Virtual Reality Engineering
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Lecture – 43
Limiting Resolution

Welcome back in one of the earlier classes we talked about the resolution which is needed for virtual reality from the anatomical point of view. We looked at the photoreceptors rods and cones from there we had derived what is the resolution possible. In the later classes we talked about psychophysics, the measurement of perception. The resolution is therefore, is it going to be limited by the perception. Psychophysics as you all know it is just not the physiology or anatomy, but actually the perception. The relation between the they are the perception on the anatomy or physiology.

So, the earlier resolution which is dictated by the anatomy and resolution how is it going to be modified by the psychophysics is what w e are going to see and we are going to come up with a further limiting resolution.

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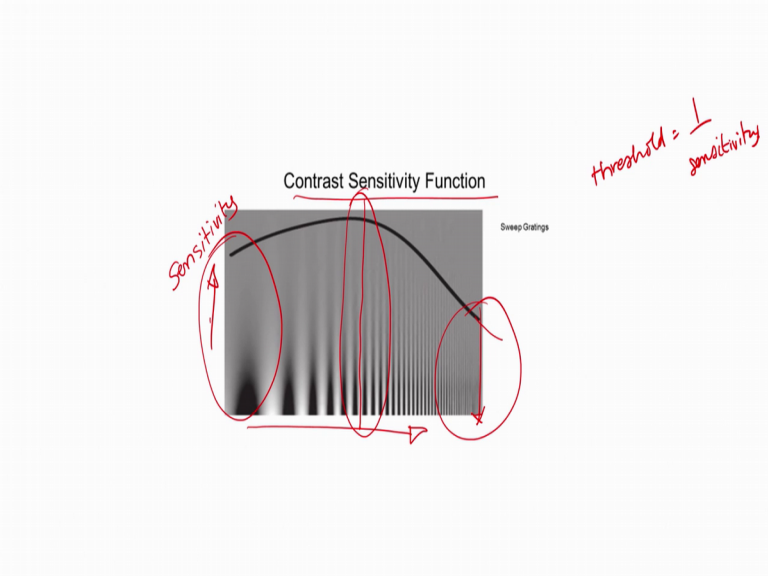

For this we will look at the Contrast Sensitivity function which we already discussed in one of the previous classes. The CSF function talks about for different spatial frequency how the threshold is actually increasing actually this y axis assesses sensitivity. Threshold is a which we are seen is the inverse of this sensitivity, sensitivity.

So, the higher sensitivity where a at this point we need a lowest 2 threshold as a sensitivity decreases we need higher and higher threshold for example, here we might need at this particular frequency we might need more threshold. So, the implication of this CSF which we have already seen in the earlier class that, if a picture which has higher frequency details then this diagram tells that we need more threshold in order to be no seen there is the implication of this graph. Suddenly very low frequency also needs higher threshold the least the threshold is necessary only for the medium frequencies that is the implication of this right.

So, how we can use this sensitivity function in order to come up with a limiting resolution is what other topic today.

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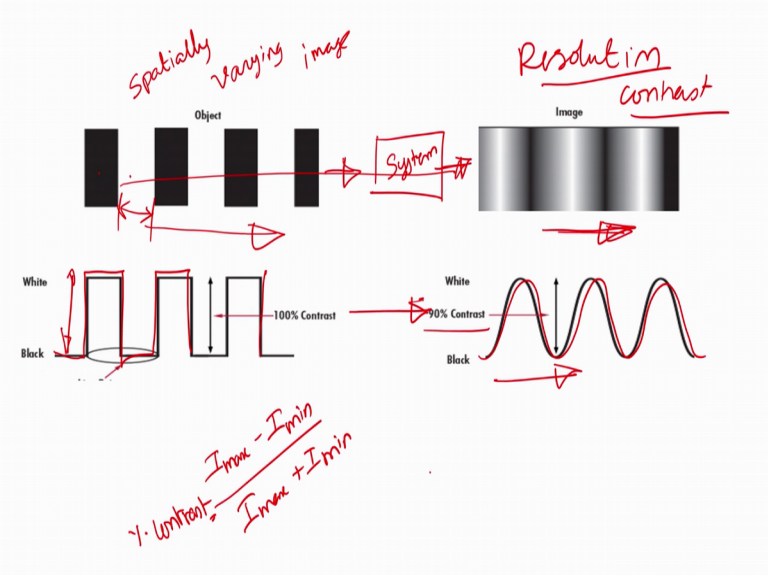

