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Practical work: human motion reconstruction

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Group 10

Alessandro Giuseppe Milazzo
Paolo Pagliaro

1. INTRODUCTION AND OBJECTIVES

Motion capture systems are used globally in many different fields, measuring human body segments and tracking their movement, in fact, has become very important in different applications; from film special effects to health care, sport performance analysis and human machine interaction are only some examples [https://doi.org/10.1108/SR-10-2018-0270]. Motion capture is a technology used to record and analyse the movement of a subject in the three-dimensional space. Optical, inertial, magnetic or mechanical sensors are used to track position, velocity and acceleration of points on the moving body.

A wide portion of experiments and studies is based on the track and acquisition of movements with multiple synchronized cameras. In the present work a camera-based OptiTrack motion capture system has been used; the use of OptiTrack systems is increasing year after year, as demonstrated by the rising number of scientific publications relying on it [DOI: 10.17667/riim.2018.1/13].

To carry out these processes, specific tools called “markers” are used: they are small objects fixed on the body of interest, which allow to track the movement of it; they can be active or passive. Active markers are led able to emit IR light which gets detected by the cameras of the system; passive markers are small spheres or disks covered by reflective material which simply reflect IR light emitted by a ring of leds present in the cameras. In this work, a system based on passive markers has been used.

Cameras involved in Mocap studies based on passive markers have specific features; they’re composed by leds emitting light in IR spectrum and by an objective through which light that gets reflected by markers is detected. In the system used, cameras’ leds are arranged in a ring-shape with the objective in the central part of the ring.

Usually, markers are placed at specific points depending on the goal of the experiment. In some applications, for example, they can be positioned on specific anatomical landmarks, typically easy to identify and not subject to relative motion between the skin and underlying structures.

As mentioned above, markers’ movement is detected and tracked by cameras, data are collected and then processed by the system; using the two-dimensional view from multiple cameras, the system is able to reconstruct the three-dimensional position of the markers. Each cameras tracks and records the position of markers in the two-dimensional space, but overlapping and processing data collected form more cameras allow to reconstruct markers’ position in the three dimensional space. To reconstruct the 3D position of a marker, the system needs at least two cameras which see the marker of interest, that is why it is important to have systems equipped with more cameras.

These kinds of systems can be very accurate and allow a very precise reconstruction of trajectories and movements enabling quantitative analysis. The system used in the present work is featured by a resolution of 1 mm.

Defining the capture volume is also a crucial step, it depends on the space required to perform the task and, naturally, on the dimensions of the laboratory. A larger capture volume requires more cameras and greater distances between them; on the other hand, a small capture volume can limit number of movements that can be analysed (some movements require larger spaces, gait analysis for example requires the physical space to perform few steps).

Motion capture technology has a wide variety of applications, in particular in the biomechanics field. In gait analysis is possible to identify abnormalities in walking patterns, useful both for clinical diagnosis and for treatments; in sport fields these systems are used to optimize athletic performances and to prevent injuries by studying high degree-of-risk movements; in rehabilitation it's possible to monitor progresses after injuries or surgeries; it's also possible to evaluate and asses the impact of orthopedic devices on patient to optimize treatment outcomes; postural analysis and ergonomics are other two linked fields where mocap can be useful, in particular in the identification of postural stability, compensatory mechanisms and evaluation of the interaction between human and machines.

The goal of this work is to better understand, through a real experiment, how it is possible to reconstruct and analyse human motion with a camera-based motion capture system. Specifically, the objectives are:

- To capture 2 different right leg movement using the Optitrack capture system
- To estimate the parameters of the right leg model
- To define the model using natural coordinates
- To reconstruct the motions
- To analyse reconstructed motions
- To write a final report of the whole process

2. MOTION CAPTURE

2.1. Materials

The Optitrack motion capture system used for the work consisted of 11 cameras strategically positioned in the room. Eight cameras were placed in the four corners of the room (four at the top and four at the bottom), while the remaining three were arranged as follows: two on the right side (one at the top and one at the bottom) and one on the left side, positioned at the top.

The work began with a calibration, an essential phase to ensure the quality of the acquired data. During calibration, the system calculates the position and orientation of each camera and the amount of distortion in the captured images to build a 3D capture volume in the software used. This is done by observing 2D images from multiple synchronized cameras and associating the position of known calibration markers from each camera through triangulation.
It is important to note that if any changes are made to the camera setup or if environmental conditions change, the system must be recalibrated to maintain accuracy.

Calibration phases:

- Preparation of the capture volume: optimization of the space for the motion capture system. The cameras must be positioned and configured appropriately to ensure complete coverage of the capture volume. Each camera must be securely mounted to remain stationary during data acquisition.
- Masking of reflections: before calibration, all foreign reflections or unnecessary markers must be eliminated or covered, to prevent overlaps with the markers relevant for the motion capture. If this is not possible, reflections detected can be masked directly in the software used.
- Sample collection through wanding: wanding is the main phase of calibration. A calibration wand with preset markers is used, shaken repeatedly throughout the volume. This process allows the cameras to detect the markers and collect sample data points, enabling the software to calculate the position and orientation of each camera in 3D space.
- Definition of the ground plane: to complete the calibration, the ground plane must be defined using a custom calibration square, consisting of three markers arranged in a right angle, with one arm longer than the other. The global origin is then set by applying a vertical offset, which represents the distance between the center of the markers on the calibration square and the actual ground.

2.2. Methods

The next phase of this work involved the placement of the markers. Nine markers were positioned as specified in Table 1, maintaining a distance of more than 5 cm between each. Ensuring a distance greater than 5 cm between markers enhances measurement accuracy by preventing overlaps or interferences that could compromise the precision of movement estimates and joint parameter calculations.

These markers are used for three main purposes:

- Defining the local coordinate system (LCS) of each segment.
- Estimating joint parameters.
- Reconstructing the movements

Segment	Description	Optitrack name (suggestion)
Thigh	Marker on landmark LFE	LFE
	Marker on landmark MFE	MFE
	Marker on the right thigh	RT
Shank	Marker on the right shank	RS
	Marker on landmark LM	LM
	Marker on landmark MM	MM
Foot	Marker on the foot	F1
	Marker on the foot	F2
	Marker on the foot	F3

Tabella 1

At this stage, the static posture was recorded, which was later used in the second phase to estimate the model parameters. In this study, the static posture of the right leg was captured with the knee and ankle in a neutral position.

Subsequently, the movements of knee flexion and extension were recorded, starting and ending with the knee in the neutral position. Then, the movements of dorsiflexion and plantarflexion of the ankle were recorded, starting from maximum plantarflexion and proceeding to maximum dorsiflexion. During this phase, the thigh was stabilized with both hands to minimize unwanted movements.

During the motion capture phase not many problems were encountered. The only two aspects that required more time was masking unwanted light sources and the initial calibration of the cameras, due to the limited space in the laboratory.

3. ESTIMATION OF MODEL PARAMETERS

3.1. Definition of joint centers and LCS of each segment

3.2. Numerical results

3.3. Leg model

4. ANALYSIS OF RECONSTRUCTED MOTIONS

4.1. Flexion/Extension

4.2. Dorsiflexion/Plantarflexion

5. CONCLUSIONS

6. DISTRIBUTION OF WORK

7. REFERENCES