UNIVERSITI TEKNOLOGI MARA

THE DEVELOPMENT OF A PASSIVE WI-FI RADAR FALL DETECTION SYSTEM FOR ELDERLY BASED ON CUMULATIVE SUM THRESHOLDING

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ABSTRACT

Falls among elderly individuals aged 60 and above create significant health risks due to age-related physical and medical impairments. These incidents often result in severe injuries or fatalities. Although various fall detection systems have been developed, existing methods have some limitations. Wearable sensors require consistent user compliance which can be inconvenient, while camera-based systems raise privacy concerns and demand high computational power. Radar-based solutions have emerged as promising alternatives due to their ability to detect and classify fall events with high accuracy. This study proposes a Passive Wi-Fi Radar (PWR)-based fall detection system that leverages existing in-home Wi-Fi signals. Key challenges include ensuring reliable signal propagation, identifying sensor placement, and differentiating falls from normal activities in multi-occupant settings. Furthermore, most radar-based systems rely on extensive post-processing, which limits their suitability for real-time applications. Hence, this study proposes a threshold-based approach using the Cumulative Sum (CUSUM) method to enable real-time fall detection. The research commences with the simulation of Wi-Fi signal propagation for determining receiver placement to enhance coverage for human motion detection. Hardware components were subsequently tested and validated to ensure optimal signal reception. The study further investigates fall detection in single and dual-activity scenarios involving multiple occupants, addressing the inherent challenges of distinguishing overlapping motion signals. Experimental validation was conducted within a controlled indoor environment under ethical approval, where trained stunt performers executed fall simulations while volunteers performed non-fall activities to refine and improve detection accuracy. The results demonstrate that the proposed PWR-based system utilising the CUSUM time-based method delivers a reliable solution, with detection accuracies of 95.83% for single falls and 93.75% for dual activities. This research advances non-wearable fall detection technologies by offering a privacy-preserving alternative to existing solutions. Future work will focus on optimising system performance and deploying the technology in real-world environments to enhance adaptability and robustness.

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CHAPTER 1
INTRODUCTION

1.1 Research Background

The growing number of elderly individuals in Malaysia each year highlights the need for effective fall detection systems, especially as many prefer to live independently in their homes [1]. Falls are sudden and unintentional descents to the ground due to loss of control over the body. It is common among the elderly who face a higher risk of severe consequences. These incidents can lead to physical injuries that may worsen over time or even result in fatalities. Research shows that accidental falls not only pose immediate dangers but also increase the likelihood of future incidents, known as recurrent falls [2]. For instance, a report in [3] mentioned that 30% of individuals who experience a fall are likely to fall again within twelve months, with many encountering multiple falls in a year. Since falls often occur unexpectedly, quick responses are crucial as prompt action by caregivers can minimise injuries and prevent complications. The urgency of ensuring elderly safety has driven the development of fall detection systems that monitor movements by allowing caregivers to respond swiftly and thereby enhancing safety and reducing harm.

Recent advancements in technology have paved the way for fall detection systems that can minimise the risks associated with falls. These systems leverage sensors to detect human movements. By monitoring motion patterns, sensors can identify irregularities and unanticipated events like falls during normal daily routines. Detection systems are broadly categorised into wearable and non-wearable types. In traditional wearable systems, sensors like buttons, gyroscopes, accelerometers, and proximity detectors are attached to the user's body [4]-[7]. While effective, these systems can be intrusive and inconvenient for day-to-day activities [8]. Hence, non-wearable sensors are introduced and installed in the user's environment rather than worn on the body. For instance, barometric sensors are commonly used to detect motion by altitude variations through atmospheric pressure changes. Although multiple papers mentioned that the combination of barometric and wearable sensors provides crucial