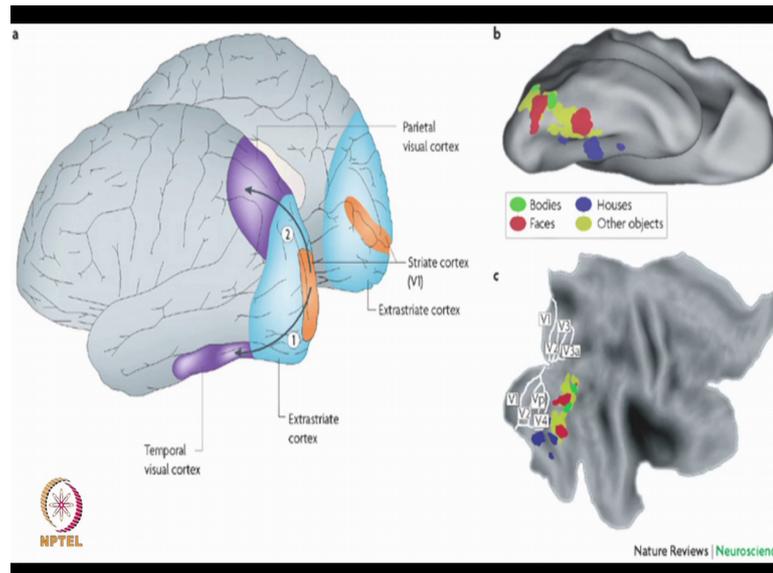


Virtual Reality Engineering
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Indian Institute of Technology, Madras

Lecture – 10-3
Human Vision (depth perception)

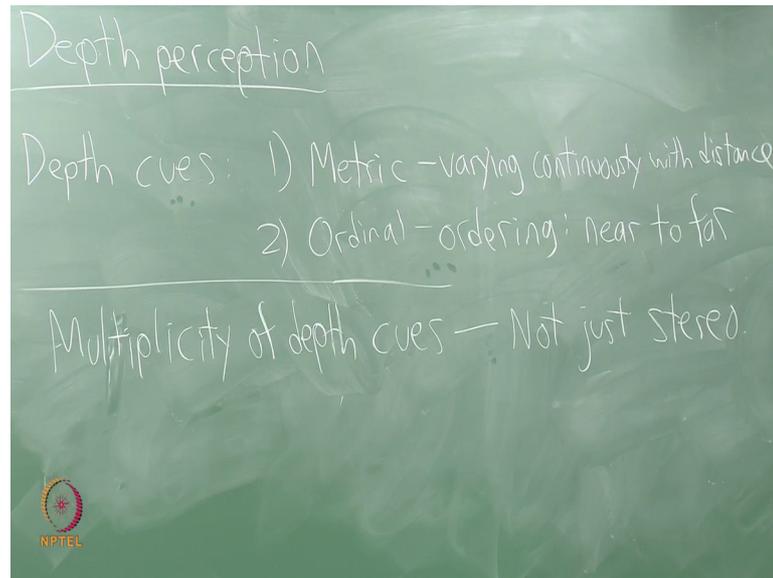
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Next topic I have which is depth perception. I will go a little bit into that this is covered in chapter 10 of the of the mather book.

Depth perceptions and invert is a very important topic for virtual reality. We like to think that one of the biggest differences in looking at a screen compared to looking through a head mounted display is that we can provide to you depth perception through stereo, but not completely true that that is the most important distinguishing feature. We get depth information from many, many sources and I want to make sure that is very clear so.

