Image Signal Processing
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Lecture 02: Applications of Image Processing – Part 1

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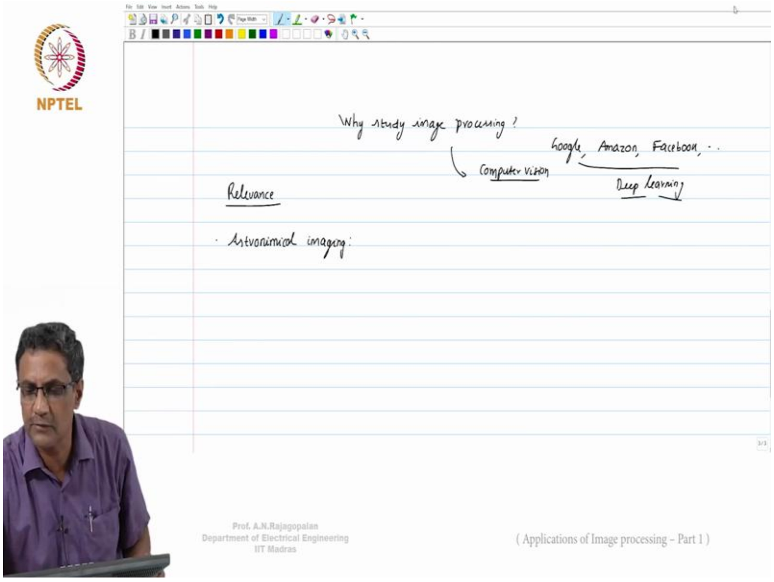

Now as far as why study image processing, so relevance. So if you really wondered that who are the people that probably first who are the most heavy users of image processing, who do you think would that have been? The folks that probably depended on image processing a lot, early on. I am not talking about last 10 years or something, I am talking about long ago, 30, 40 years ago maybe. And who do you think might have used it the most?

Student: (())(00:48).

Professor: Astronomical people. The people that were doing astronomical imaging. For them it actually mean, you know it actually meant a lot because when you actually send, when you send the space scopes and all, when you feel that you have to, you have to capture images of a hubble, when you want to capture images of things that are very far away, and then you send these space scopes.

And what can happen is along the way, something can always go wrong, in terms of the optics, because of the vibrations, whatever. Things which are not under your control. When you actually set things up here, it all looks very fine. But then when this thing is send and it has already kind of traveled billions of miles away, and then it starts to send back these images and you certainly find out something is not right with those images. And how do you know that?

For example, you have never, never seen that part of the world, part of the not world, you are not, you are not been to that part of the universe but you still have, as a human being we are all smart. In the sense, somebody gives me a picture, and I can still say whether this image is probably or something is wrong with this image. I do not really expect it to be like this. Perhaps it is not sharp, perhaps it is an oversaturated. Something is not right. So, so we have this feeling that this image could not be the right image with respect to whatever it is imaged.

So in such cases, it is impossible for somebody to go from here to fix that problem and so it is impossible. You cannot really bring it back either. So in order to save all that money, that otherwise would get spent, so these people or, or the entire, entire thing would be kind of called a failure, because whatever it is said, this is no good. So in such cases, what is done is at the earth station, people will develop algorithms wherein let us say you try to, you try to undo whatever has happened.

So there has been a degradation, then you try to undo it. While a whole idea is, if we can undo it reasonably well, and again you have to basically apply algorithms that you, that you think make sense and then you undo and then you see a picture which you think is correct, then you know that, then you know that whatever it is sending, you can still salvage all of that. For example, so throughout this course as far as possible I will try to show you examples that will actually give you a feel for what I am saying. Because like they say, unless you see a picture, any number of words is not enough.

