Considerations for Applying MediaPipe to Gait Analysis

Comparison with Commercial Software

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***Abstract*— MediaPipe, which enables skeletal analysis using videos of walking subjects without the use of markers, can be easily introduced into rehabilitation sites. Because the video used for analysis is captured from a smartphone or video camera, the viewpoint is obtained from a single camera. Therefore, the skeletal coordinates cannot be recognized during analysis and the obtained coordinates are relative values. In this study, we used data obtained from MediaPipe to calculate stride length, walking speed, knee height change, and ankle angle and compared them with commercially available software. During the measurements, a pseudo-motor restriction was applied by wearing a supporter on the right knee. We found that the presence of motion restriction and various parameters during gait can be obtained by combining the confirmation of gait trajectory with 3D analysis and clarifying the measurement range.**

Keywords-MediaPipe; skeletal analysis; smartphone; 3D analysis.

I. INTRODUCTION

Measures are urgently required to prepare for a rapidly aging population. Falling is a significant problem among the elderly, as it causes them to be bedridden and places a heavy burden on their caregivers [1]-[8]. Therefore, motion analyses have been conducted using insoles [9][10] and mat-like pressure sensors arranged two-dimensionally [11], wearable devices [12], and images [13]. For gait analysis, measurements using multiple cameras with attached markers have been used in rehabilitation facilities, as typified by the Vicon system [14][15]. A camera called Kinect [16]-[19] has also been used to analyze the movement of a camera linked to game software. However, problems remain, such as the need for an expensive dedicated system, space for recognizing the markers, and an operator who is familiar with the dedicated software. The rapid spread of smartphones has facilitated the capturing of pictures anytime and anywhere, and the threshold for capturing pictures has decreased. Moreover, affordable and easy-to-use software is available. The introduction of a system requires continuous cost. For this reason, it is currently in a state where it cannot be sufficiently spread.

Software that can perform skeleton authentication includes OpenPose [20][21] developed by Carnegie Mellon University and MediaPipe [22]-[24] released by Google. Both use deep learning and have a high certification system.

In our previous work [25], we presented a basic application of MediaPipe in the field of rehabilitation. Furthermore, for the use of a walking assist device, we reported that the effect continued even approximately 5 min after the walking assist device was removed. In this paper, we report the results of additional research on the accuracy and application range of walking parameters obtained using MediaPipe. If the analysis results from front filming can be utilized, data captured in hallways can also be used. In this study, we performed the analysis using front filming. MediaPipe, which can use Python, has the potential to be used by healthcare and welfare professionals who are not analysis experts. The ability to analyze videos from the front view using MediaPipe can also enable filming in rehabilitation rooms and hallways of hospitals and facilities; thus, healthcare and welfare professionals can use it themselves.

Section II describes the experimental methodology, including the software used and the commercially available equipment and software. Section III shows the results using MediaPipe and commercial software. Section IV discusses the results obtained with the two types of software. Section V presents the conclusions.

This study was approved by the Ethics Committee on Research with Humans as Subjects of the Teikyo University of Science.

II. EXPERIMENTS

The participant was a male in his 60s. During the measurement, his right knee was fixed with a supporter to pseudo-restrict his movement, and a comparison was made using the tool ORPHE ANALYTICS [26] to confirm the accuracy of the calculation results obtained from the 3D coordinate data obtained using MediaPipe. This software enabled us to attach ORPHE CORE®, which utilizes acceleration and angular rate meters, to the instep of a shoe using a special attachment device that can be fixed to the shoelace. The data obtained from these sensors could be analyzed to display various analysis results. A photograph of the ORPHE CORE® attached to the shoelaces of a shoe is shown in Figure 1.

Figure 1. ORPHE CORE® attached to the shoelaces using an attachment.

Owing to the limitations of the laboratory, we could not use the timed up and go method, in which the participant stands from a seated position in a chair, walks around a cone 3 m away, and sits down again while being observed and photographed from the lateral direction. Therefore, to enable analysis using ORPHE ANALYTICS from the front, we used an iPhone with ORPHE TRAC installed to receive acceleration signals from ORPHE CORE via Bluetooth; simultaneously, the data of the walking state were uploaded to the cloud service.

