calibration.

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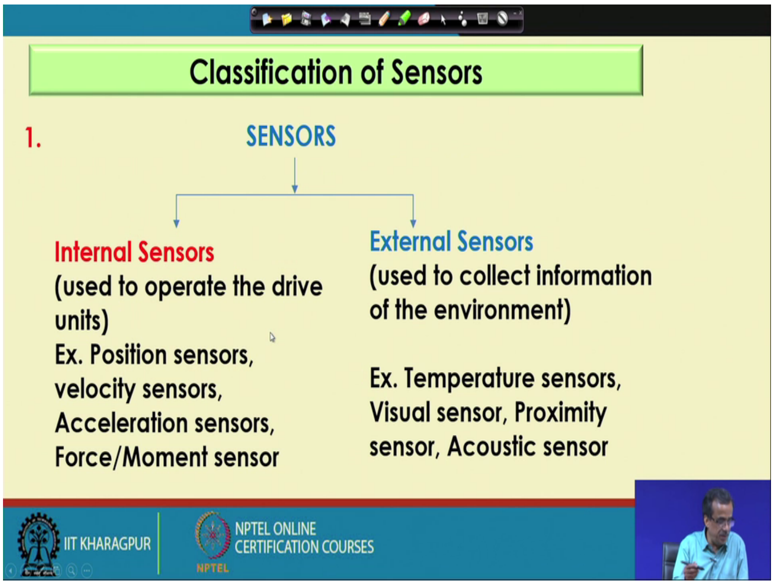

And by calibration actually we mean, it is actually the comparison with some known data. Now, through comparison with the known data like; we will be able to calibrate a particular the measuring device or a particular the sensor.

Let me take a very simple example supposing that I will have to draw a straight line of say 10 millimeter. So, starting from here; so I am going to draw supposing that this is my 10 millimeter straight line ok. Now if I am told that can you not draw one another straight line which is 20 millimeter the long. So, what I will do is if this is 10; so my eyes are going to measure with the previous one and might be this is 20. So, this will be your the 20 millimeter.

That means your my eyes are following some sort of calibration; if this is 10 millimeter; so, this will become the 20 millimeter just double of that. So, our eyes while taking this particular information; so, it is following some calibration; it is following some calibration scale same is true for any such sensor. Now you might be knowing that we use different types of sensors, we use different to take some measurement for example, to measure the joint talks we use sensor, to measure force we can use some sensor, but will have to calibrate.

Now, this calibration is a massed for any such sensor now here actually if you want to make it intelligent; as I have already discussed that sensors are to be used or cameras are to be used to collect information with the help of to collect information of the environment and then only we can do some processing to take some decision in a very intelligent way; so, this particular the calibration is a must for any such sensor. Now if you see the literature we have got different types of sensors for example, say if you classify the sensors in this way, we can classify like internal sensor and external sensor.

Now, these internal sensor are nothing, but the sensor which are used to operate the drive units. For example, we have got some position sensors then we have got the velocity sensor, acceleration sensors, then force or the moment sensors; these are all internal sensors. And on the other hand we have got a few other sensors which are used to collect information of the environment and those are known as the external sensor. For example, we can use some sort of proximity sensor, acoustic sensor then comes your visual sensor, temperature sensor; these are all external sensor.

Now here if you see in our human body we have got a few internal as well as a few external sensor. For example say whenever we try to collect information of the environment; we try to use our say eyes. So, with the help of eyes we collect information of the environment, but supposing that we are getting some pen in the muscle of leg; now how can a feel that there is some pen? So, to feel that particular pen in the muscle; we use some other type of sensors and those are known as the internal sensors. So, in our human body we use internal as well as external sensor the same is true in robots

In robots also we use a few internal sensors, we use a few external sensor. Now the working principle of the different internal and external sensor used in robots, I am just going to discuss one after another in details..

