Image Single Processing
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Lecture No. 71
Illumination Handling

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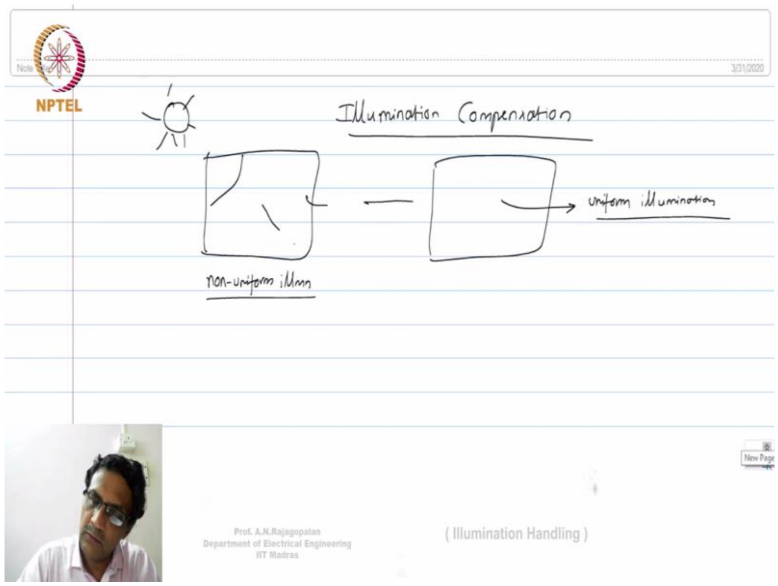

The final topic under Image enhancement is illumination compensation is illumination compensation what this really means is that like if you have an image wherein the illumination is not uniform in the sense that you would have a light source that is probably you know shining from somewhere from the top right to the shining down on this and therefore it, it creates a gradient it creates an illumination gradient wherein let us say these pixels that are actually closer to the light source are brighter and then the pixel that the farther off are kind of relatively darker.

So, the idea is that how do you really do an illumination composition. This is again consider enhancement because this is one way to enhance the visual appeal of an image in the sense that we do not like to see an image that has a gradient illumination gradient that has been artificially created by the source or because of the way the source has been placed. Therefore, the idea is that, can you kind of, can you kind of can you kind of do a compensation such that such that the output image they will have a you will have an illumination that looks uniform.

We would like to go from what is the non uniform illumination. So, such an illumination is called non uniform illumination, we would like to go from, from a situation that has non uniform illumination to an image that would then kind of transform this image so, that the illumination in the output image looks like looks, looks uniform. And, and one of the ways in which to do this is what is called Homomorphic filtering. I will talk about I will talk about what is called as Homomorphic filtering.

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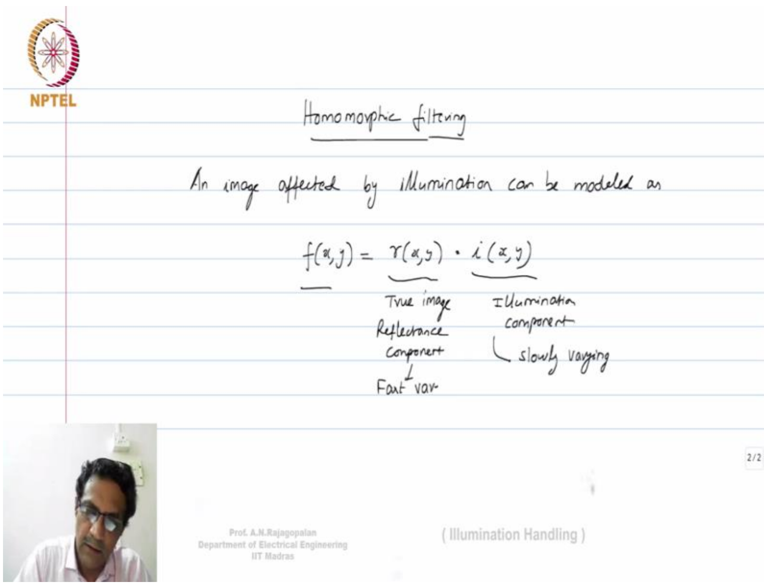

Homomorphic filtering, this is this, this kind of a (homomorph), homomorphic in the sense that some kind of similarity inside the approach that I will talk about. Now, the idea is that under an image affected by illumination, an image affected by illumination, the image affected by illumination can be modeled as I will tell you why can be modeled as f of x comma y this is your this image that is affected by some illumination radiant is r times x comma y into i of x comma y.