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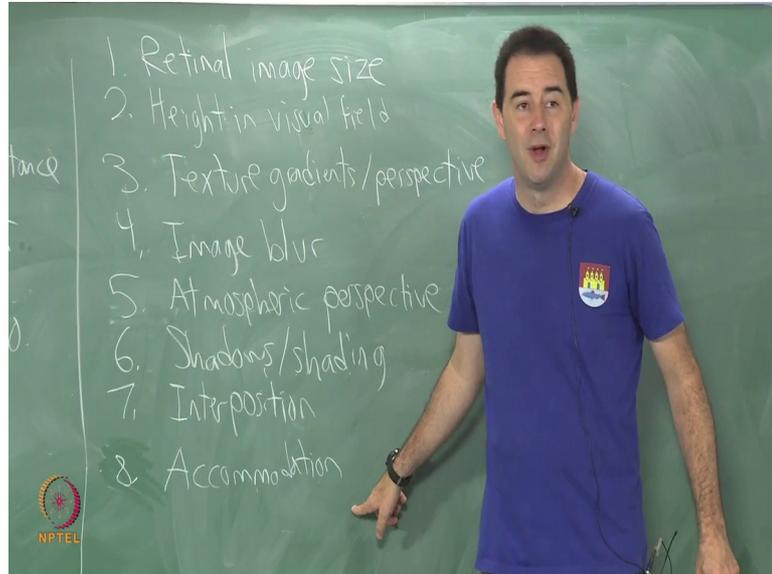
Depth perception, this is by the way a very general pattern in perceptual psychology is there is something perception. We have depth perception will talk next about motion perception there is some other things I would not have a lot of time to talk about, but we could talk about scale perception, we can talk about color perception. This is just a template here if you like. If you want to study more of these things later it will follow the same mentality.

We will be studying what are called depth cues and again in this pattern cues over and over and comes up again. If I if I am studying motion perception then I will talk about motion cues. Cues are somehow pieces of information that trigger the brain to perceive whatever it is that were trying to perceive. What is the key information that we need what are these features that are going to be used? It is going to be 2 different kinds of depth cues one nice way to separate them is into what I call metric and ordinal, in other words metric is going to be varying continuously with distance and ordinal is about ordering as the name suggests for example, near to far. What is in front of what else another way to maybe name these number one could be maybe continuous if you like and number 2 could be combinatorial. It could appeal to the computer science in you if you have that background.

Again, the thing I want to emphasize is that there is a multiplicity of depth cues. Not just stereo, when you look at panoramic images for example, if you have had a chance to

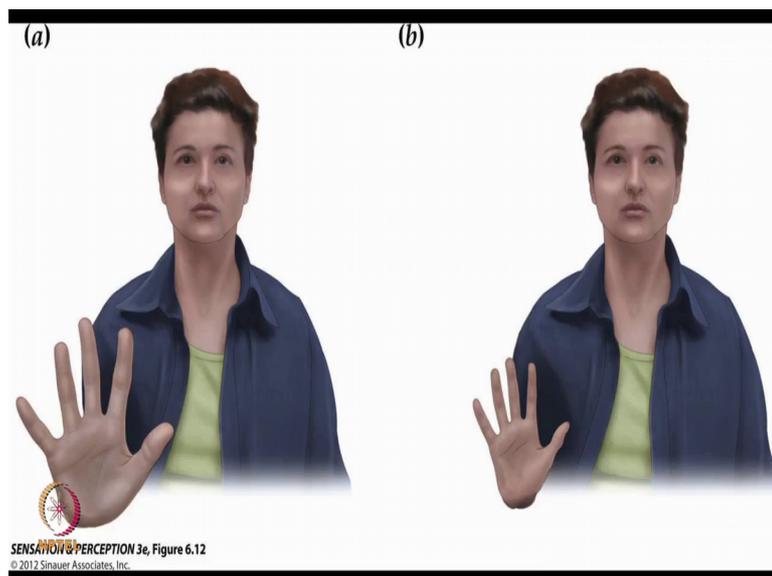
look at those in the lab they may look quite 3 dimensional even though the same image is being presented to both of your eyes. Why is that? We need to talk about that.

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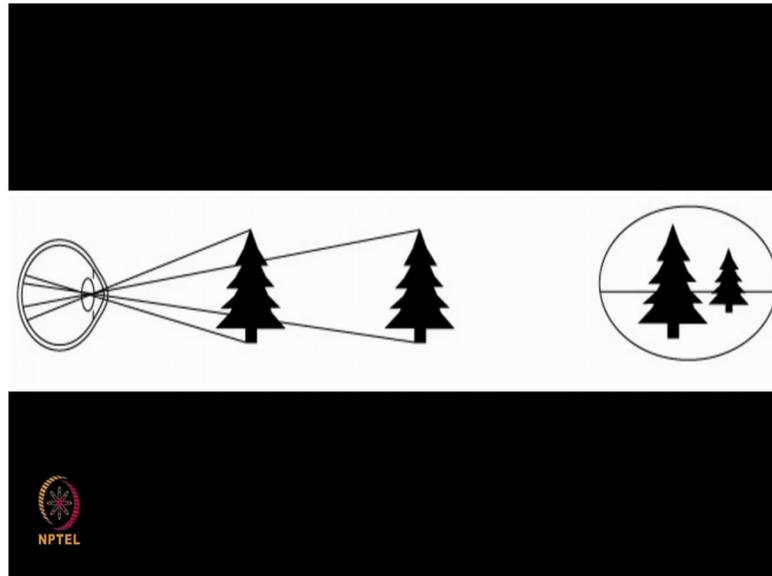
I will go through some examples one retinal image size. How far away it is may have to do with how much of your retina the image takes up, combined with your knowledge about what it is you looking at. Assuming you looking at something familiar let me give some pictures here.