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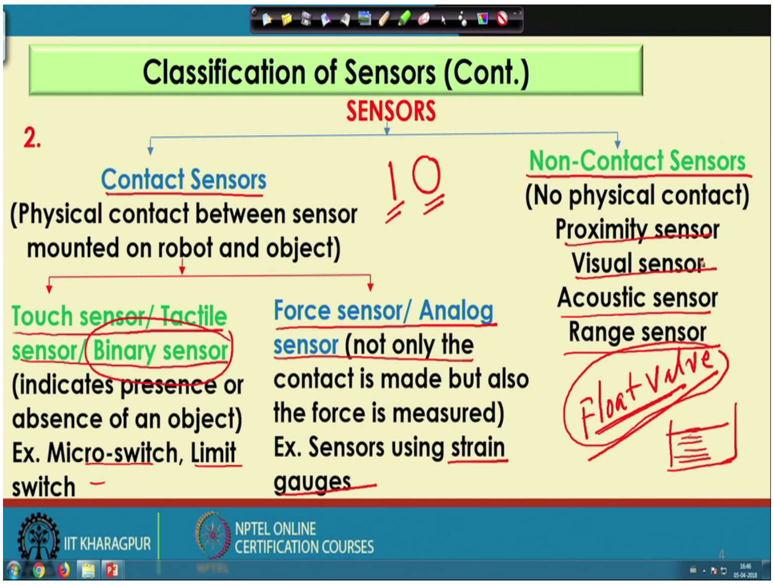

Now if you see the literature , the sensors are also classified in different ways for example, say for example, the sensors could be named as contact sensor or the non contact sensors. So, by contact sensors we mean there is a physical contact between the sensor and this particular object, whose distance I am going to measure. And if there is no such contact the physical contact between the sensor and the object that is called the non contact sensor.

Now, this contact sensor can be further classified into 2 subgroups now one is called the touch sensor or tactile sensor or the binary sensor. So, we have got the touch sensor or tactile sensor or this binary sensor, it is almost similar to our skin, skin is nothing, but our touch sensor. So, in robots also we use some touch sensor or the binary sensor for example, say the micro switch or the limit switch which is generally used in robots are nothing, but the examples of your tactile sensor or touch sensor.

Now, with the help of this touch sensor; so, it is simply going to tell that the robotic finger has touched a particular object, but it is not going to measure the force required to grip that particular object or how much is the force required to or how much is the torque required to manipulate that particular the object.

So, it only indicates whether the contact has been made or not now let me take a very simple example. Now in all the water tanks or the oil tanks we use a valve that is called the float valve. Now this particular float valve, what is the function of the float valve?

The function of the float valve; if this is the tank, the moment it reaches the water height the reaches a particular level the peaks level.

So, this particular float valve will be activated and it is going to indicate that you stop the pump. And the pump will be stopped and the water supply to this particular water pump will be stopped. So, this indicates the highest limit, the highest permissible limit for this particular the water. And that is nothing, but these float valve is an example of your the limit switch or either the touch sensor or the tactile sensor.

Now this is also known as the binary sensor for example, say the micro switch or the limit switch which is generally used in robotic hand. I am just going to take one example the next slide I will show you that we can use some sort of micro switch or the limit switch along with your the robotic hand.

Now, this is also called the binary sensor because it generates 1s and 0s. The moment it touches; so, it will generate your it will generate this particular 1 and otherwise it will generate this 1; so, it is going to generate 1 or 0s ok. So, this is known as binary because sometimes it generates 1, sometimes it generates 0; if there is a contact it will generate 1, if there is no contact it will generate 0. So, it is some sort of 1 0 0 1 something like this and that is why this is also known as your the binary sensor.

Now, I am just going to concentrate on the force sensor or this analogue sensor. Now as I told that with the help of this force sensor or this analogue sensor we are just going to actually measure the force or the torque. So, this particular portion torque which is required to grip this particular the object and generally we use some sort of the force sensor or the analogue sensor.

And here in force sensor or the analog sensor we use some sort of strain gauges. So, I am just going to discuss the working principle of this particular strain gauge in details. And as I told that we have got a few non contact sensors for example, say we have got the proximity sensor, the range sensor, the visual sensor, acoustic sensor.

So, these are all non contact sensor. So, I am just going to discuss in details the working principle of these sensors generally used in robots.

