ROBOTICS

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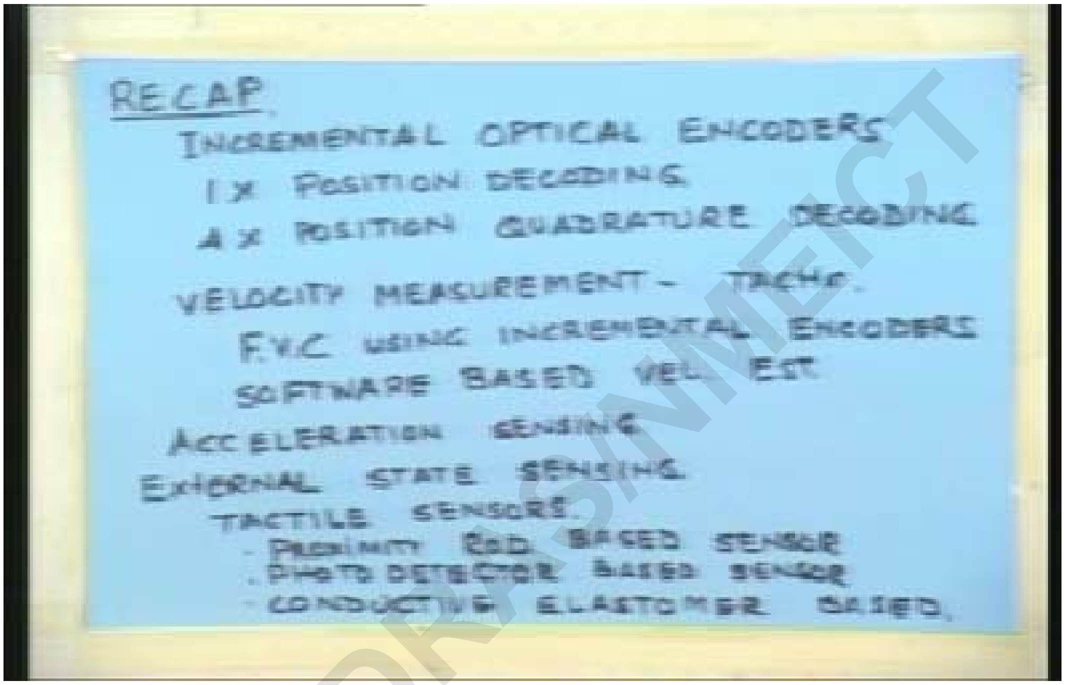
Lecture No-11

External State Sensors Time (01:22 min)

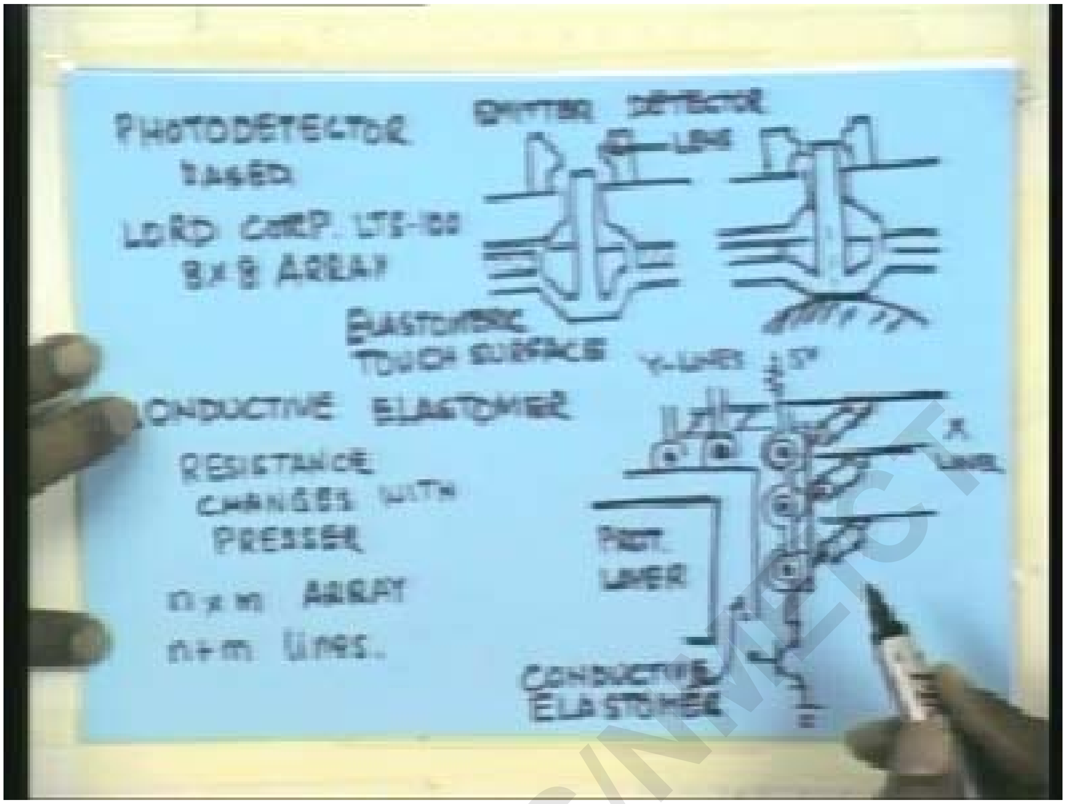
To recap what we have done last time (Refer Slide time 01:28 min)



okay we looked at the incremental encoders where optical encoder and what we saw was that it could do one x position decoding and we also saw the circuit for doing four x position what is called quadrature decoding okay then we looked at velocity measurement and first thing that we looked at was a tachometer tachs which are basically dc motors then when we also looked at frequency to voltage converter base okay using incremental encoders we also looked at the software base software based velocity estimation