A video of the walking condition displayed on the ORPHE ANALYTICS screen was recorded at 720p using the free software AG Desktop Recorder [27]. This screen was loaded into MediaPipe, which was operated using Jupyter Notebook in Python, to obtain 3D data corresponding to 33 locations on the Land Marker. From these data, we extracted data for the left and right hips, knees, ankles, and toes. Based on these data, Python displayed the trajectories of the knees and other parts of the body in 3D. In addition, Microsoft Excel was used to calculate the change in the difference between the knee and ankle. The angle of the ankle was calculated using vectors connecting the ankle and knee and the ankle and toe.

Figure 2 shows examples of measurements using MediaPipe. The image on the left shows the measurement without motion restriction, and that on the right shows that with motion restriction.

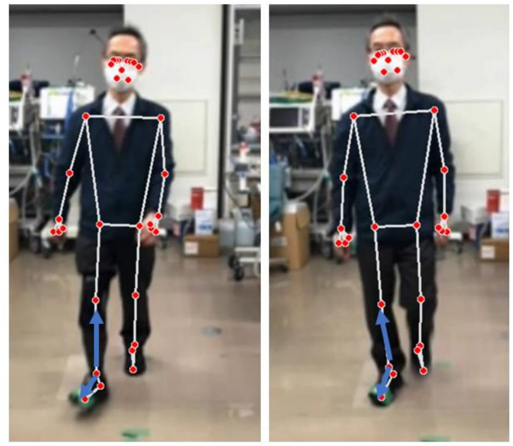

Figure 2. Examples of measurement results.

The supporter that restricts movement is worn on the right knee, although it is difficult to see from the photo.

III. EXPERIMENTAL RESULTS

A. Measurement of Strides

The right-foot ankle trajectory measured with the MediaPipe is shown in Figure 3. Only one round trip was used in the analysis. This is because plotting the trajectory of a round-trip walking state would cause the trajectories to cross each other, making them difficult to read. Because the camera is fixed, the coordinate data are x and y values corresponding to the 2D screen, except for the z-axis coordinates in the depth direction, which are relative, a characteristic of MediaPipe. Therefore, the data for one round trip were used in this study because performing a simple analysis is difficult. The amplitude increased until the change of direction occurred, indicating that the z-axis value did not change significantly during the change in direction. The area from the start of the walking to the change in direction was obtained.

The z-axis values for walking when approaching the camera are shown in Figure 4.

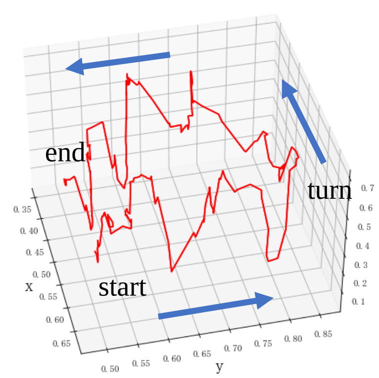

Figure 3. Right-foot ankle trajectory measured with MediaPipe.

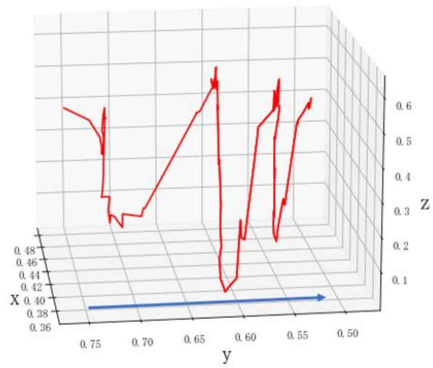

Figure 4. Z-axis values for walking when approaching the camera.

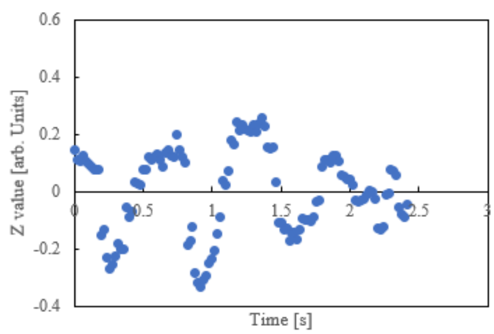

Figure 5. Result of modifying the effect of walking direction.