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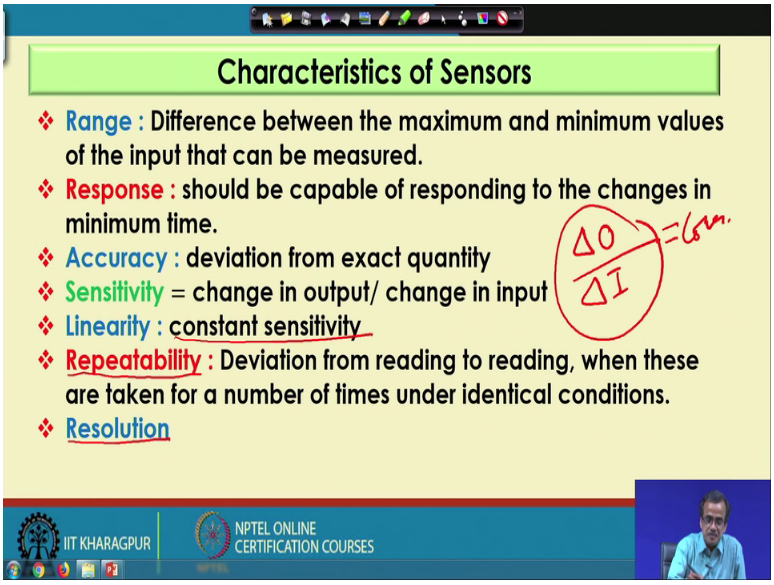

Now, before I go for the discussion of working principle of different sensors; now let me concentrate little bit the different characteristics of sensors. Like if you want to prepare the specification of sensor; so, what are the information which are to be provided and what are the numerical values to be provided?.

For example, say for example, the range, response, accuracy, sensitivity, repeatability, resolution all such things we will have to mention. The while preparing the specification of the robot the similar type of information, we also provided. And here actually or the range for the sensor; that means, what is the maximum and the minimum value that can be measured with the help of this particular; the sensor that has to be mentioned.

Then comes your the response the response should be as quickly as possible, then accuracy is nothing, but the deviation from the exact quantity. So, that we will have to mention sensitivity we know by definition sensitivity is nothing, but the change in output to the change in your, the input; so, that is nothing, but your sensitivity. So, this particular sensitivity we will have to mention how much sensitivity you need and if this particular sensor is having constant sensitivity; now then it is called the linear. So, the sensor is called a linear if it is having the constant sensitivity.

So, by linearity we mean constant sensitivity; then comes your repeatability. Now repeatability we know supposing that with the help of the same sensor. So, I am just going to measure the same thing for say 10 times or 20 times. Now the same thing if I measure 10 times or 20 times; so, there is no guarantee that all 20 times will be getting exactly the same numerical value.

Now, this particular deviation from reading to reading is nothing, but the repeatability. Now while preparing the specification of this particular sensor; we will have to mention how much is the repeatability we want? And then comes your the resolution is nothing, but the list count. So, this particular list count for the measuring device or this particular sensor; so, that we will have to know. Now let me take a very simple example now if I take ones very simple example for this particular resolution which it will be clear. Supposing that I am using one sensor and in that particular sensor I am using some electrical signal to generate some angular displacement.

Now, electrical signal cannot be a fraction. So, it could be 1, 2, 3 something like that; corresponding to one electrical impulse. So, how much is the angular displacement it can generate? That is nothing, but the least count or resolution same is true for your this sensor ok. So, these are the information which are to be provided to prepare the specification of this particular the sensor.

