Image Signal Processing
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Lecture 07
Geometric Transformations – Part 2

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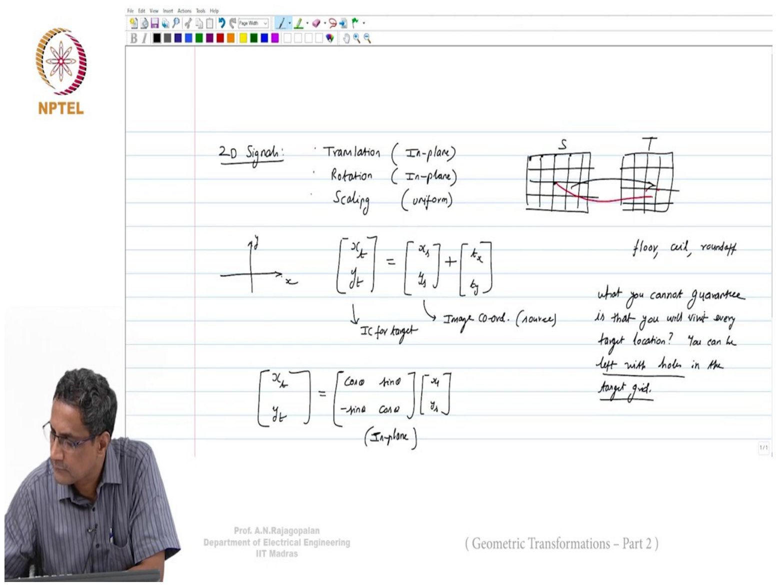

The last time, I was talking about doing a transformation, we are talking about doing what is called a geometric transformation. And yeah. So we are saying that, as far as 2D signals are concerned, as far as 2D signals are concerned, the most common things are, what you would like to do are, what is called translation. I mean, in the sense that what you are familiar with, it is probably what I would refer to as in-plane translation, this is what probably you have seen the most.

Rotation again, this is something that you would have seen as what is called in-plane. I will tell you what I, what I mean by in-plane. And then scaling, this is again something that you would have seen perhaps, what is called a, what is called a uniform scaling. These are things that you would have actually encountered, off and on, you would have seen these things. We will, we will actually see what these things actually means. So, it means that you have a source image, let us say this.

Let us call this as S, and then you have a target. And the, the idea is that you want to be able to, so, in the source, you have some image and you want to apply a geometric transformation such that you get a, get a target image. You might actually wonder why you, why you would want to do something like that. I will explain that along the way. Why somebody would want to take an image, do something on it. As a, as a simple example, I told you, you might want to zoom in. It was one of the examples I gave you last time.

There could also be, also be, say other reasons why you would like to do, why you would like to do an operation like this. But if you are thinking that, you can take a source coordinate, so, assume that, assume that you have a grid, wherein, wherein suppose we, suppose we mark these as the x y locations. Whatever 0,0 and then 1,0. If you take x to be in this direction, y to be in this direction, suppose, suppose if you assume some kind of a coordinate system and if you, if you think that, what you want to ideally do is you want to be able to start from the source, because normally your equations will look like this.

Suppose it is a pure translation, your equation is going to look like xt yt, where t is, t is supposed to be a target. I am writing it a small t. This will be some source coordinate xs ys plus some translation, let us say it is called tx and ty. Now, it is another thing, as to, as to when you can get a constant translation for all the pixels. It is not immediately obvious that when you move, see all this, and of course one more thing that I want to mention is that whenever we write these, these things, these are all image coordinates. xs ys is the image coordinate in the source.

And, and, and xt image coordinate for the source and similarly, what you have here is xt yt which is again image coordinate for, for target. Now, what is this tx and ty? So this tx and ty basically represent your image motion. So, so, so, if you are asked, if you kind of wonder, as when will it happen that all the pixels will move by the same amount. So, that, that is something which we will try to explain in terms of the camera motion and so on later.

