Detecting Gait Changes with Front-Facing Video and MediaPipe: A Hemiplegic Patient Case Study

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***Abstract*—Obtaining numerical skeletal data is a crucial method for objectively evaluating a patient's walking condition. Using MediaPipe, we evaluated data from the early stage of rehabilitation of a hemiplegic patient and five weeks later, using images taken from the front, where the area of the imaging facility is less restricted. We attempted to reduce spatial uncertainty owing to the influence of distance by measuring and evaluating changes in the height of the left and right ankles normalized by waist width, inclination of the shoulders, width between the toes and heels, and width between the left and right elbows. We proposed a method for detecting changes in the gait of patients undergoing rehabilitation. By applying this proposal, changes in gait could be determined.**

Keywords—MediaPipe; rehabilitation evaluation; skelton analysi; digital health; walking analysis; front-facing recorded video.

I. Introduction

Assessing changes in a patient's condition is crucial in rehabilitation [1]-[3]. In particular, gait assessment in the clinical setting reveals considerable potential health status and predictive information. Quantitative instrumented gait analysis is recommended for clinical gait assessment; however, it is currently insufficient. With the rapid advances in machine learning research recently, reports on rehabilitation recovery are rapidly increasing. According to previous studies, various sensors are used to measure the time taken to perform a defined exercise, and the data are used to perform k-nearest neighbor approximation, support vector machine, random forest logistic regression, and other machine learning methods [4].

Spatio-temporal parameters during gait are considered an effective means of quantifying gait performance and determining the state of physical function. Inertial measurement units have the advantage of not having measurement space limitations, as they do not take measurements in a pre-installed 3-dimensional motion capture systems, which is released by Vicon Motion Systems Ltd UK and used as the de facto standard; however, validation against the de facto standard is needed [5][6].

Kinect for Windows v1 released by Microsoft has a Green-Red-Blue (RGB) camera for color video and an InfRared (IR) emitter. The camera allows depth measurement when the baseline between the camera and projector is known, and v2 has improved skeleton tracking. Azure Kinect DK, released in 2019, integrates with Artificial Intelligence (AI) applications. The potential for clinical applications of the ever-improving Azure Kinect camera is also being investigated [7]-[11].

Recent advances in machine learning and other technologies have enabled skeletal recognition in software, such as OpenPose [12]-[16], without using an IR camera like the Kinect. Because it can estimate the whole-body skeleton and human posture, it is currently used for the knee and ankle motion analysis. MediaPipe [17]-[23] supports various frameworks and can use video cameras and images captured by smartphone cameras for analysis. It has advantages such as the use of high-performance graphics processing unit (GPU) through Google Colaboratory. However, currently, no-code programming is possible and understanding of the source code is required. Therefore, applications such as reporting gait analysis are rare. In addition, owing to the problem of the rehabilitation area required for video recording, which is necessary for analysis, analysis from the sagittal plane direction is difficult, and only a few cases of implementation have been reported.

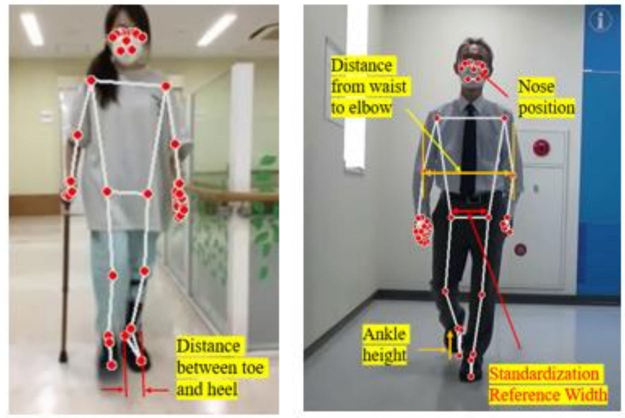
We reported on the possibility of using MediaPipe to analyze images taken from the frontal plane in terms of stride length and ankle angle at last year's conference. In addition, we measured the gait of subjects who had undergone physical and occupational therapy training and verified the effectiveness of walking aids for subjects who required hospitalization. The effectiveness of the walking aids was verified as follows: the dispersion of the nose position in the left and right directions was used as an index of body shake during walking; the tilt of the shoulders, hips, and neck during walking was calculated from MediaPipe data to determine balance; the time variation of these data was used as the basis for discrete Fourier spectrum decomposition and heel spectrograms. The effect of the walking aids on the subject's gait was demonstrated from multiple perspectives.