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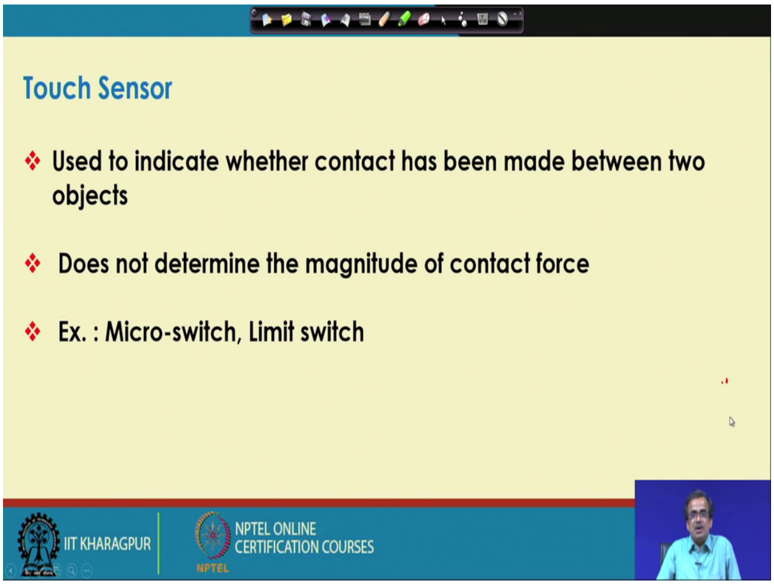

Now, I am just going to discuss the working principle of a few sensors one after another. Now this touch sensor, I have already discussed; these are use just to indicate whether the contact has been made or not. And generally we do not use this sensor to determine how much is the contact force? The examples are your micro switch, limit switch and all such things.

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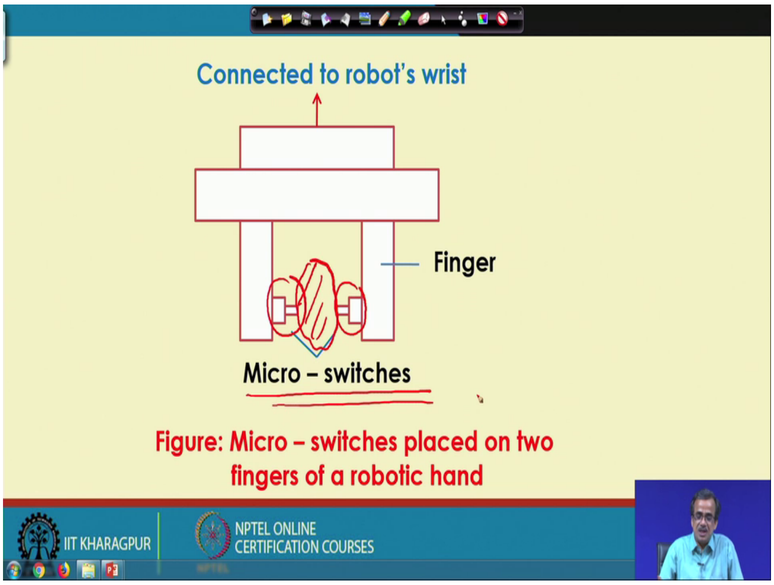

Now, here I am just going to take one typical example of a micro switch which is nothing, but a touch sensor used in robot gripper. Supposing that this is a very simple the gripper having 2 fingers and here we are just going to put some micro switch or the limit switch. Now with the help of this micro switch or the limit switch actually, it is going to indicate whether the contact has been made between the object; supposing that I have got the object here whether the contact has been made between the object and this particular the robotic finger.

So, to sub that type of purpose we use your the micro switch or the limit switch and that is nothing, but the touch sensor the same is true we have got the skin. So, with the help of this particular skin, we can touch, we can feel the presence of an object even if we are not using eyes; we can feel the shape and size or the more or less the structure of that particular object, even if we do not see with the help of our eyes.

Because we can use our skin and skin is nothing, but the touch sensor and with the help of this touch sensor; in fact, we can find out what should be the possible shape and size of this particular the object which I am going to grip.

