Biomechanics

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Lecture - 81
Single Finger Kinematics Measurement Using IMU's

Welcome to this video on biomechanics. In the past few videos, we have been looking at various methods to measure human body kinematics. We looked at measurement systems, we looked at choice of measurement method like which one or which particular approach you use rotation matrix or Euler angles are quaternions for your measurement method. In this video, we will continue our discussion on this topic.

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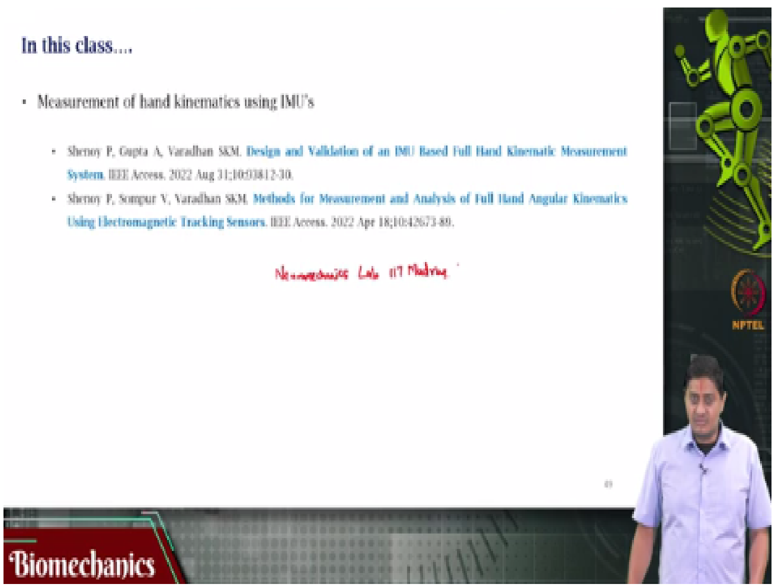

Specifically, we will discuss some of our own work done in our lab the neuromechanics lab IIT Madras. What is the work that we do at the neuromechanics lab IIT Madras. Some of these papers are here will try to see a relatively simple summary of these two papers. The details of all the methods and all the analysis and all the results are found in these two papers. These are open access papers you can find their PDFs online just Google them and you will be able to find their PDFs.

So, if you are interested in knowing the details of how we did what we did of all the analysis they are all there in these papers. Here I try to summarize these papers because of time constraints. So, IIT Madras.

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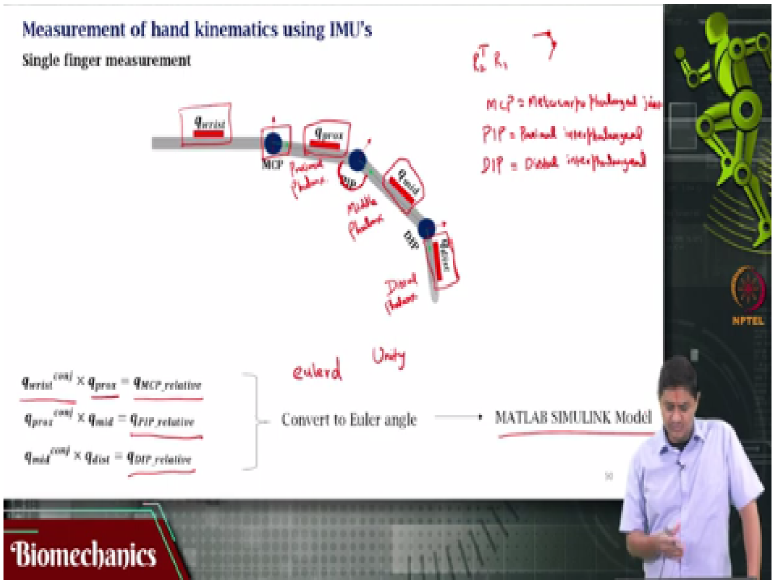

Now let us say that I am interested in measuring the kinematics of a single finger. This is something that we do in our lab we are interested in measurement of individual segmental kinematics. We tried using different methods for this purpose. Now let us suppose that I have only two IMUs. Let us start with a simple situation and I am interested in finding how much the finger has moved relative to the wrist or relative to the carbon bonds and you place the reference sensor at a point that is just distal to the wrist joint.