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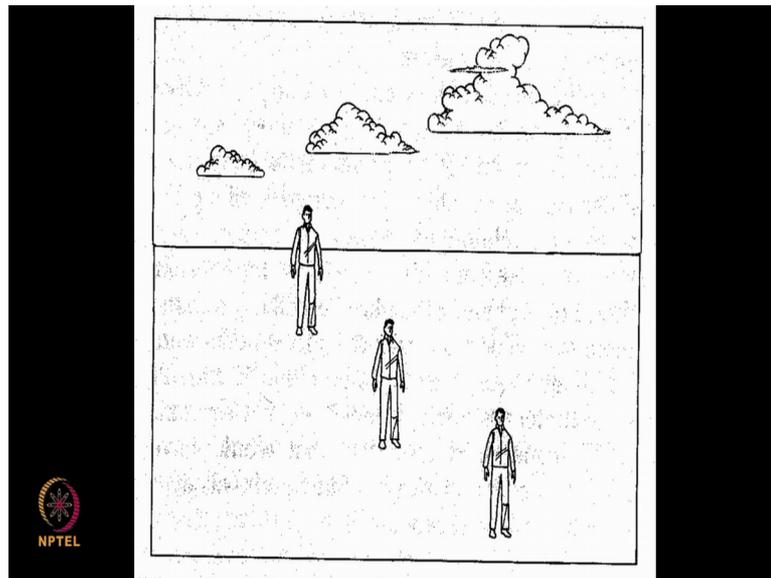
For example, just based on the size of that hand as an image on your retina in the context of a person standing there behind, you make some inferences about clothes right does a woman have an enormous hand in the in the image on the left or is it just closer you do not see an arm there really it is the same picture either way all. You are making some inference about depth and you are not using stereo.

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Again, what is the size of the image in the retina? We know maybe how large a tree should be. And so, if we see 2 trees and one is further away. The on the right there it shows that these smaller tree is perceived to be further away simply because it occupies a smaller region of the retina.

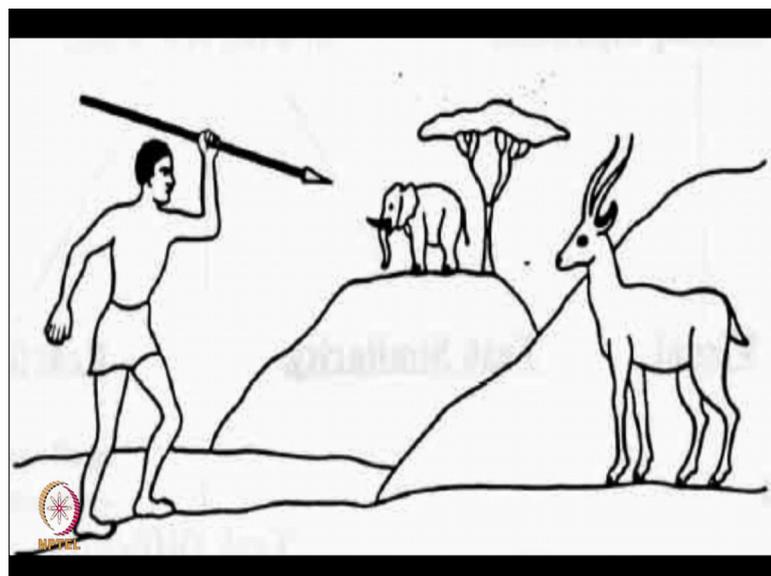
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Another thing we can look at is height in the visual field

Let me write that height in visual field. We did not change the size of the person there we just changed their height in the visual field there is a horizon line. And so, it appears that the man at the top is further away. That kinds of information were also using.

