Virtual Reality
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Lecture – 64
Visual Rendering (distortion shading)

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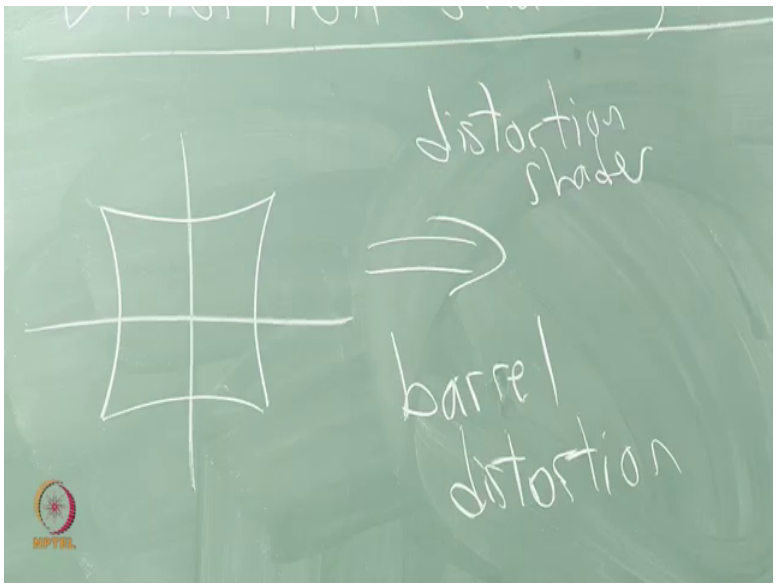

Sometimes this is called distortion shading I find it kind of unusual to use the word shading for a calculation that just does a stretching because shading does not have the propagation of light, but because this can be done in a style that looks like a GPU operation and it is in the rendering pipeline people often call it distortion shading, if I were naming things I would not call it that because it does not look like shading to me.

So, distortion shading for high field of view optical systems; so what do you do in that case? Remember that I said. So, for example, if you take a look at most head mounted displays that have a high field of view lens this exists for example, in the in the oculus rift DK 2 lenses that are in the lab if you put the lens down on a piece of graph paper if you unscrew the lens cup and you put it down on a piece of graph paper with perfect grid lines. The grid lines will look distorted inward like this, I am exaggerating a bit, but they will look distorted inward like that.

So, if you want to compensate for it you apply a distortion shader and it will be producing what is called a barrel distortion I believe I mentioned this before. So, it will

be performing a kind of stretching outward radially, so, when it stretches outward it will cancel off the pincushion distortion. So, that hopefully what were straight lines here and perfect grids here will remain perfect grids after performing this cancellation, after performing this distortion.

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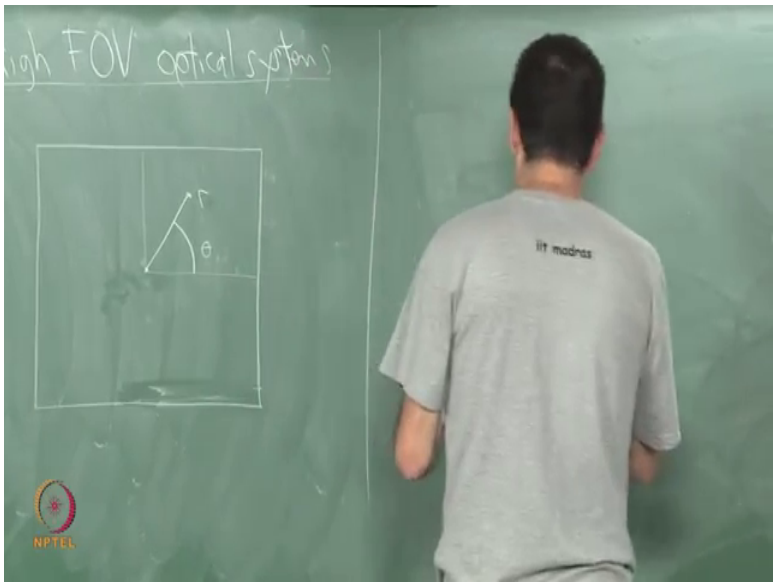

So, how does this work? Suppose, the image is square for a particular I and then; so let us put square for particular I and then I am see here I then express pixel locations in polar coordinates. So, I have theta and I have the distance r right radius let us say outward from the center. So, the reason why I am doing this is because I am going to exploit radial symmetry of the lenses.

So, I am going to assume at the lenses are radially symmetric, it should be a spherical lens and I am trying to compensate for this spherical aberration distortion.