In this paper, we report the results of an investigation into whether MediaPipe can be used to detect gait changes during rehabilitation. The remainder of the paper is organized as follows. Section II presents the experimental conditions. Section III presents the experimental results, highlighting points that were characteristically observed in the subjects during rehabilitation as previously reported. Section IV discusses the obtained results, and by applying the proposal, the effect of distance from the camera was reduced by standardizing on hip width, and changes in gait were confirmed by determining height at the feet, tilt of the right and left shoulders, toe and heel width, and elbow width during gait. Section V concludes the paper.

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

II. EXPERIMENTS

Video recordings of the walking condition on the ORPHE ANALYTICS screen were recorded using the Snipping tool and analyzed using MediaPipe. During the measurement, walking for a distance of 3 m was filmed using a smartphone camera from the frontal plane. The subject, a patient, is a female in her 40s, right-handed. Her diagnosis was right capsular hemorrhage, her disability was left hemiplegia, severe sensory impairment, and she was independent in activities of daily living before the stroke onset; she was employed full time 5 days/week and commuted to work using public transportation. She was transferred to the hospital for convalescent rehabilitation approximately 2 weeks after the onset of stroke. Physical (120 min) and occupational (60 min) therapy were provided to her, and gait training was conducted during physical therapy. The first image was taken 72 days after onset, and the second image was taken on the 109th day. The patient was discharged from the hospital 4 days after the video recording, and rehabilitation was performed on an outpatient basis (subject A in the paper). When she was discharged from the hospital, she was walking with a T-cane and Short Leg Brace (SLB) outdoors. For reference, a subject without walking disabilities (subject B in the paper) videotaped a male subject in his 60s at a university. The video for subject B's analysis was captured using a video camera.



(a) Subject A (b) Subject B

Figure 1. Definition of evaluation parameters.

As shown in Figure 1, the width of the waist was used as the standard, and the coordinates of each part were assigned and normalized by this value. This was done because we thought it would solve the problem of measurement error in parameters during walking such as stride length, as the subject's image at the start of walking is small. This makes it easier to determine stride length and walking speed from the measurement results. The values shown in the results are defined as the distance between the toes and heel, the nose position, distance from the waist to the elbow, and ankle height, as shown in Figure 1(a) and Figure 1 (b).

III. EXPERIMENTAL RESULTS

A. *Height of left and right ankles*

When the images were taken from the frontal plane direction owing to the features of MediaPipe, the z-axis values increased as the subject approached the camera, and the z-axis values of the ankles and other parts of the body at the start of walking were normalized by the width of the hips to avoid the lack of clarity in gait conditions, such as stride length. Figure 2 shows the left and right ankle heights normalized by the width of the hips for subject at 72 days after onset. Figure 3 shows the same subject's ankle heights at 109 days after onset, normalized by the width of the hips.

B. *Normalized shoulder angle*

The results at the beginning of rehabilitation and after 5 weeks are presented in Figures 4 and 5, which were obtained from the inner product of vectors using the coordinates of the left shoulder as the origin and the right shoulder angle with respect to the horizontal direction, normalized by the width of the hip. A difference in blurring was observed at the beginning of walking when measured at 72 days after onset compared to that at 109days after onset.

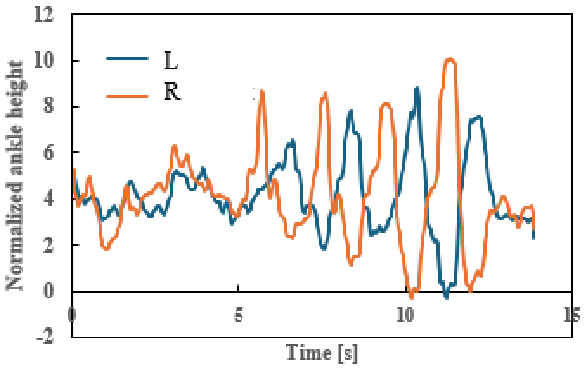


Figure 2. Normalized ankle height during gait at 72 days after onset.

