Digital Image Processing.
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Lecture-34.
Histogram Equalization and Specifications-I.

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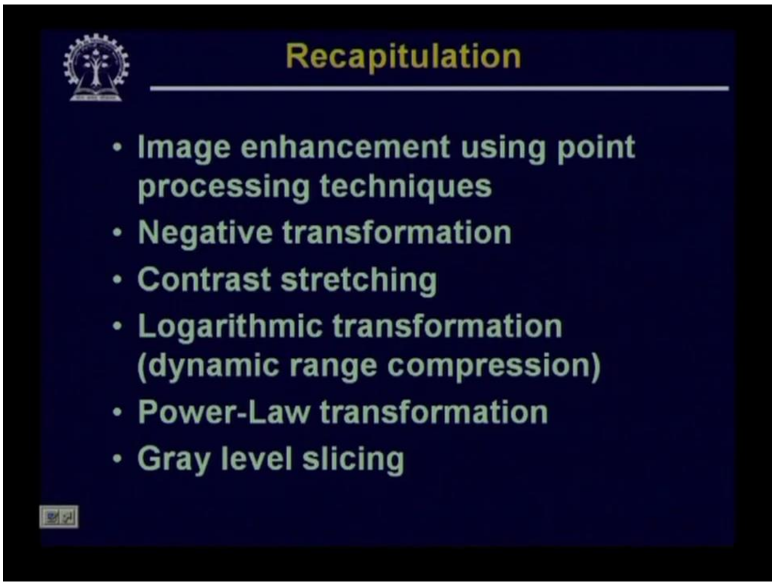

Hello, Welcome to the video lecture series on Digital Image Processing.

So we have talked about the image enhancement using point processing and on that we have talked about the various point processing techniques like Negative Image Transformation and in case of Negative Image Transformation, we have see that the processed image that we get is a negative version of the input original image. And such processed images are useful in case we have very few pixels in the original image where the information content is mostly in the white pixels or grey pixels which are embedded into large regions of dark pixels.

So in such cases if we take the negative of the image, in that case the processed image processed image, the information content becomes much more convenient to visualise. The other kind of point processing techniques that we have discussed is the Contrast Stretching operation. In case of Contrast Stretching operation, we have seen that these kind of contrast stretching operations is useful where the original image is very dark.

And we have said that such dark images we can have when the scene illumination was very poor or we can also have a very dark image where the dynamic range of the sensor is very small so that it cannot record all the intensity values present in the scene or the dark images can also be obtained if while image acquisition, the aperture setting of the camera lens is not proper. So for these different kinds of cases, we can have a dark image and Contrast Stretching is a very very useful technique to enhance the contrast of such dark images.

The other kind of transformation that we have used for image enhancement is Logarithmic Transformation and there we have said that Logarithmic Transformation basically compresses the dynamic range of the input image. And this kind of transformation, we have said that is very very useful when an image which is to be displayed on our display device. But the dynamic range of the input image is very very large which the display device cannot handle.

So for such cases you go for the Logarithmic Transformation which compresses the dynamic range of the input image so that it can be reproduced faithfully on the display. Then we have also talked about the other kind of image enhancement techniques like Power-law Transformation and we have said that this Power-Law Transformation is very very useful for image display devices, for printing devices as well as power image acquisition devices.

Because by nature all these devices provide a Power-Law Transformation of the image that is to be produced whether it is on the display or it is on the peak printer or the image which is to be captured. So because the devices themselves transform the image using the Power-Law Transformation then, if I if we do not take any action before providing the image to those devices then the images which will be produced will be distorted in nature.

So the purpose of this Power-Law Transformation is you apply a Power-Law Transformation to the input image in such a way that it compensates the Power-Law Transformation which is applied by the device. So in effect, what we get is an output image whether it is on the display or on the printer will be a faithful reproduction of the input image.

The other kind of image enhancement techniques that we have discussed about is the Gray level Slicing operation and we have said that this Gray Level Slicing operations are useful for applications. So the application demands, the application wants the enhanced values of certain gray levels. So there again, we have seen two different types of two different types of transformation functions.

In one case of transformation function, the transformation enhances all the intensity values within a given range and the intensity values outside that given range is suppressed or made to 0. The other kind of Gray Level Slicing Transformation that we have said is there within the given range, the intensity values are enhanced but outside that particular range, the intensity values remain untouched. That is whatever is the intensity values in the original image, the same intensity values are reproduced in the processed image.

Whereas within the given range, the intensity values are enhanced. So this kind of applications, this kind of transformation is very very useful for applications where the application wants that intensity values within a certain range should be highlighted. Now all these different point processing techniques that we have discussed till now. They do not consider the overall appearance of the image. They simply provide the transformation of on a particular intensity value and accordingly produces the output intensity value.