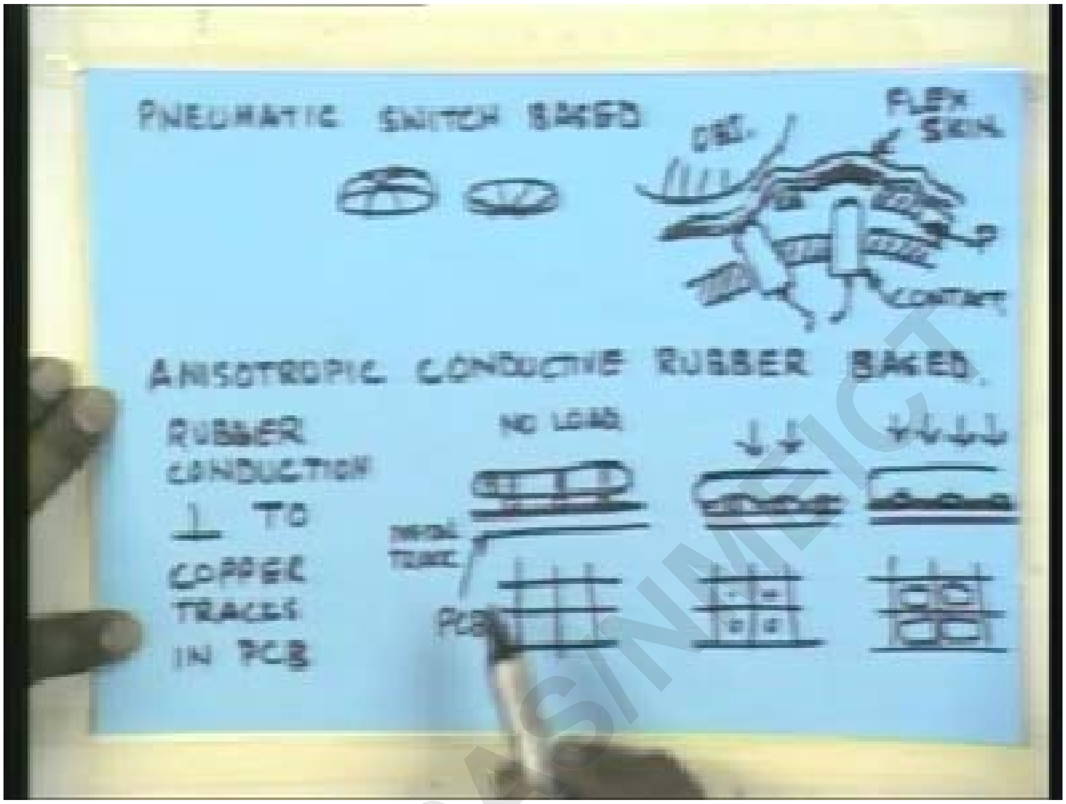
okay we briefly touched upon acceleration sensing pointing out that there would be a few circumstances where acceleration sensing is likely to be used then we moved on to the external state sensing and in this we started to see tactile sensors okay here we looked at the proximity rod based sensor we looked at the photo detector based sensors and we looked at the conductive elastomer based

okay so we can start out by just going over the last interpreted that was done in a little bit of a rush (Refer Slide time 05:14 min)



if you look at the diagram that i have show you last time dealing with a conductive elastomer what you have is say the productive layer which in the friend followed by the conductive elastomer now the property of the conductive elastomer is that when you compress it the resistance decreases okay and it is local because it is not a very highly conductive material so local effect can remains local and what you do is you have a PCV pended circuit board in the back with some electrode i shown here you have a inner part of the electrode which is shown as a dark circles and then you have the outer ring of electrode and you have a y correction we have all this electrodes and in x correction what we will do is we connecting the sensing part so this x line connecting shown here will actually be connecting the center position of this through a diode for these also this x line connects to all the x directions central spots similarly the second x line will connects to second row all the center spots

by dividing this range to x and y directions what we do if we activate one of these transistors let say when you have full up resistance here can you have depending on the resistance of the polymer elastomer that is where you contact between this two will be make you some extend depending on the resistance between them and that resistance will depends on the how much pressure is coming out at that particular spot so therefore the output from these x lines can be will be changed and we scan it by powering one of them at a time and scanning each line individually so therefore the x and y locations completely tells as the which of the electrodes are having so much resistance in that and therefore we have the map of what the pressure that the gripper is putting on the or the object is putting on the gripper this is what the basic idea about tactile sensors(Refer Slide time 7:48 min)