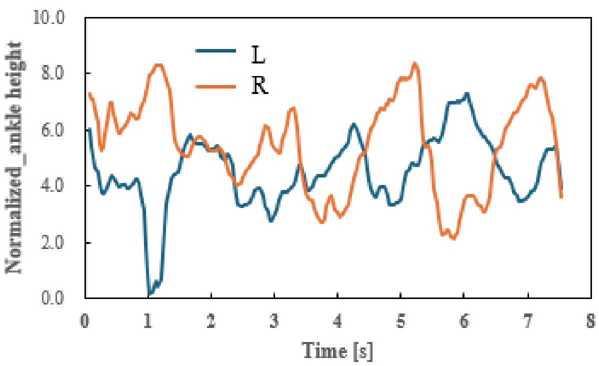


Figure 3. Normalized ankle height during gait at 109 days after onset.

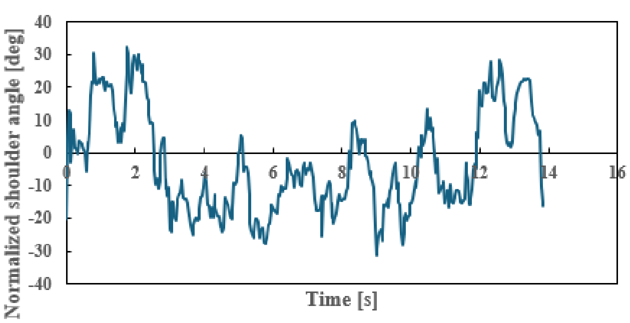


Figure 4. Angle of the right shoulder with respect to the left shoulder at 72 days after onset.

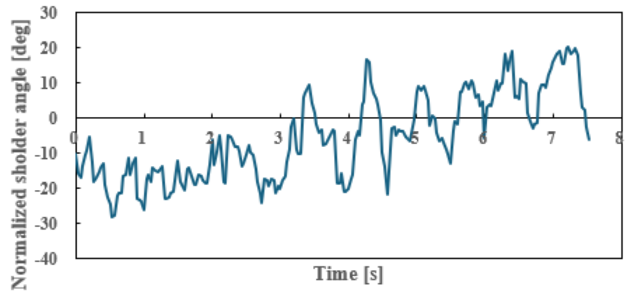


Figure 5. Angle of the right shoulder with respect to the left shoulder at 109 days after onset.

C. Blurring of the nose position

Figures 6 and 7 show the lateral swing of the nose during walking as observed from the frontal plane at 72 days after onset and 109 days after onset, respectively. The initial measurement at 72 days after onset showed a minor blurring at the beginning of walking because it took longer to start walking than the measurement at 109 days after onset; however, the overall variation in amplitude was approximately similar when viewed over the entire time period.

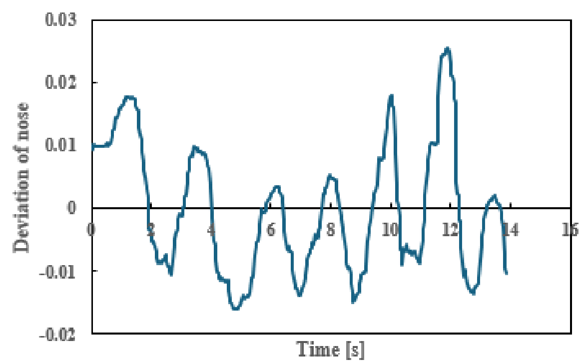


Figure 6. Nasal blurring in the left and right directions at 72 days after onset.

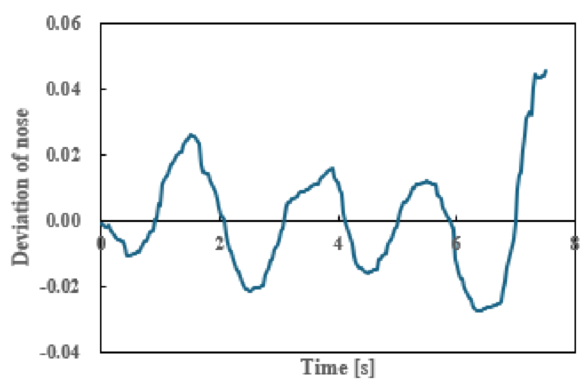


Figure 7. Nasal blur in left and right direction at 109 days after onset.

