Digital Image Processing

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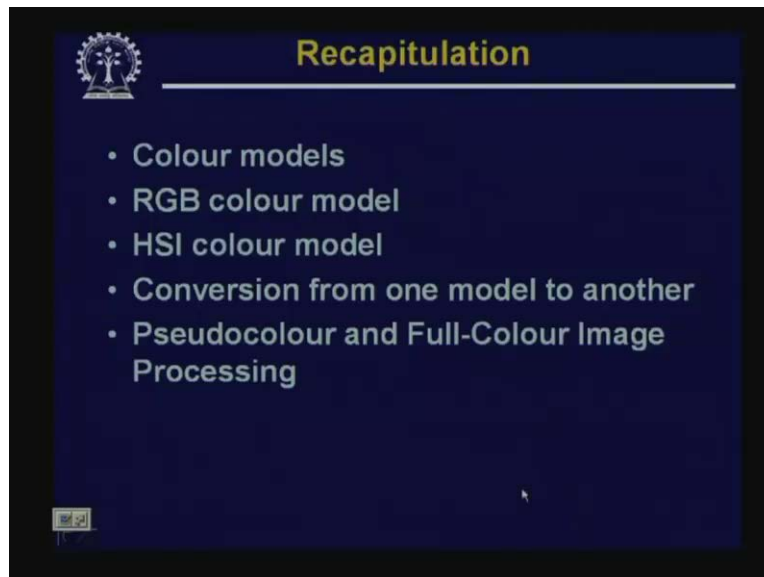
Indian Institute of Technology, Kharagpur

Lecture - 28
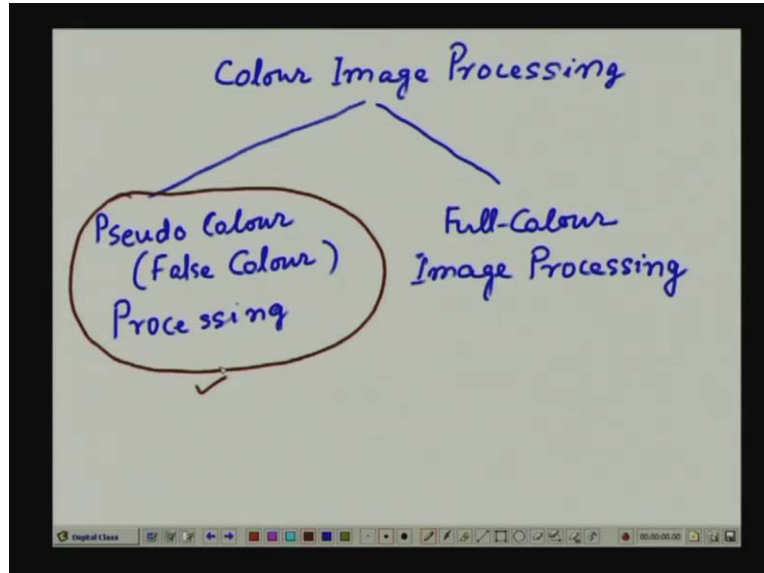
Colour Image Processing - III

Hello, welcome to the video lecture series on digital image processing. For last two classes, we are discussing on colour image processing techniques. So, for last two classes, we have introduced the concept of colours and the colour models.

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In our last class, we have discussed about the RGB colour model, we have discussed about the HSI colour model, along with RGB colour model we have also discussed about CMY and CMYK colour models. Then after discussing about the HSI colour model, we have talked about conversion from one colour model to another and we have just told about what is the difference between pseudo colour and full colour image processing techniques.

So, in our last class, we have said that when we talk about colour image processing techniques; generally, we have 2 categories of colour image processing. One is called pseudo colour image processing or this is also known as false colour; so, pseudo colour processing and the other category is what is known as full colour image processing.

So, we have just said that this pseudo colour image processing, the basic purpose of pseudo colour image processing technique is to assign different colours in different for different intensity ranges in a black and white image. The purpose is as we have told earlier that given a black and white image or human eye can simply distinguish between only around 2 dozens of black and white shades or intensity shades whereas given a colour given a colour image, we can distinguish among thousands of colour shades.

So, given a black and white image or an intensity image; if we go for pseudo colour processing techniques that is assign different colours to different ranges of intensity values, in that case interpretation of such an intensity image is more convenient than the interpretation of an ordinary or simple intensity level image.

Now, the basic way in which the pseudo colouring technique can be used that is as we said that the purpose of pseudo colouring technique is to assign different colours to different ranges of intensity values; the simplest approach in which this pseudo colouring can be done is by making use of intensity slices. So, what we can do is we can consider an intensity image to be a 3D surface.

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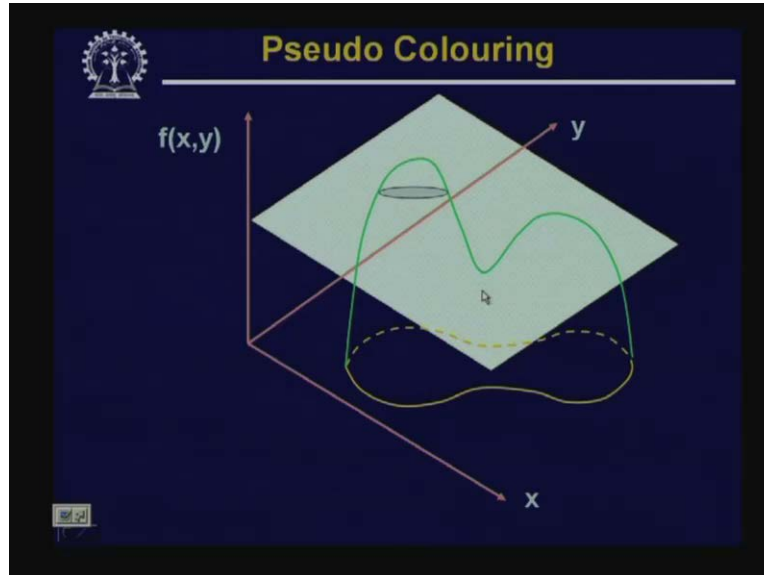
So, as shown in this particular slide that given an intensity image say f (x, y) which is the function of x and y; so different intensity values at different locations of x and y, if we consider them to be a 3 dimensional surface, then what we can do is we can place planes which are parallel to the image plane that is parallel to the xy plane.

So, as shown in this particular diagram, if I place such a plane at some intensity value say x_i so at this intensity value say l_i ; we have placed a plane which is parallel to the xy plane. Now, find that this particular plane which is parallel to xy plane, this slices the intensities into 2 different halves.