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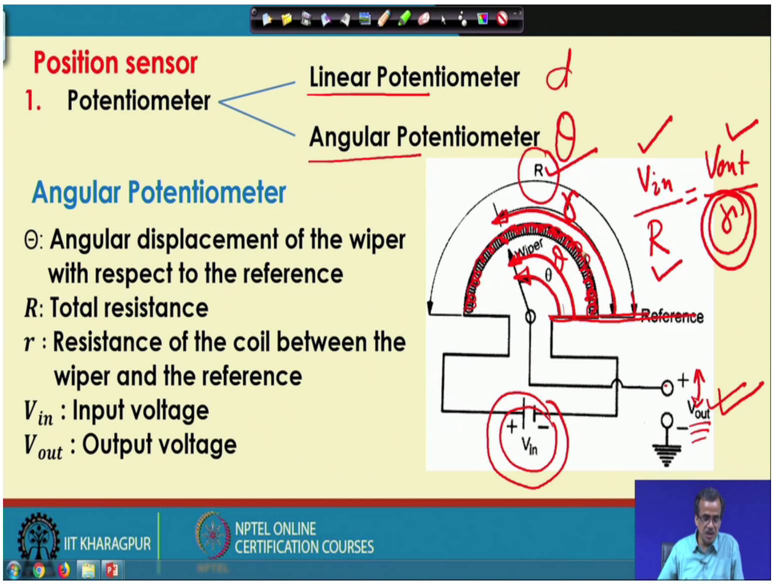

Now, I am just going to discuss one sensor one position sensor which is very frequently used in robotics or we generally use in school level, college level some laboratory classes also. This is your the potentiometer the potentiometer is actually why as I told very well known position sensor. And the potentiometer could be either the linear potentiometer or it could be angular potentiometer.

Now, with the help of linear potentiometer we can measure the linear displacement that is d and with the help of angular potentiometer we can measure the angular displacement that is nothing, but theta. Now the working principle of this particular potentiometer is very simple; for example, say so here we have got the source for the voltage that is input voltage V in for example, say we have got the battery or V is connected to some power ok.

Now what we can do is supposing that we have got the battery here so, I know the input voltage. So, what I do is your we know the total resistance of this particular wire; so, this is actually nothing, but the wire and it has got a special type of winding. So, capital R is nothing, but the total resistance and the reference here. So, this is nothing, but the reference that means, we are going to measure the angular displacement with respect to this particular the reference ok.

Now, here actually what I do is with you are going to measure this angular displacement with the help of this pointer or the wiper. So, with respect to the reference; so it is going to generate some angular displacement ok; how to measure this? To measure this the method which we follow is very simple; so, here with respect to this particular reference. So, I have got the wiper and it has got some displacement and we measure with the help of a voltmeter how much the output voltage? So, this one point is connected to the wiper and another is your the grounded. And you can find out we can measure with the help of voltmeter how much is the output voltage?

So, we know the total resistance of this particular wire, we know how much is the input voltage we can measure how much is the output voltage with the help of your the voltmeter or multi meter. And if you have measured this particular output voltage; now approximately I can find out what should be this angular displacement. Now how to how to find out? It is very simple because if I know this input voltage and if I know the your the resistance.

So, the current is nothing, but your V input divided by R and the same current will also flow here and that is nothing, but is your V out divided by your small r and small r is nothing, but the resistance of this winding up to starting from the reference; up to the end of this particular pointer or the winder wiper. So starting from here up to this; so this is the resistance small r, so from here see the V in is known, capital R is known, V out can be calculated.

So, r can we determined and if I know the value of r and if I know the nature of winding of this particular; your the wire the electrical wire. So, I can find out approximately like what should be this particular angular displacement that is theta. So, theta can be measured with the help of this particular angular potentiometer. This is the working principle of your angular potentiometer it is very simple and all of us we have used.