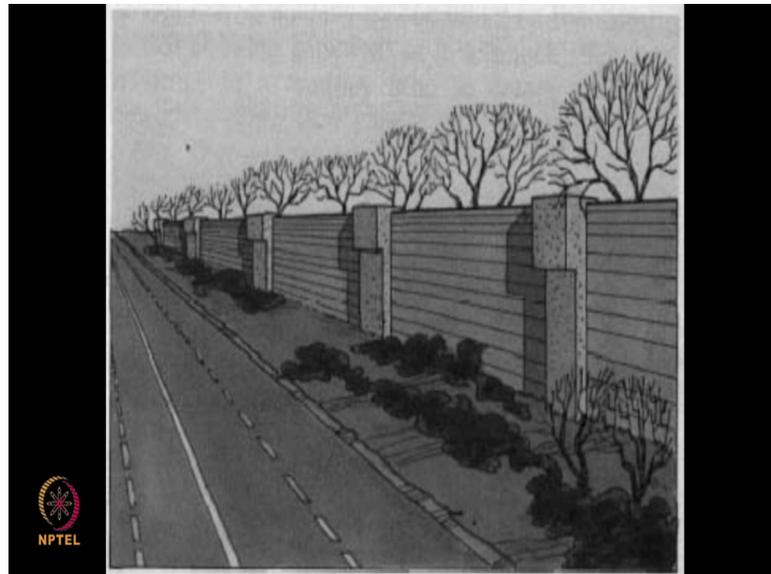
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Here is another one where is the spear going to hit. This is also some size changing there as well that is a combination of 2 of them I would say because it is height in the visual

field, but there is also differences I do not think the elephant should be smaller than the animal in the front.

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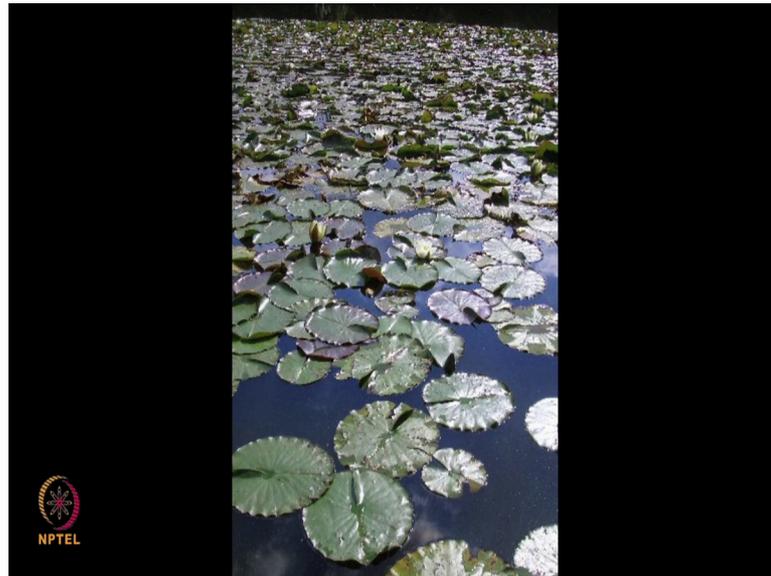
Texture gradients and perspective texture gradients and the perspective is a part of this may not be a perfect texture. We have some examples of that you perceive depth right just from the street stones in this painting.

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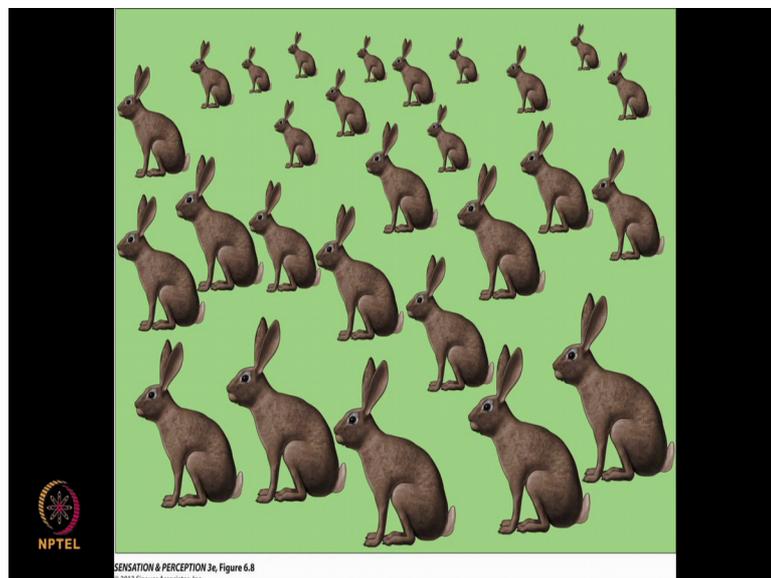
Lot of perspective near the top there in fact, it looks a bit excessive, but, but at least from the tiles on the ground you can see you get some idea of depth.

