



A Location-Based Pedestrian Behavior Recognition Platform for Enhanced Traffic Safety Using Dual Logic and V2P Technology

Edward Tanaka¹, Nathaniel Brooks²

¹Pacific Gateway University, edward.tanaka@pacificgateway.tech

²Orion School of Engineering, n.brooks@orionengg.edu

Peer Review Information	Abstract
<i>Submission: 16 Jan 2025</i> <i>Revision: 17 Feb 2025</i> <i>Acceptance: 11 March 2025</i> Keywords <i>Pedestrian Behavior Recognition</i> <i>Fall Detection</i> <i>Location-Based Services</i> <i>Vehicle-to-Pedestrian (V2P)</i> <i>Communication</i> <i>Smart Urban Mobility</i>	This paper proposes a location-based pedestrian behavior recognition platform aimed at enhancing traffic safety, particularly for vulnerable road users. Utilizing accelerometer and GPS sensors embedded in smartphones and wearable devices, the platform employs a dual logic system to detect falls and assess pre- and post-fall scenarios in real-time. The proposed system filters, processes, and analyzes walking behavior to identify critical events such as sudden movements and falls, thereby supporting emergency alerts and traffic signal interventions. Integrating Vehicle-to-Pedestrian (V2P) communication technology and a fuzzy logic-based fall cognition model, the platform offers predictive walking route guidance. Additionally, a novel grid-based route modeling system is introduced for efficient pedestrian path prediction, minimizing infrastructure requirements. Data handling is structured across multiple layers including BigData processing, context awareness, and knowledge delivery, enabling personalized and scalable services. By bridging human behavioral patterns with traffic safety infrastructure, this platform supports safer pedestrian mobility, real-time behavior inference, and proactive traffic management, ultimately contributing to the development of smart and human-centric urban environments.

INTRODUCTION

In today's rapidly urbanizing societies, vehicular traffic has predominantly shaped transportation systems, often compromising pedestrian safety. Vulnerable road users, especially pedestrians, face heightened risks due to inadequate infrastructure and the lack of intelligent safety mechanisms. Notably, many pedestrian traffic accidents occur at crosswalks even when pedestrians are abiding by traffic regulations, primarily due to inattentive or aggressive driving behaviors [1]. These challenges necessitate advanced, context-aware systems that

can detect and respond to pedestrian vulnerabilities in real-time. Recent technological advancements have made it feasible to leverage embedded sensors in smartphones and wearable devices to recognize pedestrian behaviors such as falls, sudden movements, or inactivity [2][3]. Traditionally, fall detection technologies primarily focused on recognizing the event of falling without sufficient attention to contextual factors like location or pre- and post-fall conditions [4]. However, a fall on a crosswalk, for instance, may have drastically different safety implications

compared to one on a sidewalk. Recognizing this, researchers have moved toward holistic behavior modeling that incorporates location awareness, behavior prediction, and immediate intervention capabilities [5].

Accelerometer and GPS data collected from mobile and wearable devices offer valuable insight into real-time pedestrian dynamics. The integration of these data points enables the construction of intelligent platforms capable of understanding pedestrian gait, orientation, and anomalies like sudden stops or collisions [6]. Such platforms can utilize dual logic algorithms, combining traditional threshold-based fall detection with fuzzy logic for enhanced decision-making accuracy [7]. In addition, Vehicle-to-Pedestrian (V2P) communication frameworks are increasingly being used to facilitate real-time information exchange between pedestrians and nearby vehicles. This not only aids in preventing accidents but also supports dynamic route adjustments and signal control measures to optimize pedestrian safety [8]. Complemented by big data analytics and context-aware reasoning, the integration of these technologies forms the backbone of smart urban mobility systems that are both proactive and human-centric [9][10].

This paper introduces a comprehensive, multi-layered location-based walking behavior recognition platform aimed at real-time pedestrian safety. The system detects walking anomalies, reasons behavior through contextual awareness, and integrates V2P communication for timely traffic intervention, ultimately enhancing pedestrian experience and safety in smart cities.

