Exercise & Sports Biomechanics
Dr. Rajinikumar Palaniyappan
Centre of Excellence in Biomechanics Cum High Performance Centre for Sports
Department of Sport Biomechanics & Kinesiology
Tamil Nadu Physical Education & Sports University, Chennai (TN)
Week 08
Lecture 38
Hardware Setup Marker & Camera Placement

What are the hardware components needed for a motion capture system?

First, we need a camera, particularly the infrared camera. Then, we need the cables to connect the camera and if you are using minimum 8 cameras or more, so these cameras cables has to be synchronized and the camera cables has to be connected with the synchronized unit or synchronization unit or in other words we call it as sync unit. Then we have to fix the retro-reflective markers that is passive markers on the body of the athletes and then we need a computer.

So, to summarize we need IR cameras with tripods and then the cables and the computer software and then sync unit in short the retro reflective markers has to be fixed on the athlete body and then we need a calibration kit. So, the calibration kit is used to calibrate the capturing volume area where the athlete is going to perform any movement. So, these are all the hardware components needed for a 3D motion capture analysis.

[Next comes the **camera placement and setup**].

How to place a camera?

First, we use the Daisy-Chain method. So, we have already discussed about what is Daisy-chain. So, it is minimal number of cameras where one camera is being connected with the other with the same cable because the power supply is passed from one camera to the other, so we do not need any multiple number of cables. You can see here one camera is connected with the cable and another cable takes the power and data and is connected with the other camera this is how we can reduce the size or length of the cable or number of cable. Then, we use power and data cable. So, both power and data cables are coming as a single cable. So, that helps us to do the setup faster and with maximum efficiency.

T**he importance of camera positioning:**

The cameras are positioned to see the marker. As a principle, any marker should be seen by at least two cameras. And this type of principle helps us track any marker so that if the marker is occluded or hidden, it can be tracked by the other camera. So, this will reduce the number of repeated trials by the athlete. And, so I can see the camera seeing the marker and the other camera also sees the marker. So, the marker has to be seen by at least two cameras for better movement capturing and analysis.

Calibration:

Calibration is an important part of a motion capture system because the camera capturing area has to be calibrated. The cameras may not know the size of the calibration area or the length and width. And they do not have any reference. So, the calibration is done to help the cameras understand the actual length and width of the capturing area. And here you can see the capturing area where the Calibration is being done. So, the calibration is done to locate where the markers are with respect to the x, y, z directions.

What tools are required for calibration?

First, we need a wand calibration. The wand comes with markers at the base, and then an L-frame is required. So, the L-frame has the marker for denoting the origin. Next comes the height and then the length. So, at the bottom, you can see the L-frame. The L-frame has its origin and water level, and further, it has two markers which denote the length and the height. And the L-frame can be adjusted with level adjustment screws on both ends. And both the L-frame and wand can be placed in a calibration box.

Calibration volume:

What is the volume of the area where we calibrate, where the athlete can perform an activity?

Here, you can see the boxed area is the calibration volume. So, what are the movements the athlete does within this calibration volume that are being tracked and captured by these infrared cameras through its software? So, that is the basic component that everyone should understand.

[Now we are going to discuss the marker placement on the athlete]

Marker placement on the athlete:

It is an art how to fix a marker and the number of markers on the bony segments. So, it needs trained personnel to fix the markers on the athlete's body. That is what we are going to see here. So, you can see in this picture the different markers. So, predominantly, it is with two colors. One is white, and another one is yellow. So, the white markers—you can see first—we will discuss the white marker. So, here at the top we have head front and Head left, and L means left shoulder top. That is what we call the acromion process. For easy understanding, they have given us left shoulder top. So, the same is the case with regard to the elbow. So, elbow in and elbow out that is the medial epicondyle of the humerus. It is fixed with one marker, and the same is the case with regard to the outside. You can see the markers being placed on the subject in different body parts, right from the head, shoulder, elbow, wrist, and then hip, chest, thigh, knee, ankle, and foot. So, there are a minimum of 41 markers required to capture any athlete using a motion capture system, particularly an optical motion capture system. Here you can find some of the markers which are given in yellow color.

The yellow-colored markers can be used only during static training. So, when it comes to a dynamic trial, these markers have to be removed. And a minimum of 41 markers should be used to carry out flawless 3D motion capture of the athlete. So, here you can see the table, the display names, and location. So, the head front is the forehead above the nose.

You have to fix the first marker above the nose. Then comes the head left and head right. So, this comes with a headband. It is easy for any person to fix the markers above the ear. And then left shoulder top and right shoulder top that is acromion process that is the bony prominence, and the two markers has to be fixed on right as well as the left then elbow in and out. In the elbow the outside of the elbow bony prominence so you have to fix one marker at the same time the inside of the bony marker, then next comes elbow and then wrist, wrist in and wrist out. And here you can see all the display names and the location. Whether it is chest or waist or thigh or knee out and knee in. But one thing we should keep in mind that any subject who is going to be assessed, we have to first get the marker placed on the athlete's body. At the same time, you have to conduct static trail and followed by the dynamic trail.

During the dynamic trail, the yellow colored markers may be removed by the subject, which is not necessary. And you can see here, the static and dynamic trail Movement capture, both static trail and dynamic trail is essential and mandatory.