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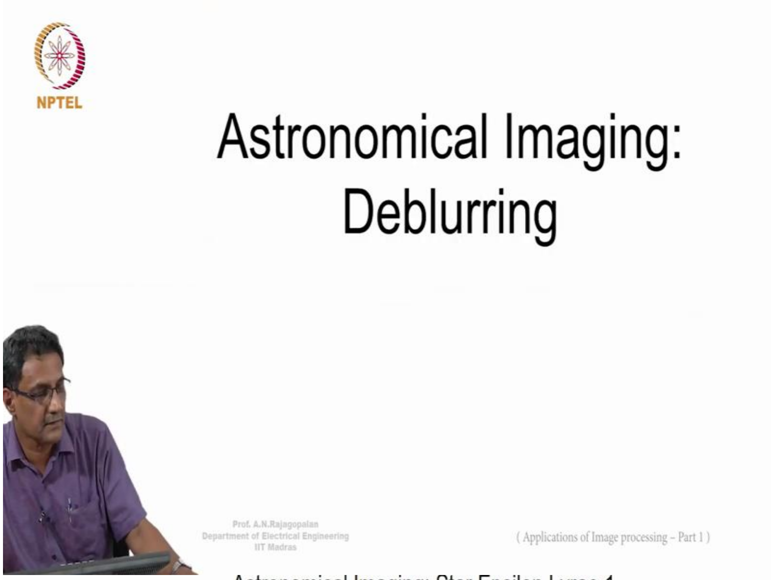

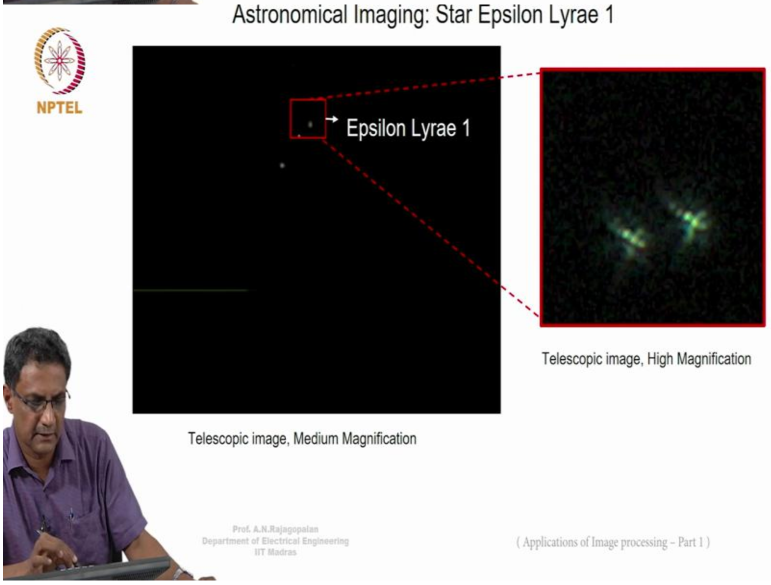

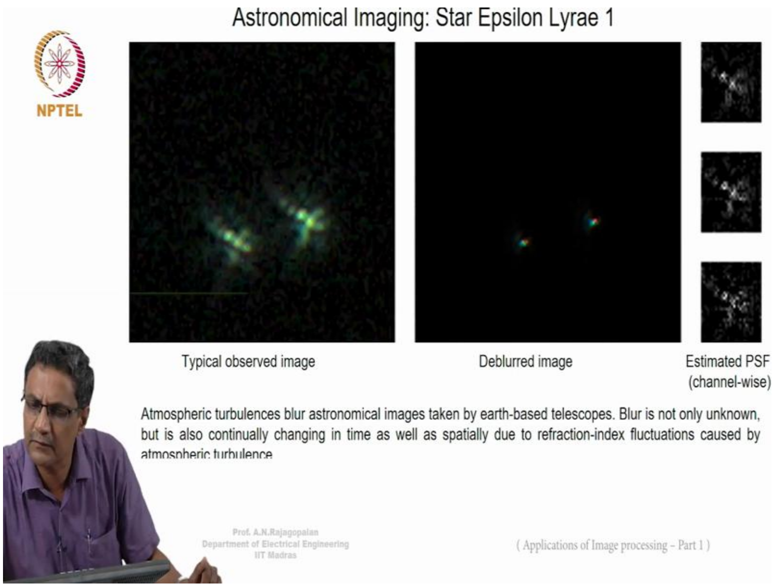

So, let me just show you this first, first set of slides and then as we go on, we will also see others. So for example, astronomical imaging. That one of the things that they like to do is deblurring. So for example, this is supposed to be a, supposed to be a star which is called Epsilon Lyrae. And if you, if you look at the image of the star, actually it is supposed to be two dots. It is not just one, I mean they are actually supposed to be two dots apparently like the one here and here. And then when you image, what you actually end up seeing is something like that, which is actually a blurred picture.

