Computer Vision and Image Processing- Fundamentals and Applications
Professor: DR. M. K. Bhuyan
Department of Electronics & Electrical Engineering
Indian Institute of Technology, Guwahati
Lecture - 18
Color Image Processing

Welcome to NPTEL MOOCs course on Computer Vision and Image Processing: Fundamentals and Applications. In my last class I discussed about the concept of image filtering in spatial domain and in frequency domain. Today I am going to discuss one or two applications of image filtering. So, one application is the background estimation. So by using the low pass filtering and the high pass filtering I can roughly estimate the background in the program.

The another application I am going to discuss is approximation of reflectance model. That concept already I have discussed in my discussion of homomorphic filtering. In homomorphic filtering, I can separate the illumination component and the reflectance component. And for the illumination component what I can do, the intensity range compression I can do for the illumination component.

And for the reflectance component I can do image enhancement. So, that concept again I am going to explain, the homomorphic filtering. And finally, I am discussing the concept of template matching, so how to do the template matching in an image. So, let us see these applications first and after this I will discussed the concept of color image processing.

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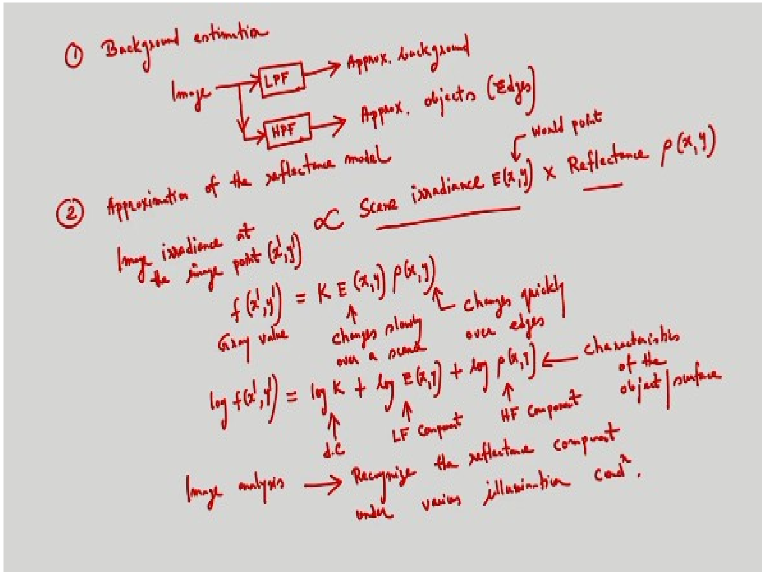

The first application I can show you, the background estimation. So, in the background estimation what I can do, suppose I have the image and I can apply the low pass filter or I can apply the high pass filter. So, if I apply the low pass filter, then I will be getting the approximate, this approx background I will be getting. And this high frequency component, the high pass filter, I will be getting the approximate objects. Like the edges I will be getting. So, you can see this is a very simple technique.

So, from the input image I can apply the low pass filter and the high pass filter, I can get the approximate background and also I can get the approximate objects like the edges. So, this is a very simple application. The another application I can show you. So, already I have discussed in homomorphic filtering, that is in homomorphic filtering what we have done. So simultaneously we are doing the intensity range compression plus the contrast enhancement, contrast enhancement for the reflectance component and intensity range compression for the illumination component, that is the irradiance.

So, second application I want to show you the approximation of the reflectance model. So, already you know that image irradiance, suppose at a particular point, at the image point x dash, y dash. So, I am considering the image irradiance at the image point x dash, y dash, and that is proportional to scene irradiance, that is the illumination, scene irradiance that is suppose E x, y.

Then in this case this x, y point, that is suppose the world point, into I have to consider the reflectance component, reflectance is suppose I can consider rho x, y that is the albedo mainly.

So, in this case for a scene irradiance, I have to consider sum of contributions from all illumination sources and what is the reflectance? Reflectance means the portion of the irradiance which is reflected towards the observer or the camera. So, that means mathematically I can write this expression, the first one is the x dash, y dash that is the image, I have the image. Then in this case this is the gray value actually, this gray value is equal to, I can put a constant, the constant is suppose K and E x, y, rho x, y I can consider.

Now, in this case already I discussed in homomorphic filtering, this E, this component, changes very slowly over the scene, that is the irradiance changes slowly over a scene. And if I considered a reflectance component, it changes quickly, it changes quickly over edges, this is mainly due to varying phase angles, changes very quickly over edges due to varying phase angles.

So, I have two components, one is the irradiance another one is the reflectance. And I can apply the log operation, the log operation in log f x dash, y dash. The objective is to convert the multiplication into addition, the summation, log K plus log E x, y and plus log rho x, y, this component. So, in this case if you see this log K is nothing but a dc component, the K is constant so it is dc. Log E x, y, that is the low frequency component. And in this case the log, rho x, y, that is the reflectance property of the object in the world.

So, then it is the high frequency component, so I can consider as a high frequency component, high frequency component this is nothing but the log rho x, y that is the actually the characteristics of the object, the surface characteristics, or you can consider as characteristics of the surface.

So, in this case you can see by applying the filtering technique, I can remove the dc component, also I can remove the low frequency component. So, my high frequency component is the reflectance component, that is the reflectance property of the object in the world. So, that is the characteristics of the object.

So, in case of the image analysis, the image analysis means, image analysis is nothing but recognize the reflectance, reflectance component under various illumination conditions. So, you can see what is the image analysis, image analysis means, recognizing the reflectance component under different illumination conditions.

So, you can see the application of the filtering because by using the low pass filter, I can remove the dc component and also I can remove the E x, y component. that is the irradiance I can remove, and my reflectance component is the high frequency component that I can observe.

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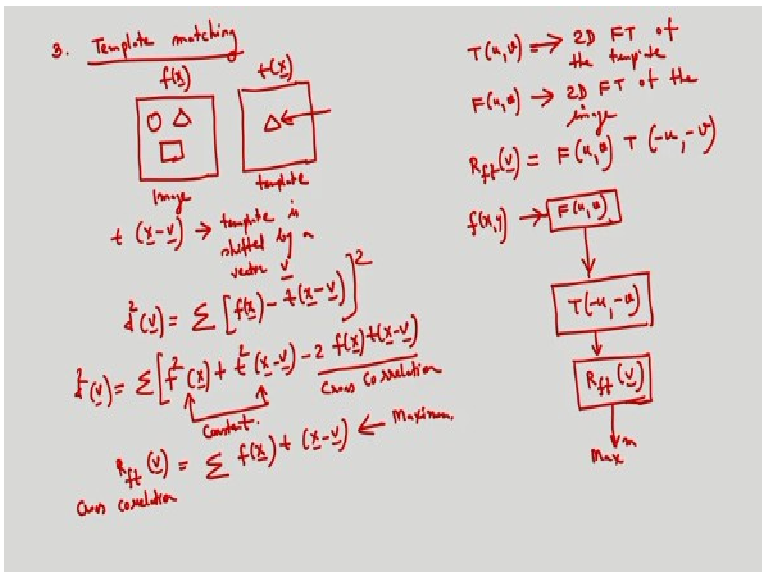

The third application I can show you, that is the template matching. So, concept I am going to explain. So, suppose I have one image, the image is f x suppose, and I have some objects in the image, this is my image. And suppose I have a template, I have a template image, the template image is suppose t x. So, the template is suppose like this, so this is a template.