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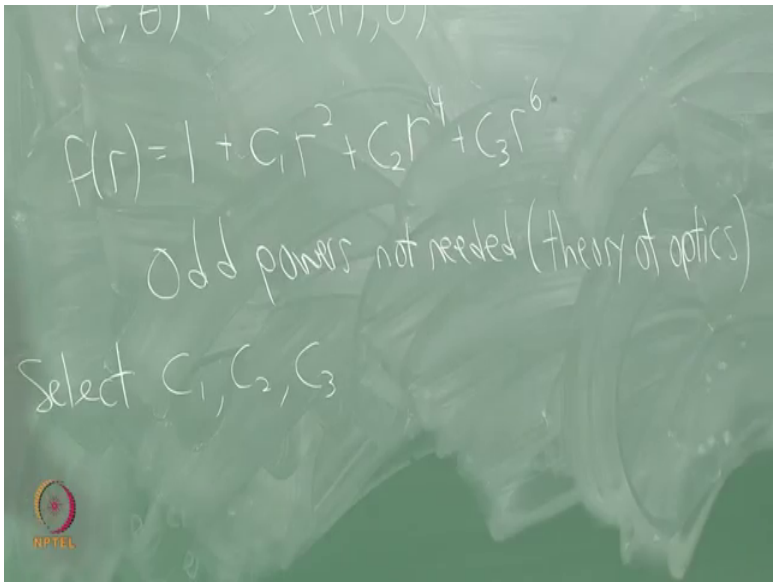

And, so, what I do is I perform a transformation as follows I take every pixel convert it to r theta coordinates and then I perform a transformation that maps that to some function of r and keeps the theta the same and so, again this is radially symmetric. And, the particular function that I perform f of r is assumed to be some general form I am going to give a general form it is just standard formula that comes from optical engineering textbooks and so, it is based on the theory of optics and how spherical the spherical shape of a lens is not perfect for maintaining the same focal depth as you get out to the periphery.

So, this is a standard formula for that has coefficient c 1 times r squared plus coefficient c 2 times r to the fourth plus coefficient c 3 times r to the sixth and if you want you can generate more terms by using even powers of the radius. There are no odd powers it is just the way the geometry works out an optical engineering which I am certainly not going to go through and ends up being a some sort of nightmare of algebra let us say to derive that. So, odd power is not needed now needed this is a theory of optics you can look in optical engineering textbooks or tutorials for that if you like.

So, basically what you do is you choose c 1, c 2 and c 3 and select c 1, c 2 and c 3 and then you keep these fixed forever and so, you keep these fixed this is some kind of radial distortion function. It performs some kind of stretching that cancels off this barrel distortion. How do you select these? Well one way to do it is you get someone who is

very good at looking at grid patterns in virtual reality. So, you render what is supposed to be a perfect grid pattern should look exactly like you are standing in front of a wall that has graph paper on it and then if you do not apply this function then it should look distorted like this in a pin cushion way after you apply this function you can adjust these three coefficients c 1, c 2 and c 3 so that it looks like a perfect grid it sounds somewhat straightforward it is actually very hard to select these three parameters and it generate leads to lots of arguments and discussion about what are the right values.

It is actually very hard even if you design a perfect let us say laser rig and you study and measure exactly the optical properties of your lens at the periphery and then work to scientifically calculate exactly what these values should be, they still might not match human perception and so, it is very very hard to get these right and one of the difficulties is that when you put the lens up in front of your eyes remember that as your eyes look out of the side of the lens you are pointing your fovea to the side of the lens.

Then the pupil is translating away from the center of the of the lens and so, that means, that the distortion is all ready changing again in some different ways and what can be compensated for here because this is making the assumption that you are looking through the center of the lens. So, if you go into the lab you put on the headset and you try to use your vestibulo ocular reflex pick one of the demo apps such as wind lens that is very clean you know beautiful looking pictures come up to a wall or a corner of a building or tree let us say and move your head back and forth you should be able to see this optical distortion. Even though it is compensated here it still cannot account for the part where as you use your vestibulo ocular reflex your pupil is not looking through the center of the lens anymore and there will be some distortions that are not compensated and you could try to change these coefficients to compensate for that, but then it will be messed up when you do some other motion.

So, it seems to be a somewhat of an unwinnable scenario if you have optics that have spherical distortion, but this is the simple compensation that is done. So, this is just applied as a last step across the image after we are done rendering. Questions about that?

Student: Sir.

Yeah.

Student: Does the value c 1, c 2, c 3 depends on lens?

Yes, that is right. So, it does. So, if you were to change the lenses you need to calculate new values for this, but beyond that once you have the physical setup done it should be fine. There is other certain things like if the lens does not fit over the center of your eyes because you have different interview pupilary distance some other setting of values here may be better for you, but again because your pupils can translate back and forth across the lenses anyway, it turns out none of the values are absolutely perfect.

So, doing this distortion shading is better than not doing it, but it is still not perfect and that is why I encourage you to go and look and see if you can still see lens distortions and take a look at a vertical line move your head back and forth and do this vestibulo ocular reflex motion and see if it looks like the line is warping as you move, it should you know. You should train yourself to to look for that problem.