The Use of Human Pose Estimation to Enhance Teaching & Learning in Physical Education

Tommy Hock Beng[1], Ng Steven Kwang San[2], Tan Shern Meng[3], Tan Wei Peng[4], Teo John Komar[5]

{hockbeng.ng@nie.edu.sg[1], steven.tan@nie.edu.sg[2], shernmeng.tan@nie.edu.sg[3]}

National Institute of Education, Nanyang Technological University, Singapore[1], National Institute of Education, Nanyang Technological University, Singapore[2], National Institute of Education, Nanyang Technological University, Singapore[3], National Institute of Education, Nanyang Technological University, Singapore[4], National Institute of Education, Nanyang Technological University, Singapore[5]

Abstract. Non-proficient demonstration, gross motor skill assessment, and subjective feedback are but a few of the perennial problems in physical education (PE). These problems stand to benefit from a technology-based solution that uses human pose estimation to guide learning. In this approach, a criterion motor action is embedded in a deep-learning algorithm (DLA). A learner can view this motor action on an iPad and uses its kinematic signatures to guide practice. The learner's movement is captured by the device and the recorded motor action enters the DLA for computation of movement proficiency. The output of the DLA is a quantitative index that informs the learner how well the movement has been executed. In this way, the learner gains timely and objective feedback. A separate device held by the PE teacher collates the quantitative indices from other students in the class. Collectively, the information facilitates the teacher's selection of instructional strategies.

Keywords: Human Pose Estimation · Demonstration · Assessment · Feedback.

1 Introduction

This paper is a proof-of-concept study undertaken by the authors. Here, we propose a novel technology-based solution to address the problems faced by teachers and students during PE. The implementation of the solution has only recently started and herein no results will be reported.

One of the perennial problems in PE is that not all PE teachers are capable of proficiently demonstrating the motor skill(s) they are teaching. When a PE teacher demonstrates a particular motor skill sub-optimally, the students do not perceive the visual information necessary for motor learning. Additionally, in a class of 40 students, viewing of the demonstration may be blocked or obscured by classmates nearby. Consequently, students are unlikely to produce movements that approximate the desired motor action, which is characterized by a combination

ACPES 2022, October 28-30, Medan, Indonesia

DOI 10.4108/eai.28-10-2022.2327418

of limb kinematic signatures. This problem requires a technology-based solution so that proficient motor skill demonstrations pre-recorded in digital devices can provide reliable visual information necessary for motor learning.

After demonstrating the motor skill, the PE teacher often finds it difficult to effectively monitor the motor performance of the class, which in Singapore school context, comprises about 40 students. In practice, the teacher either focuses on some students who are facing difficulty or through subjective ‘eye-balling’, estimates the overall motor performance of the class. The arbitrary estimation of skill proficiency could influence the PE teacher’s decision to either set aside more time for practice or progress on to the next activity in the lesson plan. To my knowledge, there is currently no objective and efficient way of assessing motor performance in large class setting. This problem will benefit from a technology-based solution. Working in pairs, while a student practices the skill, the other uses a digital device to video record the movement. The executed movement is compared with a criterion motor action that has been embedded in the digital device. The result of the comparison yields a quantitative index that represents the student’s skill proficiency. In this way, 20 students will have access to timely and objective feedback of their motor performance.

While the feedback benefits the students, it remains that the PE teacher does not have an efficient way of monitoring students’ motor performance. To address this problem, the quantitative index in each digital device (there will be 20 such devices in the class) will be wirelessly transferred to a separate device held by the PE teacher. On that device, quantitative indices representing each student’s skill proficiency will be displayed. A separate programme in the device combines the indices to yield an objective measure of overall skill proficiency.

Therefore, the proposed technology-based solution has the propensity to address the trilogy of sub-optimal demonstration, assessment, and feedback in PE.

2 Technology-based solution

The solution utilizes a process called human pose estimation (HPE). It is a computer vision-based technology that detects and analyses human postures during movement production. A skeleton-based model consisting of key joints such as the ankles, knees, and shoulders in 3D space will be developed to compute movement proficiency (Fig. 1). The steps for human pose estimation are as follows: 1) determine criterion movement parameters, 2) capture executed movements, 3) analyse the correctness of performance, and 4) display movement errors in the digital devices (Fig. 2).

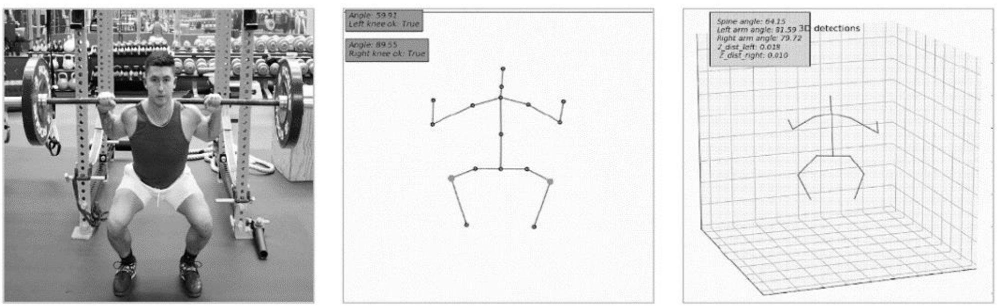

Fig. 1. Transformation of the executed movement (left) to skeleton-based model in 2D (middle) and 3D (right) space.