So, what is the objective of the template matching? Detecting a particular feature in the image. That means, in this case, in the template I have shown one object, I want to detect whether that particular object is present in the image or not. In the image I have many objects, but in that template I am considering the object, one object I am considering. So, whether that particular object is available in the image or not, I want to determine. And that is the template matching.

So, for this what I have to do, template is moved over the image, and in this case I have to do the overlapping. At a particular point, suppose this template is matching with the particular object, then in this case maximum overlap I have to find. So, for this I have to do the shifting of the template.

So, template is shifted by a vector, suppose v, the template is shifted by vector v. So, after this what I have to determine, suppose I am determining one measure, that is the distance measure I am considering summation, that is for all the image points I am doing the summation, f x minus t, x minus v, so I am finding the distance.

So, the distance will be minimum when the template exactly matches with the object present in the image. So, that is why I am considering the distance vector and I am doing the summation for all the image points. This principle is using the motion estimation, that is if I want to determine, suppose one object is moving in a frame in a video, so I can estimate the motion by considering this technique, that is the template matching technique.

So, now this expression can be expanded, f square x plus t square x minus v minus twice fx t x minus v, so just I am expanding this one. So, in this case if you see these and these two terms, these are constant terms, this is a constant term. So, and if you see this, this is nothing but the cross correlation. So, this is nothing but the cross correlation.

So, the cross correlation I can write like this, the cross correlation between the image and the template is equal to, I am considering sum of the distances, all the distances, fx t. So this is the cross correlation, and this will be maximum, this will be maximum when the template matches with the object in the image.

In continuous domain if I consider this expression, then in this case the summation will be replaced by integration. Now, this in the Fourier test from suppose, the T u v I am considering, the T u v is the 2D Fourier Transform, this is a 2D Fourier Transform of the template. And also I am considering F u v is the Fourier Transform of the image, the 2D Fourier Transform of the image.

Then in this case I can express the cross correlation like this, the cross correlation in the frequency domain will be multiplication, the multiplication between F u v, that is the 2D Fourier

Transform of the image into the template, template is minus u minus v, this template is shifted. So, this is the cross correlation in the frequency domain, that is the multiplication between F u v and that T u v.

Now, what will be the block diagram for this template matching? So, my input image is f x y, I can determine the 2D Fourier Transform of this image. So, this is I can determine F u v I can determine. This F u v is multiplied with the template, the template is T minus u minus v, it is multiplied.

And from this I can determine the cross correlation I can determine, the R ft and v I can determine, the cross correlation I can determine. And in this case I have to find, I have to find the maximum value of R ft, maximum value I have to find. Determine at which point the R ft will be maximum, so that I can determine. So, this is the fundamental concept of the template matching.

So, up till now, I discussed about the concept of image filtering and the applications. One is the background estimation, one is the approximation of the reflectance component and one is the template matching. Now, I will discuss the concept of color image processing.

So, in case of the color image processing, I have two types of processing. So, one is full color processing and another one is pseudo color processing. In case of the full color processing, I can process a color image just like a grayscale image, in color image I can consider a pixel, a pixel is a vector pixel, because I have to consider the R value, G value, and blue value, these are the primary colors.

So, vector pixel I can consider and I can do the processing. So, I can give some examples, I can do the image enhancement for the color image, I can remove noises in the color image. So, like this I can do all the processing in the color image.

The second one is the pseudo color processing; pseudo means the false color. So, for some applications for better visualization, I can convert the grayscale image into color images. I can apply some transformation, so that the monochromatic images can be converted into color image. Now, in case of the color image processing, I can consider two process, one is the marginal processing, another one is the vector processing.

In case of the marginal processing, I can consider the R channel, G channel, blue channel separately, and I can do the processing for the R component, G component and the blue component separately, this is called the marginal processing. But in another case that is a vector processing I can consider RGB together, that is the vector pixel and I can do the processing for this pixel, that is the RGB pixel. So, one is marginal processing, another one is vector processing.

So, today I am going to discuss about this concept, one is the full color processing, another one is a pseudo color processing, and after this I will discussed some color models like color models like RGB color models, CMY color models, so these color models I am going to discuss now.

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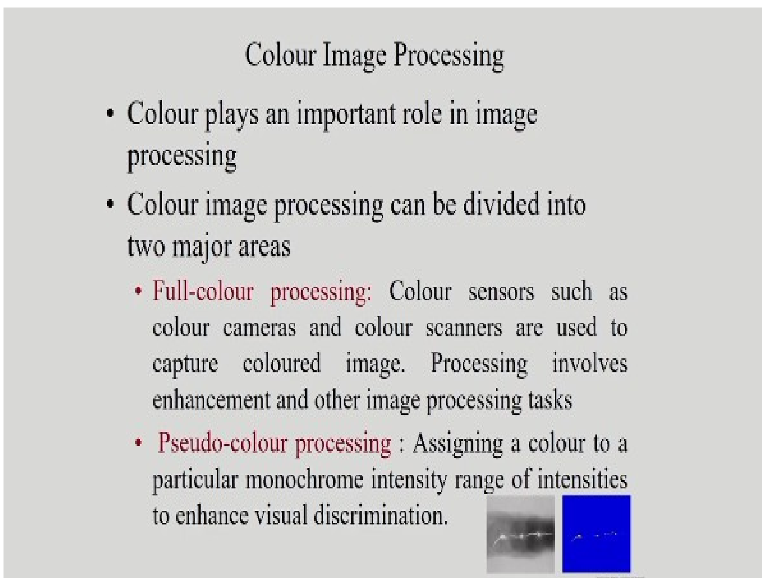

So, you can see here I have two types of processing, one is the full color processing. So, already I have explained about the full color processing. And pseudo color means the false color processing, so that is assigning a color to a particular monochrome intensity range of intensity, that is to enhance visual discrimination.

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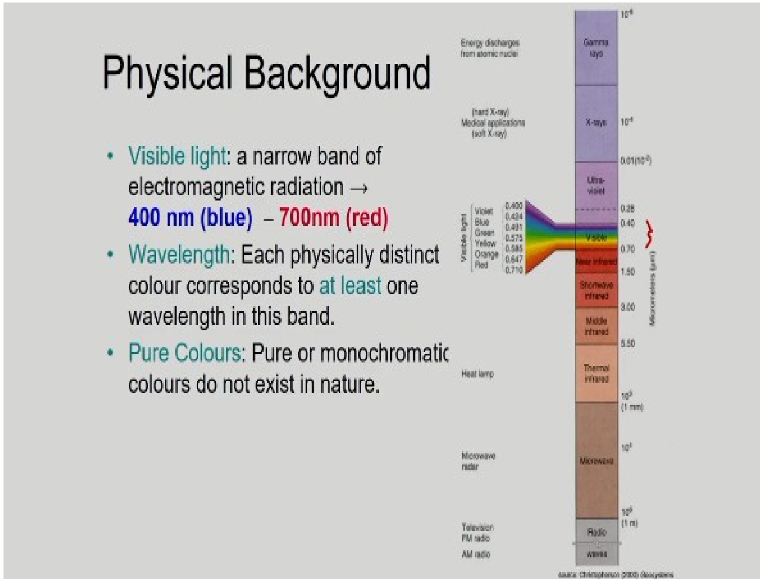

And in this case I have shown the electromagnetic spectrum and corresponding to the visible light you can see the wavelength is from 400 nanometers to 700 nanometers, 400 nanometer corresponds to blue color and 700 nanometer corresponds to red color. So, you can see the visible spectrum, that is the visible range of the spectrum, that is from 400 to 700 nanometers.