What this really means is that ideally r of x comma y is the kind of true, true radiance or to true, true, true intensities. So, this is the this the two images that you would like to see is the true image that you would like to see, unfortunately that has been that has been that has been effective, by this by this is illumination component. And therefore the final f of x y which you have, now is no longer it is uniform in illumination.

Now, there is also it is sometimes referred to as the reflectance component and this one is referred to as the 0 illumination component. Now, ideally i of x y is 1 or simply a constant for all intensities, but in this case it is not normally it is not I think it is a constant and of course, you would have had a uniform illumination, but then let in it is not then you get what is called a non uniformly illuminated image.

Now, the way it works is that it assumes that this is a slowly varying component this is a slowly varying this is slowly varying, which is which is a reasonable thing to assume because in an image like I showed in the earlier picture, when you have this illumination, rays shining from one side you would expect to expect that his illumination would kind of slowly change as your travels across the image. You do not expect any sudden sudden variations.

Whereas the reflectance that is typically a fast way to be fast reading it, because the because for example, when you could have meant the underlying underlying scene intensities, could be it could be really rapidly varying depends upon the material characteristics depends upon, depends upon what is called its own albedo, and so on. And, and then, typically, there is no reason to believe that that you should have a reflectance that would not, that would not be no that. So, so so it is normal to assume that that reflectance, reflectance is fast varying.

Now, if you come back here, so what this really means is that now now because of the fact that there is a product right of course, when you like to do some kind of processing on f it can order to be able to remove the effective illumination, you may not be able to completely remove it, but then you would like to see decrease its effect. What are what is called as ameliorating the effect of the changing illumination?

Now, now, what is done is the following that because of the fact that there is a product, you would (di), you cannot directly apply Fourier transforms. Because you could apply then it could really lead to anything meaningful. Instead, what is done is you apply the apply the natural logarithm on both sides of that equation.

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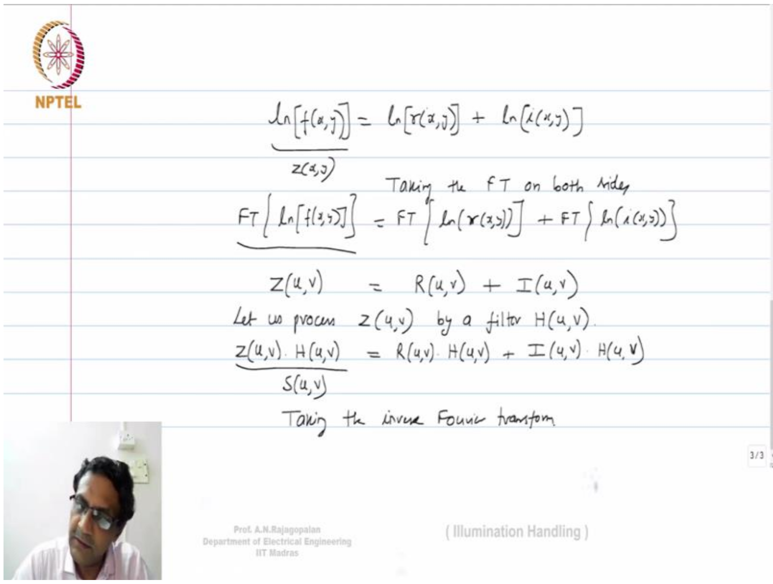

So, in that getting log of f of x, y, and end up getting log of x y is equal to ln of r of x y plus ln of i of x y. This is what was little amount after you applied if you take the take the natural logarithm on both sides. Now let us call this as z of x y. And now that now that you have been able to convert the product into an addition, let us take the Fourier transform, taking the Fourier transform of both sides on both sides will give you something like let us call the after taking the Fourier transform, let us call this a z of u comma v.

Or let me kind a write this as, we will let us write this as Fourier transform of ln of f of xy is equal to Fourier transform of ln of r ln of r of x y plus Fourier transformer of ln of I of xy. And suppose this Fourier transformers causes a z of u v, let us call the Fourier transform of this as r of uv. And let say, the Fourier transform of of this is for example, I of u v. Now, let us process that this process, z uv by a filter h u v that I will tell you, I will tell you what, what kind of characteristics this filter has.