Numerical data were displayed in Excel, and the inclination due to the walking direction was obtained; the corrected results are shown in Figure 5. Using this diagram, we considered the point corresponding to the landing to be the minimum value based on the change in amplitude. As the figure shows, the amplitude increased as the participant approached the camera, and the center of the amplitude also increased. Therefore, the center of the amplitude was approximated as increasing with a linear function, and the difference from the coordinate data was considered. The minimum value was set as the landing point of the foot when the amplitude varied periodically, although a certain variation was observed. The actual measurement was obtained from the screen position, and the stride length was determined as the distance between the landing points. Walking speed was calculated from the respective times.

In the MediaPipe, the stride length was 0.80–0.90 m, and the velocity obtained was 0.8 m/s. The stride lengths of the left and right legs were 0.70 and 0.80 m, respectively. In the right leg with restricted motion, the stride length was larger owing to the hip motion.

The left and right stride lengths obtained from ORPHE were 0.75 and 1.0 m, respectively, which were larger than the values obtained from MediaPipe. In both cases, the value for the right leg was larger. The walking speeds on the left and right sides were 0.78 and 0.76 m/s, respectively, which were almost the same.

B. Results of knee height measurements

Figure 6 shows the results of MediaPipe for the changes in the right and left knee height during walking. Red indicates the right knee with limitation of motion by the supporter, and blue indicates the left knee without limitation of motion. Here, the results are also shown from the beginning of walking to turning, considering the effect of rotation.

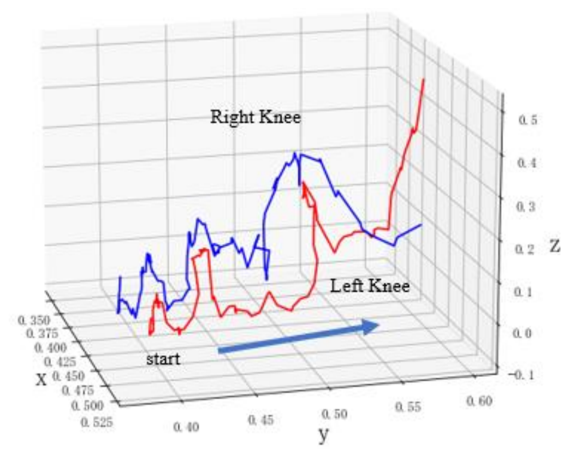

Figure 6. Height of the knee position evaluated using MediaPipe.

The results of the ORPHE ANALYTICS measurement of knee height are shown in Figure 7. The upper-left corner of the screen is the origin, and the maximum y-axis corresponding to the vertical direction is represented by 352 pixels. Therefore, the height of the right knee, which is a small value in the figure, had a higher value. The horizontal axis represents the number of measurement points for data analysis and not the time axis. The y-axis value for the x-axis, which corresponds to the direction of motion, changed significantly when the participant changed the direction of gait during the measurement. When comparing knee heights, we used not only moving images but also changes in the x-axis direction, which is characteristic of a change in direction, and deleted data from points in the range that appeared to indicate a change in the turn direction.

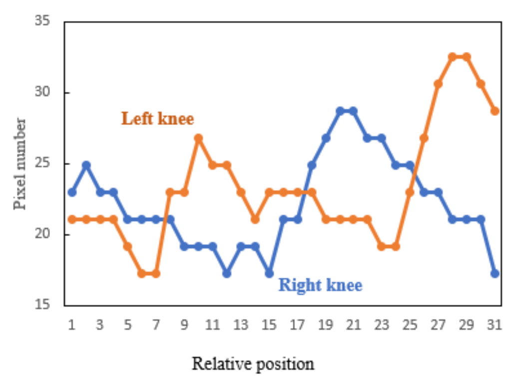

Figure 7. Knee height measurements with ORPHE ANALYTICS.