So, once I get these 2 different halves, what I can do is I can assign different colours to different to 2 different sides of this particular plane. So, on this side, I can assign one particular colour whereas on the other side that is this side, I can assign another colour. So, this is the basic techniques of pseudo coloring. That is you slice the intensity levels and to different slices, you assign different colours.
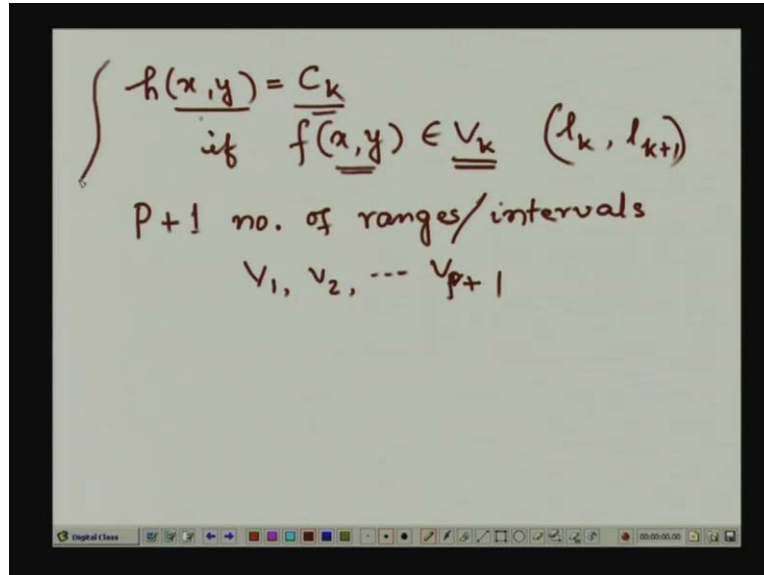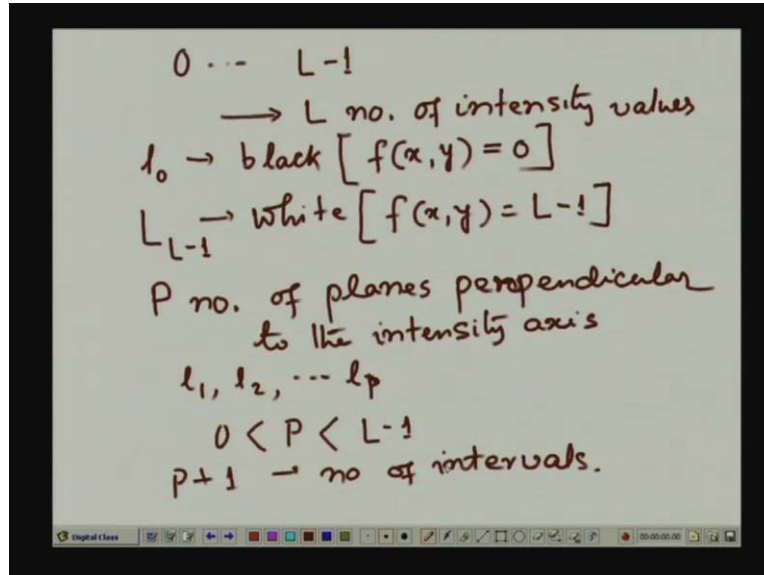
So, in our case we assume, let us assume that our image, the intensity values, the discrete intensity values in a black white image varies from say 0 to capital L minus 1. So, I have total L number of intensity values in our image, L number of intensity values. So one, we have this L number of intensity values and we assume that an intensity values say l_0 which represents an intensity levels say black; this means that the corresponding f (x, y) at locations xy where the intensity is l_0, this is equal to 0.

Similarly, the L minus first intensity level, I assume that this is equal to white that means all the corresponding pixels f (x, y) will have a value equal to capital L minus 1. And, let us also assume that we have we will draw P number of planes number of planes perpendicular to the intensity axis. So, perpendicular to the intensity axis means they are parallel to the image planes and these planes will be placed at the intensity values given by say l_1, l_2 upto say l_p. So, first plane will be placed at intensity value l_1, the second plane will be placed at intensity value l_2 and this way the p'th plane will be placed at intensity value l_p.

So obviously, in this case, P - the number of planes has to lie from 0 to capital L minus 1 where L is the number of gray level intensities that we have. So, once we place such P numbers of planes which are perpendicular to the intensity axis, these P number planes divide the intensities in to p plus 1 number of intervals. So, once I divide the intensity ranges into p plus 1 number of intervals, then our colour assignment approach will be that a particular location, the colour to a location f (x, y), this colour will be equal to C_k or instead of calling it f, let me call it some function say h.

So, the colour assigned to location xy which is h (x, y) will be C_k if the corresponding intensity value at that location xy, f (x, y) lies in the range V_k where V_k is the intensity range which is defined by the planes placed at the locations l_k and l_k plus 1. So, as we said that there are P numbers of planes, so these P number of planes will divide our intensity range into P plus 1 number of ranges or intervals and we call this intervals as interval v_1 v_2 upto interval $v_{p\ plus\ 1}$.

So, we assign a colour C_k to a particular location xy; so we write h (x, y) will be equal to C_k if the intensity value at the corresponding location which is given by f (x, y), this intensity value belongs to the intervals V_k. Now, by using this simple concept that is you divide your intensity range into a number of intervals and to a particular location in the intensity image, you assign a colour which is determined by in which of the intervals the intensity of the image at that particular locations belong; then, what we get is a pseudo coloured image. So, let us see some examples of this pseudo coloured image.

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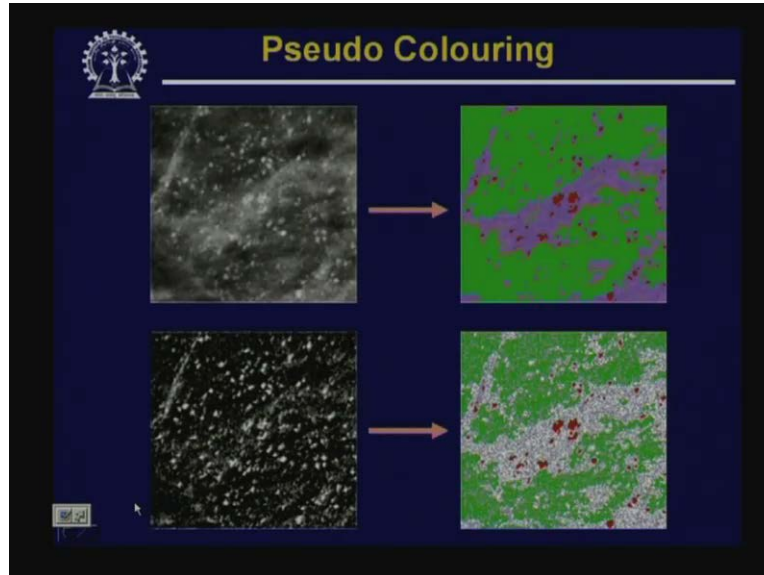
Here we have say said that on the left hand side, we have an intensity image of black and white image. If I apply pseudo coloring, if I go for the pseudo coloring techniques, then the pseudo coloured image is as shown on the right hand side. Similarly the bottom one, this is an image which is an enhanced version of this and if I apply pseudo colouring technique to this particular black and white image, then the corresponding pseudo coloured image is given on the right hand side.

So, here you find that interpretation in the pseudo coloured image or the distinction between different intensity levels in the pseudo coloured image is much more easier than the distinction in the corresponding intensity image or gray scale image.

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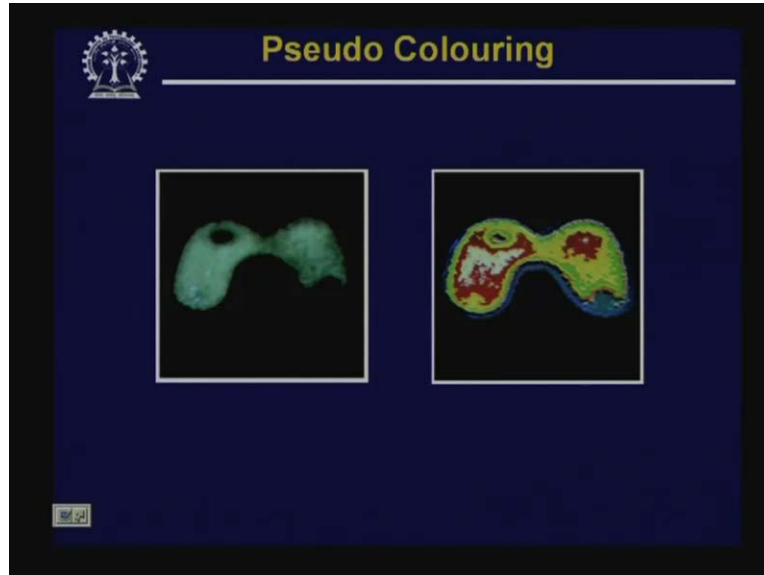
Now, this particular application will be more prominent in this particular diagram. Here again, you find that on the left hand side, we have an intensity image or a gray scale image and you find that in these regions, the intensity values appears to be more or less flat. That means I cannot distinguish between different intensity levels which are present in this particular diagram or as on the right hand side if I go for pseudo coloring, you find that these different colours which are assigned to different intensity levels in this particular black and white image, this clearly tells us that what are the different regions of different intensity values in this particular black and white image.