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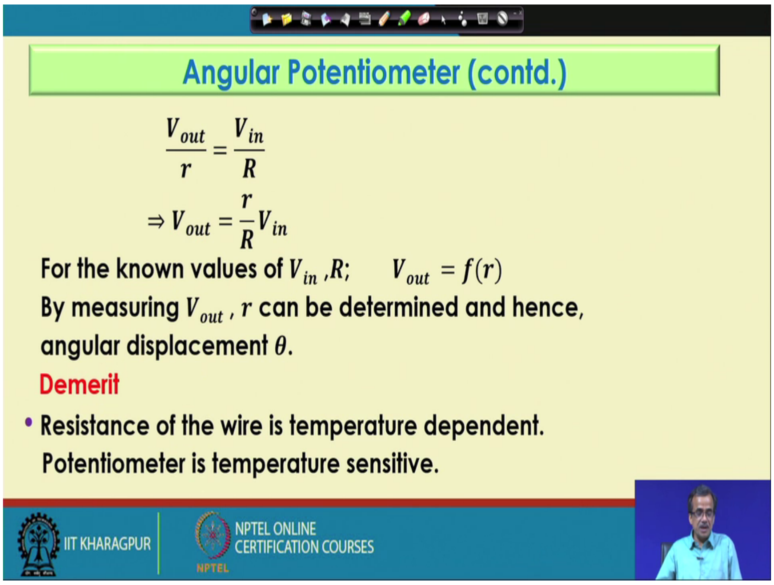

So, this is the working principle of your angular potentiometer, but this angular potentiometer has got one demerit or one drawback; all of us we know that the resistance of wire that depends on actually the temperature.

The moment we pass some current through electric wire; so, due to the heating effect of the current that is that I square r effect. So, what will happen? There will be some heat generated in that particular electric wire and its temperature is going to increase and as temperature increases; so the resistance of the wire is going to change and if resistance changes. So, you will not be getting very accurate measurement with the help of this angular potentiometer.

And that is why if we use this particular angular potentiometer at a stage for a long time; so, initially we may get some accurate results, accurate measurements. But with time, so after might be; so half an hour or one hour there is a possibility we will be getting some erroneous results with the help of this angular potentiometer. So, this is actually the drawback of this angular potentiometer, but its working principle is very simple and this is infact one of the most popular the position sensor used nowadays.

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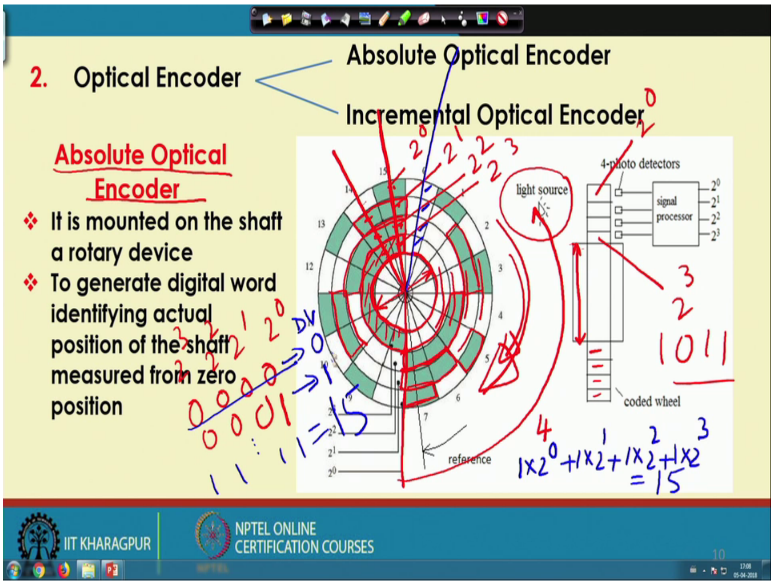

Now, then comes your another position sensor that is called the optical encoder. And this is also very popular and if you see we have got 2 types of optical encoder. One is called the absolute optical encoder and we have got the incremental optical encoder. And in robotics actually very frequently; so this type of optical encoders are used as feedback device. For example like, if it is servo control robot; so, there must be a provision of feedback device and there must be a provision to measure the angular displacement. So, what you can do is; we can take the help of, so this type of optical encoder as a feedback device.

Now, let us see how does it work? Now this optical encoder now let me first try to explain the principle of this absolute optical encoder first. Now this absolute optical encoder consists of a number of concentric rings placed one after another. Now supposing that say this is the output shaft, this is the output shaft of this particular motor I have got the electric motor here.

So, this output shaft is rotated; now I want to measure what should be the angular displacement or what is the rotation of this particular shaft? What I do is here I put this particular absolute optical encoder and absolute optical encoder is nothing, but a collection of a few concentric rings placed one after another and what I do is. So, here we have got the concentric rings and on this particular concentric rings; there will be the marking zone; that means, there will be dark zone and the light zone. That means, through the dark zone the light will not pass and for through this particular light zone the light will pass now on.

