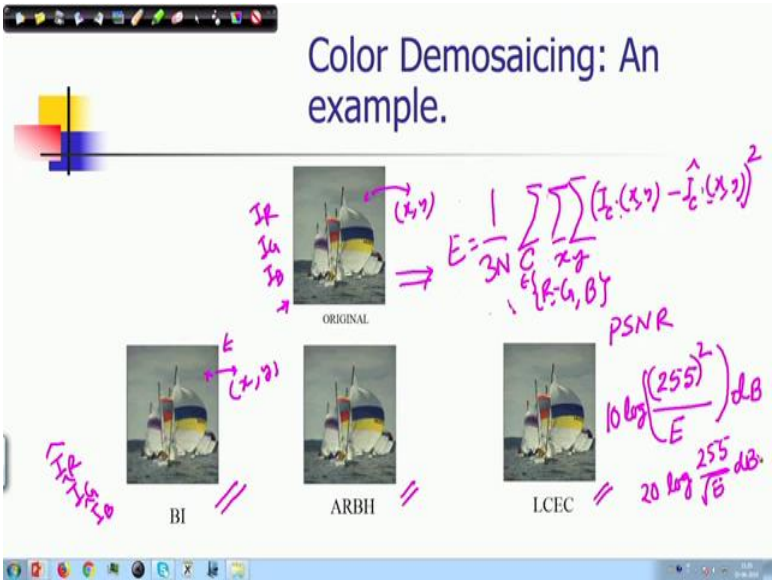
Computer Vision
Prof. Jayanta Mukhopadhyay
Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur

Lecture - 40
Color Fundamentals and Processing (Part VII)

(Refer Slide Time: 00:25)



So, we continue our discussion on color interpolation. In the last lecture, I have discussed three particular techniques of interpolation; one is bilinear technique, then averaging of red and blue hue and then Laplacian correction of edge co related technique, which in acronyms are shown here ARBH, LCEC, for the this two and the bilinear is BI.

Now, here I have shown a few examples of demosaic patterns, just to explain how this algorithm has been applied. What we did from the original color image, we have extracted the CFA image using the Bayer's pattern as I have described. So, it is a simulated here color filter array from the original image. So, you we can compare and then you carried out interpolation say you apply bilinear interpolations, then you observe this particular result and this is average of red, blue and hue and this is Laplacian corrected edge correlated techniques LCEC.

So, you can see that visually, they look almost similar though, in the close examination you may find there are some color artifacts and blurriness in some cases and there is a measure by which this quality of this techniques could be evaluated. Suppose, you

consider this image that is the reconstructed image and this is your original image. So, you have a pixel value, consider at any location, the correspondingly same location of the original. Say, this is a location say let me write this location as xy and same location xy, this image let me consider this image has three component. So, this is reconstructed image so, we have $\hat{I}_R$, $\hat{I}_G$, $\hat{I}_B$

So, these are the three color components and this is the original color image of this component. So, what we can consider; we find out the corresponding error between this color channel. So, for the red we will be doing say $(I_R(x,y) - \hat{I}_R(x,y))$. So, if I perform the square of that error that would give me the red components error and overall red components error would be, if I sum over all the x and y values, that is for red.

That is a error of the red and you compute this error for all the channels for even blue and for green and the all this channel, if I take the average which means that if there are N samples I should compute it, so, if there are three channels. So, I will be writing this expression mathematically in this way that there are three channels. So, let me put those channel C and C could be either red or green or blue and if there are N pixels.