And then the idea is that if you were to do a, to do a deblurring, then what you would find is that you will find something like that. Now so the idea is that you can, and the time is not of your sense because in these things it does not matter whether you do it in real time or not, because as long as you can do it. There are applications where you might say that I need to be able to do it in real time but, but now there are several especially in astronomy and all, people do not really worry about the time.

They do not really worry about, worry about how many hours it takes. All that they want to do is if you can, if you can identify what has gone wrong if you can mathematically model that and if you can undo that, then it is fine. Because after that all the images that are being beamed, that are being beamed to you, you can salvage all of that. So astronomical imaging is one and where some of the other things that let us say one can actually do is….this all requires a little bit of practice.

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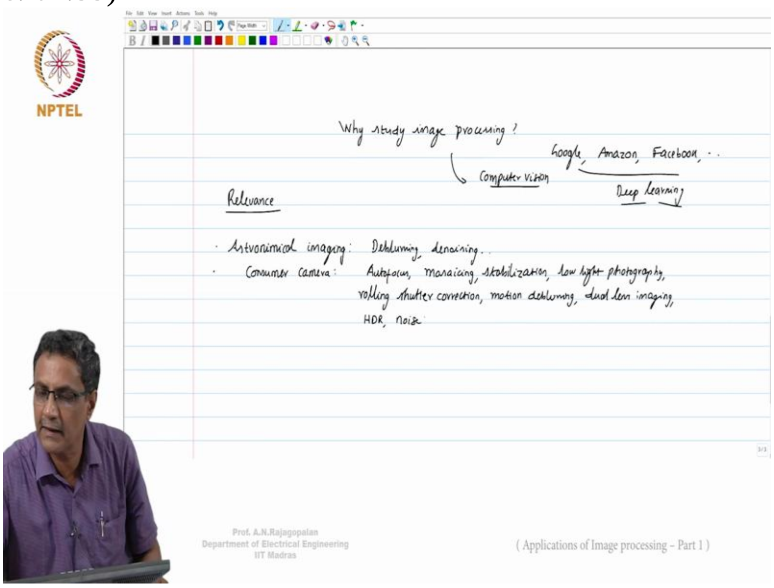

So, deblurring is one thing that they, that they have always done. Then denoising and so on. Then the second application that I would like to point out to you is what are called, what I think you are all very familiar with, which is a consumer camera, which is something that is handheld and then we all like to have them wherever we go. Now some of these things we will actually do, for example, denoising, deblurring. You may not actually do it for an (astronomy) astronomical image, but you will definitely learn what does it mean to say deblur, what does it involve, why is this problem will post and so on.

So consumer camera again, there is something called an autofocus which you all know. That is again it is not automatic. There is an, there is, there is some amount of image processing involved which again is something that you will learn while we go through. Then the other application is actually a mosaicing which I am sure you all heard about. That is to stitch a bunch of images which I think you all do probably, day in and day out, wherein you want to, you want to acquire a wider field of you.

You have a camera that has only, only a fixed field of you, but then you want to go to the beach and then you see it expands the way you see it with your eyes. But then when you actually take an, take an image of it, this looks like, looks like a small little thing. So when you want to expand the field of you, you want to be able to put, so you kind of sweep the camera. What do you do normally? I mean you will take it and then you will sweep it, what is called a pan motion.