So, here we have got the optical encoder; so, as the shaft rotates the optical encoder mounted on it is also rotating. Now on one side I have got the photo source, other side we have got the photo detector. The moment during the rotation; so, this particular the disc the circular disc or the rotating disc; the light zone comes in front of the light source, the light will pass and it is going to activate that particular the photo detector. The same thing I am just going to discuss in more details with the help of this particular the sketch.

Now as I told that it is consisting of a large number of concentric rings. Now here for simplicity I am just going to consider; so, there are only 4 concentric rings. Now supposing that this is nothing, but the diameter; this is the diameter of the shaft whose angular displacement or rotation I am going to measure.

Now, here surrounding this we consider say one concentric ring, another concentric ring, another concentric ring. So, I am considering 4 concentric rings here now you concentrate on the first one that is this particular concentric rings. Now here what I do is; so this part is made black, this part is made black on the first concentric ring. So, this is made black this part is made black and this is your the white portion through which the light will pass. Next we concentrate on the second concentric rings on the second concentric rings starting from here up to this is made black; so, this part is made black.

So, no light will pass then it is white once again this part is made black and then there is a white portion, then you concentrate on the third one. So, here so this is the black part and this is the white part, then this is the black part, then comes a white part, then comes this is the black part, this is the white part, this is the black part, then comes the white part and so on and on the outermost ring we have got the black portion here.

So, this is the black part, white part, black part, then white, black, white, black and so on. So, this type of marking we have and here we are considering only 4 concentric rings. The outermost ring is going to indicate actually 2 raised to the power 0. And this particular thing is going to indicate 2 raised to the power 1, this is 2 raised to the power 2 and this indicates 2 raised to the power 3 and so on.

Now, if you see the other view for example, say in this particular view supposing that so this particular shaft it is not drawn here properly. So, this particular shaft supposing that this is actually you are the diameter of the shaft and on which I have got this concentric rings mounted one after another ok; that means, this is going to indicate 2 raised to the power 0; that is the outer most and this is going to indicate 2 raised to the power 3..

So, here this is the, another view; so on this side we have got the light source and this particular thing is rotating. So, this particular thing is rotating; this is mounted on the shaft the shaft is rotating, optical encoder is also rotating and the light source is on put on; the moment the dark zone is coming. So, here there will no signal the moment I will be getting the light zone then only there will be light will pass through this and it is going to activate that particular the photo detector.

So, depending on the relative position of the dark zone and the light zone; so, sometimes light will pass, sometimes it will not pass accordingly it will be generating some 1s and 0 sort of thing ok. For example, say so here so this is the reference line; so there initially the reference line is here ok. Now the reference line is fixed and this particular optical encoder is rotating; now what I do is, here on the screen I cannot rotate. So, what I can do is; so, I am just considering as if this optical encoder is fixed and I am rotating this reference in the reverse direction. If I just the rotate the reference in the reverse direction.

The moment my reference is here, the moment my reference is here thoroughly speaking the optical encoder is rotating reference is fixed. But here this is almost equivalent of the situation, my optical encoder is fixed because I cannot rotate it here on the screen; so, I am rotating the reference in the opposite direction. Now supposing that the reference is here and if it is here then this is the dark zone, dark zone, dark zone and dark zone..

So, it is going to generate 4 such 0s say this is 2 raised to the power 0, 2 raised to the power 1, 2 raised to the power 2, 2 raised to the power 3 the moment this particular reference comes here supposing that it is here. So, through the outer most; so, the light will pass; this outer most corresponds to a 2 raised to the power 0. So, here it is going to generate 1, but corresponding to 2 raised to the power 1; there will be 0, there will be 0, there will be 0; so 0, 0.

Similarly, the moment we consider that this particular your the reference is here. So, what will happen? The light will pass through all four; so, through here light will pass, light will pass through this, light will pass through this, light will pass through this. So, it is going to generate actually 4 such 1s ok; so if it generate 4 0; its decoded value will be equal to 0. Because 0 multiplied by 2 raised to the power 0; so decoded plus 0 plus 0 plus 0 it will be 0.

