Digital Image Processing

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Lecture - 17

Image Enhancement

(Point Processing - I)

Hello, welcome to the video lecture series on digital image processing. During our last few courses, few lectures; we have talked about various image processing techniques.

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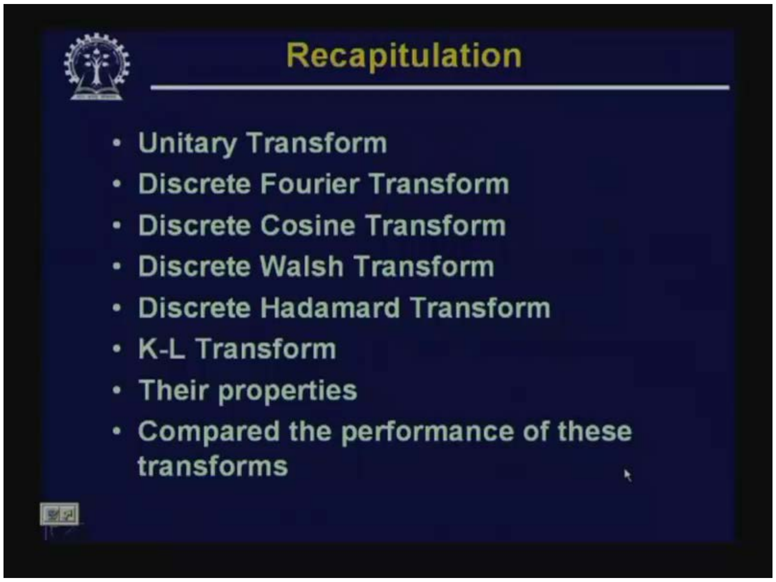

So, during past few lectures we have talked about the unitary transformation, then some specific cases of unitary transformation like discrete Fourier transformation, we have talked about the discrete cosine transformation, we have talked about discrete Walsh transformation, discrete Hadamard transformation, K - L transformation and we have seen that the K - L transformation is fundamentally different from other transformations like DFT or DCT or DWT or DHT in the sense that for all these transformations, the transformation canal is fixed whereas for K-L transformation, the transformation canal has to be derived from the image for which the transformation is to be taken.

Then we have also seen the properties of these different transformation techniques and we have compared the performance of these transforms with respect to certain results.

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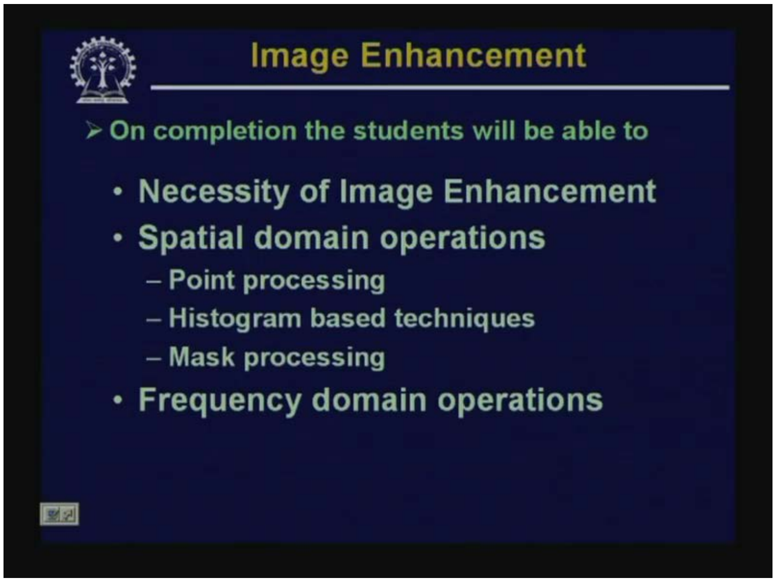

Today and for coming few lectures, we will be talking about image enhancement techniques. First we will see that what is the necessity of image enhancement. Then we will see that image enhancement techniques fall under 2 broad categories. One of the category is spatial domain operations. In spatial domain operations, the enhancement techniques work directly on the image pixels and then these spatial domain operations can have 3 different forms. One is the point processing, other one is the histogram based processing techniques and the third one is mask processing techniques.

Of course, histogram based processing technique is also a form of point processing technique. For these spatial domain operations, we said that we do not do any P processing on the images; the images are directly operated in their spatial domain to give us the transformed images which are the enhanced images.

The other category of these image enchantment techniques, they work on normally the discrete Fourier transformation coefficient of the images. So, they are called as frequency domain operations and we will see later that there are different operations which can be done in frequency domain like low pass filtering, band pass filtering, high pass filtering and so on and then also we have different forms of these different filters.

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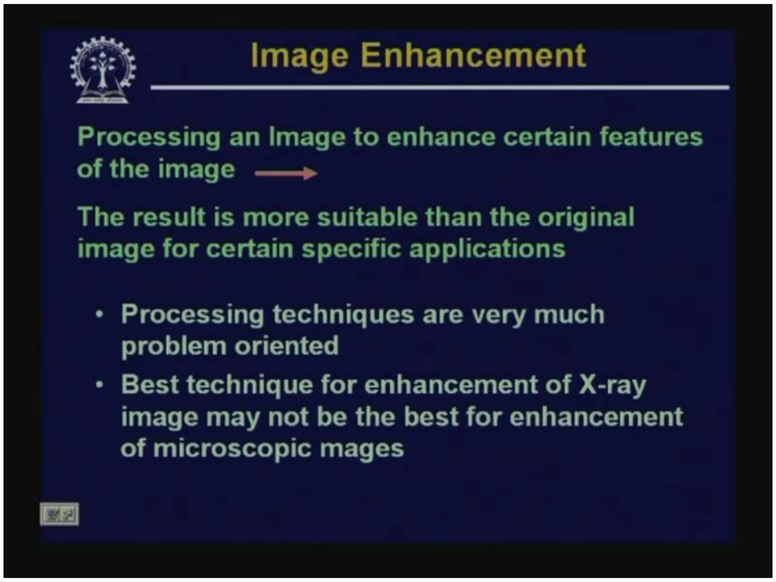

Now, let us see that what meant by image enhancement. By image enhancement what we mean is it is a technique of processing an image to enhance certain features of the image. Now, as it is said that it is for the enhancement of certain features of the image; so obviously, depending upon which feature we what to enhance, there are different forms of image enhancement techniques. Some applications may demand that are input images noisy? So, we want to reduce the noise so that the image becomes better visually. So, reduction of this noise or removal of the noise from the images is also a form of image enhancement.

In many cases, we have found that the images which are captured by image capturing device say for example camera, they are very dark and image may become very dark because of various reasons. So, for such kind of applications, the image enhancement technique may need to increase the contrast of the image or to increase the intensity of the image. So, far that kind of application, we will have some other type of image enhancement techniques.

Some applications may need that the applications need that the ages of the objects present in the image, those should be highlighted. So, again in such cases, the image enhancement techniques should be able to highlight the ages of the objects present in the image. So, you find that the image enhancement techniques, these techniques vary depending upon the application, different types of applications need enhancement of different types of features in the image.

So, the result, the ultimate aim of the image enhancement techniques is such that we want to process an image so that the result becomes more suitable than the original image for certain specific applications. So, as we have already said, obviously the processing techniques are very much problem oriented because different kinds of problem demand enhancement of different kinds of features in the image. So obviously, the processing techniques will be application dependent and naturally our technique which is best suitable for this kind of application is not best suitable for some other kind of applications.

So, a technique for enhancement of x-ray image may not be the best for enhancement of microscopic images. So, this is broadly what we mean by enhancement of an image and obviously these are application dependent.