So you can actually pan, so you have a sequence of images and then the idea is that, and during the sequence what might happen is, it does not mean that everything will come very aligned, because you cannot, you cannot hold your camera such that it will do, it will undergo only one kind of motion. So it might, it might go a little forward also, it might come back a little bit. You may try to do it like this but then it is not entirely in your hand. It is not entirely, when you do that, you get a bunch of images and then you cannot directly stitch them like that.

So you want to be able to align them so that, so when you actually put them all together, you get a feel for a wide field of you. So this is available in all cameras but then there are certain, do you, suppose I ask you, are there, I mean there are still things that it cannot do. What kind of things can it not do? Let me just, let it not be a one-way track where I keep on talking and then you are just listening. And so this stitching, do you think that certain things it can still not do? I would want you to go and check this. (When) When will it fail do you think?

Student: Through rotation.

Professor: Through rotation, no, need not fail.

Student: (())(07:09) the images.

Professor: Well, yeah, it is correct. That is a fair enough answer if something is moving. Suppose I assume that everything is still, even then something can go wrong. Assume that the scene is completely static, even then something can go wrong. For, for what kind of scene can things go wrong?

Student: (())(07:29)

Professor: No, no. See, it is like this, see, if you actually go back and check your camera, you will notice that you are able to, you are able to stitch these kind of, these kind of images provided they are sufficiently far away from the camera. You try something which is very close. Like for example, here, in this classroom suppose you keep somebody here, somebody is sitting there. Of course, people should not be in the same one line. One guy will include everyone else.

And then suppose you have a 3D kind of a scene. And then if you are translating, then, then you would all know that there is something called a parallax. A parallax means our eyes function like that. Why do you have a pair? Because, because when I, when I actually look through this eye, I get a certain image. When I look through this other eye, I get a certain image and then the way these image points are moving, is all a function of who is where.

For example, this guy at the front, this boy at the front, his image will move a lot more because he is very close to me. Whereas that girl at the back if I see her image, it would have hardly moved in the two images. That is called, that is this stereo effect which is a parallax. Now that kind of parallax when it happens, you cannot, you cannot directly stitch, you cannot align the two images with just one transformation, because he requires a different transformation, she requires a different transformation.

So all this mosaicing algorithms that you see in your cameras are all those are kind of the simpler ones. They just assume that the world can be assumed to be flat. Or the only other way that you can do is you do not, you do not move the camera, you simply say rotate, then it is okay. These things I will tell later why rotation is okay but not translation. These are things that we will talk about later but I am just saying that some of these things you would have realized but do not think that all these are solved problems.

There is still a long way to go. Fortunately, otherwise you all would have the jobs. So fortunately, there is still a long way to go in terms of bringing these things to fruition. Then stabilization is something that you would have heard. Stabilization is like if you have to, if you have to, there is a small shake in the camera which is not intentional, stabilization actually accounts for those effects.

Low light photography, this is again very interesting. If you see all these guys that they try to sell their cameras, one of the things that they keep harping on is, low light imaging and all. So that is again something which is very very fundamental because the entire image formation, if you look at the noise that underlines it. It is kind of short noise because you are, because you are trying to get in photons. You keep the window open, you are trying to acquire as many photons as you can.

Each sensor pixel that is sitting, each sensor element that is sitting there is trying to acquire as many photons as you can. Now when there is a low light, and there is an uncertainty in how many photons you can capture. Even if you keep the time fixed, if I take it today for let us say one second, at a sensor element how many photons do I get? And after let us say 5 minutes, I again expose for one second, the number of photons will not be the same. Always an uncertainty because it is an arrival process.

So, so this short noise what it will do is, we should see images where if you have a short noise, if you have a low light, then the uncertainty actually will be higher. That we will see. It is called sort of signal dependent noise. It is not like your AWGN. This is a signal, this is a function of the signal strength itself. And when the signal strength falls, noise level becomes more and more, more and more what you call rare. So the noise will be more and more strong.

So low light photography is one thing. Then there is something called rolling shutter, this is slightly advanced. We will not actually talk about these things but rolling shutter is what, is what all your cameras have by the way. Most of the cameras that you are carrying have a rolling shutter. If you are, if you are thinking that all the sensor elements get exposed at the same time, you are wrong. What happens is there is one row that gets exposed and then after a delay the second row comes on.