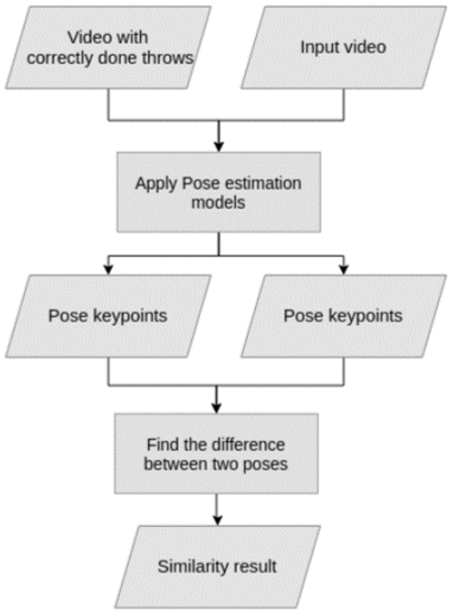

Fig. 2. Process flow of the pose estimation model.

Step 1 - The authors will video record the criterion motor action based on parameters defined in PE textbooks [2]. These videos are entered into deep learning algorithms (DLA) with convolutional neural networks and dilated temporal convolutions to identify crucial kinematic features of the action. These algorithms are housed in the digital devices.

Step 2 & 3 - During practice, one student will use the digital device to video record his/her partner's executed movement. The information will enter the DLA, which computes the degree of deviation from the criterion motor action. The processes of the DLA are as follow: i) match the speed (i.e., frame per second) of the input and criterion videos, ii) align and normalize the skeleton models of the executed and criterion motor action, iii) compare keypoints frame by frame and detect motion inconsistencies, and iv) repeat the process for different groups of joints. The difference between the executed and criterion model will be calculated using the cosine function (see equation 1).

$$\cos\theta = \frac{\vec{a}\cdot\vec{b}}{\|\vec{a}\|\cdot\|\vec{b}\|}$$

When an executed movement moves in the direction of the criterion motor action, the angle subtended by the executed and criterion keypoints will be near zero degree. In this case, the cosine function of the deviation angle will be close to one, approximating 100 percent. Conversely, when an executed movement moves in the opposite direction relative to the criterion motor action, the angle subtended by the executed and criterion keypoints will be near one hundred and eighty degree. In this case, the cosine function of the deviation angle will be close to minus one, approximating -100 percent (Fig. 3).

Step 4 - The output of the computation will be a quantitative index in terms of percentage compliance, that is, higher positive percentage reflects better motor performance.

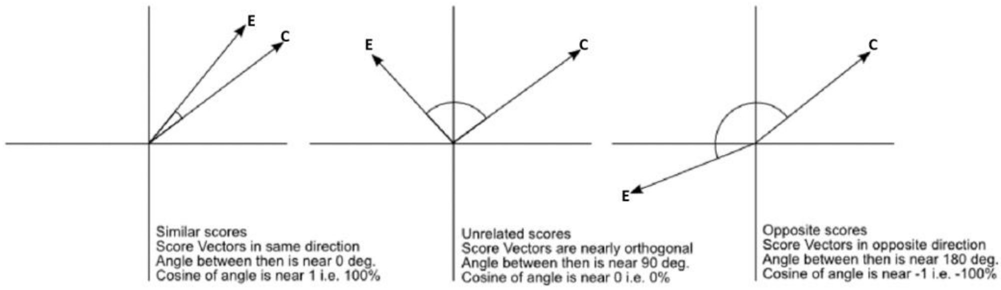

Fig. 3. Calculation of skill proficiency based on angle of deviation subtended by keypoints on the executed (E) and criterion (C) models.

3 Brief history of technology in PE

The turn of the century saw a concerted push for the infusion of technology in PE [8,9,11]. PE teachers were introduced to the use of electronic devices such as heart rate monitors, bioelectrical impedance devices, and pedometers to assess health-related physical fitness. More recently, PE teachers have access to software applications such as Calorie Counter and Google Fit to track students' dietary trends and physical activity levels. In some parts of the world, applications such as PE Manager has been used to alleviate arduous processes in PE assessment [13,5]. Albeit advantageous, it may be argued that the benefits afforded by technology have up till now been teacher-centric rather than student-centric. Therefore, a crucial question to ask is whether technology can be strategically implemented in PE to enhance both teaching and learning experiences.

Applications of HPE in the real world are evident in the areas of human-computer interface, autonomous driving, and sports [14,7,4,15,10,6]. The paucity of its application in education is unequivocal. Therefore, a significant gap exists for educators to explore HPE as a technology-based strategy to enhance teaching and learning in PE. Therefore, in our proposed study, we will use HPE to analyse movements produced by students during PE. The deep learning algorithm in HPE will assign loci to joints of a human body in space thus enabling the computation of movement errors given the criterion parameters [12,1,3]. We hypothesize that HPE will enhance PE teachers' ability to monitor and assess motor performance, and in doing, enable them to provide more engaging and meaningful activities for the students.