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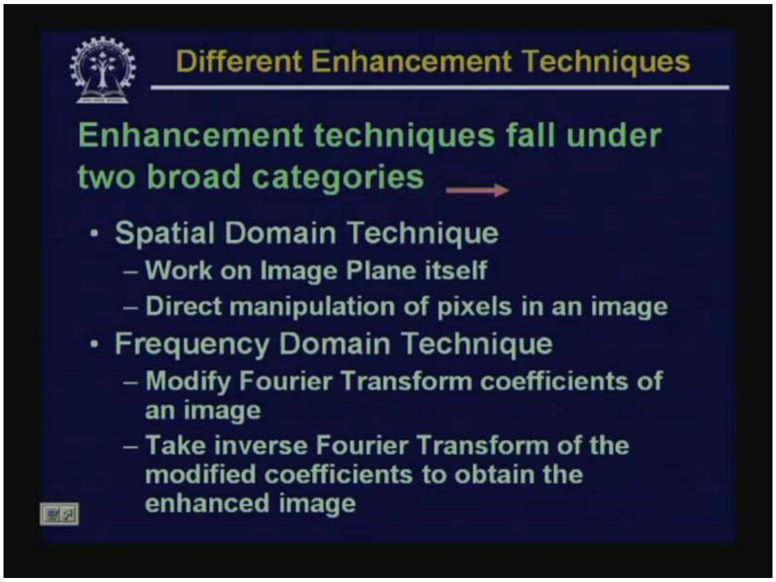

Now, as we have already said that image enhancement techniques fall under 2 broad categories; the first category is the spatial domain technique where the image enhancement processes, they work directly on the image plane itself that means these techniques try to directly manipulate the pixels in the image. The other category of image enhancement techniques is frequency domain techniques.

So, in case of frequency techniques, first we have to take the Fourier transformation of the image, then whatever is the Fourier transformation coefficients that we get, you modify those Fourier transformation coefficients and these modified set of coefficients, you take the inverse Fourier transform of that to obtain the enhanced image or the modified image as we need.

So first, we will be talking about the image enhancement techniques in the spatial domain. So, let us see that what are the different spatial domain image enhancement techniques that we can have. So, as we said that the spatial domain techniques work directly on the image pixels; so naturally we have to define a transformation function which will transform an image pixel from the original image to a pixel in the enhanced or processed image.

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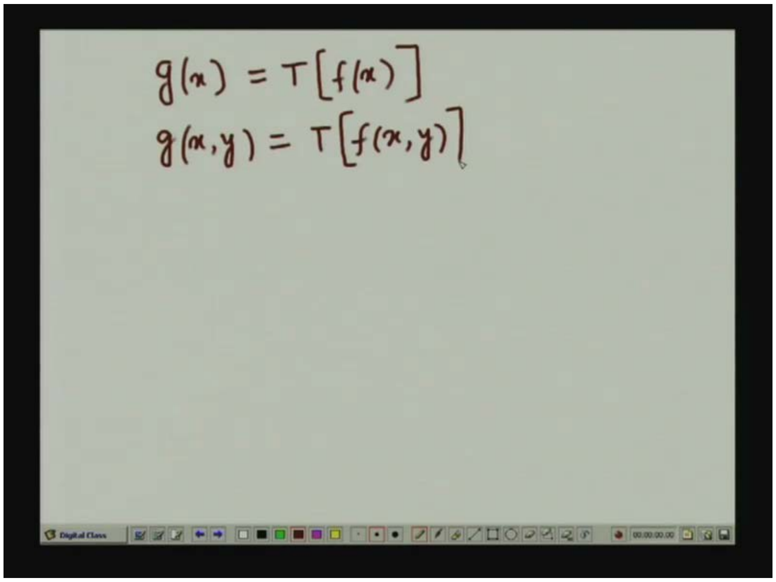

So, such a function can be defined in this form: we can write that g (x) is equal to some transformation T into f of x or because in this case, we are dealing with the 2 dimensional images. So, we will write the expressions as g (x, y) is equal to some transformation T of the image f (x, y). So, in this case f (x, y) is the original image, T is the transformation which is applied on this original image to give us the processed image g (x, y).

Now, as we said that in case of spatial domain techniques, you find that this transformation T is working directly on f (x, y) that is in the spatial domain or in the image plane to give us the processed image g (x, y) where T is an operator which is to work on the original image f and this operator is defined over or neighborhood of the point (x, y) in the original image f (x) and later on we will see that this operator T, this transformation operator T can also operate on more than one images.

So, for the time being, we are considering the case that where this operator T, the transformation operator T works on single image and when we want to find out a processed image at location (x, y); then this operator T works on the original f at location (x, y) considering certain neighborhood of the point (x, y) to determine what will be the process pixel value at location (x, y) in the processed image g.

Now, the neighborhood of a point (x, y) is usually a square sub image which is centered at point (x, y). So, let us look at this particular figure.

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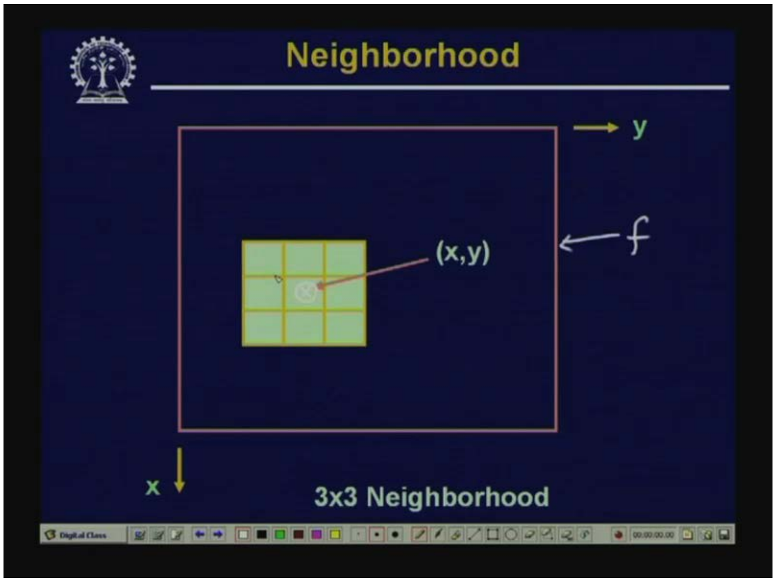

Here, you find that we have taken a rectangular image. So, this outer rectangle represents the image f and within this image f, we have taken pixel at a particular location (x, y). So, this is the pixel location (x, y) and the neighborhood of this point (x, y) as we said that it is usually a square sub image around point (x, y). So, this shows a 3 by 3 neighborhood around the pixel point (x, y) in the image f.

Now, what happens in case of point processing? We said that this operator, the transformation operator T operates at point (x, y) considering a certain neighborhood of the point (x, y) and in this particular case; we have shown a neighborhood size of 3 by 3 around point (x, y). Now, for different applications, the neighborhood size may be different. We can have a neighborhood size of 5 by 5, 7 by 7 and so on depending upon the type of the image and the type of operation that we want to have.

Now, in case of point processing, the neighborhood size that is considered is of size 1 by 1. So, the neighborhood size of a point in case of point processing is of size 1 by 1.