But right now, for the time being, just just assume that there is some h of uv with some frequency response to filter. Now processing, this will mean that you just multiply h uv weight on both sides. So, you get into h of uv is equal to r uv into h uv plus I uv into h uv. And we will see what kind of characteristic this does h should have. But for the time being, let us simply say that we have done the processing.

Now, let us do the following, let us call this as s uv. Suppose, this is s uv Now taking the Fourier inverse or taking the inverse Fourier transform, taking the inverse way transformer know that we have done we have done the processing.

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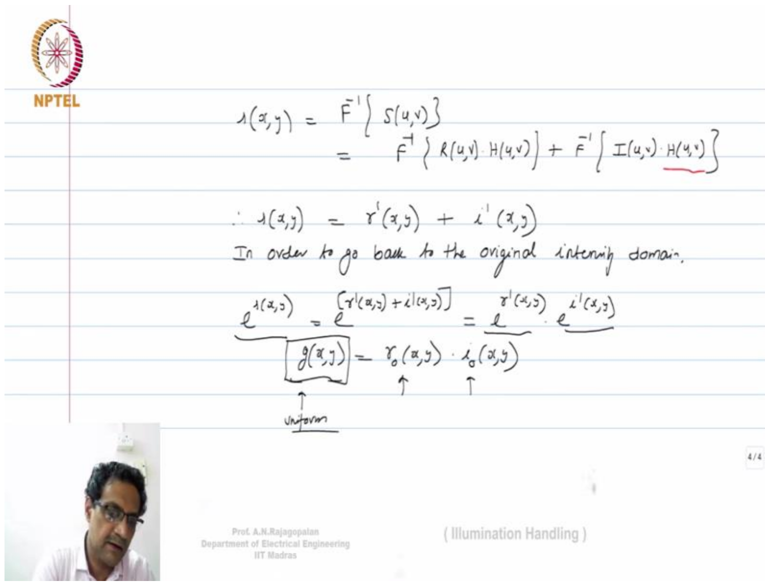

Now, taking the inverse Fourier transform will mean that you will get let us say s of x comma y is equal to 48 inverse of s of uv where now s of uv, As we indicated before, it is simply the quantity here. And this in turn will be equal to 40 or inverse of your r uv into h uv plus Fourier inverses of I uv into h uv. Therefore, you will have s of x comma y, let us say the Fourier inverse of this, let us indicate this is r dash of xy. And let us call this as i dash of xy.

Now, we are still on the and he should get a note that that we took a natural logarithm in order to arrive at all of this. Therefore, we need to get us to do the do the inverse operation in order to go back to the original domain. In order to go back to the original intensity domain in order to go back to the original intensity domain, original intensity domain, we need to do exponential of this quantity because at the time we took natural logarithm so, so we should revise this quantity so as to an exponential there is why it is called Homomorphic.

So, so it is kind of what we what we did at the beginning when we are applying a similar operation the, the inverse of it in a sense in order to be able to go back. So, e power s xy is equal to e raise to r dash xy plus I dash xy. And this was can this could split to e raise to r dash xy into e raise to, e raise to I dash xy. Or we can rewrite this as some let us say let us call this as what do we want to call it let us say that this is of a g of xy and this is equal to r naught of xy supposed because this is r naught this quantities r naught these quantities I naught into I naught of xy.

So, now what we observe is g of xy now. And since you have this kind of say processing, of course we do not get to get to see these individually, but then having, having read done this kind of processing is equal into doing something like this, which in turn is el g of xy. So, g of xy is what you will what you will see.

Now the hope is that g of xy will capture with capture reflectance and would have and would have taken care of the illumination component in the sense that it should have it should it should this should look look uniform, close to being uniform. Now, all of this hinges upon what this guy does. So, all of this depends upon what was his h uv look at that we have used. So, in order to understand what is h uv looks like, it is a kind of a standard filter give the so what is homomorphic filter.

