Virtual Reality
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Lecture – 3–1
Geometry of Virtual Worlds (Transforming Models)

I want to now switch to transforming models. So, I want to talk about transforming rigid bodies. So, I will go over and some changing topics a bit, I will erase here.

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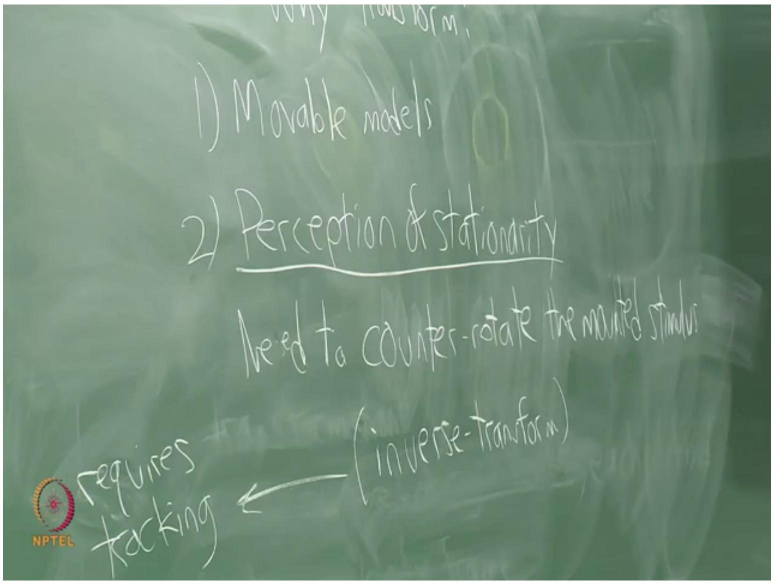

Transforming rigid bodies; probably all of you have had some experience in performing transformations to bodies. You may have done translations and rotations before in other subjects that you have studied. What might not be as familiar is thinking about the space of all transformations that could be applied and representing those in some nice way or performing estimation designing filters on the space of all transformations. So, that is considerably more complex and my goal is to make that hopefully simple and clear today. So, I want to try to explain some of these things about the space of all transformations.

In terms of why transform, I want to make some connection back to the last lecture that we have. So, why are we performing transformations? Well, it should be clear in the case of moveable models I just talked about that. But, there is another case which I think connected very nicely to our lectures from last time which is perception of stationarity.

So, that is somewhat counterintuitive. So, I need to perform transformations because I need to unmoved something that has moved. Now, here is the idea. So, I see all of you today in the real world when I rotate my head you all move appropriately, in the way that I am familiar with all right with respect to my head you are essentially counter rotating in the opposite direction. So, if I design a virtual reality system suppose it is a cave like system or it is a surround sound audio system it is fixed to the world. So, that when I turn my head the stimulus is counter rotating appropriately.

Now, if I mount the stimulus on my head if I wear ear phones or eye phones I have a head mounted display let us say, now, when I rotate my head the stimulus is unfortunately going to follow it. So, if I want to simulate stationarity, if I want to simulate the stimulus being fixed to the outside world I have to counter rotate. Does that make sense? So, it confuses people a lot. So, you end up applying an inverse transformation to simulate stationarity. We talked about the vestibulo-ocular reflex going back and forth like this where that is another kind of perception of stationarity where your body is designed to have your eyes counter rotate with respect to your head.

Now, we are designing a virtual reality system that is mounted. So, when you mount a stimulus to your body you have to compensate for the transformations that your body is performing. You have to undo those and take that into account. Hopefully do it with very low latency. So, that your brain does not become confused right it becomes unfamiliar input then.

