Optical Methods for Solid and Fluid Mechanics
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Lecture - 07
Image Processing Operations

So welcome back. So, last time we had left off at this location where we were trying to use image J. I had asked you to download this software and I hope you have done that. Now what I am going to do is I am going to play around with one image and I am going to show you some of the features I am not going to obviously image J as a software has a lot of image processing capabilities and this is not meant to be a tutorial on this. I just want to illustrate some of the points that we were discussing before.

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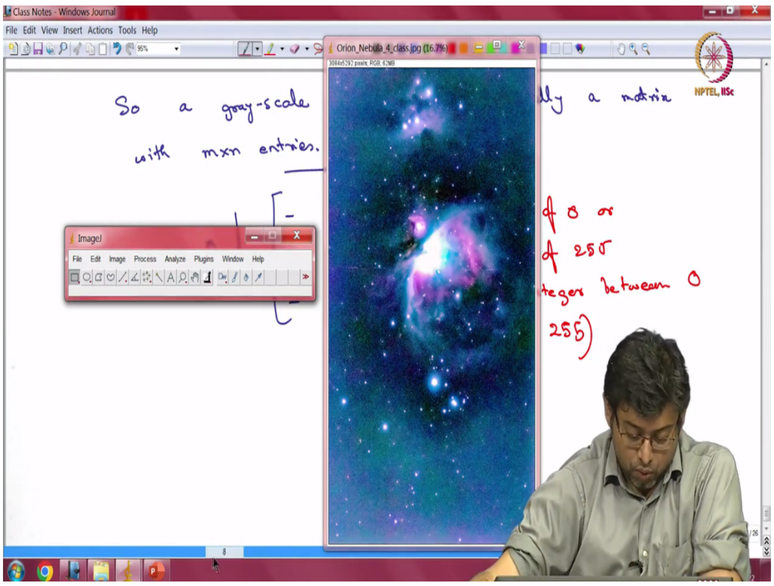

So, what I have done here is I have opened this particular image right here and you can see this image J box is open here and this is my window. Now it is a bit difficult to see, but here it tells you about the image type. So, for me it is, for example, I can read it out it says 3084 into 5292 pixels. So, it is telling me the m cross n that I just mentioned in the last lecture and then it also tells me that this is an RGB type of image.

So, it has the word letters RGB and then it tells me the size of this which is 62 MBs that is not something we are interested in that much, but now as I move this cursor along I hope you can see in my cursor which is a plus sign right now on the screen. As I move it around you will see that there are some numbers that are going to appear right here in this region. Right now it is blank because I moved my cursor away from the image.

But when I put the cursor on the image certain numbers come up. So, the first number corresponds to an x and y and you can see that these are integer values. So, these are going to, change between different integers what it is telling you is its changing between right now both of them are integer values. One of them is greater than 1,000 the other one is greater than 2,000.

Here this is the 00 if you take the cursor here you can start seeing this is x y 00. So, the image 00 is on the left top side of the image and this is by convention that this is considered as the 00 of an image. So, the image 00 is not at the bottom left hand corner which is what we usually do for let us say graphs. So, this is 00 and as you go along at the different x's and y's here the number of the first two numbers they signify the x and y.

Then they it reads out the value. So, it says x equal to some number y equal to some number comma value equal to and then where I have kept it reads value is 69, 121,181. These three numbers what do they signify? They signify nothing else, but the entries in the matrix. So, we spoke about how basically you have matrices which will have those three values for R and G and B.

And how those numbers must lie between 0 and 255 and that is exactly what is happening at some intermediate location you get some value. Now there is a very bright section here if I carry my cursor to this particular location. Now my first value has now maxed out to 255 the second and the third value are very close they are 253, 254 where I have kept my cursor. So, it is almost saturated in this region.

And you can see that how that looks up in the image its extremely bright. All the three RGB are present and, they are all almost equal. So, the entire area is looking as white right. Similarly, if you go to some other location it has a more of a reddish tinge. You will see that the R value now is reading out to be 221 whereas the G and the B are 135 and 224 respectively.

So, you can see one of the color starts to dominate over other and you start seeing these nice beautiful colors. Similarly, you can go to other locations and you will, for example, at this location the blue dominates. So, my cursor value reads 89, 162 and 231. So, the blue value is larger than the R and the B values. Similarly, if you go to a location which is very dark and almost black here, for example, I see a value of 3, 6 and 0.