The particular color corresponds to at least one wavelength in this band. So, if I consider suppose blue color corresponding to a blue color, a particular wavelength I have to consider, the wavelength to corresponding to the blue color. And one important point is the pure or the monochromatic colors do not exist in nature. The pure color, it is very difficult to get pure colors, corresponding to only particular wavelength, that is very difficult to get.

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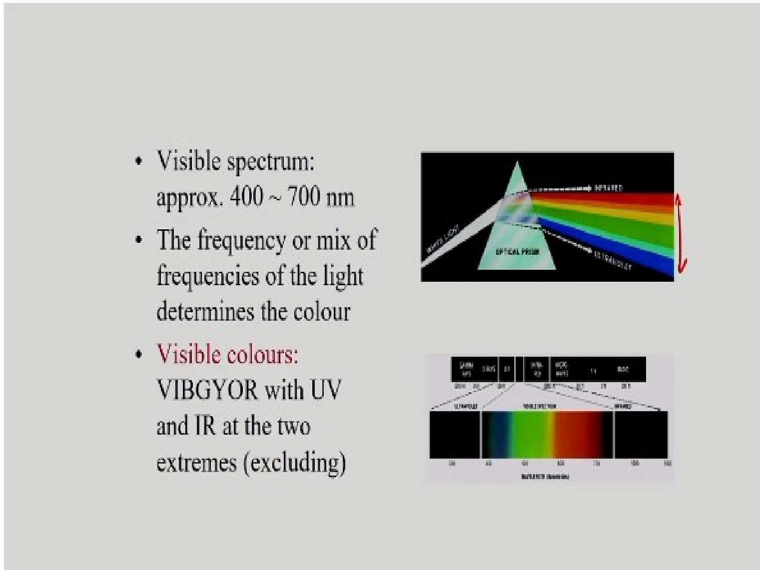

In this case also I am showing the visible spectrum, the spectrum is from 400 to 700 nanometers. And you can see all the colors, you can see all the colors in the spectrum. And in this case, if I consider a particular color, that means the frequency or mix of frequencies of the light determines a particular color. So, that is you can see here in the spectrum.

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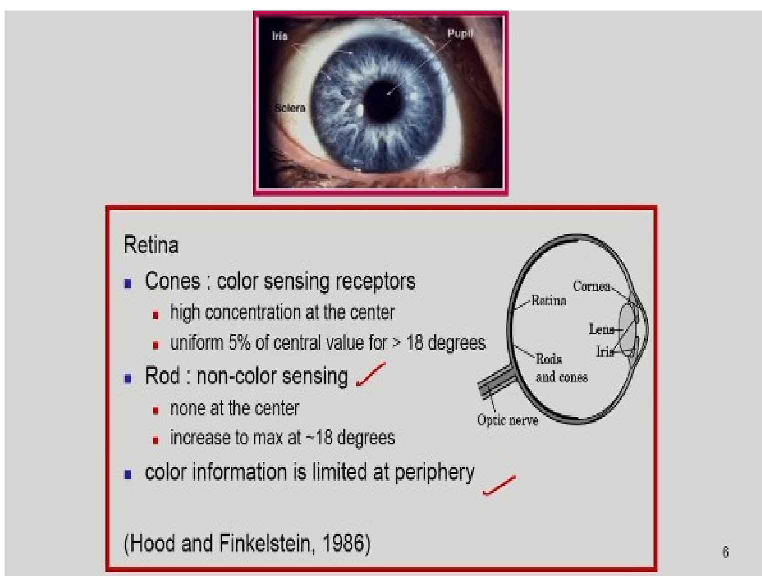

And let us see the structure of the human eye. So, if you see the retina in human eye, so retina has two types of photoreceptors that converts the light photon into electrical signal. So, we have photoreceptors and two types of photoreceptors, one is called a rod and another one is called cones. Rods are non-color sensing receptors and the cones are color sensing receptors, that means the concert responsible for color vision and rods responsible for the monochromatic vision.

And if you see the distribution of these cones and the rods, you can see here, so for cones high concentration at the center, that is for the cones. And if I consider the rods, none at the center and it increases to maximum at 18 degrees, that you can see the distribution of the rods and cones. And the color information is limited at periphery. So, this is the roughly the structure of the human eye, you can see the lens, but here I am only discussing the concept of the rods and the cones, mainly the retina.

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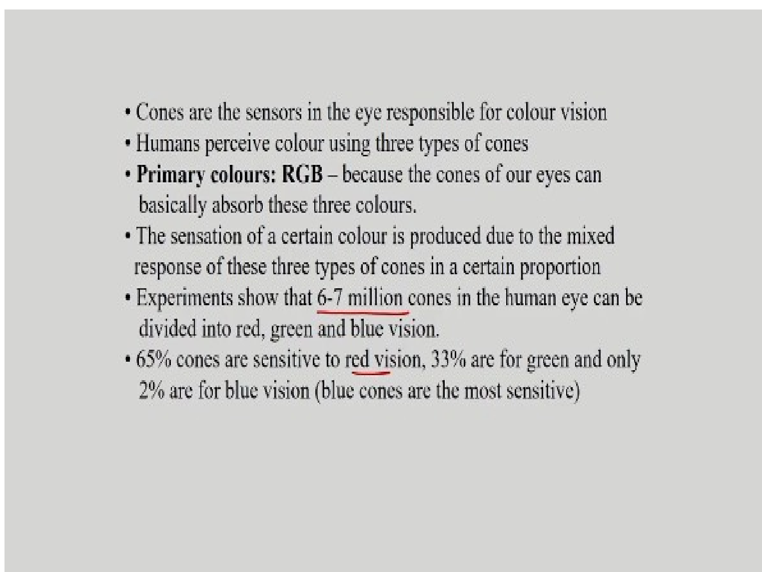

So, in the cones, we have three types of photoreceptors, one is R, one is G and other one is B, a red, green and blue, these are the primary colors. So cones are responsible for color visions. And in human eye we have three types of cones, that is R, G and B. And what about another colors? Suppose, if I consider another color that means the sensation of a certain color is produced due to the mix response of these primary cones in certain proportion. What are the primary cones? The primary cones are R, G, B.

So in human eye we have 6 to 7 million cones in human eye, and that is divided into red, green and blue cons for this red vision, green vision and the blue vision. And you can see 65 percent cones sensitive to red vision, 33 percents are responsible for the green vision and only 2 percent for the blue visions. So that is why the blue cones are most sensitive.