After a delay which is simply the read time, the third row comes on and so on. So as long as scene is still right, you will not feel anything. It will just look as good as the image that you have taken with a still camera. But then if some motion happens, and what happens is not all row see the same motion. So the rolling shutter is something very strange. It can actually, it can actually bend a light into a curve which does not happen otherwise at all.

We can never with the camera bend a line into a curve, but rolling shutter effect can do it. Unless, I mean then there are other effects like your (())(11:47) distortion, those are something else. But I am saying if otherwise if a camera is ideal, due to motion you can never bend a line into a curve. But then a rolling shutter camera can, in a rolling shutter camera it can happen and that is why there is something that let us say people….there is again an unsolved problem trying to…..what is this called? A correction. Rolling shutter is called a correction.

So all these are things that you will find, these are not yet there but then these are all very advanced things that are right now happening. As I am speaking, there are these papers that are being written on how to do rolling shutter correction. And then it will not be far before these things get translated into a camera and then they start, you start seeing their effects. Then motion deblurring, which is again a very very common phenomenon. In fact, in fact I find it strange.

Whenever, whenever of course not that I have a great camera, I have a camera that is five years old. But then, if I have to take a sharp picture, especially if I have to send my student something which I have done a correction, they want to send me back a smart, a sharp picture. The moment, the moment you take it in your head that you want to capture a sharp picture, that is when it will always come out blurred because you are just overstraining yourself to capture something very sharp and then some shake happens and then it just goes off.

So the motion deblurring is more common because your cameras are all very light now. If you had a heavy camera, it will not shake. But all of you love to carry one phone, two phones, three phones in your pocket for God knows what. But then the more lighter they are, you see problem is, the shake is also very very common. So motion deblurring is another thing this is still not implemented in your camera. Please tell me if you have seen a camera that does, that does an automatic sort of a deblurring that can sense that there is a motion and it ought to deblur. Then dual lens.

This is again something very interesting. Why they stop at dual lens? People have four lenses and all right now. So all these, all this simply to now to sort of enhance your experience. So when you have dual lens, it means you can have stereo effects which means that you can get a sense for the 3D nature of the world and therefore you can do a bunch of, bunch of other things. And then dual lens imaging. Then there is something called high dynamic range imaging, HDR. I will show some examples of this and then anyway noise removal and all that. Now let me just go back and now I have said too many things, let me just show you some of these effects.

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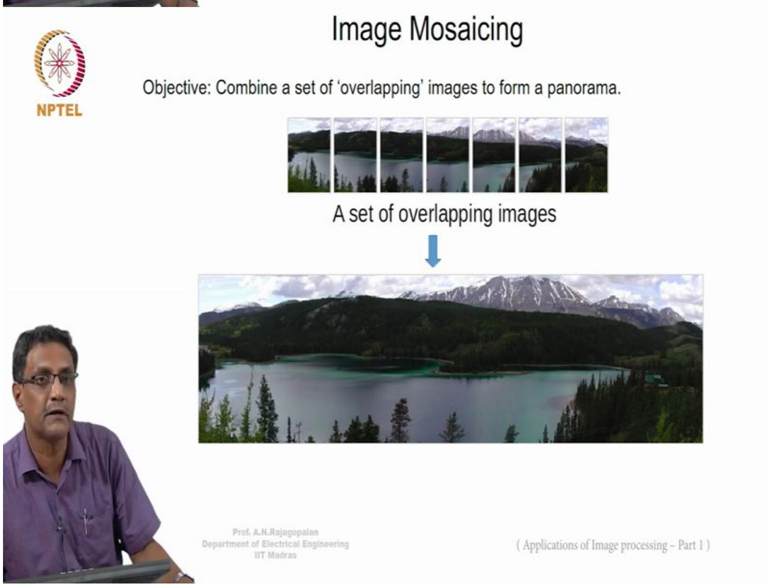

And after this, if you take, if you take a consumer camera, this is what you mean by stitching. You, you want to, you want to acquire a wide field of you, but then you have a camera, that can only do so much. That has only a limited field of you, so you kind of stitch them all together and again this is a lab assignment that you will do.