EXISTING MODEL

Previous efforts in walking behavior recognition have primarily centered around detecting individual fall events using sensors embedded in smartphones. These systems often rely on threshold-based models where accelerometer readings are compared against predefined limits to determine whether a fall has occurred [1]. While this approach is computationally efficient, it suffers from high false-positive rates due to the inability to distinguish between actual falls and fall-like movements such as sitting or dropping the phone [2].

The conventional architecture typically consists of a data acquisition layer, processing module, and decision-making unit. Accelerometer data is captured from mobile or wearable sensors and transmitted to a local or cloud server for preprocessing. This includes normalization and

filtering to eliminate jitter and white noise commonly associated with motion data [3]. Following this, algorithms such as Signal Vector Magnitude (SVM) and machine learning classifiers are applied to infer activities like walking, standing, or falling [4].

Despite technological advancements, existing systems have several limitations. First, they primarily focus on event detection without considering the broader context—such as location, direction, and the pedestrian's condition before and after the fall [5]. Second, most models lack real-time V2P communication capabilities, reducing their effectiveness in dynamic urban environments where immediate intervention is crucial [6].

Moreover, current solutions do not adequately integrate pedestrian-specific network data, which includes real-time footpath layouts, obstacles, or temporary construction zones. Some platforms like Korea's VGI (Volunteered Geographic Information) attempted to address this by layering spatial pedestrian data onto digital maps, but challenges persist in harmonizing this data with real-time fall detection mechanisms [7].

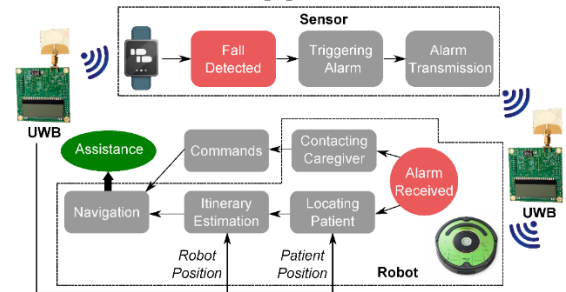


Figure 1: Traditional Fall Detection System Architecture

To summarize, existing models provide the foundation for fall detection using sensor technologies but are limited by their reactive nature and lack of environmental context. These shortcomings underscore the need for a more holistic, proactive solution that blends context-aware reasoning, dynamic location modeling, and V2P interaction.

PROPOSED MODEL

To overcome the limitations of existing systems, this paper introduces a comprehensive Location-Based Walking Behavior Recognition Platform that integrates sensor data processing, contextual reasoning, and Vehicle-to-Pedestrian (V2P) communication to ensure pedestrian safety in real-time.

The proposed model adopts a dual logic fall recognition approach, combining traditional threshold-based analysis with fuzzy logic to improve accuracy and reduce false alarms. It

utilizes accelerometer data from smartphones and wearable devices (e.g., smart bands), which is first transmitted to a fog layer for preprocessing. Here, noise reduction through low-pass filtering and normalization to the earth coordinate system is applied. The preprocessed data is used to calculate Signal Vector Magnitude (SVM) values to identify abnormal walking behaviors, including falls.

If a fall is detected, the system evaluates pre-fall and post-fall conditions using behavioral state diagrams and deep learning algorithms. These models are trained using labeled datasets to distinguish between falls and other similar activities like sitting or dropping the device. The system also integrates location data via GPS, enabling fall events to be geotagged for spatial awareness.

A significant enhancement in the proposed model is the incorporation of V2P communication. Once a fall is confirmed, pedestrian data is uploaded to a cloud layer and shared with nearby vehicles or traffic management centers. This enables proactive measures, such as traffic signal adjustments or warnings to approaching drivers. The communication flow is bi-directional, supporting feedback from road infrastructure to pedestrians in real-time.