For this, let us again get into the definition of what is the resolution what is the contrast and then see whether we can connect these 2 things. The spatial frequency let us say an image spatial spatially varying image such as this one where there is a black and white. Let us say we are giving this as input to our system, the system let us say it is a generic one. Let us say the system outputs an image which is transformed in some way in this case is this is giving an image like this. The input image where binary the black and white image is converted into a gray image. If you look at the black one with the blue picture the black and white image which has this change in the contrast this is the black this is the white the square grating kind of things right and when this is given to the

system this is transforming the image into a single (Refer Time: 04:41) the gray level are image. So, here the contrast is 100 percent because there is only black and white and the contrast definition and if you look at it you can say this is a I max minus I minimum divided by I max plus I minimum. This in terms of the percentage contrast this is one definition of contrast, right.

So, in this case this is going to be 100 percent there is a here this contrast has reduced over here let us say this is a 90 percent. So, here this there are 2 concepts the concept of resolution also we can look at it the concept of contrast also we can look at it. There is a connection between there a concept of resolution and contrast. Resolution is the closest to 2 lines that can be separated. Suppose if we give this image in as an input to the system the output can it be resolved into 2 separate lines or what is the what is the highest frequency which can and be resolved all into 2 different lines in the output system right there is a resolution. You can see that this resolution from the output image which we are today meaning that is limited by this contrast, again to look into a little more detail.

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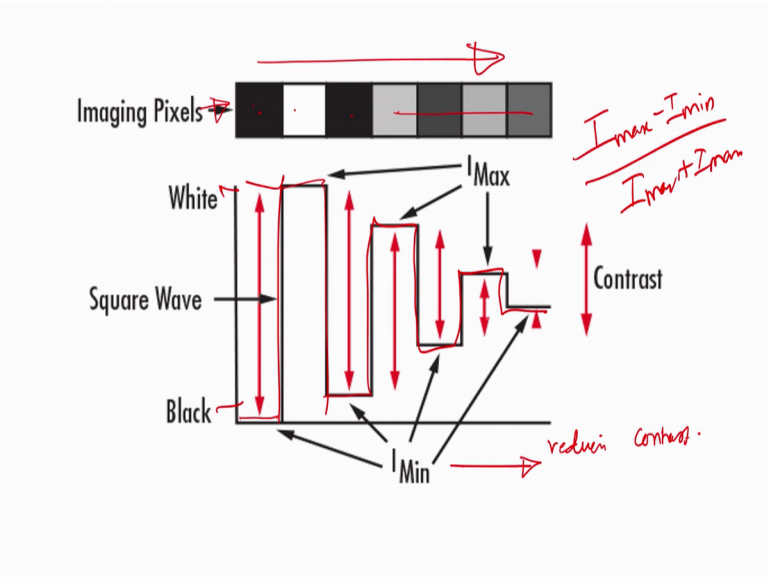

Let us look at the how this contrast is limiting the resolutions. Suppose if we change the contrast gradually from left to right we have only black and white but slowly we are con reducing this is contrast or is reducing the contrast here and the contrast is reducing contrast.

This is a black this is the white and initially it is the completely black and white and this is a comp this is a white and the black is reduced and finally, we reach some. So, that the again using the definition what we have written I max minus I minimum dived by I max plus I minimum will tell you what is the contrast over here this contrast is what limiting the resolution.