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You get ideas of depth from this right just an arrangement of lily pads. Again, it is depth from this kind of texture gradient.

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Again, it is a kind of texture here a texture gradient.

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Another one is image blur. It looks in this one that the blurry parts are farther away. Further away just by the way we drawn this image we perceive the other pink flower to be closer.

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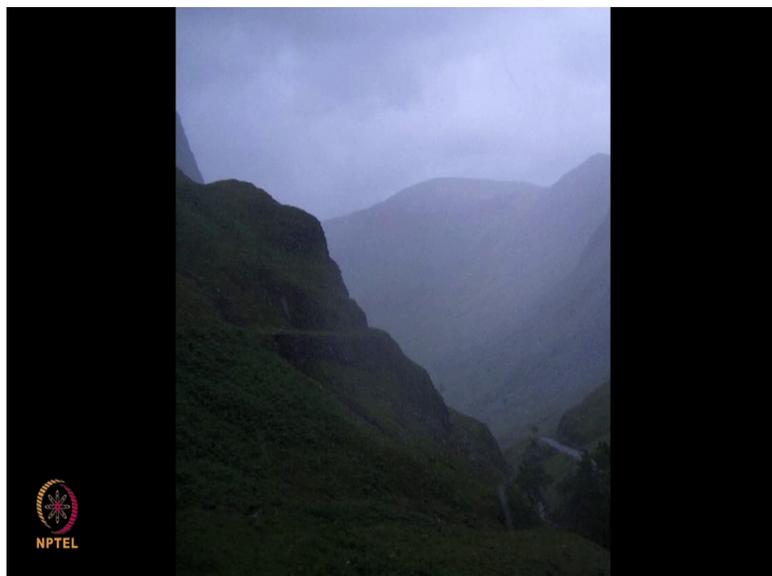
In this case we have blurring up in the front we perceive the garden gnome to be further away.

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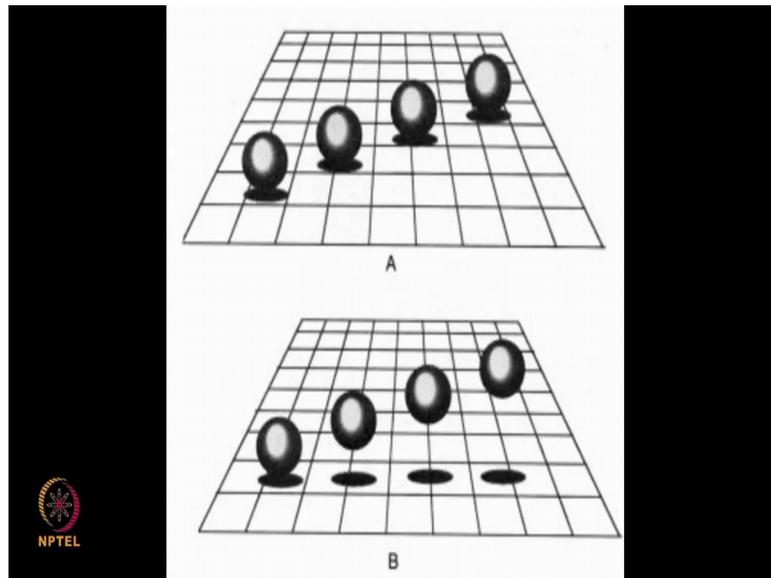
This is a case before.