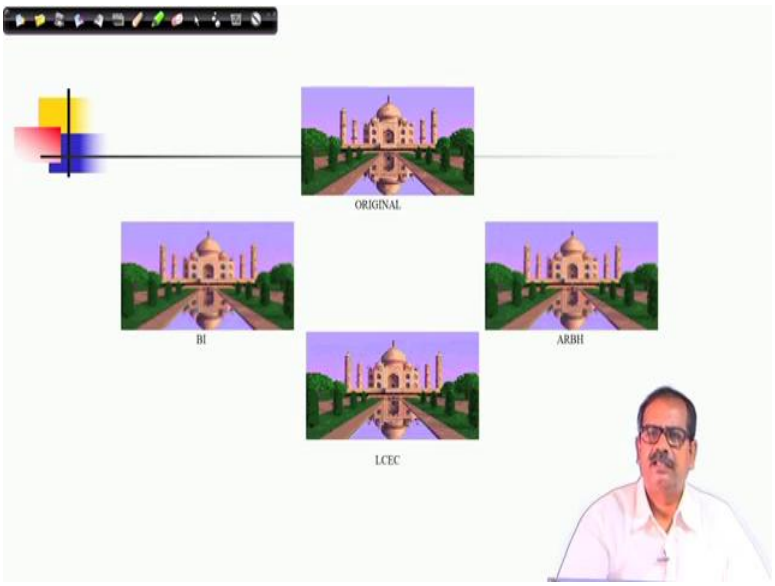
So, what I will do I will take the average of this error; that means, every sample, every instance is considered for squared deviations of the true values with the predicted value and count that many number of instances which is 3N in this case. N is the size of the image for every channel.

So, this is the error and when we define a peak signal to noise ratio, what we do? We perform the signal to noise ratio as $\frac{(255)^2}{E}$. So, this is this peak signal to noise ratio, in terms of ratio now, this value that you can see that signal strength has been taken as the constant that is the very convenient way of expressing.

It gives little, it quite inflated measure but it is very popular in image processing and then you express it in dB which is $10\log\left(\frac{255^2}{E}\right)$. When you express in this form, then in it becomes so you can see that, which means that I have to take root mean square sometimes it is written as $20\log\frac{255}{\sqrt{E}}$ dB that is ok.

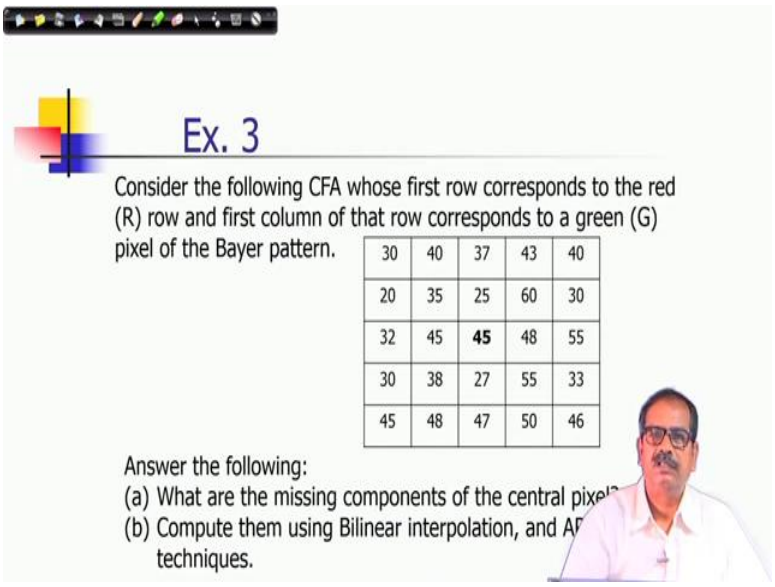
So, this is the PSNR value and you can compute this PSNR value it is not shown here in my slides and we can find that actually, LCEC will give you the highest PSNR and which shows that this LCEC technique is better than the other techniques in terms of PSNR .

(Refer Slide Time: 06:08)



This is another example of reconstruction. Once again, the same experiments have been carried out only, we have shown another example.

(Refer Slide Time: 06:19)