So, another application, the other application of pseudo coloring technique is from gray to colour of transformation. So here, what we have shown is to different intensity intervals, we have assigned different colours. Now, when we go from gray scale to color transformation, then what we have to do is if I have an intensity image or gray scale image that corresponds to a single plane, I have to convert that to 3 different planes that is R, G and B - red green and blue planes and those red, green and blue planes when they combine together, they are combined together, they give you an interpretation of a colour image.
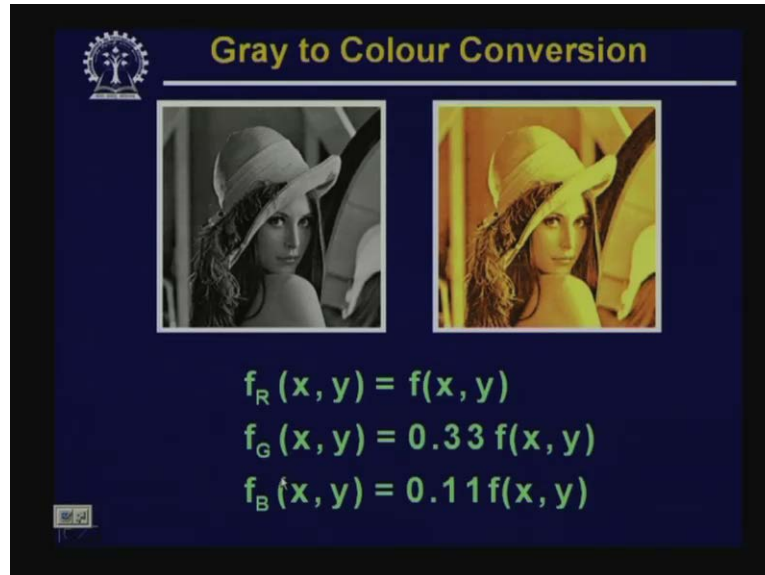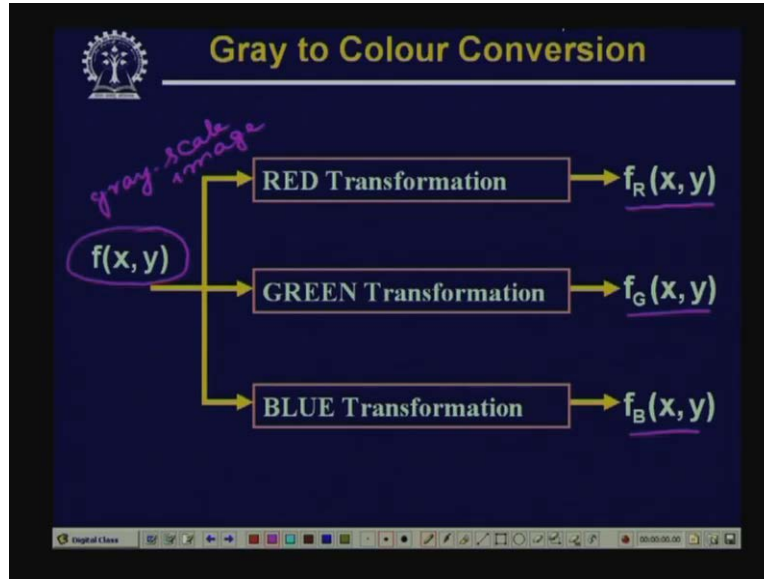
So, that kind of colour gray to colour transformation can be done by using this type of transformation functions. So here, you find that our input image f (x, y), this is an intensity image or gray scale image. Then, what we are doing is this gray scale image is transformed by 3 different transformations; one corresponds to the red transformation, the other one corresponds to the green transformations and the third one corresponds to the blue transformation.

This red transformation generates the red plane of this image which is given by f_R (x, y), the green transformations generates the f_G (x, y) or the green plane corresponding to this intensity image f (x, y) and the blue transformation generates f_B (x, y) which is the blue plane corresponding to this intensity image f (x, y).

So, when these 3 images that is f_R (x, y), f_R (x, y), f_G (x, y) and f_B (x, y) - the red, green and blue planes they are combined together and displayed on a colour display, what we get is a pseudo coloured image. But in this case, you find that the colour is not assigned to different intensity ranges but the colour is decided, the colour of entire image is decided by the corresponding transformation functions. So, the colour content of the colour image that we will generate that is determined by the transformation functions that we use.

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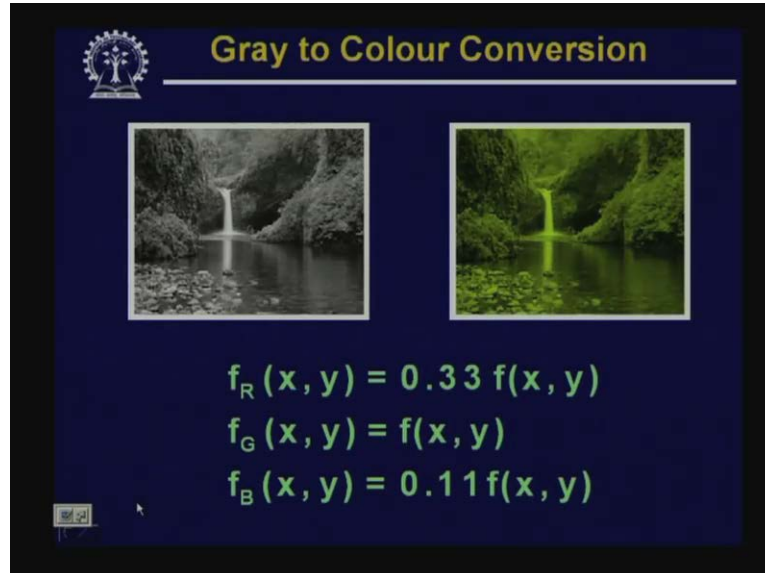Now, let us see that what are the kind of colour images that we can obtain using this gray scale to colour transformation. So, in this diagram as it is shown, on the left hand side, we have an intensity image or black and white image which is transformed into a colour image. So, on the right hand side is the corresponding colour image and the colour transformations that has been used are like this - here we have used that $f_R (x, y)$ is equal to $f (x, y)$ that is whatever is the black and white intensity image that is simply copied to the red plane. The green plane, the $f_G (x, y)$ is generated by $0.33 f (x, y)$. That means the intensity value at any location in the original black and white image is divided by 3 and whatever value we get that is copied to the corresponding locations in a green plan.

Similarly, $f_B (x, y)$, the blue plane is generated by dividing the intensity image by multiplying the intensity image by a value 0.11 or dividing the intensity image by a value 9. So, by these transformation functions, we have generated f_R - the red component, f_G - the green component and f_B - the blue component and when you combine this red component, green component and blue component; the corresponding colour image which is generated is like this.

Now here, you should remember one point that this colour image that is being generated it is a pseudo coloured image. Obviously, it is not a full colour image or the colour of the original image is not generated in this matter. So, the only purpose is the different intensity the different intensity regions will appear as different colours in our coloured image. So, this colouring is again a pseudo colouring, it is not the real colouring.

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Now, we have another example on this pseudo coloring. Here, it is a natural scene where again on the left hand side, we have the intensity image or the black and white image and when you go for gray scaling to colour transformation, now the transformations are like this - here, the green component is same as the original intensity image. So, we have taken $f_G (x, y)$ is equal to $f (x, y)$ where $f (x, y)$ is the original intensity image, the red component is generated as one third of (x, y) and the blue component is generated as one nineth of (x, y).