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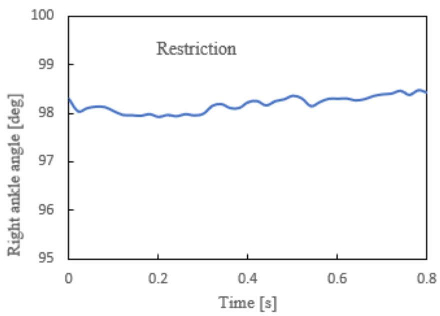
C. Measurement Results of the ankle angle

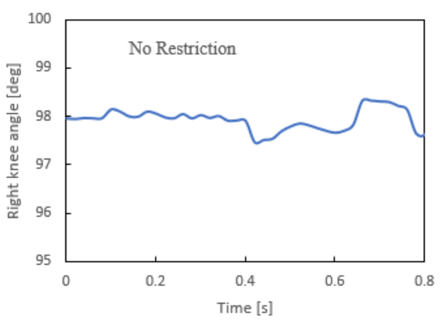
The results of the evaluation of the right ankle angle with and without pseudo-motor restriction are shown in Figure 8. (a) shows results with motion restriction added and (b) without. For the right foot with pseudo-motor restriction, almost no change in the ankle angle was observed during walking, whereas for the right foot without motor restriction, the amplitude of the angle widened in the last part of the gait, although it was very slight.

For comparison, Figure 9(a) shows the left ankle angle without pseudo-motor restriction, and (b) shows the left ankle angle change without restriction. The values were large owing to the shooting angle. No characteristic waveform changes were observed in the left foot. This may reflect the difference in flexion and dorsiflexion of the participant's left and right feet.

The ORPHE ANALYTICS data were not directly displayed as an ankle angle, but the Euler angle obtained from the accelerometer was considered to correspond to it. The angle changed abruptly at regular intervals, which was considered to correspond to the kicking of the foot. The plastic fixture was used to hold the shoelaces in place; therefore, the changes may have been large and different, but we considered that more absorption changes could be measured with the plastic fixture than with MediaPipe.

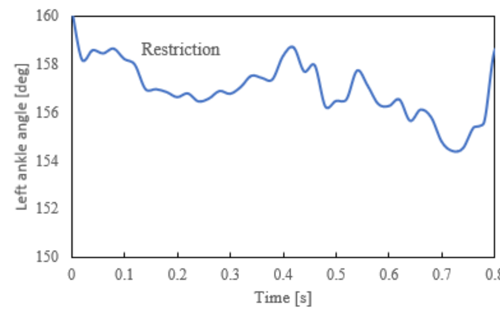


(a)

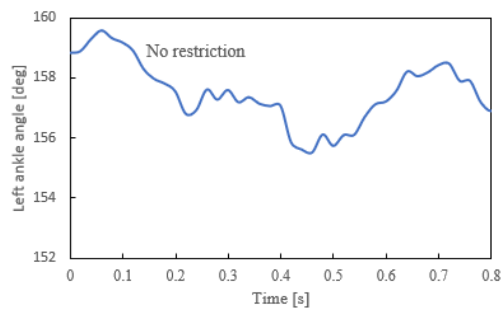


(b)

Figure 8. Angles of the right ankle without restriction.



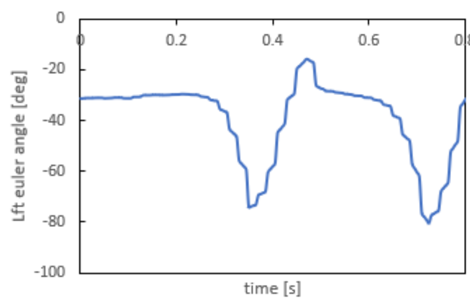
(a)



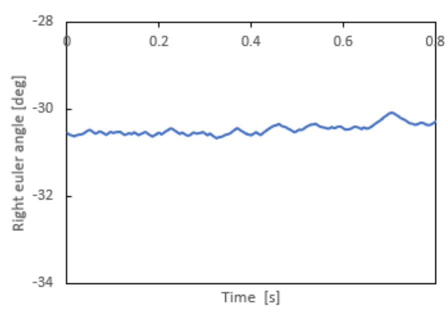
(b)

Figure 9. Angles of the left ankle without restriction.