But as of now, just assume that, just as you would take a 1D signal and translate it by some amount x of t plus b, similar to that, you are doing on a spatial grid now, except that your coordinates, except that your shifts are like along x, it is tx and along y, it is ty. It is interesting to ask as to when this will happen, does it always happen, no. It is not true that you can just take a camera and move around and then hope that all the, all the scene coordinates will move by, by the same amount, it won't normally happen, unless certain conditions are satisfied.

What those conditions, conditions are, we will see later. But for the time being, we will simply assume that. Now if you say that it will start with an xs ys, let us say, which is here, and the idea is that, of course, these are still the spatial coordinates, these do not represent intensities. These are just the, just the spatial coordinates. And the idea is that you want to start from some xs ys, let us say, let us call this as our, as our xs ys location, and, and we want to see, after we apply tx and ty, it is going to go somewhere, somewhere here, let us say, onto, onto a target grid.

Now, if let us say, if tx and ty are pure, pure integers for some, for some reason, again, that we cannot assume that they will always be integers, they could be positive, they could be negative, which means you could be shifting up down left right, whichever way, but these are all pure translations and, and these all mean in-plane translations. And, so the idea is that, so when you land here, now, if you land, if you are lucky, and then for example, if these are integer coordinates, you will of course, land somewhere, on the, on this grid where you have integer locations.

But suppose let us say, your tx is something like 3.7 and ty is something else, let us say minus 1.5 or something, then it means that you will land in some area which is no man's land. You will, you will end up in some box inside, you may land somewhere here depending upon whatever, whatever is your translation. Now, if you think that, now the whole point is what, you want to, you want to say as to, as to now what should, if I land there, what should I do now.

Now, one of the things, which you could do is, you can simply, you can simply assign the intensity that is here to let us say, to, to one of these pixels depending upon whichever is nearest. You might say that, I might either floor, floor this coordinate, floor will mean that you know the operation of floor, from 5.8 it will be 5, 5.1 will also be 5 or you may ceil, in which case 5.1 will become 6 or you may simply do, do a round-off.

So you, so you, so you could try using a floor or ceil but whatever it is that you use, you will use the same all over the, for all over, for all the coordinates. You do not change it. So, ceil or you can do what is called a round-off. You can do any of this. But then what, what, what, the issue is that what you (can), you cannot guarantee, it is that, by doing, by starting from the source and landing in the target grid.

What you cannot guarantee is what you cannot guarantee is, is the fact that, is that, is that you, what you cannot guarantee is that you will visit every, every target location, visit every, every target location, visit all target locations or on every target location, every target location. What does that mean? Which means that, which means that in the, in the, in the target grid, you can be left with holes. You can be left with holes, can be left with holes in the target grid, in the target grid.

What does that mean? The holes, it simply means that these are all unassigned locations, it does not mean that the intensity is zero there, it simply means that some of these locations here in this target (gri), target grid could go unassigned. Now, in order to understand this, I will just take one simple example just to see as to, you can, you can of course later on try it on your own, but then, prior to that let me just, let me just give you, give you an example. Suppose you had, let us say, okay, now I have not talked about scaling yet. Alright, I will kind of, say come back to this, in a minute.

The other operation that you will tend to do, I will kind of, say come back to what I mean by, what I really mean by you will be actually left with holes in the target grid. I will come back to this once I talk about rotation and scaling. The, the other two operations which are in-plane are as follows. So, when you have xt yt, and then if you are talking about a clockwise rotation, then it will be like, again assuming that, that the convention is, this is x and that is y, assuming that to be the convention, then xt yt will be some cos of theta sin theta, minus sin theta cos theta. And then multiplying your xs and ys.

This will be like, you, you, you take your source coordinate, apply this transformation on that and then it takes you to a target coordinate xt yt. The whole idea is that you want to be able to assign it, so ideally whatever is the intensity here, that should get, get assigned, assigned in your, say, target grid, but then, if it falls somewhere, somewhere in this kind of a, kind of a, what you call, in the center or somewhere within the box, then, then you wonder what you need to do with that. So, that is what will create issues.