So, we need to counter rotate the mounted stimulus more general than counter rotate is inverse transform and because we have to do that this requires tracking or filtering estimation whatever you like to call it, we need to use sensors and estimate the motion that has occurred of the human body and then when we figure out what that transformation was we apply the inverse of it to compensate to give you again this great idea the perception of stationarity, that makes sense. So, those are 2 reasons why we are studying transforms today. The first one is somewhat obvious, models are moving in the world. But, the second one is little bit less obvious is to give you the perception of stationarity to make you think that the outside world is in fact, not moving. Of course, both of these could be happening together making a big complicated mess all right.

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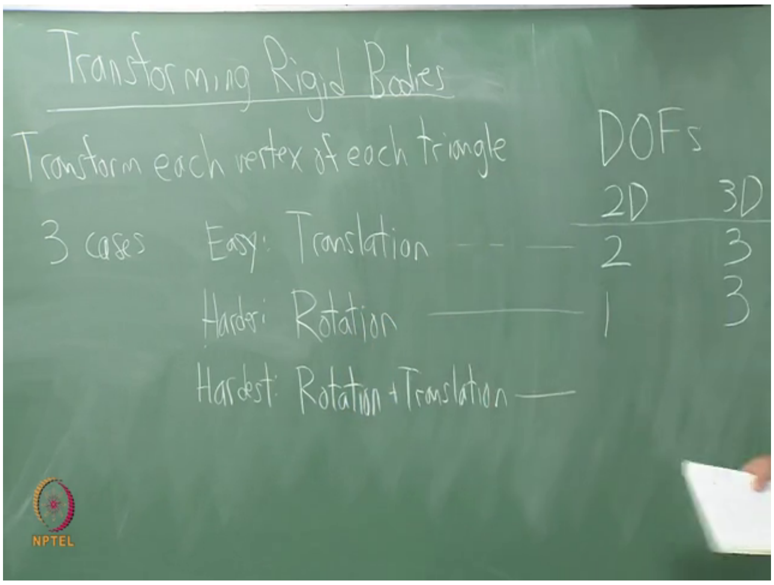

So, under transforming rigid bodies, let us imagine transforming each vertex of each triangle simple as that. There is going to be 3 cases that I cover today; 3 cases, we have the easy case which is translation and in that case I am going go over and I am going to talk about the number of degrees of freedom. So, the DOFs in 2D and 3D, for translation only we have 2 degrees of freedom in 2D and we have 3 degrees of freedom in 3D and this is really mathematically the easiest case to define to understand, no problems really. The harder case is going to be rotation which in 2D is very easy. How many degrees of freedom do we have for 2D rotation?

Student: 1.

Just 1 and in 3 dimensions we have 3 and this is the part where it gets harder. So, things get a little more complicated. It is not hard to apply a rotation matrix and see the result, but it is a lot harder to reason about the space of all 3D rotations. So, it ends up getting considerably complicated I hope to convince you of that and show you some of the kinds of problems and then help teach you to step around the problems and do things in a nice way so that you do not end up with a unfortunate difficulties later. And, then the hardest case which is not too much harder than the 3D rotation is we put them together. So, you get rotation followed by translation. So, once I have that then I can put a rigid body into any configuration that I like. I can translate it and I can rotate it. So, I can place it anywhere into the world without distorting the body.

That will be a very important property that is why we write the word rigid here it means that the body itself does not get distorted it just gets translated and rotated, does not mean it is rigidly attached to the ground. It just means the body itself is internally rigid. So, all distances between pairs of points remain preserved and so forth, there is more than that, but I will get to it soon.