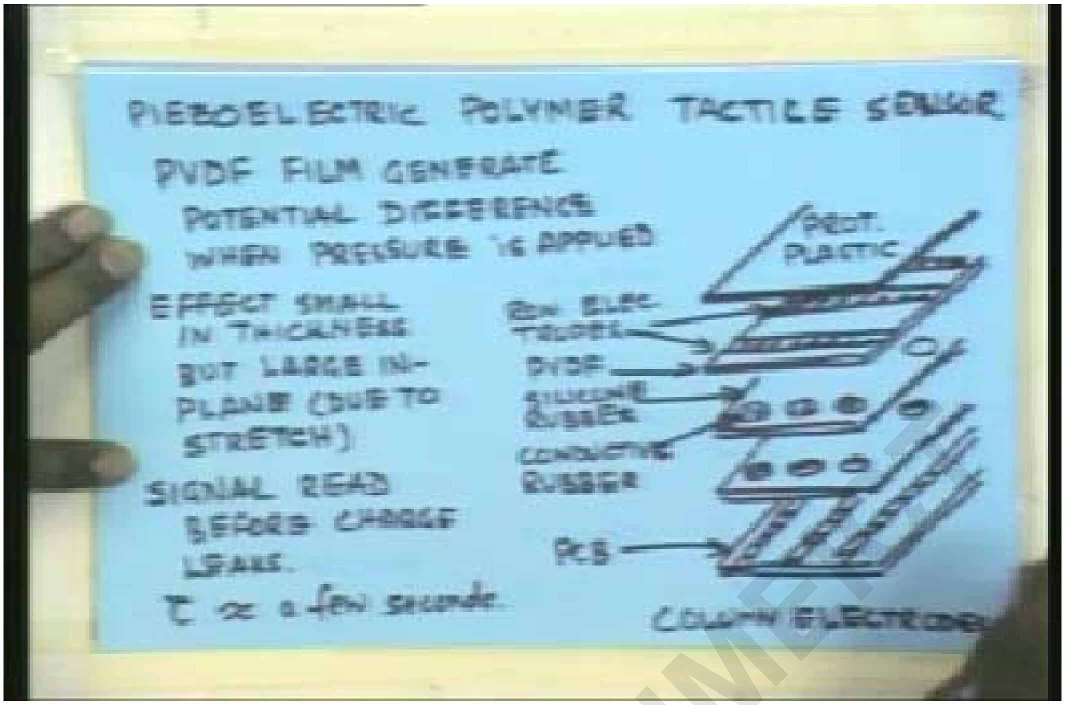


okay lets move on to different types of some more types of tactile sensors we have this was developed by ibm this is called pneumatic switch based okay basically what is consist of is a flexible skin iam showing here it is a rubber type of skin underneath it there is the thin metal diaphragm so thin metal diaphragm is shown here then you have a support structure and there are electrical contacts getting out so this is being our support structure

iam stating that in a dashed line what is there is you pressurize this chamber pressure is apply to that so in the normal positions because of the pressure is disk which in a curve shape part of the metal diaphragm it can have two stable positions it can be up like this or it can be down like this label so if there is a object suppose if there is a object here and the continue arc flex in here so what iam showing is that instead of it being up here now because of object its being press down and it is in the other stable position and the metal diaphragm which is behind this is now making contact with the contact that we have so this contact will go to some electronic circuit it and this is the our contacts we are in here and so because the object here the skin has been depressed this is the flex skin it has been depressed and because this is a metallic disk which is like a dimple you must be familiar with fact that if you have a round disk with a curvature like this then if you press on it then it take a stable position which is going to be curvature up from curvature down okay this is what happening this capture to a down position and then it make a contact and then contact can be mirrored off then we know you exactly which locations the object is causing it to deform and they contact now the task of the applying the pressure here is obviously to make sure that when the object is remove from there this pressure is sufficient to make the disk go back into the original position okay

lets look at the another one is called anisotropic conductive rubber based okay what you here is you have a conductive this is anisotropic meaning it as conductivity in one direction but doesnt have the conductivity in other direction so assume that this is conductivity coming out of the paper coming out of your board and what we do is segment this so that there are strips of conductive material put together you put it on nylon spring and then you have underneath this you have a metal track track is running along the direction that i have shown you and of course this is mounted on some pcb this is are printed circuit board right when there is no load then you have this equation what is to be recognizes that this transaction that iam showing here this basically that rubber conduction is perpendicular to the copper tracks okay in the pcb

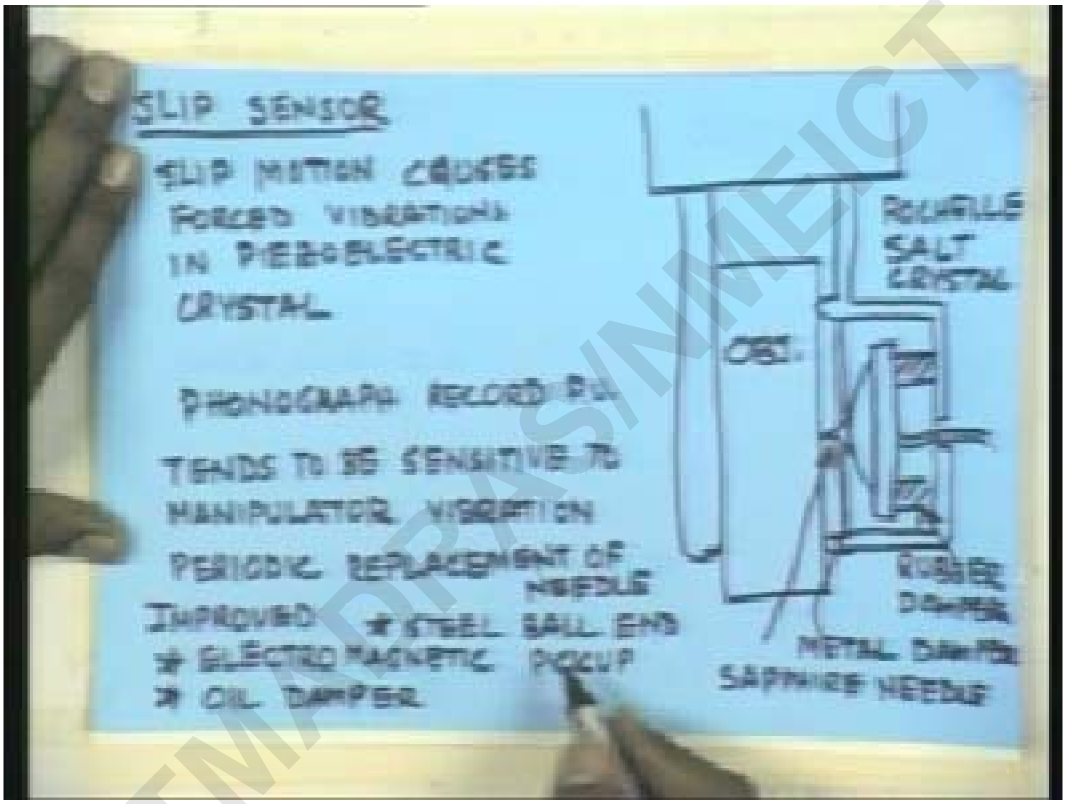
now suppose applying the moderate load on it then what happens is this conductivity deform an assume say shape like that this kind of restrain because there are this nylon insulating so if you start to make some contact and if i look at them image you can say of each of this width and the distance between the track on the pcd and then we get a grip and here no contact at all and then we come to this equation when there is some amount of contacts developing because of pressure which is applied on the elastomer and the conductive rubber if you put heavier load then this rubber deforms to make much more contacts these are nylon rope and then we have the pcb so this kind of image that will be generated here will be making contact in rigor areas and therefore the resistance between a electrode put on the top of the rubber at the bottom in the pcd will change and once again because you have x y grid structure you will be able to find out exactly where the pressure is coming yes it is used in making sure that you have tracks which are basically okay actually you dont have separate this what iam showing here for your convenient to understand that the current is not flowing in this direction it is flowing out of the paper so this is the basic thing otherwise you have to make separate strip and you will have to join them together so then proxy etcetera whichever which ever we use to join it will create a problem and therefore this an isotropic property can be used here but the current flows in one direction this preferred direction is out of the board not across the paper (Refer Slide time 15:58 min)