This is one of those assignments that you will do yourself in the sense that you will actually, I will want you to capture images from your camera and do it, not like, it is not like we will give you images.You go, find some images and maybe you even show when it fails. Like I said, prove that what I said was correct, for my sake.

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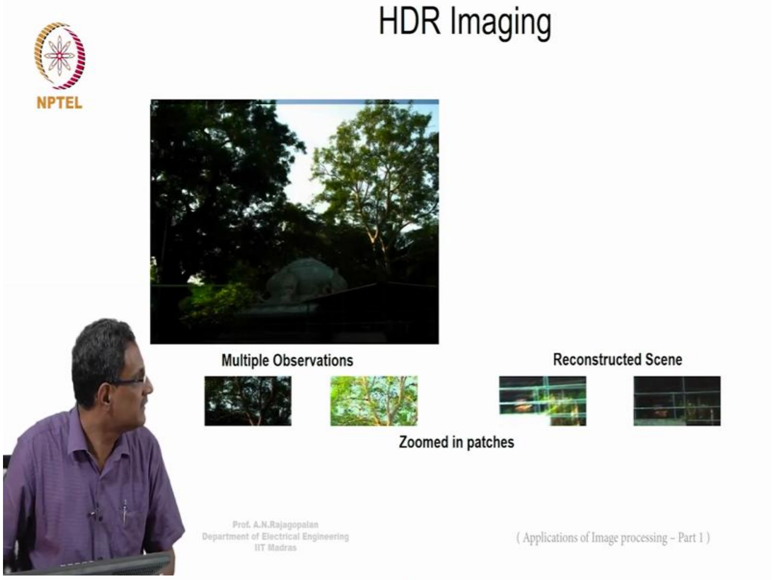

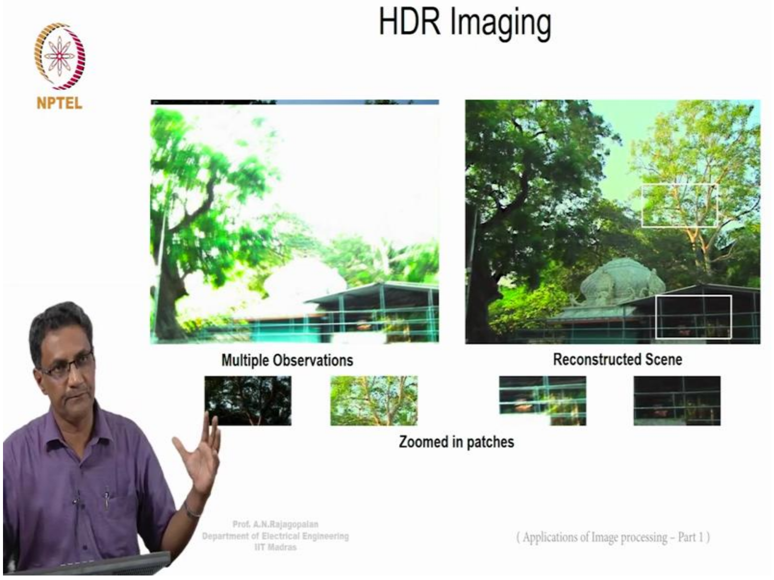

Then high dynamic range imaging. What does that mean? That actually means that when you actually take a, take a camera and so this high dynamic range involves, so if you have a fixed exposure, if you have a fixed exposure, what it means is that, see for example, as I am kind of sitting here and there is a light which is falling on me, it actually means that, it means that somebody on whom the light is not falling, he will appear dark and whoever, on whom the light is falling will appear bright.

But ideally, you would like an image in which let us say all of us are, all of us are uniformly illuminated. It is not happen that somebody is totally dark, you cannot see him at all or it so happens that you just shine so much light that you cannot see any light. Because then there is kind of oversaturation. We could saturate a picture. Have you seen such pictures? There will be some portions will just be totally saturated and then some other portions you can see.