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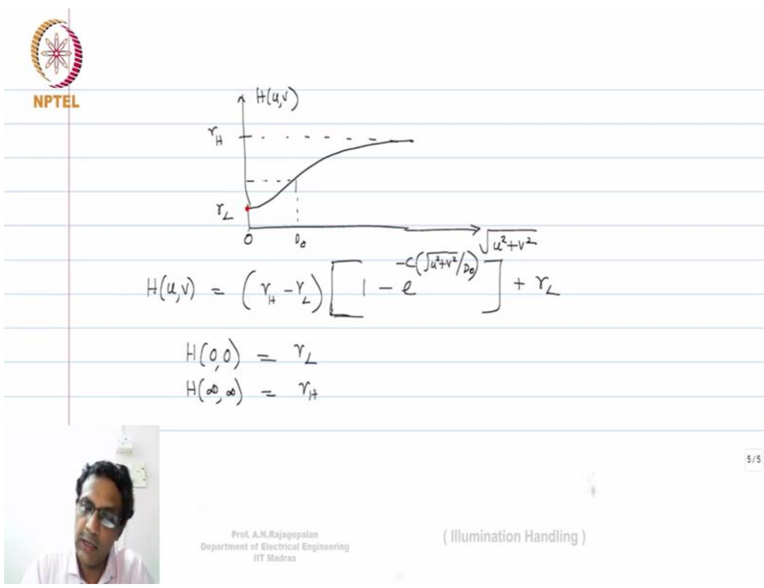

And the filter, filter characteristic the frequency characteristic, so, this filter can be drawn like this. So, this is a h uv and let us say suppose I call a one d axis let me call this as u square plus v square And the way this takes values is that it starts from some gamma L and then goes all the way up to gamma H. And somewhere here, it is some quantity called d naught which again, I will explain what it is.

And, and this h of uv, the expression for h of uv looks as follows. This gamma H minus gamma L this is a standard homomorphic filter of (())(12:47) into, into I do not what is happening let us see into 1 minus e raise to minus root u square plus b square by d naught plus gamma L plus gamma L therefore, H is 0 comma 0, H is 0 comma 0 if you substitute 0, u is equal to 0, v is equal to 0 then this goes away and you get gamma L.

Which is the point here this gamma L and then when you do h of infinity comma infinity that very high frequencies this goes very big gamma minus gamma plus gamma therefore, you get gamma H. So, so, at high frequencies you hit, you hit this gamma H, the low frequency that it shows 0 comma 0, 0 comma 0. So, 0 comma 0 so, this u square plus v square therefore it is called it as 0 and from 0 you get gamma L.

Now, there is also one C here which I forgot if it was minus C times c times rooters u square plus v square d naught. Now the role of this d naught is such that now, for example, if you notice here, when, when this when the root u square plus v square equals e naught. So, this expression when this equals d naught then you get 1 minus 1 minus e raise to minus C and now the values of gamma H gamma L and C.

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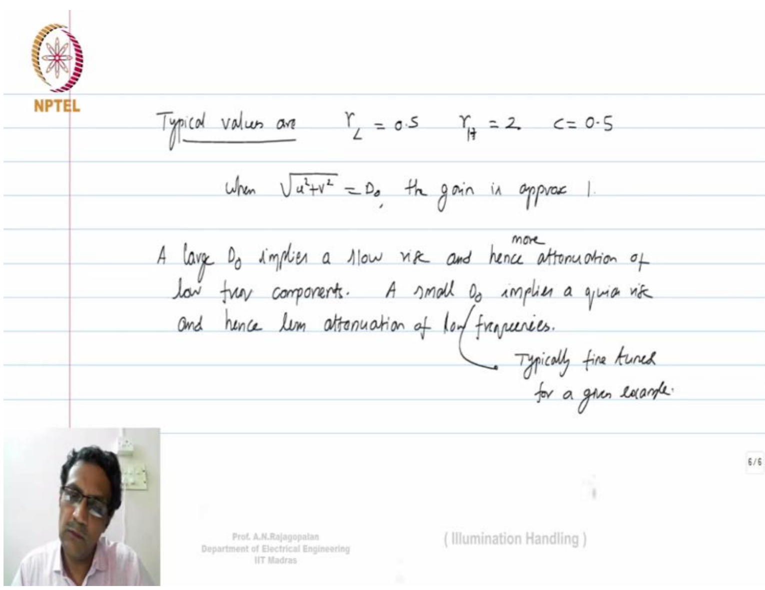

Now, the values of gamma H and gamma L are typically chosen as typical values these are again typical for a homomorphic filter, typical values are gamma L is equal to 0.5 gamma H is equal to is equal to a and c is equal to minus of, c is equal to 0.5. Now if you can plug in these values what you will realize is that when, when root u square plus v square equals d naught at the time you get 1 minus e raise to minus C and if you put c equal to 0.5 and then you have gamma H is equal to 2 and gamma L is equal to 0.5, gamma L is 0.5 we solve this what you will realize is that when, when root u square plus v square is equal to d naught the gain is about 1 the gain is approximately 1 after that of course, it will start to increase is approximately one.