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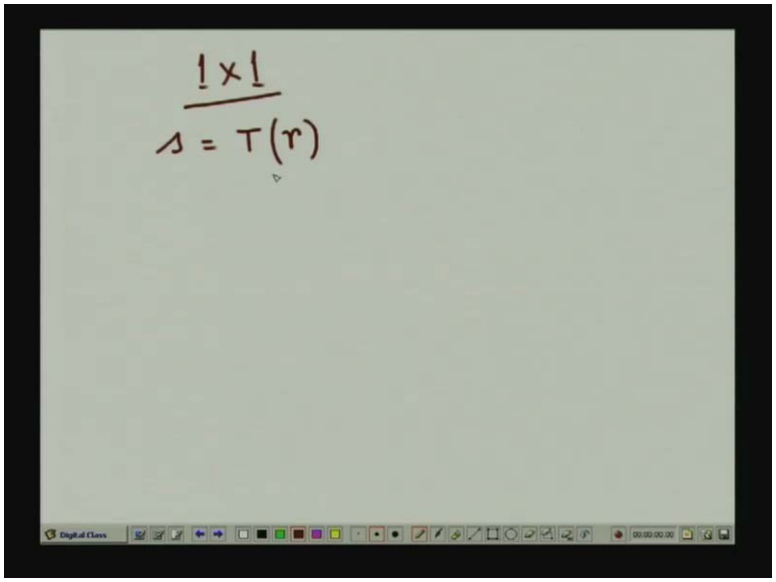

So, that means that this operator T, now works on the single pixel location, so it works on only that particular pixel location (x, y) and depending upon the value, depending upon the intensity value at that location (x, y), it determines what will be the intensity in the corresponding location in the processed image g. It does not consider the pixel values of its neighboring locations.

So, in such cases, we can write the transformation function in the form s is equal to some transformation T of r where this r is the pixel value in the original image and s is the pixel value in the corresponding location in the processed image. So, this transformation function, it simply becomes of this form s equal to T and T of r where s and r are independent pixel values at different locations. Now, this transformation functions can be put in the form of these 2 figures.

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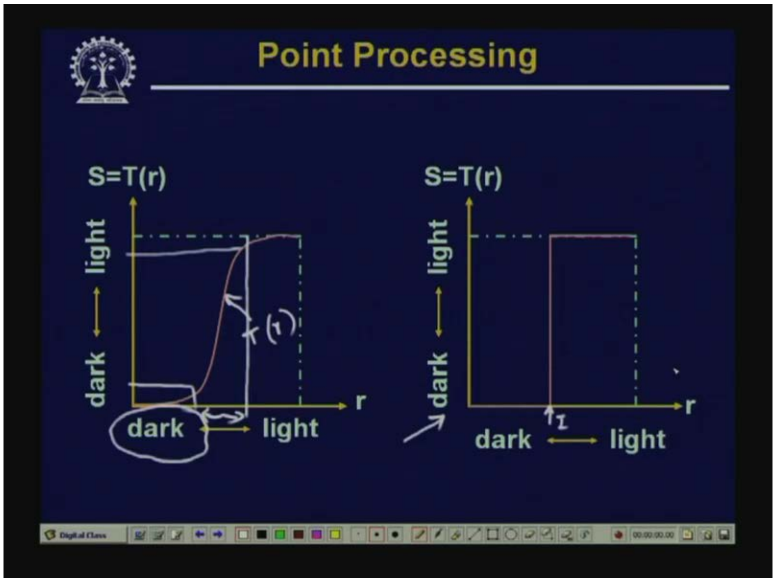

So, in this particular case, the first figure shows a transformation function where you find that here in this case along the x axis or the along the horizontal axis, we have put the intensity values r of the original image and along the vertical axis, we have put the intensity values of different pixels in the process image g and obviously they are related by s equal to T (r) and the transformation function is given by this particular curve.

So, this is our T of r and in this particular figure as it is shown that the point, so the pixel values near zero has been marked as dark regions. So, it is quite obvious that in an image if the intensity values of the pixels are near about 0 that is very small intensity values, those regions appear as very dark and the intensity values which are higher in an image, those regions appear as light regions.

So, this first one, the first transformation function shows that in this particular range, a very narrow range of the intensity values in the original image is mapped to a wide range of intensity values in the processed image g and effectively, this is the operation which gives enhancement of the image. In the second figure that we have shown, here you find that this particular transformation function says that if I consider say this is some intensity value say I; so far all the pixels in the input image, if the in intensity values are less than I, then in the processed image, the corresponding pixel will be replaced by a value 0, whereas a pixel where the intensity value is greater than I, the corresponding pixel in the processed image will have a maximum value.

So, this second particular transformation operation, it actually generates a binary image consisting of only the low values and the high values and this particular operation is known as thresholding operation. Now, what happens in case of so, this is the kind of operation that will be done for point processing.

Now, the other kind of spatial domain operation where the neighborhood size is larger than 1, say neighborhood size of 3 by 3 or 5 by 5 and 7 by 7 so on; that kind of operations is usually known as mask operations. So, in case of mask operation, what we have to do is we have to define a neighborhood around every pixel (x, y) at which point we want to get the intensity value in the processed image and for doing this, it is not only the intensity value of that particular pixel but also the intensity values of the pixels around that point which is within the neighborhood of that point. All of them take part in deciding what will be the intensity value at the corresponding location (x, y) in the processed image g. So, let us see that how that operation is done.

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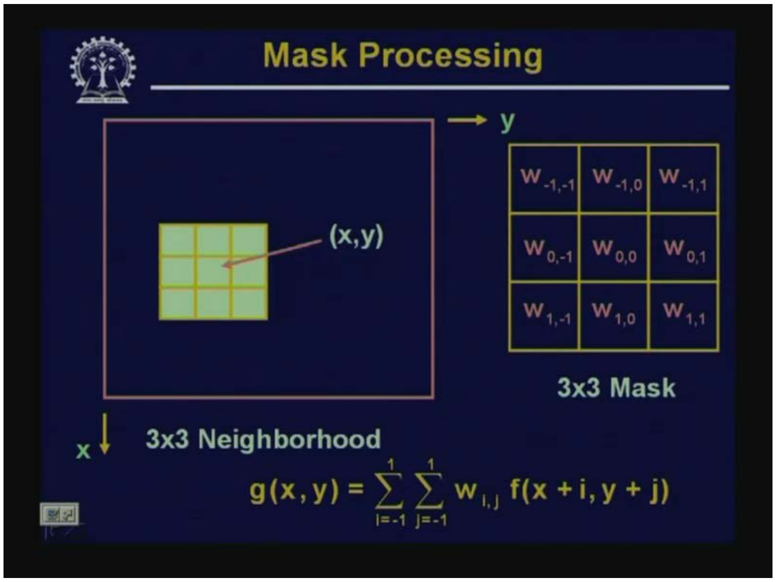

So here, again we have copied the same 3 by 3 neighborhood what we have seen in our previous slide. So, if I consider a 3 by 3 neighborhood, then for mask processing what we have to do is we have we also have to define a 3 by 3 mask and in this particular case, you find that on the right hand side of the figure, we have defined a mask where the values in the mask are represented as W $_{\text{minus 1, minus 1}}$ W $_{\text{minus 1, 0}}$ W $_{\text{minus 1, 1}}$ W $_{\text{0, minus 1}}$ W $_{0,\,0}$ W $_{0,\,1}$ W $_{\text{1, minus 1}}$ W $_{1,\,0}$ and W $_{1,\,1}$. So, these are the different values which are also known as coefficients which are present in this 3 by 3 mask.

Now, to generate the intensity value at location (x, y) in the processed image, the operation that has to be done is given by the expression at the bottom where it says that g (x, y) is equal to double summation w $_{ij}$ into f (x plus i, y plus j) and you have to take this summation over j equal to minus 1 to 1 and I equal to minus 1 to 1.

So, what does this actually mean? This means that if I place this mask on the image centered at location (x, y), then all the corresponding pixels under this mask of the image and the corresponding mask coefficient, they have to be multiplied by together then take the sum for all such mask locations and what I get, that gives me the processed image the intensity value of the processed image g at location (x, y).

