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Comparison Gait Analysis of Normal and Amputee: Filtering Graph Data Based on Joint Angle

Junhyung Kim[1], Seunghyun Lee[2], and Soonchul Kwon[3*]

1Department of Smart System, Kwangwoon University, South Korea
2Ingenium College Liberal Arts, Kwangwoon University, South Korea
*3*Graduate School of Smart Convergence, Kwangwoon University, South Korea*
E-mail: hyung_71@kw.ac.kr, shlee@kw.ac.kr, ksc0226@kw.ac.kr

Abstract

Gait analysis plays a key role in the research field of exploring and understanding human movement. By quantitatively analyzing the complexity of human movement and the various factors that influence it, it is possible to identify individual gait characteristics and abnormalities. This is especially true for people with walking difficulties or special circumstances, such as amputee, for example. This is because it can help us understand their gait characteristics and provide individualized rehabilitation plans. In this paper, we compare and analyze the differences in ankle joint motion and angles between normal and amputee. In particular, a filtering process was applied to the ankle joint angle data to obtain high accuracy results. The results of this study can contribute to a more accurate understanding and improvement of the gait patterns of normal and amputee.

Keywords: *Amputee, Gait Analysis, Gait Data, Joint Motion, Rehabilitation*

1. Introduction

Gait is one of the most basic human activities, and it has a huge impact on our daily lives and health. Gait varies depending on the individual's physical characteristics, health status, and how the nervous system works. The characteristics of gait are a key research topic in the fields of rehabilitation and sports science [1]. Gait analysis is important for assessing the health status, function, and normality of the body's gait pattern [2, 3]. Joint angles are used as important indicators to understand movement patterns and gait efficiency or to detect problems. With recent advances in technology, various tools have been applied to gait analysis, among which MediaPipe is useful for measuring joint angles using computer vision [4]. However, data filtering is essential for accurate analysis of gait data, as noise and variability in the data collection process can distort the results [5, 6].

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Corresponding Author: kcs0226@kw.ac.kr
Tel: +82-2-940-8637, Fax: +82-50-4174-3258
Associate professor Graduate School of Smart Convergence, Kwangwoon University, South Korea

In this study, we aimed to compare and analyze the gait of normal and lower limb amputees. Joint angles were tracked using MediaPipe's pose estimation framework. The tracked joint data is then filtered using the Savitzky-Golay Filter [7]. Data filtering is the process of ensuring that the extracted data has only accurate and meaningful information. This is especially essential when we are dealing with data related to movement. Movement data is prone to noise due to a number of external factors, which, if not removed, can significantly reduce the accuracy of the analysis results. In this study, we apply filtering techniques to gait data from amputees and normal, compare the differences in gait patterns and joint angles between normal and amputees, and analyze the results to see how data filtering affects the accuracy and reliability of gait analysis.

2. Background Theory

2.1. Degrees of Gait cycle

In gait analysis, the concept of "gait cycle" is often used. A gait cycle is a sequence of movements from the moment one foot touches the ground to the moment the same foot touches the ground again [8, 9]. The cycle is the basic unit of gait, which allows us to understand and analyze walking patterns and movements. The gait cycle is represented by two phases: the Stand Phase and the Swing Phase. The support phase accounts for about 60% of the gait cycle, and is where the feet are in contact with the ground, supporting the body's weight. This is the phase that allows you to stand steadily. The swing phase makes up the remaining 40% of the gait cycle and involves the movement of one foot off the ground to the moment the next foot touches the ground [10]. This is the phase that helps us move forward. In gait analysis, there are angles of joint motion. The movements of the ankle and knee joints have a significant impact on the gait pattern. At the ankle joint, we mainly look at two movements: plantarflexion and dorsiflexion. Plantarflexion refers to the downward motion of the ankle. Conversely, dorsiflexion is the upward motion of the ankle [11, 12]. These joint movements and angles are important criteria for evaluating the efficiency and stability of gait. Figure 1 below shows an illustration of one cycle of gait.

