Prediction of Resident's Outing Time for Energy Saving

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Abstract—**By analyzing the occupancy pattern of the user, it is possible to find out the time when they are expected to go out. Based on this, if Heating, Ventilation, and Air Conditioning (HVAC) can be controlled in advance, energy consumption can be reduced. The buildings are basically equipped with insulation technology, so they can maintain indoor comfort for a certain period of time even after ceasing HVAC system. Therefore, by predicting the time when the user goes out and performing the pre-control of the HVAC, the energy-saving effect can be obtained. In this paper, we propose a technique to detect periodic and repetitive outing of the resident by analyzing user's occupancy pattern. By pre-control of the HVAC with occupancy, the energy consumption can be reduced without harming the comfort of the user.**

Keywords- Occupancy Sensor; Occupancy Probability; Energy Saving; HVAC.

I. INTRODUCTION

Reducing energy use is a very important issue in terms of economic, environmental and social aspects. Users can achieve economic benefits by reducing energy costs, and the government can realize social values by reducing the cost of constructing power plants and the cost of energy imports. This energy saving is very important because it can slow down climate change and protect the environment [1]. For this rea-son, various technologies have been developed as energy saving methods; however it is known that it is most important to reduce wasted energy.

Some researches on room temperature control based on occupancy probability have been carried out [2][3]. However, these researches focused on the comfort of the users and did not consider saving energy.

In this paper, we analyze user's repetition pattern (absence and presence) by energy conservation method and try to find out the time of going out. By using this point of departure, energy consumption can be reduced by shutting down or lowering the output of devices, such as Heating, Ventilation, and Air Conditioning (HVAC). Since the buildings are equipped with basic insulation technology, the comfort of the room is not significantly degraded even after the cooling / heating interruption. Therefore, when the user is expected to go out, even if the HVAC device is shut down earlier, the comfort of the user is not impaired and the energy consumption is expected to be reduced.

This paper is organized as follows. Section 2 describes the outing prediction process. Section 3 describes the brief results obtained from our experiment. Finally, Section IV presents our conclusions and future works.

II. OUTING PREDICTION

The proposed method performs clustering based on user's occupancy data. This is because the user's repetition pattern changes depending on whether the day is working day or not. At this time, it is also possible to consider using calendar information, user schedule and location; however in this paper, only the occupancy sensor data is used. By using the information such as the planner and global positioning system (GPS) of the smartphone and Google calendar, it is possible to know the time when the user goes out. In this case, however, there are side effects such as a risk of personal information leakage and hardware unit price increase. Therefore, in this paper, we tried to predict user outage time by analyzing only occupancy data.

Since the calendar data is not used in this study, data for each date are assigned to 7 groups in order (using the repetition of seven days in a week), and finally divided into two clusters using K-means clustering algorithm [4] (holidays and working days). For each of these two clusters, the non-parametric estimation technique kernel density estimation (KDE) [5] with Epanechnikov kernel is used [6]. Through the process, the discrete-time probability is converted into continuous-time probability and smoothing effects can also be expected.

III. RESULTS

In order to evaluate the performance of the proposed technique, Passive Infra-Red (PIR) sensor is used. Data received from the sensors were divided into 30 minute intervals, and the decision whether the user is occupied or not was made.

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In this paper, we use three experimental rooms to obtain the resident's occupancy information and to derive the probabilities. The list of rooms used is shown in Table 1. Experimental occupancy data were obtained from August 1 to August 30, 2018 (this is the hottest season in Korea and has the most energy use). The clustering results were shown in Figure 1. Clustering results are the same in all three experimental rooms. Therefore, only one representative is shown. Data of working days were extracted from these two clusters. During the working days and holidays, we focused on working days (i.e., cluster 1 from Figure 1.). Figures 2 to 4 show the probability of occupancy. In these figures, it can be seen that the probability of dropping below 0.5 is the estimated time of going out. Therefore, energy savings can be achieved by turning off the HVAC systems before that point.

IV. CONCLUSIONS AND FUTURE WORKS

In this paper, we have performed outing time prediction based on the user's occupancy probability, and found that energy savings can be achieved by shutting down or lowering the output of HVAC equipment before the user's estimated time of departure.

The actual energy saving effect is under investigation, and we will find out by demonstration how much energy we can save. In addition, although this paper focuses on offices only, studies on general housing will be conducted. The authors are preparing a paper containing these new contents.

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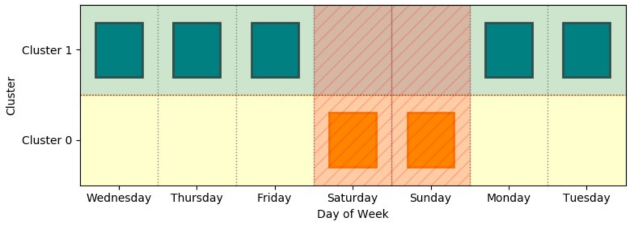

Figure 1. Clustering results of the occupancy data.

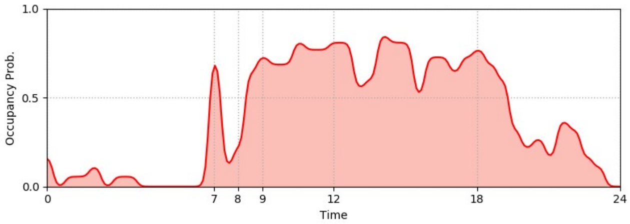

Figure 2. Occupancy probability of the first experimental room 1.

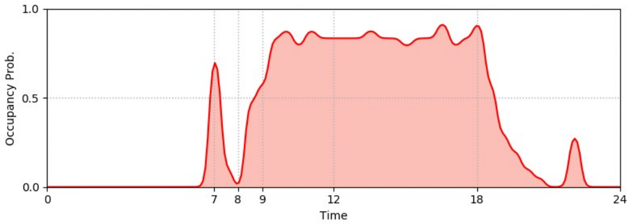

Figure 3. Occupancy probability of the second experimental room.

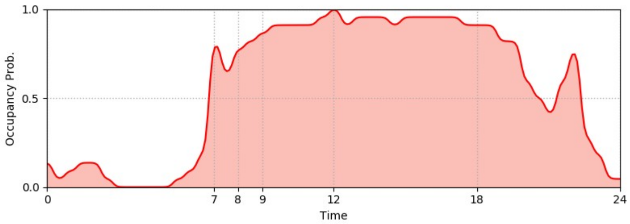

Figure 4. Occupancy probability of the third experimental room.

TABLE 1. LIST OF ROOMS FOR DATA ACQUISITION AND EXPERIMENT.

Place	Type	Area	Number of Usual Resident
Room 1	Office	57.36 m^2	4
Room 2	Office	60.66 m^2	7
Room 3	Office	79.34 m^2	4