So, by generating the red, green and blue components, blue planes from the original $f (x, y)$ in this manner and if you combine them, the corresponding pseudo coloured image that we get is given on the right hand side. So here, you find that if I compare the earlier image with this; in our earlier case, the coloured image was showing more of red component because in this case, f_R was same as $f (x, y)$ where as green and blue were scaled down versions of $f (x, y)$ whereas in this particular case, our pseudo coloured image appears to be green because here $f (x, y)$ here the green component, the green plane is same as $f (x, y)$ whereas red and blue are taken as scaled down version of $f (x, y)$.

So, if we change the weightage of these different functions of these different red and blue green, red and blue planes, the colour appearance will again be different. So, a gray scale image can be converted to a pseudo coloured image by this kind of conversion by applying different transformations for different red, green and blue planes.

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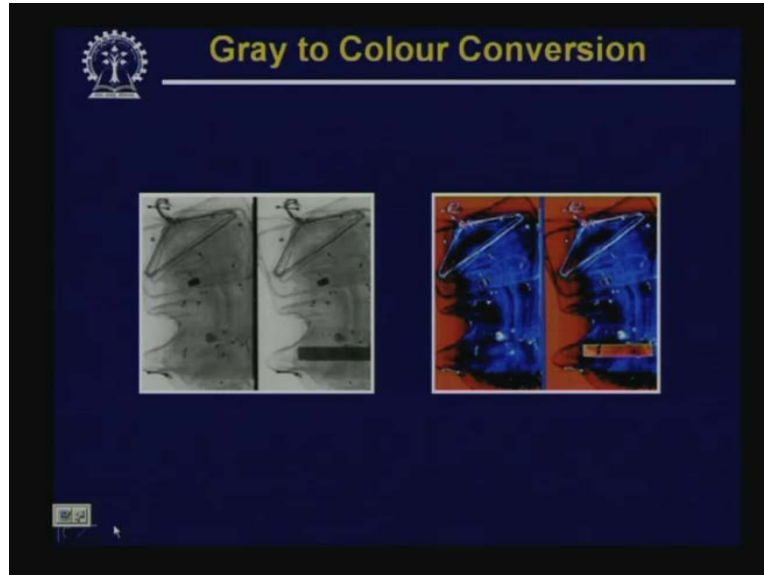
Now, many of you might have seen the x-ray security machines like what is used in airports. Here, you find that this is an x-ray image on the left hand side of a baggage which is screened by an x-ray machine. If you have looked at the screen which the security people checks; on the screen, this image appears in this particular form where you find that the background has appeared as red, the different garments bags, they have appeared as blue. Of course, there are different shades whereas there is a particular region over here which is appeared as again red.

Now again, this is a pseudo colouring technique which is applied to obtain this kind of image and the purpose is if you have a pseudo coloured image like this, you can distinguish between different objects present in this particular image and in this particular case, normally the kind of transformation functions for red, green and blue which are used are given like this.
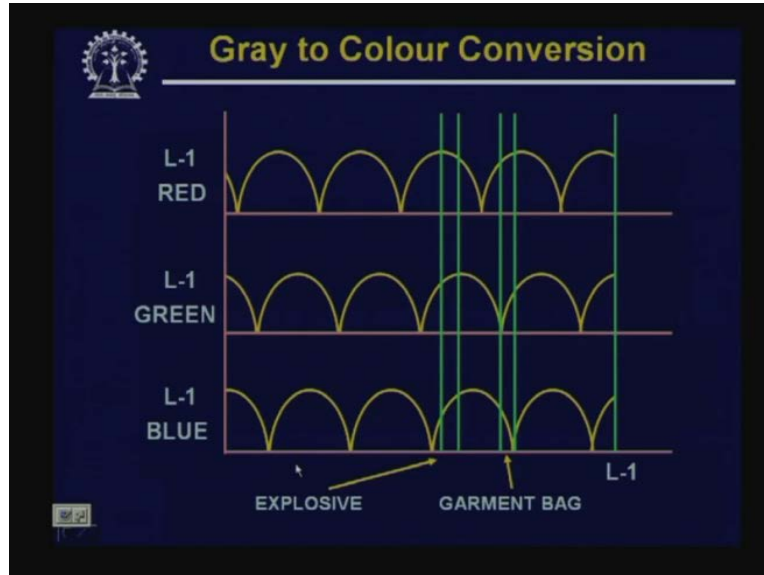
The transformation functions are usually sinusoidal functions. So here, what you have is you have this is the red transformation, this is the intensity values along the horizontal access we have the intensity values of the gray scale image which varies from 0 to the maximum value capital L minus 1. The top curve, sinusoidal curve, it shows the red transformation; the middle one shows the green transformation and the last one shows the blue transformation and here you find that these different sinusoidal curves, it appears to be a fully rectified sinusoidal curve is shifted from one another by certain amount so as if we have given some phase shift to this different sinusoidal curves.

Now, when the transformations are given like this; so if you have an intensity values say some were here, then the corresponding red component will be generated as this value, the corresponding green component will be generated as this value and the corresponding blue component will be generated at as this value. So, this particular intensity level will be coded as a coloured point as a colour pixel having red component given by this much and the green component given by this much and blue component given by this much.

Now, what is done for this pseudo coloring purpose is that you define different bands of input intensity values and the different bands are given to different objects. For example, a band somewhere here, the band somewhere here, this is for identification of say an explosive, a band somewhere here is for identification of the garments bags and so on.

So here, you find that if this is the band which is given which is used to detect the explosives, the amount of red light which is generated, the amount of red component which is generated by this particular band is the maximum one. So, an explosive will appear to be a red one whereas for this particular one which is for the garment bags where the red component is not as high as this; so this will not appear as bag red as an explosive.

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So, different band of frequencies are identified or the different band of intensity values are identified or specified to identify different types of items and by using this kind of transformation, we can distinguish between different object which are there in the bags. So, by using this pseudo coloring techniques, we can give different intensity values to different intensity ranges and as you have just seen that we can convert a gray scale or an intensity image to colour image where the colour image as it is a pseudo coloured image, it will not really have the exact the colour components but the pseudo colour image gives us the advantage that we can distinguish between different objects present in the image from its colour appearance.

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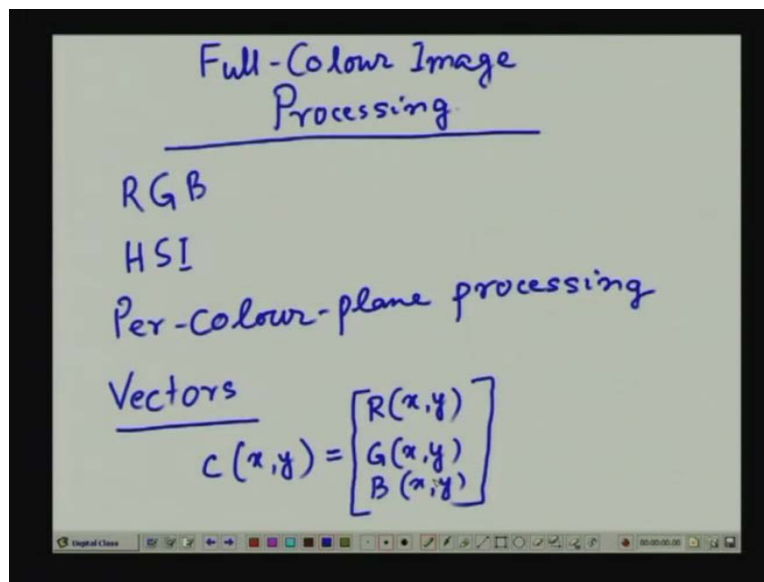
The next type of image processing techniques: so these are the 2 different pseudo colouring techniques that we have discussed. The next kind of the image processing techniques that we discuss is full colour image processing and as we have said that unlike in case of pseudo colour techniques, in case of full colour image processing, what we will do is we will consider the actual colours present in the image and as we have said that as there are different colour models, a colour image can be specified in different colour models.