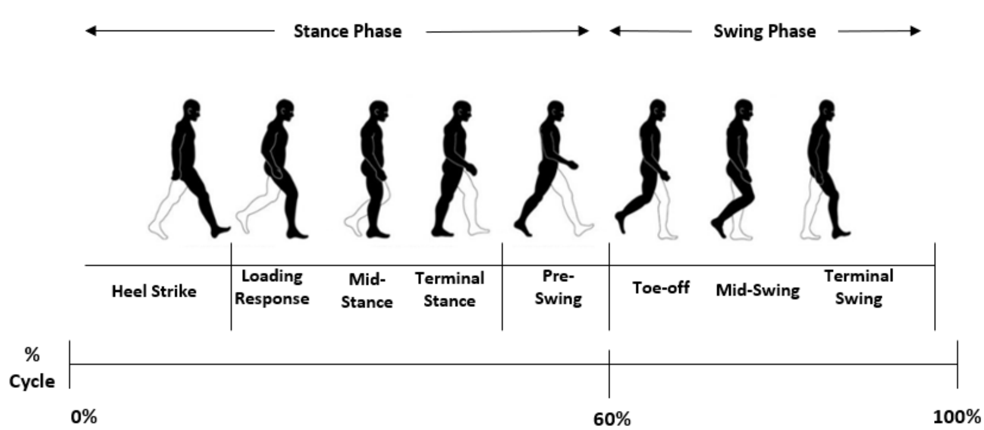
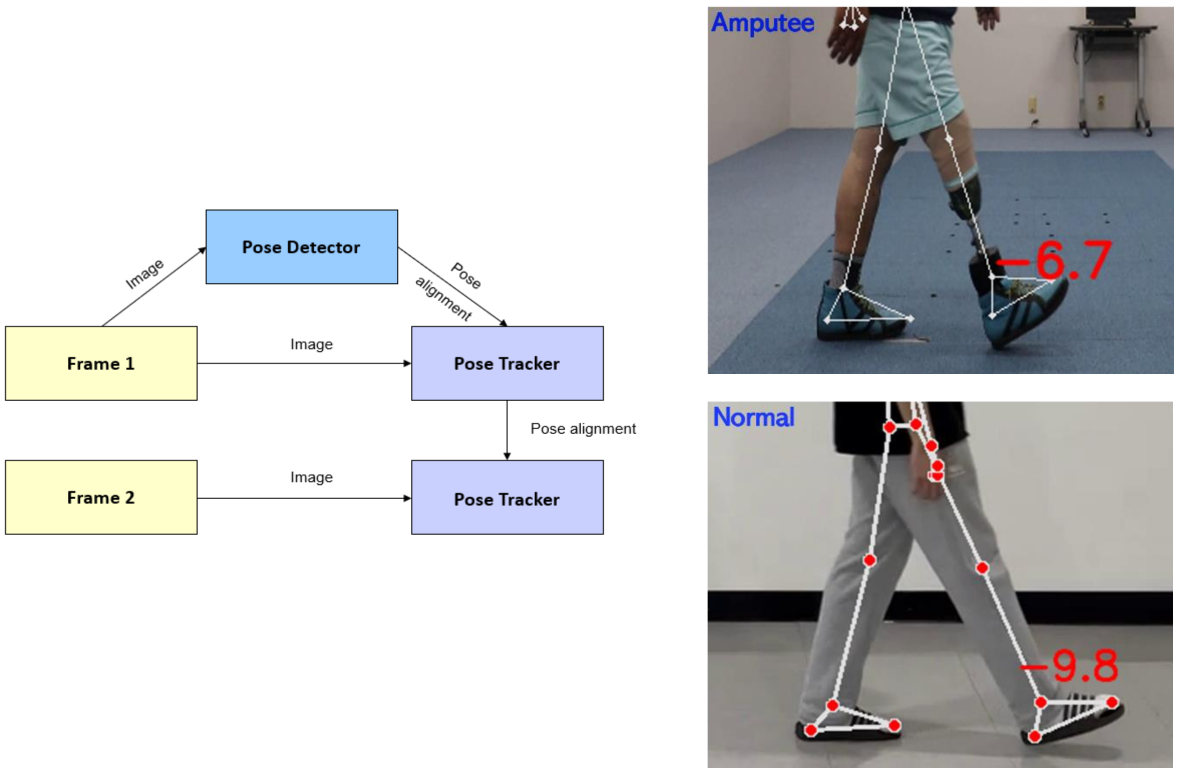


Figure 1. Cycle of Gait

2.2 Data Collection Using MediaPipe

In this study, we utilized MediaPipe as our data collection tool. MediaPipe is an open-source, cross-platform framework that provides customized machine learning solutions, making it a suitable tool for effectively collecting and analyzing gait data [13]. MediaPipe's pose estimation feature is used to accurately determine the joint positions, movements, and angles of the human body.