4 Evaluation of the technology-based solution

The proposed study involves the production of a beta version of the HPE algorithm. Once completed, the model will undergo testing using small number (e.g., 2 to 3) of digital devices. There will be numerous rounds of testing to improve the efficiency of the model. Once the model stabilizes, the current study will be scaled up for implementation in large class with 40 or more students. Testing at this stage will involve not only the increased number of digital devices (e.g., 20 or more) but also the network capability that is crucial for the operation of the proposed solution.

The impact of the proposed solution will be evaluated using interviews and surveys. Two to three university course instructors will be interviewed. A sample of the interview questions is provided below.

1. What are the benefits and challenges of using the digital device as a teaching tool?

2. What impact did the proposed solution have on assessment and its implications on lesson progression and pedagogical development?

Two to three university courses will be selected for the study. At the start of the semester, the instructors will provide a brief description of the study, its aims, and intended outcomes. A survey will be administered at the end of the course to gather feedback on the useability of the digital device. Feedback will be garnered from the students on how their learning needs have been addressed by the proposed solution. A sample of the survey questions is provided below.

1. Did you encounter any technical issues while using the software application? Yes / No

2. Did you find the criterion motor action videos useful? Yes / No

3. Was the slow-motion playback of the demonstration useful ? Yes / No

4. Did the software application enhance your learning experience? Yes / No

5. To what extent did the software application afford collaborative and experiential learning?

6. Comment on your experience regarding this type of pedagogical approach for teaching and learning in PE.

References

[1] Andriluka M, Iqbal U, Insafutdinov E, Pishchulin L, Milan A, Gall J, Schiele B. Posetrack: A benchmark for human pose estimation and tracking. In: Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition; 2018. p. 5167–5176.

[2] Colvin AV, Egner Markos NJ, Walker PJ. Teaching The Nuts and Bolts of Physical Education: Building Basic Movement Skills. United States, Champaign: Human Kinetics; 2000.

[3] Dantone M, Gall J, Leistner C, Van Gool L. Human pose estimation using body parts dependent regressors. In: Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition; 2013. p. 3041-3048.

[4] Du X, Vasudevan R, Johnson-Roberson M. Bio-lstm: A biomechanically inspired recurrent neural network for 3-d pedestrian pose and gait prediction. IEEE Robot. Autom. Lett. 4 (2); 2019. p. 1501–1508.

[5] Franklin RM, Smith J. Practical assessment on the run – ipads as an effective mobile and paperless tool in physical education and teaching. Research in Learning Technology. 2015; Andriluka 23(1): 27986 - https://dx.doi.org/10.3402/rlt.v23.27986
[6] Hwang J, Park S, Kwak N. Athlete pose estimation by a global-local network. In: Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition; 2017. p. 58–65.
[7] Kim W, Ramanagopal MS, Barto C, Yu MY, Rosaen K, Goumas N, Vasudevan R, Johnson-Roberson M. Pedx: Benchmark dataset for metric 3-D pose estimation of pedestrians in complex urban intersections. IEEE Robot. Autom. Lett.4 (2); 2019. p. 1940–1947.
[8] Koehler MJ, Mishra P. Introducing TPCK. In AACTE Committee on Innovation and Technology (Ed.), The handbook of technological pedagogical content knowledge (TPCK) for educators. New York: American Association of Colleges of Teacher Education & Routledge; 2008.
[9] Liang G, Walls RT, Hicks VL, Clayton LB, Yang L. Will tomorrow's physical educators be prepared to teach in the digital age? Contemporary Issues in Technology and Teacher Education. 2006; 6(1): 143-156.
[10] Scott J, Collins R, Funk C, Liu Y. 4D model-based spatiotemporal alignment of scripted Taiji Quan sequences. In: Proceedings of the IEEE International Conference on Computer Vision; 2017. p. 795–804.
[11] Settlage J, Odom AL, Pedersen JE. Uses of technology by science education professors: Comparisons with teachers: Uses and the current versus desired technology knowledge gap. Contemporary Issues in Technology and Teacher Education. 2004; 4(3): 299-312.
[12] Wang J, Tan S, Zhen X, Xu S, Zheng F, He Z, Shao L. Deep 3D human pose estimation: A review. Computer [13] Vision and Image Understanding. 2021; 210: 103225 – https://doi.org/10.1016/j.cviu.2021.103225.
[14] Woods M, Karp G, Miao H, Perlman D. Physical educators' technology competencies and usage. Physical Educator. 2008; 65(2): 82-99.
[15] Zhang Z. Microsoft kinect sensor and its effect. IEEE Multimedia; 2012. 19(2): p. 4-10.
[16] Zecha D, Einfalt M, Eggert C, Lienhart R. Kinematic Pose Rectification for Performance Analysis and Retrieval in Sports. In: Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition; 2018. p. 1791–1799.