For example, a colour image can be specified in RGB colour space, a colour image can also be specified in HSI colour space. Now, because we have this different colour components of any particular colour pixels, so we can have 2 different categories of colour image processing; one category of colour image processing is per colour plane processing. So, in case of this, in this category, what you do this you process every individual colour components of the colour image and then this different processed components that you have, you combine them together to give you the coloured processed image.

And, the other type of processing is by using the concept of vectors. So, as we have said that every colour pixel has 3 colour components, so any colour can be considered as a vector. So, if it is the colour specified in RGB space, then it is the vector drawn to the point which specifies the colour from the origin of the RGB colour space.

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So, there are 2 kinds of processing; one is per colour plane processing in which case, every plane is processed independently and then the processed planes are combined together to give you the processed colour output and the other type of processing, the other category of processing is when all the colour components are processed together and there the colours different colours are the considered as vectors.

So obviously, the colour at a particular point x y C (x, y), if we are going for an RGB colour space if it is specified in RGB colour space, the point (x, y) will have 3 colour components; one is the red component at location (x, y) and the other one is green components at location (x, y) given by G (x, y) other one is blue component at location (x, y) which is given by B (x, y).

So, every colour is represented by vector and the processing is done by considering these vectors. That means all the colour components are considered together for processing purpose. So, accordingly we will have two types of colour processing techniques.

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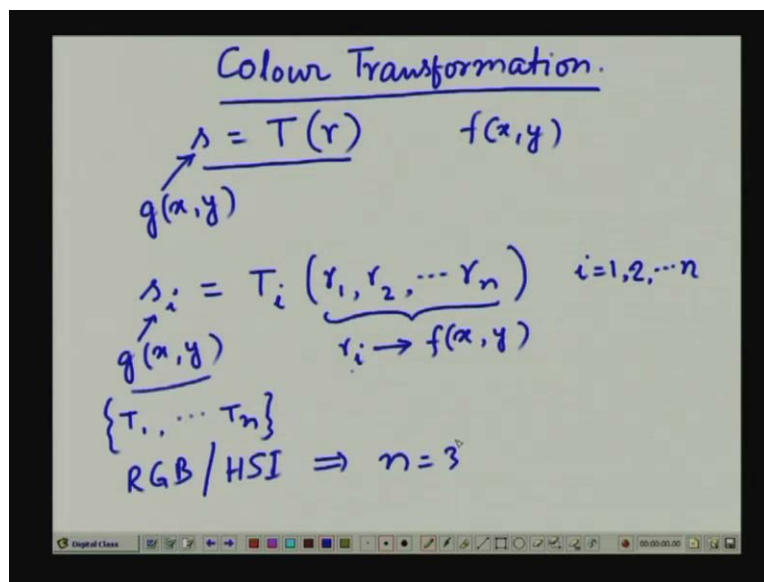
The first kind of processing that we will consider is what we call as colour transformation. Now, you may recall from our discussion with the gray scale images or black and white images that where we have defined a number of transformations for enhancement purpose and there we have defined the transformation as say s is equal to some transformation T of r where r is an intensity value, intensity at a location in the input image f (x, y) and s is the transformed intensity value in the corresponding location of the processed image g (x, y) and there the transformation function was given by S is equal to T (r). Now, we can extend the same idea in our colour processing techniques.

The extension is like this - now in case of intensity image, we had only one component that is the intensity component, in case of colour image we have more than one components that is may be RGB component if the colour is specified in RGB space or HSI component if the colour is

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specified in HSI space. Correspondingly, we can extend the transformation in case of colour is s_i is equal to some transformation function T_i of r_1 r_2 upto r_n for i equal to 1, 2 upto n.

So here, we assume that the colour, every colour is specified by a 3 component vector having values r_1 to r n. s_i is a colour component in the processed image G (x, y) and r_i, every r_i is a colour component in the processed image f (x, y). So, s_i is a colour component in the processed image G (x, y) and r_i is a colour component in the input image, in the input colour image f (x, y) and here, n is the number of components in this colour specification and T_i that is T_1 to T_n, it is actually the set of transformations or colour mapping functions that operate on r_i to produce s_i.

Now, if we are going for RGB colour space or HSI colour space; then actually, the value of n is equal to 3 because in all these cases, we have three different components.

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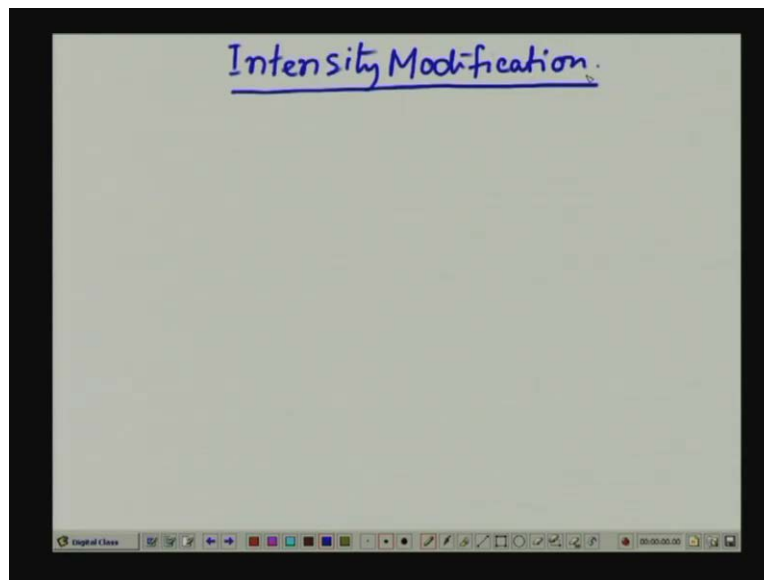
Now, first application of this intensity transformation of this colour transformation that we will use is intensity modification. Now, as we can represent a colour in different colour models or different colour spaces; so theoretically, it is possible that every kind of colour processing can be done in any of those colour spaces or using any of those colour models.

However, it is possible that some processing, some kind of operation is more convenient in some colour space but it is less convenient in some other colour space. However, in such cases, we have to consider the cost of converting the colours from one colour model to another colour model.

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Say for example, in this particular case, you find that if I have a colour image which is given in RGB colour space, the different colour planes of the same image; this is the red colour plane, this is the green plane and this is the blue colour plane. So, this colour image can have these different 3 different colours planes in the RGB model. Similarly, the same image can also be represented in HSI colour space where this left most image gives you the H component, this gives the saturation component and this gives the intensity component.

Now, from this figure it is quite apparent as we claimed earlier that it is the intensity component in the HIS model which is the chromatic notion of brightness of image. So here, you find that this actually indicates what should be the corresponding black and white image for this colour image. So, as we can represent a colour image in this 3 different, in these different models; so it is possible, theoretically possible that any kind of operation can be performed in any of these models.

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Now, as we said that the first application that we are thinking of that we are talking about is intensity modification. This intensity modification transformation is simply like this – say, G (x, y) is equal to some constant k times f (x, y) where f (x, y) is the input image, this is the input image and G (x, y) is the processed image and in this particular case, if we are going for colours scaling; then our intensity scaling, intensity reduction, the value of k lies between 0 and 1.

Now, as we said that this operation can be done in different colour planes; so, if we consider the RGB colour space, then our transformation will be s_i is equal to the constant, same constant k times r_i for i varying from for i is equal to 1, 2 and 3 where 1 the index 1 will used to indicate the red component, index 2 is used to indicate the green component and index 3 is used to indicate the blue component.

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So, this indicates that all the different colour planes; the red plane, green plane and blue plane, all of them are to be scaled by the same scale vector whereas, if I do the same transformation in HSI space, then as we said that the intensity information is contained only in i. So, the only transformation, the transformation that will be needed in this particular case is s_3 is equal to the constant k times $r_3$where as the other 2 components corresponding to hue and saturation can remain the same.