okay we will look at one more tactile sensor placed on piezoelectric property it is the polymer type of piezoelectric tactile sensor okay and basically it is based on what is PVDF polyvinyl in chloride film which is a good piezoelectric material good in the sense that its generates fairly large electric potentials okay when it is subject to it pressure okay the basic construction of these is some what similar what we have it one again you have a productive layer then you have pvdf material and it is pvdf material we deposit some metallic tracks so you have this metallic tracks okay underneath so this is of course sheet here then underneath you have a silicon rubber seat and what you do in this seat is you make it of two types of rubbers you have silicon rubber which is not a very good conductor and you make holes in that and you fill in the conductive rubbers so this portion is not a hole but a conductive rubber okay this is our protective plastic this is our pvdf layer this is the silicon rubber okay we have materialized electrodes and row electrodes okay and then we have one more layer which is again insulating and it is got holes in the same place and these are holes right and finally we have a pcb which got column tracks now if we look at the this of course all together and you look at the track locations you put them on top of each other intersection where all these circles are shown

okay the basic way it will work is that when some pressure comes on it some objects placed on this this is all in the robot hand and the robot hand is holding an object then at various places pressure will be rare because of the safe of the object and that correspondingly you will have a stretch of that pvdf layer because there is a hole here this has a tendency to go into the hole and that as goes into that hole pvdf structures now there are both effects in the pvdf you know the thickness direction the effect is small okay thickness but it is large in plane okay that is due to stretch okay right so that is the whole purpose that you have conductive parts here and these when the pressure comes these conductive parts goes into the holes here and so they may conduct with the lower tracks and consequently the pvdf layer also deforms and that because of that bending that take place there is a stretch taking place and therefore there is a larger piezoelectric effect in those areas okay then of course what you have to do with all piezoelectric type of sensors is that here to read this sensor signal before the charge leaks

fortunately pvdf time constant is of the order of the few second so it is not a major problem because in a few seconds we have to scan through the whole array and determine where the pressure is and that is not too much of problem because there is a sufficient time of it if the time constant goes much smaller like in the pcd pcd type of piezoelectric materials then it could be a much duffer problem to be able to scan it in time probably different spots (Refer Slide time 22:50 min)



okay now let us look at another type of sensors quite important and that is called a slip sensor what we want to do is if you imagine what we do when you hold an object in our hand is that we adjust the pressure between the fingers so that objects doesnt slip if you hold a heavier object obviously pressure has to be greater so that we can generate sufficient friction force wherever its a light objects pink palm ball or something like that and you dont hold it to that tight it because you know that hold too tight you may damage it so same thing needs to be done for robots because different types of robots it they are may to handle when it has to have some kind of a sensor which will help it to determine whether the slipping will take it right so what can be done is basic idea that you can have is you can have a gripper and you have something those of the gripper one side iam showing a basic finger the other side i have modified the finger to include a slip sensing device so if you have a object an object will making a contact this are object sitting here and what iam have is inside this cavity i have some rubber tamper on top of which i have a piezoelectric crystal rochelle salt crystal okay these are what i said these are rubber dampers

okay on top of this you have a spring like structure on top of which you mount a sapphire needle okay this is need to have one more damper that is the metal sheet damper if you think about it this is basically nothing but the whole phonograph needle type of device so what happen is when the gripper is closed on the object the needle touches the object and then if there is any slipping taking place then slip will causes force vibrations in piezoelectric material as i say it look like a phonograph record pickup so if the object slipping in the gripper then this needle is exited an it starts to vibrate this vibration is transmitted to the piezoelectric crystal and piezoelectric crystal will give some output which can be sensed so if you start getting a output then you know that the object starts slipping then whatever mechanism in the gripper to start closing in further so the object doesnt slip

now problem with this type of device turned out to it was tending to be sensitive to manipulator motion itself these rubber dampers are actually used for protecting it from that type of vibration coming from the robot body however if you make this damp a lot then you end up killing off the signal also and therefore the sensitivity too slept then also be reduced there is a trade off and of course like a phonograph sapphire needle required periodic replacement of the needle several improvements where made by various other researchers so some of the improvements or improved device had steel steel ball instead of the sapphire needle of the order of about half a millimeter diameter ball was used and instead of using a piezoelectric crystal they use electromagnetic pickup and instead of using these rubber types of dampers we use oil dampers so the construction of the device is little different but if you do this things then it will become much more robust in terms of sensing only the slip motion and not so much the motion of robot itself