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D. Change in the width between the toe and heel

Figures 8 and 9 show the changes in the width between the toes and heel of the left and right foot at 72 days after onset and 109 days after onset. It can be observed that the width is smaller at 109 days after onset.

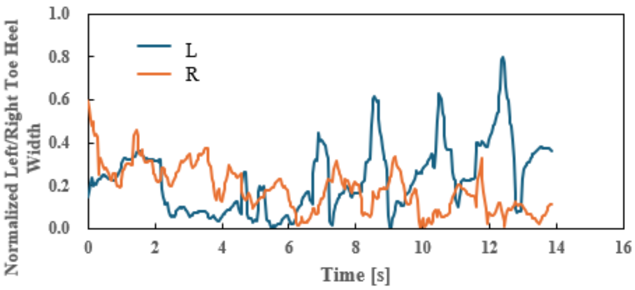

Figure 8. Normalized Width between the toe and heel of the right and left foot at 72 days after onset.

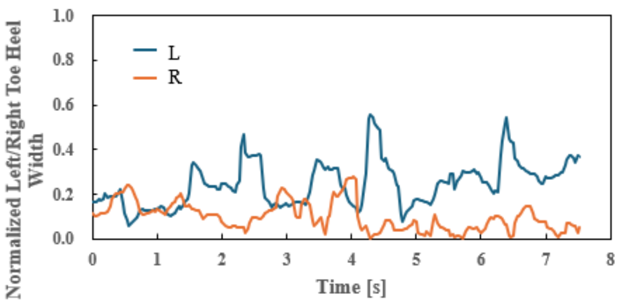

Figure 9. Normalized width between the toe and heel of the right and left foot at 109 days after onset.

E. Blurring between the left and right elbow widths

Figures 10 and 11 show the blurring between the left and right elbow widths at 72 days after onset and 109 days after onset, respectively. It can be observed that the width decreased at 109 days after onset.

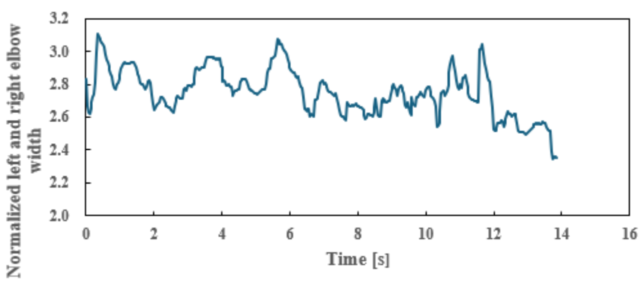

Figure 10. Normalized left and right elbow widths at 72 days after onset.

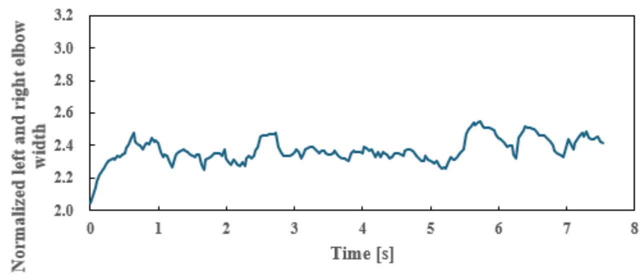

Figure 11. Normalized left and right elbow width at 109 days after onset.

F. Temporal changes in knee and ankle during gait

Figures 12 and 13 show the left and right knee and ankle heights at 72 days after onset and 109 days after onset normalized by the width of the waist.

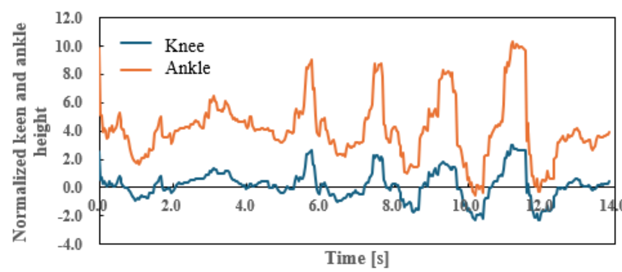

Figure 12. Normalized left knee and left ankle height at 72 days after onset.