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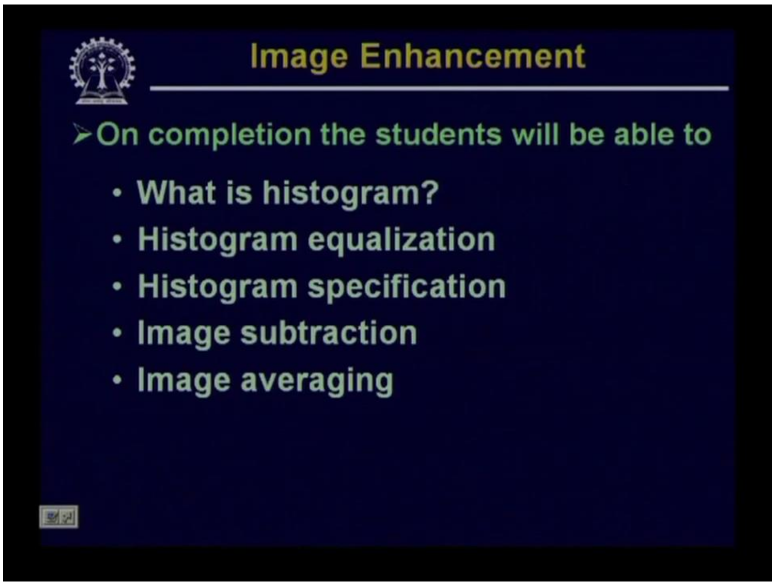

Now in today’s discussion, we will talk about another approach where the transformation techniques also take care of the global appearance of the image. So Histogram is such a measure which provides a global description of the appearance of an image. So today what we are going to discuss the enhancement techniques that we were going to discuss, few of them are based on histogram based processing.

So in today’s discussion we will talk about initially what is an histogram? Then we will talk about two histogram based techniques, one of them is called histogram equalization and the other one is called histogram specification or sometimes it is also called histogram matching or histogram modification. Then apart from this histogram based techniques, we will also talk about two more image enhancement techniques.

You remember from our previous discussion that when you have said that a transformation function T is applied on the original image f to give us the processed image g and there we have said that this transformation function T transforms an intensity in the input image to an intensity value in the original image. And there we have mentioned, that it is not necessary that the transformation function T will work on a single image.

The transformation function T can also work on multiple images, more than one images. So we will discuss two such approaches. One approach is image enhancement using image subtraction operation and the other approach is image enhancement using image averaging operation. So first let us start discussion on histogram processing and before that let us see that what do we mean by the histogram of an image. So to define the histogram of an image we consider that an image is having grey level intensities in the range 0 to L minus 1.

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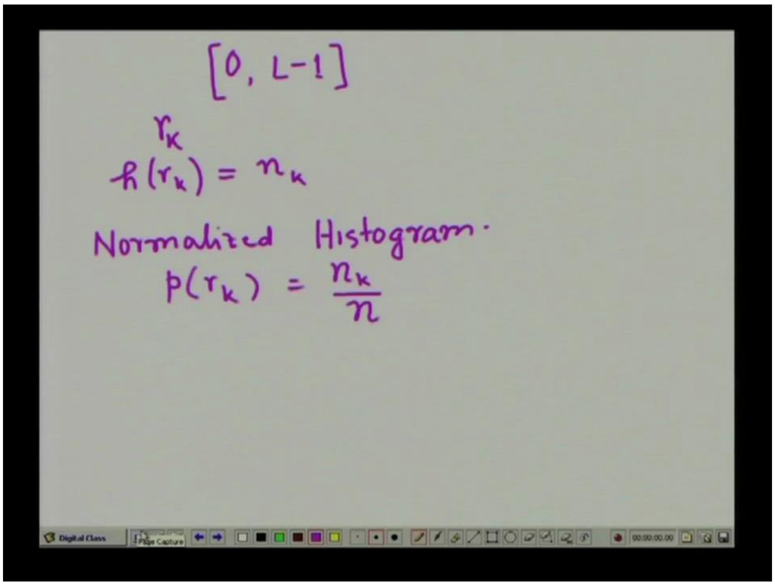

So we will consider that the digital images that we are talking about, it will have L number of discrete intensity levels and we will represent those intensity levels in the range 0 to capital L minus 1 and we say that a variable say r K represents the Kth intensity level.