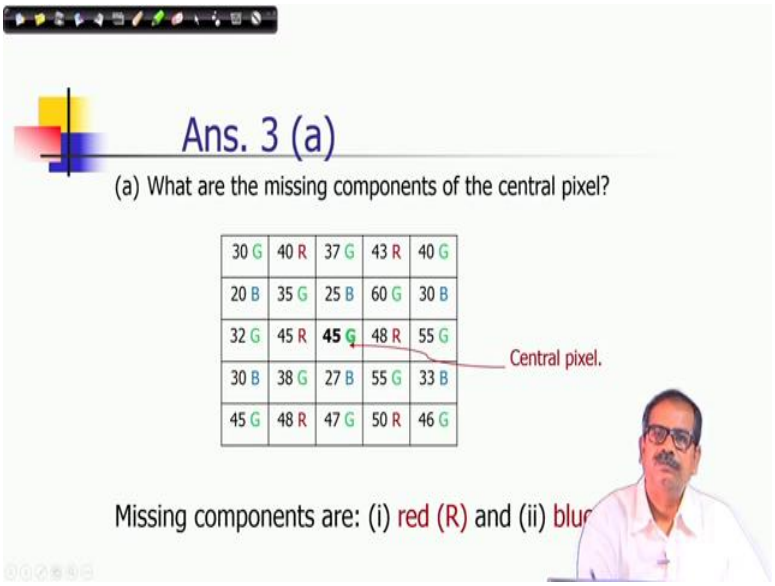


So, let me discuss one particular exercise to once again to make your understanding better for estimation of the missing spectral samples. So, let us do this exercise. So, it says that you consider the following color filter array, whose first row corresponds to the red row and first column of that row corresponds to a green pixel of the Bayer pattern, which means the leftmost and top most position of the array location, in this particular display that element corresponds to red row and green column in our convention of denoting any location.

And then what you are asked to answer the following that what are the missing components of the central pixel, which has been shown by the bold font and whose value is 45 here and then you should compute those missing components using bilinear interpolation and average of red and blue hue.

So, these are the two parts of this exercise. So, this is a central pixel as I mentioned.

(Refer Slide Time: 07:33)



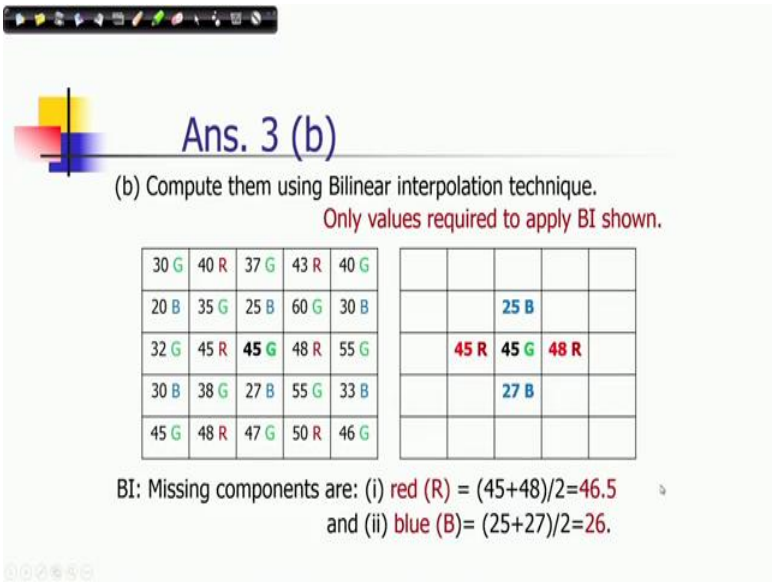
So, first let us consider what are the missing components of the central pixel . Now, in this particular diagram, I have just displayed the corresponding pixel types or which spectral samples are available in the locations corresponding locations to the pixel. As we have seen the first row we have the red row and green column.

So, which means the pixel value available at that location is green and then alternatively, or periodically, in that row the in an interleaved fashion green red green red in that way

the pixel samples are available. So, if I follow those Bayer pattern then the central pixel, we can say which we have highlighted that is also a green column pixel and it is also in the red row.

So, anyway since if the column if the type of column there it is green. So, we consider that is a only the green value is available. So, that missing components in those cases would be red and blue. So, this is a central pixel and missing components are red and blue.