So, this is what is meant by mask operation and depending upon the size of the mask that we will want or the size of neighborhood we consider, we have to define the 3 by 3 mask or 5 by 5 mask or 7 by 7 mask and so on. And, the coefficient values this different W values in the mask that determine that what kind of image enhancement operations that we are going to do; whether this will be a image sharpening operation, image averaging operation, s enhancement operations and so on. All of them depend upon the mask values that is the w_{ij} present in this particular mask.

So, this is the basic difference between the point processing and mask processing and obviously both these processing techniques fall under the category of spatial domain techniques because in these cases, we have not considered the discrete Fourier transform coefficients of the original image which is to be processed.

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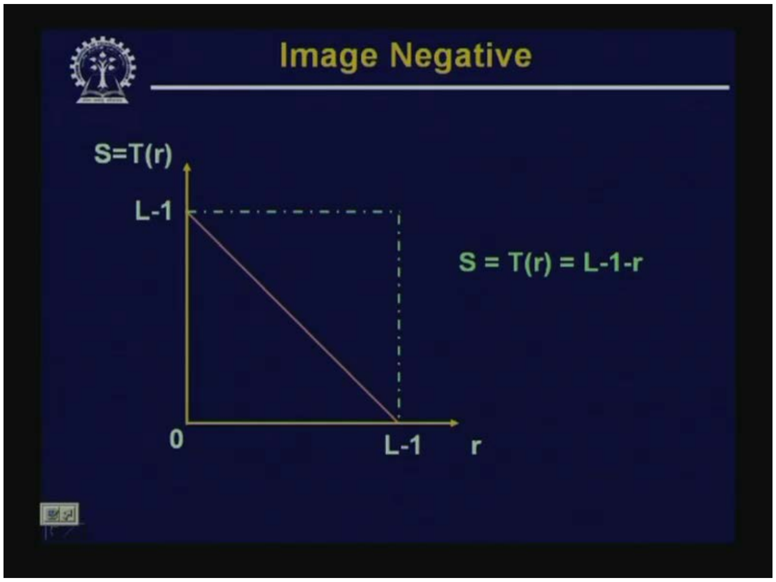

Now, let us come to the point processing techniques. The first one that we will consider is a point processing techniques which we call the negative image. Now, in many of the cases, the images that we get, they contain white or grey level informations embedded in black pixels or very very dark pixels and the nature of the information is such that we have very few white or gray level informations present a white background which is very much dark. So, in such cases, finding out the information from the images, from the raw images, input images becomes very very difficult.

So, in such cases, it is beneficial that instead of considering that raw image, if I just take the negative of the images. That is all the white pixels that we have that we have in the image or the larger intensity values that we have in the image, you make them darker and the darker intensity values, you make them lighter or brighter.

So in effect, what we get is a negative of an image and within this negative image, we will find through result that visualization or extracting information which we want will be more convenient than in the original image. So, the kind of transformations that we need in this particular case is shown in this figure.

So here, we consider that the digital image that we are considering that will have capital L number of intensity levels represented from 0 to capital L minus 1 in steps of 1. So again, along the horizontal axis, we have put the intensity values or gray level values of the input image and along the vertical axis, we have put the intensity values or gray level values of the processed image and this corresponding transformation function T, now can be represented as s is equal to T (r) which is nothing but L minus 1 minus r.

So, we find that whenever r is equal to 0, then s will be equal to L minus 1 which is the maximum intensity value within our digital image and when r is equal to capital L minus 1 that is the maximum intensity value in the original image; in that case, s will be equal to 0. So, the maximum intensity value in the original image will be converted to the minimum intensity value in the processed image and the minimum intensity value in the processed image will be converted to maximum intensity value in the minimum intensity value in the original image will be converted to maximum intensity value in the processed image.

So in effect, what we are getting is a negative of the image and graphically, this transformation can be put in the form of this figure. So, here you find that this transformation is a straight line with a slope of minus 45 degree and passing through the points (0, L minus 1) and (L minus 1, 0) in this rs plane. Now, let us see what is the kind of result that we will get by applying this kind of transformation.

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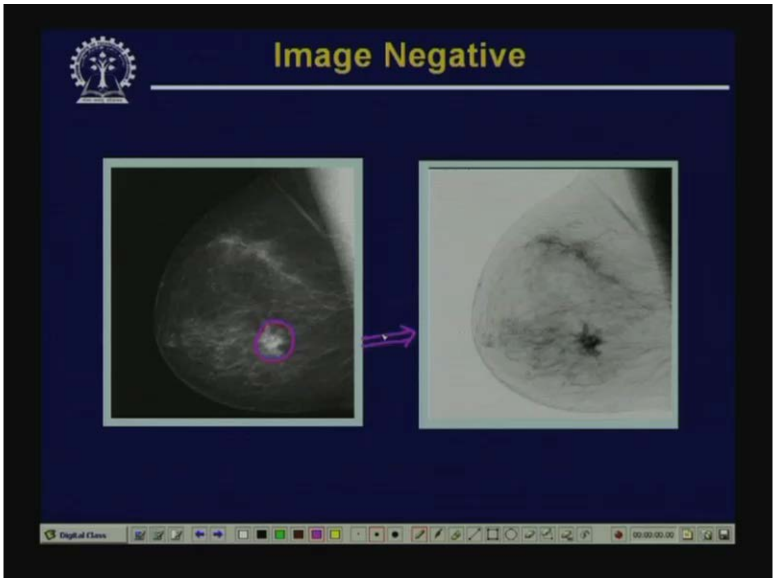

So, here we have shown 2 images. On the left hand side, we have a digital mammogram image and on the right hand side, we have the negative of this image which is obtained by the transformation that we have just now discussed. So, you find that in this original image, we have some white grains and there is a white patch which indicates a cancerous region and this grains corresponding to the issues corresponding to the tissues, they are not very prominent. I mean it is very difficult to make out which is what in this original image.

Now, if I take the negative of this particular image; so on the right hand side, we have got this negative. So here, you find that all the darker regions in the original image has been converted to brighter regions in this process image and the brighter regions in the original image has been converted to darker regions in the processed image.

And now, it is very convenient to see what information we can get from this negative image and this kind of transformation, the negative transformation is very very useful in medical image processing and as this is just an example which shows that understanding of this particular digital mammogram image, the negative transformation gives us much more information than that we have in the original.

And as we said, may be this is the transformation which is best suited for this particular application but this transformation may not be the best transformation for other kind of applications.

So now, let us see that what are the other kind of image enhancement techniques that we can have. The next image enhancement technique is again a very very simple enhancement technique that we are going to discuss is called contrast stretching. So, we will talk about the contrast stretching operation.

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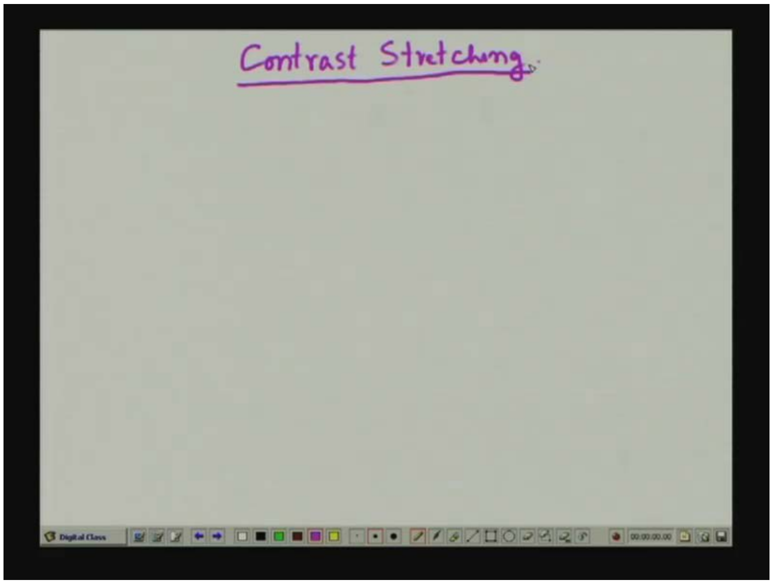

So, why do we need such contrast stretching? You might have found that in many cases, the images that we get from an imaging device is very dark and this may happen because of various reasons. One of the reasons is when you have taken the image of certain object or certain scene, the illumination of the object or the illumination of the scene was very poor. That means the object itself was very dark. So, naturally the image has become very dark.

