LOWER LIMB KINEMATICS THROUGH MODEL-FREE MARKERLESS MOTION CAPTURE

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INTRODUCTION

In recent years, the development of new techniques for motion capture not involving the use of skin markers is receiving great interest. This is mainly due to several potential advantages that a non-invasive (markerless) technique has over stereophotogrammetry. These are mainly: i) no subject preparation, ii) intrinsically more robust with respect to soft tissue artifacts, and iii) potentially applicable in outdoor environments. A common way of capturing human motion is the construction of visual hulls. Human body segments are typically extracted by employing an articulated model. In this study a model-free approach for extracting human body kinematics from visual hull sequences through Laplacian Eigenmaps is presented.

METHODS

A virtual gait sequence of 120 frames of a human form was created using Poser (Curious Labs, CA). Visual hulls of different quality using 8, 16 and 64 cameras were created using most favorable camera configurations [1]. Each visual hull was constructed as volume data set with a resolution of 2 cm. Human body segments were identified by mapping visual hulls to a multi-dimensional space through Laplacian Eigenmaps [2,3] (implementation code by Belkin, Surendran, and Bundschoten, University of Chicago). The resulting mapping (location) in the multi-dimensional space was invariant with respect to pose and position in the original Euclidean space, that is the same body segment mapped to the same location. Locations for the head, neck, torso, arms, forearms, hands, thighs, shanks and feet were determined allowing the identification of these segments in all frames in the Euclidean space (Figure 1a). The main geometric axes were calculated, approximating a segment's anatomical axes. Joint angles for the sagittal and frontal plane were calculated as angles between corresponding axes of neighboring segments. Accuracy of human body kinematics was calculated as the average deviation of joints angles derived from visual hulls compared to joints angles derived from the Poser sequence over the gait cycle.

RESULTS

The accuracy of visual hulls is greatly affected by the number of cameras used [1], which potentially affects body segment identification. Body segments were identified accurately for visual hull sequences constructed using 16 or more cameras. The patterns of sagittal and frontal plane kinematics derived from all visual hulls were very similar to those derived from Poser (Figure 1). The accuracy of hip, knee and ankle flexion-extension and ab-adduction angles for visual hulls constructed using 16 cameras was 1°, 3° and 8°, and 3°, 3° and 5°, respectively.

DISCUSSION

This study demonstrates the feasibility of accurately measuring 3D human body kinematics using a model-free markerless motion capture system on the basis of visual hulls and Laplacian Eigenmaps. The ankle joint angles are the most critical to measure due to the small size of the foot. The approach can be easily extended to upper limb measurements.
The model free approach described here represents an important step towards making markerless motion capture practical, since the total time and manual intervention for a complete analysis are substantially reduced. The presented gait cycle of 120 frames takes approximately 3 hours to be processed in the Matlab code on a 3GHz pc.
Limitations of this study are the use of a rigid human form for constructing visual hulls. However, inaccuracies in visual hull construction, might outweigh segment deformations in the living human. Thus, it is expected that similar results will be obtained in experimental set-ups with limitations due to camera calibration and fore-background separation.

REFERENCES

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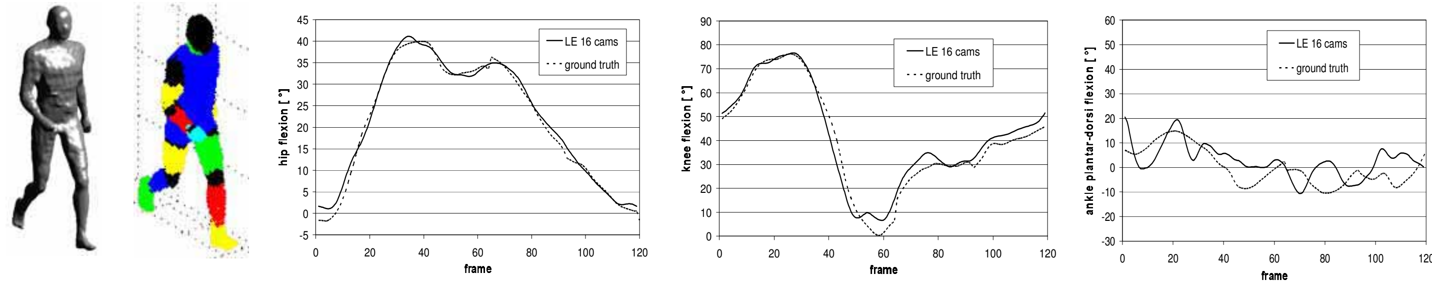

Figure 1: a) Visual hull and b) identified body segments. c) Hip, d) knee flexion, and e) ankle plantar-dorsiflexion.