Now, this one, this one is called actually in-plane rotation, which actually means that, if you had a camera like this, suppose assume that this is a camera sensor plane, then it actually means that in-plane rotation is something like that. So, so, it is about the, suppose you assume that the camera optical axis is coming out like this, then if you were to rotate, rotate this image plane, now, about, about this optical axis, then what you will get is, actually what is called an in-plane rotation, right. That is the angle theta.

So, it is, it is more or, it is more or less like, theta z, if you wish you can be more, more explicit, but right now, we will just simply write, write it as theta. So, this is really a rotation about the optical axis and then your camera kind of rotates like that. So, so that is why it is called an in-plane rotation. Out-of-plane would be something like that or something like this, would all be in out-of-plane. And out-of-plane, eventually, of course, we will be, we would like to be able to deal with all kinds of motion, right.

We do not, we do not want to stick to just, just an in-plane (trans), in-plane translation is something like that, where you can go within, within the sensor plane. You can go up and, you can go up down or you can go left right, in-plane sort of a rotation is this. And ideally, a camera, camera will undergo what is called a 6D motion, which means it can actually, it can, it can undergo a rotation about all the three axes, and it can also translate along x, it can translate along y, it can also translate along z.

So, eventually, you want to be able to have this kind of transformation that will take you from one image to another, under a gentle camera motion. But for the time being, just, just to, just to set the tone, what I thought is, we will start with a simple case, something that you are all familiar with. So, such a rotation is called in-plane. And this is called an, this is called an in-plane rotation. And then, when you, when you kind of go to, go to scaling, scaling, of course, you would, you would guess what it may look like, sometimes this can be trouble.

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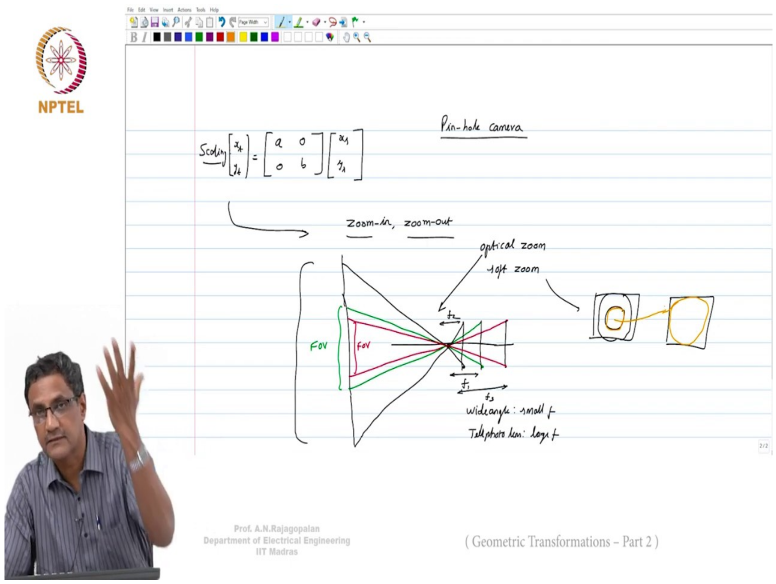

So, then what you have is scaling. Scaling would typically look like a 0, let us say 0 b what is called a, what is called a, what is called a non-uniform scaling. Again, of course, you have your xt yt on the left and then this is the, acts like xs ys, so, it is simply like a times xs is xt and then yt would be b times ys. So, it is simply scaling and this is called a non-uniform scaling because a and b need not be the same. If it is uniform scaling, then, or isotropic as it is called, then a is equal to b.

This is, this is, this is what is, this is what is referred to as scaling. And, and, and these operations which we are saying that we will take an image and then go to another by doing some kind of a geometry transformation. Suppose, for example, I look at scaling, this is something that you can associate with, with let us say something that you are familiar with, is zoom in and zoom out. This is like zoom in and zoom out. And on, and then all of this, please bear in mind that the image size is not changing.