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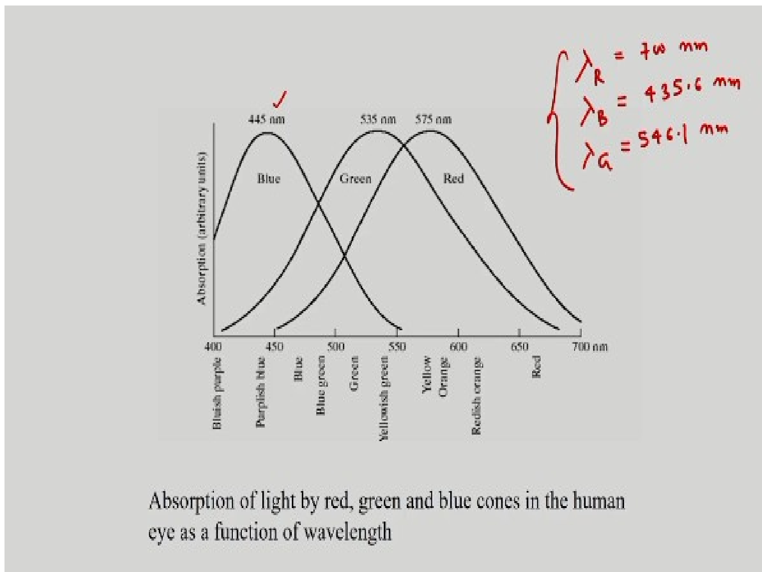

And in this figure you can see the absorption of light by red, green and the blue cones in human eye as a function of wavelength. So corresponding to blue, you can see the wavelength that is 445 nanometers, corresponding to green this is 535 nanometers and corresponding to that is red these 575 nanometers, the standard wavelength for the red color is 700 nanometers and corresponding to blue color the standard is 45.6 nanometers the wavelength and corresponding to green the wavelength is 546.1 nanometer wavelength.

These are the standard wavelength corresponding to R component, G component and the blue component. This is the color mainly, but in this figure I am showing only the response of the cones, the red cones, blue cones and the green cones.

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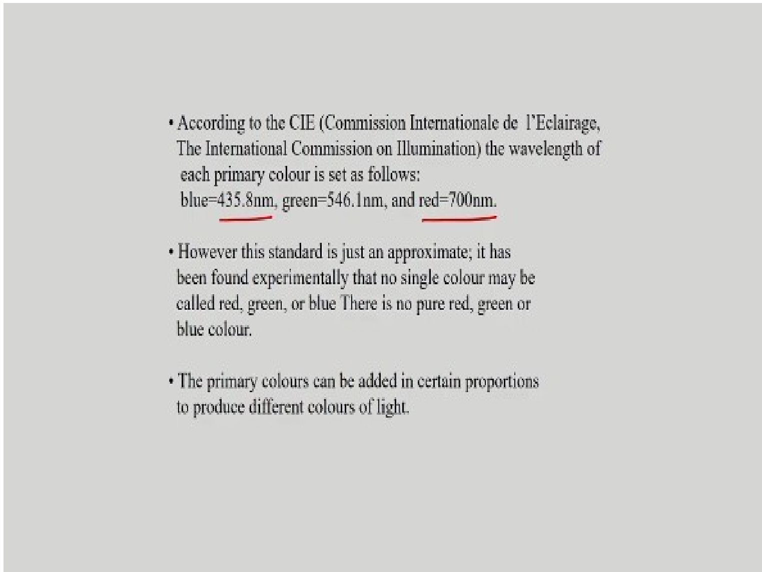

So, according to the International Commission on Illumination, the wavelength corresponding to the blue is 435.8 nanometers, green is 546.1 nanometers and red is 700 nanometers. And the primary colors can be added in certain proportion to produce different colors of light.

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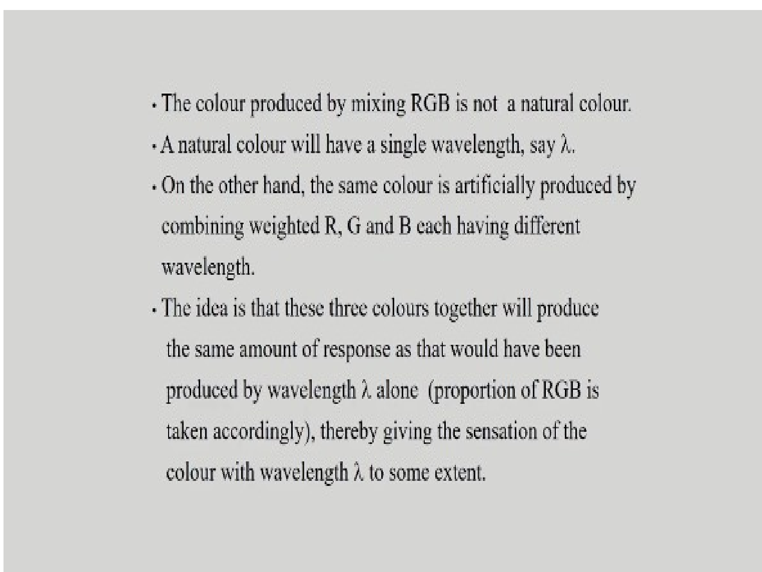

And in this case, the color produced by mixing RGB is not a natural color. So, for a natural color, we have only single wavelength, that wavelength is lambda. But in this case, if I considered the same color is artificially produced by combining the weighted R, G and B is having different wavelength. That any color we can produce artificially by combining R component, G component and blue component. And in this case, the color produced by mixing RGB is not a natural color, because for a natural color we have only single wavelength.

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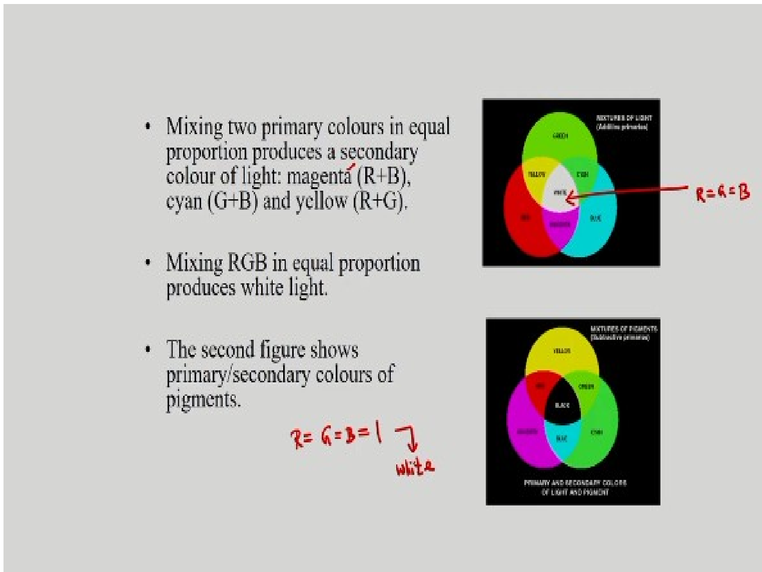

And in this case, I am showing these cases. So, mixing two primary colors in equal proportion produce secondary colors. So, you can see I am combining R plus B I am getting magenta, in equal proportion I am combining G plus B I am getting cyan, I am combining R plus G in equal proportion, so I am getting yellow. So, this magenta, cyan and the yellow, these are the secondary colors. And if I combine suppose in equal proportion R is equal to G is equal to B is equal to 1, that corresponds to the white color, the white light.