Now, so, it actually means that at this point that we have we have approximately a gain of 1. Now, this read d naught is some kind of a lever d naught is some kind of a handle which you have. So, it does so, what does actually means is that if you choose your if you choose your d naught to be not to be to be large, so a large d naught. So, again d naught, d naught is something like a hyper parameter you can choose it a large d naught implies, implies a slow rise, slow rise because it is 1 minus e raise to minus the exponential rate.

So, slow rise and hence and hence attenuation of and hence attenuation of low frequency components more and more attenuation of low frequency components a small d naught on the other hand d naught implies a quick rise, a quick rise and hence less attenuation, less attenuation, attenuation of low frequency components of, of lower frequencies of the low of lower frequencies.

So, so, so, the as soon as d naught has to be so, the d naught 2 is typically fine tuned for an example for, for typically fine tuned for a given example typically fine tuned for a given example so in order to see appreciate. So, in order to appreciate this now what we can do is we can actually take a take a look at our homomorphic filter example. Let me just see that if I have one for you to one to show it to you, there we go, homomorphic filtering example, if you see this,

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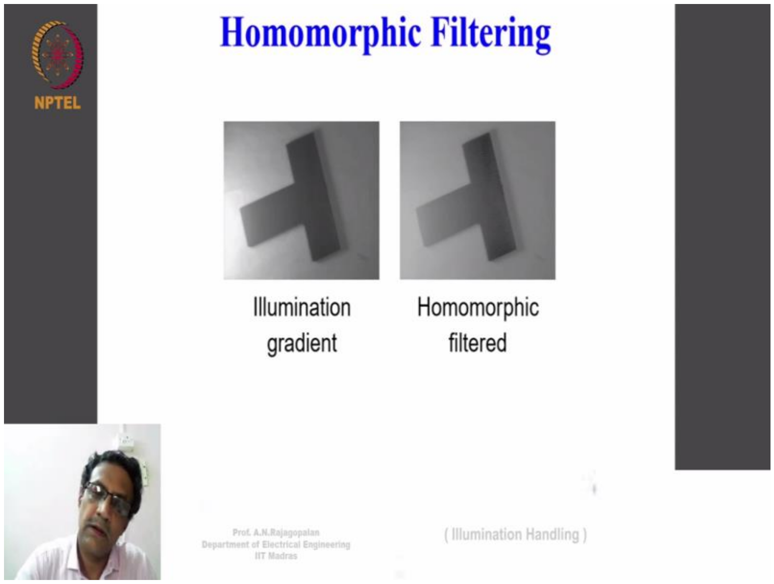

I think this image, so if I did this image, you will notice that that it on the left is an image that needs to be compensated for illumination because the light source is very strong at this point it is it is action is very strong and then the intensity kind of fades away as you go away right from the side. And therefore, if you apply a homomorphic filter of the type that I just now explained, what you get is a filtered image that looks that looks more or less uniformly illuminated for this may not be a perfect kind of illumination composition, but it works very well it is simple and read it can be fine tune, to work for work for a nominal given example. So, that that is the that is the nature of homomorphic filter.

Now, for those of you who are interested in knowing what is the latest, the latest is what are called Adaptive, Adaptive histogram equalization algorithms where you break down the image into see different regions and then and then perform an on histogram equalization region wise in order to in order to make the make the illumination model is uniform, across the image that again variants of that there will be various that have that have not that have been advocated what are called contrast limited adaptive equalization and so on.

So, for those of you who are interested, you could actually look at look at those methods that are that are kind of most recent and which are, which are being used now in order to handle illumination variations inside an image. Now, now read so far as image enhancement is concerned that we covered what I would say kind of low level topics in the sense that we talked about Change Detection, we talked about Thresholding. We talked about we talked about Segmentation, we talked about the Clustering it and then we talked about Noise filtering, we talked about Illumination compositions, all these are going to low level tasks.