Because I am interested in understanding the fingertip kinematics and because I have only two IMUs to start with. I am placing the second IMU at the distal segment of course because if I am placing it somewhere else, I will miss the segmental the total kinematics of the distal phalanx place it in a more proximal place but the distal phalanx will also include excursions that happen at the previous joints. Although I do not know what these excursions are.

So, I am placing it like this. Now for the time being there is no sensors or IMUs that are placed at the proximal phalanx under the intermediate or middle phalanx. Let us say now if I use Euler angle as the method of choice then it is possible that the angles could bridge the 90 degree requirement because I am measuring with respect to the wrist and that is the distal phalanx and I am going to do that for example that might be more than 90 degrees.

In fact, I can do that I can close my hand like this. When I do that the distal phalanx obviously crosses may even cross for example from here may even cross 180 degrees. So, the angle requirements are the constraints that you have on the angular measurements will not be met. So, if you are using Euler angles and if you are measuring only the distal segment kinematics you may get into this singularity issues simple lock issues and all this.

It is better to avoid Euler angles as a method of choice in this best to use quaternions. A better method would be suppose you have access to some more IMUs. Suppose you have two more IMUs it might be better that you measure the orientation between this IMU this mid IMU and the this IMU. This will give you the relative angle and it is unlikely that the relative angle even in Euler angle terms in the human body the relative angle between specific joints are at least in the fingers even in Euler angle terms may not cross these constraints.

So, it might be better to avoid these constraints facing these problems. It may be better to use relative measurements between segments. Of course, there might be segments where even this constraint is breached that there may be body segments where there may be a relative moment that is more than 90 degrees. But here we are taking the example of fingers and it is very unlikely that constraint would be breached and many other segments of the body this will likely not be breached.

So, you find the relative remember we discuss how to find the relative orientation using quaternions. Remember if I use rotation matrixes that would be R 2 transpose times R 1. Remember if you do not remember pause this video go back to the rotation matrix video where this was described, watch it one more time and make sure that you now remember this that is how you do it in rotation matrices. How do we do it in quaternions?

You find the complex conjugate of one of the quaternions and multiply it with the other quaternion. We saw this in one of the previous videos again review that video review that information. With that I can find the relative orientation between two segments. So, I am finding the complex conjugate of the wrist quaternion and I am multiplying by the proximal segment quaternion to get the relative orientation at this joint.

What is this joint? What are these? Let me describe this. So, I am interested in measuring the kinematics of a single finger. What are these? Let me describe this and let us say that I am using an IMU based system. I am using an inertial measurement unit and I am measuring I am placing this inertial measurement unit in the three segments. Let us say that I have a distal segment in which I place this and middle segment sensor and proximal segment sensor and a wrist sensor.

What are the three segments in each finger? We know this, this is called as DP or distal phalanx. This is intermediate or middle phalanx; this is the proximal phalanx and the part of the hand that is more proximal to the metacarpophalangeal joint are that is distal to the wrist joint. This joint where the metacarpal bones meet the fingers is called as MCP joint or the metacarpophalangeal joints.

We did discuss this, when we discussed the finger anatomy and biomechanics of finger early in one of the early videos. And that joint that forms between two phalanges and then there are two of these joints. These two phalange joints where the proximal segment is one for phalanx of the finger the distal segment is also the other segment of the finger. There are two interphalangeal joints these joints are called as interphalangeal joints and there are two of them.

Why? Because I have three segments between them that is two joints. These are called as interphalangeal joints and then there are two of these interphalangeal joints. The one that is proximal is called as the proximal interphalangeal joint or the PIP joint. The other is called as the distal interphalangeal joint or the DIP joint. In our lab we use this language where we say dip joint, pip joint. So, what is DIP, what is PIP.