Imagine that, imagine that you have a camera which is actually capturing a picture of a scene from here and suppose it moved here and then ready to capture, took one more image. The whole idea is that, ideally what we would like to, like to eventually be able to do is why you are even talking about going from one image to another, how to, how to do that operation is to eventually be able to go from, be able to relate two images taken from a camera, but then, but then, views are not the same.

So, you could have, let us say, one viewpoint from here you take and then you take another from another viewpoint, these two images, you know, that they are, they are exactly of the same scene, except that, it need not have been taken from the, from the, from the same, that is original viewpoint. And you want to be able to, able to, say, relate the two. And there are several, several reasons why you would want to relate the two, which I will, which I will talk about.

But right now, one of the things that, that I thought when I, when I talk about scaling, right, I will actually mention is what is called zooming in and zooming out. I mean, when you buy a camera, let us say, when they, when these guys advertise, they talk about what is called an optical zoom, they talked about something called a soft zoom. So, when they say, when they say optical zoom, what they mean is the real optical zoom. See, so there is something called the optical zoom, and there is something else which is called the soft zoom.

The soft is like, like I can say, algorithmic zoom. By soft, we mean it is not like software, so it is like soft zoom. So, so it has to do with some, some, some algorithm, some signal processing or image processing that is going on. Optical means you are actually having a lens whose focal length can be changed. Now, now in reality, when you actually zoom in, you, you actually expect that you would be able to see finer things. Now how do you see an optical zoom, in order to see an optical zoom imagine that, imagine that, let us say you have actually a pinhole camera.

All that we are talking about is really, if I have not mentioned it already, this is all for what is called a, what is called a pinhole camera. This is not the same as what you carry with you which is basically a lens based camera. All of us carry what you call, what a, what a lens placed, why we, why we carry a lens camera is something which we will talk about later. But right now, it is like, what we are assuming is simply a pinhole model, because, because the moment, moment you bring in a lens, there are so many other things that, that, that start to happen.

So, what you can focus, what you cannot focus and so on whereas if you take a pinhole, that, that issue is simply not there. And pinhole is the simplest model to start with and then one can start to say, escalate it. So, so what it means is that you have, let us say, so, so you could have a scene, on the left and then the entire scene, so you could have a scene that is mapping to get through this pinhole and then imagine that, let me just, let me just, let me draw the same colour. Now here is your image plane and from, from here to here is your, is your say focal length of the camera.

Now, what this actually means is that if I, because a sensor plane is fixed right now, so if I, if I approximately draw something with the green lines, then what it means is that, probably I can see. Now, let us assume that the sensor ends there and, I cannot draw it too accurately but let us assume that. So, so what it means is that your, your field of view is this. That means, so much of the scene, you are able to see. Now suppose for some reason, you actually bring the, you make the f smaller, in the sense that you bring the sensor plane forward.

So, now the sensor size cannot change, the image plane, so we will keep it at the same size. But now what we have done is, we have actually reduced the f. Under this circumstance, if you see, where, what all you will be able to see, they are kind of going right there, I am not drawing a straight line, but then imagine that it would be going like that and then from here, it would be going like that, somewhere there. Oh, that's, that's too bad. Let us try, try a little better. Yeah. So, this is going to look somewhat like this.

So now, now, so now you will see that, with a smaller f, when you have change the focal length, that, what has happened is, you have, you have a field of view, which is now, which is much larger, which is, which is like, which is, which, which actually means that, means that you are able to see a larger (por), larger portion of the scene, but then, which also means that you will actually lose out on finer details, because if you see, a larger scene is now mapping onto the same sensor area. Earlier, you had a smaller area of the scene mapping into the same sensor area.

Now, you have a larger scene, kind of you see mapping into it, correct. So, so when you have a small f such the lenses are called wide angle. Wide Angle is like small f. On the other hand, if you had the flexibility to, let us say, to change f and then you would increase it, let us say, let us go here, increase our f, make it whatever. Let us say initially it was f1 then maybe this was f2 and now we go like f3 then you can, you can clearly see that, maybe I will draw with red.