So, this gives you an idea of how the image is what this computer is rendering for me is basically nothing, but a matrix with integer entries that is a beautiful way of understanding images. Now just one second I want to quickly see what are the; I am going to **(Video Starts Here: 05:16)**. So, I can do a lot of different things here with the image and some of the things include, for example, I will be able to wait just one second I am going to find the correct.

So, if I go under analyze I see there is a drop down menu and one of the drop down menu reads histogram. So, this when I do this it is nothing, but a histogram of the values between 0 and 255. You do not see R, G and B separately because it is sort of mixed together here into flattened out into a grayscale value. So, it tells you that this is the on the y axis you have a relative frequency of sorts relative frequency actually.

And on the x axis you have the minimum and the maximum value that can be stored again all integers. So, these are bins and if you plot this it looks something like this curve. So, it also tells you that there is a, for example, a fair bit of pixels with values close to 225 or saturation right which is what you also see in the image there is saturation here. There is also images some pixels which are close to 0 and some of the other pixels they are all in between.

Now, if you wanted to see, for example, if I draw this rectangle here and then I want to go to let us say image no sorry if I go to analyze and then I say plot profile it plots out this curve for me. What it shows you on the y axis you have the grayscale value and this is your distance in pixels. So, it is measuring the distance of pixels from your left hand side of the rectangle on to the right hand side.

And it shows you that in the beginning you have this (()) (07:26) curve and then you go up here this flattens out you can see this. This is your pixel saturation. So, the pixels of saturated with the high value of 255 this is a grayscale value by the way. So, it is not really reading R G and B separately is reading R G and B as if it is all been merged into one and then this starts to fall off later on.

So, you can get an idea of how the values in a particular row, for example, in this image how they are behaving with the values and you can read it off from here. So, basically an image is nothing, but a two dimensional matrix that we can read off. You can do a lot more things obviously, for example, I will come back to this in some in due time, but I just want to just go over what we did.

So I have this I showed it to you with the software, but now I have just I have done this before just in case and made sure that I have just taken screenshots of my screen before and I wanted to show you these things again. So, you can see on this side of the image you can read out the number of pixels that are there then it says RG and B it tells you the number of megabytes this image occupies.

And then if you keep your cursor at some point it is not this image does not show you where the cursor is, but here the cursor is placed at this location x equal to 1614 y equal to 2190 and then when you do that it reads the value 255 for R a value of 253 for G and a value of 254 for B. So, almost saturated so it must be somewhere around this region perhaps, but you can read off the values with image J like that.

And then what we did is we went in under analyze and we looked at the histogram and this is a grayscale normalization that you are doing and here this is the values that are the bins from 0 to 255 and on this you have the y axis with the relative count and this is a plot of the profile and then we took a rectangle and then we saw how the grayscale value behaves and you saw this top off.

This tells you that this pixel saturation that has happened and this is not really that good, you should have pixel saturation. This signal could have looked something like this, it could have even looked like this, but that now is lost that information because of saturation. So, saturation is not a good thing you should avoid it. What we are doing right now with respect to image J this can also be done using Matlab or some other software like python.

And one of the advantages of other softwares is that you can now start writing your own code I mean what you have is essentially a matrix. So, if you can extract the matrix out then you can start doing a lot of operations on them. **(Video Ends Here: 11:15)**. So, with the software like Matlab you will be able to go in and you will be able to read the matrix in. So, what I have done is I have done this myself we have a copy of Matlab in my system.

And I went ahead and I have done some of these and some of, these commands I have written down for you so that you might want to use it. If you do not have subscription to Matlab you can also use open source softwares like python. You need an appropriate image processing toolbox to be able to handle images, but you should be able to do something similar over there.