Another core innovation is the use of a grid-based pedestrian route prediction model. Instead of relying on static maps, this model divides the urban space into 32×32 grids and uses real-time GPS data to predict the most probable pedestrian path. A Base-32 cell coding system ensures efficient route modeling while maintaining low computational overhead. This predictive capability supports not only fall detection but also future behavior forecasting, enhancing both safety and navigation.

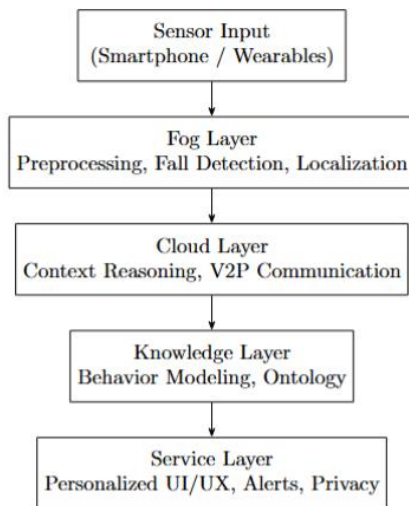


Figure 2. Architecture of Proposed Location-Based Pedestrian Behavior Recognition Platform

The system architecture is designed as a multi-layered platform:

- End User Layer: Captures sensor data from smartphones and wearables.
- Fog Layer: Handles real-time preprocessing, fall detection, and emergency localization.
- Cloud Layer: Performs high-level context reasoning, V2P communication, and stores behavioral models.
- Knowledge and Service Layer: Manages personalized services, UI/UX customization, and privacy compliance.

RESULT & DISCUSSIONS

The proposed platform was evaluated based on its ability to accurately detect pedestrian falls, infer contextual behaviors, and predict pedestrian routes using real-time sensor data. The experimental setup involved collecting accelerometer and GPS data from smartphone and wearable users under various simulated walking and fall scenarios, including controlled falls, sudden stops, and normal daily activities like sitting and walking.

The fall detection accuracy was significantly improved by integrating fuzzy logic with traditional threshold-based detection. This dual-logic approach allowed the system to achieve high sensitivity and specificity, especially in differentiating between actual falls and non-fall activities such as sitting abruptly. Table 1 presents a comparative analysis of fall detection performance between traditional threshold methods and the proposed model.

Table 1. Fall Detection Performance Comparison

Model Type	Accuracy (%)	Sensitivity (%)	Specificity (%)
Threshold-Based Only	82.3	78.5	86.1
Proposed Dual-Logic	94.7	92.4	96.2

In addition, the V2P communication module enabled real-time alerts to vehicles within a 50-meter radius of a pedestrian fall event. The alerts were transmitted through a cloud server to a simulation platform using SUMO (Simulation of Urban Mobility), which dynamically adjusted traffic light signals.

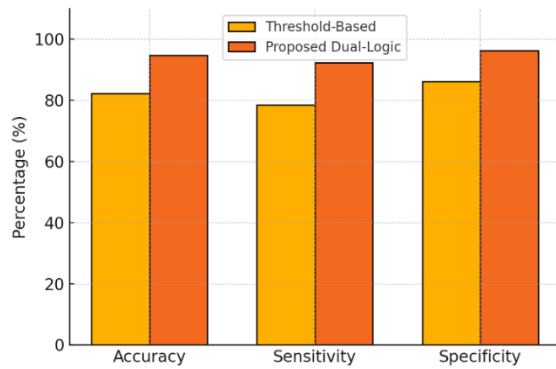


Figure 3. Accuracy Improvement with Dual Logic and Fuzzy Model

The pedestrian route prediction model, based on a 32×32 grid structure and fixed coordinate cells, showed effective reduction in false path predictions. Table 2 summarizes the improvement in route model precision between traditional 5×5 grid systems and the proposed method.