So, in these figures you can see that is the primary colors and the secondary colors. So, corresponding to this white than R is equal to G is equal to B in equal proportion I am doing. And you can see the black color also in the second figure, so in these two figures I have shown the primary colors and the secondary colors.

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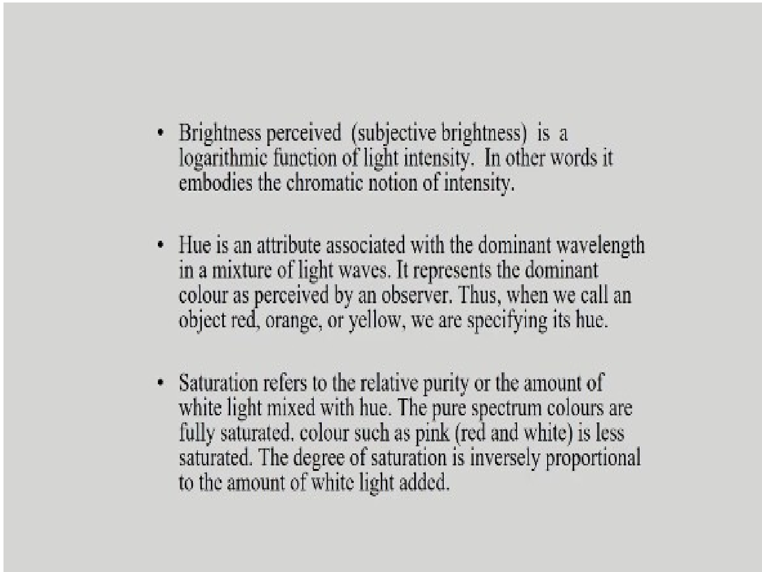

Now, in this case, in case of the color, color has mainly three components, one is the brightness, another one is hue, another one is saturation. So, brightness means, it is the intensity, the light intensity, that is the logarithmic function of light intensity. And hue means a particular color, that means it is associated with the dominant wavelength in a mixture of light waves. And saturation means the relative purity or the amount of white light mixed with a particular color that is the saturation.

So, you can see the light I can consider as one property is the brightness, one is the hue, hue means the color corresponding to a particular wavelength, and saturation means the purity of the color, that is the relative purity or the amount of white light mixed with a particular color.

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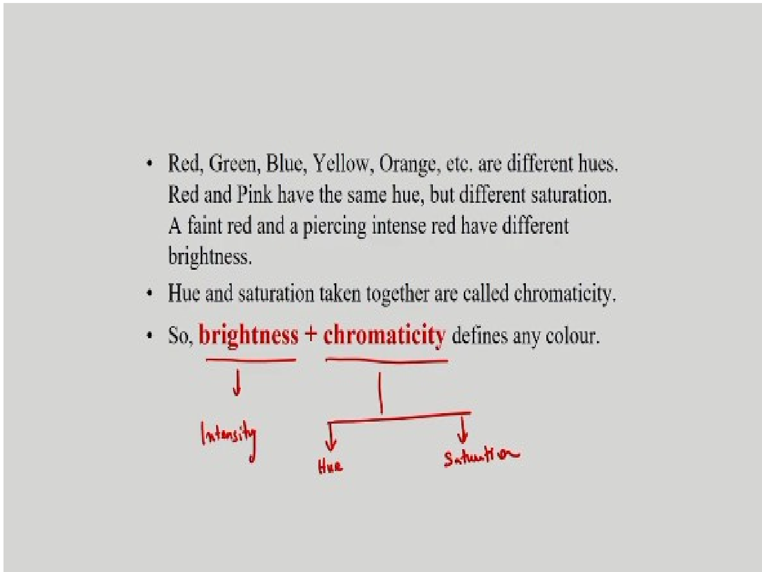

So, that means I can consider color as like this. So, brightness is one component, another one is the chromaticity. Brightness means the intensity. And chromaticity has two components, one is hue, another one is saturation. Hue means the color and saturation means the purity of the color. So, color is defined like this, one is the brightness, that is the intensity, brightness means intensity and the chromaticity, so this is the definition of color.

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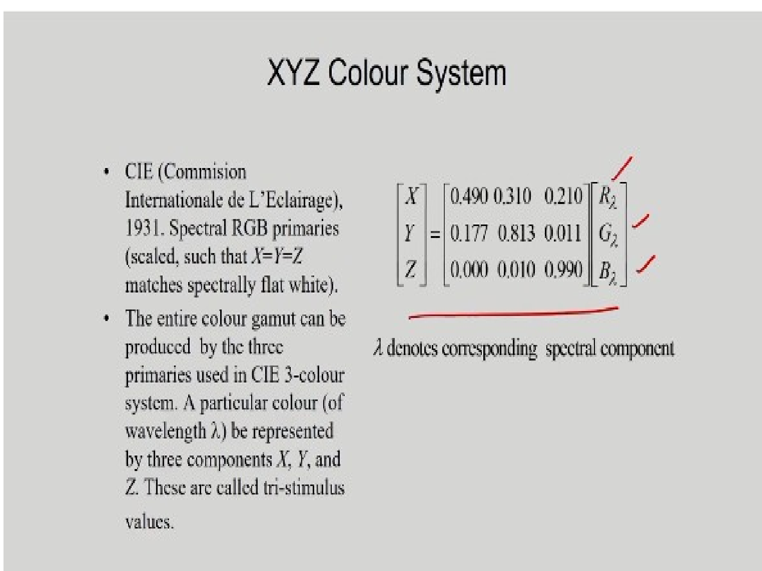

Now, I will discuss some color models. The first color model is X, Y, Z color model, you can see that this matrix, this is experimentally found, that is that the CIE means the International Commission on Illumination. And in this case, the entire color gamut can be produced by three prime primaries.

That is I am considering the R, G and B, corresponding to the wavelength I am considering R lambda, G lambda, B lambda and corresponding to this you can get X, Y, Z, this X, Y, Z is called the tri-stimulus values. So, from this equation you can determine X value, Y value, and Z value. So, by using X, Y, Z you can represent a particular color.

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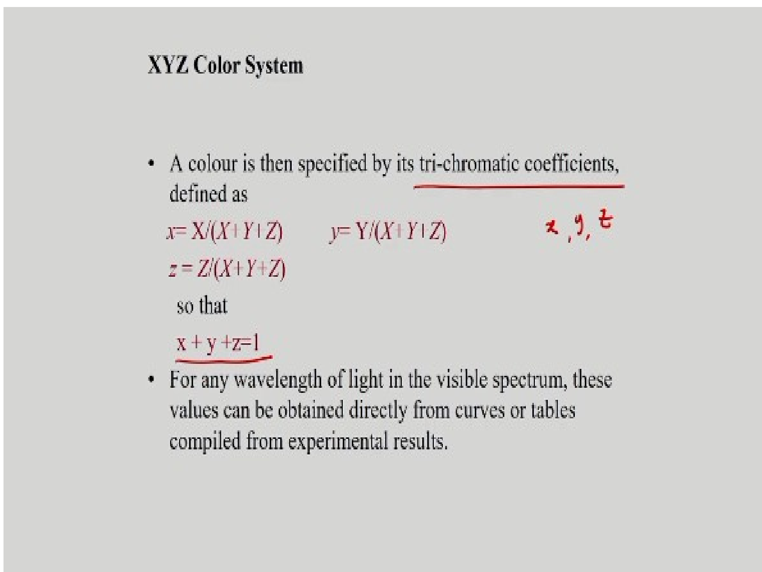

This X, Y, Z can be normalized and I am getting the tri-chromatic coefficients. So, I am getting the tri-chromatic coefficients, the coefficients are a small x, small y and small z. That means the capital X, capital Y capital Z that is normalize and I am getting x, y, z. So, by using X, Y, Z I can represent colors.