Now an histogram is represented by h(r K) which is equal to n K where n K is the number of pixels in the image having intensity level h (r K). So once we get, the number of pixels having an intensity value h having an intensity value r K and if we plot these number of pixel values with the number of pixels having different intensity values against the intensity value of that of those pixels then the plot that we get is known as a histogram.

So in this particular case you will find, that because we are considering the discrete images so this function, the histogram h(r K) will also be discrete. So here r K is a discrete intensity level n K is the number of pixels having intensity level r K and h(r K) which is same as n K this also assumes discrete values. In many cases, we talk about what is called a normalised histogram. So instead of taking a simple histogram as just defined, we sometimes take a normalised histogram.

So a normalised histogram is very easily derived from these original histograms where the normalised histogram is represented as p(r K) is equal to n K by n. So as before, this n K is the number of pixels having intensity value r K and n is the total number of pixels in the digital image. So you find that from this expression the p(r K) equal to n K by n. This p(r K) actually tells you that what is the probability of occurrence of a pixel having intensity value equal to r K.

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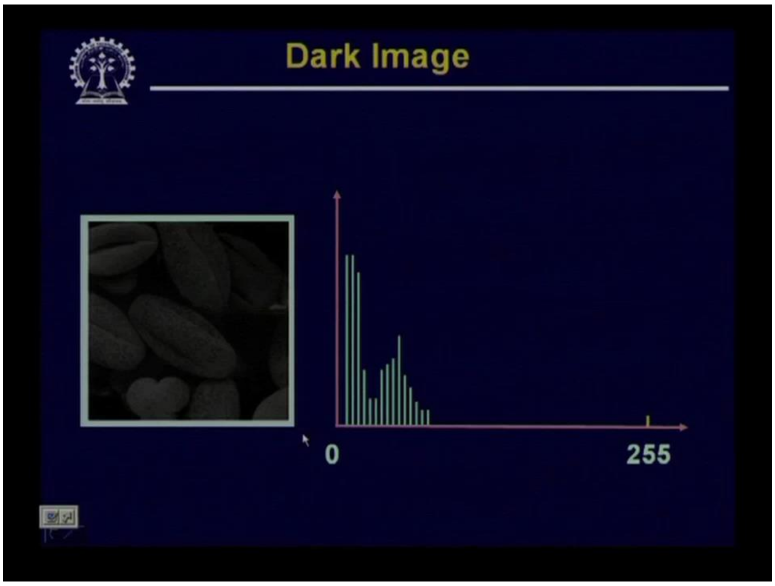

And such type of histograms, give as we said information a global description of the appearance of an image. So now let us see that what are the different types of images that we can usually get and what are the corresponding histograms. So here we find that the first image as you see that it is a very very dark image. It is very difficult to find out, what is the content of this particular image.

And if we plot the histogram of this particular image, then the histogram is plotted on the right hand side. You will find that this plot says that most of the pixels of this particular image have intensity values which are near to 0. So here this particular image because we are considering all the images which are digitized and every pixel is digitizing digitized using 8 bits. So we will have total 256 number of intensity levels and those 256 number of intensity levels are represented by intensity values from 0 to 255.

And for this particular case, this particular dark image, you will find that most of the pixels have intensity values which are near to 0 and that gives a very very dark appearance of this image.

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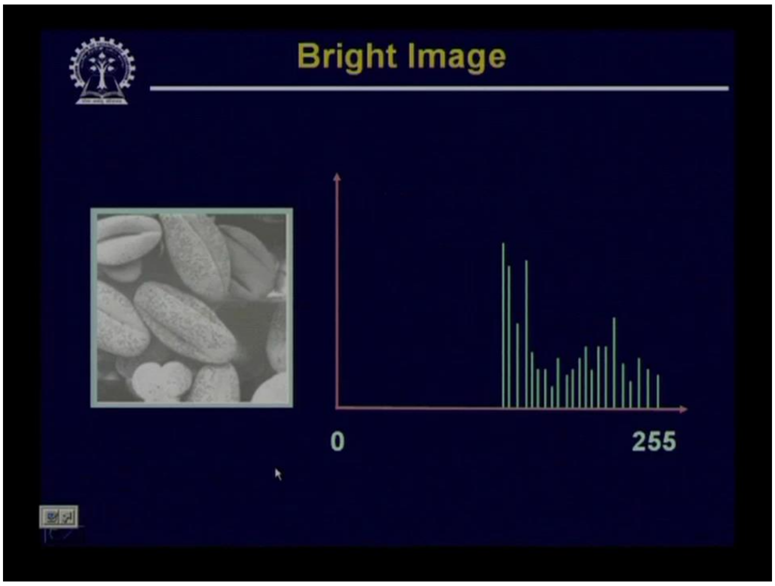

Now let us see a second image. Here you find that this image is very bright and if you look at the histogram of this particular image, you will find that for this image the histogram shows that most of the pixels of this image have intensity values which are near to the maximum.