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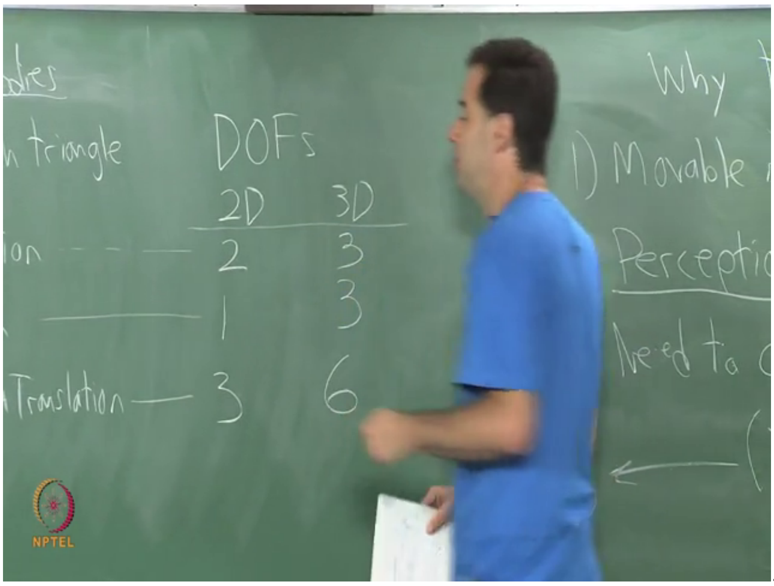

So, all we do is add the degrees of freedom here. So, we get 3 degrees of freedom in 2D and 6 degrees of freedom per rigid body in 3D for 3 dimensional models. So, that is the case we are going to be handling of course, most often because a probably 2 dimensional virtual reality is not very interesting and to think about that.

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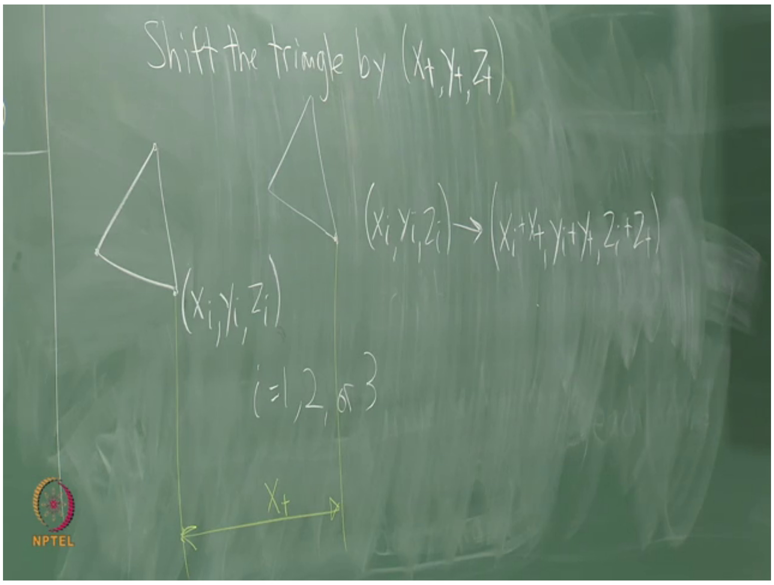

So, let us start off with the very easy case just for completeness and consistency even though this one should be so simple that you might be a bit bored. So, translation; suppose, we just want to essentially shift the triangle by some amount I will write it as X sub t for translation, Y sub t for translation and Z sub t for translation. So, we want to shift it by some amount. So, we just take the coordinates of the triangle. I do not think I want to write out all 3 coordinates, let us just pick one of the coordinates here and we will call it X i, Y i, Z i and so, if we want to take this point and translate it then we just apply the following transformation we take X i, Y i, Z i and transform it to X i plus X t, Y i plus Y t, Z i plus Z t again very simple we are just performing some translation to it and of course, here I mean i could be 1, 2 or 3, if we just number these as 3 different points X 1, Y 1, Z 1, X 2, Y 2, Z 2 and X 3, Y 3, Z 3 right. So, that is the easy case, everybody agrees that is very simple. You should have done that somewhere before.

So, if that is the case then the amount of translation that is performed when we move the triangle somewhere else suppose this triangle gets moved over here, after performing the transformation then the amount of displacement for example, along the x direction here would be X sub t. So, that is all we are doing here just translating it along. Questions about that, not very much here to talk about.