And in this case, after normalization x plus y plus z is equal to 1. So, I have this expression that is corresponding to X, Y, Z color system. And for any wavelength of light in the visible spectrum these values can be obtained directly from the curves or tables that is compiled from experimental results.

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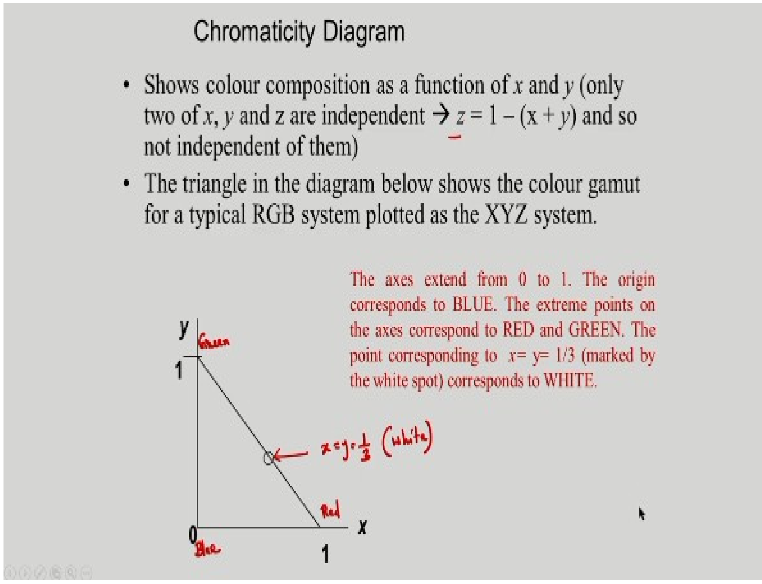

And in this case, based on this x, y, z color system, I can draw a chromaticity diagram suppose, if I consider z is the dependent variable and if I write like this z is equal to 1 - x + y, then in this case in terms of x and y, I can determine z. So, based on this information, I can draw the chromaticity diagram.

So, in this case, you can see I have the axis extent from 0 to 1. This origin corresponds to the blue. I have two extreme points, one is the red, red is the extreme point, and another one is the green. And corresponding to this point, the x is equal to y is equal to 1 by 3 and that corresponds to white color, this point.

So, you can see how to get the chromaticity diagram from the x, y, z color model, the x, y, z system. So, you can see the origin corresponds to the blue color. I have two extremes, one is the red color another one is the green color, the white point is x is equal to y is equal to 1 by 3. So, that means, by using x y and z information I can represents color.

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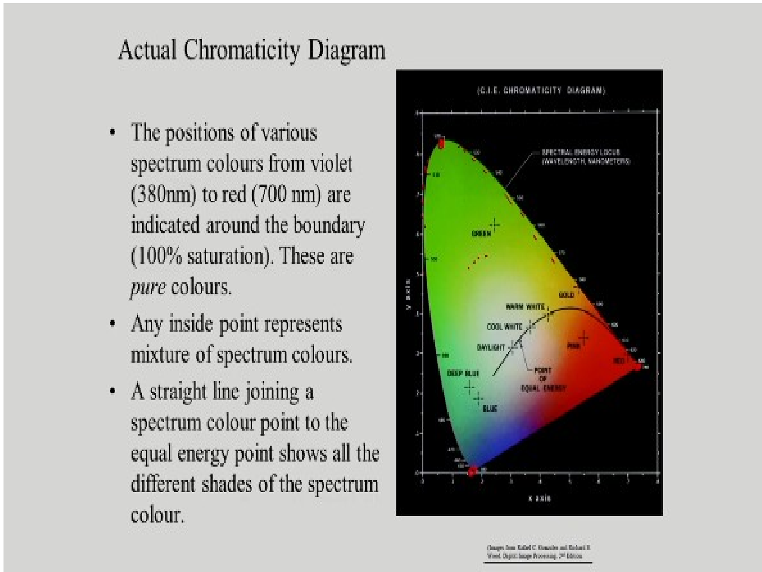

And in this case, this is the actual chromaticity diagram you can see here, so you can see the blue color, this is the blue point, another point is the red point and this point is the green point. And in this case, you can see that violet corresponds to 380 nanometers to red is 700 nanometers. And in this case, if you see the boundary of this chromaticity diagram, these boundary colors are pure colors.

So, if you see all these boundary colors, these are the pure colors. Pure means the saturation is 1, saturation is defined like this, the purity of the color. And in this case if I consider inside these colors, so inside point represents the mixture of the spectrum colors. So my spectrum colors are RGB, that is the primary colors, and by mixing the RGB I can get other colors and you can see this chromaticity diagram. So, in the boundary I have the pure colors, so that corresponds to 100 percent saturation.

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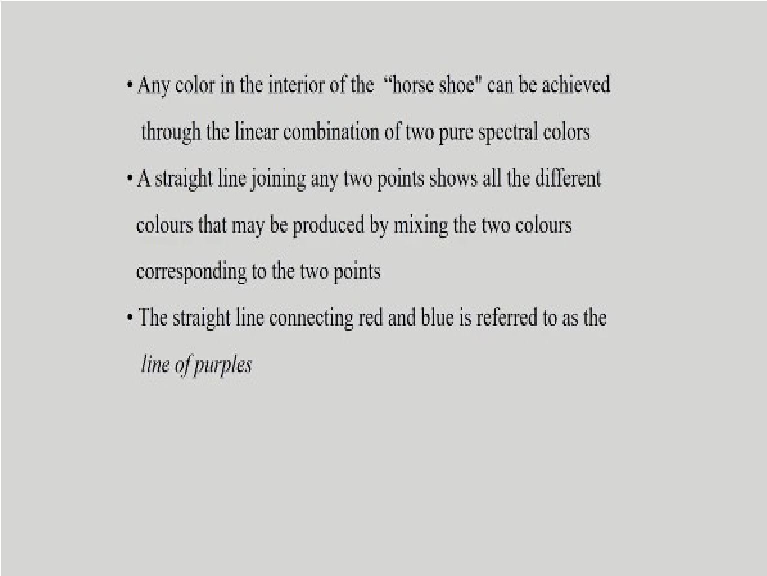

And so, you can see any color inside this the chromaticity diagram can be achieved through the linear combination of the pure spectral colors and a straight line joining any two points shows all the different colors that may be produced by mixing the two colors corresponding to the two points.

