Medical Image Analysis
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Lecture 15
Image Coordinates

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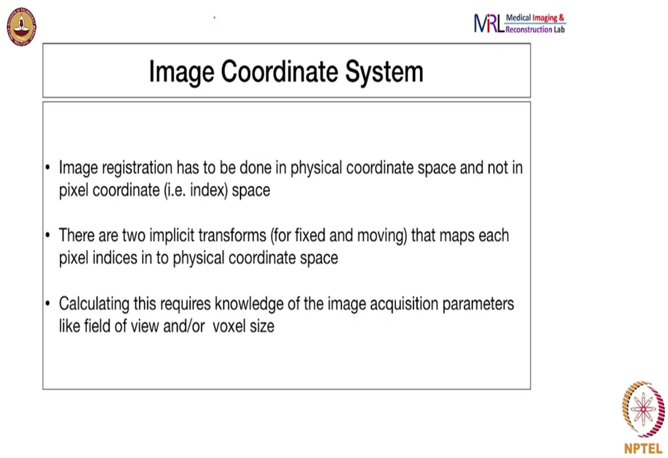

Hello, welcome back. So, in this series on rigid registration, we are going to look at the image coordinate system, are note that this applies for any kind of image registration. So, the general mistake that people would typically make is to actually perform this coordinate transformation that I have been talking about.

On the index of the images take, for instance, (i , j) is the pixel index or the voxel index, and you typically end up applying the transformation on that. And that is wrong. The problem with that is because when you are considering two different images, even though they are on the same patient, they might have different resolution.

And the resolution in the sense is actually just spacing between the pixels in terms of a physical distance. So, typically, all medical images have the have a resolution defined for them, in terms of the field of view and the discretization grid. So, every pixel voxel actually corresponds to a certain physical size. So, even though there would be two images, which are the same dimensions in terms of the number of pixels in, let us say, x-y direction in which 2-D images, they are.

The spacing between the pixels might be completely different, which corresponds to a different field of view. So, before you do any image, or registration or apply coordinate transforms, we have to do an implicit transform, which maps key pixel indices into some physical coordinate space. So, this is an implicit transform, you will have, you do not have to estimate this, you will have all the parameters necessary to do this.

And typically, this requires field a view voxel size. And this is also an origin of the lab coordinate or the imaging system coordinates. So, that origin once you define it, then you are all set to go. So, we will look at this slightly more detail with the help of some images.

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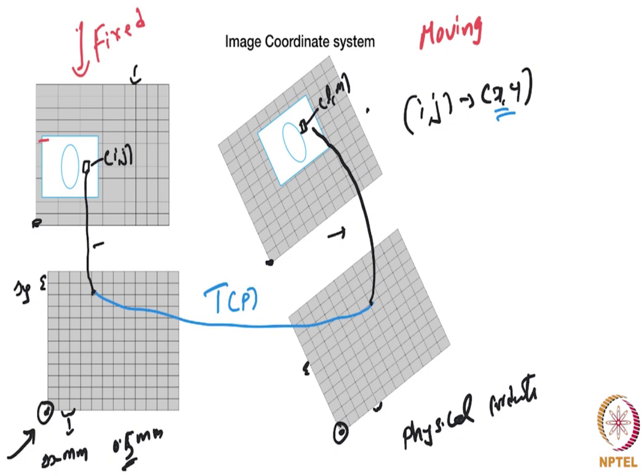