We focused on comparing the gait patterns of normal and amputee, both of whom used MediaPipe to track and record the movement and angles of each joint during a standard gait cycle to analyze the differences in their walking mechanisms. Data collection took place in a standardized environment: we filmed a person walking at a constant speed on a flat surface and collected one cycle of gait data. Figure 2 shows examples of the pose estimation pipeline architecture and application.



(a) (b)

Figure 2. Pose Estimation Pipeline Architecture and Application Examples

(a) Pose Estimation Pipeline Architecture (b) Application Examples

2.3 Data Filtering

In this study, the Savitzky-Golay Filter was used to process data based on normal gait and gait of an amputee. The Savitsky-Golay Filter is widely used in the field of signal processing and is mainly applied to continuous data such as time series data or spectra, aiming to effectively remove noise while preserving the basic shape of the data. It is particularly useful for removing noise from joint angle data and preserving peak values. It works by using a least-squares smoothing of neighboring data points and has the advantage of being suitable for applications where small signal changes are important [14, 15]. In particular, the Savitsky-Golay Filter allows the user to choose the polynomial order and frame length. The choice of these parameters largely determines the performance of the filter and its suitability for the data. Higher-order polynomials can capture complex data patterns but run the risk of overfitting. Low-order polynomials, on the other hand, minimize the impact of noise. The formula below is the Savitzky-Golay filter. Where i is the index number of the input signal, x is the input signal, and k is the filter length.

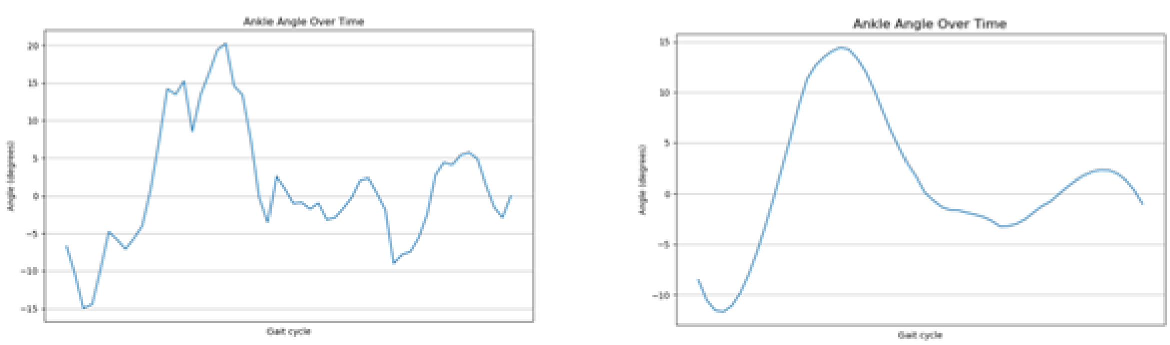
$$f_{sg}(x_i) = \begin{cases} (-2x_{i-3} + 3x_{i-2} + 6x_{i-1} + 7x_i + 6x_{i+1} + 3x_{i+2} \pm 2x_{i+3})/21, & i \geq 3 \\ x_i, & i < 3 \end{cases} \quad (1)$$

3. Experimental

3.1 Analysis of Joint Angle Data

In this section, analyzes joint angle data before and after filtering is applied. To do so, we plot the evolution of certain joint angles over time, compare the graphs before and after applying the Savitzky-Golay Filter, and analyze how the filtering technique affects the accuracy and consistency of the angle measurements.

It is important to compare the agreement between the actual gait pattern and the filtered data. For example, by examining how well the filtered data matches the movement patterns of specific joints observed during real-world walking, we can get a clearer understanding of which filtering method was more effective at removing noise from the joint angle data, and to what effect. Figure 3 shows the filtered joint angle data.



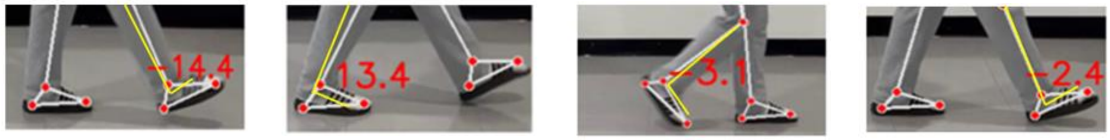
(a) (b)