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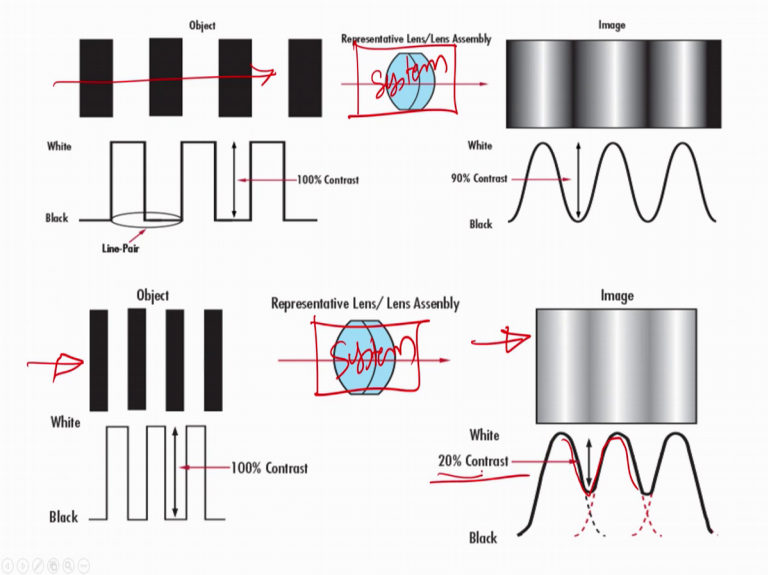

For example, again we have our system over here if we increase the frequency let us say in this case we are increasing the frequency doubled, then other system we are talking about system is no more separating the lines in the output image. You can see that the output image has lesser contrast let us say in this case it is 20 percent of the contrast. So now, the resolution we will define in terms of the modulation.

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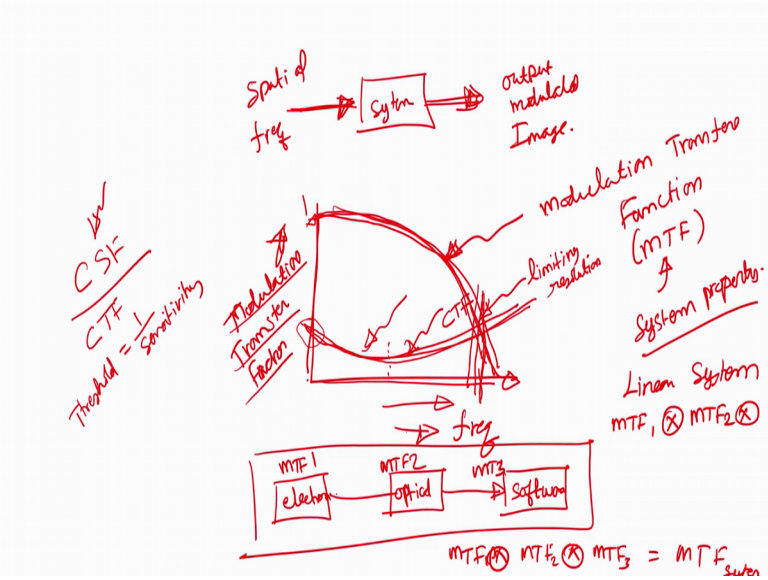

So, if you have a system input frequency and a output spatial input frequency output frequency output modulated image output modulated image. So, we will see how this contrast is transferred. So, if you draw a graph let us say in the x axis we have this frequency and you y axis we have this threshold function MTF factor let us say Modulation Transfer Factor. So, yeah system transferring the modulation of the given input to the output if it is completely transferring then it is let us say this is number 1. If it is reducing then it may be now lesser than 1.

So, modulation transfer function factor let us draw it in the let us plot it in the y axis for a various frequencies this may be 1, but all of a sudden it may be reducing this function is called the modulation transfer function or MTF. This MTF is a system property, system property and this system property can be measured using various approaches assuming all this is a linear system MTF of different components can be controlled with many other MTF for example, in our system we have the electronics in our virtual reality systems we have electronics, we have a optical system and then we have the software system, each one may have a MTF, MTF 1, MTF 2, MTF 3. So, the system MTF can be tremendous convolution of a MTF 1, MTF 2, MTF of 3 kind of this is the system MTF right? So, this system MTF let us say we have some of found out from some test for other virtual reality h, h.

Now, as long as MTF is concerned there is no perception involved in it. The perception will come into picture when there is a the conscious sensitivity is involved. The contrast sensitivity involved the CSF function if you remember, but can be now brought in together here, but CSF is a sensitivity is measured here because the y axis is a modulation transfer function it can be the inverse of CSF needs to be needs to be plotted in this graph. So, instead of CSF we will say contrast threshold function. So, we remember our threshold is equal to 1 over the sensitivity. Therefore, or the same function can be plotted something like this this is the CTF there is a contrast threshold function. So, this threshold function tells you what is the threshold necessary as we increase the frequency. So, as we seen in the CSF there is a maximum frequency or that there is a frequency at which it needs the least resolution, sorry in least a threshold. At a lower frequency it has the high it needs higher threshold similarly as we increase the frequency it needs a higher threshold as well.