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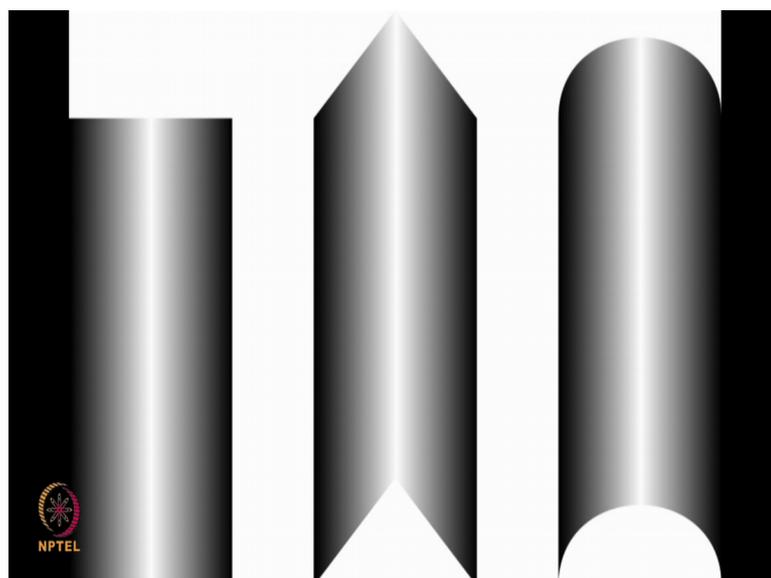
Another one is atmospheric perspective. The hazy mountains in the distance seem to be further away.

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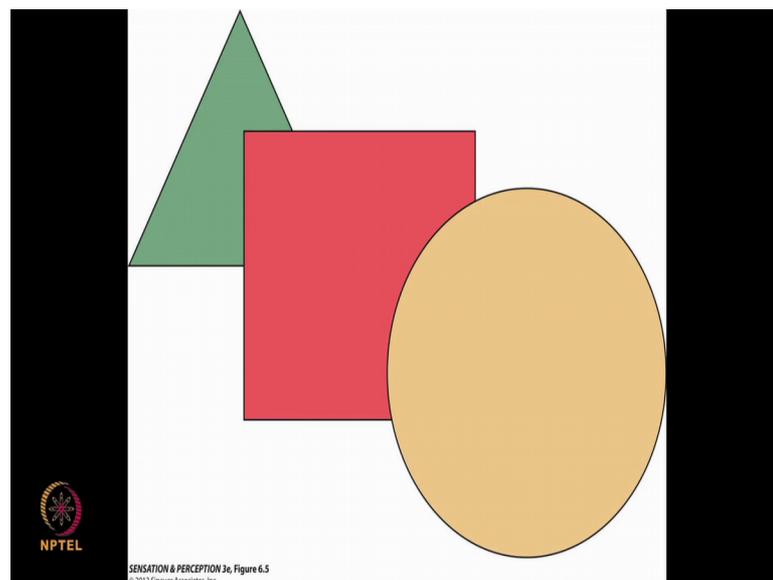
Some additional cue this one's great shadows let us see 6 shadows are shading. In the top picture, I perceive the balls to be going further and further away. As we go from left to right, but in the bottom picture I prefer them I perceive them to be at the same depth, but just different heights in the air right and the only difference between the top and the bottom is how the shadows are rendered. Clearly, you are using some additional information from the shadows to help you reason about depths happening all the time for us.

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Um you can also look at these shadings to figure out whether it is a cylindrical shape just from the way the shading works here. In addition to just straightforward shadows there is just shading across the object it is the one on the left and inward cylinder outward cylinder I am not sure we can tell there may be ambiguities there looks like the other 2 are a little bit clearer maybe not sure you know. Maybe the last one looks clear that one looks outward. Be careful with those, but you do get some depth information.

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Another one is interposition and so, I perceive the yellow disc to be closer than the red square which is closer than the green triangle.

We get some kind of depth ordering that is an example of ordinal information.

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And the same kind of thing is happening in this complex picture. There is a lot of boats out there people in the front waving, but we get a lot of information just from the ordering and not necessarily using any of the other cues. In this particular case, it is not a lot of extra information there, but we start to infer about various sailboats and where they located with respect to each other from this interposition. Let me give a few more here goes on and on does not 8 accommodations and this we talked about before. Is this refocusing of your eye? Just based on your brains knowledge that your eye has had to refocus you perceive something as being closer.

Now, if you messed that up with your head mounted display by making everything appear to be at infinity all the time you lost this cue. What is the effect of that? I do not know someone should study it some people have studied it, but there still a lot of unknowns. Your losing that cue many people would argue that is a very important cue to keep for depth may be more important in stereo.