Now, research wise if you try to see kind of things are going on and one of the things that I thought I would just highlight for you people just to appreciate, so what is going on on the see the search front? I am just going to show you show you a few examples of what is called what is called in painting. So, in painting in a way, this is again an image enhancement technique.

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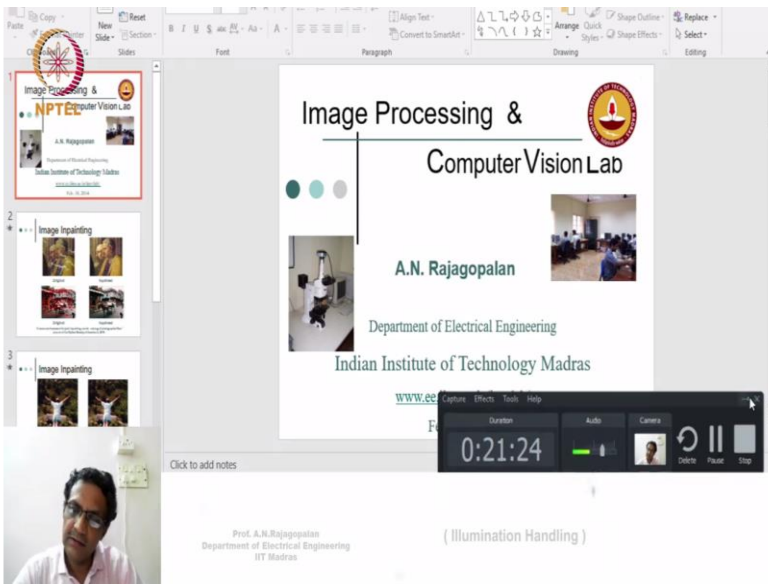

So the so the idea is that, idea is that I mean, if you have something like this, for example, in this case, in this case, let me just go and go to the next slide.

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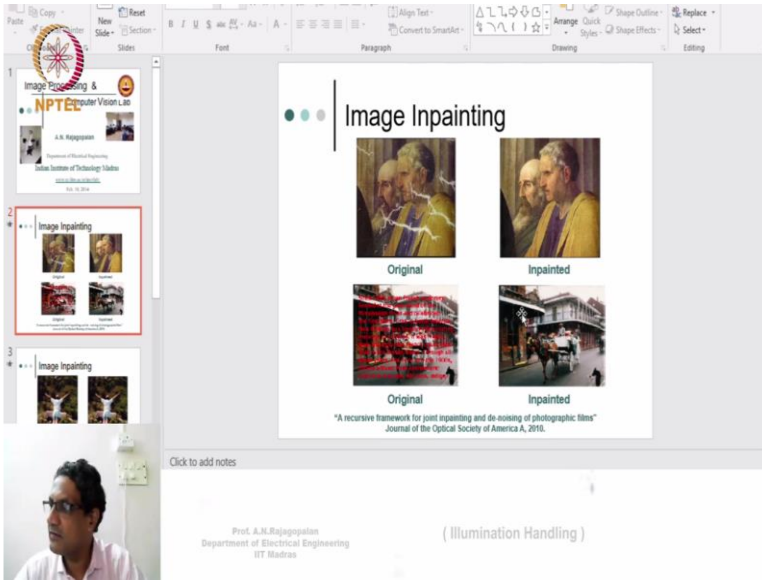

So, for example, see this image, that you see on the left, get this image is kind of not a lot of information that has been lost, maybe it will be greater than others, because somebody stashed a photo inside the trunk for a long time, it forgot who forgot to take a look at it. And therefore, it may take the image out, it has been attacked by that by insects, roaches and so on.

And therefore, what you find is that there are several blotches and streaks and all on this image, and you would like to fill this information in a manner that after you fill it up, you are not able to make out that somebody has actually filled it up. Similarly, the second image is, again, something red, which, which of course not no, which has just kind of a different kind of degradation, in the sense that there is a lot of running text icons image and which is a little annoying.

So, enhancing the visual appeal of this image is equal to saying that can you fill out the text such that it can borrow from neighboring intensities, whatever the scene intensities can borrow from them. So, I should be able to give you a picture, when which will which will be which will be, which will be, which will be without this text. So, as both of these are, both of these are Inpainting examples and the whole idea behind this behavior in painting is to be able to to be able to fill up lost, lost intensity information.

