A Model for Detecting Abnormality in Activities of Daily Living Sequences Using Inverse Reinforcement Learning

***Abstract*—ADL abnormality detection has been the focus of many recent healthcare studies, some of which addressed the issue by using deep learning techniques. In this paper, we provide a novel approach for examining ADL sequences to detect meaningful deviations from the individual's routine behavior. This approach can benefit older adults in several ways, including timely care, early detection of health conditions to stop them from getting worse, reducing the burden of monitoring on family members, and maximizing self-sufficiency without interfering with daily activities. We present an Inverse Reinforcement Learning (IRL)-based method for detecting behavior abnormalities in older adults through the analysis of ADL sequences. To do this, we model the problem of abnormality detection in behavior sequences as a Higher-order Markov Chain model. Using the IRL method, from observed trajectories of behavior, we infer the reward function that drives the individual to perform ADLs. The inferred reward function will then be utilized to detect potential behavior abnormalities through a threshold-based mechanism.**

1. Introduction

With the world's aging population, the need for technologies supporting healthy aging and independent living for older adults is growing. Aging often brings behavioral changes that may indicate cognitive decline or other health issues. Detecting these changes can enable early intervention by caregivers and healthcare professionals, potentially improving older adults' health outcomes and quality of life.

Tracking changes in behavior over time using ADLs data, which includes information about daily activities like eating, sleeping, and personal hygiene, is valuable. However, it is challenging to detect behavior changes from ADL data due to the complexity and variability of human behavior. Advancements in sensor technologies have promoted the monitoring of ADLs. Decreased ADL performance is associated with the progression of chronic diseases and cognitive impairment in older adults [23]. A study comparing two groups of older adults found that the activity maps of dementia patients displayed disorganized behavior patterns, and there was a notable difference in heterogeneity between the healthy group and the group with the disease. [25]. Therefore, the study of life patterns in older persons can be used to quantify changes relevant to ADLs in the course of diseases. Although there is plenty of research on ADL recognition and ADL impairment detection, studying irregularities in the pattern of daily life has not been studied enough. The existing research on behavior anomaly detection in older adults has primarily focused on point anomalies, neglecting the potential of utilizing temporal features to their fullest extent. While these studies have successfully identified anomalies where individual data points deviate from the norm, they have overlooked collective anomalies that can only be detected by analyzing the sequential nature of the data. Moreover, some investigations have been limited to identifying abnormalities within specific activity classes, failing to account for higher-level analysis of activities. Thus, it is crucial to consider appropriate behavior granularity in developing effective anomaly detection methods. Additionally, it is desirable for the method to offer a generalizable solution that can be adjusted for different target users within a reasonable timeframe, enabling it to leverage pre-learned models and accelerate the learning process.

In this work, we propose an IRL-based model for detecting behavior abnormalities in older adults. The model infers the reward function from observed expert behavior, referred to as trajectories. It learns from sequences of ADLs performed by individuals to capture the underlying motivations. IRL has shown promise in modeling human behavior and inferring underlying motivations [13]. By leveraging Inverse Reinforcement Learning, the model trains the agent through a semi-supervised task, which is effective when defining the reward function is complex. Additionally, the reward function has been demonstrated to exhibit greater transferability compared to the policy function [20], leading to the development of more generalizable models. Unlike supervised methods, the model learns from expert observations rather than labeled data. It can adapt to changes in behavior over time and detect early indicators of cognitive decline or other health issues.

The main contributions of this research are as follows: (1) A novel representation of the abnormality detection in ADL sequences as a higher-order Markov Chain model. (2) A semi-supervised IRL-based model for detecting behavior changes in older adults from sequences of ADL data. (3) An evaluation of the proposed model on a real-world dataset of ADL data from older adults.

2. Related Works

Abnormal behavior can be defined as "actions that are unexpected and often evaluated negatively because they differ from typical or usual behavior" [9]. Because the