The second reason why an image may be dark is that dynamic range of the sensor on which you are imaging is very small. Now, what I mean by dynamic range is it is the capacity of the sensor to record the minimum intensity value and the maximum intensity value. So, the difference between the minimum intensity value and the maximum intensity value is what is the dynamic range of the sensor.

So, even if your scene is properly illuminated but your sensor itself is not capable of recording all those variations in the scene intensity, that also leads to an image which is very very dark. The another reason which may lead to dark images is that when you have taken the photograph, may be the aperture of the lens of the camera was not properly set, may be the aperture was very small so that a very small amount of light was allowed to pass through the lens to the imaging sensor. So, if the aperture is not properly set, that also leads to an image which is very very dark.

So, for such dark images, the kind of processing techniques which is very suitable is called the contrast stretching operation. Now, let us see what is the kind of dark image that we can have.

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Here, we show an image which is a low contrast image. So, here obviously you find that the contrast of the image or the intensity of the image is very very poor and overall appearance of this particular image is very dark and the purpose of contrast stretching is to process such images so that the dynamic range of the image will be very high, will be quite high so that the different details in the objects present in the image will be clearly visible.

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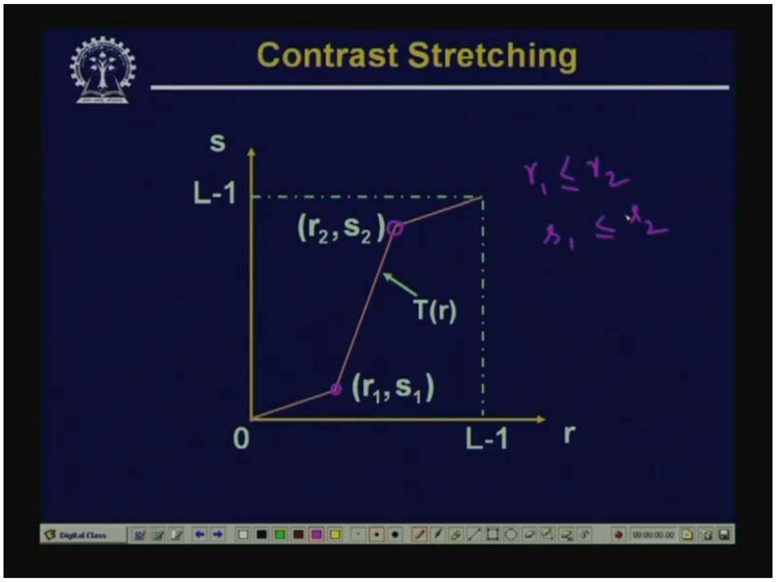

Now, a typical transformation which may be applied for contrast stretching operation is shown in this particular figure. So, here you find that in this particular transformation, we have indicated 2 different points; one is (r_1, s_1) that is this particular point and the other 1s point (r_2, s_2) that is this particular point. Now, it is the locations of these points (r_1, s_1) and (r_2, s_2) which controls the shape of this transformation function and accordingly, it influences upon that what are the different types of contrast enhancements that we can obtain in the processed image.

Now, the locations of this (r_1, s_1) and (r_2, s_2) are very very important. You will find that if we make r_1 equal to s_1 and r_2 equal to s_2, then the transformation function becomes a straight line with a slope equal to 45 degree. That means that whatever 1s the intensity image that we have in the processed image, we will have the same intensity level. That means by applying such a transformation where r_1 equal to s_1 and r_2 equal s_2 in this transformation function that we have said, by applying that kind of transformation, the processed image does not undergo any variation from the original image.

For other values of other combinations of (r_1, s_1) and (r_2, s_2), we really get some variation in the processed image. So, the values which are mostly used is here you find that if I make the other extreme, if I make r_1 equal to r_2 and s_1 equal to s_2 and if I make sorry r_1 equal to r_2 and s_1 equal to 0 and s_2 equal to L minus 1, then that leads to thresholding operation. So, the corresponding transformation generates the binary image which is the processed image. Now, for enhancement operation, usually what is used is r_1 less than r_2 and s_1 less than s_2 which gives us a transformation function as given in this particular figure and this transformation function generally leads to image enhancement.

Now, the condition that r_1 less than or equal to r_2, that is very very important. So, the condition, we have just said that r_1 less than or equal to r_2 and s_1 less than or equal to s_2; now, this particular condition is very very important as you find that if this condition is maintained, then the transformation function that we get becomes a single valued transformation function and the transformation is monotonically increasing. So, that is very very important to maintain the order of the intensity values in the processed image that is an image which is dark in the original image will remain darker in the processed image and image which is brighter in the original that will a point which is brighter in the original image, that will remain brighter in the processed image.

But what difference we are going to have is the difference of intensity values that we have in the original image and the difference of intensity values we get in the process image. That is what gives us the enhancement. But if it is reversed, if the order is reversed; in that case, the processed image will look totally different from the original image. And, all the transformations that we are going to discuss except the negative operation that we have said initially, all of them maintain this particular property that the order of the intensity values is maintained. That is the transfer function is monotonically increasing and we will have our transfer function which is single valued transfer function.

Now, using this particular transfer function, let us see what kind of result we can obtain.

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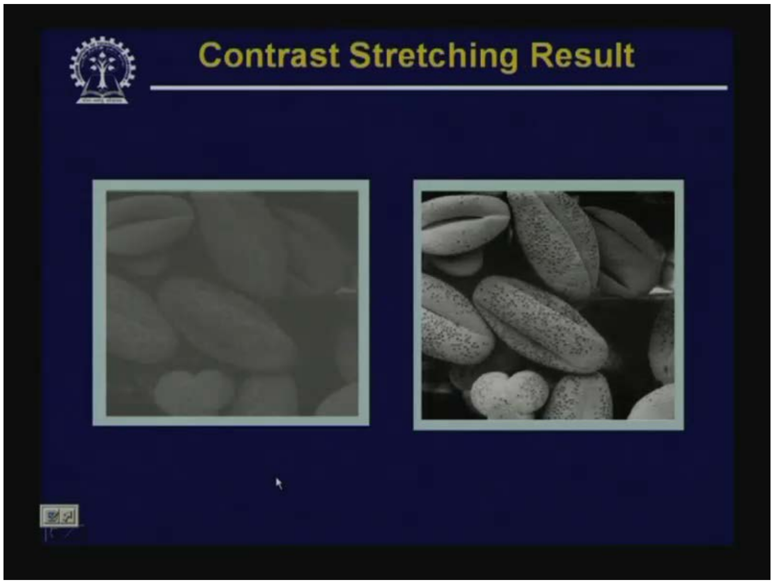

So, in our earlier slide, we have shown an image which is a low contrast image as is shown on the left hand side of this particular diagram of this particular slide and so this left hand side image; this is original image which is a low contrast image and by using the contrast enhancement operation, what we have got is an image which is the processed image shown in the right hand side and here, you can clearly observe that more details are available in the processed image than in the original image.

So obviously, the contrast of the processed image has become much much higher than the contrast in the original image. So, this is a technique which is called contrast stretching technique which is mostly useful for images where the contrast is very very poor and we have said that we can get a poor contrast because of various reasons; either the scene illumination was poor or the dynamic range of the image sensor was very very less or the aperture setting of the camera lens was not proper and in such cases, the dark images that we get that can be enhanced by using this contrast stretching techniques.