That is near value 255. And because of this, the image becomes very bright. Let us come to a third image category.

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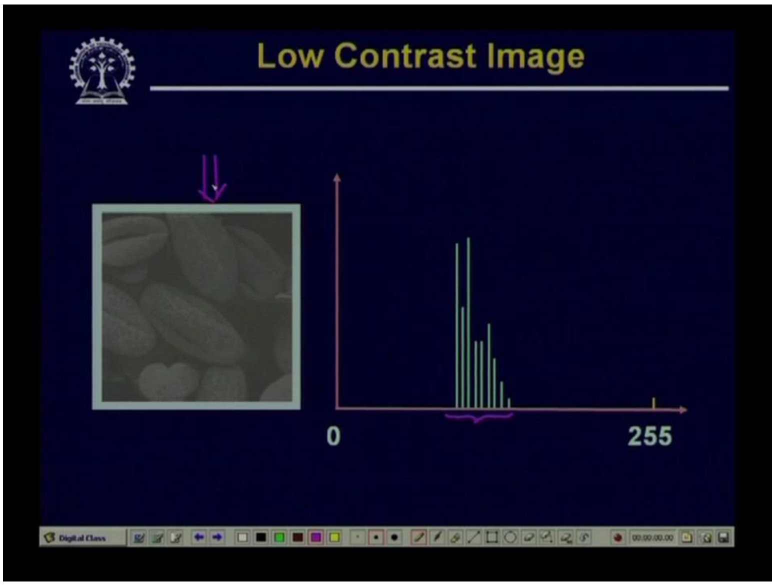

This is an image where you find that the intensity values are higher than the values of the first image that we had shown. It is lower than the intensity values of the just previous image that we have shown. Ok? So this is something in between and the histogram of this particular image shows that most of the pixels of this image have intensity values which are in the middle range and not only that, the spate of the intensity values of this pixels are also very low. The spate is very very small.

So this image appears to be a medium kind of image, it is neither very dark nor very bright. So the image is a medium kind of image but at the same time, the variation of the intensity values of this particular image is very poor and as a result, the image that we have got over here, this image gives a medium kind of appearance not very bright not neither very low but at the same time, the variation of intensities is not very clear.

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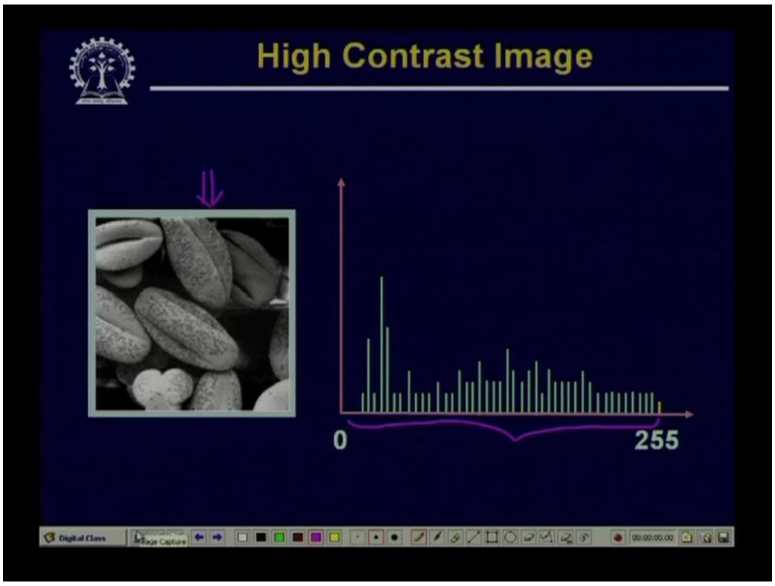

That means the contrast of the image is very very poor. So let us look at the fourth category of image. So this one. In this image, the histogram plot shows that the intensity values vary from very low values to very high values. That is it has a wide variation from 0 to 255 levels. And as a result, the image appears to be a very very prominent image having low intensity values high intensity values and at the same time, if you look at the image, you find that many of the details of the image are easily visible from this particular image.

So as we said that the histogram that the nature of the histogram shows that what is the global appearance of the image of an image and which is also quite obvious from these four different types of images that we have shown. The first one was the gray image which is a dark image.

The second one was bright image, the third one was a medium category image but the but the contrast of the image was very poor and we will say that this fourth one is an ideal image at least for the visualisation purpose where the image brightness is proper and at the same time, the details of the objects present in the image are also can also be very easily understood. So this is an image which is a high contrast image.