Now, after you in paint, what you see is this kind of image, and clearly, you can see that all entities is being very nicely filled up. It is even hard to even know hard to know as to where the inpainting has been done. Similarly, if you look at this image after you filled in the text by borrowing from neighboring entities, again, that only one dimension, how only this, this degraded version with you, and you are supposed to fill in these fill in these blotches.

And again, here, this text has to be filled in by borrowing from neighboring values, which it has been able to do very well. And some people might say, might actually like this image rather than this. In fact, that is often seen in movies in the beginning when they tried to scroll text on the scene, sometimes it is a little annoying, and then you would want to cut somebody not remove that text for me. So, inpainting can actually do that. So, inpainting is a typical image enhancement research problem. I can show you a few more examples it does not end with this.

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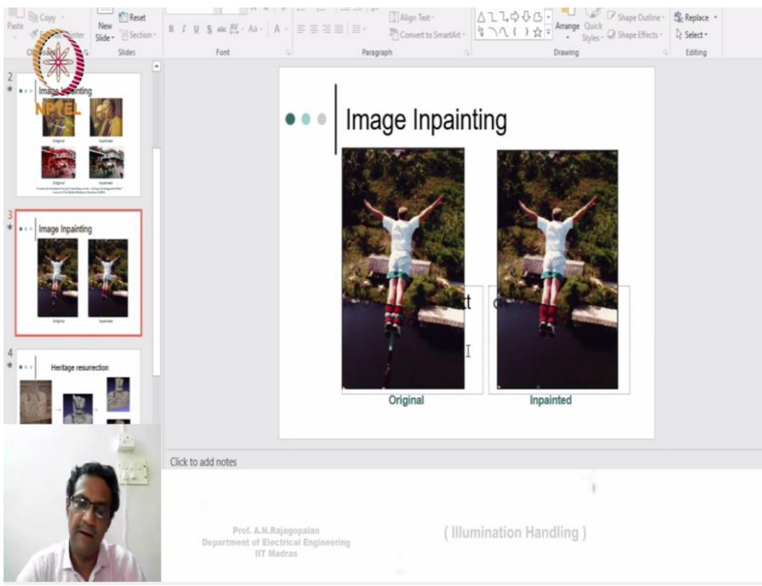

You can also you can also do a little kind of fancy things. See, for example, here is a guy read who is still doing a kind of see bungee jumping. And if you want to show you this is a brave guy, what colors you could inpaint the ropes so that the knot looks like the rope is simply not even there, so basically people even do it for fun. So, so it gives, gives, gives a sort of a Macho feeling. That Yes, now I can do things like this.

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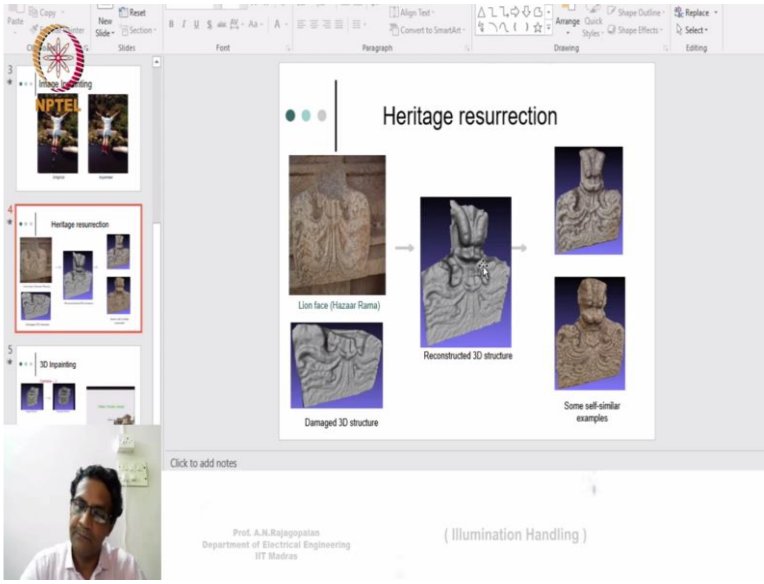

Now, yet another thing, that that you could do inpainting that know that we in our lab have done this what is called what is called 3D ipainting, early on that issue solvers was actually Dd in painting. In 3D inpainting, what you have to do is you have to generate a point cloud, it is more like a structure. It is kind of it is kind of a 3D information, if it is a point cloud. And the whole idea is that, you know, if you have been to Hampi, which has the UNESCO heritage site, in India, if you go to Hampi, then you find that, right, you have got several of these of these sculptures that have been broken, and, and broken in a manner that, that that kind of a glove that kind of takes away the sheen for those sculptures.