Now, there are some other kind of applications where we need to reduce the dynamic range of the original images. Now, the applications where we need to reduce the dynamic range is say for example I have an original image whose dynamic range is so high that it cannot be properly reproduced by our display device. See, normally we have a gray level display device or a black and white display device which normally uses bits. That means it can display intensity levels from 0 to 255 that is total 256 different intensity levels.

But in the original image if I have a minimum intensity value of say 0 and the maximum intensity value of say few thousands, then what will happen that because the dynamic range of the original image is very high but my display device cannot take care of such a high dynamic range; so the display device will mostly display the highest intensity values and the lower intensity values will be in most of the cases suppressed and by that, a kind of image that we will get usually is something like this.

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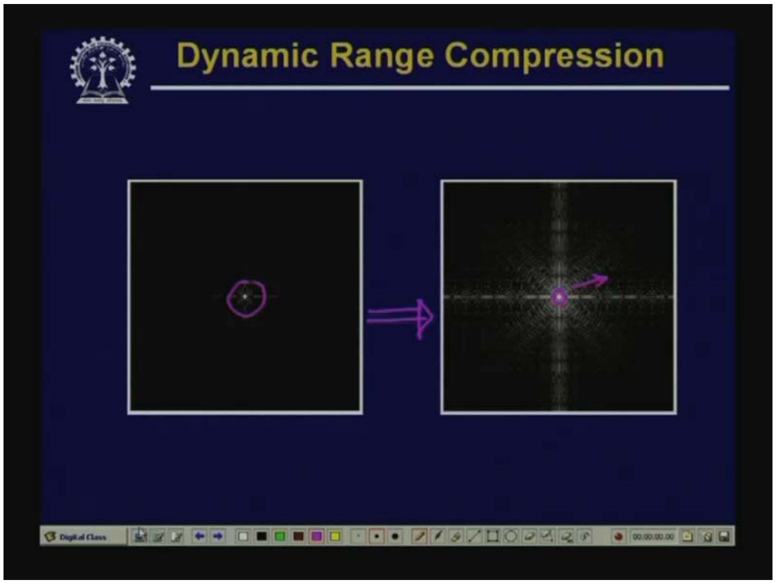

So here, you find that on the left hand side, we have shown an image this is basically the Fourier transformation that is DFT coefficients of certain image. So, on the left hand side, we have shown an image, the Fourier coefficients and here you find that only at the center, we have a bright dot and outside this, the image is mostly dark or mostly black. But actually, there are a number of intensity levels between the 0 and the minimum that is 0 between this maximum and the minimum levels but which could not be reproduced by this particular device because its dynamic range is very poor.

On the right hand side, we have shown the same image after some free processing that is after reducing the dynamic range of the original image by using the image enhancement techniques and here you find that in the processed image, in addition to the bright spot at the center, we have many other coefficients which are visible as you move away from the center. So here, our application is to compress the dynamic range of the input images and the kind of transformations which can give us this dynamic range compression is a transformation of this form which is a logarithmic transformation.

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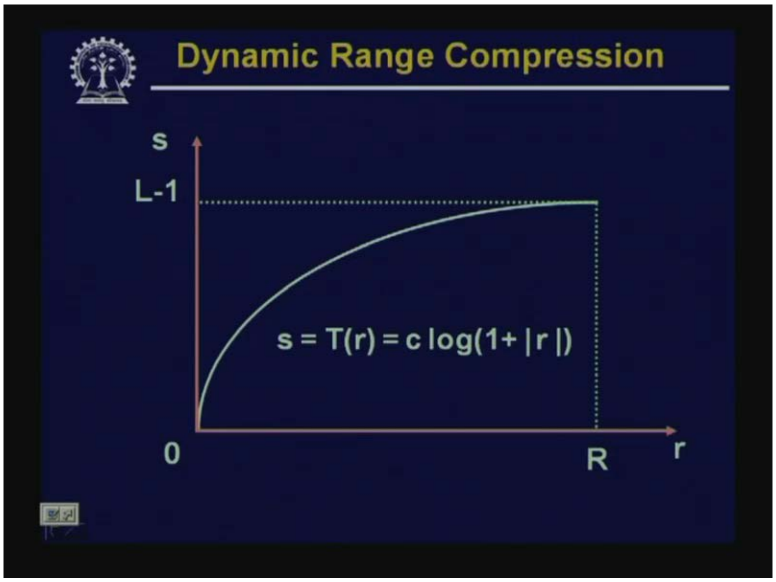

So here again, we assume that r is the intensity of a pixel in the original image and s is the intensity of the pixel in the processed image and the relation is s is equal to T (r) which is equal to c log into 1 plus modules of r where this c is a constant. This constant has to be decided depending upon the dynamic range of your display device and the dynamic range of the input image which is to be displayed and then log of 1 plus modules of r is taken because otherwise whenever r is equal to 0 that is an intensity level in the input image is equal to 0, log of 0 is not defined.

So, to take care of that we take 1 plus modules of r and if you take c log 1 plus modules of r, that gives a compression of the dynamic range and the image can be properly displayed on a display where the dynamic range is limited.

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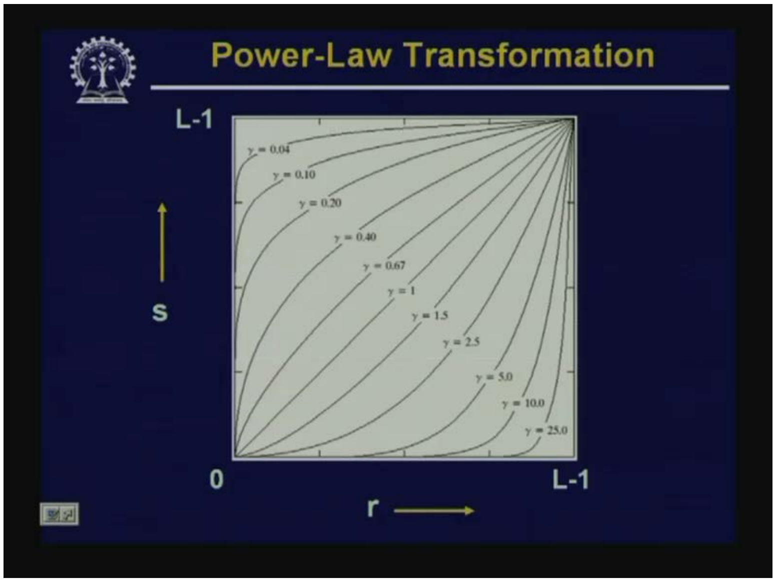

A similar such operation, again for enhancement that can be used is called power law transformation. The power law transformation is normally used for different imaging devices. It is used for image capturing devices; it is used for image printers and so on. In case of power law devices, the transformation function between the original image, intensity and the processed image intensity is given by s is equal to T (r) which is nothing but c into r to the power gamma.