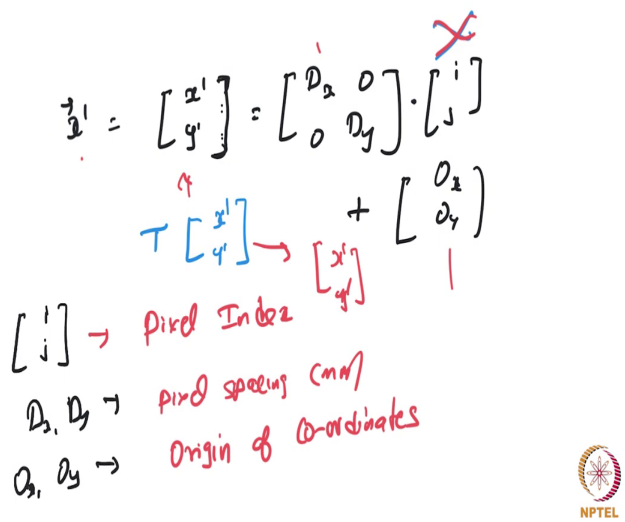

So, if you look at this particular illustration, here, I have our two images? With the grid on them, so that in which if you understand what we are looking at one second, let me just squeeze them down to manageable size. I hope these are visible now. So, this is, let us say, your fixed image. Let us just find this out.

This is your fixed image. And this is your moving image. And my handwriting is going bad. So, this is basically your moving. So, what we want to do is estimate a transformation. But before you have to do the transformation, remember that this, let us say, for instance, I have superimposed a grid on top, but you can always, this is the actual picture here.

So, if you take a grid somewhere some pixel in the image, let us say it is some pixel in the image under this black. So, this is some pixel, this has coordinates (i , j). So, this grid represents that coordinates. However, underlying this image grid is (i , j) grid, there is a physical coordinate spaces is write here.

So, what is this correspond to here, the spacing between this pixel is given in millimeters. So, there is spacing in x is a δx, and there is a δy, typically, they are the same. So, let us say 0.5 millimeters is a typical spacing between the pixels in medical images could be lesser, or this is not surprising.

So, when you come to the moving image, it has so this has its usual pixel coordinate system, wherein you can, also can do this indexing. So, for instance, this will be this particular pixel here, let us say could be (l,m) or something like that. So, I have shown this tilted because I am looking at the same image which has been rotated, I can translate it.

So, this is an affine this is a rigid transformation. So, but associated with this picture is another underlying physical coordinate system. So, what you have to do is in order to apply, so if you want to figure out what this pixel corresponds to here, let us say you have the transformation ready.

What are to do is from here to there, so (i,j) to some (x,y), you have to figure out using a one transformation. And from here to a corresponding pixel, let us say here somewhere this is the T that you are going to apply. So, this transformation is applied to the x the transformed from ij to xy.

And from here, you are going to have to estimate one more transformation that takes you sorry, I got the whole thing that takes you let us say right there. So, there are these implicit these are two are the implicit transformations these can be done if the parameters of the imaging system. So, for instance.

The field of view or some scanner fixed or coordinates are usually given and with respect to the scanner fixed coordinates, the xy positions of the images are typically known. Shows, the z if you are considering a 3-D image. So, using that you have to figure out the transformations and not operate on the indices of the image.

Because of this problem, not problem because the fact that, the medical images, actually, the pixels mean something in terms of dimensions, both along x, y, and z direction, there is size of the pixel that is the extend with doc wise, as well as the spacing between the pixels. So, you have to understand you have to know what the spacing between the pixels is in order to go from ij to (x , y).

And then from after doing the transformation to the moving image, figure out what its indices are. So, here also, this is where interpolation comes. So, once you figure out this (x , y), when you apply a transformation metrics, it would land on a grid, I have shown it landing on somewhere on a grid, but it might land on a not on a grid point, but an off grid point, because these transformations operate on real numbers.

So, then what you have to do is, then you have to do interpolation in order to figure out the value of the intensity. So, if you want to know the intensity value at a particular location that you are mapped into, you have to do interpolation from the original image. So, for that also, you need the physical coordinates, rather than working with the indices.

Now, there are some cases you can work directly indices, like I said, if they are the same modality, I know same patient or the same field, same field of view, or the same scene, and same resolution, same everything has the terms of the origin of coordinates, etcetera. So, then this is an issue. So, here, there are two things that you have to map, you have to know the origin of these coordinates on this coordinate systems, like maybe here, this is, it is always (0,0) origin of these coordinate systems, you would have to know before you can, and you also have to know this pixel dimensions for both your, moving and fixed image.