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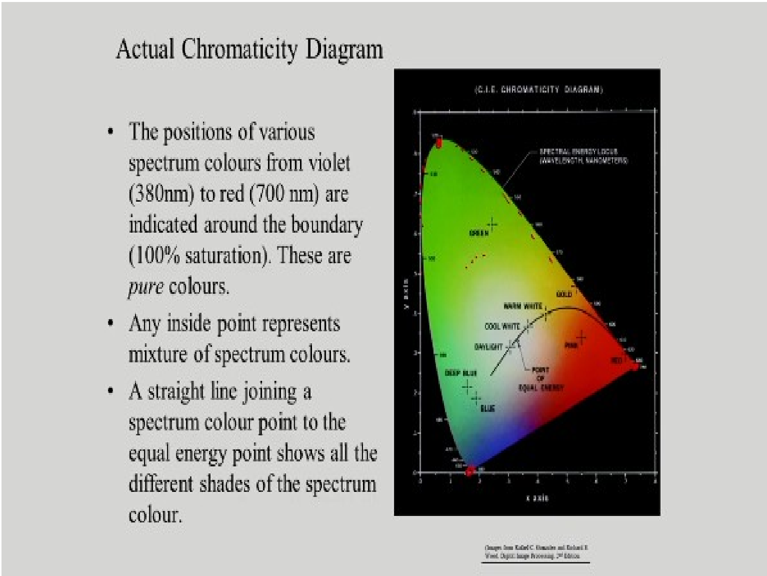

You can see the straight line here, you can see the straight line you can see and you can see how to produce the colors by mixing the colors.

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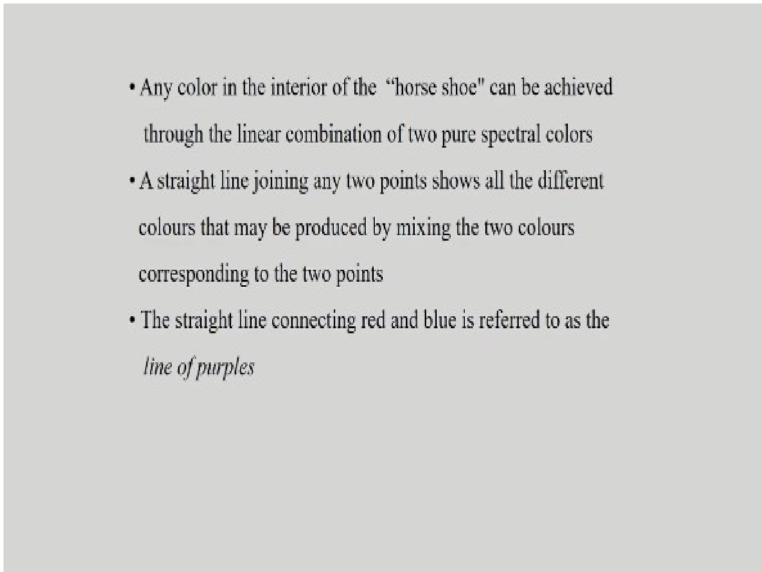

The straight line connecting red and blue is called a line of purple. So, this line, the red and the blue, this is called the line of purple, this line.

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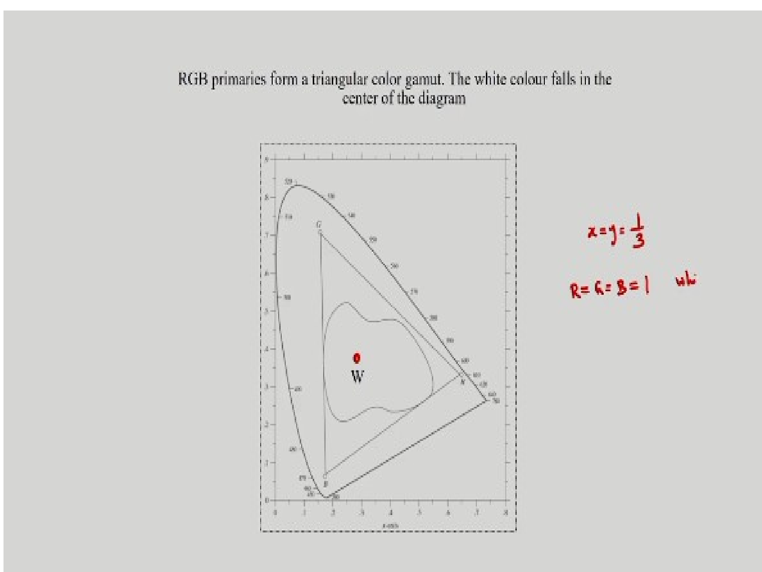

So, here again I am showing the chromaticity diagram and in between you can see this is the white point you can see, and all other points you can see. And that is the RGB primaries form a triangular color gamut, and the white color falls in the center of the diagram.

Because corresponding to white, in X, Y, Z color system what we can consider, that is x is equal to y is equal to 1 by 3. So, corresponding to this I have the white color. But if I consider the RGB color model, then in this case R is equal to G is equal to B is equal to 1, that corresponds to white.

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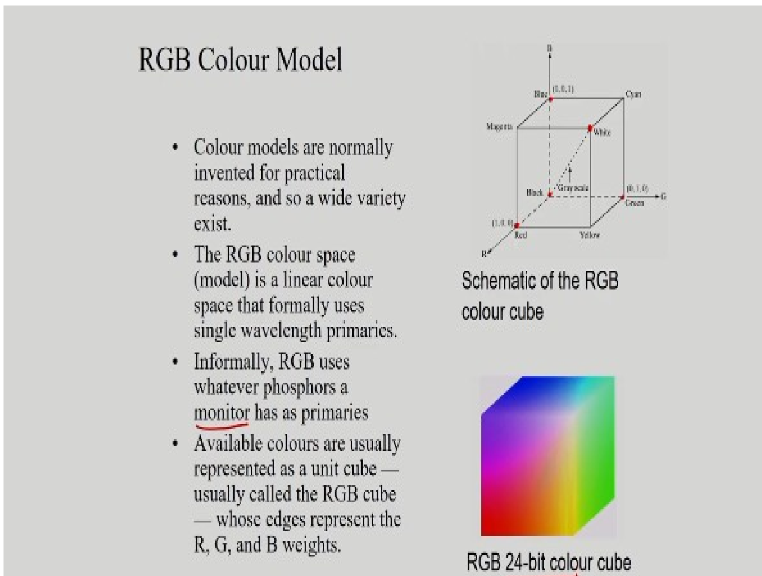

So, another model is, that is the RGB color model. So, sometimes it is called the hardware color model, because it is used the hardware devices like computer monitors, even in the camera this model is used, the RGB color model. So, in the RGB color model you can see the RGB color cube here.

So, I have mentioned all the points here, you can see this origin is the black and this point is the white point. And you can see the line joining the black and white, that is the intensity axis. So, the grayscale I have shown. And you can see all the colors, the primary colors and the secondary colors in the cube, the RGB cube, you can see this is the red point, the green point and the blue point.

So, corresponding to the red axis what is the red point? It is 100, corresponding to green it is 010, and corresponding to the blue, because it is RGB, so 001. So, that coordinates you can see in the RGB cube. And in this case, it is RGB 24 bit color cube, because why it is 24 bit color cube? Because for R component I need 8 bits, for G component I need 8 bits and for the blue component I need 8 bits. So, that is why it is RGB 24 bit color cube you can see. And all the colors, the primary colors and the secondary colors you can see here. So, this is color RGB color model or sometimes it is called a hardware color model.