So, now what will happen is, you will have, you will be able to see this portion and similarly out here, right you might be able to see that portion of, so, again, now you have, now your field of view has now, has now also become smaller and such a thing is called a telephoto, a telephoto lens, a telephoto, telephoto lens, or what is, what has a large f. Right now, this is what is an optical zoom in the sense that, in the sense that you, you change the focal length of your lens and then, that kind of allows you to, allows you to capture the way you want.

So that is why when you are kind of, when you sort of zoom in, then you are able to see things which are of a finer detail. And then when you zoom out, you tend to, you tend to occupy a larger part of the scene. Now, when you do a soft zoom, you, you are not doing, doing this. With respect of soft zoom all that so, these are all optical. This is what you mean by an optical zoom, where you can actually change the focal length and then, then start to, image, see image portions of the scene according to the way you want.

Now, as far as soft zoom is concerned, this is algorithmic. So, what it means is that if I had somebody's face here, suppose I had somebody's face here and then suppose I want to zoom in. So what I would, what I would kind of, say, effectively I am asking is, a part of this should occupy, should (occu) so, in a sense, what I am asking is, this portion out here should go and you see, occupy this, this whole thing. That is what, that is what you mean by zoom in. So, for example here, if you feel that the nose and the eyebrows are the only things that I could present here within this, within this inner circle, then, then, that is what will appear here but then, yes?

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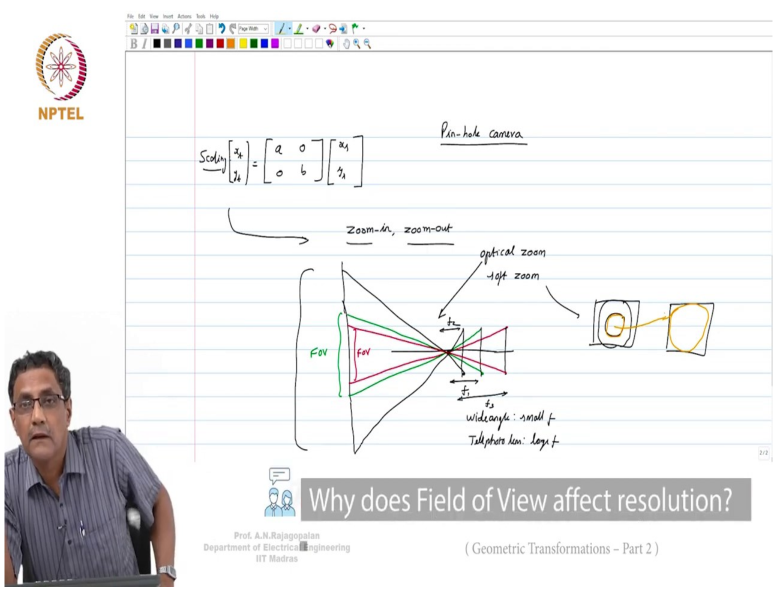

Because, because here, now you see, in this case, when you actually increase the focal length, see, I mean so see this, see this region of this 3D scene that is kind of, that is getting, getting kind of mapped onto your image plane. You are now, you are now mapping a smaller region onto the same area. Your sensor is not changing. Whereas in the other case your field of, when you are seeing a lot more of the scene but then your ability to see finer details is no longer there because a larger portion of the scene is occupying the same sensor area.

A large portion coming on and mapping to a smaller, to the same sensor area versus a smaller scene area mapping into the same sensor area, you would naturally, naturally be, be able to see finer details with respect to the one that has the, that has the, that has the larger f. Because your, because your field of view is now, is now kind of, say, restricted. So, the point is, so when you have a soft zoom, so what you are saying is this, this inner portion, should actually map on to this, to this image grid that you have.

But then, when you do an algorithmic thing, you cannot really, so, unlike, unlike this, in an optical zoom, where let us say now, where let us say when somebody says that he is zooming in, he is actually picking up, picking up finer features, whereas, here, I mean for the same reason, as this, this person asked. So, so the fact that, fact that a, fact that a smaller portion of the scene is now getting mapped onto the same. same area, that means your, your, your, you see your ability, ability to see finer details is higher now.