And the decoded value for this; so, 1 multiplied by 2 raised to the power 0 that is equals to 1, plus 0 multiplied by this equals to 0, 0 and 0; its decoded value will be 1. And corresponding to this 1 1 1 1 the decoded value will be your something like this 1 multiplied by 2 raised to the power 0 plus 1 multiplied by 2 raised to the power 1, 1 multiplied by 2 raised to the power 2, 1 multiplied by 2 raised to the power 3.

So, 8 plus 4 that is your 12 plus 2; 14 plus 1; so, 15. So, its decoded value will be 15 ok. So, corresponding to rotation of this particular your optical encoder and depending on the position of angular displacement with respect to the fixed reference; I will be getting some binary. This binary will be generated here and I can just do the decoding and I will be getting your, the decoded value corresponding to that particular the rotation.

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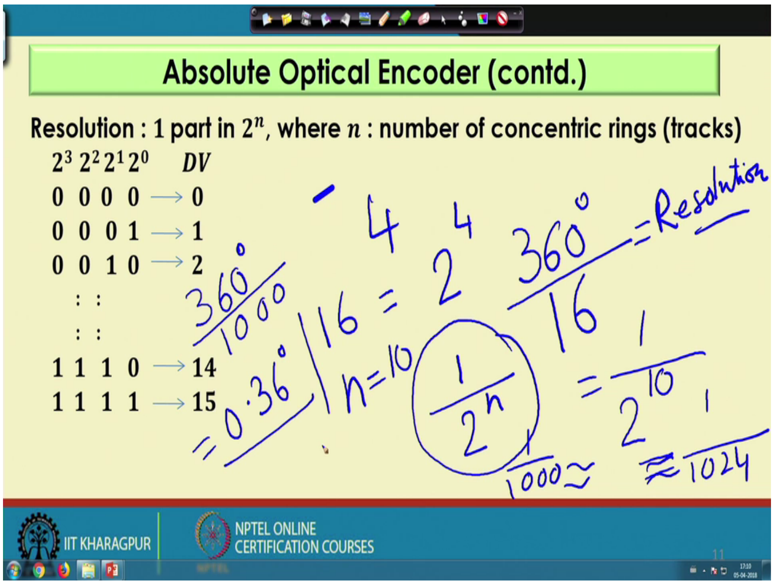

And whatever I discuss the same thing I have written it here. So, corresponding to this 0 0 0 0, I will be getting 0 and this is the way actually I will be getting this particular your the decoded value. Now supposing that I have got some decoded value; now if I use like 4 concentric rings, if I use 4 concentric rings then your, if I use 4 concentric rings then how many divisions? We are getting we are getting only 16 divisions.

So, 16 divisions is nothing, but is your 2 raised to the power 4. So, 2 raised to the power 4 is actually your 16 ok; that means, corresponding to the whole rotation for this particular shaft that is nothing, but 360 degree corresponding to one rotation. So, this particular 360 degree I am just going to divide equally into 16 parts; that means, your; so, this 360 divided by 16 will be the resolution of this particular optical encoder if I use only 4 concentric rings.

Similarly, if I use n number of concentric rings then it will have the resolutions like one part in 2 raised to the power n. So, this is nothing, but the resolution of this particular optical encoder for example, say if I take n equals to say 10; then the resolution will be 1 divided by actually 2 raised to the power 10 that is nothing, but approximately that is equal to 1024 and approximately that is equal to 1 divided by say 1000 ok.

That means your 360 degree rotation for one complete revolution that will be divided into 1000 equal parts and that is nothing, but 0.36 degree. Now this particular 0.36 degree will be the resolution of the optical encoder, if we use actually 10 concentric rings. Now this is the way actually with the help of this optical encoder absolute optical encoder; we can measure how much is the angular displacement of a particular the shaft which is rotating.

This is the working principle of this absolute optical encoder which is very frequently used in robots as a feedback device.

Thank you.