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Activity Recognition and Abnormal Behaviour Detection with Recurrent Neural Networks

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Abstract

In this paper, we study the problem of activity recognition and abnormal behaviour detection for elderly people with dementia. Very few studies have attempted to address this problem presumably because of the lack of experimental data in the context of dementia care. In particular, the paper investigates three variants of Recurrent Neural Networks (RNNs): Vanilla RNNs (VRNN), Long Short Term RNNs (LSTM) and Gated Recurrent Unit RNNs (GRU). Here activity recognition is considered as a sequence labelling problem, while abnormal behaviour is flagged based on the deviation from normal patterns. To provide an adequate discussion of the performance of RNNs in this context, we compare them against the state-of-art methods such as Support Vector Machines (SVMs), Naïve Bayes (NB), Hidden Markov Models (HMMs), Hidden Semi-Markov Models (HSMM) and Conditional Random Fields (CRFs). The results obtained indicate that RNNs are competitive with those state-of-art methods. Moreover, the paper presents a methodology for generating synthetic data reflecting on some behaviours of people with dementia given the difficulty of obtaining real-world data.

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Keywords: Smart Homes; Sensor based Activity Recognition; Recurrent Neural Networks; Dementia; Abnormal Behaviour Detection

1. Introduction

Studies indicate that by year 2030, 19% of people will be aged 74 to 84 and nearly half of people who are older than 84 will have dementia[1]. Elderly people may suffer from the consequences of dementia, which is a condition that causes problems with mobility, physical and mental abilities such as memory and thinking[2]. It also may cause decrease in the ability of speaking, writing, distinguishing objects, performing motor activities and performing complex functional tasks (paying bills, preparing a meal, shopping, managing medication, etc.)[3]. An elderly person having such cognitive decline loses independence in daily life and requires care and support from caregivers.

Cognitive diseases like dementia need to be detected at an early stage so that early treatment will be possible. However, research shows that 75% of dementia and early dementia cases go unnoticed[4] and many such cases are only

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diagnosed when such impairment reaches moderate or advanced stage. The detection of early signs of motion and cognitive impairment (MCI) via activity recognition will be useful to track motion and cognitive capabilities of the elderly, thus improving their life quality and financial saving. Unfortunately, currently there are no dementia friendly smart homes addressing these people's special needs.

Most common types of dementia (Alzheimer, Parkinsons disease) can be identified by behavioural changes like sleep disturbances, difficulty of walking and inability to complete tasks. Such changes can provide key information about memory, mobility and cognition of a person. For instance, an inhabitant suffering from Alzheimer may forget his lunch, take multiple lunches instead, wake up in the middle of the night, go to the toilet frequently, or have dehydration problems because of forgetting to drink daily amount of water.

Recent studies suggest that changes in complex daily life tasks can be indicators of early decline[5]. The best markers of cognitive decline may not necessarily be detected based on a person's performance at any single point in time, but rather by monitoring the trend over time and the variability of change in a duration[5]. Thus, tracking an elderly person's life over time in a specially designed smart home, doing in-home health assessment and detecting the indicators of dementia at an early step would be beneficial.

The identification of early onsets of dementia using non-medical diagnosis methods requires the development of new diagnostic tools. Although a few promising methods have been experimentally validated[6,7,8,9,10], the translation of the current knowledge into smart homes still requires more dedication and work. Current assessment methods mostly rely on queries from questionnaires or in-person examinations, which depend on recall of events or brief snapshots of function that may poorly represent a person's typical state of function. Moreover, these studies include some pre-defined tasks given to the patients in order to do automatic assessment of cognitive decline by trained experts.

The main motivation for our work is that cognitive decline can be observed in daily activities and routines of an elderly. Real-time monitoring of activities performed by elderly in a smart home would be beneficial for the early detection of such decline. In this study, we firstly recognise activities by variants of RNNs, namely VRNNs, LSTMs and GRUs and model the daily behaviour routines of a person. Whenever a new sequence is introduced, any abnormality deviating from these regular behaviours are detected and could be used for further investigation by formal or informal carer.

Unfortunately, there exists no publicly available dataset on abnormal behaviour of people with dementia. Producing such a dataset require time and adequate experimental environment. Thus we propose in this paper, a way to artificially produce data on abnormal activities reflecting on typical behaviour of elderly people with dementia. We believe that this an important contribution.

The rest of the paper is organised as follows. Section 2 provides a brief overview of the related research to both activity recognition and abnormal behaviour detection. Section 3 presents the details of the proposed methodology together with the datasets and models used. Section 4 describes the experimental set-up and results of the experiments followed by a discussion. Finally, Section 5 concludes the paper.

2. Literature Review

Activity recognition has been addressed using methods such as decision trees, Bayesian methods (Naïve Bayes and Bayesian Networks), k-Nearest Neighbours, Neural Networks (Multilayer perceptron), SVMs, Fuzzy logic, Regression models, Markov models (Hidden Markov Models, Conditional Random Fields) and classifier ensembles (Boosting and bagging)[11]. Recently, there has been growing interest in deep convolutional neural networks[12,13,14,15], Deep Belief Networks[16], Restricked Boltzman Machines (RBMs)[17,18,16,19] and RNNs[14,15,20]. Previous work shows that RNNs are useful, but leaves a lot of room for improvement. It is worthwhile to stress that to the best of our knowledge, this study is the first applying RNNs to detect abnormalities related to dementia in the daily life routines of an elderly person.

In[17], RBMs are used for feature extraction and selection from sequential data. In[14], the authors use a combination of deep convolutional networks and LSTM to do multi-modal wearable activity recognition by showing that their approach outperforms some of the previously reported results by up to 9% on OPPORTUNITY dataset. In[21], the authors utilised convolutional networks to classify activities using time-series data collected from smart phone sensors. Experiments show that increasing the number of convolutional layers increases the performance, but the complexity of the derived features decreases with every additional layer. In[15], the authors explore deep, convolutional and recurrent