Abstract

In the context of the ongoing digital transformation, there is a crucial need to revolutionize monitoring human actions and behaviors. Human activity recognition (HAR) plays a central role in this effort, where wearable and remote sensors use motion data to detect actions and movements autonomously. With its powerful capabilities, radar technology stands out as a promising sensor for HAR. It can operate in diverse environments, addressing privacy concerns associated with video cameras, making it a pivotal tool for automatic activity identification. In this thesis, we introduce a human activity recognition system based on radar technology, with a particular emphasis on fall detection. We begin by providing an overview of radar technology and the general framework of human activity recognition. We discuss the essential tools utilized in HAR and review significant works in the field. The subsequent chapters of this thesis detail our contributions, divided into two phases.

The first phase deals with our collected dataset in a home setting with continuous wave radar. Available HAR systems are of high cost and also lack post-fall health tracking. To address this gap, in the first contribution, we develop a low-cost fall detection system based on CW Doppler radar, designed hierarchically to enhance its robustness. This system's final hierarchical stage also includes a facility to monitor post-fall respiration rates. Earlier studies have predominantly centered around routine activities, often overlooking transition activities such as sit-to-stand, stand-to-sit, stand-to-walk, and others. These transitional movements, marked by sudden accelerations, can pose challenges as they raise confusion with other high-acceleration activities by the system. In our subsequent second contribution, we address this limitation by incorporating transition activities into our system for more robust training. Our approach involves a multiclass classification framework, categorizing activities into three classes: stationary, transitions, and fall activity.

In the second phase of our research, we delved into applying deep learning methods on publicly available datasets using FMCW radar to enhance the accuracy of the Human Activity Recognition (HAR) system. These deep learning-based HAR systems alleviate the need for manual feature extraction, enabling high-quality feature extraction. However, a common challenge is the limited availability of human fall data for training deep learning models. To address this issue, as a third contribution, we introduce Generative Adversarial Networks (GANs) to augment synthetic data, thereby expanding the volume of the fall dataset. This augmentation technique, coupled with convolutional neural networks, significantly improves fall detection accuracy compared to other methods. Despite the advancements made in deep learning methods for HAR, there is a sense of saturation, prompting the exploration of new deep learning approaches. The final and fourth contribution explores the potential of a novel deep learning method: Graph Neural Networks (GNNs). These networks demonstrate competitive accuracy in classifying six different human activities, highlighting their effectiveness in learning spatial dependencies among the various human activities.

In summary, our exploration underscores the significance of radar technology for cost-effective and privacy-conscious human activity recognition. The thesis contributes novel approaches, such as hierarchical fall detection and innovative deep learning methods, addressing critical gaps in this transformative field.

Keywords: Continuous Wave Radar Sensor (CW), Frequency-Modulated Continuous Wave Radar Sensor (FMCW), Human Fall Detection, Human Activity Recognition (HAR), Graph Neural Networks (GNN), Generative Adversarial Network (GAN), Deep Learning (DL), Machine Learning (ML).