Sensor-based Daily Activity Understanding in Caregiving Center

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***Abstract*— Sensor-based activity recognition is an important area for various applications, especially for elderly people in caregiving centers, smart-homes, etc. Activity recognition deteriorates while partial data are lost due to various reasons. It is a realistic challenge. Hence, we have proposed an approach to improve activity recognition in the presence of missing data. Afterwards, we have developed activity recognition system using LoRaWAN sensors. We have studied data loss performance analysis in a caregiving center in Japan by deploying 42 LoRaWAN sensors. We also have developed a large dataset of elderly peoples' daily activities from various sensors, with ground truth data that are collected from the nurses. We are exploring various activities of the elderly people from this dataset. We are working to understand the movements' dimensions, locations, sleeping patterns, etc. of them by exploiting smart features and machine learning algorithms. Our work is going to have a huge impact on the healthcare monitoring system, especially for the elderly people in the world.**

Keywords- Activity Recognition; Healthcare Monitoring; Assisted-living; Machine Learning; Sensor Network.

I. INTRODUCTION

Automatic recognition of physical activities has emerged as a key research area in mobile and ubiquitous computing. Sensor-based activity recognition is important for assisted living, healthcare monitoring system, fall detection, and elderly support system. Vision based action recognition approaches are well-known for more than a decade but the progress is not enough. Plenty of methods are dealing different kinds of actions but little work has been done on elderly people's normal and critical activity detection like fall detection. A person may fall down and sustain injuries that limit mobility or encounter events that may lead to worsening health. The identification of inconsistent patterns, especially in daily activities monitoring systems, can be significantly valuable for caregivers to make decisions or diagnoses in emergency situations.

In this paper, we concisely summarize our published research works during my 1st year of PhD, and present the on-going research activities for future guidelines. We would like to develop a sensor-based daily activity recognition approach for a smart caregiving center to improve the quality of life of the elderly people living there.

II. PUBLISHED RESEARCH WORKS

During my first year in PhD, we analyzed sensor data to detect human activities, by focusing the improvement of recognition in the presence of missing data. Based on our proposed method, we explored our developed simulated dataset to evaluate the impact of features [1,7]. Afterwards, we investigated on a benchmark dataset named HASC dataset. However, the dataset has no missing data. Therefore, we developed various levels of missing data randomly to demonstrate the strength of our method. This work achieved *Best Paper Award* in 7th ICIEV 2018 [2] (Fig. 1 shows a flow diagram of the system). Apart from these works, analysis of Dynamic Source Routing protocol in wireless sensor network is explored to detect daily activities of elderly people [3].

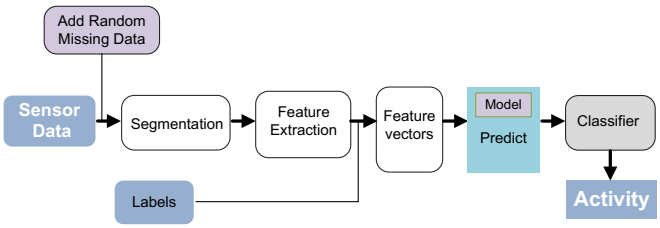

Fig. 1: Flow diagram of our approach having missing data in both training and testing modules.

We proposed an activity recognition framework by exploiting LoRaWAN (Long Range Wide Area Network) sensor and its accelerometer data. In our framework, by exploring a LoRaWAN Gateway, we transfer the sensor data to the cloud. Then we aggregated the time series data from the cloud to recognize various activity instances. We trained the data to induce a predictive model for activity recognition. For classification, we utilized the K-Nearest Neighbor and Linear Discriminant Analysis. The result provides promising prospect for LoRaWAN sensor for improving healthcare monitoring service. This work achieved the *Best Poster Paper Award* in ACM UbiComp 2018 [4].

