

PERFORMANCE OF TWO POSE ESTIMATION ALGORITHMS IN GAIT ANALYSIS AGAINST THE VICON REFERENCE SYSTEM

Abdul Aziz Hulleck (1), Mahdi Mohseni (2), Mohd Khalil Abu Hantash(1), Rateb Katmah(1), Murad Almadani (1), Navid Arjmand(2), Kinda Khalaf (1), Marwan El Rich (1)

1. Khalifa University, Abu Dhabi, United Arab Emirates; 2. Sharif University of Technology, Tehran, Iran

Introduction

An affordable, easy-to-use, yet accurate gait analysis system is necessary for design of effective diagnostic and treatment programs (Yamamoto et al., 2022). Pose estimation is a low-cost alternative to the traditional optical and IMU-based motion capture systems. In this study, we examined the performance of two RGB-camera based human pose estimation methods, i.e., AlphaPose (Lv et al., 2022) and Google MediaPipe (Bazarevsky et al., 2020) for the lower limb joint kinematics extraction during self-selected walking against the Vicon motion capture system as the gold-standard reference tool.

Methodology

Five healthy male individuals (179.7 ± 6.7 cm, 69.5 ± 7.4 kg) walked through a four-meter path six times at self-selected normal walking speeds while their full-body movement was measured using two synced systems: 1- a ten-camera Vicon motion capture system at a sampling rate of 120 Hz and full-body plug-in gait markers (the reference system) and 2- a GoPro RGB camera capturing the motion in the sagittal plane. The anatomical angles of hip, knee, and ankle joints were subsequently calculated using the reference system coordinates and Cardan method with a YXZ sequence. The AlphaPose which gives seventeen 2D body landmarks and the Google MediaPipe that offers high-fidelity body pose tracking inferring thirty-three 3D body landmarks from RGB video frames were also used to estimate the coordinates of important landmarks. Body segment vectors were used to determine the sagittal plane angles for the left/right hip, knee, and ankle joints. The MediaPipe and AlphaPose predicted joint kinematics were compared to the Vicon reference system by calculating the normalized (divided to the range of data) root-mean-square-error (nRMSE) and performing one-way analyses of variance (ANOVA).

Results

One-way ANOVA reported significant differences ($p < 0.05$) between Vicon and MediaPipe for both hips and left ankle as well as Vicon and AlphaPose for right hip and left knee (Table 1). Comparisons of mean \pm standard deviation (SD) of the right/left hip, knee and ankle kinematics parameters of the Vicon and pose estimation algorithms (MediaPipe and AlphaPose) indicated lower range of motion by MediaPipe as compared to AlphaPose and Vicon at the hip and knee joints (Figure 1a). As compared to Vicon, MediaPipe overestimated the ankle joint angles during dorsiflexion. AlphaPose reported lower nRMSE as compared to MediaPipe except for the left knee (Figure 1b).

Table 1: P-values of one-way ANOVA comparing joint angles between Vicon and pose estimation algorithms.

p-values	Vicon vs. MediaPipe	Vicon vs. AlphaPose
R HIP	0.0000	0.0001
L HIP	0.0000	0.1230
R KNEE	0.9796	0.3170
L KNEE	0.8769	0.0069
R ANKLE	0.1653	-
L ANKLE	0.0000	-

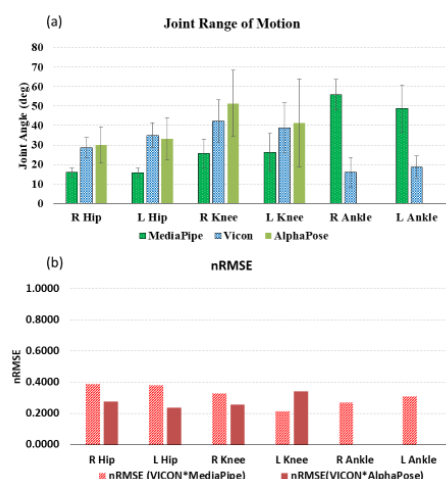


Figure 1: (a) Joint range of motion in sagittal plane, (b) nRMSE of MediaPipe and AlphaPose predictions as compared to Vicon.

Discussion

Ankle kinematics cannot be reported by AlphaPose due to the absence of heel and toe detections thus limiting their joint angle measurements. MediaPipe is a cross-platform open-source framework, which can be used to design applications for gait analysis by providing real-time pose estimation. AlphaPose, with lower nRMSE, however, fails to predict ankle joint angles. Adoption of telerehabilitation is beneficial for reducing pain from low back pain, lumbar stenosis, neck pain, and osteoarthritis (Fiani et al., 2020). MediaPipe's ease-of-use, accessibility, and real-time analysis demonstrate its advantages for remote gait monitoring and its growing applications in future for crucial telerehabilitation purposes.

Reference

- Bazarevsky, V., Grishchenko, I., Raveendran, K., Zhu, T., Zhang, F., Grundmann, M., 2020. BlazePose: On-device Real-time Body Pose tracking.
- Fiani, B., Siddiqi, I., Lee, S. C., Dhillon, L., 2020. Telerehabilitation: Development, Application, and Need for Increased Usage in the COVID-19 Era for Patients with Spinal Pathology. *Cureus* 12, e10563.
- Lv, X., Ta, N., Chen, T., Zhao, J., Wei, H., 2022. Analysis of Gait Characteristics of Patients with Knee Arthritis Based on Human Posture Estimation. *BioMed Research International* 2022, 7020804.
- Yamamoto, M., Shimatani, K., Ishige, Y., Takemura, H., 2022. Verification of gait analysis method fusing camera-based pose estimation and an IMU sensor in various gait conditions. *Scientific Reports* 12, 17719.