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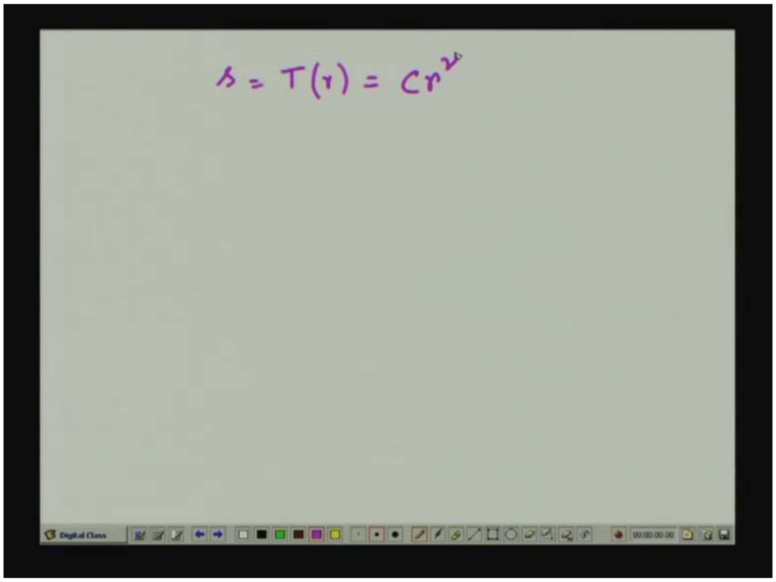

So, in this plot that we have shown, this plot is shown for different values of gamma where c is equal to 1. So, you find that for value of gamma which is less than 1; this transformation function usually towards the lower intensity side, it expands the dynamic range of a very small intensity range in the input image whereas, for a higher intensity side, a higher range of input intensity is mapped to a lower range of intensity values in the processed image and the reverse is true for values of gamma which are greater than 1.

Now, for this kind of transformation, the exponent is conventionally represented by the symbol gamma and that is why this kind of transformation this kind of correction is also known as gamma correction and this kind of processing is used as I said for different types of display devices, it is used for different types of printing devices, it is used of ah different types of capturing devices. The reason is all those devices mostly follow these power law characteristics.

So, if I give an input image that will be converted by power law before the image is actually produced. Now, should compensate for this power law which is introduced by the device itself, if I do the reverse operation beforehand; then the actual image that I want to display that will be displayed properly. Say for example, in case of a CRT display, the relation between the intensity to voltage that follows the power law with the value of gamma which varies normally from 0.8 to 2.5.

So, if I use the value of gamma equal to 2.5 and if I come to this particular figure, then you find that with gamma equal to 2.5, this is the curve or this is the transformation function that will be used. So, whichever image I want to display, the device itself will transform the image using this particular curve before displaying the particular image and as this curve shows that the image which will be displayed will normally be darker than the original image that we intend to display.

So, what we have to do is we have to take some corrective measure before giving the image to the CRT for the display purpose and because of this correction; we can compensate this power law so that our image will be displayed properly.

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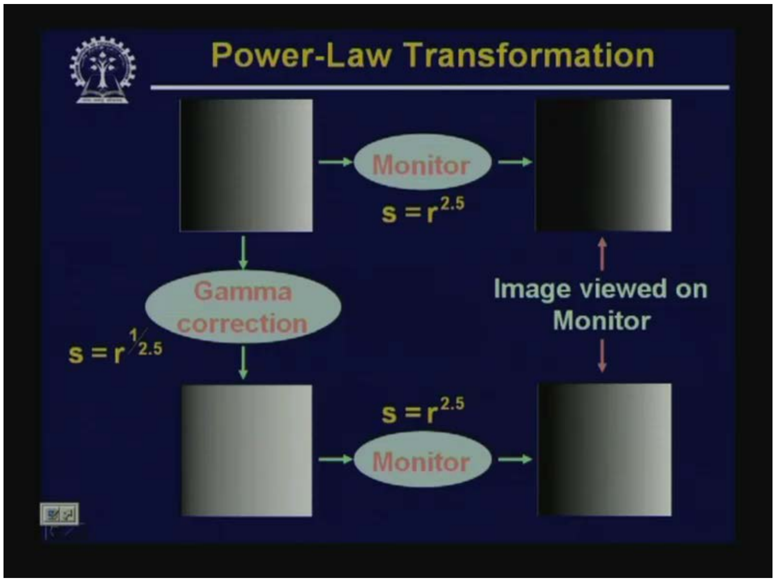

So, coming to this next slide, you find that here we have shown an image which is to be displayed and the image is on the top left corner. The monitor has a characteristics of power law, it has a power law characteristics which is given by s equal to r to the power 2.5 and as we said that because of this power law characteristics, the image will be darker and which is obvious that the image as displayed on the device is given on the right hand side and you find that this image is darker than the original image.

So, to compensate for this what I do is before giving this image to the CRT for display, we go for a gamma correction. That means you transform the image using the transformation function s equal to r to the power 1upon 2.5. So, by this transformation and if you refer back to our power law curves you find that the original image now becomes a brighter image. That is the lower intensity ranges in the input image has now been mapped to a larger intensity range in the processed image.

So, as a result the image has become brighter and when this brighter image is given to the CRT display for display operation, the monitor will perform its characteristic power law that is s equal to r to the power 2.5 and because of this characteristics; the earlier correction, the gamma correction that we have incorporated that gets nullified and we get the image and now we find that on the right bottom, this is the actual image now which will be displayed on the CRT screen and this image now appears to be almost same as the original image that we want to display.

So, this is also a sort of enhancement because if I do not use this kind of correction, then the image that we are going to display on the CRT screen that will be a distorted image but because of this power law correction or the gamma correction as it is called, the image that we get on the CRT screen will be almost same as the original image that we want to display.

Now, this kind of power law transformation, it is not only useful for imaging devices like CRT display or image printer and so on; similar power law transformations can also be used for enhancing the images. Now, the advantage that you get in case of power law transformation is that the transformation curve gets various shapes depending upon different values of gamma and as we have shown in our previous slides that if the value of gamma is less than 1, then on the darker side, the lower range of intensity values will be mapped into a larger range of intensity values in the processed image whereas on the brighter side, a larger range of intensity values will be mapped into lower range of intensity values in the processed image and the reverse is true when gamma is greater than 1.

So, by using different values of gamma, I can have different power law transformations and as a result, what I can have is a controlled enhancement of the input images. So, as it is shown in this particular case.

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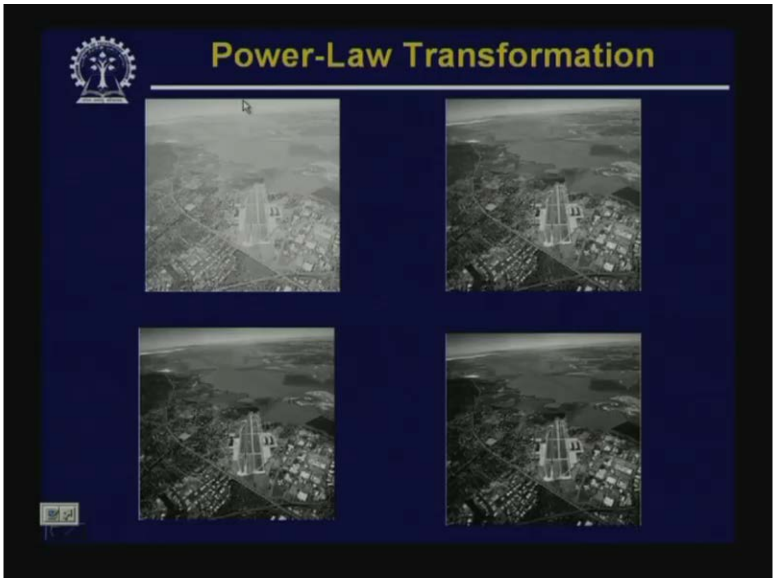

Here, you find that on the top left we have shown an Arial image and you find that the most of the intensity values of this Arial image are on the bright brighter side. So, as result what happens is you find that most of the portions in this image are almost washed out we cannot get the details of the image very easily.

Now, if we process this image using the power law transformation, then you find that the other 3 images that is the right top image is obtained by using the power law of transformation with certain value of gamma. Similarly, the bottom left image using some other value of gamma and the right bottom image is also obtained by using some other value of gamma and here you find that for the first image that is right top image has been corrected with a value of gamma which is less than the value of gamma used for the image shown in the left bottom image which is again less than the value of gamma used for getting obtaining the image shown in the right bottom side.

