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APPLICATION OF A NONPARAMETRIC GAIT MODEL AND FEATURE GENERATION BASED ON INSOLE DATA

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Abstract. Gait and balance disorders pose significant risks of injury and negatively impact quality of life, especially among the elderly and individuals with neurological conditions. In this work, a novel feature generation method based on a nonparametric gait model (NPWM) for plantar pressure data is proposed for early fall risk assessment. Unlike traditional gait analysis methods that rely on fixed parameters or predefined models, the proposed approach directly extracts spatiotemporal features from real world data collected by wearable plantar pressure sensors. These features include raw spatial distributions, gait temporal characteristics, balance stability metrics, energy expenditure features, and informative feature ratios. Experimental results demonstrate that the proposed method achieves a fall risk prediction accuracy of 0,9, offering significant advantages over conventional clinical assessment methods.

Keywords: plantar pressure, nonparametric gait model, feature generation, fall risk assessment.

Introduction

With the acceleration of global aging, fall risk assessment has become a hot topic in health management. Traditional methods (such as the TUG test [1] and Berg Balance Scale [2]) suffer from high subjectivity, time consumption, and significant limitations. In recent years, gait analysis based on data collected from plantar pressure sensors has gradually attracted attention [3]. However, generating representative features from the vast amounts of data remains a key challenge [4]. To address this problem, this paper proposes a feature generation method based on a nonparametric gait model. By analyzing plantar pressure data from multiple perspectives, the method comprehensively reflects gait variations and balance status, providing a new approach for early fall risk identification.

Method description

We propose a fall risk feature mining method (FRFMM). The core idea of this method is to use nonparametric walking methods (NPWM) to directly extract spatiotemporal information from raw plantar pressure signals without relying on the fixed parameter assumptions of traditional models. The main process includes data collection and preprocessing, raw feature generation, and feature ratio construction.

After participants wear smart shoes, they walk along a designated corridor while the pressure signals of both feet are collected in real time. The preprocessing module filters, normalizes, and segments the signals temporally to ensure the accuracy of subsequent feature extraction.

Based on the plantar pressure signals, features that reflect changes in the foot center of pressure are extracted in both the lateral and longitudinal directions. Raw spatial features are then constructed using the pressure distribution from various sensors across different regions. In addition, temporal gait features are extracted by combining peak values and time intervals within the gait cycle, to reflect balance status, balance features describing the differences in pressure distribution between the left and right feet are incorporated, along with energy expenditure features estimated from body mass and movement speed.

To enhance the discriminative power of the features, the method further constructs ratio features such as the left and right pressure ratio and time interval ratios. These ratios are used to reveal the underlying balance and stability issues present in gait.

Experimental and results

The feature generation and selection process are based on a dynamic gait fall risk dataset [5]. Each participant wore smart shoes equipped with eight insole pressure sensors, with the right foot sensor placement shown in Figure 1. Under medical supervision, participants walked along 20 meters' corridor for over two minutes while being evaluated with the BBS and TUG test. Plantar pressure data were collected at a sampling rate of 20 Hz and transmitted in real time to a mobile phone.

Figure 1. Distribution of insole pressure sensor placement

A random forest classifier was used to train and validate the extracted features. In Figure 2 illustrates the precision of various feature selection methods. The FRFMM achieves the highest precision at 0,93, demonstrating a strong ability to reduce false positives. The simulated annealing (SA) and genetic algorithm (GA) methods also perform well, with precision values of 0,83 and 0,80, respectively. In contrast, the recursive feature elimination (RFE) method shows the lowest precision at 0,54, suggesting limited effectiveness in identifying discriminative features. The correlation-based (CB) feature selection method yields a moderate performance, indicating that although correlation provides some relevance guidance, it may not be sufficient to isolate the most predictive subset of features in complex classification tasks.