See, for example, it does not have to see the sculpture at its whole head is gone. And the whole idea is that can you kind of fill in missing information like that, in order to be able to give maybe somebody a virtual walkthrough as to what the statue might have looked like. It is not at the point, at some point determined, it was actually originally intact. Now doing that is not easy, because there is no neighboring information from which you can borrow in order to be able to fill this up, fill this point cloud.

Therefore, it was know when we, when we actually when we actually executed this project, as a VST project. So, that what we did was we went around it luckily, what happens is in Hampi, architecture known the rocks like these are sculptures like the like this, which are important they are not there is not just one but there are many of them. For example, look at this, the one on the right there are these two examples that are shown here, there are many more like that. And, and all these look very similar to the one right there has been no what has been vandalized.

So now, the idea is that, you kind of construct 3D Point Clouds of these objects of these of these other, other sculptures that you have with you. And what you do is you can have and then that information that 3D Point Cloud you port onto the one that is broken. So the point for this guy is broken. So, align these point clouds and use a tensile voting approach in order to be able to fill up this head and you can actually fill it up pretty, pretty you can see decently, not a to be able to show up, but reconstructed the reconstructed 3D structure.

So, this structure is called inpainted now. So, this is an Inpainted 3D structure. And you can see that I mean and you can see that it has a significant effect.

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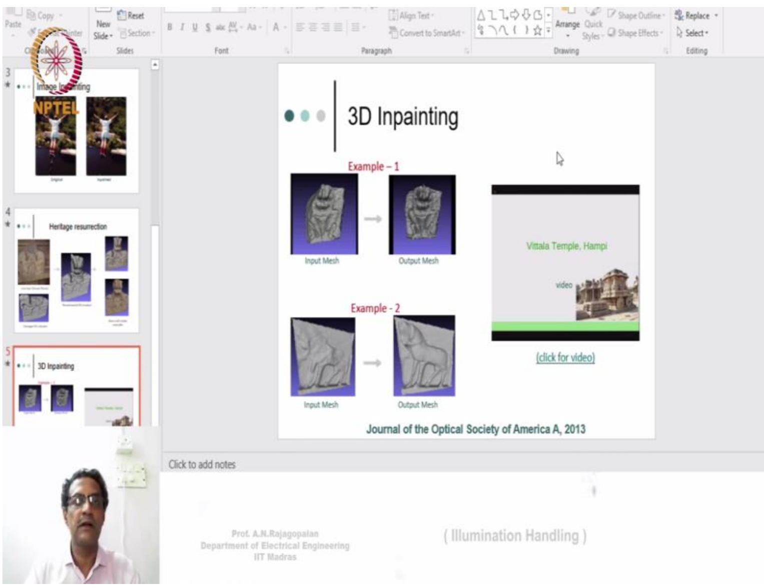

And you can actually do and you can actually do similar things, even for other objects. For example, here is a horse, which has been 3d inpainted. And then and here is here is actually a Narsimha statue whose shoulder was broken, and that shoulder has been reconstructed using again, something as 3D inpainting.

So, so so in a sense. So basic 3D inpainting is again, something that, that that is very advanced in terms of the research in the area of image enhancement. I just wanted to show this to you. So, that you get an idea that now that we made, that image enhancement is not just something that you can do at a low level, when you can actually you can actually elevate it escalate the research challenges, in order to solve some very hard problem something like 2D and 3D printing and so on.

(())(25:59) our are aimed at enhancing the visual appeal. Again, it is a subjective matter, for example, historians and, and, and the culture people. It may not entirely agree with this, they may say that the original thing should have been maybe it was something else maybe that we have not been able to able to see capture all the findings that we would have liked to, so in that sense that there is again a notional subjectivity here.

But the point is instead of having broken statues, you can at least make an attempted, you can at least make an educated guess as to what might have been there and be able to reconstruct and then show to this world has to know how these things might have looked like.