

Chapter 7

Conclusion and Future Work

This chapter summarizes the main contributions of this thesis along with promising directions for conducting future research in supporting independent living of the elderly and improving their life quality.

Conclusion

The thesis has studied the problem of supporting the elderly living alone at home to lead an independent life. Although this problem has remained a great interest of the researchers, its solutions are still lacking to handle some critical challenges, such as long-tailed class distribution problems in ADL datasets and non-privacy invasive sensing. The existing literature on ADL recognition considers class balanced data, while the real-life datasets are significantly imbalanced. Such imbalanced training data can result in a biased system optimized to favor the majority classes while failing to recognize the minority classes. Moreover, the prior works mostly consider video or wearable sensors. The video sensors are the best in terms of accuracy; however, these sensors are not practical in smart home settings due to privacy-invasiveness and the accuracy of wearable sensors relies upon the body attachment position. The main objective of this thesis is to support the independent life of the elderly while dealing

with these challenges.

In this thesis, we have developed different smart sensing based approaches to fulfill this objective. The strengths of the proposed approaches are they handle the class imbalance problem of real-world ADL datasets. Furthermore, the proposed approaches considered only environmental/external sensors for non-privacy invasive data collection, such as PIR motion and magnetic door sensors. These sensors are embedded in the environment or objects of daily living. Their non-intrusive characteristics make them suitable for assistive technologies where user acceptance and privacy are needed. To summarize, this thesis has achieved the objectives of supporting the independent living of the elderly while addressing the stated challenges.

Chapter 2 presented the existing work on supporting the independent living of the elderly. For this, we focused on the problems of early dementia detection, future ADL prediction, online ADL recognition, and recognizing ADL through transfer learning. We reviewed the state-of-the-art solution approaches for these problems. We categorized the existing work based on the underlying sensor modalities utilized to gather data and different feature extraction methods.

Chapter 3 addressed the problem of early dementia detection by using unobtrusive sensor data. Our objective was to detect dementia at an early stage by classifying the elderly travel patterns. A significant challenge in dementia is achieving an accurate and timely diagnosis. If the patient can have proper medical treatment early, then the dementia growth can be delayed by months to years. Inefficient travel patterns are one of the first indicators of progressive dementia. We use the environmental passive sensor signals for sensing the movement of the elderly. The proposed system segments the movements into travel episodes and classifies them using a recurrent neural network. We used focal loss for handling the unbalanced classes of travel patterns and center loss to enhance the discriminative power of the deeply learned features. Finally, the system handles the unbalanced classes of travel patterns using the focal loss and enhances the

discriminative power of the deeply learned features by the center loss function. We conduct several experiments on real-life datasets to verify the accuracy of the system. We believe that the proposed system can be beneficial for automated dementia detection at an early stage.

Chapter 4 presented the design, implementation, and evaluation of an ADL prediction system to jointly predict the label, location, and starting time of future activities. Existing conventional machine-learning and deep learning-based ADL prediction systems do not address the multi-task learning, where three separate models increase the time and space complexities and reduce accuracy. The proposed system uses cross-entropy and mean absolute error loss functions for capturing the discrepancy between the predicted output labels and actual labels. The experimental results illustrate that the multi-task system comparatively gives higher accuracy than the single-task system. We use publicly available four real datasets to evaluate the system's performance. In addition, we validate the effectiveness of the system on collected data.

Chapter 5 addressed the problem of online unobtrusive ADL recognition with the long-tailed datasets. We proposed an ADLR system that generates hand-crafted and high-level features using conventional learning and deep learning, respectively, covering both technologies' advantages to recognize the ADL. We effectively combine deep learned features with hand-crafted features via an ensemble technique. ADLR system minimizes a loss function, which is a linear combination of focal loss for addressing the long-tailed class distribution problem and center loss for enhancing the discriminative power of the deeply learned features. We conducted several experiments on real-life long-tailed datasets to verify the accuracy of the system. The proposed system achieved new state-of-the-art performance on the CASAS datasets. Moreover, the experimental results illustrate that the system gives high accuracy for the under-represented classes.

Chapter 6 presented a transfer network for activities of daily life recognition through

unsupervised domain adaptation between smart home datasets having different sensor deployment and spatial layouts. Proposed transfer network learns the domain invariant yet target-discriminative feature representations by utilizing MMD, focal, and center loss. Experimental results on real-world CASAS datasets show the effectiveness of the proposed transfer network.

Future Directions

This thesis points out several important research directions for supporting the independent living of the elderly. We list some of the promising extensions of our work as follows.

- In this thesis, we focused on the problems of early dementia detection, future ADL prediction, online ADL recognition, and recognizing ADL through transfer learning. In the research related to supporting independent living of the elderly, there also exist other problems. In the problem of ADL prompting, the aim is to provide a reminder or prompt to older adults with cognitive impairment who fail to initiate or complete everyday ADL. Smart homes that can detect when assistance is needed and automatically deliver prompts can reduce caregivers' burden and allow aging adults to retain their functional independence longer. In the problem of fall detection, the aim is to detect falls and alert a designated person or emergency services to facilitate rapid assistance. If the elderly living alone in their homes fall, it may be challenging to request help. Falls are the leading cause of death due to injury among the elderly population. As future works, we can consider these problems, which have great importance in supporting the independent living of the elderly.
- This work considers activities performed in a sequential or interleaved fashion (*i.e.*, more than one activity is performed by a person switching from one to another). There may be concurrent activities in real-world settings, *i.e.*, a person

performs more than one activity at a time point. As future work, concurrent activities can be considered, and learning methods designed to include these activities can be explored.

- In this work, we consider a single resident scenario intending to support the elderly who live alone. Incorporating a multi-resident scenario can be a potential future research work in this area.