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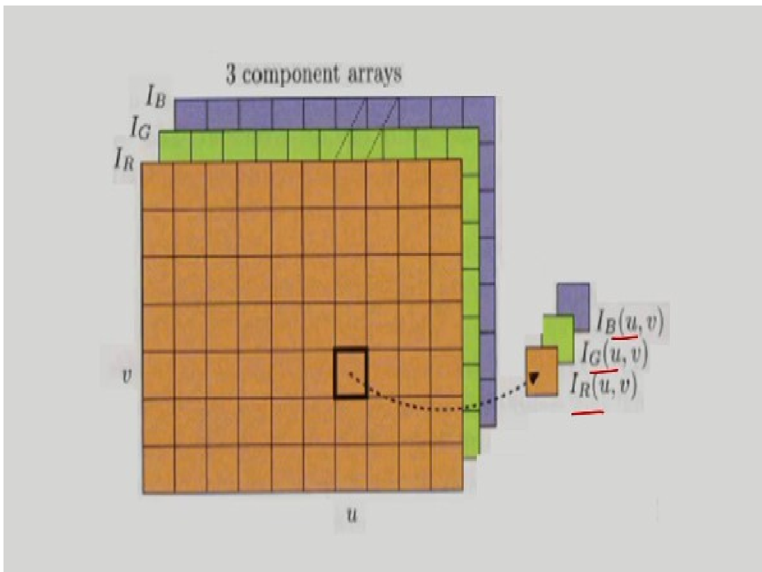

And in this case, you can see the 3 components of the colors, that is vector pixel I have shown, corresponding to a particular pixel I have the red value, the green value and the blue value. So, I have three components corresponding to a particular pixel, and that pixel is called the vector pixel.

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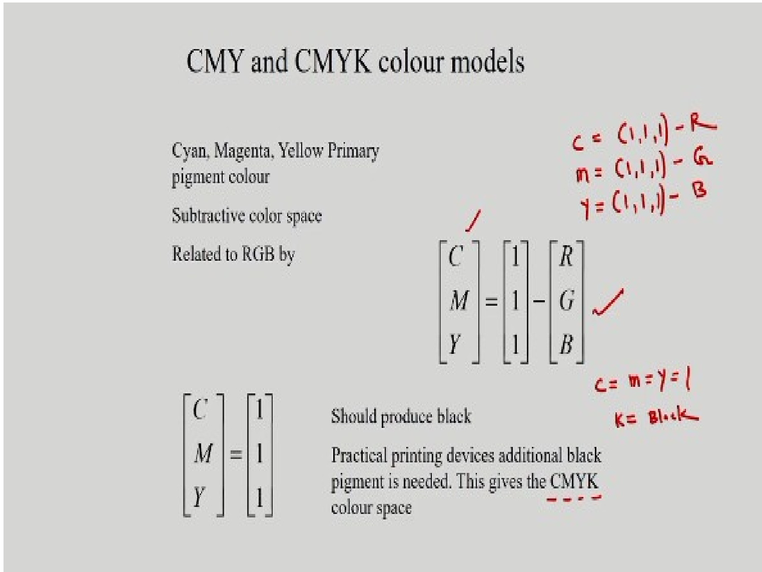

The next model is the CMY and the CMYK color models. So, that means I can get the secondary colors from the primary colors. So, how to get c color? You can see, c is nothing but c is equal to 1, 1, 1 minus R, so you can get c color. What is magenta? Magenta, you can get, 1, 1, 1 minus G, so you will get the magenta color. What is yellow? Yellow 1, 1, 1 minus B, so you will be getting the yellow colors.

So, you can see by using this expression you can get the secondary colors. The secondary colors your cyan, magenta, and the yellow. Now, in this case, if I consider suppose c is equal to m is equal to y is equal to suppose 1 equal, then it should produce the black color, but practically the black color is not obtained. If I mix in equal proportion the c is equal to m is equal to y is equal to 1, then the perfect black color is not possible, I am not getting. So, that is why extra pigment I am considering, and that is the K, the K pigment is color it is the black pigment.

So, you can see in the inkjet printers or the laser printers, I have four toners, one is the toner put a c color, one is for the magenta, one is for the yellow and k is for the black, that is a perfect black color. So, this is called a CMYK model, CMY is the secondary color and K is the black color. So, this CMYK model is used in the printing devices.

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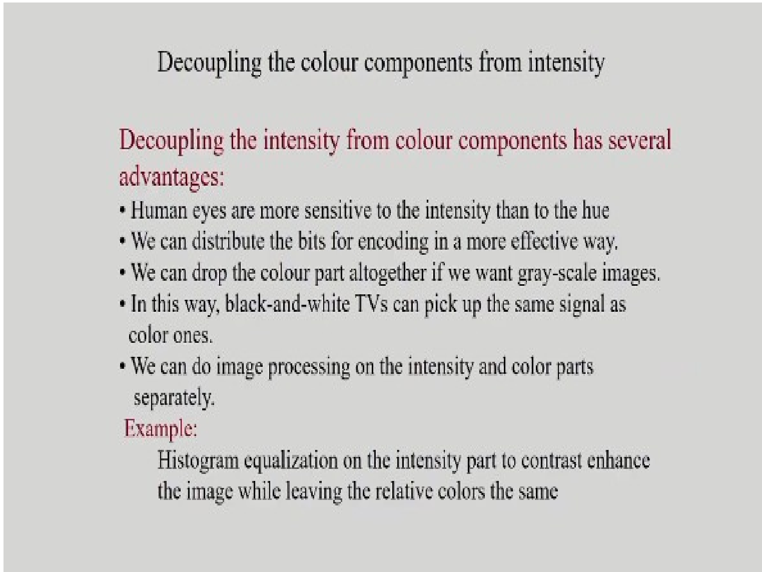

After this I will discuss one important concept, and that is decoupling the color components from the intensity information. Because the color has two components, one is the intensity component another one is the chromaticity component. Intensity means the brightness and chromaticity means it has two components, one is the hue and other one is the saturation. I can decouple the color information from the intensity information.

So, there are some advantages, the first advantage is you can see. The human eye is more sensitive to intensity variation as compared to color variation. Suppose, if I want to do image compression, the color image compression, then in this case I have to give maximum weightage or maximum preference to the intensity component as compared to color components.

So, that means, in the bit allocation strategy what I have to do, I have to allocate more number of bits for the intensity component as compared to the color components, this is for the color image composition, that is the bit allocation I have to do, more number of bits should be allocated for the intensity component as compared to the color component.

And suppose if I considered a black and white TV, transmission, then in this case only I can consider the intensity component, I can neglect the color components, that I can do. And for image processing, what I can do, the RGB can be converted into some other models like HSI color model, I will discuss later on what is this color model. So, I can decouple the color information from the intensity information and I can process the image, only the intensity component I can consider.

Suppose, if I want to apply histogram equalization technique then only I can only consider the intensity component, I can neglect the color information. Similarly, suppose I want to remove the noises in the image, then in this case I can only consider intensity component of the color image, I can neglect the color information.

So, that is why the decoupling of color information from the intensity information that is quite important. And based on this I have some color models like HSI color model, Y-Cb-Cr color model, YIQ color models. So next class I am going to discuss about these color models.

So, let me stop here today. Thank you.