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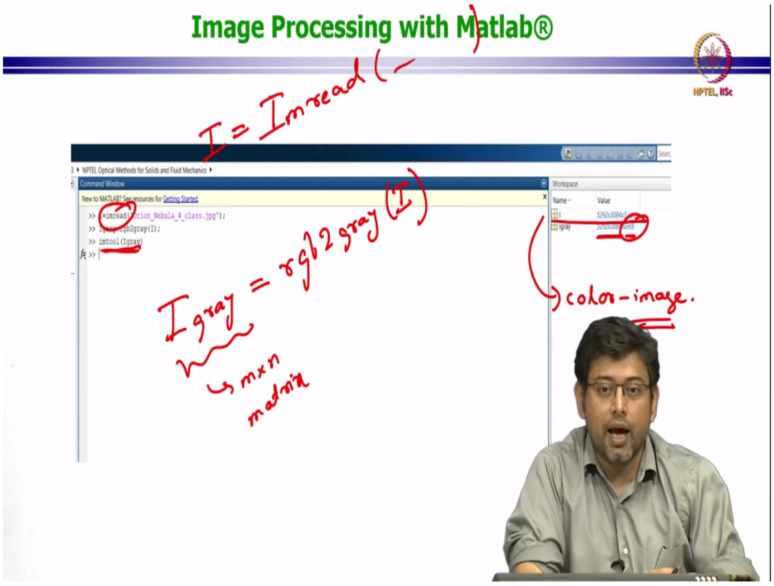

So, what I have done here now I have used the same image that I have shown you with image J and I have read it using the command called I am read. So I am read is image read basically and I have read it so that I have called my matrix I as I am read whatever by name right of the of the image. In this case it is Orion Nebula for class dot jpg and then what it does is once you enter this command it will; so the image is obviously in the same folder in which I am operating.

So, it reads that and it tells you here what it does. So, I now is a matrix with m cross n where m is 5292 and then this it also tells you the other value and then it tells you into 3. So, this tells you that the image is a color image; so this is a color, but I have told you before for many of our work we actually do not have to use color images we are good with monochrome images.

So this color images not always necessary for many of our analysis we will see actually for almost all our analysis we will see monochrome images are as good. So, what I want to do is now although the camera was a color camera I want to convert everything to monochrome. Here camera itself is monochrome you will not get a m into n into 3 matrix you will just get an m into n matrix, but in our case we have this was a from a color camera.

So, what I do is I write this command called I gray which is the name of a matrix and then the actual command is RGB 2 gray and I as an input I give it the I matrix which I have already read and defined before. So, now my I gray becomes an m into n matrix and you can see it here on this side it is the workspace is displayed it says I gray and it says m into n and this unt 8.

So, this is 8 bit, it signifies that this is an 8 bit image you can use two commands like imtool and when I do imtool and I put I gray as my input it reads this matrix I gray and it renders it for you again as an image which is what you often want to do.

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Once you do that this ends up like a box like this where Matlab has rendered the matrix as an image and this is what it looks like and I have my cursor again somewhere and the cursor is at this location 15513494 and it tells me that there is a grayscale value of 251 at that location.

So, it is similar to the operation that we are doing at the image where we are just changing our cursor location or we could read off the value at that place.

So, these are very good tools so before I go to this part I want to explain a few things. So, we go back to our notes. Now you saw that there are different ways in which different softwares that you can use with the software like the ones I was using later Matlab I could read the entire image as a matrix. So, basically your images.

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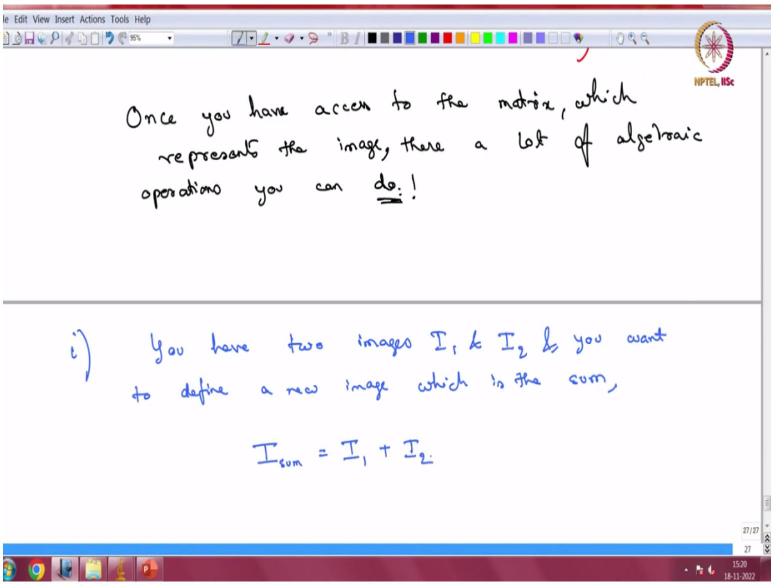

So once you have access to the matrix which represents the image. There are a lot of algebraic operations you can do and this is interesting and very important. So, for example, let us say you had two images so you have two images I 1 and I 2 and you want to define a new image which is the sum then all you have to do is just say you have to define a new variable called I sum and you will just say it is my matrix I 1 plus I 2 and you just do a matrix addition and there you have it.