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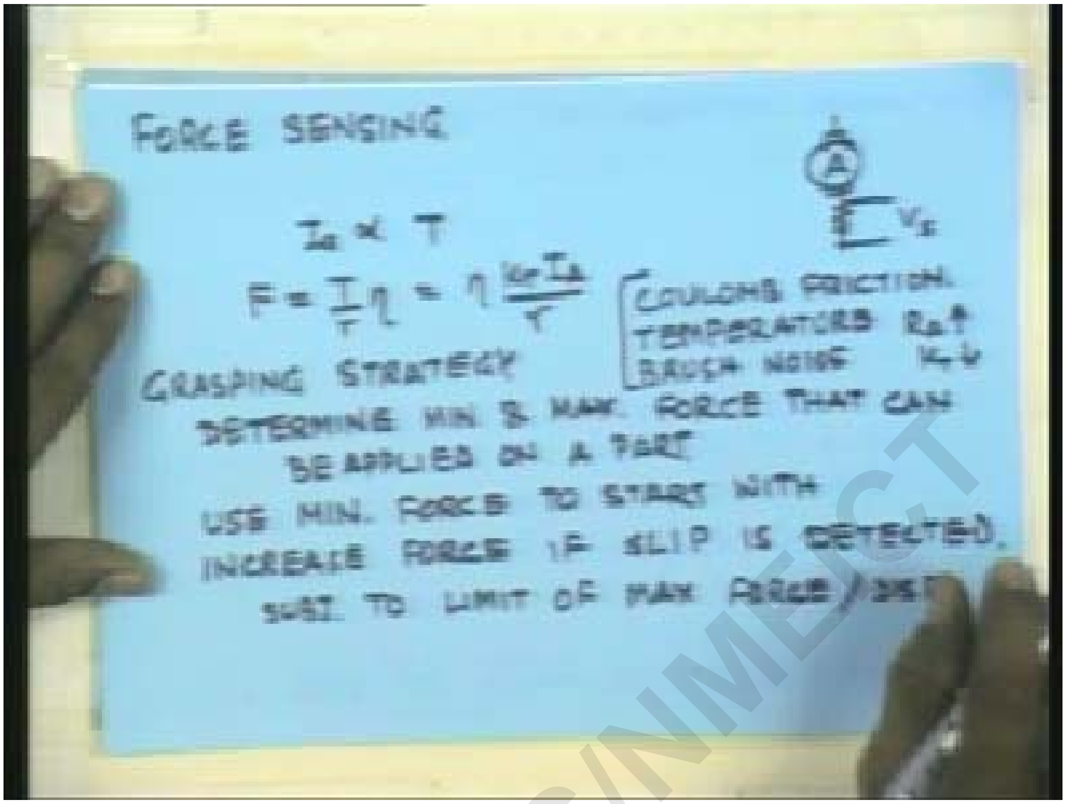
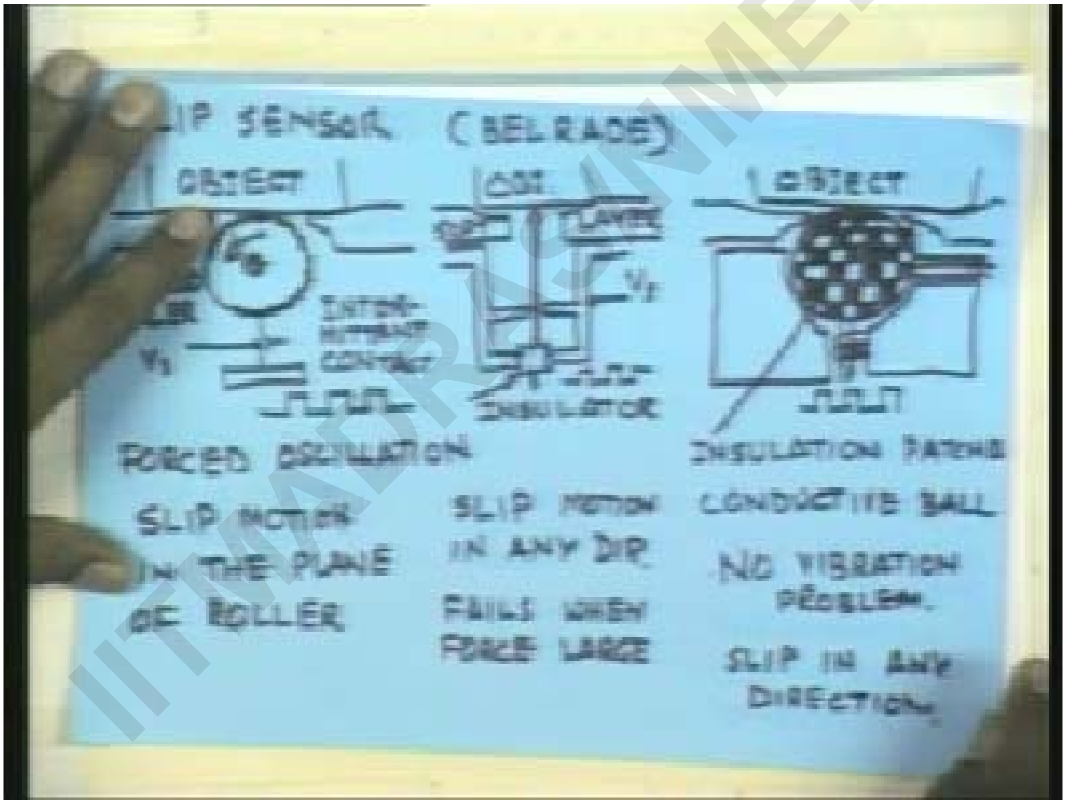


yes please sorry [noise] yah yah that is of course a you know that a question of how you do the we will talk about that lets talk about that now see basically it voice down to force sensing issue so okay issue is that what should be your graphing strategy so supposing we using force sensing one of the ways do to force sensing would be to look at the motor current and so if you have a armature you connect a series resistance to it and then you look at the voltage across that okay v sense let say then v sense will give you an idea about the armature current and we know that the armature current is proportional to the torque that is generated by the motor so it could be a motor that actually try to close a finger or it could be a motor somewhere else in the robot but if you talk about slip motion then of course you have to talk about the motor which is trying to close the fingers and that is iam assuming this is servo motor when you know that the torque is related to the force so some kind of transmission and may be there will be some kind of efficiency coming in and that means this will be equal to theta times kt Ia divided by the whatever the transmissions right we can measure a force and then i will grasping strategy could be see first of all half line you determine minimum and maximum force that can be applied on the object on a part right