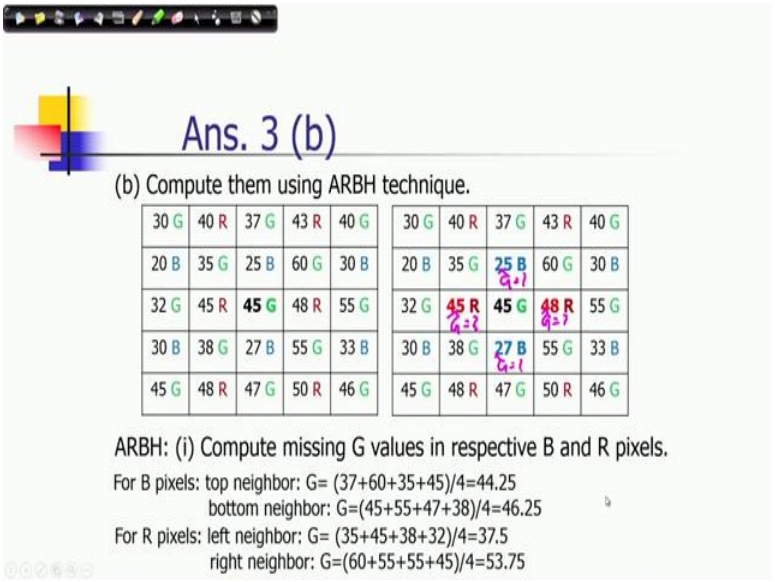
(Refer Slide Time: 08:50)



Now, we have to compute the missing components red and blue. So, you can see; we have to apply the bilinear interpolation technique. So, we will be using bilinear interpolation. So, here I am showing part of these array the pixels samples which are used for our computation and by the color, I am showing those samples also the red is shown in red color and blue is shown in blue color.

So, for missing samples of red you simply you have to take average of 45 and 48 and for blue, you have to take average of 25 and 27. So, that is what you need to do to get red and blue for the bilinear interpolation technique.

(Refer Slide Time: 09:33)

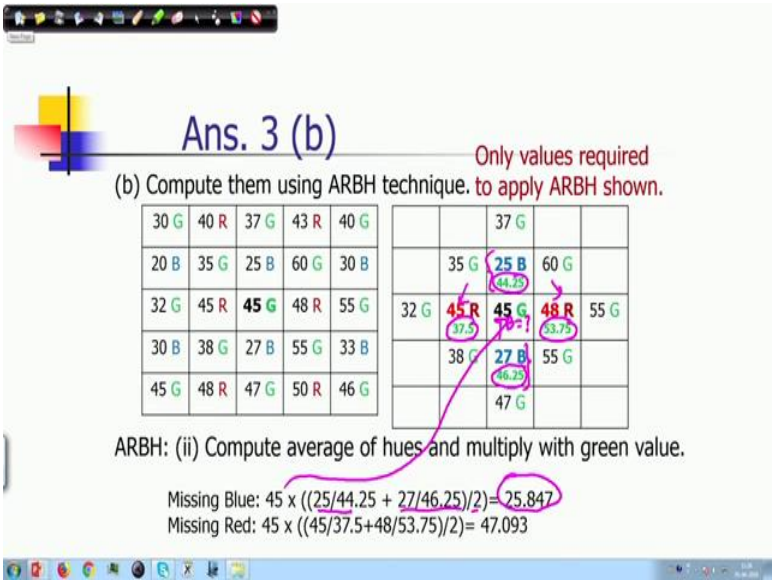


Now, let us consider the other technique that is averaging of red and blue hue. Here, once again I am showing those patterns, showing the highlighting those pixel values which are required for computing the corresponding know red and blue interpolations, but we need to compute the hue in those locations also; that means, in this location you need to compute the red hue, which means I should know I should also try to know what is the value of estimated green here.

Similarly, what is the value of estimated green here. So, I should know green value before computing hues that is what we require and for estimated green once again, you apply the same bilinear interpolation technique. So, the step would be first I will estimate this green values and then I will be applying the averaging of red and blue hues steps. So, computing missing G values; in respective B and R pixels.

So, for B pixels these values are computed and for bottom neighbor also these values are, I mean B pixels this is computed, the top neighbor it is 44.25 and bottom is 46.25 and red also is computed using left neighbor and right neighbor out here, it is corresponding left and right neighbors.