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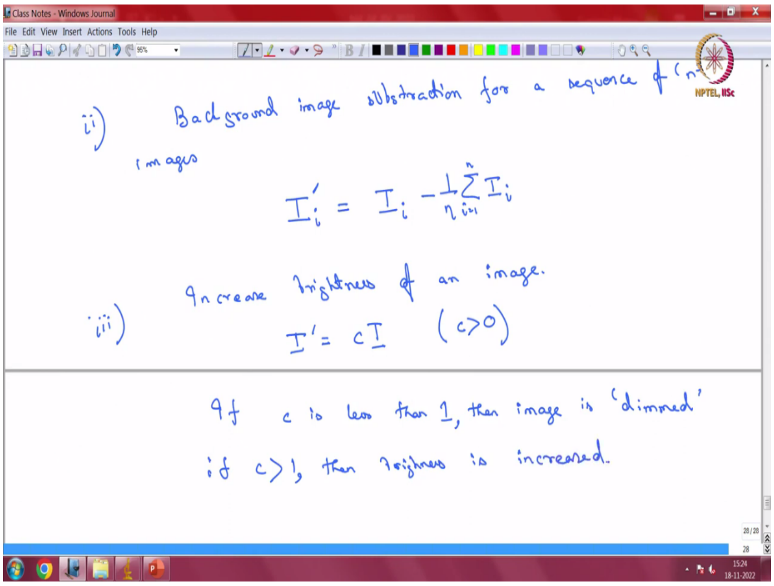

So, this is you can see hopefully you can begin to see what kind of a powerful tool now you have once you have access to the actual matrix. So, now for example if you wanted to do a background image subtraction when I mean background what I mean is this is a commonality between let us say background image subtraction for a sequence of n images which means you have images I 1, I 2, I 3 all the way up till I n.

And what you wanted to do is to figure out what is the exact commonality between all of them and subtract that out then what you could define is as a new averaged I so let us say you want to do it from the ith image. So, what I will do is I will do this particular algebraic operation where I define an averaged I as or sorry background subtracted I this is not an average. So, this is some my I dash is equal to I i minus 1 by n I i summed over all I's.

So, you could easily write this command and get this new matrix and this new matrix will be now a background subtracted image. You can define other types of background subtraction also I am just defining one particular type, you can see my motivation for doing that and let us say you wanted to increase brightness. So, let us say increase brightness or change the brightness of an image.

Then you define a new I dash as being equal to c times of I where c is not 0 it is greater than 0 then for c less than 1 between 0 you will get I dash which is okay me put this here sorry. So, if c is less than 1 then image becomes dimmed right so the values are smaller. So, you are closer to the 0 which is basically is dimmed if c is greater than 1 then brightness is increased. There are obviously other types of algebraic operation you could do.

You could multiply it with a c square, you could multiply with c cube or some other function you want to desire, but I am just giving you out the most simplest of things you can do.

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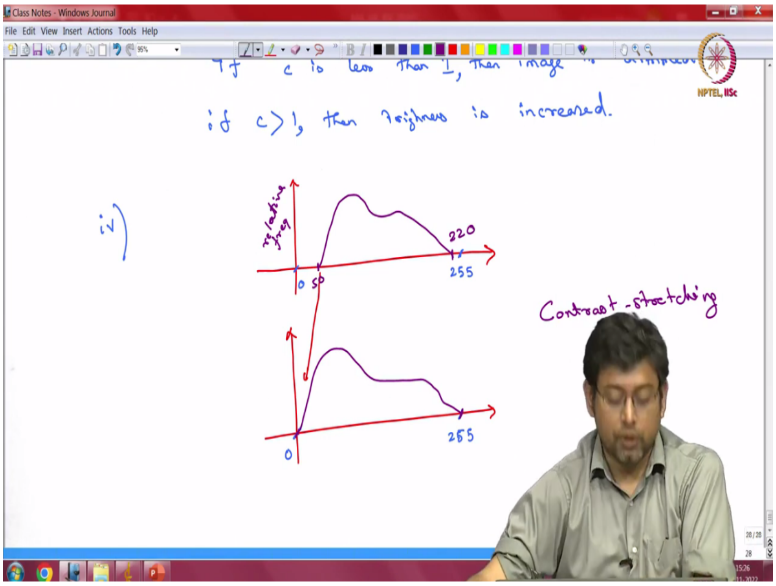