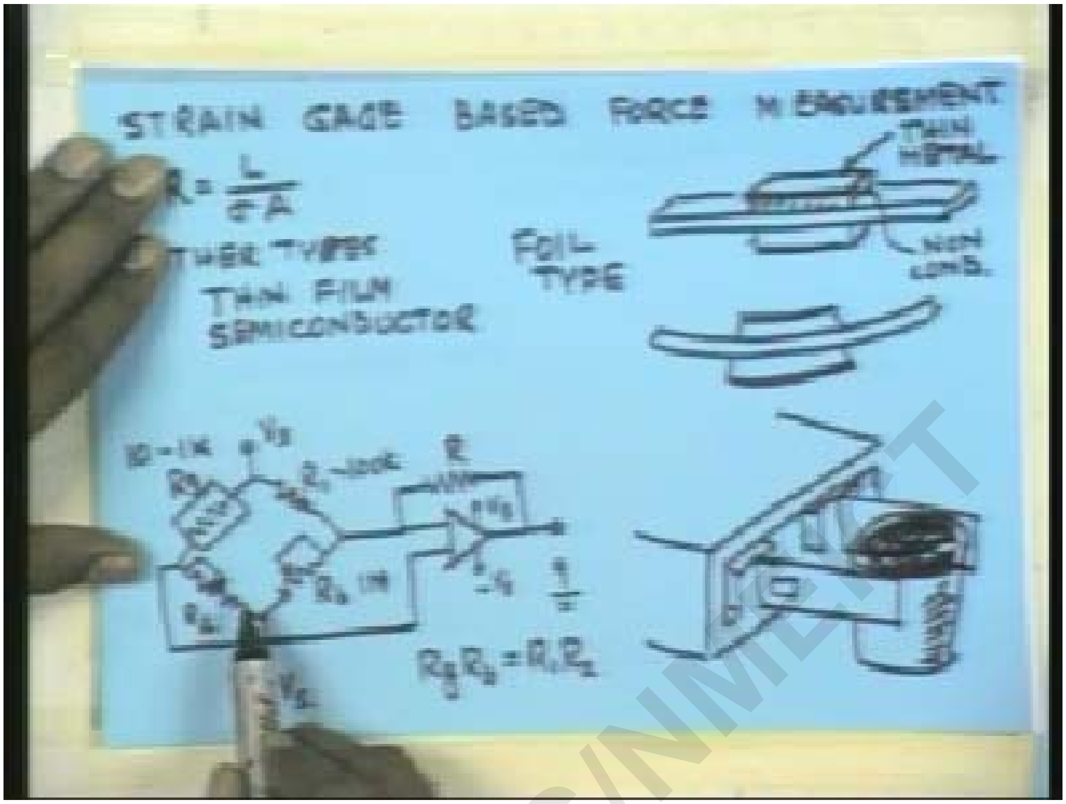
we have some idea before hand what is the force that can be applied then if you use minimum force to start with and then increase force if slip is detected right but we have to subject is to limit of max force or max displacement you cannot allow the gripper to keep on closing because when we know that the object will get crashed and we can take this two up to the maximum force that will be permissible so there will it will many time it will depend on the orientation of the gripper whether the slip happens are not so if the fingers are keeping like this the object are having ends to pull down if the gripper is like the object will not tend to fall down right so there could also be a more complex strategy in which you try to reduce the force wherever the slipping is not taken place to see whether slip starting take place you could bring it to the border of slipping taking place and then increase the force by a certain amount could be one step now this all this depends on how accurately we are able to measure the force and the slip for example in this type of force sensing use the motor current it is not going to give perfect its not matching the force actually it is matching the current therefore if you have coulomb friction then the current will have overcome the coulomb friction and then apply a force so what will be actually applying would be less than what the current is telling you so this is one problems the other problem would be supposing the temperature changes okay the temperature increases let say then your armature resistance will increase your k value will generally decrease and both of the text will decrease the torque okay then of course the issue of brush noise all those kind of issues are there okay these are getting in to the details how to make this work basically you can apply this type of strategy for grip (Refer Slide time 35:16 min)



okay let us look another slip sensor which is little different principle this was developed in belrade yugoslavokia as while yugoslavia okay basically it consist of a softer surface at the gripper and there is a wheel inside with this as the axis and the wheel when the object is grip this is one of the fingers that i have shown and the object is between the two fingers and the other finger is above rate so iam not showing this is my object this wheel has got marling on it so the surface is not smooth this is the knolled surface and what we do is underneath you put a little cantilever one type of device and you apply some voltage to it and then you put a contact very close to it so you have a applied some supply voltage and you have contact very close to it if the object starts slipping then this wheel is going to rotate if it rotates this cantilever were stiff which is engaged in a knolling knoll portion is going to start vibrating starts vibration this will make intermediate contact so you are going to get some kind of output voltage which is going to vary between vs and zero depending on where the contact is made or not okay so basically it is using forced oscillation which is similar to what we have seen in the sapphire needle type of setup but it is more simpler in the sense it is not using any of the piezoelectric material it is only very mechanical action which is sensing the motion of the object direction of the in the plane of the roller right so this doesnt have as much of problem of sensitivity to robot vibration but it can only be detects slip motion in the plane of roller so they they improved that by another version of these sensor in which you have this is same kind of soft layer and then you have some structure here connected to the soft layer which is conductive and you have a needle which is passing through here and then you have some insulator here to which the needle passes and comes out here so this is insulator and then you apply some supply voltage to this if the object was slipping then again there are vibrations induced in this visker light cantilever and then it will starts make contact to the with this thing then we get the output of the same type the advantage is that this could be made in three dimension like this so that if the vibration where in the plane or out of the plane both will have some contact at this point