Now, but here when you do a soft zoom or when these people say that I have 100 times soft zoom, it does not mean much actually. Because all that, all that, they are actually doing is, they are kind of taking the existing information and trying to, trying to kind of, say, fill up this grid, but there is, but there is no new information that they have in order to be able to tell what are the, what are, what are really the finer details, that is also the reason when you actually do a soft zoom, you tend to see images that do not look so great.

Whereas when the same thing you do with an optical zoom, you have this feeling that you are able to see, which is why optical zoom is, zoom is a lot more expensive, you pay for it, because it gives you the ability to actually, actually see things in a finer form. Whereas when you do a soft zoom, it all depends upon what kind of an algorithm you are using in order to be able to take information that already exists and it is simply trying to, trying to kind of use existing information in order to be able to, be able to, to build-up an image that seems like, that seems to give you, give you, give you finer information, fine information but that is actually not true.

Because there is no new information that is coming. Now, this does not mean that, mean that people have not done anything, from when going from, what is called a super resolution alright. People do talk about going from one image to high resolution, but that is something else totally. Here the way your cameras operate the soft zoom and all is simply this. They are not doing any kind of deep learning and all. This is a simple algorithm. It just takes this image and then, say tries to, tries to build this.

Now, again in all of this, you will, you are going to start from a source and then, you are going to try to go to a target. So, what I, what I want to now do is come back to this issue, which is, which is, which is the issue about the holes, which I actually mentioned. So, if you think that you can start with the source and then directly start filling up the grid in the target, you, you could have issues and what those issues are likely to be, we will see in a short while. So, let us say that, let us, let us kind of go to the scaling example itself.

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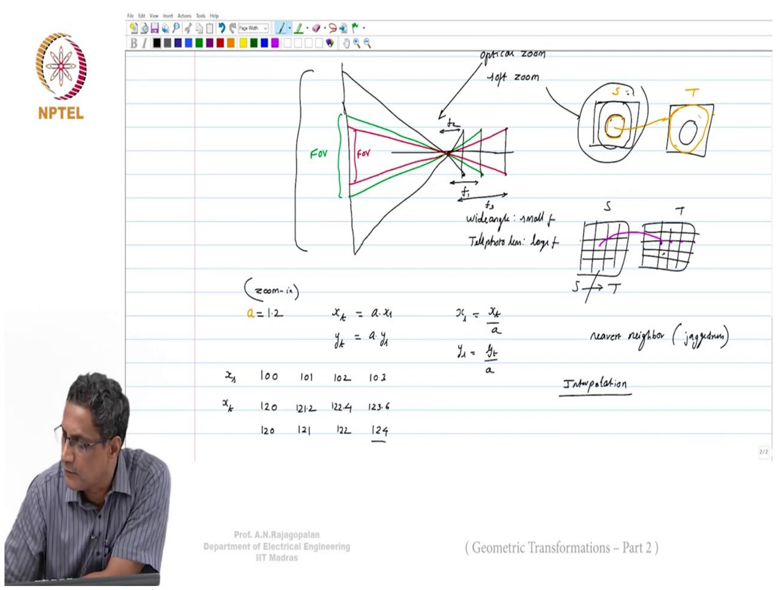

And since we have already seen it, let us say that I have, I have my a which is equal to 1.2. Suppose I take some a and which is equal to 1.2 which then means that now if you go back to the equation, it means xt is equal to a times xs and then yt is equal to, let us say a times ys. Suppose we assume that we have uniform scaling, yt is equal to a times ys. Now, since, since a is a number right now which is actually more than 1, greater than 1. Now what do you think this might be, would this be a zoom in or zoom out?

If a is actually greater than 1, zoom in, it will be a zoom in because then how do you, one way to guess it is that suppose you see xs. Suppose you do write xs, xs is xt by a and therefore what will happen is, no, prior to that let me just, let us do this whole business or I may be leaving that. Let us kind of come back to this, in a minute, but this zoom in. Now, look at let us say, look at, suppose I have, I have these locations. I am writing xs 100, suppose this is like the hundredth column. Whatever, whatever be the y coordinate, let us not worry about y coordinate right now 100, 101, 102, 103 let us say.