So, that this distance now if you want to zoom in and show you usually, if I zoom it, everything goes to the dark. So, the pixel dimension is basically is between the distance between the centre point of the pixels, let us say, here, in this case, if you go from here to there. So, this is the distance, this is typically your, what you would, let me go back to the original picture.

So, that is the distance that you want to know that you will know based because the imaging scanner will have it calibrated, and you should be able to estimate that. So, what is that transformation? These implicit transforms that we are talking about, what is it? What do we how do we do that? So, the way to that, we just write it down quickly.

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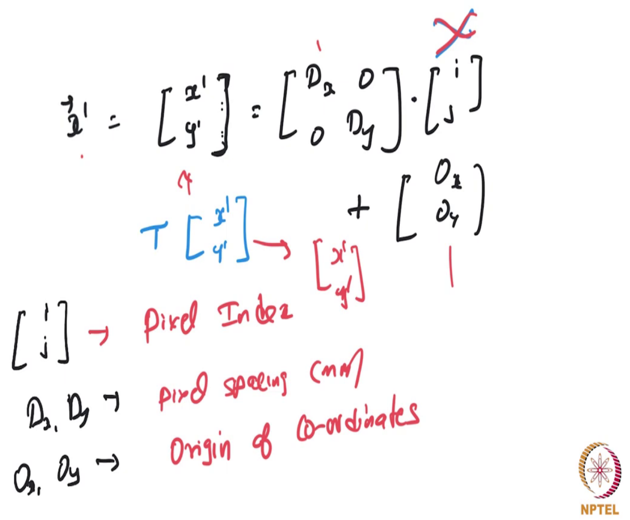

So, there is x’, we want to go to, in this case, this is a vector, I write it as x’, y’. So, you are going from the index to the coordinate, you have this (D_x,0,0,D_y) times (i,j), so this is your pixel index. There is a plus O_x, O_y. So, this is (i,j) is your pixel index. That is typically how you would access the elements in an image array. So, this D_x, D_y, or basically your pixel spacing, typically these are in millimeters.

And finally, you have the O_x, O_y sorry my D and O my looks slightly same but O_x, O_y this is basically your origin code, origin of coordinates. This is in 2-D conduct similarly for 3-D also typically will work in 2-D a lot of cases. So, how do you like I said, when you get these values from sometimes they may not be available, then you have to get creative about you about how you fix the origin etcetera.

So, for instance, you can always fix the origin at the bottom left pixel or the top left pixel of the image and things of the sort, but these values are expected to be available to you from the scanner itself. So, once you do this, so once you have your ij, you transform to this x’ , xy , you apply your transformation to that.

So, your transformation metrics should be applied to your coordinates not to ij so this is not done. So, I will do this in red, so that you do not apply to ij but rather xy and then once you from here then you will get a new set of (x', y'). Because after the transformation, now you have to convert this back into in pixel indices again, you can just have to invert this transform to do the same. So, this is something that is always coming up in image registration. So, hopefully I have addressed this problem once again to just to reiterate, all medical images have a have finite, pixel sizes.

Where the there is a dimension to the pixels, they cover a certain area or volume in your body. So, there is a pixel spacing is in millimeters, there is actually the origin of coordinate is available in the sense where is (0,0) for the physical coordinates, it is there, it is there for both the mixed as well as the moving images.

So, all your transformations will be applied to those physical coordinates. And you will convert them into the indices. Using this transformation I showed you provide that, the pixel spacing as well as the origin of the coordinates, this can be done trivially. So, this is a calculation you do not estimate D_x, D_y or O_x, O_y you just x time.

That is typically how is done. So, the next few lectures we will look at different types of transformations that are available and different types of metrics. Basically intensity based metrics that are used for image registration.