Now with that image, you cannot, you cannot do much, histogram, none of these things will work because you fundamentally lost the information that is supposed to being captured. So in such cases what you can do is you, you do not stop with one exposure, you capture actually several of them. So, so when you capture let us say multiple exposures, so you start with a low exposure, go till high.

Then what happens that at a low exposure, things that are already bright will be all right. At a low exposure, in the sense that they will not saturate. But then things that are dark, you will not see. Then you keep increasing the exposure, what will happen when you have increased exposure sufficiently, then things that are dark will start to emerge. You will see them. But then things that are bright would have, would have already reached saturation. But that is okay because you have, you have captured them in some other frame, in some other exposure.

So the idea is that how do you now combine information coming from all these exposures together so as to be able to build a picture. Now here is an example. Do you get to know this place? What is this place? Have you seen this before? Either something is wrong with you guys or this is within the campus, this is called the Pilliamen temple. So all of you, so it looks like none of you guys go to that temple. Anyway we are not here to talk about that.

We are saying that this is something that is, and all the images that I am showing you are all real. So most of them are real and typically done within the lab, not the earlier one. That is mosaicing is not from the lab. This is from my lab. Now ideally, so, so you see that some of these pictures are undersaturated, no underexposed. Let us say underexposed. Then reasonably exposed, then something is overexposed. If you (comb), if you combine all this, what you would get is something like that.

Just one picture, which looks uniformly illuminated. This is called high dynamic. Actually, high dynamic range imaging means, means actually much more than that. That actually means that you can actually increase the, increase the dynamic range of your image. In fact, it is solved in terms of the radians that you get. But then in order to show high dynamic range imaging, you should have a display that can accommodate that many, that many levels. Typically, you will have like 2, 3 ray levels.

You will go probably up to 5, 12 but then high dynamic imaging actually means that you can go to, you can go to many more levels and you should have a display that should actually show it. All these are, this is all done after some kind of a tone mapping. What the tone mapping means is that you have several of these levels but then your tone mapping so that you can show it on a regular display. Those real high dynamic range you cannot show it on this kind of display and all, you need a special display for that. But this is explains the idea that what does it mean to do high dynamic range imaging.

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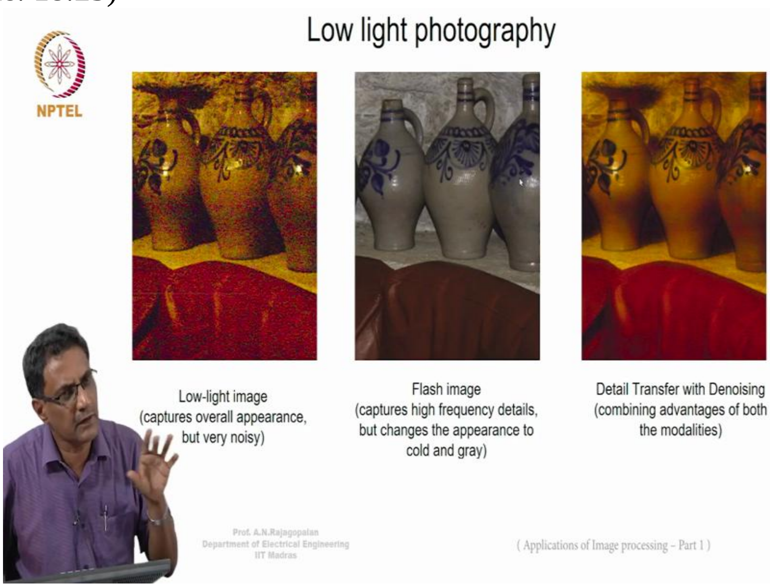

Now, let me go to the next one which is, this is like low light photography. See the one on left, that is actually taken in the low light. See the spottiness on the image, that is all, that is not really a part of the scene. Those are all noise, this is purely a short noise. And the short noise has, has several implications, which we will see down the line.