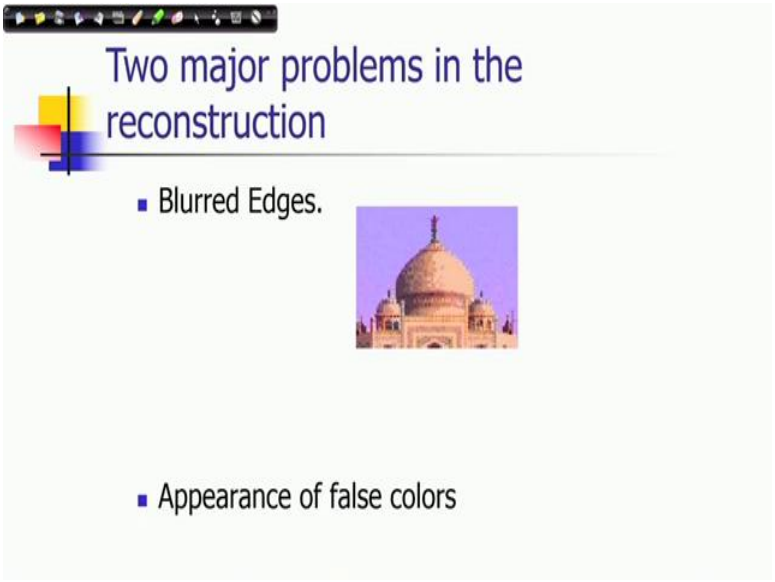
(Refer Slide Time: 11:01)



So, (Refer Time: 11:03) just to show you what are those values. So, you can find out here, these values are shown here. So, this is the estimated green in those locations, following those rules. So, now, you can compute the corresponding hues. So, you can compute average of hues and multiply with green value. So, this is the missing blue, you can see that these are the hues we are computing. So, this is 25 by 44.25. So, corresponding to this location and 27 by 46.25 and then you have taken the average by dividing it by 2 and then you are multiplying the corresponding green pixel value and finally, you obtain the missing blue component at this position. So, this value is 25.847. In the same way you perform red by considering these two neighbors that value is coming as 47.

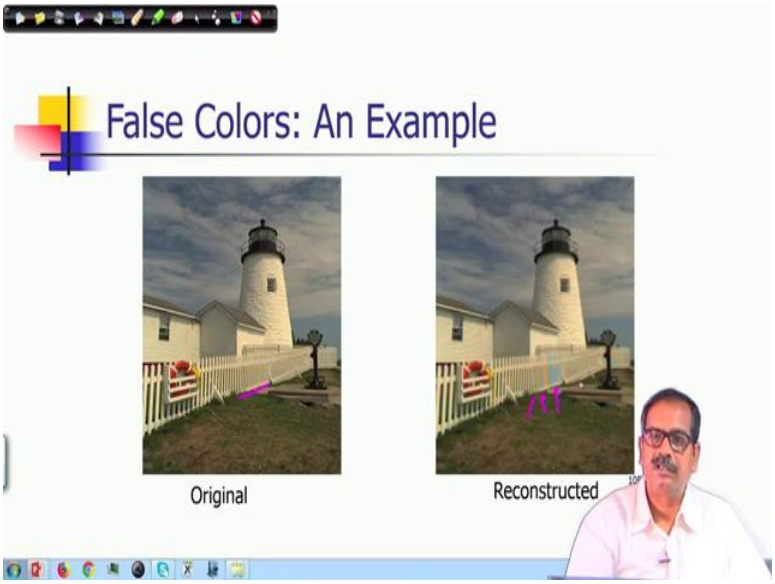
So, in this way you can get this result.

(Refer Slide Time: 12:16)



So, there are two major problems of the reconstruction. I talked about blurriness of edges even though, we can use the less gradiant directions still, you can have the edges blurred. So, I have shown by know zooming the interpolated image what I have displayed earlier, the dome of the Taj Mahal in that picture and you can see that there the edges are a quite blurred in the zoomed portion, you can see and also there are appearance of false colors.