So when you talk about this histogram based processing. Most of the histogram based enhancement techniques, they try to improve the contrast of the image whether we talk about the histogram in equalisation or the histogram modification techniques. Now when we talk about these histogram based techniques, this histogram based techniques the histograms just give you a description, a global description of the image. It does not tell you anything about the content of the image and that is quite obvious in these cases.

Just by looking at the histogram, we cannot say that what is the content of the image? We can just have an idea of what is the global appearance of that particular image. And histogram based techniques try to modify this histogram of an image to have an image to appear in a particular way; either dark or bright or the image contrast is very high. And depending upon the type of operations that we do using this histograms we can have either histogram equalization operation or we can have histogram modification operation.

So now let us see that once we have given that what is an histogram, and what does the histogram tell us, let us see that how this histograms can be processed to enhance the images. So the first one that we will talk about is the image equalisation or histogram equalisation operation. So for this histogram equalisation operation, initially we assume, that r to be a variable representing the gray level in an image.

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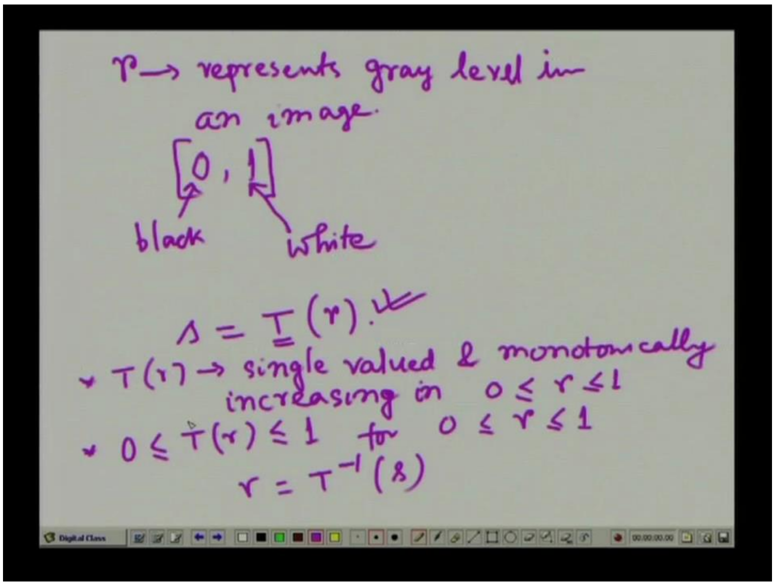

So this r represents the gray level in an image. And for the time being, we will also assume that the pixel values in an image are continuous and they are normalised in the range 0 to 1. So we assume, the normalized pixel values and the pixel values can take values in the range 0 to 1 where 0 indicates a black pixel.

So 0 indicates a black pixel and 1 indicates a white pixel. Later on we will extend our ideas to discrete formulation where we will consider the pixel values in the range 0 to capital L minus 1 where L is the number of gray level discrete gray levels present in the image.

Now as we said that for point processing we are interested to find out a transformation where the transformation is of the form s is equal to T(r) where r is the intensity in the original image and s is the intensity in the processed image or the transformed image or the enhanced image. Now this T the transformation function has to satisfy two conditions. Firstly, the T(r) has to be single valued and it has to be monotonically increasing in the range 0 to 1.

So the first condition is T(r), it must be single valued and monotonically increasing in the range 0 less than or equal to r less than or equal to 1; and the second condition that T(r) must satisfy is 0 should be less than or equal to T(r) which should be less than or equal to 1 for 0 less than or equal to r less than or equal to 1. Now the first condition is very very important because it maintains the order of the gray levels in the processed image.

That is an pixel which is dark in the original image should remain darker in the processed image. A pixel which is brighter in original image should remain brighter in the processed image. So the intensity ordering does not change in the processed image; and that is guaranteed by the first condition that is T(r) should be single valued and monotonically increasing in the range 0 to 0 to 1 of the values of r.

The second condition that is 0 less than or equal to T(r) less than or equal to 1. This is the one which ensures that the processed image that you get that does not lead to a pixel value which is higher than the maximum intensity value that is allowed. Ok? So this ensures that the processed image will have pixel values which are always within the allowable minimum and maximum range. And it can be found that if these conditions are satisfied by T(r) then the inverse, that is r is equal to.

The inverse of this that is r is equal to T inverse of s will also satisfy these two conditions. So we want a transfer function T which will satisfy this conditions and if this conditions are satisfied by T(r) then the inverse transformation will also satisfy this particular condition. Thank You.