Because in static trail we have many markers and the subject is captured when he is standing in the calibrated volume area and the static trail is captured. And the purpose of the static trail is to establish a reference for the body segments. So, when the athlete goes for any dynamic movement, so the static trail reference points are used to create the segments and followed by the static trail. So, we go for the dynamic trail. In the dynamic trail, you can see here the anatomical position and the athlete stands in the anatomical position and at the same time he is asked to wag his arms and move his legs. During the dynamic trail, the athlete is being captured and for further analysis may be in visual 3D. Post-processing the file using the Visual 3D or using MATLAB or Python. So, both static and dynamic trials play a vital role in further analysis of any movement of the athlete.

[Next, we are going to discuss about the PAF]

What is PAF?

Path means project automated framework. So, in project automated framework, you can see the athlete performs the bowling action and the algorithm automatically framing the markers of the model. So, if there is no path, so we have to digitize each markers on our own manually. But when there is a path, so the project automated framework easily locates the markers and creates the 3D model.

In the picture on the right side, if there is no project automated framework, so the biomechanist has to identify the markers, name the markers and integrate the markers. And so here we have seen the path that is project automated framework for running and the object which is being digitized manually without project automated framework.

How the 3D motion capture system can render the results automatically using PAF?

First, we have established in the QUALYSIS has come out with lot of project automated framework. One such PAF is cycling analysis. You can see the number of cameras and the cycle, and here we can get the automated results from QUALYSIS. Next comes treadmill running. In treadmill running, we can also fix the cameras in and around the treadmill to capture the running movement of the athlete. Then comes the golf PAF, golf analysis.

The golf analysis is created with the project automated framework in QUALYSIS, and we can track both the club and the subject's movement for further correction. And the baseball PAF is also there. Next comes the clinical gait. So, the clinical gait PAF is also there to help clinically diagnosed persons.

What is the advantage of PAF in a motion capture system?

It automates tasks. In what way does it automate tasks? The athlete is fitted with markers and comes for a performance. The moment their performance is captured by the IR cameras, the raw file is automatically stored in the system.

But, we have to take those files and check whether the automation has been done or we have to digitally or manually digitize the markers. So, that is the question. Then, when the PAF is there, so the project automated framework helps you to efficiently perform and improve the speed of the work.

The **consistency** - it is the major key in motion capture system. Then comes **scalability** followed by **pre-automated metrics**. So, these are all the advantages of PAF in motion capture system. Further, we are going to see about the workflow of the motion capture system.

Workflow of the motion capture system - in the workflow, first we have to keep the cameras and fix the cameras either on the tripod or on the railing. Then, next comes the calibration. The moment the camera is set up, we need to calibrate the area, and that is why we have the wand and calibration kit then the athlete is fixed with the markers, then followed by the calibration. So, once this is done, and we go for the capturing of the athlete movement and collect the data and then. After collecting the data, the raw file is fixed and saved in the computer. And in the file, we have to name the markers, and then we have to do the modeling. And during the modeling, what we use is the third-party softwares, Visual 3D, MATLAB, Python. But Qualisys has come out with their own biplane called Calculus. So, using Calculus, we can also get the data.

Next, we are going to discuss the **common challenges and solutions in using optical motion capture systems:**

The first one is **occlusion** - Occlusion means the hiding of markers. So, when the marker is hidden from the camera's view, when the athlete performs multiple movements, obviously some of the markers may be hidden by adjacent segments, making the motion capture analysis complex. To avoid that, we use more cameras where complex movements are happening. That is the first step.

Next comes **marker misidentification** - Sometimes the markers will be misidentified, meaning they are wrongly named. So, that kind of marker misidentification has to be sorted out.

Next, we need to use multiple cameras because, for any analysis, we use a minimum of 6 to 8 cameras. But when you want to capture the Complex movements, say for an example, rotation style in shot put or hammer throw or discus throw. These are all the multi-planner activities where we need more cameras to track the markers placed on the athletes. And

then reflections and noise. So, there should not be much reflection and noise in and around the area of capture. So, that will obviously will affect the motion capture system.

Then, we need to adjust the camera threshold settings and filter noisy data. Sometimes, we get calibration drift. That means, over time calibration accuracy may decrease.

How many times once the camera system has to be calibrated?

Normally when the system is set and when it is calibrated, it can remain for two hours. So, in the meantime, no one should even move any part of the system, particularly the camera should not be moved. If that is the case, again we have to go for recalibration. And, so, we are going to compare the motion capture system with other methods. Say, for an example, in this table, we have given, so, the optical marker-based motion capture system and optical markerless motion capture system.

Then comes the IMU-based inertial sensors, followed by force plates. So, accuracy, when it comes to accuracy, optical marker-based motion capture systems have higher accuracy.

The **setup complexity**- refers to how long it takes to set up the IR cameras. Obviously, it requires good experience and a team of people to set up the cameras.

Portability - is lower in optical motion capture systems, whereas the markerless system may have better portability. Then, real-time processing can be done by all optical marker-based, markerless, or IMU-based systems.

What are the environmental constraints?

The marker-based system must be used in a controlled environment. When it comes to optical markerless systems, they work in dynamic settings.

We do not need much time to attach the markers to the athlete. The athlete can come comfortably, and we do not need to disturb them. So, the markerless system is emerging, but it must be validated only with optical motion capture systems. The IMU-based inertial systems can be used anywhere in an open field.

We do not need any cameras, and the IMU sensors can be placed on the athlete's body for movement analysis. So, we have a PAF module for cricket. Here the moment the motion capture is done, the raw file is uploaded, and we get the results immediately using calculus. So, calculus gives us the important data in cricket bowling.

[Thank you, and meet you in the next video].