Suppose I want to know where these coordinates are going to go. Assume that let us say y is, y is, y is the same for all of them just for simplicity, a or ys. So, so, it could be like 100, 50 101, 50 102, 50 103, 50 something like that. But of course, in this case even y will change because it has some a times ys, but let us just focus on xs. Now, if you look at xt. So, suppose we take this, this relationship as it is. That means, we start from a source coordinate and then, and then, we try to see where the, where the target coordinate will go.

So, when you take xt right, it will be 1.2 into 100 , which is actually 120, which is fine, which means that we should be able to actually map it. So, that means, suppose 100, whatever is the y coordinate, intensity there will get mapped to 120, whatever is at yt, correspondingly. Suppose, suppose let us say ys was 50, then yt in this case would be 50 into 1.2, 60. So it will go to 120, 60. That is where the intensity will go, these are not intensities. These are the coordinates. Now when you take 101, now I have the value again. 101 goes to 121.2 okay, this I have it here. So, 121.2.

So, suppose we do a, do a rounding, let us say, because 121.2. So what, so what you would typically do is what is called really a, really a nearest neighbor, or in a sense, you may just do can say a rounding off. So, what you will do is in your target grid, if you are, you are somewhere here, and 121.2, could be let us say, somewhere here, and then what you could do, you can do any of them. You can do round, you can do ceil, or you can do floor but suppose let us say we do some rounding. Suppose we decide, we will do rounding, then what it will mean is you will actually map it to 121. 121 will get that intensity because we are just doing a simple rounding off.

So 121, so 120 has gotten filled up, 121 has also gotten filled up because, becauae we did this rounding. 102 if you look at it that will go to 122.4. Now again, 122.4 is again, we can, no man's land so what we could do is we could round that and we will say that, so 120, so there is no issue here, so 121 then 122 we are able to map so till now I do not see any holes. Now, 103 when you do what do you find you get some like 123.6, if you multiply 1.2 with 103 you will get 123.6. Now, if I do round off 123.6 will go to actually 124 right.

Now, now what will happened is so, this pixel, this intensity at 103, whatever it is, whatever is the corresponding y, wherever it is supposed to go, so that we will get mapped to say, 124. Now, what do you see, between 122 and 124 there was a whole row which is actually 123 right, which. which we did not land at all. After this, you will just go on, and then what may happen is, not just, just, this is a small example to illustrate the fact that why when you start from the source and then you try to land on the target, there is no real guarantee that you will, you will land on each of these, each of these locations.

There is no such guarantee. If you try something else, maybe if you try ceil, then somewhere else you might actually miss out. So, which is why people never do source to, source to target transformation, people always do what is called a target to source transformation. So, S to T is not the thing that, that you do, principally because of the reason that, that it can cause holes. This is what we mean by holes. And holes does not mean that those locations have zero intensity, it simply means that, those are all un-assigned because, because you never landed there.

So, if you look at the target image, you will see that you have got intensities in many places, but then there are places where you have not been able to assign any value at all, which is, which is bad, right, You do not want to take an image in which let say some of these locations do not have any intensities at all. That means these are unassigned. You do not want unassigned, unassigned location. So, instead what is done is a target to source, at target to source, what you can do is, you can definitely ensure that every, every location in the target is assigned an intensity. So, what that means is going the, going the inverse way.

So you, so now, what you do is instead of going this way, you go the inverse way, so, ys is equal to yt by a, and now you will also see why this should be a zoom in. Now, what it will mean is, so, if you take. so, suppose you take the maximum value in xt, well let us say that it is 245 cross

256 size the,n then, when you take a maximum of 256 and divide by a, which is actually 1.2, which is a number greater than 1, then it means xs and ys will fall inside the, inside of 256 which means, which means that a smaller portion in S is getting mapped to a larger portion in T.

