https://nbn-resolving.org/urn:nbn:de:bsz:ch1-qucosa2-806704

OpenPose and its current applications in sports and exercise science: a review

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Abstract

The aim of this scoping review is to investigate current applications of a markerless human pose estimation (HPE) algorithm in sports and exercise science. 17 studies are selected for this purpose. Results show that HPE is applied already in a variety of sports for different aims and purposes. Even though it provides many advantages over marker-based approaches, it still comes with challenges that need to be tackled in future research.

Keywords: openpose, sports, exercise, application, scoping review

Introduction

In recent years, human pose estimation (HPE) has become a big field in computer vision. One of the most prominent HPE algorithms is OpenPose (Cao et al., 2021). A wide range of validation studies using OpenPose exist (Badiola-Bengoa & Mendez-Zorrilla, 2021), but some questions still remain open: *I) Has OpenPose found its way into being applied in sports and exercise science? II) What are the current applications and research questions when applying OpenPose in sports and exercise science? III) What are the current challenges?*

Methods

To answer these questions a scoping review has been conducted using PubMed as a primary search engine and the following search strategy: *openpose AND ((sport) OR (physical exercise) OR (exercise))*. This search resulted in 20 publications from which 12 were excluded being either review papers, studies with little or no relation to sport or exercise. 9 additional publications were identified through references in the aforementioned publications that were included in this review which resulted in a total of 17 studies that were studied more closely to answer the research questions of this scoping review.

Results

The selected publications that were included in this scoping review can be seen in Table 1. For each study the type of sport investigated and the goal of the study is presented.

Table 1: Publications included in this scoping review (CMJ = counter movement jump, MBMC = marker-based motion capture, NN = neural networks, OP = OpenPose).

Study	Type of sport	Goal
Arbues-Sanguesa, Martin, Fernandez, Rodriguez, et al. (2020)	Soccer	OP is combined with a super-resolution network to obtain the body orientation of players during the game from video data.
Arbues-Sanguesa, Martin, Fernandez, Ballester, and Haro (2020)	Soccer	Estimation of the feasibility of passes using the passing and receiving player's body orientation (obtained using OP).
Baclig et al. (2020)	Elite-level Squash	Estimation of distance traveled, court position, 'T' dominance and average speed.
Echeverria and Santos (2021)	Karate	Extract features of karate movements from OP to identify the postures using machine and deep learning algorithms.
Haralabidis et al. (2020)	Boxing	3D inverse dynamics analysis of punching kinematics using data inputs from wearable sensors and OP.
Hirasawa et al. (2020)	Squats	Detection of key points for evaluation and scoring of squat postures for feedback.
Nakai et al. (2019)	Basketball	Pose estimation as an input for a posture analysis model to predict free throw.
Nakano et al. (2020)	Walking, CMJ, Ball Throwing	Evaluation of differences in joint positions from OP and a MBMC system.
Needham, Evans, Cosker, and Colyer (2021)	Sprinting & Skeleton push start	Evaluation of 3D mass center positions and velocities comparing OP and MBMC.
Needham, Evans, Cosker, Wade, et al. (2021)	Walking, Jumping, Running	Accuracy evaluation for (reconstructed) 3D joint center location of OP and other HPE methods.
Palucci Vieira et al. (2022)	Soccer	Evaluation of OP for obtaining lower limb kicking kinematics comparing to manual digitization.
Park et al. (2020)	Push-Ups	Counting and classification of correct and incorrect push-ups.
Pinheiro et al. (2022)	Soccer	Evaluation of OP to determine body orientation during penalty kicks and investigate its interplay with the goalkeeper strategy.
Shimizu et al. (2019)	Tennis	Prediction of shot direction with NN using OP joint positions and player positions during time of impact as inputs.
Suda et al. (2019)	Volleyball	Prediction of ball trajectory using body joints from OP (2D) and Kinect (3D) applying NN.
Wang and Wang (2022)	Walking, Running, Swimming, Situps, Pullups, Basketball, Rope Jump	Identification and evaluation of movements using OP joint position data as input for a convolutional NN.
Webering et al. (2021)	Vertical Jump	Evaluation of vertical jump height using OP to approximate the body's center of mass.

Discussion

I) Application in sport science: OpenPose is already applied in a diverse range of sports from body-weight exercise (Hirasawa et al., 2020; Park et al., 2020; Wang & Wang, 2022) to walking and running (Nakano et al., 2020; Needham, Evans, Cosker, Wade, et al., 2021; Wang & Wang, 2022) as well as team sports such as Basketball (Nakai et al., 2019), Volleyball (Suda et al., 2019) and soccer (Arbues-Sanguesa, Martin, Fernandez, Ballester, & Haro, 2020; Arbues-Sanguesa, Martin, Fernandez, Rodriguez, et al., 2020; Palucci Vieira et al., 2022; Pinheiro et al., 2022).

II) Current research questions: Some of the studies deal with the validation of the algorithm in determining different parameters, such as joint and mass center positions and velocities (Nakano et al., 2020; Needham, Evans, Cosker, & Colyer, 2021; Needham, Evans, Cosker, Wade, et al., 2021; Wang & Wang, 2022). While in other studies data is used to identify postures (Echeverria & Santos, 2021; Hirasawa et al., 2020; Nakai et al., 2019; Park et al., 2020), to estimate kinematic parameters (Baclig et al., 2020; Haralabidis et al., 2020; Palucci Vieira et al., 2022; Webering et al., 2021) or body orientation (Arbues-Sanguesa, Martin, Fernandez, Ballester, & Haro, 2020; Arbues-Sanguesa, Martin, Fernandez, Rodriguez, et al., 2020; Pinheiro et al., 2022). Some studies use the derived data for predictions of sports-specific parameters (Nakai et al., 2019; Shimizu et al., 2019; Suda et al., 2019).

III) Current challenges: The advantages of OpenPose over conventional marker-based motion capture in sports and exercise science are manifold. On the one hand it only requires one non-specialized camera meaning lower costs (Nakai et al., 2019). On the other hand, limited manual intervention and expertise is required to prove near-time analysis (Baclig et al., 2020). Furthermore, it does not require a laboratory setup which allows to analyze video data from competition or from sports that formerly could not be analyzed. However, there are still challenges that need to be considered. Poor performance can be the result of fast and explosive movements (Shimizu et al., 2019), rare or challenging body poses common in some sports (Badiola-Bengoa & Mendez-Zorrilla, 2021; Needham, Evans, Cosker, & Colyer, 2021) or occlusions and interactions of players with each other or with equipment (Badiola-Bengoa & Mendez-Zorrilla, 2021). In some cases the algorithm fails to correctly detect left and right side of the body which requires either a correction of such failures (Nakano et al., 2020) or 3D instead of 2D motion data (Nakai et al., 2019; Park et al., 2020). Generalization to other sports or applications still needs to be treated with caution and more diverse and sports-specific datasets to train these algorithms are needed.

Conflict of Interest We declare no conflict of interest.

Funding This work was funded by funds of the Professorship of Sports Equipment and Materials.

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