okay therefore you can detect slip in any direction right only thing is that this failed when you applied larger forces okay fails when force is large and the reason for that is that this needle been very thin and pointed needle dicks in to the object and then stops vibration already so this is not extremely satisfactory also so they came out with third idea in which you have this soft surface where the object is being gripped and then you have behind this then you have a some kind of housing where you put a spherical ball here and then there are spring loaded contact here and here the ball is made out of conductive material right so basically you can recognize as the or mouse computer mouse type of setup this sphere is made out of a conductive material and what is done is you take you divide this into strips in the two directions and you paint some of these squares alternate squares in fact by some insulating paint oops that is wrong

okay anyway i will continue to paint here i should have been not colored this colored this colored like that alternate squares are insulted so now get the idea of what is happening right now this is not suppose to be okay idea is that the ball roles due to the motion of the object here going to get some this will either detect conduction or no conduction and therefore they will give out some kind of a change modulation in the voltage that can be detected now here we have so this is called insulated insulation patches okay and there is no vibration problem okay in of course slip in any direction can be detect right so this is the series of developments over several years that some researchers in yugoslavia okay this is fairly effective this is improved version is quite effective (Refer Slide time 44:25 min)

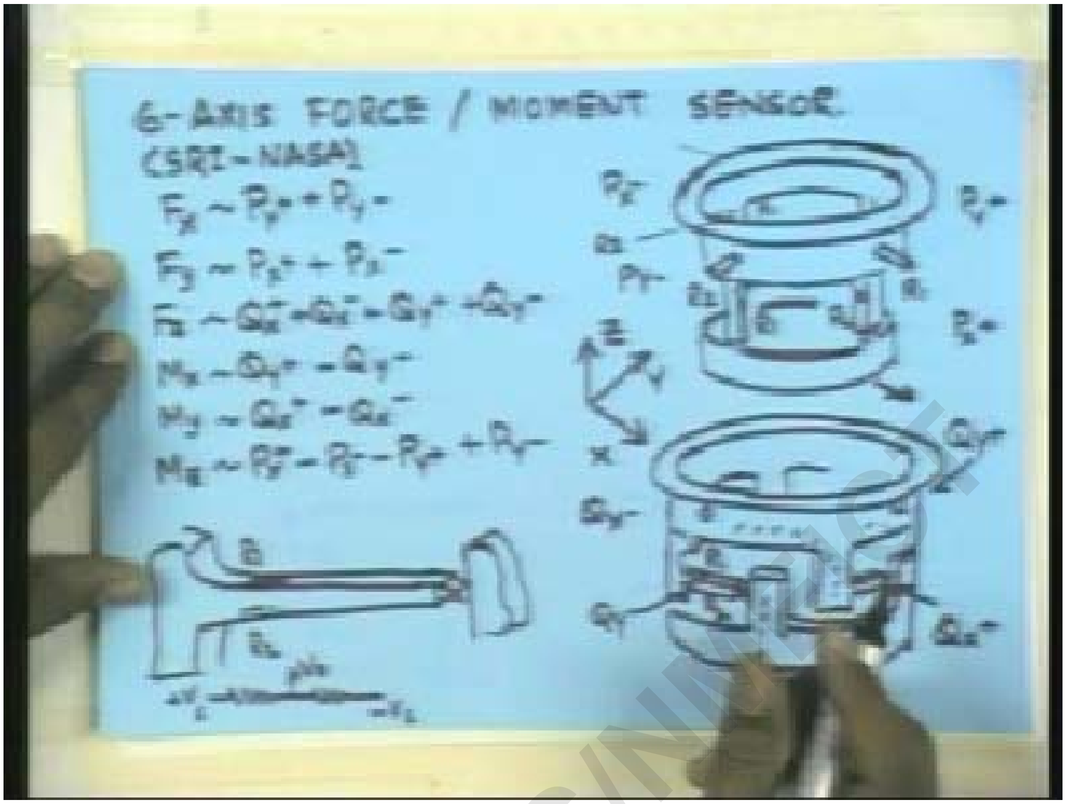


so now let us look at force sensing you have seen tactile sensing in the sense of where the pressure is developing in different parts of the gripper and we have seen slip sensing that which the object starts to slip then we have that is detected if we look at the we would like to sometime actually measure the force okay as i mentioned earlier that if you are using some this like motor current to sense the force when sometimes you will be wrong because coulomb friction and temperature will change and then what you measuring is the current not the force so direct measurement of force can be attempted and that can be done by using strain gages measurement of sensing now basic principle is very simple and iam sure all your are familiar to take some kind of cantilever beam and mount on it