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Motion parallax, motion parallax if I move back and forth because I need to hold some kind of object stationary here, but if I if I hold the station I go back and forth then I see this object passing in front of you who are further away at a faster rate. The objects at varying depths intermingle in a certain way where the closer objects are moving more quickly as I move back and forth. Very important motion parallax that is important for visual sense it is important for your audio sense. It shows up in other places. It is important here as well.

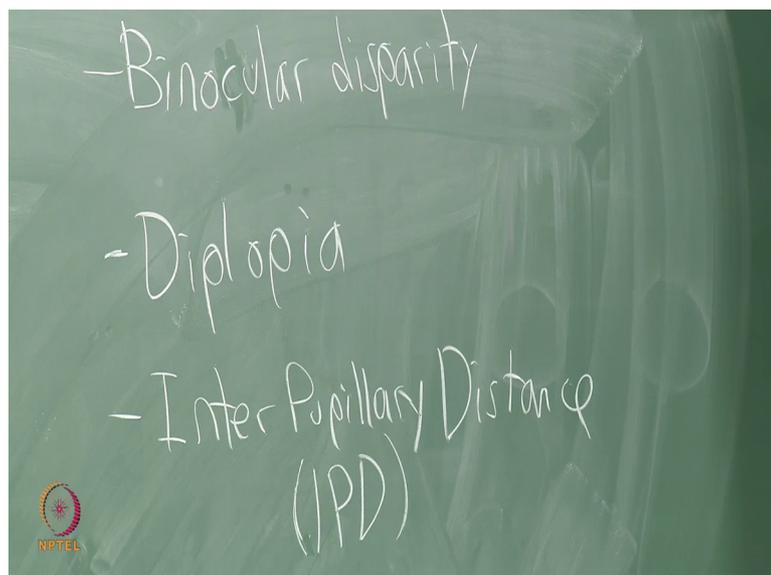
Now, if I have a head tracking algorithm that is running with sensors and such for a head mounted display if I can only rotate I get some motion parallax if I simulate the translation of my pupils still using rotation, but if I move like this I will not get motion parallax. If I look at a panoramic display and it was taken by a panoramic camera at some fixed location and then I start doing to do these parallax motions I will not get this beautiful arrangement of objects moving back and forth. You will lose that if you capture a panorama with a stationary camera. You lose that bit of information. It is very important to have that, but that gets lost.

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In that case and finally, number 10 I say this for the end the obvious 1 which is a stereo cues. What are these there is the vergence angle. And so, your brain knows how your eyes are oriented? How much they have converged? You have a signal for that you have what is called binocular disparity. How much how different are the images between the 2 eyes.

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Now, there would not be because your eyes are rotating it would not be the same as if I just had 2 cameras facing forward and then I move them apart to get stereo, I am not

rotating the cameras to face the object like I would wipe my eyes actually rotate to face the object of interest. Your cameras would not right unless you put some special motors on them to rotate them. Be a little bit careful. I mean doing stereo computer vision you get a very large displacement, when you when were talking about the human eyes that are rotating and converging to fixate on the object of interest, but there is still some disparity in the images. Even though they cannot look identical because, your looking at them from 2 different perspectives.

That is what I mean by this binocular disparity it is not as much as it is in the engineered case, but nevertheless your brain can detect that information. There is diplopia which I mentioned earlier if I fixate on some closed object then there are multiple images in the periphery. That is additional information, a couple of more things I say about stereo you have to pay very close attention to what is called the inter pupillary distance or IPD. The IPD in the real world becomes very important if you going to place lenses in front of your eyes then you have to line them up correctly.

That your eyes are centered when you are looking forward that is the best you can do if you do not get that right if you do not have adjustments for this do we have adjustments for those in the lab does not look like it. If your IPD is far from the average what you might not even know this what your IPD is most people do not know this my IPD happens to be lower than most. I am I can remember maybe the 15th percentile or tenth percentile or something some eyes are actually close together, you know who would have thought I know compared to the world average.