(Refer Slide Time: 12:48)

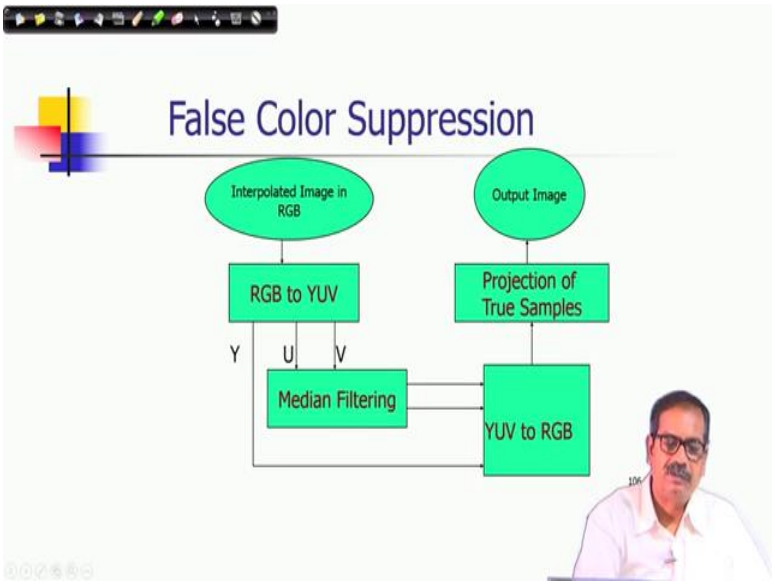


So, particularly it is severe, when you have a very high transitions of the paints here, very high frequency transitions and the color is white.

Since, the color is white, no all red and red, green, blue, they are to be estimated very accurately representing white. Even when a slight change in those estimations, slight error will cause appearance of know different kinds of colors. So, this is called the false color artifacts and those artifacts are quite visible, when you have this kind of images and this particular image is known for showing these artifacts and this image is also heavily used for testing algorithms for evaluating the quality of interpolation, quality of results.

So, these are the two particular concerns, but the thing is that for removing blurred image there a different filtering techniques and there are different other post processing techniques, which I am not going to discuss which is quite, which requires a bit more complex. You know concepts to be discussed, but whereas, for removing false color, I can describe a very simple technique and effective technique that is by using the median filtering.

(Refer Slide Time: 14:08)

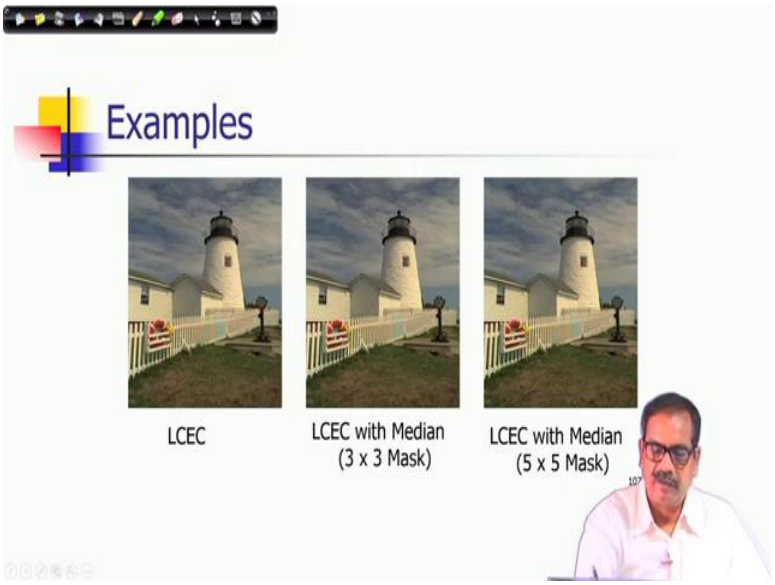


But what you are doing you know, in this case? you are performing median filtering in a different color space. You are separating out, the luminance and chroma components. You could have done in other color spaces also, where you can, you could have separated out, but I have used the U and V it is U and V is nothing but modified complementary blue and complementary of red of *YCbCr* transformation. So, which is linear transformation and there you perform median filter in each component and after

that you again, you project back to then you again transform it back to RGB and interesting is that while since, you are doing filtering some of the true pixel values are also getting modified.

