A Novel Methodology for Gait Pattern Recognition Using Instantaneous Center of Rotation Trajectories of Lower Limb Segments

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Summary

This study introduces ICR-LLS, a novel kinematics-based methodology for gait pattern recognition. By analyzing the spatiotemporal trajectories of the instantaneous center of rotation (ICR) of the lower limb segments in the sagittal plane, the method maps gait patterns in a three-dimensional space using dissimilarity measures and clustering techniques. A sensitivity analysis with controlled gait asymmetries confirmed that the approach effectively identifies movement similarities at an individual level.

Introduction

Gait analysis plays a crucial role in clinical diagnosis, rehabilitation, and performance evaluation by providing valuable insights into human movement. Traditionally, it relied on specialized laboratories equipped with motion capture systems, force platforms, and EMG sensors. Recent technological advancements, such as IMUs and video-based motion analysis, now enable assessments outside controlled environments, enhancing accessibility and versatility. While advanced methods integrating skeletal models, covariance-based techniques, and machine learning offer a more detailed understanding of locomotion [1], many gait studies still primarily focus on joint kinematics, leaving other important parameters underexplored.

This study presents the ICR-LLS methodology, which analyzes the instantaneous center of rotation (ICR) of lower limb segments in the sagittal plane. By applying dissimilarity measures, the method represents gait patterns as nodes within a 3D network, enabling the identification of movement similarities and subject-specific characteristics.

Methods

The ICR-LLS methodology consists of five stages: acquiring kinematic data, computing ICR trajectories of lower limb segments, performing pairwise comparisons of these trajectories, mapping gait trials in three-dimensional space, and identifying similar gait patterns through clustering. Gait trials were conducted on 15 subjects, each performing four trials with varying gait asymmetry induced by polyurethane heels added to the footwear. ICR trajectories of the shank were computed from the collected data and preprocessed before applying selected dissimilarity measures.

The gait trials were then embedded in three-dimensional space using a force-directed graph layout, which minimizes network energy by applying attractive and repulsive forces between nodes.

Results and Discussion

Figure 1 shows the network generated using the Förstner dissimilarity measure, where node colors represent different gait asymmetry levels, and each subject is labeled consistently across trials. The network does not reveal clear clusters, as most nodes are grouped within the same area, suggesting that differences in gait asymmetry are not pronounced enough to form distinct groups. However, closer inspection reveals that nodes from the same subject are generally positioned near each other, indicating that, the methodology is still able to recognize and differentiate gait patterns within the same subject across varying asymmetry levels.

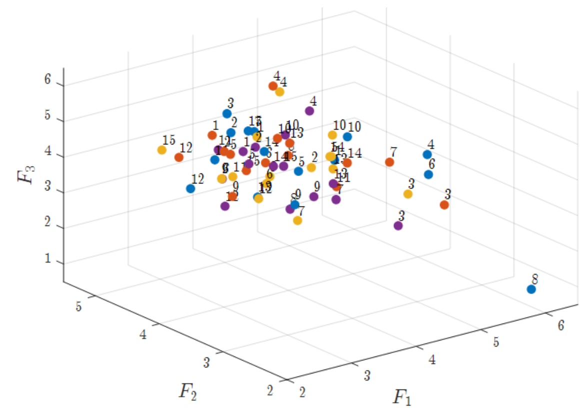

Figure 1: Network generated from gait trials under different asymmetry levels.

Conclusions

This study introduces a novel approach to gait pattern recognition by analyzing the ICR trajectories of lower limb segments in the sagittal plane. To evaluate the performance of the method, gait asymmetry was intentionally induced to test whether clusters of similar gait patterns could be identified across subjects. The results demonstrate the methodology's potential for recognizing subject-specific gait patterns, emphasizing its applicability in personalized gait analysis and rehabilitation monitoring.

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References

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