Figure 3. Comparison of Unfiltered and Filtered Joint Angle Data

(a) Unfiltered Angle Data (b) Filtered Angle Data

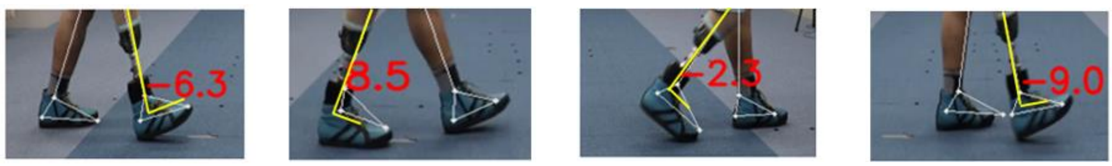
3.2 Comparison of Gait Patterns between Amputee and Normal

The joint angle data extracted in this paper is used to compare the gait patterns of lower limb amputees and normal. To do so, we first use the features of the MediaPipe to precisely measure the joint angle and gait data of the two groups, and then analyze the differences. The gait graph shows the difference between normal and amputees. You can see the difference in ankle angles from the free swing phase, which is the last part of the stance phase of the gait cycle. The normal person is consistent in their gait pattern, and the extension of the ankle angle is clearly reflected in the graph. This indicates a regular and predictable pattern, especially in the movement of the ankle. On the other hand, for an amputee, the extension part of the ankle angle is not well reflected in the graph, and a negative angle is displayed in the mid-swing part. This suggests that the shape of the prosthetic limb and the extension and flexion of the ankle affect the angle changes. Figure 4 visualizes the ankle joint angles of an amputee and a normal person, and Figure 5 compares the gait patterns of the two.



Heel Strike **Mid Stance** **Pre–Swing** **Terminal Swing**

(a)



Heel Strike **Mid Stance** **Pre–Swing** **Terminal Swing**

(b)

Figure 4. Visualization of Ankle Joint Angles in Amputee and Normal

(a) Normal (b) Amputee

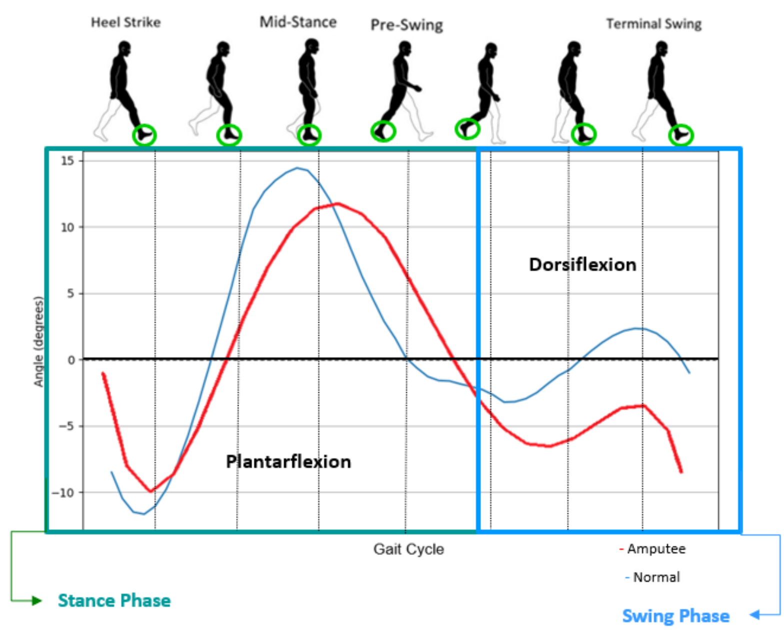


Figure 5. Gait Pattern Difference Between Amputee and Normal

4. Conclusion

In this paper, a gait analysis was performed to compare the gait of a normal person and a lower limb amputee. The joint angle data was collected using a MediaPipe, and the data was de-noised using the Savitzky-Golay Filter to improve accuracy. The data after this filtering process was analyzed in detail through graphs, and the experimental results showed that the data with the Savitzky-Golay Filter was effective in removing noise and extracting accurate movement information. This improved the accuracy and consistency of the gait data. In addition, when comparing the gait patterns of lower limb amputees and normal, the difference in ankle joint angle during the free swing phase of gait was clearly visible. While normal have a regular and predictable pattern of ankle angle extension, amputees' ankle angle is affected by the shape of the prosthetic limb and the unnaturalness of extension and flexion. This study confirms that gait analysis is an important tool for understanding and improving gait in lower limb amputees. This study indicates that gait analysis can play an important role in understanding and improving the gait of lower limb amputees.

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