Now, the frequency at which this MTF and then CTF joints could be a valuable information. This could be called as the limiting resolution. This limiting resolution is dictated by this perceptual graph this is where the psychophysics come into picture. So, the resolution earlier it was dictated by the anatomy and physiology this MTF is dictated by the system properties the outside at a system properties, now this resolution c CSF which is a psychophysical cow together we can we can put them together to find out what is that limiting resolution. Now let us look at the CSF cow in one of these CSF cows.

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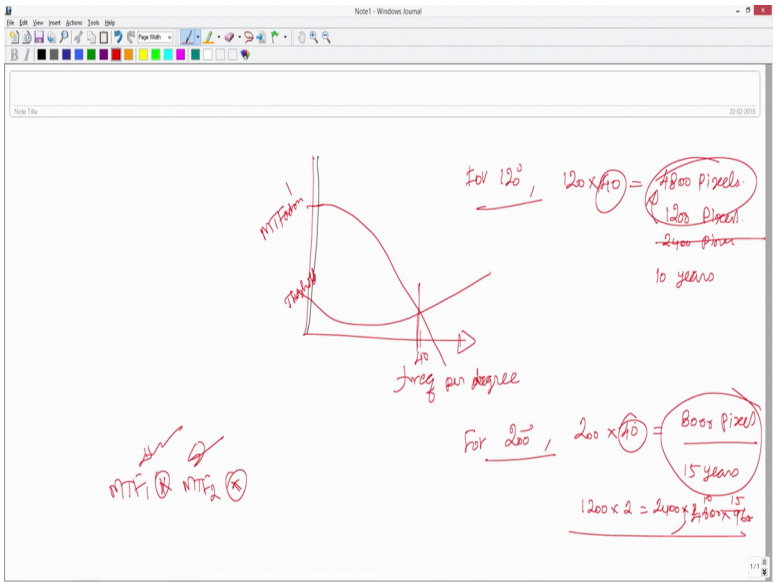

So, the CSF cow is mentioned as it is about 40 cycles per second is where the limiting resolution happens this is one let us say this is the modulation transfer factor this is a threshold.

So, this graph tells that at about forty cycles per second there is the limiting resolution happens this is the now arc. So, if you have field of view 120 degree. So, this is 40 cycles pearl arc this is a frequency per arc we can say there arc their degree their degree. So, number of pixels needed for 120 degree is going to be 120 into 40 which is going to be 4800 pixels. As of now we are we have about 1200 pixels. There is a let us say said state of the arc. So, in order to reach this 4800 pixels we might need 10 years, 10 years we will reach this limiting resolution. Assuming the moores law is constant and that is valid

So, every 5 years those pixels is going to be doubling therefore, after 5 years this is going to be 2400 pixels and after 10 year we will reach the 4800 pixels, but that is assuming 120-degree field of view, but our industries are going to consider a much more field of view a as we are going to see in the later classes. So, for 200 degree let us say this is going to take 200 into 40 it is about 8000 pixels. To reach this 8000 pixels we might need it up probably 15 years let us see again assuming the moores law is constant and that is valid.

And so, we are right now at 1200 elda. So, it will get doubled in 5 years there is going to be 2400 that is again going to be double 2 times that is going to be 4800 that is in 10

years and that is again is going to be double 9600 that is about 15 years it will take. All these things again we are going to come we are going to assume that this MTF up of different components of the system MTF 1, MTF 2, MTF 3, all these things are assuming those things as constant maybe each of the same MTF will be improving therefore, the requirement of this forty may be reducing in the future.

So, this might become now 30 or better if that is the case the number of resolutions required this all will be lesser. So, I hope you see the point of how our psychophysics can be used to find out what is their limiting to resolution that can be useful design of the better imaging systems are better visual systems which is used in virtual reality will stop here.

Thank you.