Image Signal Processing
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Lecture 18
Real Aperture Camera - Introduction

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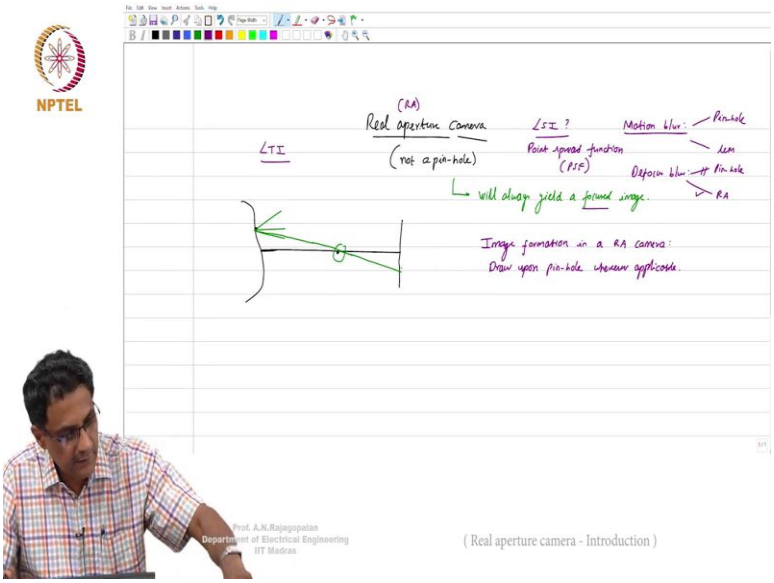

So, we were at this point where this is not view, but a real aperture camera, it is a camera. And the whole idea is that similar to the way you look at a pinhole image, we want to actually understand, how is the image formed in a real aperture camera, by real aperture yesterday itself I told you this is not a pinhole and the whole idea is that because one way to increase amount of light is to maybe increase aperture itself.

You can still have a pin you do not call it a pinhole but maybe (())(01:03) maybe increase a size of the hole and then say that I can let in more light then, but then what will happen? If you simply made the aperture bigger instead of a pinhole, like I told you yesterday that pinhole may actually means that out of all the rays that are coming out of the object like this. So, here is your sensor plane and here is your pinhole and you could have a 3D scene sitting there.

And what happens to you look at a point on the scene, let me where indicate by different colour that were point in the scene and then you know that there are kind of so many rays which are actually coming out of it. And only that ray which is able to pass through the aperture is seen by the image plane.

So, in a sense it gives you a dark picture. If you simply use it that way or you have to wait for a very really long time collect rate enough number of photons by this waiting longer, but then we you know that, one cannot wait for too long because one it decreases your frame rate and all that and secondly things could begin to move, while you are imaging and that will cause issues.

So, we said that we will go for lens, so one of the things that you could ask is why not we just make this aperture bigger that would mean that you will end up with an image which will start to already look blurred. Because of the fact that some of these rays that are coming out it is no longer true that they will hit one point. So from one scene point multiple rays come out and some of them could actually hit adjacent sensor pixels and therefore we will see an averaging effect.

One of the nice things about a pinhole is that whatever be the scene whether the scene is planer, whether the scene as 3D it does not really matter everything comes into focus, just have to wait longer so as to be able to collect enough number of photons. And if you can afford that then you get a picture that is always, so pinhole will always yield a focused image, always yield a focused image

You can never see a defocused image with actually a pinhole camera. So, this focused image is what is important. Now what we are saying is all right, so we know that we cannot really just arbitrarily increase the aperture size and all. So instead of that what we say is we should actually bring in a lens. Because then a lens can collect these rays and it will focus them. Because you cannot see when these rays are coming in arbitraryily through an aperture there is no more to focus them. They can just spread all over the all over the scene.

So, instead of that what you could do is you could actually make some system such as a convex lens that will actually make this rays, come to focus at some point. And then and then it looks like we are done. Because now we are collecting more rays, so we are gathering now as much intensity as we could.

And the idea is that now you can actually you get, get an image that is going to be much brighter, which is actually lot more quick to grab and of course these are the kind of images that you see outside. But then one also realizes that when you capture with a camera with a lens, which is what all cameras typically have to see that not all images are focused even if you are still.

So when you talk about so there is a phenomenon called actually motion blur. Now, this motion blur is something that is common to both pinhole. So when I save it will always yield a focused image, what I really mean is that there is only no optical sort of this one de-focusing. It does not mean that we are going to pinhole camera we cannot get a blurred picture or something.