So, you should project those true samples in this locations. that is another thing, you can you should do and that that is how you get the output of the image.

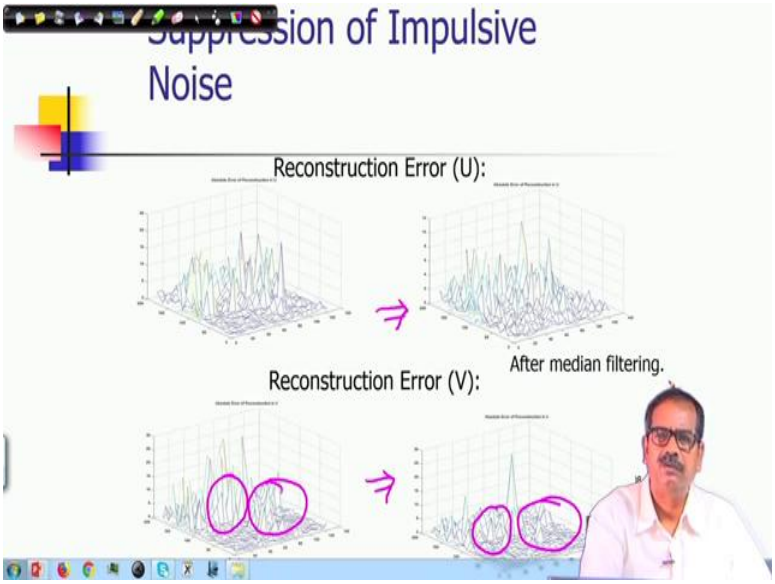
(Refer Slide Time: 15:10)



So, if you perform these operation, I can show you the effect here. So, you can see that this was the original reconstruction image, reconstructed image using this technique LCEC which we have discussed. If I apply a 3×3 three cross three mask of median then you can find out this artifacts are getting reduced and 5×5 is reduced but the there is you know some disadvantage of having larger mask, it will blur the edge also. So, there is a trade-off between these.

So, this is one example. In fact, we can show also the, how the noise gets reduced in the corresponding space of U and V.

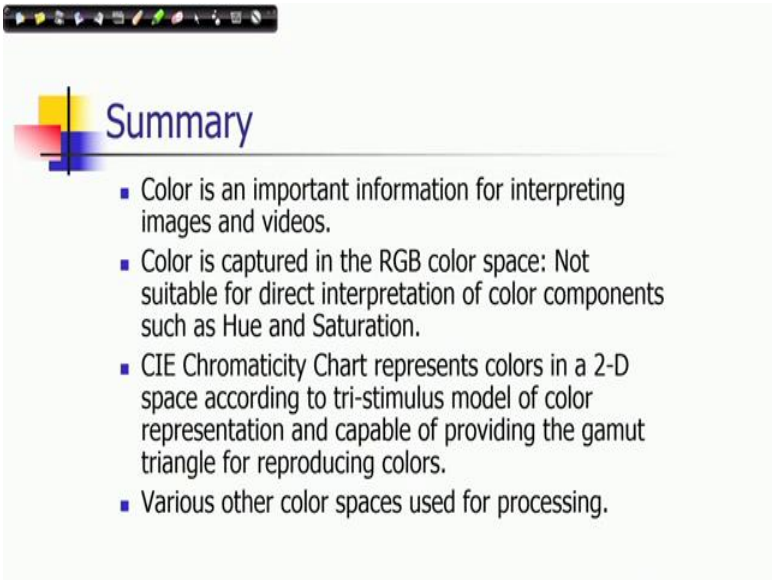
(Refer Slide Time: 15:53)



So, this is typical plot, this plot corresponds to the reconstruction of the lighthouse image, what I have shown you before and in the error of reconstruction of U and V samples using the original interpolation technique LCEC, those errors are plotted against the locations, against the pixel locations. So, I have given you the surface plot. The top, it is showing the surface plot of error for the U component and the bottom, it is showing the surface plot of error of the V component. So, when we apply the median filter, then we can see the magnitude of this error is getting reduced.