Now another important thing that is often done with respect to images is let us say; so let us say this is 0 and this is and what I am going to draw is the image histogram. So this is 0, this 2.55. Let us say the original image is such that what you have is a histogram something like this and this is obviously relative y-axis is some type of relative frequency. I am not writing it down for the second graph it is the same thing.

Then what you could do is you could map this old image to a new image such that this histogram now changes and you end up with a curve like this and what I have done is whatever this value was let us say this was some 50 and let us say this is some 220 then I have stretched it out so that in the new image my 50 now corresponds to 0 and this 220 now corresponds to 255.

So, you could use tools, for example, there are good tools like Photoshop which will allow you to do this kind of a histogram stretching and this is also called contrast stretching. The image at the bottom has a better contrast in the image at the top and that is just done through managing the relative histogram and that you can do by changing the transfer function that allows that is something tools that are there in many different softwares. Now image J also allows you to do that. **(Video Starts Here: 22:45).**

And let us take a look at how you might want to do something of that sort. So, let us just use image J and let us say you have this image and what I am going to do is there is two ways just a second I want to try and find. So, if I go here under process it allows me to do something called enhanced contrast then it asks me for a number here maybe I will shall just tell change. Before I do this one second I want to have the histogram.

So, that we can show the difference okay and I had found the histograms where so here so this is the histogram of the original image. Now, if I go in and if I change let us say; so maybe I will just go here and I will do enhance contrast and maybe I will put some other number some 10 and do equalize histogram. If this has not changed the image much maybe do maybe not do equalize histogram.

It is not changing this image a whole lot. I think I am not able to find the exact it appears that the version I have on my computer versus the version here is slightly different. So, if you go ahead and start making certain changes to this image. Yeah, if you look here what it allows you to do you can see there is a lot of different mathematical operations it allows you to do Math you have add subtract, multiply, divide.

Now, if you are wondering before if you did not know the background of how images actually are they are just matrices this could set you off as to what exactly is happening, but now that you know you know what are the things you can; what is actually probably happening right behind the back in the software. You can also do Fourier analysis again as since it is just a set of numbers you can do that.

And there is a lot of other things you can do for example it allows you to do Gaussian Blur and all that and convolutions and all. So, if I try to do a Gaussian Blur let us say 50. This oh it is showing up here okay I do not know why I tried to do a Gaussian Blur there. No, it is on the Math yeah sorry Gaussian Blur. So, you see this image has now gotten blurred. So, the blurring process has done that and if you go now and look at histogram your histogram you see here is very different than the one you started out with.

So, the mathematical operation that you did on this is effectively changed the histogram quite a bit. **(Video Ends Here: 26:27)**. So, there are different you in image processing you want to be able to control this kind of a process, you want to be able to be able to know exactly what type of histogram you want and that sometimes comes from it comes the exact operation you want to do it sort of depends upon the exact need that you have which is very situation dependent.

Now I am just going to go over some of the basic ones that we usually do and this one more this is 4. So, maybe I will just do another one.