okay you have a thin metal either it could be a paint or it could be a thin deposition and you may have a sub state which is non conductive okay this is the sub state portion here and similarly you may know something in the bottom also and this is our basic setup this is basically the foil type of stain gage and of course if there is force coming on this cantilever the cantilever deforms and this metal portion here be the structures or contracts depending on which side which is on and the resistance which is basically depends on the length of the stain gate and the conductivity and the area of cross section now the gage is very thin cross section area doesnt change when the deformation takes place mostly the length that changes and therefore the resistance will increase of decrease depending on you contracting it or expanding it other type of same gage is possible other types will be same thin film deposition directly without using a sub state you can deposit or you can spatter some thin film or you may have semiconductor type which is much more sensitive and its may doubter by using vlsi type of technology and for processing this one can have a big circuit and we will have some adjustments this is our gage so let us called as Rg this is some resistance R1 this is balance resistance and this is some resistance R2 you will connect this two to the v supply and this connects to the minus v supply and that output is taken from this part of the you may give this in two a operational amplifier type of circuit with some gain that you will selected depending on these registers so thus order of gage resistance will be from ten ohms to about one kilo ohm supply voltage you may choose like five volts or fifteen volts using half ohms of the same supply perhaps fifteen volts then this resistance have to be fairly high so that limit the current so something like hundred k can use here one mega ohm may be used here what you ensure is that Rg times Rb is equal to R one plus R two

okay and then you can see the if there was this was not the case then some output will develop here it can be measured and it will be the indication of the strain that is develop which will be the indication of the force that is coming on the finger so supposing you have the gripper this is the parallel motion type of the gripper so i have some fingers moving on some moving flops here okay similarly have another finger here and this is moving on some flop here okay then of course you have an object here this is my object here

okay i will mount the stain gages here and mount the other surface may be inside or may be outside depending on what configuration i want and then i can use this type of circuits i can use two circuit like this look at the differential output or i can put this gages in different arm of the same pitch and this way i can measure the force on the fingers more directly how many times you are not only interested in one component of force this will give you the force in the direction of the whether the gripping what the gripping forces is sometimes if you are interest in much more would to use when you are thinking about assembly process when you are making one part and another part there are forces which develop because of the this interaction with the environment and one people started doing assembly using the robots we found that simple operation of putting a bag in a hole they could not do there is a sufficient clearance there was chamber in the front of the sprat but still they could not put the bag in the hole then the found that various devices of course were developed and i think remote center complaint may be mentioned but another way to do is actually look at all of force which are developing due to the reaction force and then corrective action can be taken (Refer Slide time 51:00 min)



so if we look at that type of sensor which is you can call as a six axis force slash movement sensor when i will try to draw the configuration of this this is little complex you have basically two cylindrical members this is follow and then you have some arms sticking out of it and there is narrowed portion neck so if i have this is another one cantilever basically there is a neck and there is a bottom ring okay and then there will be some other features of this which i will tell you what they are basically you mount the stain gages here and on the back side and here on the back side and there is two more on the back they will have stain gages on both side of the cantilever this is not all and you have another concentric cylinder okay now this one is having cantilever which are going to be perpendicular to the one that i have shown you there and this will be something like this obviously getting a little small but there are futures in the top and the bottom cylinder here from which the cantilevers are mounted so this cantilever for example is here this is the arm which is coming out from the top then this bottom ring here is the other part of the arm okay

so this is basically iam shown part of it let me okay iam not drawing all of it but you get the idea this is the portion where metal is there and there are gaps here right so there is two set of you see the top going in the bottom ring they have columns between the column of the top ring and one column of the bottom ring you have a horizontal cantilever there so there four such cantilevers around the circle here we have four such cantilevers pointing downward here the basic structure of the cantilever is that its a narrowed portion and then you have neck portion before it connected to the other body right so this you will paste here spain gage is here at the bottom let call this R one call this R two the direction are shown that if you look at your x is say this are x axis this are y axis this are z axis then if you go from R two to R one you are always pointing in the positive direction of your x y or z axis okay so here R x axis is this way so this is going to be R one this one is going to R two on the other side okay now positive y direction is this this way you going to have R two here and R one on this side right if you look at this particular column here then positive y direction on this way R one and R two would be on this side here now this columns are name let say there this is p y minus p x plus what is there here is p y plus what you have here is p x minus which is hardly seen similarly you will because the stain gages is mounted here you have R one here and R two here because going from R two to R one you are in the positive z direction right so naming convention is consistence and you have Q x minus here and Q y plus here and you Q x minus and Q x plus here which is not seen right so with this type of arrangements what you can do is you can connect these R one and R two as a potential divider so with some voltage here and some voltage here and this will tell you directly the deformation it is not a good circuit much simpler than that because there is so many streams circuit because so many start to apply the big circuit it will become very complex

and so if you can simply write the expression for the estimation of force as P y plus plus p y minus similarly F y is going to be approximately equal to P x plus plus P x minus the z direction force will be obtained from the queue sensor Q x plus plus Q x minus plus Q y plus plus Q y minus the movement about the x axis can be gotten from Q y plus minus Q y minus similarly the y axis torque can be obtained as Q x plus minus Q x minus and the Z direction movement can be gotten from P x plus minus P x minus minus P y plus plus p y minus right so this way if this type of structure you can see what is actually happening if you look at the effects for example we want to measure the force into the x direction

okay of course the x direction would not be given this columns at all because this are deforming in the perpendicular plane where as if you look at these then the deformation takes place you have x direction force acting here with respect to this part so this is going to be deform this will contract and this will expand similarly this will be effective so these are the stain gages of the two bridge bridge column where we sensing stain these are the two which are going to give as x directions forces that is what is here this is to be simply adding to together because the way we are defining R one and R two consistently

okay similarly the y direction force will depend only on this plane gage and this plane gage z direction will depend on all the four horizontal cantilevers this will be add up the output of the volts the movement about x this is the x axis the movement about the axis this way so you have look at the difference between these two and that is what is done
so basically because of the construction you are able to isolate different components of forces and you can measure so this was actually developed by the stanford research institute in collaboration with nasa and actually it was the work of the victor shine man for his master pieces to develop a this type of a force sensor i think we are out of time so this module basically what we have done is we have looked at different type of sensors which are useful in the robotics internal type as well as external type there is one major external type which we have not talked about and that is vision and we will talk about that at length in later module thank you