So, we will have s_1 equal to r_1 that is hue of the processed to image will then remain same as the hue of the input image. We have s_2 is equal to r_2 that is saturation of the processed image will remain same as saturation of the input image. Only the intensity component will be scaled by the scale factor k. The similar such operation if we perform in CMY space, then the equivalent operation in CMY space will be given by s_i is equal to the constant k times r_i plus 1 minus k and this has to be done for all the i that is all the planes C, M and Y planes.

So, if I compare the operations that we have to do in RGB colour plane, RGB space, the operation in HSI space and the operation in CMY space; you find that the operation in HSI space is the minimum of these 3 different spaces because here only the intensity value is to be scaled, hue and saturation value remain unchanged whereas both in RGB and CMY space, you have to scale all the three different planes.

However, as we said that though the operation, the transformation takes minimum time in the HSI space, transformation has minimum complexity in HSI space but we also have to consider that what is the complexity of converting from RGB to HSI or CMY to HIS because, that conversion also has to be taken into consideration. Now, if I apply this kind of transformation, then the transformed image that we get is something like this.

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Here, the operation has been done in the HSI space. On the left hand side, we have the input image and on the right hand side, we have the intensity modified image. So, this is the image for which the intensity has been modified by a scale factor of around 0.5. So, we find that both the saturation and hue, they appear to be the same but only the intensity value in this particular case has been changed. Of course, this equivalent operation can as we said, can also be obtained in case of RGB plane as well as in CMY plane. But there the transformation operation will take more computation than the transformation operation in case of HSI plane where we have to scale only the intensity component keeping the other components intact.

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The next application of this full colour image processing that will consider is colour complements. Now, to define this colour complements, let us consider let us first look at a colour circle.

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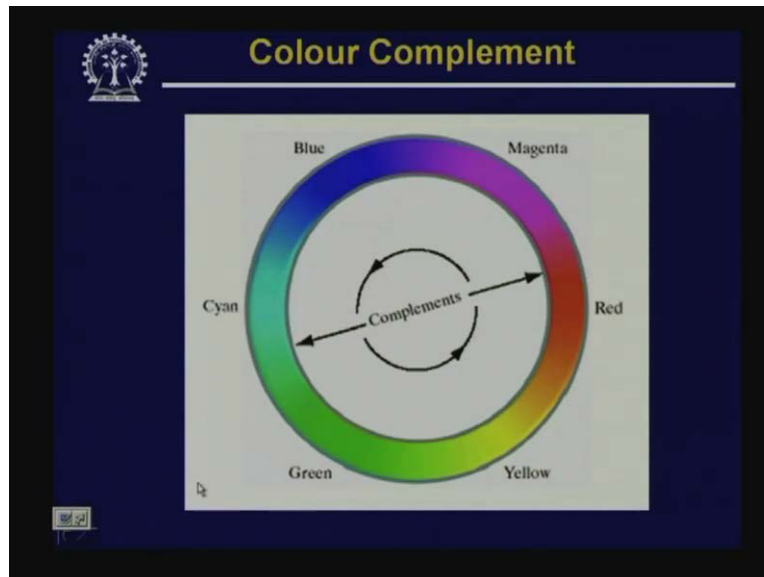
So, this is the colour circle. You find that in this particular colour circle, if I take the colour at any point on the circle, the colour which is located at the diagonally opposite location in this circle is the compliment of the other colour. So, as shown in this figure that here if I take a colour on this colour circle, its complement is given by the colour on this side and similarly the reverse, the colour on this side has a complement on the colour on the other side.

So, this simply says that hues which are directly opposite to one another in the colour circles, they are complements of each other. Now, this colour complement as we have said the colour complement, this is analogous to the gray scale negatives. When we have talked about the gray scale or intensity image processing, we have also talked about the negative operation. This colour complements is analogous to that gray scale negative operation.

So, the same operation which we had used in case of gray scale image to obtain its negative, if I apply the same transformation to all the R, G and B planes of a colour image represented in RGB space, then what I get is our complement of the colour image or this is through really the negative of the colour image.

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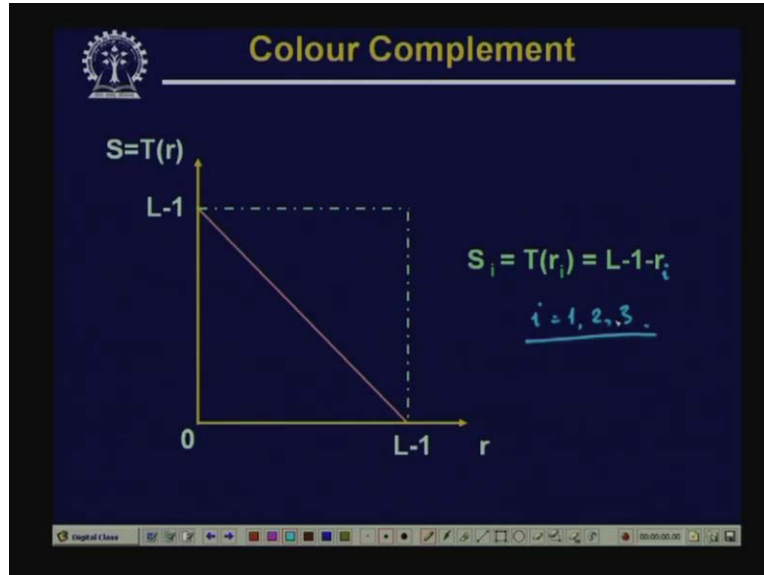
So, those colour images can be obtained by a transformation function of this form. In case of intensity image, we had a single transformation but in case of colour image, I have to apply this same transformation on all the colour planes that is I have to get it s_i equal to T of r_i which is equal to L minus 1 minus r_i. This should be r_i for all values of i that means here i will be from 1, 2 and 3. That is for all the colour planes – red, green and blue, I have to apply this same transformation.

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So, by applying this, I get an image like this. Here, you find that on the left hand side, I have a colour image and on the right hand side, by applying the same transformation on all the 3 planes

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that is red, green and blue planes, I get a complement image or you find that this is same as the photographic negative of a colour image.

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In the same manner, this is another colour image and if I apply the same transformation to red, green and blue components of this particular colour image, then I get the corresponding negative of the complement colour image as shown on the right hand side.

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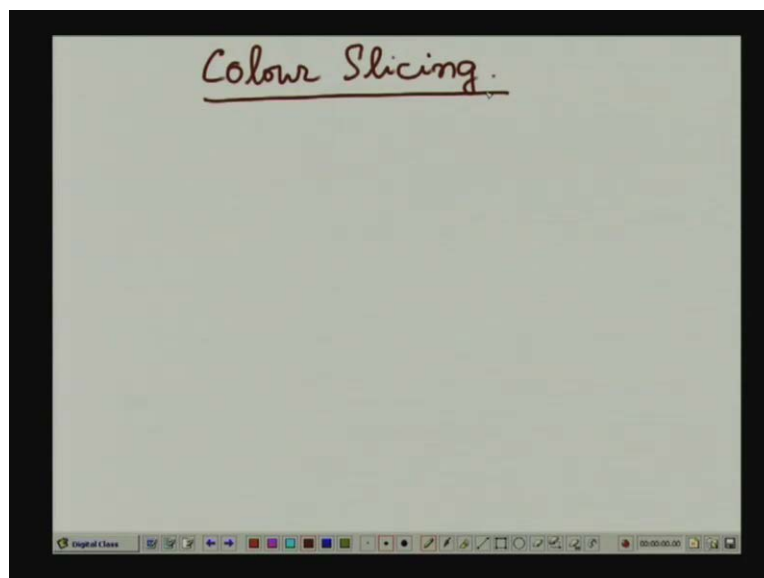
The next application that we will consider of this full colour image processing is colour slicing. You will find that incase of RGB image, we have said that the application of colour slicing is to highlight the regions of certain intensity ranges or certain intensity region. In the same manner, the application of colour slicing in case of colour image is to highlight certain colour ranges and this can be applied, this is useful for identification of objects of certain colour from the background or to differentiate objects of some colour from some other colour.