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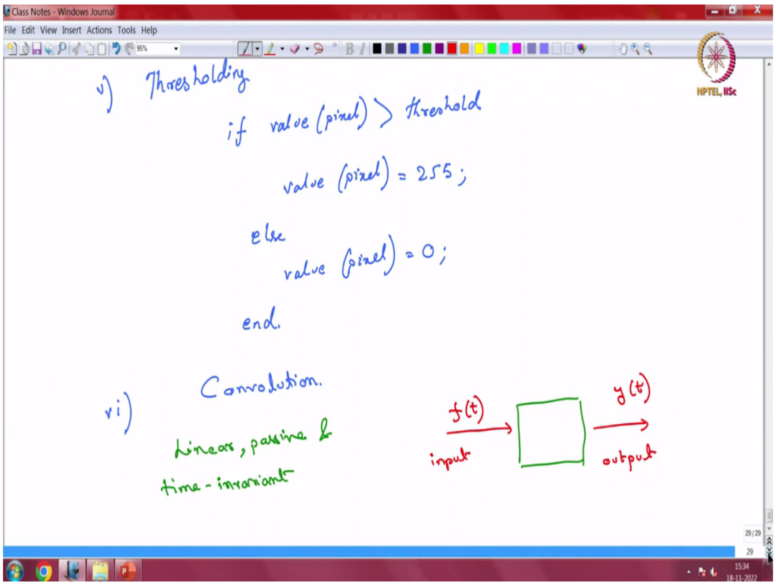

There is a very common operation that people do which is called thresholding. Now the thresholding also you can define a complicated algorithm for that, but usually a simple thresholding operation is you look at the pixel value and you define a certain threshold. And if the value at that pixel at that particular pixel is greater than the threshold then you set the value of pixel to the max.

So, in this case it is 255. So, else so if it is not greater than the threshold then you set the value to be 0 and this algorithm gives you thresholding of a certain type. You can of course define different types of thresholding also. So, you could potentially define a thresholding where you leave the pixel value as is if it is below the threshold or you may need not have to go it to the maximum.

Your threshold value could be different for RGB etcetera. So, there are different types of thresholding operations you can define, this is the simplest type and how you should the question I would ask is how do you visualize this kind of an operation graphically. So, I leave that state problem to you to check out how to do that. Now when you have a matrix like this one very important operation that we do in image processing is something called convolution.

Now convolution you may or may not be familiar with. So, if you are not familiar with give a very brief quick introduction to convolution. So, let us assume so you have a linear passive and time invariant system. Time invariant meaning how it is changing in the input and output. So, let us say you have some a system like that the system is going to be represented by this box.

And in this I feed certain input function called f t this is my input function and I want a certain output function or I get a certain output function from the system and what kind of a system is this? It is linear, passive and time invariant system then if I have to calculate this f y t for an arbitrary input f t.

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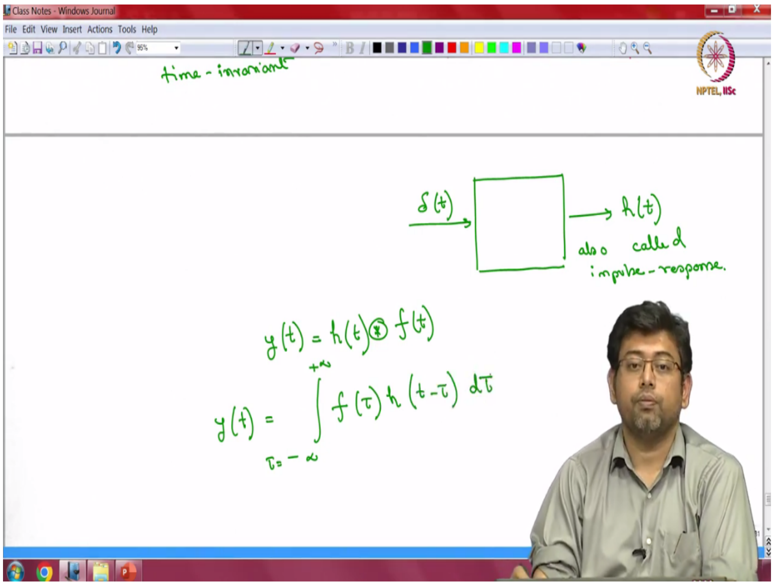

Then what is usually done is you; so you do this same the experiment. The first you feed it the delta or the impulse function as an input and you should get some output. So, this is also called the impulse response. Now once you have this theory says that my y t which is my I output that I wanted to calculate this is given as a convolution between this impulse response function and my f t.