And, as it is quite obvious, in all these cases, you find that the washed out characteristics of the original image have been controlled that is in the processed image, we can get much more details of the image content and as you find that as we increase the value of gamma, the image becomes more and more dark and which is obvious from the power law characteristic, the power law transformation function plot that we have already shown.

So, this is another kind of processing operation, the power law transformation that can be also used to enhance some features of the input image. The other kind of transformation that we can use for this power image enhancement is called gray level slicing. So in case of gray level sizing, some applications may need that the application may not be interested in all the intensity levels but the application may be may need the intensity levels only in certain gray level values.

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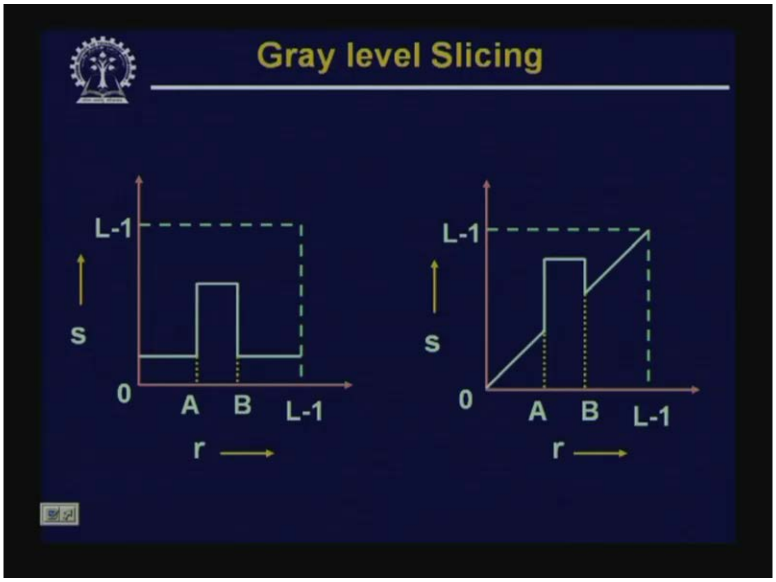

So, in such cases, for enhancement, what we can use is the gray level slicing operation and the transformation function is shown over here. Here, the transformation function on the left hand side says that for the intensity level in the range A to B, the image will be enhanced for all other intensity levels, the pixels will be suppressed.

On the right hand side, the transformation function shows that again within A and B, the image will be enhanced but outside this range, the original image will be retained and the results that we get is something like this.

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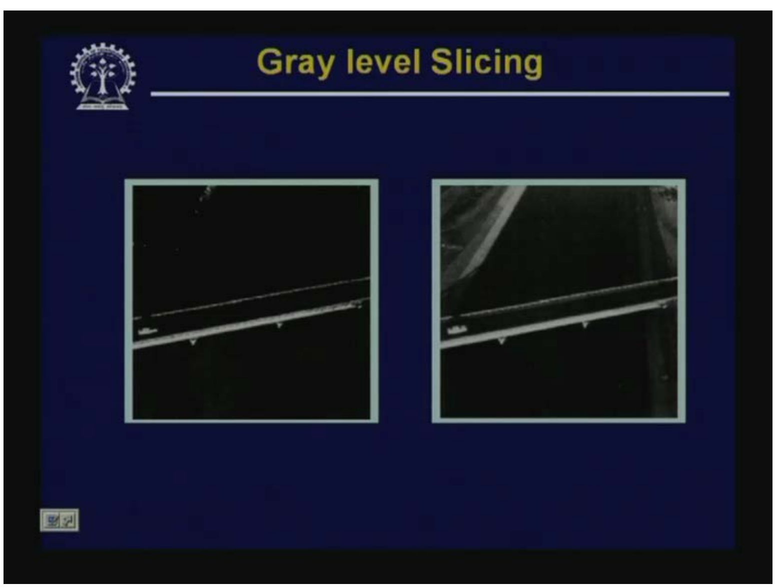

The first image shows that only the desired intensity levels are obtained or retained with enhancement. All other regions, they have been suppressed. The right hand image shows that the desired range of intensities have been enhanced but other intensity levels have remained as it is. So, with this we stop our today's discussion on point processing. We will continue with this topic in our next lecture.

Now, let us come to some questions on today's lecture topic.

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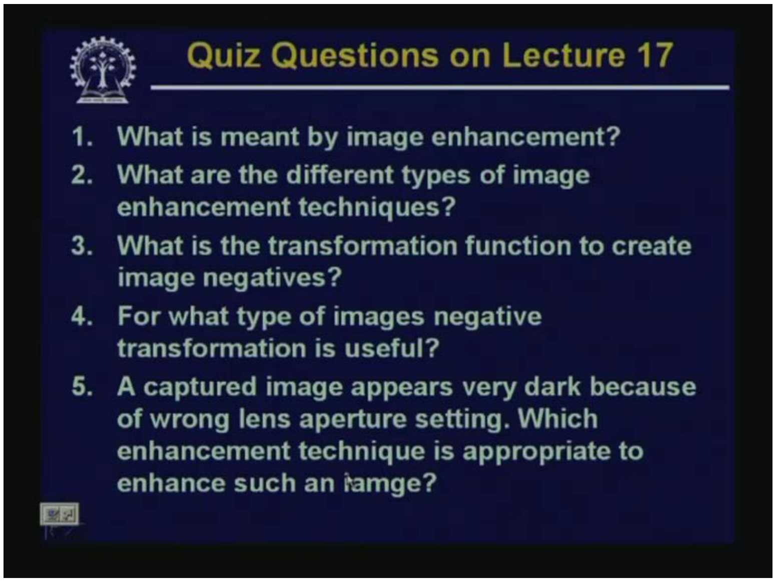

So, today's quiz questions are first question is what is meant by image enhancement? What are the different types of image enhancement techniques? What is the transformation function to create a negative image? For what type of images, negative transformation is useful? A captured image appears very dark because of wrong lens aperture setting. Which enhancement technique is appropriate to enhance such an image?

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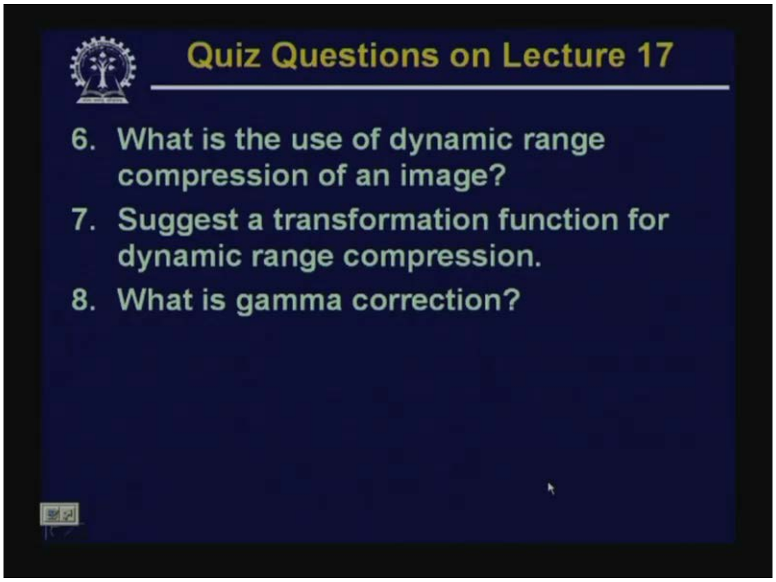

Then, what is the use of dynamic range compression of an image? Suggest a transformation function for dynamic range compression? What is meant by gamma correction?

Thank you.