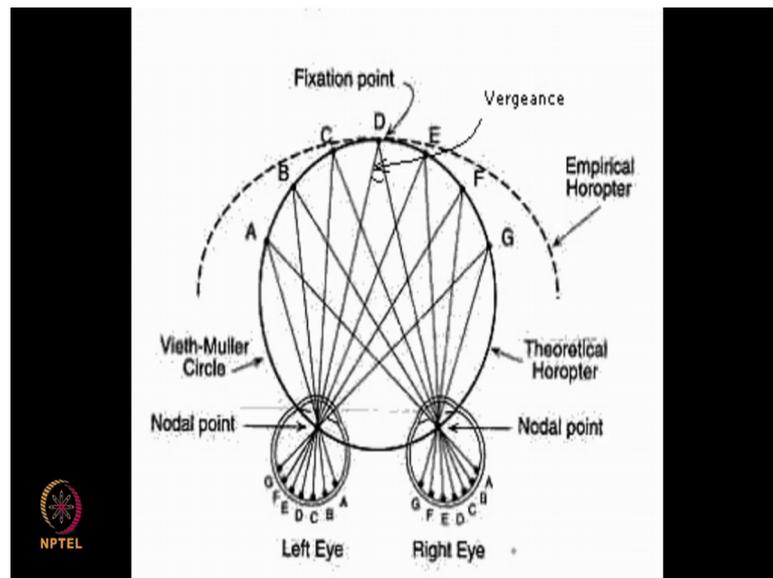
If you that is one questions are you looking through the center of the lenses that is very important for the optical part of a head mounted display. Another interesting question is in virtual reality now. Have I matched you know if you believe in a perfectly scaled world? Have I matched the interpupillary distance perfectly? Or is it too small or too large if you make it very, very large in virtual reality you will feel like a like a big monster or something right now you may look like godzilla or something.

You can make an entire city look very small or feel very small you move your head around and you know it looks like it is been miniaturized. If you make your IPD very small you might feel like you become tiny. There are some there are some applications people have written where you can make yourself feel like you suddenly maybe 10

centimeters high. And so, part of the way to achieve this is by using the interpupillary distance.

That definitely has a lot to do with your perception of depth and your perception of scale. Let us see here.

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This figure just shows what is called the horopter which is the region when you fixate it is the stereo region that you get. A common stereo focal region when you consider the clear images projected onto the retina, there is you know remember we did all this study of focal planes this is showing the stereo focal surface that is common for your 2 eyes. There is the calculated theoretical surface for that and then there is what has been determined empirically, which does not seem to match exactly I personally do not know why they do not match.

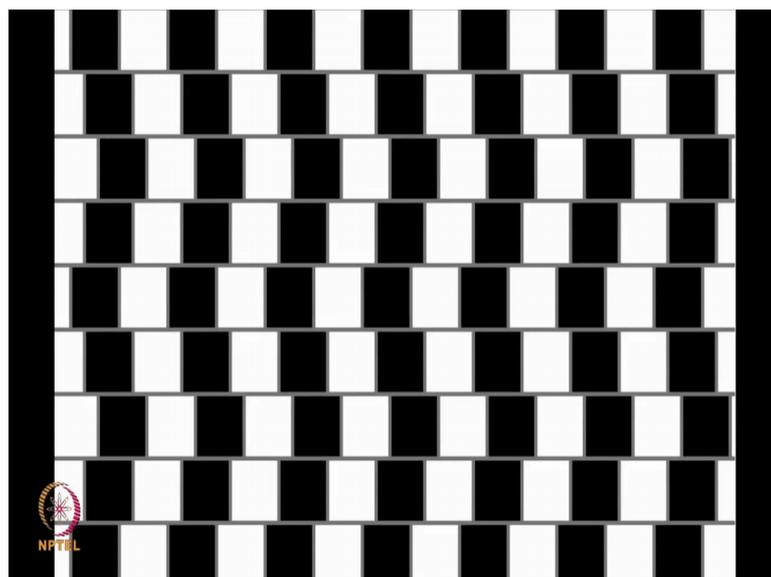
I do not know what theories there are for that, but that is what we get and.

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This may also provide some motivation for people advertising curved displays perhaps. If you sit exactly in the right place, then it may give you a perfect a perception, but you know who knows. Let us see are there any questions about anything I gone over today. I leave you with one final optical illusion just 4 4 final surprises, but see if you have enough background to explain why this might be occurring.

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Does that look strange to you? This is the it is called the cafe tile illusion. All of those lines are horizontal back going back and forth, but they seem to be bending do not they,

but there not. I will leave you with one optical illusion there to think about. That is it for today.

Thanks.