In another work, we studied the relationship between data loss and activity recognition performance on LoRaWAN sensor data in a real caregiving center. In LoRaWAN technology, the amount of sensor nodes connected with a single gateway have an impact on the performance of

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sensors' ultimate data transfer capability in terms of packet loss. In a caregiving center, our setup has 42 LoRaWAN sensors for these research works (Fig. 2). We also studied different types of environmental sensor data in the healthcare center to analyze data transfer performances.

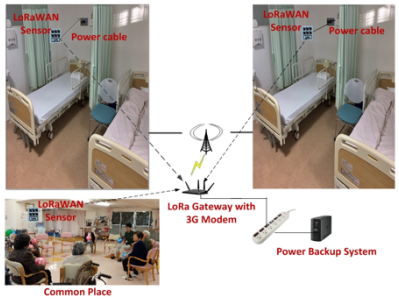

Fig. 2: LoRaWAN setup in the caregiving center.

We also participated in *Sussex-Huawei Locomotion Challenge* in ACM UbiComp 2018, and we achieved 11th ranking among 39 participants from all over the world) [8].

III. On-going Research and Future Plans

Activity recognition having missing data:
Based on our above works, we are working to improve feature-based analysis for missing data-based action recognition. Earlier, we developed a simulated dataset and we exploited a benchmark dataset (HASC dataset) for activity recognition in missing environment. We considered missing at random pattern, which is the most realistic scenario in wireless sensor network. We are planning to explore different missing patterns, e.g., not missing at random, for few other benchmark datasets. We want to verify our proposed method in different datasets and we want to see how much the recognition results will improve under various missing levels. We need to explore the allowed percentage of missing data in different datasets. It is very crucial but still an unearth issue for sensor-based activity recognition. These are some realistic challenges, because there is not any good dataset having missing data in terms of missing at random or not missing at random patterns. There are not enough published works related to these issues for activity recognition under missing data.

LoRaWAN-based activity study in caregiving facility:
LoRaWAN technology has received a lot of attention because it can be a promising technology for healthcare monitoring system in future. The reasons are: it features low data rate (27 kbps) and long communication range (2~5 km in urban areas and 15 km in suburban areas) [6]. According to our study, we have explored the LoRaWAN technology for the first time for activity recognition [4-5]. However, there are challenges to be solved.

During the caregiving center experiment, we observed that there are some dependencies of this technology on the number of nodes, connected with a single gateway connection. In LoRaWAN technology, the amount of sensor nodes connected with a single gateway have an impact on the performance of sensors' ultimate data sending capability in terms of packet loss. From the indoor experiment, we want to evaluate data loss pattern for our 3 months dataset. Already, we observed that during 1-minute interval sensing, ~5% data loss happens by the sensors with a single gateway. This challenge is yet to be deciphered. On the other hand, to improve activity recognition, we need to add smarter features for more activity classes with more sensor nodes. We are planning to evaluate LoRaWAN sensor dependency with number of devices in single gateway communication.

Caregiving Center Activity Database (CCAD) exploration for daily activity understanding:
Our laboratory, recently, we have developed a huge activity dataset. We collected data for three months from different sensors (LoRaWAN, iBeacon, accelerometer, Luna nurse sleep monitor, etc.). Along with the data collection, for ground truth data, nurses input various information in a mobile application to give coherent data of the residence. It is indeed a very important and big dataset from which we can work to identify many relationships of various activities. For example, data on sleeping patterns, medicine intake, food intake and amount, water intake, toileting, daytime exercise, nighttime activity, visits of family members, vital records, etc., under more than hundred categories/sub-categories – can be explored to understand different conditions and daily activities of the residence in the caregiving center. It is a complex dataset due to multiple relationships among multitude of classes and their mutual correlations. We have collected data from different platforms, hence data preparation and data review are also challenging for daily activity understanding. We need to find out that which activity classes are good among the regular activity records. This study can have immense impact to understand the statuses of elderly persons (whether living in a caregiving center or in a hospital).

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