Sensitivity of OpenPose in capturing knee joint angles across varying camera angles

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Summary

This research aims to assess the performance and sensitivity of OpenPose estimating 2D projected lower-limb joint angles across eight camera angles compared to traditional 3D marker-based motion capture. The results of the study show there is variation in joint angles between camera angles and the ground truth system. This highlights the importance of proposing specific camera angles when collecting markerless video data for accurate human pose estimation and demonstrates our combined video-based and marker-based dataset for evaluating markerless technologies.

Introduction

Deep learning video-based pose estimation algorithms have shown promise for enabling large-scale movement studies in real-world environments, free from the limitations associated with marker-based motion capture systems. However, there is limited research regarding the accuracy and applicability of human pose estimation outside of the lab [1]. One of the main reasons is due to challenges like multi-axial movements of lower limb joints and inconsistencies in camera angles. Previous studies have demonstrated that certain camera angles can lead to occlusion, affecting accuracy in defining joint centers [2]. However, there is a need to evaluate computing joint angles from the joint centers for biomechanical research. Our study aims to investigate the sensitivity in estimating joint angles between varying camera angles that can be used to optimize data collection in out-of-laboratory environments.

Methods

25 healthy participants (24±4.1yo; 15F) completed a series of dynamic maneuvers while wearing 50 active LED markers (34 anatomical and 16 tracking). Marker data were captured using an 8-camera PhaseSpace system (960 Hz). 3D marker positions were interpolated to account for marker drop-out, filtered using a 20Hz low-pass 4^{th}-order lag-less butterworth filter, and downsampled to 60Hz to match the sample rate of our video collection system. We applied manual inverse kinematics of markers on the shank and thigh referenced to anatomical markers on the hip, knee, and ankle to calculate knee joint angles defined based on ISB recommendations [3].

Simultaneously, we collected video using eight Sony RX0II cameras (60Hz) placed at a 2m distance around the measurement space at 45° angle intervals (Figure 1b). Videos from each camera were processed using OpenPose to extract joint centers, which were filtered matching the marker data filter. Using the hip, knee, and ankle joint centers, we used planar trigonometry to determine the projected 2D knee angles. We computed the Root Mean Square Error (RMSE) between the marker-based 3D knee flexion angle against the OpenPose 2D projected knee angle from the various camera angles. The RMSE was normalized by the peak flexion angle from the 3D marker-based system.

Results and Discussion

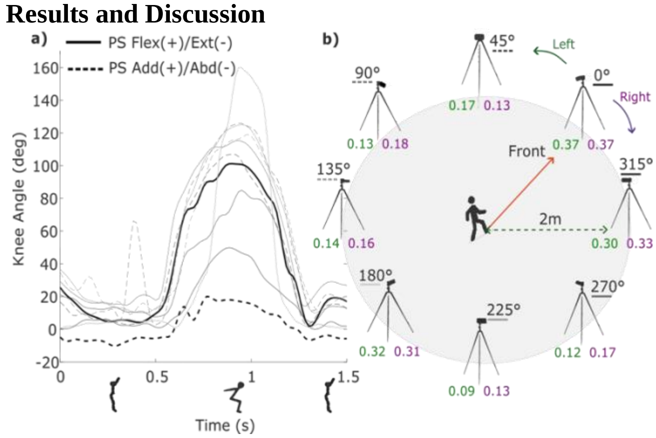

Figure 1 (a) Right Knee Angle during the Landing Phase of a Drop-Jump (b) Video Camera Set-Up Around Measurement Space

For a single participant performing a drop-jump, we observed video views with the sagittal plane components (45°, 90°, 135°, 225°, 270°) had lower knee flexion normalized RMSE, as knee flexion is projected into the sagittal video plane. RMSE values are shown in Figure 1b in green (left leg) and purple (right leg). Meanwhile, frontal video views (0°, 180°) have larger normalized RMSE, which is expected since flexion and extension angles are not projected effectively into the frontal plane. Curiously the camera at 315° also has a higher normalized RMSE, perhaps because the leg was offset and facing frontal views. Furthermore, we expected symmetry from the left and right-side cameras evaluating the contralateral or ipsilateral knee. However, results show higher RMSE in the right knee in most camera views.

Conclusions

The result of this study demonstrates that camera angles do have an impact on the accuracy of joint angle estimation. Based on the movement being performed and the direction of the knee angle, proper camera position can affect the performance of OpenPose. We will continue evaluating other pose-estimation algorithms over all participants and movements to better generalize these findings. Understanding more about the differences in methods and varying camera angles will help provide valuable insight into how to best collect data in an out-of-laboratory setting that non-technical experts can easily capture.

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