The ORPHE ANALYTICS data did not directly display this as an ankle angle, but the Euler angle obtained from the accelerometer was considered to correspond to it. The results of the motion restriction are shown in Figure 10. (a) and (b) for the left and right ankles, respectively.



(a)



(b)

Figure 10. Euler angle of the right ankle.

The angle changed abruptly at regular intervals, which was considered to correspond to the kicking of the foot. The angle was already approximately 30° because a plastic fixture was used to hold the shoelaces in place. Although a large change in the measurement angle may have been measured owing to the fixing method, a more absorbing change was considered to be measured compared with MediaPipe.

IV. DISCUSSION

In this experiment, the main reason for the difficulty in analysis was that the measurement had to be performed under conditions where frequent changes in direction occurred owing to the limitations of the measurement location. Because the left and right foot coordinate values were different owing to the camera angle, simple comparison and analysis were not possible, and a combination of 3D plots is considered necessary for motion analysis of the knee and ankle. In contrast, ORPHE ANALYTICS®, a commercially available software, provided data with correction, but although it provided sufficient characteristic data of gait in terms of coordinate values, it was more difficult to handle than MediaPipe owing to the limited number of pixels; therefore, it may have not provided sufficient accuracy. However, owing to the limitation of the number of pixels, it was more difficult to handle than MediaPipe.

Because only one participant was used in this measurement, the data were limited to a specific individual. It would be important to increase the number of participants in the future. In addition, an accurate evaluation can be conducted by changing the fixation position of the ORPHE CORE® to the inside of the shoe for measurement and comparison.

V. CONCLUSIONS

The values obtained through calculation from MediaPipe, which can display skeletal certification, were compared with those of commercially available gait measurement systems to investigate the differences. The study revealed that the effects of different angles of video recording during gait should be considered in programming and in determining the results obtained with MediaPipe. However, MediaPipe can be an effective tool for determining walking conditions when the cost of implementing the system and the data required are limited.

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REFERENCES

[1] Y. Uchida, T. Funayama, and Y. Kogure, “Investigation of the Application of MediaPipe to Gait Analysis,” in *GLOBAL HEALTH 2022*, pp. 1-6, IARIA, 2022. ISBN: 978-1-61208-995-9.

[2] L. G-Villanueva, S. Cagnoni and L. Ascari, “Design of a Wearable Sensing System for Human Motion Monitoring in Physical Rehabilitation,” Sensors, vol. 13, pp. 7735-7755, 2013.

[3] Y.-L. Zheng et al., “Unobtrusive Sensing and Wearable Devices for Health Informatics,” IEEE Trans. Biomedical Engineering, vol. 61, pp. 1538-1554, 2014.

[4] M. M. Alam and E. B. Hamida, “Surveying Wearable Human Assitive Technology for the Life and Safty Critical Applocations: Standards, Challenges and Opportunities,” Sensors, pp. 9153-9209, 2014.

[5] M. J. Deen, “Information and Communications Technologies for Elderly Ubiquitous Healthcare in a Smart Home,” Personal and Ubiquitous Computing, pp. 573-599, 2015.

[6] S. Hong and K. S. Park, “ Unobtrusive Photoplethymographic Monitoring Under the Foot Sole while in a Standing Posture,” Sensors, pp.3239, 2018.

[7] V. Bucinskas et al., “Wearable Feet Pressure Sensor for Human Gait and Falling Diagnosis,” Sensors, pp. 5240, 2021.

[8] P. M. Riek, A. N. Best and R. Wu, “Validation of Inertial Sensors to Evaluate Gait Stability,” Sensors, vol. 23, pp. 1547, 2023.

[9] T. Funayama, Y. Uchida and Y. Kogure, “Assessment of Walking Condition Using Pressure Sensors in the Floor Mat,” in *GLOBAL HEALTH 2022*, IARIA, pp. 7-12 , November 2022, ISBN: 978-1-61208-995-9.

[10] T. Funayama, Y. Uchida and Y. Kogure, “Detection of motion restriction with smart insoles,” Sensors & Transducers Journal, Vol. 259, Issue 5, pp. 61-68, 2022.

[11] Y. Uchida, T. Funayama, K. Hori, M. Yuge, N. Shinozuka and Y. Kogure, “Possibility of Detecting Changes in Health Conditions using an Improved 2D Array Sensor System,” vol. 259, pp. 29-36, 2022.

