Chapter 6

Smartwatch-Based Semi-Supervised Fall Detection Using Anomaly Detection Techniques

Meshall Alshalaan
https://orcid.org/0009-0005-5356-7574
King Abdullah University of Science and Technology, Saudi Arabia

Fouzi Harrou
https://orcid.org/0000-0002-2138-319X
King Abdullah University of Science and Technology, Saudi Arabia

Ying Sun
King Abdullah University of Science and Technology, Saudi Arabia

ABSTRACT

Fall detection systems are crucial for seniors to mitigate significant health risks and severe fall-related injuries. Traditional supervised methods rely on extensive labeled datasets, which are challenging and time-consuming. Imbalanced datasets, where fall events are rare compared to daily activities, further complicate training. To bypass these challenges, we propose a semi-supervised fall detection approach using a One-Class Support Vector Machine (1SVM) with accelerometric data from smartwatches. 1SVM needs only fall-free data for training and effectively detects falls without labels. Specifically, we applied 1SVM to six features extracted from the accelerometric data, smoothed magnitude, moving window min-max difference, variance, maximum, and minimum. We evaluated this approach using publicly

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available smartwatch data named the SmartFall dataset, demonstrating 1SVM's superior performance with an accuracy of 87%, outperforming SVM, k-nearest neighbors (KNN), and Naive Bayes.

1. INTRODUCTION

Falls represent a major public health concern, particularly for the elderly population, where they often result in serious consequences such as fractures, head injuries, reduced mobility, and long-term functional decline. According to the World Health Organization (WHO), falls are the second leading cause of unintentional injury deaths globally, with older adults being the most affected demographic. Beyond the immediate physical harm, falls can trigger a cascade of adverse outcomes, including loss of independence, increased fear of falling, social isolation, and higher healthcare utilization. These outcomes collectively reduce the quality of life and contribute to a higher risk of subsequent falls. As such, timely and accurate detection of falls is essential to enable rapid intervention, minimize complications, and support aging in place through proactive healthcare monitoring.

Despite significant advancements in fall detection using supervised machine learning, these approaches face several limitations when deployed in real-world settings. Supervised models rely heavily on large, labeled datasets that include representative examples of both normal activities and fall events. However, fall incidents are inherently rare and unpredictable, making it difficult to collect sufficient annotated fall data, particularly for diverse populations and contexts. Moreover, the variability in fall types, user behaviors, and sensor placements can lead to poor generalization and overfitting to specific training conditions. Labeling fall data also raises ethical and practical challenges, as inducing real falls for data collection poses safety risks. As a result, supervised models often fail to maintain high accuracy and robustness when deployed outside controlled environments, limiting their applicability in continuous, real-time monitoring scenarios.

Over the last decade, significant advancements have been made in fall detection technologies, driven by the development of various sensing modalities. Fall detection systems are typically categorized based on the type of sensors used: wearable sensors (e.g., gyroscopes, accelerometers, smartwatches), camera-based systems (e.g., RGB, depth, infrared), and environment-based sensors (e.g., acoustic and pressure sensors) (Zerrouki et al. 2021). Figure 1 illustrates this taxonomy. Wearable sensors, such as smartwatches, gyroscopes, smartphones, and belt-mounted devices, are among the most widely adopted due to their portability and direct motion capture (Pierleoni et al., 2015; Nooruddin et al., 2022; Newaz & Hanada, 2023). These devices commonly include inertial measurement units (IMUs) to track acceleration and angular velocity,