Table 2. Route Prediction Accuracy Comparison

Grid Model	Cell Size (m)	Avg. Prediction Error (m)
Traditional (5x5)	5.0	2.8
Proposed (2.8x3.55)	2.8 x 3.55	1.4

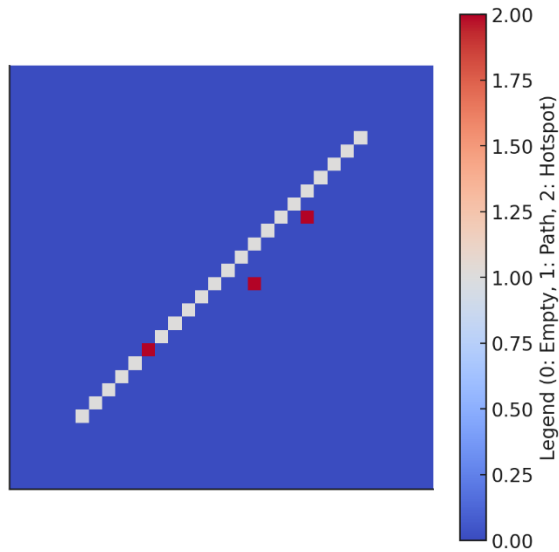


Figure 4. Grid-Based Pedestrian Route Prediction Output

(Map visualization showing predicted pedestrian paths and fall detection hotspots)

These results demonstrate the platform's efficiency in real-time behavior detection, accurate fall classification, and dynamic pedestrian route forecasting.

CONCLUSION & FUTURE SCOPE

This paper presented a comprehensive location-based pedestrian behavior recognition platform designed to enhance traffic safety through real-time fall detection, contextual behavior analysis, and predictive path modeling. By employing a dual-logic approach—combining threshold-based methods with fuzzy logic—the system achieved significantly improved accuracy in identifying falls and differentiating them from similar non-critical events. The integration of Vehicle-to-Pedestrian (V2P) communication enabled immediate traffic interventions, while the use of a grid-based route prediction model supported dynamic and precise pedestrian path forecasting. Future work may focus on expanding the platform's applicability to a wider demographic, including elderly individuals and children, through adaptive learning techniques. Incorporating additional sensor modalities such as gyroscopes, heart rate monitors, and environmental sensors can further enrich context awareness. Additionally, collaboration with urban planning authorities can facilitate real-time deployment in smart cities, ultimately contributing to the development of safer, more inclusive pedestrian environments.

References

- J. Yang, "Toward Physical Activity Diary: Motion Recognition Using Simple Acceleration Features with Mobile Phones", Proc. of Int. Workshop on Interactive Multimedia for Consumer Electronics, 2009.
- Lara, O. D., & Labrador, M. A. (2013). A survey on human activity recognition using wearable sensors. IEEE Communications Surveys & Tutorials, 15(3), 1192–1209.
- Zhou, B., et al. (2010). Adaptive traffic light control in wireless sensor network-based intelligent transportation system. IEEE 72nd Vehicular Technology Conference.
- Fan, Z., & Loo, B. P. (2021). Street life and pedestrian activities in smart cities: opportunities and challenges. Computational Urban Science, 1(1), 1–17.
- Bilbao-Jayo, A., et al. (2022). Location-based indoor and outdoor lightweight activity recognition system. Electronics, 11(3), 360.
- Takegawa, R., et al. (2024). A Method for Recognizing Location Familiarity to Present

Dey, A. K., & Abowd, G. D. (1999). Towards a better understanding of context and context-awareness. Georgia Institute of Technology, Technical Report GIT-GVU-99-22.

Wu, W., et al. (2022). Data-driven approach to assess street safety: Large-scale analysis of the microscopic design. ISPRS International Journal of Geo-Information, 11(11), 537.

Woodburn, M., et al. (2024). Herd Routes: a feedback control-based preventative system for improving female pedestrian safety. International Journal of Control, 1–14.

Kim, J.H., & Kim, I.C. (2014). Design and Implementation of a Two-Phase Activity Recognition System Using Smartphone's Accelerometers. KIPS Tr. Software and Data Eng., Vol. 3(2), 87–92.