Video-based methodology for markerless human motion analysis

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ABSTRACT
This study presents a video-based experiment for the study of markerless human motion. Silhouettes are extracted from a multi-camera video system to reconstruct a 3D mesh for each frame using a reconstruction method based on visual hull. For comparison with traditional motion analysis results, we set up an experiment integrating video recordings from 8 video cameras and a marker-based motion capture system (Vicon™). Our preliminary data provided distances between the 3D trajectories from the Vicon system and the 3D mesh extracted from the video cameras. In the long term, the main ambition of this method is to provide measurement of skeleton motion for human motion analyses while eliminating markers.

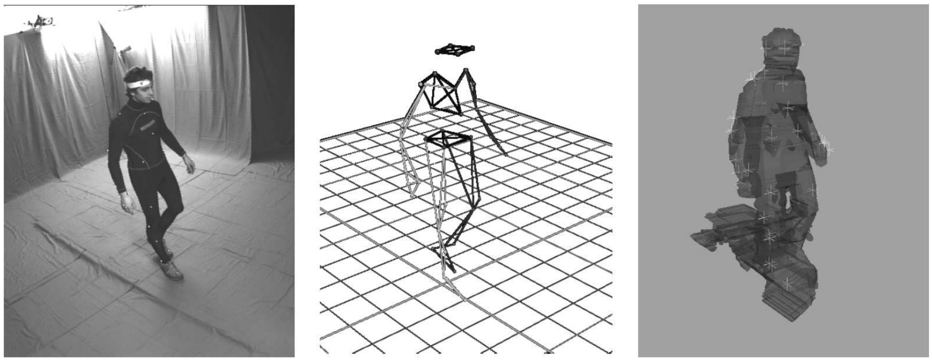
INTRODUCTION
Human motion analysis gives the essential data for neurobehavioral and biomechanical studies, especially in sport, clinic and rehabilitation research. To analyze the body movements, accurate 3D data must be extracted after the motion capture procedures. Usually, marker-based methods are used to provide 3D coordinates of anatomical markers through time. These markers are used to deduce inner body coordinates, such as the joint rotation points or the center of mass of body segments. Although these marker-based methods are widely spread they present some drawbacks. Firstly, they require expensive and heavy equipment which necessitate a dedicated room for experiments. Secondly, setting-up the patient with markers is tedious, time consuming, and only provides a discrete and biased description of the motion (Leardini et al 2005). The fact that, in our method, only multiple video camera system is necessary to acquire data would facilitate data acquisition. Moreover, building the entire body surface of the subject during the entire image sequence would increase the accuracy of the motion description.

METHODS
Data acquisition. The experimental room (Figure 1.A.) was set up with uniform background to allow the automatic image segmentation. A subject was asked to walk naturally and move along a limited walking track (3m). The acquisition area was 2m long x 2m height x 2.8m width. The Vicon system consists of 13 infra-red cameras recording at 250Hz the 3D position of 39 markers attached on the subject body, following the Vicon Conventional Gait Model (Figure 1.B.). The area was calibrated by the Vicon system, using the “5 marker Active Wand” calibration tool. Data were recorded from the Vicon capture software (Nexus 1.8). The multi video system consists of 8 Basler™ (acA1300-30g) cameras, synchronized with the Vicon system. Cameras were recording the same volume at 25Hz, using StreamPix software. We used the same calibration tool to scan the field of view of each camera and used the 3D coordinates of the 5 markers of the calibration tool to calibrate the video cameras. Given the distance between the cameras and the acquisition volume, the resolution was 5mm/pix.
Data analysis. For the Vicon data, we tagged each marker and exported its 3D trajectory for each frame of the sequence. For the video data, we extracted the 8 silhouettes of the subject

for each frame. We obtained a mesh using a visual hull approach (Laurentini, 1994). The Vicon and Video 3D data sets were merged using 3D reconstruction software (Autodesk® Maya®) (Figure 1.C.).

RESULTS

The coupling of Vicon and Video data acquisition allows extracting two synchronized sets of 3D movement coordinates, illustrated Figure 1.



A B C

Figure 1. Subject in the experimental room, viewed from one video camera (A), reconstructed using Nexus Vicon (B), segmented with video-based method (C)

The mean distance between the mesh and the marker has been calculated through a walking sequence. The lowest distance corresponds to a marker on the shoulder (0.45±0.32cm) the highest to a marker on the hip (2.3±1.3cm). Considering that the diameter of the markers is 1cm, this method provides accurate information about the skin surface.

CONCLUSION

This work presents preliminary results on a video-based method. It shows promising application for (1) a simplification of movement analysis procedures that (2) hopefully preserve acceptable 3D data accuracy required to access to the inner mechanism of human movement, and (3) to analyze the implicit neuromechanical processes. Although our method highly depends on the quality of the video data (mainly segmentation quality linked to the number of cameras), we believe this ergonomic aspect of our video-based human motion analysis opens great possibilities in fundamental and applied human motion analyses. This is a first step as the meshes reconstructed from visual hull are not temporally coherent across time. Ultimately, it will be necessary to apply mesh tracking methods on these data to assess the real capability of such an approach to replace marker-based systems (Duveau et al. 2012).

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