Now, in the case of continuous functions this convolution is defined as this integral. This goes from minus infinity to plus infinity my tau. So, I define a dummy variable for myself and this is now becomes f tau and this becomes h t - tau f t tau. I am not going to go into the details of how this really comes about is that goes into the theoretical idea, but if you had to think of it simplistically what basically it is doing is it is evaluating the impulse response function and then deciding that okay my response is nothing.

But this summed over in an integral sense it is summed over the input function f t h t multiplied by f t and that sort of summed over in an integral sense.

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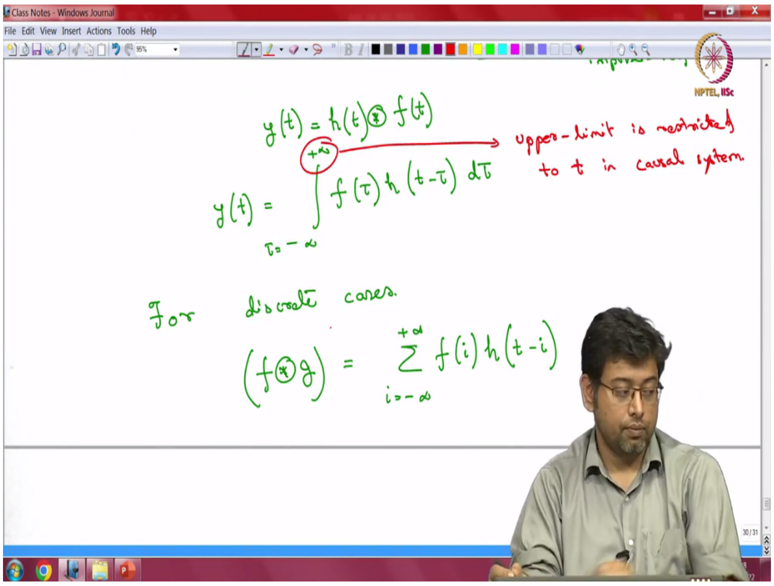

Now, this is for a continuous case. For discrete cases my convolution is defined as nothing, but let us say I now define a new variable I which goes from minus infinity again to plus infinity and this is my f i and this is my h again t minus i. Now interestingly when you have causal systems the upper limit in this integrals cannot go up till infinity. So, in causal systems this upper limit is restricted to t in causal systems which means that my future.

So, if it you integrate from minus infinity to plus infinity if you are thinking of tau as a time thing then your future functions are impacting the current and that you do not allow. So, then you restrict the top here to t and similarly in this particular case. So, there are different properties of convolution and they are because integration is a linear operation you have many of the properties of linear operations that reflect in convolution.

So, f convoluted with g is the same as g convoluted with f. I hope you remember this kind of a behavior when we are discussing some other mathematical preliminaries. Similarly, if there are three functions where f is convolved with a convolution of g and h then the order does not matter I could have as well as convolved f and g first and then convolve this that with h and that will be the same thing.

Similarly, if you are multiplying f with some scalar alpha and convolving alpha f with g then it does not matter where you multiply the alpha so it the same.

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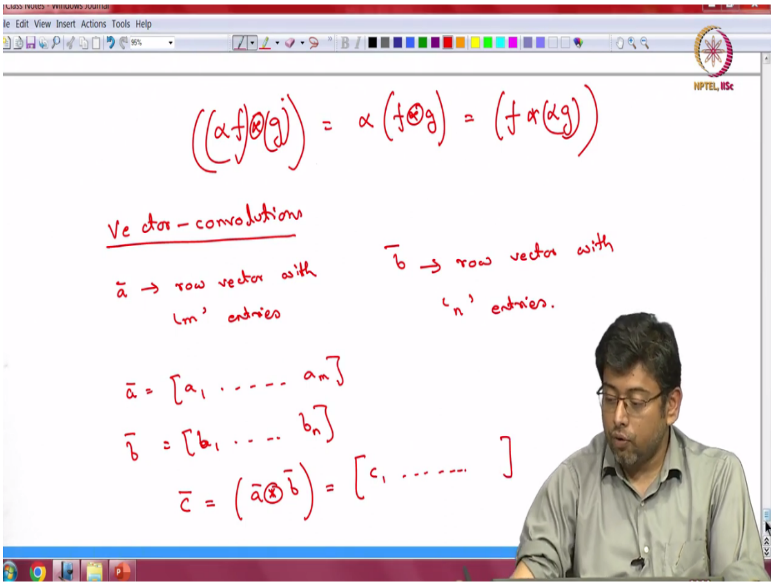

So, alpha f convolution g is the same thing as alpha f convolved with g or f convolved with alpha times g. So, this all comes because you have a linear operation at hand why are we discussing this obviously because we are going to start convolution with the image matrix. So, images also allow you can do convolution operations with matrices, but before we understand convolution operations with matrices we should understand convolution operations with vectors.