The simplest form of colour slicing can be that we can assume that all the colours of interest lies within the cube of width say W and this cube is centered at a prototypical colour whose components are given by some vectors say a_1 a_2 and a_3; so, as given in this particular diagram.

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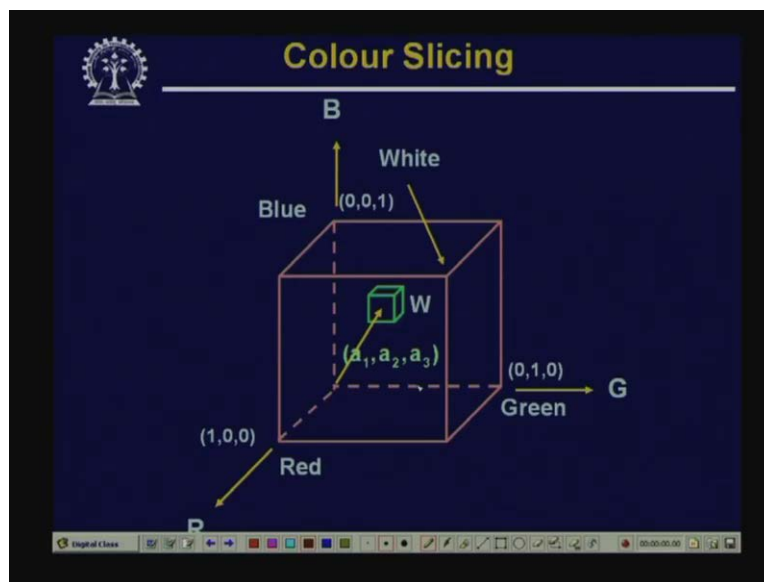
So here, I assume that I have this cube of width W and the colours of interest are contained within this cube and the center of this cube is at a prototypical colour which is given by the colour components a_1 a_2 and a_3 and the simplest type of transformation that we can apply is we can have the transformation of this form that s_i is equal to 0.5 if say r_j minus a_j, this is equal to W by 2 for all values of j in 1 and 3 and I set this is equal to r_i otherwise and this computation has to be done for all values of i, i equal to 1, 2 and 3.

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So, what it means that all those colours which lie outside this cube of width W centered at location a_1 a_2 a_3, all those colours will be represented by some insignificant colour where all the red, green and blue components will attain a value of 0.5 but inside the cube, I will return the original colour.

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So, by using this transformation, you find that from this colour image if I want to extract the regions which are near to red, then I get all those red components as extracted in this right edge for all other points where in the colour is away from red, you find that they have got a gray shade. Now, for this kind of application, instead of considering all the colours of interest lying

within the cube, we can also consider all the colours to be lying within a sphere centered at location a_1 a_2 and a_3.

So here, it is neglect neglects to say that a the vector centered location a_1 a_2 a_3, this tells you that what is the colour of interest and the width of the cube or the radius of the sphere which ever may be the case, tells us that what is the variation from this prototype colour that we say that those colours are also of interest.

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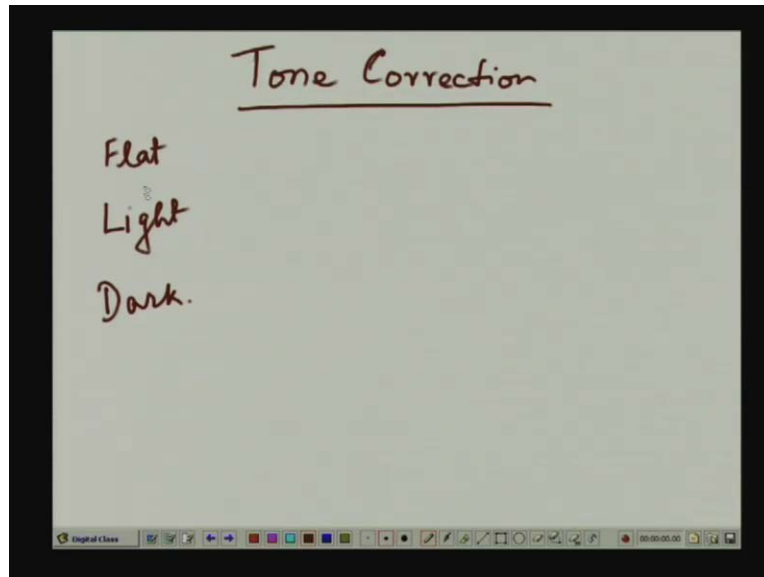
The other kind of application of this full colour image processing is say, correction of tones or tone correction. Now again, I can find on analog in intensity image, in the simple black and white intensity image where we have said that an intense an image can be low contrast, it may be an image may be dark, it may be light or bright or it may be low contrast depending upon the distribution of the intensity values.

In the same manner, for colour images, we define the tone. So, a colour image may have a flat tone, it may have a light tone or it may have a dark tone and these tones are determined by the distribution of the intensity values of different RGB components within the image.

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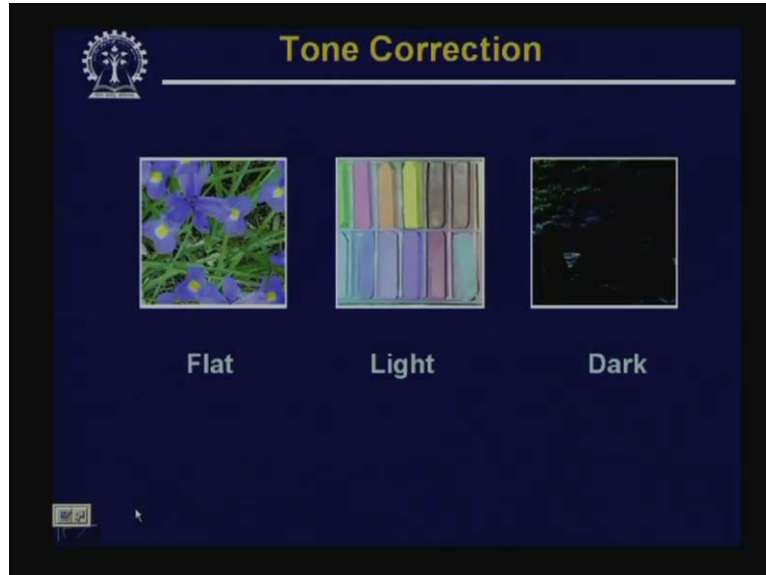
So, let us see that how these images look like incase of a colour image. So here, we find that on the left, we have shown an image which is flat in nature, in the middle we have an image which is having light tone and on the extreme right, we have an image which is having dark tone.

Now, the question is how we can correct the tone of this colour image? Again we can apply similar type of transformations as we have done in case of intensity image for contrast enhancement.

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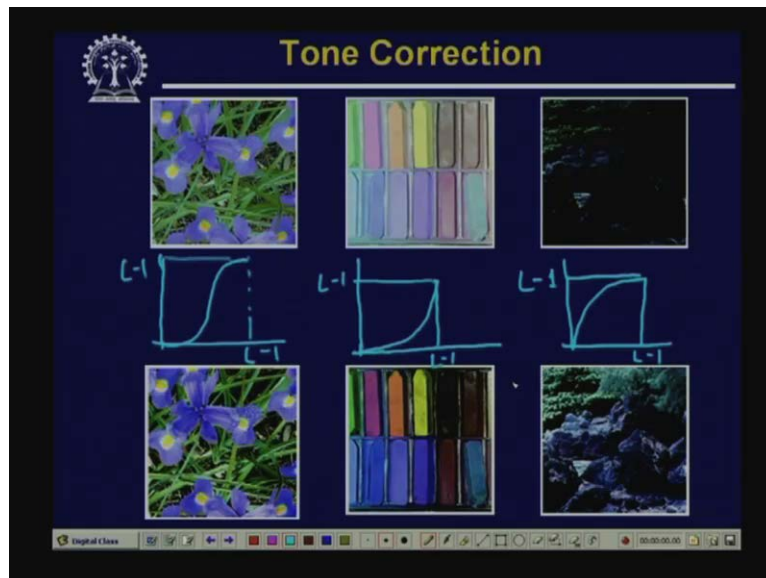
So, the kind of transformations that we can be that can be applied here is something like this. If an image is flat, the kind of transformation function that we can use for this flat image is of this form. So here, it is L minus 1, here also it is L minus 1. So, if you apply this type of transformation to all the red, green and blue components of this flat image, what we get is a corrected image.

