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Short communication

Design and evaluation of a new three-dimensional motion capture system based on video

J.L.Garrido Castro [a], R. Medina-Carnicer [a,*], Alfonso Martinez Galisteo [b]

[a] *Department of Computing and Numerical Analysis, Córdoba University, 14071 Córdoba, Spain*
[b] *Department of Anatomy and Applied Anatomy, Córdoba University, 14071 Córdoba, Spain*

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Abstract

This technical note describes the development and evaluation of a low-cost motion capture and analysis system (SOMCAM3D). From diverse video sequences obtained by commercial cameras, synchronized by a certain event, and calibrated from a calibration process, the system is able to reconstruct three-dimensional positions in a reference system defined by the calibration process. From these positions, a wide variety of kinematic variables could be calculated. This system aims to analyze movement in applications of gait analysis, sports, animals, ergonomics, robotics, etc. It is designed to work with low-cost equipment (commercial cameras, computers, etc.). Also it allows us to work in 2D, outdoors, and without marks. Finally, this technical note includes a study of how precise and accurate this system is.

Keywords: 3D motion capture; Movement analysis; Measurement; Biomechanics; Kinematics

1. Introduction

Motion measurement is a concept used in biomechanics to describe the compilation and analysis of data of any kind of 2D or 3D movement. These data are obtained from video cameras, VCR, magnetic or mechanical devices, etc. and are processed in order to calculate linear and angular displacements, velocity, acceleration, etc. This information can be used to quantify, to analyze and to improve movement patterns in a wide variety of applications.

Several commercial motion capture systems for kinematic analysis have been introduced [6] following the publication of studies [5,4]. Basically, there are two different methods to capture and analyze movement: on-line and off-line systems.

In the first case, active or passive markers are attached to the subject. The description of the movement in the computer appears almost immediately after the movement itself. Therefore, the measurement is obtained in real time (on-line).

Videos fall into off-line systems. These systems are based on video sequences (from standard or high-speed cameras), where the movement is recorded. Later (off-line), movement is evaluated with the aid of image processing methods.

This paper describes SOMCAM3D, a new off-line system based on video.

2. Technique description

2.1. Planning

First, we must design the distribution (spatial model) of the markers or the point to be measured on the target. Certain universities and research laboratories have defined spatial models used mainly in gait analysis [7].

2.2. Camera calibration

With 2D we could use a simple multipliers method. This method is very imprecise and gives rise to a great deal of error (no perpendicular camera placement, movement

* Corresponding author. Tel.: +34 957 21 83 46; fax: +34 957 21 86 30.
E-mail address: rmedina@uco.es (R. Medina-Carnicer).

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Table 2
Results compared with other systems

System	Mean abs. error (mm)	Max error (mm)	S.D. (mm)	Processing time (min)
Ariel APAS	11.61	13.47/ −24.07	5.36	28
Dynas 3D/h	18.42	27.20/ −51.48	0.24	16
Peak 5	3.85	8.10/ −10.39	2.07	7
SOMCAM3D	2.12	8.39/ −6.24	2.48	6.3

committed, 2.12 mm over 5 m; and the marker's diameter, 30 mm.

Table 2 compares the results obtained by Ref. [3] and those obtained by the authors following the same test process. This table only includes video-based systems that could work off-line and outdoors.

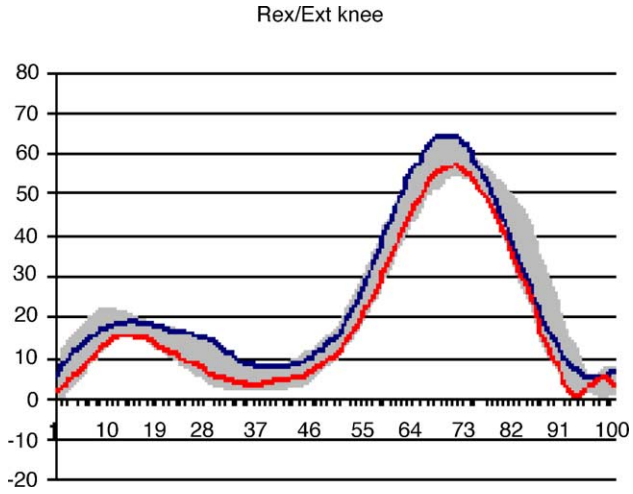

Fig. 2. Knee angle joint in gait analysis.

5. Conclusions

Motion capture on-line systems have some serious disadvantages, when carrying out biomechanical analysis outdoors and with animals: they do not show the image of the subject simultaneously (which can be interesting from the point of view of qualitative analysis); they are not viable outdoors; experiments cannot be repeated later on (without the subjects) in order to review, collect or edit data depending our needs. Systems with active infrared markers, ultrasound, mechanical, etc. also have to 'wire up' the subject, and there are consequential problems with the reflections of the infrared signals off the walls and the ground. This kind of system are only viable under rigid laboratory conditions.

The systems based on video are less expensive that the others because they can use off-the-shelf cameras, video capture based on firewire and personal computers.

SOMCAM3D is a low-cost motion capture and analysis system based on video. It is a more flexible system, but all processes must be carried out at a later stage. This fact is a limitation with regard to real-time motion capture systems.

Our system has been proven in a wide range of applications related to motion capture. In gait analysis, the results obtained have been very similar to those published by several authors (Fig. 2).

The experimental results obtained in system evaluation reveal that this system performs better than other similar systems with which it has been compared.

The system fulfills the necessary requirements of a low-cost analysis system of three-dimensional movement for a wide range of applications including outdoors.

Actually, we are working on incorporating data from analog sources (force plates, EMG, etc.).

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References

[1] Abdel-aziz YI, Karara HM. Direct linear transformation from comparator coordinates into object space coordinates in close range photogrammetry. In: ASP symposium on close range photogrammetry. Falls Church, USA: American Society of Photogrammetry; 1971 . p. 1–18.
[2] Borghese NA, Ferrigno G. An algorithm for 3D automatic movement detection by means of standard TV cameras. IEEE Trans Biomed Eng 1990;37:1221–5.
[3] Ehara Y. Comparison of the performance of 3D camera systems II. Gait Posture 1997;5:251–5.
[4] Marey EJ. Le mouvement. Paris: Masson, 1894.
[5] Muybridge E. Animal locomotion. In: Down LS, editor. Animals in motion. London: Chapman Hall; 1899. p. 264.
[6] Richards JG. The measurement of human motion: a comparison of commercially available systems. Hum Mov Sci 1999;18: 589–602.
[7] Zatsiorsky VM, Seluyanov VN. The mass and inertia characteristics of the main segments of the human body. In: Matsui H, Kobayashi K, editors. Biomechanics VIII-B. Champaign, IL: Human Kinetics Publishers; 1983. p. 1152–9.