Predicting Gait of Transfemoral Amputees from Qualitative Surveys using Gaussian Mixture Model and Extreme Gradient Boosting

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Summary

This study proposes a two-stage machine learning approach to bridge the gap between qualitative prosthesis evaluation and quantitative gait analysis. Using data from 10 transfemoral amputees with six prostheses, a Gaussian Mixture Model (GMM) generated synthetic data, while an Extreme Gradient Boosting (XGB) regressor predicted gait parameters. The GMM-XGB model achieved over 90% accuracy, demonstrating its potential for estimating quantitative gait metrics from qualitative questionnaire scores, offering a cost-effective alternative to traditional gait analysis.

Introduction

Assessing prosthesis function and gait in amputees is essential for enhancing their quality of life [1]. While gait analysis remains a primary method for evaluating amputee gait and prosthetic performance, it is often time-consuming and costly [2]. As an alternative, questionnaires, such as the Prosthesis Evaluation Questionnaire (PEQ) provide a convenient yet qualitative assessment [3]. To address this limitation, the integration of machine learning (ML) approach is necessary to establish a connection between qualitative evaluations and quantitative gait assessments.

Methods

A total of 10 transfemoral amputees participated in this study with six different prosthetic legs, Fig. 1a. Participants conducted marker-based gait analysis, plantar pressure measurement, and a PEQ survey, Fig. 1b. The marker-based gait analysis was conducted with 3D motion capture system (Motion Analysis Corp., USA), while plantar pressure was assessed by Gait Analysis Treadmill (Ghiwell, Korea), Fig. 1c.

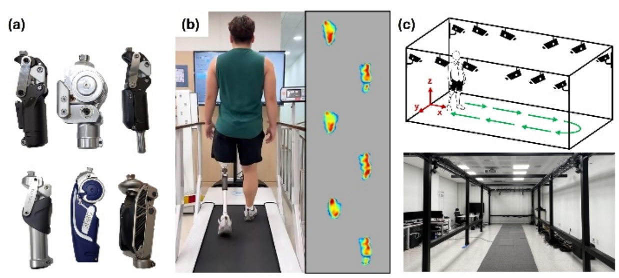

Figure. 1. Photos of (a) prostheses, (b) plantar pressure experiments, and (c) marker-based gait analysis environment.

The XGB supervised ML regressor is employed as a predictor applied to the database of PEQ and quantitative data. However, the limited sample size (10 participants) and high dimensionality of variables constrained regression accuracy. To address this limitation, synthetic data was generated using GMM. Through this GMM-XGB framework, PEQ was employed as input features to predict i) plantar pressure and ii) gait parameters.

Results and Discussion

Figure. 2 presents prediction results for plantar pressure and gait parameters based on PEQ survey. For plantar pressure, the average deviation is ~3%, while gait parameters showed the average deviation of ~5%. The primary objective of this study is to estimate quantitative variables (plantar pressure and gait parameters) from qualitative surveys. The GMM-XGB model showed consistent prediction accuracy across various prostheses.

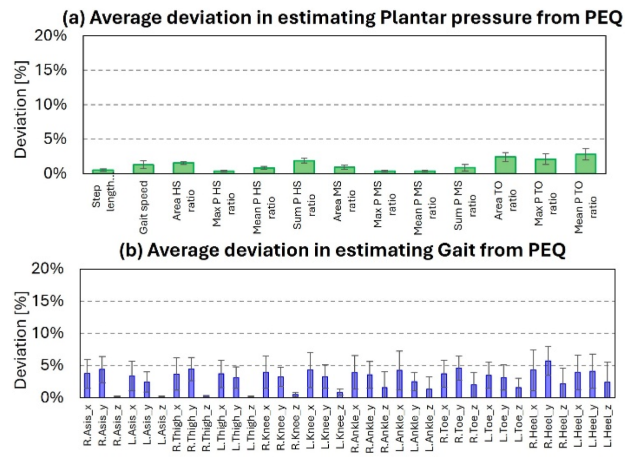

Figure. 2. Prediction results of (a) plantar pressure and (b) gait from PEQ

Conclusions

GMM-generated synthetic data enhanced feature detection, addressing database limitations, while the XGB regressor proved reliable and accurate prediction. This study shows that a well-trained machine learning model can predict quantitative variables from qualitative ones, which could be useful in other fields with limited data and qualitative data.

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