[12] S. Diaz, J. B. Stephenson and M. A. Labrador, “Use of Wearable Sensor technology in Gait, Balance, and Range of Motion Analysis,” Applied Sciences, vol. 10, pp. 234, 2020.

[13] S. Majumder et al., “Smart Homes for Elderly Healthcare-Recent Advances and Research Challenges,” Sensors, vol. 17, pp. 2496, 2017.

[14] M. Windolf, N. Gotzen and M. Morlock, “Systematic Accuracy and Precision analysis of Video motion Capturing Systems-Exemplified on The Vicon-460 system,” Journal of Biomechanics, vol. 41, pp.2776-2780.

[15] T. B. Rodrigues, D. P. Salgado1, C. O. Cathain, N. O’Connor and N. Murray, “Human Gait Assessment Using a 3D Marker-less Multimodal Motion Capture System,” Multimedia Tools and Applications vol. 79, pp. 2629-2651, 2020.

[16] P. Plantard, E. Auvinet, A. S. Le Pierres and F. Multon,”Pose Estimation with a Kinect for Ergonomic Stuidies: Evaluation of the Accuracy Using a Virtual Mannequin,” Sensors, pp. 1785-1803, 2015.

[17] R. A. Clark, B. F. Mentiplay, E. Hough and Y. H. Pus, “Three-Dimensional Cameras and Skeleton Pose Tracking for Physical Function Assessment: A Review of Use, Validity, Current Developments and Kinect Alternatives,” Gait & Postture, vol. 68, pp. 193-200, 2019.

[18] Y. Ma, K. Mithratatne, N. Wilson, Y. Zhang and X. Wang, “Kinect v2-Based Gait Analysis for Children with Cerebral Palsy: Validity and Reliability of Spaial Margin of Stability ad Spationtemporal Vaiables,” Sensors, vol. 21, pp. 2104, 2021.

[19] D. Imoto, S. Hirano, M. Mukaino, E. Saitoh and Y. Otaka, “A Novel Gait Analysis System for Detecting Abnormal Hemiparetic Gait Patterns during Robo-assisted Gait Training: A Criterion Validity Study among Healthy Adults,” Frontiers in Neurorobotics, 16:1047376, 2022.

[20] M. Ota, H. Tateuchi, T. Hahiguti and N. Ichihasi, “Verification of validity of gait analysis systems during treadmill walking and running using human pose tracking algorithm,” Gait and Posture, vol. 85, pp. 290-297, 2021.

[21] Y. Saiki et al., “Reliability and validity of OpenPose for measuring hip knee ankle angle in patients with knee osteoarthritis,” Scientific Reports, vol. 13, pp. 3297, 2023.

[22] V. Bazarevsky et al., “BlazePose: On-device Real-time Body Pose tracking,” arXiv:2006.1204v1 [cs.CV] 2020.

[23] G. Kaur, G. Jaju, D. Agawal, K. Lyer and C. M. Prashanth, “Implementation of Geriatric Agility Detection Using MediaPipe Pose,” International Journal of Recent Advances in Multidisciplinary Topics, vol. 3, pp. 119-124, 2022, ISSN:2582-7839.

[24] J.-L. Vhung, L.-Y. Ong and M-C. Leow, “Comparative Analysis of Skelton-Based Human Pose Estimation,” Future Internet, vol.14, pp. 380, 2022.

[25] Y. Uchida, T. Funayama, and Y. Kogure, “Possibility of Gait Analysis with MediaPipe and Its Application in Evaluating the Effects of Gait-assist Devices”, International J. of Advances in Life science, vol.15, no 1&2, pp. 45-55, 2023.

[26] Y. Uno et al., “Validity of Spatio-Temporal Gait Parameters in Healthy Young Adults Using a Motion-Sensor-Based Gait Analysis System (ORPHE ANALYTICS) during Walking and Running,” Sensors, vol. 23, pp. 331, 2023.

[27] AG Desktop Recorder: https://streamgaga.com/how-to-use-ag-desktop-recorder, retrieved: August, 2022.