So, this is the plot of U. So, this corresponds to U component and this is for V, you can see that it is significantly reduced. This part, if you are observant this part it is significantly reduced even this part it is significantly reduced, for U component it is not so prominent still it is reduced and there is a remarkable improvement of PSNR value which I am not quoting here. So, around 3 to 4 UV improvement those are reported.

(Refer Slide Time: 17:38)

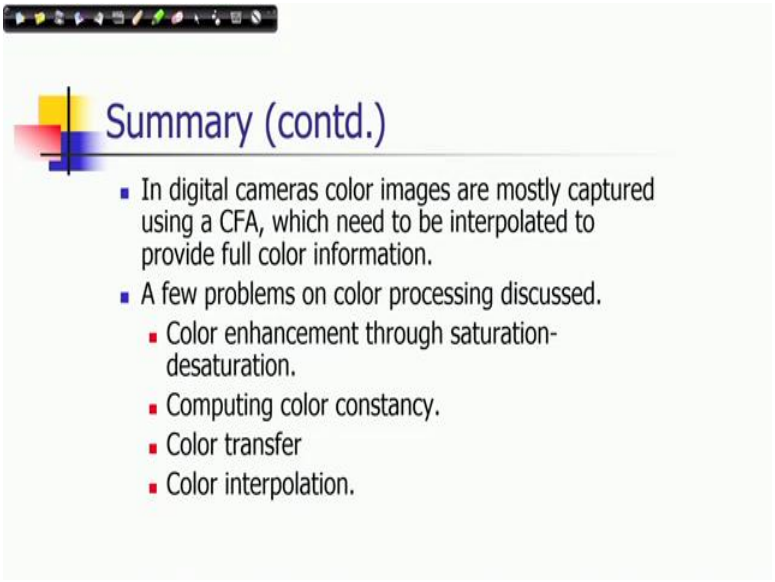


So, with this I will be concluding our topics in color fundamentals and color processing. So, just to summarize that what are the issues we have covered in this topic and what are the what is the take home, information regarding this particular topic that color is an important information for interpreting images and videos. you know that and it is understanding of it is representation is very important.

And we have seen how color could be represented and so, it is captured in the RGB color space, but it is not suitable for direct interpretation of color components such as hue and saturation and that is why there are spaces where you can separate them out. In particularly CIE, which is the international body of colors and they have recommended a chart which is called chromaticity chart and it represents colors in a 2-D space according to tri stimulus model of color representation. So, they have standardized the color representation and it is capable of providing the gamut triangle for reproducing colors.

There are various other colors spaces that we discussed that is used for processing in the just in the previous example; I have shown you processing in YUV color space, but there are others spaces also; we have mentioned using chromaticity chart itself, we have given some examples of processing; that means, you can convert from RGB to xyz, from xyz to normalized xy chromaticity space and there you can process in the hues and saturation to get different kind of information.

(Refer Slide Time: 19:32)



So, the other topic, the last topic, what we discussed that is on color demosaicing. So, this is required when color images are captured using a color filtered array and mostly in present day widely used all the digital cameras, which are not expensive to that extent there it follows this principle of imaging and there is an interpolation process in built with that system itself.

So, it is needed to be interpolated to provide full color information, if you take get the image in the form of color filter array and we have discussed also a few problems on color processing. So, those are the some of this problem that is we discussed in color enhancement through saturation desaturation operation and we have seen how it could be done with the help of CIE chromaticity chart, that is one operation. Then we discussed also about computing color constancy there are two particular steps estimation of color of the illuminants and also correcting colors using the estimated color.

Then color transfer is more general competitions of transferring colors, which is the what the illumination is seemingly coming from a different target image from a target image or from a source image and that is the target illumination, which is described by target imageand the color of the source image to be transferred as if it has been illuminated by the illuminated of the target image.

So, there is a problem on color transfer then in the last examples of processing, we discussed about color interpolation. So, these are the four typical color processing of

color images that we discussed in this topic. With this let me conclude my lecture on this color processing and color fundamentals; we will go to the next topic of range image analysis, in my next lecture.

Thank you very much for your attention.