Similarly, an image which is light whose tone is light; here also we can apply a kind of transformation. Here you find that what is needed to be done is if this image appears to be darker, then that will be a corrected image. So, the kind of transformation that we can apply is something like this; so here, it is L minus 1, here also it is L minus 1. So here, what happen is wide range of intensity values of the intensity values in the input image is mapped to a narrow range of intensity values in the output image. So, that gives you the tonal correction for an image which is light.

Similarly, for the image which is dark, the kind of transformation that can be applied here is just reverse of this. So, the transformation that will apply in this case will have this type of nature. So, here we will have L minus 1 that is the maximum intensity value, here also we have L minus 1 that is the maximum intensity value.

So here, the kind of operation that we are doing is a narrow range of intensities in the input image is matched to a wide range of intensities in the output image. So, by applying these type of transformations, we can even go for tonal correction of the colour images. Of course, the other kind of transformation that is histogram based processing can also be applied for colour images as well where the histogram equalization or histogram matching kind of techniques can be applied on different planes and different colour planes - red, green and blue colour planes of the input colour image and of course in such cases, in many cases, it is necessary that after the processing, the processed image that you get that needs to be balanced in terms of colours.

So, all this different colour image processing techniques that we have discussed till now, you find that they are equivalent to point processing techniques that we have discussed in connection with our intensity images or black and white images. Now, in case of our intensity image, we have also discussed another kind of processing technique that is the neighborhood processing technique.

Similar neighborhood processing technique can also be applied in case of colour images where for processing an image, it is not only the colour at a particular intensity location that we will consider but we also consider the colours at the neighboring intensity values.

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So, we will talk about 2 such processing operations. The first one that we will consider in this category is smoothing operation. So, for this smoothing, what we have is that in a smooth image, the colour component c (x, y) c bar (x, y) will be given by 1 over K summation of c (x, y) where this c (x, y), this is actually a vector having 3 components in RGB space, this will be red, green and blue components and this averaging has to be done for all (x, y), for all locations (x, y) which is in the neighborhood of point (x, y).

So here, I can simply do this operation in a plane vice manner where we can write that c bar (x, y) is nothing but 1 over k into summation R (x, y) for all (x, y) within the neighborhood of $N_{x, y}$. Similarly, 1 upon k summation of G (x, y), again for all (x, y) within the neighborhood of $N_{x, y}$ and 1 over k summation of B (x, y) for again this summation is carried out over the same neighborhood of (x, y) and these vectors, the average of these vectors gives us what is call the smooth image.

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So, the smoothed image in this particular case, you find that on the left hand side, we have the original colour image and on the right hand side, we have the smoothed image where this smoothing is ==carried over== carried over a neighborhood size of 5 by 5.

So, as we done the smoothing operation, in the same manner, we can also go for sharpening operation and we have discussed in connection with our intensity images that an image can be sharpened by using second order derivative operators like Laplacian operator. So here, again, if I apply the Laplacian operator on all 3 planes - the red plane, green plane and blue plane separately and then combine those results, what I get is a sharpened image.
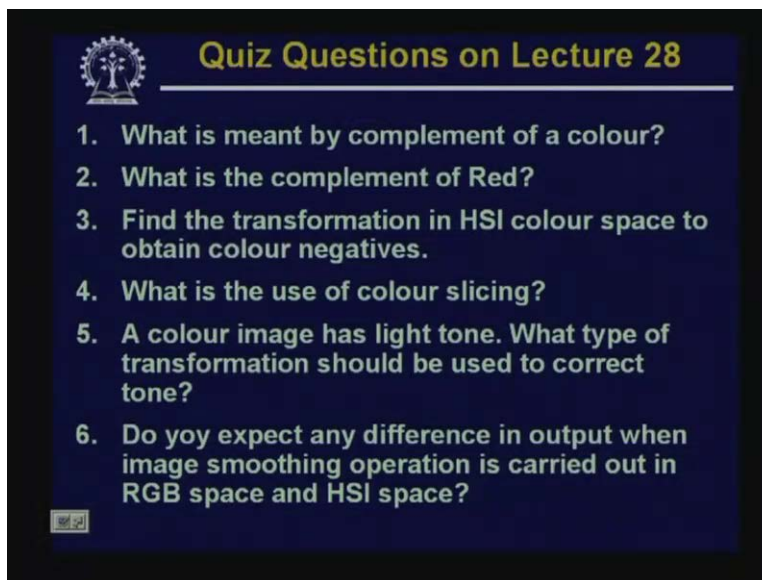
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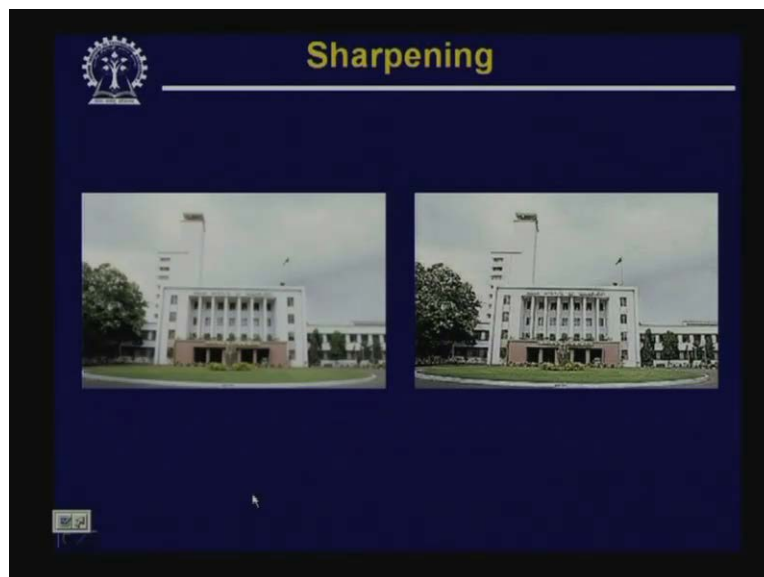
So, by applying that kind of sharpening operation, a sharpened image can appear something like this. So here, on left hand side we have shown the original image and on the right hand side, you find that the image is much sharper than the image on the left.

Now, when you come for these neighborhood operations like image smoothing or image sharpening, the type of operations that we have discussed is park colour plane operations. That is every individual colour plane is operated individually and then those processed colour planes are combined to give you the colored process image.

Now, as we said, the same operation can also be done by considering the vectors. Or if I do the same operation in the HSI colour plane where we can modify only the intensity component keeping the H and S components unchanged; in such cases, the results that you obtain in the RGB plane and the result that you obtain in case of HSI plane may be different and I give you as an exercise to find out why this difference should come. So, with this we finish our discussion on colour image processing.

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Now, let us see some of the questions on today's lecture. The first question is what is meant by complement of a colour? The second question is what is the complement of red? Third question, find the transformation in HSI colour space to obtain colour negatives? Fourth question, what is the use of colour slicing? Fifth question, a colour image has light tone, what type of transformation should be used to correct the tone? Sixth question, do you expect any difference in output when image smoothing operation is carried out in RGB space and HSI space?

Thank you.