So, let us say we want to do a vector convolution where let us say you have a row vector a is a row vector with m entries and b is another row vector with n entries. So, you have two vectors with different number of elements. So, basically your a looks something like this where you have a 1 all the way till a m and b is a sorry b 1 all the way till b n and we want to do a convolution operation of these.

So, the convolution operation of these two gives me another vector and this vector is essentially another vector with c 1 some elements. Now you have to find a rule which gives you this.

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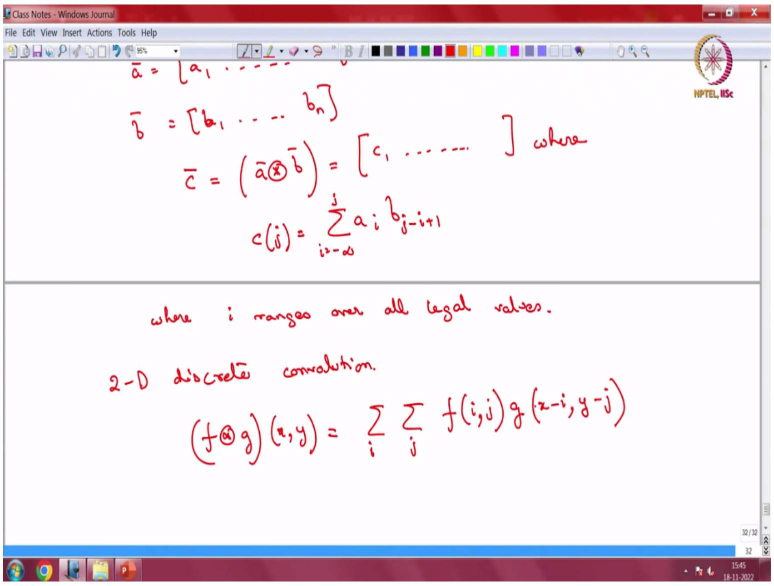

And the rule is that such that or rather where every element. So, if I have to give the jth element of my c vector that can be found as integral of sorry summation of a i into b i sorry j – i. This I am doing just simply by sort of copying the discrete version right here except that now since these are vectors I have to do a plus one because the 0th element does not mean anything with respect to vectors.

The first element is 1 so I have to do a + 1 and this is i from all the way minus infinity to the element j for causality. So, with the notation that where I ranges over all values, all legal values. So, I cannot have minus infinity because when I am dealing with vectors there is no entry called minus infinity there. You have entries from 1, 2. 3. 4. So, you cannot take arbitrary i that is what it means.

Similarly, you can do a convolution of vector of matrices. Now two dimensional so 2d convolution discrete convolution looks like this, f convolved with g let us say x, y I am going to run out of variables to name. So, let us say the 2d a you have x and y is the in the convolution and on this side you are using i and j as the entries. So, then I will say i, j and now these are the dummy entries because I am going to sum over i and j.

So, this is i and j all possible values of i and j and on this side you have x - i and y – j. So, now you can do this you can use this formula for 2d discrete convolution you can apply that for matrices and once again just as we did before here we have to do a plus one you would have to do something similar. Now once you do that you can actually do the summation and get the convolution for two matrices if you had to do that operation.

And you can do convolution operations in softwares like Matlab where Matlab allows a particular command called conv2. I will show it in the next class and that operation allows you to convolve two matrices or even two vectors conv2 I think is for matrices and conv is for vectors. I will have to look that up, but I urge you guys to also take a look and see which commands if you are using something like python what other commands for in that particular case.

And I would like you to go ahead and try some discrete convolution yourself so that when I am explaining convolution operation or images, it will you will be better able to understand and follow. So, for today's class I am going to stop here and in the next class we are going to look at convolution, some examples of convolution specifically for images and yeah with that I will end today's class. Thank you.