You see that, no, so when you are dividing by a, the target coordinate, assume that you are at the extremity of the image, let us say you are at the end of the image, when you multiply by a, which is greater than 1, that means you will actually go back to a source which is, which is inside that grid, which means that, which means that a smaller portion of S is coming and falling on a kind of larger, it is being splashed on a larger sort of a grid. That is what is happening.

That is why, that is why it is zoom in, if it was the other where it was 0.8 or something, less than 1, it would have been the zoom out. In a real camera, of course, in a zoom in and zoom out, you do not, see zoom in is easy you do not, I mean, you see that, you can easily see that a portion here will come and, come and sit there. But, but if it is a zoom out, let us say, then what might happen is, you might, you, so, what that means is, means is, I mean, you might, you might actually end up with some, when you do, especially when you write a lab assignment, what will happen is you won't be able to access information outside this grid.

Because, because you do not know what lies outside and therefore what will really, so zoom out will mean what, that this entire thing, will come and set as a smaller region here. Now, in order to fill something here, it will go outside the grid now, but then when it goes outside the grid, you do not know what those values are. So, typically what we do is, we just leave them as zeros, in a lab assignment. In a real, in a, in a, in a real camera, it does not happen because some new information will come and sit there when you zoom out, you do not find zeros there, simply because the rest of the scene will come in.

So, imagine that, if you had access to information outside, you can actually, you can actually plant those values here. But that will mean that you will have to look at the images being on a larger grid, and then the image as being sitting inside it, and then when you, do you see this, so for example, when you, when you divide 256 by let us say 0.8, then it will be a number outside this 256 cross 256. Now, if you knew what was outside, you could of course, bring that and kind of copy it here. But then if you did not know, which will be normally the case, then we simply ask you to put zeros here.

That is only an implementation issue. That does not mean that in a real zoom, that is what will happen. But zoom in is not a problem because only a smaller region is going there and therefore, therefore, there is no reason to believe that it you will have any empty regions here. Zoom out can, can have empty regions in your own implementation. That is all. Some people want to, they will just assume that them they will assume that they know the values outside of, of this grid and then they will copy, which is okay. But then they should, they should tell upfront that they are, can doing something like that.

Now, why, why does this not have a problem, in order to see if I go from target to source, why that is okay, in order to see that, so, so, so imagine that, imagine that you are starting from, from some xt yt and then that is your target. And then, you have your source here. It is, again, your target is your source, and now you are starting from target. So here, here are your integer locations on the grid, you do not know those locations, you do not know what intensities to assign, so suppose you start from here and then, suppose it so happens that, that you end up, end up somewhere again in a kind of no man's land here.

But now the, the advantage which you have is, you could try what is called really a nearest neighbor, nearest neighbor in the sense that, you could, you could, you could assign any of these four location intensities, four locations, depending upon whichever, whichever this guy is closest to, which means that if it happens to be closest to this pixel, then that intensity will get assigned here. If this, if this lands such that, it is closest to this pixel, then that intensity will get copied here and so on.

So, in that way even with a simplest and simplest nearest neighbor, you will always be assured that, that you will land here and then for every, every, every guy here, there is a value here that that you can assign. But normally if you do something like a simple nearest neighbor, this can lead to what I call, what is called jaggedness. I know, it won't look, look, look very natural. The, the kind of good thing about this is that, you are of course completing the grid. You are not leaving anything unassigned. For every location, you are able to assign an intensity, but what will happen is, doing something like this will give, will give what is called a jagged appearance.

I mean, if you actually look at images like that, which I will show today, they will have a kind of a wavy or what is called a jagged appearance. Instead, what is done is, people do what is called as interpolation, interpolation is, is, is what, interpolation is what is actually normally done. By interpolation, what we mean is, we try to make use of as much information as we have, in order to be able to make a, make a, make a reasonable guess about what this, what this intensity should be like. Now, there are there are various ways to actually interpolate, and the one that that we will talk about is one of the simplest but then, that should give you an idea about how these things work, what is called, what is called a bilinear interpolation.