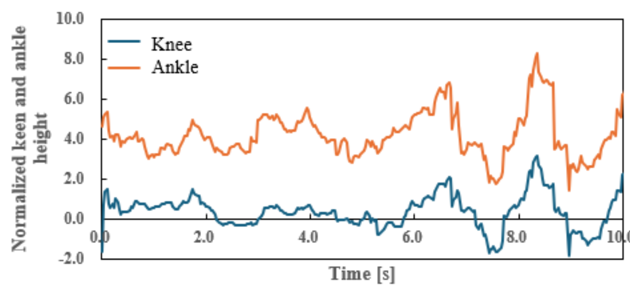

Figure 13. Normalized right knee and right ankle at 109 days after onset.

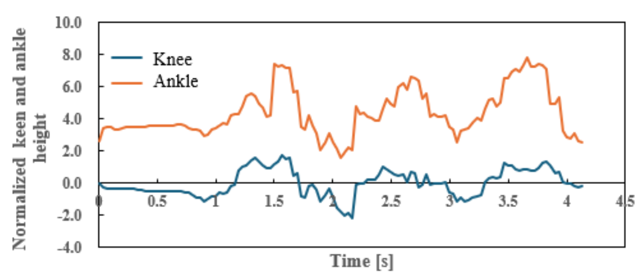

Figure 14. Left knee and left ankle height of subject B.

Figure 14 shows the left knee and left ankle heights normalized by the width of subject B's waist.

IV. DISCUSSION

We will separately examine the extent to which differences can be detected between subject A's initial rehabilitation and five weeks later using MediaPipe's skeletal recognition data with videos taken from the anterior forehead direction.

A. *Difference in normalized left and right ankle height due to width of the hips*

Because the normalization by the width of the hips allows us to obtain the amplitude of the foot height even in the early phase away from the camera and a flat area can be observed, it can be used to determine the stance and swing phases, although a detailed study has not been currently conducted.

B. *Normalized shoulder angle*

The first-order component was not in the exact forehead direction at the time of video recording; which was thought to be because the gait started slightly to the left of the center of the screen and eventually shifted to the right. The linear component could be because the gait started slightly to the left of the center of the screen and eventually shifted to the right side.

C. *Blurring of the nose position*

When the variance of the horizontal value in the direction of travel was used to blur the nose position, the blurring width was almost the same and the variance values were 1.6×10^{-4} and 2.7×10^{-4}. This may be owing to an increase in walking speed at 109 days after onset. When normalized by the width of the waist, the component horizontal to the direction of travel became smaller as one approached the camera and could not be evaluated.

D. *Change in the width between the toe and heel*

In the early phase of rehabilitation, the toe and heel width of the left foot, which is paralyzed, is wide, and it can be observed that the width of the right toe and heel is also affected by this effect. At 109 days after onset, the left toes and heels became narrower and improved, and the right toes and heels also became smaller owing to this effect.

E. *Blurring between the left and right elbow widths*

The elbow width during walking was reduced by approximately 20% between the pre-rehabilitation period and at 109 days after onset, confirming the improvement effect of rehabilitation.

F. *Temporal changes in the knee and ankle during gait*

The temporal difference between the knee and ankle was not evident in this experiment with MediaPipe, although the knee was slightly ahead of the ankle when evaluated on a time axis in some cases. As a comparison, the analysis of the experiment conducted with subject B did not reveal a time difference between the knee and ankle onset of movement.

V. CONCLUSIONS

The effect of rehabilitation was verified using images taken from the forehead direction using MediaPipe. Standardization by the width of the hips reduced the influence of the distance from the camera, and the change in gait could be confirmed by determining the ankle height during walking, tilt of the left and right shoulders, width between the toes and heels, and width between the left and right elbows. The evaluation method for cases where it is difficult to take images from the sagittal plane and only from the forehead plane owing to limitations on the direction of imaging that occur in actual rehabilitation settings was demonstrated.

In clinical gait assessment, both the ability to walk and the method of walking pattern are crucial. Quantitative instrumental gait analysis is recommended for clinical gait performance and gait quality; however, it is currently insufficient. Although this study was conducted over a short time and distance and it cannot be said that this method of assessment is highly relevant to the evaluation of walking ability in real life, the walking ability of one of the patients studied also improved in real-life.

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