You can get motion blur, if you just start to move whether you have pinhole or whether you have a real aperture camera, there is the lens that will anyway happen. So if there is motion blur so this can, this will affect a pinhole image as well you know that is even if you are capturing through a pinhole simply because of the fact that you are moving and therefore multiple scene points will get averaged or whether you use a lens or a real aperture. This I will call the RA Real Aperture camera.

So whether you use a pinhole or a lens motion blur is something that can happen in both depending upon what is moving who is moving and so on. But as far as there is another thing which is called a defocus blur which is not something that will happen in a pinhole. This can never happen whereas a real aperture camera it will happen. Again, it did not always happen does not mean that every image that you capture with a lens is going to be de-focused. Depends upon what this, what does particular camera so this real aperture camera what kind of scene it is actually looking at.

So, the whole idea behind now so the way we now want to kind of shift these gears is such that we understand what are it, what kind of pinhole, what does a pinhole model mean and what does it mean to capture an image with a pinhole camera. We want to understand image formation. So our idea goal, it is really to understand image formation in a real aperture camera.

And during the process we will try to draw upon whatever we know already in terms of pinhole. So if there is a parallel that we can draw between what we have learnt in pinhole and we feel that some of those laws are still applicable here we want to draw upon them. And draw upon a pinhole where needed, wherever applicable or rather wherever not say let us not say wherever we are needed, let us say wherever applicable.

So, then it basically means that so, like I was kind of giving an example yesterday you go take a DSLR camera you capture an image you see a, typically you go near a flower or something and

then you want to image an insect or something. And then you suddenly see that the insect is in focus and everything else comes blur.

There is also some people do it for this artistic reasons. That such pictures look more real to people they feel that when you show somebody picture like that and they feel that is more realistic. The other reason is not simply realism or something simply because of the way this lens works that the whole image formation happens.

Now what you would want understand is how is that image formation going on and then during the course we would like to also understand just as right you have these things called LTI systems in 1D. We say that having a linear and the sort of a time invariant system this is somewhat ideal in the sense that I mean, if you have an LTI system, you know the advantages in the sense that they could be convolution that there is a convolution that explains all the operations.

And then there is an impulse response which helps with gives you all the window into that system. You want to examine stability you want examine causality whatever you want to do, all that there is just one impulse response that you have say defined for the LTI system and that explains everything then, going from a Fourier to the time domain and all so easier, going back and forward everything is invertible. So, many advantages if you see, if you look at an LTI system.

Now, if you look at a real aperture camera and suppose you look upon this is again an image. Similarly, if I know same thing also hold for actually pinhole, the pinhole is much more easy, along the way I tell you why what happens but what we are also looking at is what is called LSI just as we have something called the time invariance, in imaging system we have what is called the space in variance or shift invariance. Some people call it linear shift invariant. Some books call it linear space invariant.

So what it means is just as you asked if it is LTI, X of T produces Y of T. Then X of T minus T naught for whatever it for all values of T any value of T naught should produce Y of T minus T naught, and not Y of T minus alpha T naught or something it should be exactly T naught we do not accept anything other than T naught.

Similarly, we want examine whether a lens is actually such a system whether it is linear, whether it is shift invariant then because if it is so then there are some nice kind of say relationships that we can draw in terms of an equivalent of what we call as impulse response with respect to 1D systems.

We have something called actually a point spread function with respect to a 2D system, what is called a point spread function or typically this is referred to as a PSF point spread function. Now so the whole goal now as we move on is to sort of place these things in order. So, examine all of this and be able to explain as to why you see an image that you see and how do you going to relate that to the scene itself and you should be able to appreciate the fact that given this scene this what should have happened anyway.

So that should be no surprises in terms of what you see. There can be some surprises that may be I will talk to you about later but most of it should be very straight forward to sort of figure out. So with respect to that now, let us just move on and kind of and sort of look at the lens. Let me just draw this one figure and then we will take it from there I this such worn out paper.

Now, let me maybe draw it on the, here itself we will draw. So what I have what I am going to show is now so such like this. So the way I want you to understand is, now what we want to see is I have let us say I have a system like this, where of course this is my focal length and then I have a scene here. What will happen and then with a respect to this I see an image. Because this is like, a pinhole image.

Now, if I throw in a lens here all remaining same nothing changes. The scene that the plane nothing changes. I replace this with a lens. I mean not drawing it very correctly, if I now replace it with a lens I want to see what all happens now and I want to be able to explain as to how was this related to a pin-hole image if there is something, so that we can draw, if there is a relation that we can draw between the two. And secondly are there some other (() (12:07) principles in pinhole that will still be applicable here. And thirdly what is this, what is this image formation? How does the image formation change, when I replace the pinhole with a lens? That is a idea.