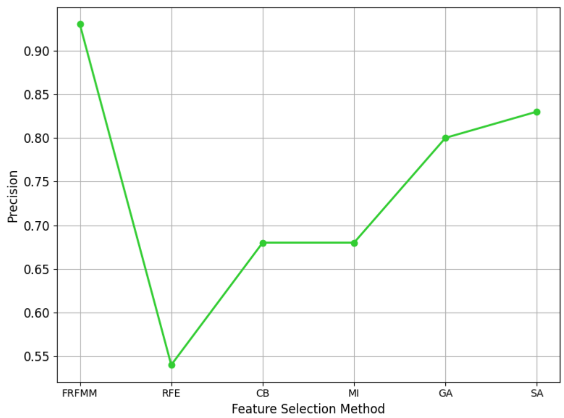

Figure 2. Precision assessment of random forest classifier using the proposed FRFMM and five well known feature selection methods

In Figure 3 illustrates the recall values. FRFMM once again leads with a recall of 0,90, indicating strong ability in identifying true positive instances. GA and SA also demonstrate effective detection capabilities. In contrast, RFE shows the lowest recall at 0,50, indicating significant miss rates.

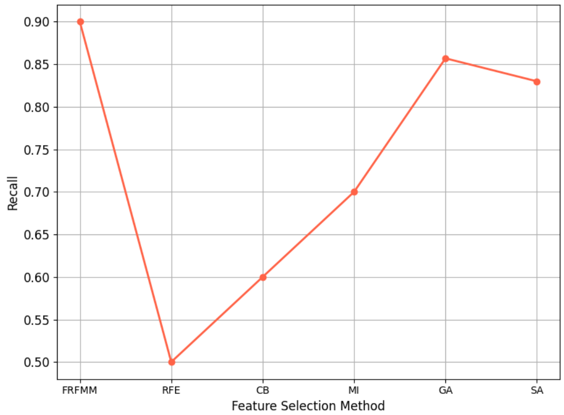

Figure 3. Recall assessment of random forest classifier using the proposed FRFMM and five well known feature selection methods

In Figure 4 compares the F1-score, which is the harmonic mean of precision and recall and reflects the balance between them. FRFMM again achieves the highest F1-score of 0,90, indicating a well-rounded performance. SA (0,83) and GA (0,792) also perform effectively. RFE shows the lowest F1-score at 0,52, reaffirming its poor performance.

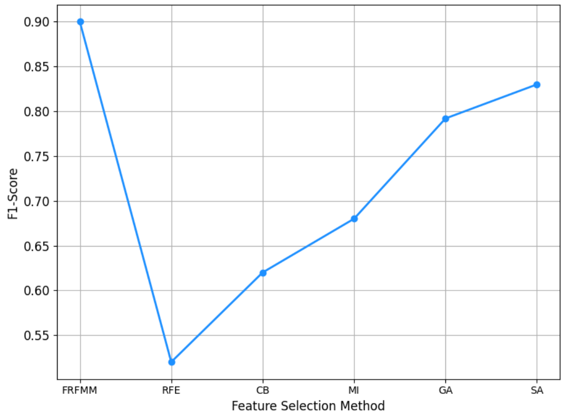

Figure 4. F1-score assessment of random forest classifier using the proposed FRFMM and five well known feature selection methods

In Figure 5 compares the accuracy across different feature selection methods. FRFMM ranks first with an accuracy of 0,90, indicating superior overall classification performance. SA and GA also demonstrate strong effectiveness. RFE again performs the worst with an accuracy of 0,50, consistent with its precision and recall. The CB method and the MI method show moderate performance, with accuracy values of 0,60 and 0,70, respectively.

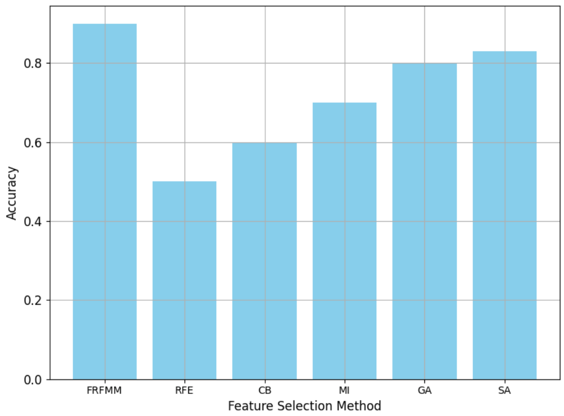

Figure 5. Accuracy assessment of random forest classifier using the proposed FRFMM and five well known feature selection methods

Conclusion

The FRFMM based on a nonparametric gait model proposed in this paper effectively extracts key information from plantar pressure data, enabling early fall risk assessment. Experimental results demonstrate that the method achieves high prediction accuracy and real time performance, providing strong support for practical applications.

References

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