An intern is coming if there is someone new in the lab, they do not understand what is DIP, what is PIP. DIP is the distal interphalangeal joint; PIP is the proximal interphalangeal joint. The more proximal joint is called as MCP joint are the metacarpal phalangeal joint. These are not new all these were discussed while we discussed the hand biomechanics and anatomy quite some time ago perhaps about eight weeks ago or maybe even nine ten weeks ago quite some time ago do check out those videos and review them.

Because we are very close to finishing the course and the exam is coming. So, better that you prepare yourself by reviewing previous content. We always go back and forth; the idea is not to discuss very advanced concepts. This course builds some solid foundation that is the aim and we discuss maybe one or two weeks of advanced content. We bring you up to the level but to go to advanced concepts and more advanced topics it is you are ready for it and you need to take that step yourself.

So, this is a more of a foundation course or it is a course that helps everybody to come on board. It is more like a bridge course remember that. So, we use these relative orientations. For example, if I want to find the relative orientation between the proximal phalanx and the resident, I multiply the conjugate of this joint by the quaternion of the proximal phalanx. But if you want to find this angle, say for example that is the angle at the PIP joint.

Then I have to multiply the complex conjugate of the proximal phalanx quaternion with the quaternion that represents or that I get from the middle phalanx. So, that will also give me a relative quaternion and this will also give me a relative quaternion and then there is or there are straight forward methods to convert from this quaternion to Euler angles. You can develop the algorithm or you can simply use MATLAB.

Remember in one of the previous videos we used a specific function that converts from quaternions to Euler angles. Remember that what is that in MATLAB what is that called? That is called Euler D, is it not? Check it. So, you can do that there are also algorithms that you can use to develop your own code to convert from one to other. Usually many of the other packages or languages will have the equivalent to this Euler D.

And then there are some advanced tools or some visualization or virtual reality type of tools like unity. Unity is just a tool that is used to build games for mobile applications. Many of these games are built using unity these days. Unity simply accepts quaternions and does the processing itself. So, you do not even have to worry about you know conversion, you just give quaternion and it will help you visualize straight away. So, there are tools that do this dirty work for you.

Nowadays these kind of tools are available but if you are someone who likes to do things yourself then MATLAB your own algorithm are the ways to go. But if you are interested in visualizing like you are in the case of unity then you just give coordinates and it will straight away output to the or help you visualize or create a model using Euler angle. Straight away it will take care of the conversion all the problems for you.

Of course, you can use MATLAB SIMULINK model if you use either D and then convert to Euler angles then you can develop a solid model using MATLAB SIMULINK that will help you animate this for you. Unity will straight away take quaternions and help you animate. These are different tools they have their own advantages and disadvantages. So, it is not like one is better than the other. It is all about how much conversant you are with that particular tool.

It is useful to learn more than one of these tools so that you know you understand how these things work and maybe you can also try and find jobs that have application. For example, unity has extraordinary potential for jobs something to keep in mind. So, this is how we measure kinematics of a single finger for example using IMUs. Not necessarily only using IMUs even electromagnetic trackers use and if you use coordinates in electromagnetic trackers use approximately a similar method.

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So, here is an example where we used the principles that we discussed in the previous slide to demonstrate movement of a single finger. Remember the model that we have used so each finger segment is modelled as a solid or a rigid body and their DIP joint and the PIP joint are modelled as hinge joints one degree of freedom joints. The MCP joint is modelled as a two degree of freedom joint and you can see now as I am speaking that the second degree of freedom is also captured.

That is that moment that abduction adduction movement is also being captured by this. Relatively accurate system and you see that it is outputting this in real time. This is a system that we developed in our own lab using IMUs. So, in the next few videos I will describe how we developed this measurement system. So, with this we come to the end of this video, thank you very much for your attention.

(Video Ends: 18:09)